East Coast Hydrogen

East Coast Hydrogen Feasibility Report

Northern Gas Networks

Cadent
Your Gas Network

nationalgrid

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East Coast Hydrogen

Foreword

East Coast Hydrogen

Hydrogen is essential for us to get to Net Zero. This year the UK Government published its eagerly awaited Hydrogen Strategy outlining an ambitious vision for the development of the hydrogen economy across the UK. Analysis by BEIS for Carbon Budget 6 suggests that between 20-35% of total energy consumption in the UK should come from hydrogen[1].

Earlier this month the UK Government hosted COP26 in Glasgow and the key theme of the conference was delivery. As we enter the 2020s, it is critical that we deliver on the ambitions laid out at COP26 to bend down the curve on emissions and keep the target of keeping temperature change to within 1.5°C of pre-industrial levels alive.

Hydrogen was outlined as a breakthrough technology at COP26 and it's imperative that we make progress from trials and step in to delivering hydrogen at scale for industry business, and homes. East Coast Hydrogen is an ambitious 15-year programme which would see up to 39,000 businesses and over 4 million homes converted to hydrogen across the Northern Powerhouse.

With the announcement of East Coast Cluster and HyNet as Track 1 clusters in the mid-2020s, East Coast Hydrogen provides a solution to connect these industrial clusters with other supply points, such as the East Midlands Hydrogen Innovation Zone, and export hydrogen production across the North of England – enabling the seamless conversion of businesses and homes to 100% hydrogen where it is best deployed.

This collaborative programme between Northern Gas Networks, Cadent Gas and National Grid represents an opportunity for the Government and the private sector to work together in delivering on our ambitious decarbonisation targets. East Coast Hydrogen has the potential to connect over 7GW of hydrogen production by 2030, alone exceeding the UK Government's 5GW by 2030 target in a single region.

East Coast Hydrogen can utilise the natural assets of the North of England, including existing and potential hydrogen storage facilities, and build on the hydrogen production in two of the UK's largest industrial clusters in the North East and North West and in turn ensure significant private sector investment in the UK's industrial heartlands.

This is the first step in the conversion of our national gas grid to hydrogen and will act as a blueprint for subsequent conversions across the UK. We will demonstrate the innovation, engineering capabilities and opportunity in the North and create tens of thousands of highly skilled Green jobs in the future hydrogen economy.

Henri Murison

Director

The Northern Powerhouse Partnership

1. BEIS, UK Hydrogen Strategy, 2021

Executive Summary

East Coast Hydrogen objectives

East Coast Hydrogen

Connect hydrogen supply with demand across multiple end use cases

- Low carbon hydrogen from multiple production methods will be supplied to major industry, local businesses, transport hubs, power stations and domestic end users.
- Industry will have the opportunity to assess the feasibility of fuel switching to hydrogen against other methods such as electrification and CCS.

Transport hydrogen through repurposed and new build pipelines

- Repurposing existing infrastructure is more cost-effective than the development of new capital infrastructure and, where possible, repurposing will be delivered.
- The continued resilience of a natural gas supply will remain a priority by the networks and this will be achieved through a dual-pipeline natural gas and hydrogen system.

Build resilience with interconnectivity and storage facilities

- Large-scale existing and potential geological storage sites within the region could provide inter-seasonal storage and system resilience through providing demand points with access to a greater supply market.
- Storage facilities will support the increased generation of green hydrogen through the generation from renewable power.

Balance supply and demand to support effective market growth

- As new hydrogen suppliers enter the market, there will be a need for a highly flexible and integrated hydrogen transportation system to manage hydrogen across a region and support the rapid market scaling.
- With the announcement of the Track 1 Industrial Clusters, there will be a need to get hydrogen production to industrial and residential demand across the UK.

East Coast Hydrogen is about being ready for UK Government decisions

- UK Government has set a clear agenda for hydrogen through the release of the UK Hydrogen Strategy and a number of funding options.
- With the announcement of Track 1 Industrial Clusters and many industries assessing the feasibility for running on hydrogen, networks must be ready to get the hydrogen to where it is needed.

East Coast Hydrogen is a blueprint for a GB wide conversion to hydrogen

- East Coast Hydrogen will look in detail at the specific engineering requirements for network conversion in the region and will act as a blueprint for regional conversion.
- It will build on the successful innovation projects delivered by Northern Gas Networks, Cadent and National Grid, including the Hydrogen Home and HyNTS.

East Coast Hydrogen is a perfect region to commence the national conversion

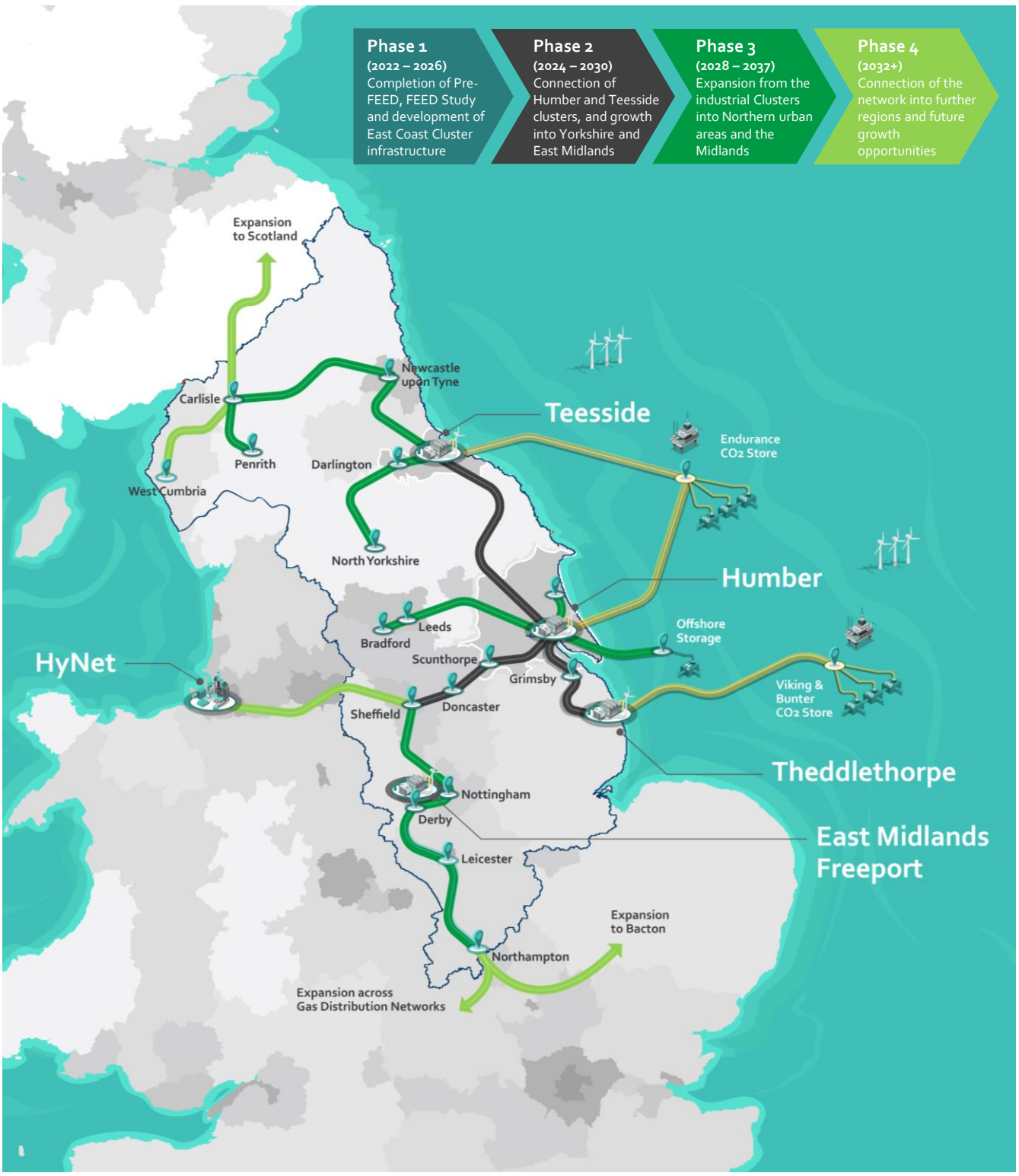
- East Coast Cluster represents up to 50% of the UK's industrial emissions and a concentrated proportion of the publicly announced hydrogen production.
- The East Coast of the UK is home to some of the UK's largest offshore wind sites which provide a valuable opportunity for the production of green hydrogen.

East Coast Hydrogen will act as a blueprint for cross-network conversion of existing assets and the application of business models to provide investor confidence in the hydrogen opportunity

East Coast Hydrogen proposed phases

East Coast Hydrogen

East Coast Hydrogen is a 15 year programme that will be carried out in multiple discrete phases to decarbonise industrial processes and domestic heating in the East Coast region.

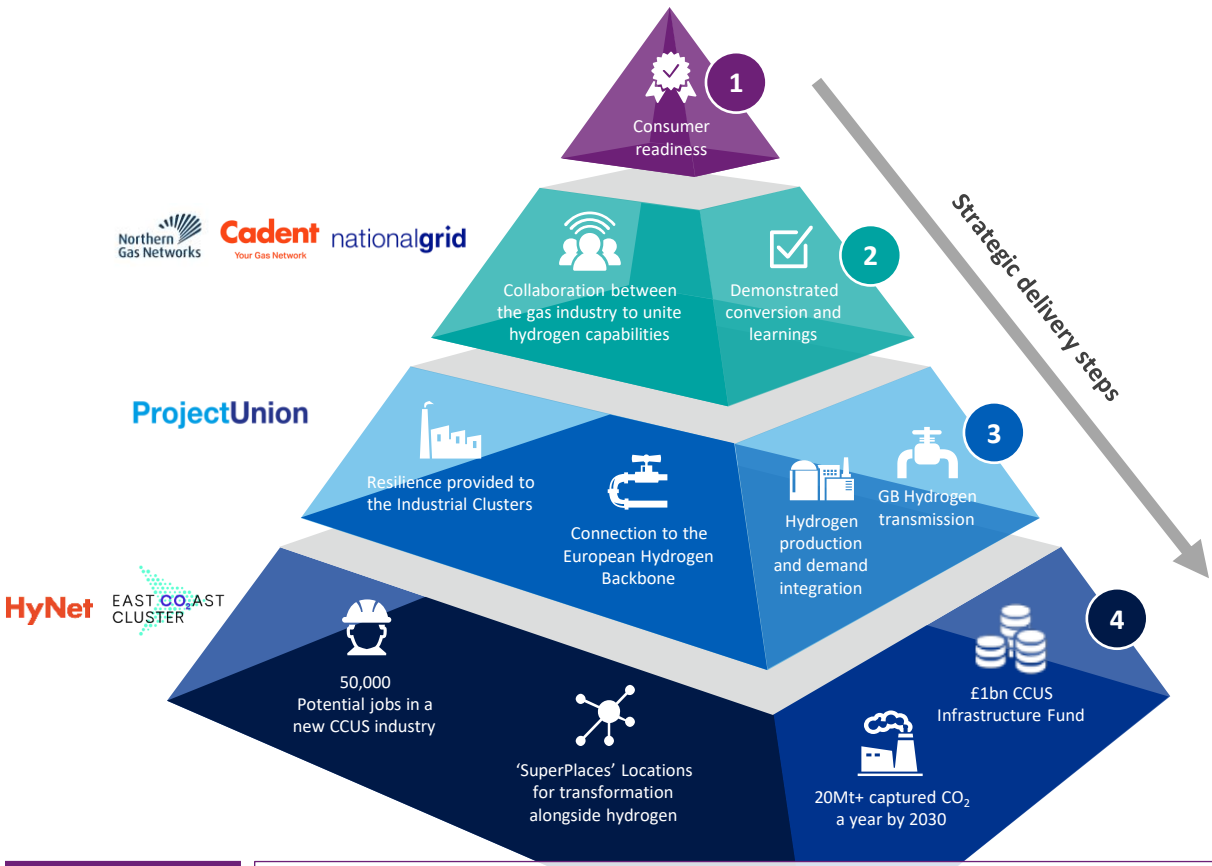


The East Coast Hydrogen Feasibility Report is the first step in the decarbonisation of industrial, commercial and domestic demand across the East Coast Hydrogen region and beyond

East Coast Hydrogen interaction with the UK Hydrogen Economy

East Coast Hydrogen

Building on the success of GB gas distribution network readiness, East Coast Hydrogen is the next step in a route to delivering a fully decarbonised gas system with Project Union, enabling the scaling of industrial clusters and in turn a hydrogen economy in the UK.



1 Consumers *Readiness*

The Gas Distribution Networks (GDNs) are delivering **substantial progress in converting the UK's regional GDNs to polyethylene**, which is capable of transporting hydrogen through towns and villages. This, along with proving the safety case for converting domestic appliances to hydrogen, will ensure that the UK consumer is ready for hydrogen.

2 East Coast Hydrogen *Deployment*

In order to demonstrate a first conversion, **East Coast Hydrogen will act as a blueprint to convert UK regions to hydrogen**. East Coast Hydrogen will connect the UK's largest industrial regions – Teesside and Humber – alongside industry and homes through repurposing existing infrastructure and building new hydrogen infrastructure.

3 Project Union *Integration*

As the Industrial Clusters develop, a **UK Hydrogen Backbone can enable UK-wide industrial integration and support deep decarbonisation with hydrogen alongside Carbon Capture and Storage (CCS)**. Project Union, led by National Grid, will re-purpose 25% of the current gas network to create a 2,000km Hydrogen Backbone by 2030.

4 Industrial Clusters *Delivery*

The UK Government has launched a competition to sequence four of the UK's clusters – Track 1 in the mid-2020s (HyNet and East Coast Cluster) and Track-2 by 2030 – and initiate infrastructure development within these regions. **The Industrial Clusters will enable hard-to-decarbonise industries to decarbonise and support the growth of hydrogen production.**

East Coast Hydrogen is a key component of the delivery of the UK hydrogen economy by facilitating the delivery of hydrogen to consumers from supply points across the UK

East Coast Hydrogen Stakeholder Consortium

East Coast Hydrogen

A wide range of stakeholders across the hydrogen value chain, industry and local stakeholders have signed Letters of Support for the East Coast Hydrogen programme to date.

Cross-value chain
Hydrogen value chain participants

bp | EAST CO_2AST CLUSTER | EQUANS EMPOWERING TRANSITIONS | equinor

DelpHYnus | kellas MIDSTREAM | SIEMENS energy | VPI

Upstream
Hydrogen production

BOC A Linde company | CPH2 CLEAN POWER HYDROGEN

ECO ENERGY WORLD | HiROC

ITM POWER Energy Storage | Clean Fuel | uniper

Midstream
Transportation and storage

centrica storage

Navigator

Downstream
Sector-specific utilisation

Enertek International

sembcorp

TOYOTA

TRITON POWER

Vaillant

Local stakeholders
Regional and local partners

CATCH | D2N2 Derby Derbyshire Nottingham Nottinghamshire | Greater Lincolnshire Local Enterprise Partnership | MIDLANDS ENGINE

North East Local Enterprise Partnership | TEES VALLEY COMBINED AUTHORITY | West Yorkshire Combined Authority

30 stakeholders have committed to contribute through their respective capabilities to support the successful delivery of East Coast Hydrogen

Siemens Energy is a trademark licenced by Siemens AG. 28 of the 30 stakeholders who have committed Letters of Support have approved to show their logos above.

Key East Coast Hydrogen Feasibility Study results

East Coast Hydrogen

East Coast Hydrogen is an ambitious 15 year large-scale infrastructure programme aiming to decarbonise the most carbon-intensive sectors in the UK through the provision of low carbon hydrogen.

01 Interconnectivity

Over 7GW
Current planned hydrogen production by 2030 in the East Coast Hydrogen region

~800km
Total repurposed and dedicated new-build hydrogen national and local transmission pipelines

~10TWh
Planned hydrogen storage capacity in the East Coast Hydrogen region

02 Industrial decarbonisation

Up to 39,000
Commercial and industrial sites supplied with low carbon heating and process fuel

Up to 24%
Annual UK industrial and commercial gas demand decarbonised by East Coast Hydrogen

Up to $11MtCO_2$
Annual avoided commercial and industrial emissions by fuel switching from gas to hydrogen

03 Domestic decarbonisation

Up to 4.4 million
Domestic properties switched to a low carbon heating solution

Up to 17%
Annual UK domestic gas demand decarbonised by East Coast Hydrogen

Up to $9MtCO_2$
Annual avoided domestic emissions from switching to a hydrogen gas supply

East Coast Hydrogen will act as a blueprint for the transition of the gas industry to a Net Zero future and decarbonise a large proportion of the UK's homes and industry

Sections of the report and key takeaways

East Coast Hydrogen

The existing infrastructure in the East Coast is extremely valuable to the region in terms of jobs, economic benefit and asset value. By enabling a transition to hydrogen in the East Coast networks, we can develop the existing infrastructure and realise the significant benefits of a decarbonised gas grid in the North East and East Midlands.

Section	Content	Key messages	Pages
Section 1: East Coast Hydrogen is a mega infrastructure programme supporting the role of hydrogen in the UK	→ The decarbonisation challenge and hydrogen economy. → Hydrogen blending and 100% hydrogen. → Industrial, residential, and transport decarbonisation.	→ **Hydrogen is expected to play a key role in a Net Zero future** across all of National Grid's Future Energy Scenarios (FES). → The UK Government's **current hydrogen policy is trailing behind industrial ambition.** → Hydrogen has significant potential to play a **key role in the decarbonisation of the industrial, residential, power generation and transport sectors.**	→ 11 - 22
Section 2: East Coast Hydrogen represents a low regrets opportunity to decarbonise the East Coast	→ The East Coast region as a starting point and anchor. → Exploring the Industrial and Residential decarbonisation potential in the East Coast Hydrogen region.	→ East Coast **Hydrogen's proximity to large industrial sites, large scale gas storage, and offshore wind power** makes it ideally placed to anchor the decarbonisation of the region through hydrogen. → Multiple projects are **already demonstrating the safety and equivalent consumer experience** of hydrogen blending and 100% hydrogen networks.	→ 23 - 30
Section 3: What is East Coast Hydrogen and what are the benefits?	→ Outline, overview, and timeline. → Industrial and residential decarbonisation impact. → Expansion opportunities. → Contribution to the UK.	→ East Coast Hydrogen has the potential to decarbonise **up to 39,000 industrial and commercial sites, up to 4.4 million homes,** and avoid up to 20MtCO_2/year in direct emissions. → East Coast Hydrogen can play a significant role in **achieving HMG's target across job creation, hydrogen production, decarbonisation and investment**.	→ 31 - 40
Section 4: How will we deliver East Coast Hydrogen?	→ Programme roadmap, milestones, and development. → Stakeholder engagement. → Regulatory engagement. → Next steps.	→ East Coast Hydrogen is a **15+ year mega programme that will be carried out in multiple, discrete phases** which align with HMG's decarbonisation ambitions. → East Coast Hydrogen has **already engaged with multiple supply chain stakeholders and public and local authorities** who have shown overwhelming support for the programme.	→ 41 - 52

Disclaimer

East Coast Hydrogen

This report is a Feasibility Study which provides a strategic outline vision of a proposed programme for the East Coast region. It is by no means a defined project and the proposals laid out within this report do not constitute firm plans.

The infrastructure outline routing has been developed with the best intention and the value chain analysis of production, storage and demand has been compiled based on publicly available information. As the programme develops, this data is likely to change for the production of the Feasibility Report due to; transition towards a mix of hydrogen production methods, including renewable forms of hydrogen; the assessment of fuel switching opportunities for individual forms of asset; and the scenarios assessed for conversion (i.e. beyond those of a new Local Transmission System).

Data has been provided by the appropriate teams across Northern Gas Networks, Cadent, National Grid ("We") and builds upon assumptions within readily available documents from HM Government. Figures included in the report that are not referenced have been provided by one or more of the 3 parties included in the preparation of this report: Northern Gas Networks, Cadent, National Grid. Due to the early-stage nature of many of these projects, the plans for infrastructure developments are subject to change. Therefore, the analysis and data outputs are built with the most recent information, but these are also subject to change.

Certain companies included within this report have provided Letters of Support to 'East Coast Hydrogen' which is a shared body of the three parties. These Letters of Support are non-legally binding documents indicating early-stage strategic support for the high-level ambitions of the programme. East Coast Hydrogen reserves the right to amend pipeline routing and the strategic business case throughout subsequent stages of project development. All plans within this report are indicative at this time and remain as proposals which are not fully costed.

The logos shown on pages 27 and 35 shows companies that are located in the East Coast Hydrogen region based on publicly available information and does not necessarily indicate support of the East Coast Hydrogen programme.

East Coast Hydrogen and its logo are trademarked and protected.

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Key assumptions used for calculations within this report: domestic emissions are based on an annual household gas use of 12,000kWh/year, vehicles are assumed to emit 1,735 kgCO_2 per vehicle/year in the UK; mitigated emissions are calculated as the difference in Scope 1 emissions associated with gas consumption with emissions associated with hydrogen production; all hydrogen production is assumed to come from auto thermal reformation with a 95% CO_2 capture rate; investment cost is currently calculated as the total cost of the new, feasible hydrogen transportation pipeline for the Gas Distribution Networks and the conversion cost of the Humber-Tees pipeline of the National Transmission System excluding compressors and feeds.

01

East Coast Hydrogen is a mega infrastructure programme supporting the role of hydrogen in the UK

1.1) Net Zero and the UK's decarbonisation challenge

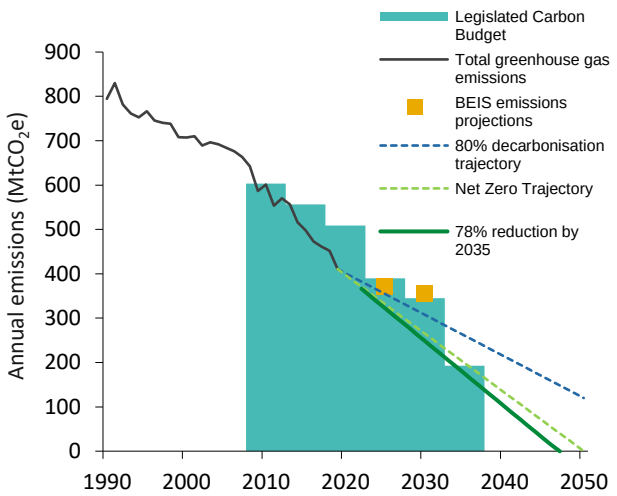
East Coast Hydrogen

The UK has made a number of commitments to reduce emissions to Net Zero by 2050 with hydrogen expected to play a key role.

Commitment to Net Zero

- **In June 2019, the UK Government revised the Climate Change Act (2008) to mandate a Net Zero greenhouse gas emissions target by 2050.** This was based on recommendations made by the Climate Change Committee (CCC) and represented a significant tightening of the previously held 80% reduction target.
- In December 2020, **the CCC published the Sixth Carbon Budget (CB6) which recommended a 78% reduction in greenhouse gas (GHG) emissions by 2035 which the UK Government has committed to as a legally binding target.**

The UK's carbon emission trajectories to 2050



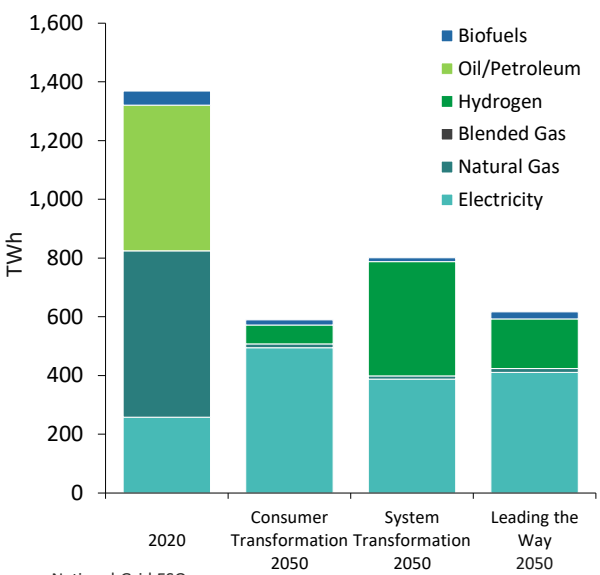
Source: BEIS

"The Government's announcement of the Track 1 Carbon Capture & Storage clusters in Teesside and the Humber, provides industry with the certainty it needs to invest in the low carbon hydrogen production at scale. East Coast Hydrogen takes that one critical step further; providing both connection and opportunity to export hydrogen into the regions – decarbonising heat, power and the heavy transport. It is only through combined efforts like this, that we will create a hydrogen economy and achieve Net Zero."
Jacob Young MP, Chair of the All Party Parliamentary Group on Hydrogen

The UK's emission trajectory

- Low-carbon hydrogen is expected to play an **essential role in a Net Zero UK across the heating, transport, power, and industrial sectors** according to the CCC and National Grid Future Energy Scenarios (FES).
- BEIS suggest that the UK could require between 250-460TWh of hydrogen by 2050, making up between **20 – 35% of the final energy consumption**[1].
- Across National Grid FES Net Zero compliant scenarios, **hydrogen is expected to provide between 11% & 49% of final annual energy demand in the UK by 2050**[2].

2050 annual end consumer energy demand[2]



Source: National Grid ESO

1. HM Government, "UK Hydrogen Strategy," 2021.
2. National Grid ESO, "Future Energy Scenarios," 2021 – Consumer demand includes homes, transport, industry and commerce and excludes demand for aviation, rail and maritime

Hydrogen infrastructure will need to rapidly develop in order to achieve Carbon Budget 6 and the UK's Net Zero target

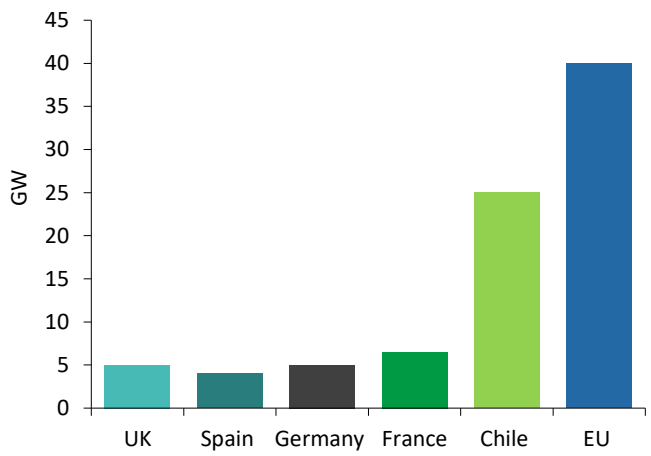
1.2) The UK's hydrogen policy and project pipeline

The UK's recently released Hydrogen Strategy is a step forward for hydrogen policy, focused on achievable actions and progress by 2030, reaffirming its target of achieving 5GW of hydrogen production in the UK by 2030.

H_2 The UK's hydrogen policy

- In August 2021 the UK Government published the UK Hydrogen Strategy which outlines the approach to developing a low-carbon hydrogen sector.
- The Strategy sets out the aim to achieve **5GW of low carbon hydrogen production by 2030, with at least 1 GW of production capacity by 2025**.
- £900 million has been made available in funding across the hydrogen value chain.
- The Hydrogen Strategy seeks to support over **9,000 UK jobs** and over **£4 billion in investment**.
- Other countries, such as Chile, have shown greater ambition in their 2030 Hydrogen production targets.

2030 Hydrogen Production Targets



Source: National Hydrogen Strategies

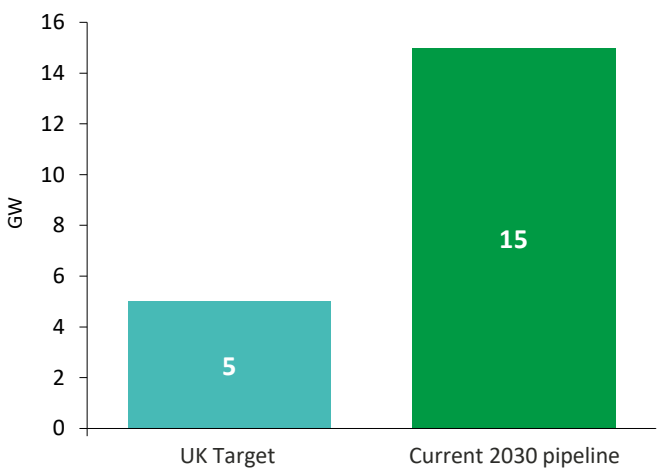
equinor

"Equinor is pleased to support the East Coast Hydrogen project in its ambitions to support the unlocking the value of hydrogen in the UK. This aligns with Equinor's wider hydrogen ambition, starting in the Humber region where we're planning to kick-start the hydrogen economy by building our flagship H2H Saltend low carbon hydrogen plant."
Dan Sadler, VP UK Low Carbon Solutions, Equinor

UK's hydrogen pipeline

- Five candidates have already been announced by the UK Government for the cluster sequencing programme **with 10GW+ of hydrogen production alone supported by the announced Track 1 Cluster projects (East Coast Cluster & HyNet)**.
- The UK Hydrogen Strategy stated that the **UK Government is aware of a pipeline of over 15GW of hydrogen production projects.**
- This **includes plans for over 1GW of electrolytic hydrogen projects,** ranging from concept stage to fully developed proposals, which are aiming to deploy in the early 2020s.

The 2030 UK target compared to the projected 2030 UK hydrogen pipeline capacity



Source: UK Hydrogen Strategy

Industry will aim to demonstrate to Government that even more ambitious hydrogen production goals can be achieved, providing the right conditions for investment can be met

1.3) Hydrogen economy

East Coast Hydrogen

The two current front-running hydrogen technologies (blue and green) have different upstream segments, but share similar midstream infrastructure and downstream end uses.

Upstream

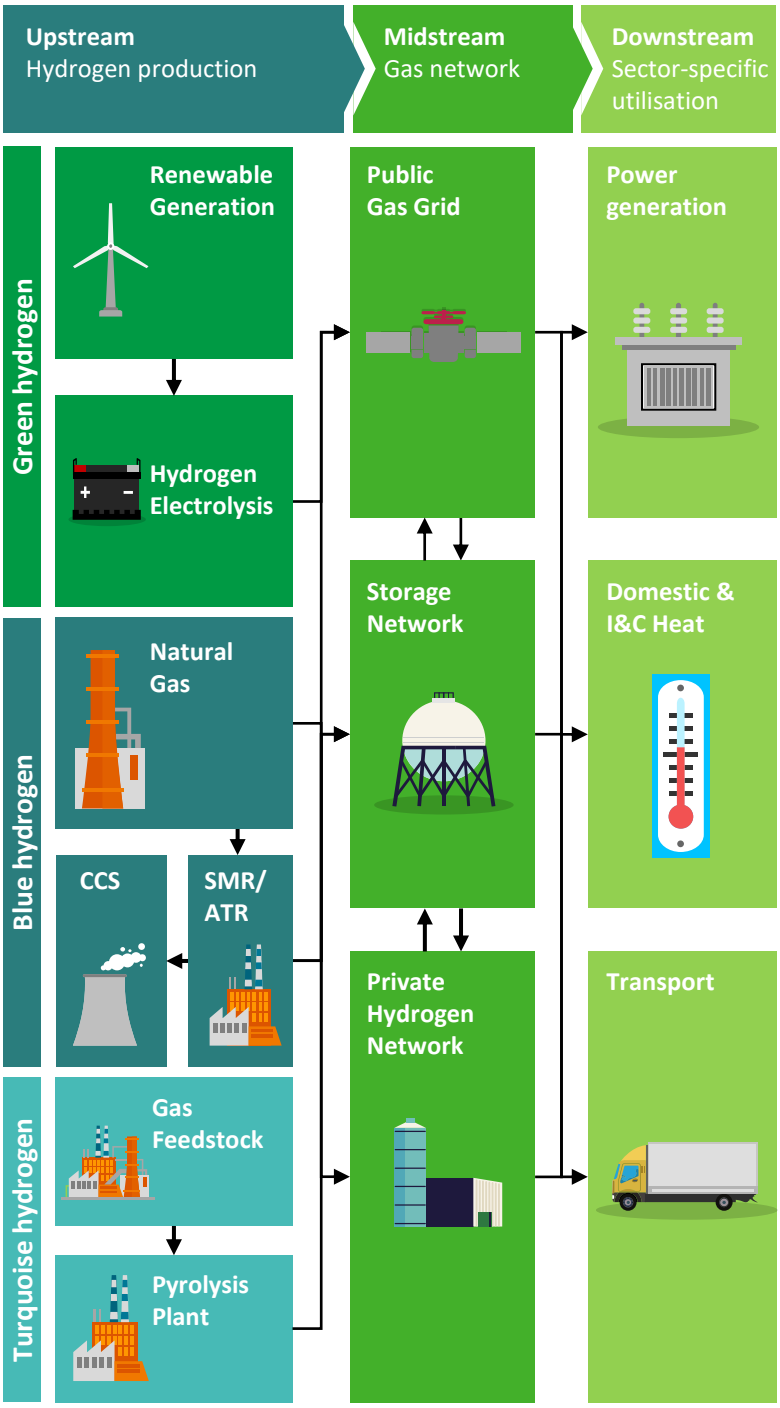
- **Green hydrogen** (produced by electrolysis) and **Blue hydrogen** (from Steam Methane Reforming (SMR) or Autothermal reforming (ATR)) have distinct upstream value chains, with unique chemical processes.
- **Blue hydrogen** production results in direct emissions, which are mitigated by utilising Carbon Capture and Storage **(CCS)**.
- **Green hydrogen**, produced using renewable electricity, presents the opportunity for truly zero carbon hydrogen production.
- **Pyrolysis (turquoise hydrogen)** is produced by splitting natural gas or biomethane directly into hydrogen and solid carbon.

Midstream

- **Both production technologies rely on the same midstream infrastructure** if production is located remotely from the application: injecting hydrogen into the gas grid; or direct delivery to large industrial users (via the cluster hydrogen network).
- Hydrogen can be transported through the gas grid by blending hydrogen into the existing natural gas mix, through dedicated new hydrogen infrastructure or repurposing existing gas infrastructure to carry hydrogen.

Downstream

- In many cases, blue and green hydrogen can be **used interchangeably for applications in industrial processes, power generation and domestic and commercial heat**.
- **Fuel cell applications (such as transport) require a higher purity of hydrogen** which is most easily achieved by utilising green hydrogen but can also be achieved through purification of blue hydrogen.

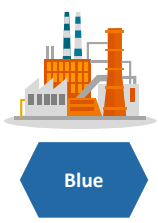
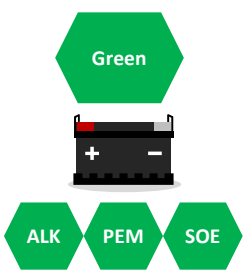


Rapidly growing demand for low carbon hydrogen production has driven an expanding pipeline of blue hydrogen enabled by CCS and green hydrogen from electrolysis projects

1.4) Hydrogen production methods

East Coast Hydrogen

Hydrogen is currently produced through an emissions-intensive process, but alternative methods provides an opportunity for emissions reduction potential.

Hydrogen Technology	Production method	Production Infrastructure	Estimated Construction Period	2030 Hydrogen production GHG emission ranges ($gCO_2eq/MJ\ H_2$) [2]
	• Produced in SMR or ATR plants, which separate hydrogen from natural gas through a chemical reforming process. • Around 96% of global hydrogen is produced from fossil fuels, mainly from SMR and ATR without CCS [1].	SMR / ATR	3 years	SMR: 78.3 – 91.7
	• As with Grey hydrogen, but with the addition of CCS which is integrated with the SMR/ATR plant. CCS has been successfully deployed globally across a number of end uses. • During SMR operation, heat is generated separately from the reformer requiring carbon to be captured from two streams. ATR generates heat directly in the reformer, allowing for a simpler capture process. • **Up to 90% of the carbon emissions can be captured and stored from the SMR process, while higher capture rates of up to 95% can be achieved from ATR**. However, the rate of carbon capture varies by facility [3].	SMR/ATR and CCS infrastructure	4 years	SMR: 13.0 – 42.1 ATR: 8.6 – 19.6
	• Renewable electricity is delivered to electrolysers, which pass the current through distilled water. Hydrogen separated from the water molecule passes through a membrane and is collected. • Alkaline electrolysis **(ALK)** is the most mature and cost-effective technology. However, proton-exchange membrane **(PEM)** electrolysers offer advantages in current density and producing high pressure hydrogen ready for transport or storage. Solid oxide electrolysis **(SOEs)** is the least developed technology but are the most efficient, requiring high temperatures to operate [4].	Electrolyser	1 year for small projects, but 1-3 years for larger projects	Grid: ~22.5 Renewable: ~0.64
	• Produced via **methane pyrolysis** which splits methane into hydrogen and solid carbon. • This process opens 'carbon-to-value' potential as the solid carbon can be used for several existing applications and can be sold as an additional product stream.	Thermal, catalytic, liquid metal/salt, or plasma methane pyrolysis infrastructure	1 year for small projects, but 1-3 years for larger projects	0*

* Methane pyrolysis produces solid carbon by-product, further research on end to end supply chain emissions is ongoing

1. R. Howarth, M. Jacobson, "How green is blue hydrogen?" 2021.
2. BEIS, "Consultation on a UK Low Carbon Hydrogen Standard," 2021.
3. Gorski *et al.*, "Carbon intensity of blue hydrogen production," 2021.
4. IEA, "The Future of Hydrogen," 2019.

Green and blue hydrogen, as well as emerging hydrogen technologies such as pyrolysis, will play a key role in delivering the volume low-carbon hydrogen required to end users

1.5) Hydrogen blending in the gas grid

East Coast Hydrogen

Blending presents a high benefit and low regret option for supporting the development of the hydrogen economy and decarbonising the gas network.

Immediate Emissions Reduction

A UK-wide rollout of a 20% blending mix can reduce annual emissions by approximately 6 million tonnes of CO_2 – equivalent to 2.5 million cars off the road[1].

Flexible Offtaker

Blending acts as a backstop demand and flexible off-taker for hydrogen, removing volume risks for producers and allows early scaling of production facilities distributed around the UK.

Consumer Experience

Hydrogen blending allows consumers to familiarise themselves with hydrogen in their home as part of a transition to decarbonised heating.

Jobs & Skills Creation

Facilitates and maintains skilled job creation in the energy sector.

Net Zero Delivery

Complies with the 6th Carbon Budget and progress to Net Zero as part of the Government's 10 Point Plan.

"We are delighted to be part of the East Coast Hydrogen development. As a start up in the Humber area it is crucial for us to ensure our unique zero emission turquoise hydrogen is included in the hydrogen development planning here in the UK." *Tim Davies, HiiROC CEO*

Case study: HyDeploy

- The first phase was successfully deployed at Keele University and demonstrated that **20% hydrogen blended** by volume gas can be used in homes **without requiring changes to appliances.**
- Phase 2 (HyDeploy2) which commenced in August 2021 is **supplying 668 homes in the town of Winlaton with a 20% hydrogen blend** and will last around 10 months.
- The project demonstrated the **safe and low-disruption service** hydrogen blending can provide to decarbonising residential heating via the distribution networks with FutureGrid assessing the blending future for the National Transmission System (NTS).

Northern Gas Networks | Cadent Your Gas Network | Progressive energy | ITM POWER

Case study: Project Knapton

- **HiiROC are supporting Third Energy to develop the former Knapton Generating Station** in North Yorkshire into Knapton Energy Park - a sustainable energy generation hub.
- Working with NGN and Centrica**, the park is looking to develop 40-50 tonnes per day of zero emission hydrogen from HiiROC's unique Thermal Plasma Electrolysis** with a number of uses including hydrogen blending into the gas grid from the facility, due to begin in the second half of 2023.

THIRD ENERGY | Northern Gas Networks | HiiROC | centrica

1. Energy Networks Association, 2021

Demonstration projects are proving the case that blending a mix of up to 20% hydrogen in the gas network can provide a safe, low disruption service with no changes to current appliances

1.6) 100% hydrogen in the gas grid

East Coast Hydrogen

The provision of a 100% hydrogen gas mix in the gas grid is currently being demonstrated across a number of projects with larger scale trials earmarked as part of the Government's Hydrogen Strategy.

Distribution:
What are the GDNs doing?

- The gas network is already being adapted to accommodate high volumes of hydrogen mix through the **Iron Mains Risk Reduction Programme (IMRRP)**, where the existing iron pipe networks are being replaced with polyethylene substitutes.
- NGN has already converted 76% of its network and Cadent already converted 78% of its Eastern Region to polyethylene.

Transmission:
Is the high-pressure system ready?

- Additionally, the suitability and safety of repurposing the existing Local Transmission System (LTS) and the National Transmission System (NTS) is being investigated in the **LTS Futures and FutureGrid NIC** projects.
- New-build LTS pipes have been proven to be hydrogen-ready through existing programmes and are ready to be deployed immediately.

End use:
Are our homes ready?

- The ease of use and safety of 100% hydrogen appliances are being demonstrated in the **Hydrogen Homes project,** opened in July 2021.
- This will be demonstrated on a larger scale with the Hydrogen Village trials which are currently in the outline design phase. These trials aim to deliver a 100% hydrogen network to around 2,000 properties by mid-2025.

Case Study: Hydrogen Home

- As part of the Hy4Heat innovation programme, **two semi-detached homes have been built which are supplied with 100% hydrogen**.
- The project aims to demonstrate the **readiness, ease-of-use, and safety** of a home operating with fully hydrogen-fed appliances including boilers, hobs, cookers, fires, and a barbeque.
- The project opened in July 2021 and forms part of the Government's Ten Point Plan to establish a hydrogen neighbourhood by 2023, hydrogen village by 2025 as well as a hydrogen town before 2030.

Cadent Your Gas Network | Northern Gas Networks | Department for Business, Energy & Industrial Strategy

Vaillant

"Blending up to 20% hydrogen into the gas grid is just the beginning, having been part of these trials we're proud to support the East Coast Hydrogen project, enabling the generation and delivery of hydrogen to achieve a 100% hydrogen system to truly decarbonise UK homes."
Klaus Jesse, Managing Director, Vaillant Group UK and Ireland

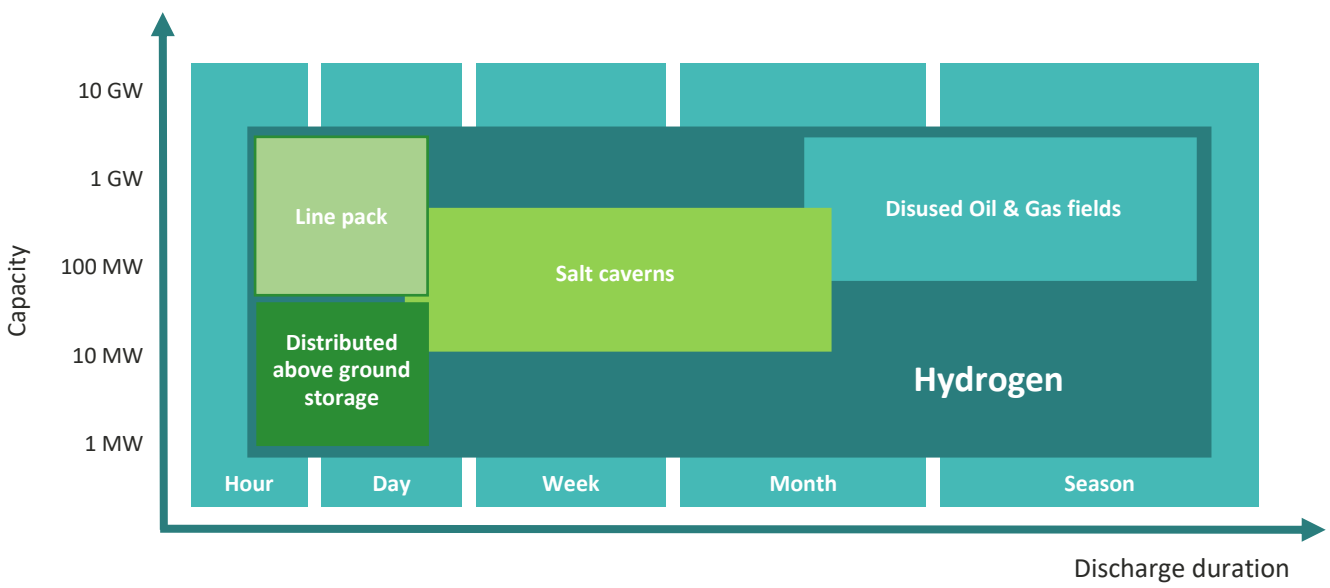
A number of planned and existing projects are already setting the course for a 100% hydrogen gas grid – ensuring that the industry is ready for the decision to decarbonise the gas grid

1.7) Hydrogen storage

East Coast Hydrogen

Hydrogen storage offers a clean and flexible energy storage option which can be stored in large volumes for long periods of time. Hydrogen storage plays a key role across all National Grid FES Scenarios with requirements for 12-51TWh of storage by 2050[1].

Technology group	Storage characteristics & services
Line Pack	• Line pack is the storage of gas in the higher-pressure pipelines of the transmission and distribution network. • **Line pack is used to provide large scale intra-day storage capacity.** The scale of its use shows the critical role of the gas network in the UK's energy systems.
Distributed above ground storage	• Generally smaller in capacity and **distributed close to areas of high demand**. • Similar to current natural gas storage, this generally takes the form of large above-ground storage vessels – reutilising existing gas storage assets. • More suitable to delivering **within-day flexibility and short term grid services**.
Salt caverns	• Generally involves large volumes of hydrogen for **weekly to monthly storage of energy to account for within-season weather fluctuations**. • The UK is well-suited for salt-cavern storage with **over 30 locations available for current or future use**.
Disused oil & gas fields	• Seasonal storage of energy to account for seasonal patterns in renewable energy generation. This service could also be delivered by developing sufficient numbers of smaller facilities. • **Disused offshore gas fields connected by pipeline to onshore gas terminals offer a huge storage potential** across the East Coast Hydrogen region.



1. National Grid ESO, "Future Energy Scenarios," 2021

Hydrogen offers both short-term and inter-seasonal storage solutions on a scale that no other low carbon technology can offer, and will form a vital part of future energy storage mix

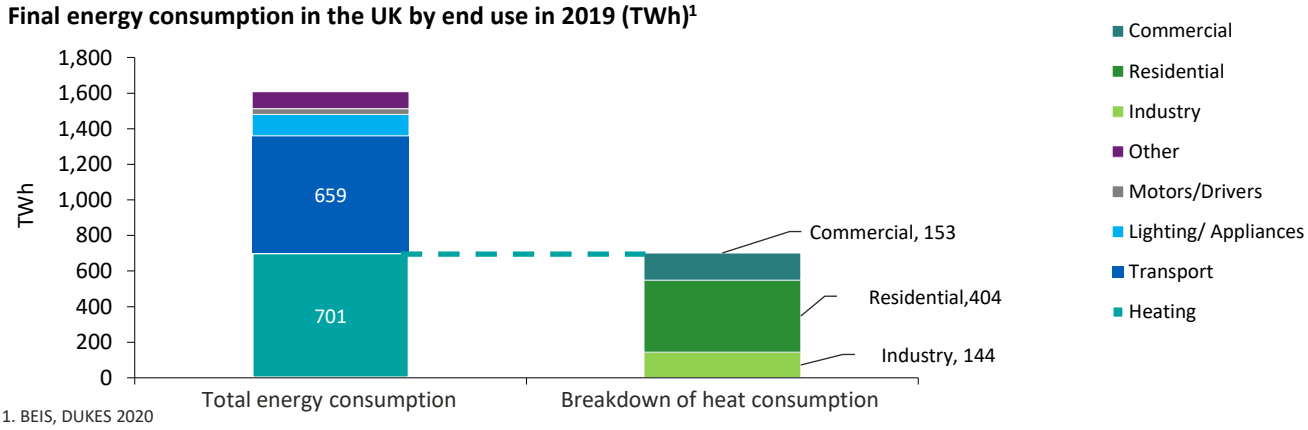
1.8) Heat decarbonisation

East Coast Hydrogen

Heating consumes around 701TWh of energy across the residential, commercial, and industrial sectors, accounting for 44% of the UK's final energy consumption in 2019[1]. This represents the largest potential source for hydrogen demand in the future net zero economy.

Sector	Current energy demand[1]	Decarbonisation pathways	Role of hydrogen
Industrial & Commercial	297 TWh	Hydrogen is a credible decarbonisation pathway for high temperature industrial processes (>400°C) where electrification is unsuitable or uneconomic as recognised by the £55m BEIS Industrial Fuel Switching Competition. Electrification is best suited for decarbonisation of industrial processes that require medium and low temperature heat (>400°C). Carbon capture and storage (CCS) is a alternative pathway for industrial processes located in areas where CCUS infrastructure is readily available.	A number of industries such as the glass, ceramic, cement, and iron/steel manufacturing require high temperature heat which can be provided by low-carbon hydrogen.
Residential	404 TWh	Heat pumps which can draw heat from air, land or water offer a potential decarbonisation pathway for residential heating. Hydrogen combustion in hydrogen-ready boilers offers the opportunity to utilise existing gas heating infrastructure with limited appliance modification. Heat networks with one central energy source that produces and distributes heat through insulated pipes to a network of homes can also contribute to the decarbonisation of heat.	Blending of hydrogen into the existing gas supply offers a low regret option for decarbonising the gas network in the short term. Provision of hydrogen in the gas grid has significant potential to decarbonise homes where alternate solutions are unsuitable.

Final energy consumption in the UK by end use in 2019 (TWh)[1]



1. BEIS, DUKES 2020

Hydrogen is a credible decarbonisation solution for carbon-intensive industrial sectors, offering a low-disruption natural gas fuel replacement which can reutilise existing infrastructure

1.9) Transport decarbonisation

East Coast Hydrogen

The transport sector accounts for 27% of the UK's total GHG emissions[1]. Hydrogen will likely be essential in achieving Net Zero by providing low emission solutions in transport modes such as heavy goods vehicles (HGVs), buses, trains, aviation, and shipping.

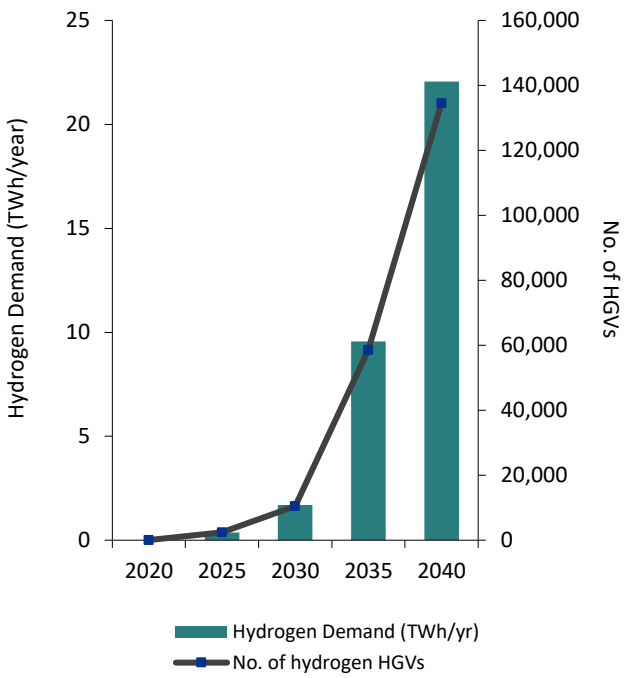
Opportunities

- UK Government's vision for hydrogen in transport focuses on the heavy transport and freight sectors.
- Freight transport hubs in the UK Midlands (Immingham, East Midlands Airport, DRIFT) present an important opportunity for developing hydrogen networks in freight decarbonisation.
- Fuel cell **HGVs are expected to make up 54% of new HGV sales in the UK by 2035, and account for 37% of the total fleet by 2040** to meet 6th Carbon Budget targets[2].
- The CCC assume that hydrogen powered rail will play a role where electrification is not cost effective in future energy scenarios.
- **Development of hydrogen internal combustion engines as an alternative to fuel cells** could enable grid transported hydrogen to be used in vehicles with limited purification.

Challenges

- **Depot-based transport and hydrogen purity requirements favour distributed green hydrogen production facilities** as hydrogen transmitted in networks will likely require purification or a wide roll-out of hydrogen combustion engines.
- Hydrogen fuel cell HGVs are still in the prototype phase with very limited commercial operation. The proof of concept will need to be demonstrated on a large scale before refuelling infrastructure roll-out and commercial uptake.

Projected Hydrogen HGV deployment and hydrogen demand per annum



Source: CCC

Hydrogen demand for **road freight** is expected to reach 1.7 TWh in 2030, increasing to 22.1 TWh by 2040 **– a 13-fold increase in 10 years[2].**

SIEMENS energy

"Hydrogen will be a vital part of delivering the UK's commitment to net zero greenhouse gas emissions by 2050. Siemens Energy is working on a range of relevant technologies involving production, handling and use of hydrogen. We therefore understand the need to develop and build a hydrogen network through the repurposing of existing gas infrastructure as well as the creation of new gas infrastructure."
Steve Scrimshaw, UK Vice President, Siemens Energy

1. BEIS, Energy and Emissions Projections 2019, 2020
2. CCC, The Sixth Carbon Budget: The UK's path to Net Zero, 2020

Hydrogen offers a easily transportable and storable solution to decarbonising carbon-intensive supply chains in the freight transport sector

1.10) GB Gas Industry

East Coast Hydrogen

The GB gas industry has delivered a reliable, safe natural gas supply to Great Britain for over 50 years through world-leading gas infrastructure.

GB coverage

- For over 50 years, natural gas has been transported through the network with **85% of UK homes, or 23 million, connected to natural gas through a network of 284,000km of pipelines.**
- In March 2018, when the UK was hit with an unexpected cold snap with temperatures as low as minus 14 Celsius, it was the gas networks that met the 55% increase in energy demand.

Future readiness

- The GDNs are delivering the **Iron Mains Risk Reduction Programme (IMRRP) to replace around 100,000km of low-pressure distribution pipelines** – essentially those that connect our homes – with polyethylene (PE). **This programme commenced in 2002/03** provides the added benefit of an ability to transport hydrogen.
- **Between 2014 and 2032, the programme will have invested £28bn in creating a hydrogen-ready gas grid** in towns, villages, and communities across the country. As it stands, the networks have converted 60% of the infrastructure and remain on track for completion by 2032, subject to regulatory funding approvals.[1]

Safety

- The GB pipelines are a national asset and a world-leading example of effective infrastructure operating at the **highest levels of safety and with reliability levels of 99.9%**[1]. In other words, on average, there is unplanned interruption to customer's gas supply once every 140 years.
- The IMRRP is delivering enhanced safety and reduced methane leakage, resulting in an even safer and more reliable gas grid.

HICP HUMBER INDUSTRIAL CLUSTER PLAN

"The Humber Cluster Plan is delighted to see the launch of the East Coast Hydrogen programme. The plans of East Coast Hydrogen to broaden the reach of hydrogen by repurposing existing gas infrastructure where possible, will provide a complementary route to significantly decarbonising large areas of northern England."
Jonathan Oxley, Humber Cluster Plan Manager

1. Energy Networks Association, 2021

The gas industry stands ready to continue to deliver on Great Britain's energy needs in a decarbonised future

1.11) Future of the UK gas system

East Coast Hydrogen

The current gas network connects 85% of homes and supplies 39% of the industrial sector's energy demand and will have a key role in supplying energy to a Net Zero UK.

World-leading H2 network

- **Project Union (see right)** is already aiming to develop a hydrogen 'backbone' by connecting industrial clusters across the UK**. Up to 25% of the National Transmission System will be repurposed to accommodate hydrogen**.
- This hydrogen transmission system will play a vital role in achieving the UK's net zero targets and future grid services.

Net Zero targets

- A national hydrogen & CCUS transmission system will be essential for achieving industrial net zero targets. Fair access to low-carbon hydrogen will be given to industrial emitters outside of the main industrial clusters.
- **Across all FES Net Zero scenarios, a minimum of 12TWh of hydrogen storage is required by 2050**[1] and a national hydrogen system will need to integrate storage facilities.
- Additionally, intra-day energy storage and grid services will rely on line-pack in the transmission network to manage the intermittency of renewable electricity generation.

Efficient system with resilient demand

- **Project Union has the opportunity to facilitate the connection of hydrogen production and storage,** initially concentrated in industrial clusters to decarbonise industrial demand and further to domestic and commercial users across Great Britain.
- The industrial clusters will form a baseload hydrogen demand to facilitate the fast expansion and growth of further hydrogen production.
- **The future grid system will aim to provide access for hydrogen to European and Irish markets**, further incentivising an integrated and resilient gas system.

The gas transportation systems:

System	Pressure level	Ambition
National Transmission System (NTS)	45 - 85 bar	**Project Union** aims to repurpose **25% of the NTS** by 2030 to connect the UK's industrial clusters with hydrogen. **East Coast Hydrogen will utilise this re-purposed infrastructure.**
Local Transmission System (LTS)	>7 - 70 bar	**As part of East Coast Hydrogen, Cadent and NGN will develop parallel new Local Transmission Systems** to enable a seamless conversion to hydrogen with further conversion of existing pipeline at a latter date for resilience.
Gas mains	Less than 7 bar and consists of the **Intermediate Pressure** (IP), **Medium Pressure** (MP), and **Low Pressure** (LP) systems	The **Iron Mains Risk Replacement Programme** is already underway to replace around **100,000 km** of distribution pipelines with hydrogen-ready materials. **East Coast Hydrogen will connect with this mains which are ready to accept hydrogen.**

1. National Grid FES, 2021

The gas system will be essential in achieving the UK's Net Zero targets and stimulating job creation as part of the UK Government's Green Industrial Revolution

02

East Coast Hydrogen represents a low regrets opportunity to decarbonise the East Coast

2.1) Why is the East Coast Hydrogen region the place to start?

East Coast Hydrogen

The existing gas infrastructure in the East Coast is extremely valuable to the region in terms of jobs, economic benefit and asset value. By enabling a transition to hydrogen in the East Coast networks, we can develop the existing infrastructure and realise the significant carbon benefit.

The East Coast region hosts concentrated industrial sites, large scale gas storage and offshore wind power. This makes it ideally placed to anchor the decarbonisation of the region through hydrogen production from multiple sources connected to a variety of demand points.

1. Interconnectivity

- **20% of the UK's domestic, industrial and commercial gas usage is in the East Coast Hydrogen region**[1].
- Access to the **Endurance, Bunter, Cygnus and Viking offshore storage sites** make the East Coast ideally placed for CCS and blue hydrogen production.
- **Proximity to the Theddlethorpe and Teesside** gas terminals provide access to future European hydrogen markets.
- Planned hydrogen infrastructure including concentrated hydrogen production centres and **salt cavern storage across Humber, Teesside and the East Midlands**.

2. Industrial decarbonisation

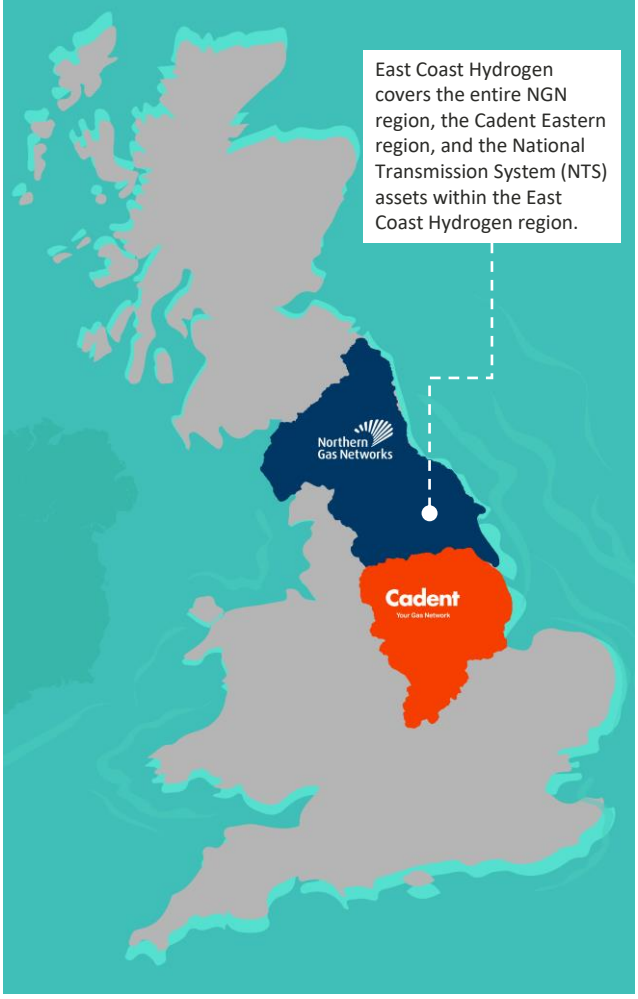
- The Humber and Teesside industrial clusters account for up to **50% of the UK's industrial cluster emissions**[2].
- The **East Coast Cluster has been selected as Track 1** in the sequencing process to be one of the UK's first industrial carbon capture programmes and is to be operational by **2025**. This cluster includes industries such as refining, and cement, lime, chemicals, and steel production.
- Hydrogen will play a key role in acting as a renewable feedstock and **replacing natural gas in many types of industries as a form of low-carbon heat**.

3. Domestic decarbonisation

- **Almost 90% of homes in the East Coast Hydrogen region are already connected to the gas network**[3]**.** Hydrogen is expected to have a role in decarbonising heating in these homes alongside electric heat pumps and other solutions.
- With a gradual replacement of appliances with hydrogen-ready versions over the replacement cycle**, hydrogen can provide a low-disruption heating solution** by replacing natural gas in the existing gas network.
- **HyDeploy, Hydrogen Homes, and H21 projects** in the region are demonstrating the safety, reliability, and minimal disruption to consumers of hydrogen in homes.

1. BEIS, "UK Energy in Brief", 2021 (Demand includes Industrial, Commercial, Domestic and Energy Services demand)
2. East Coast Cluster, 2021
3. Office for National Statistics, 2020.

East Coast Hydrogen region



Kellas Midstream

"Kellas Midstream are excited to work with the East Coast Hydrogen programme to significantly reduce carbon emissions in the North East and begin to develop the infrastructure needed for the UK's hydrogen economy. We see the East Coast Hydrogen project as a key enabler for collaboration within the industrial cluster." *Andy Hessell, Managing Director*

East Coast Cluster, access to storage & transmission assets, industrial areas, domestic properties and freight transport hubs make the East Coast region the logical place to start

2.2) East Coast Hydrogen is an anchor

East Coast Hydrogen

The development of a national hydrogen supply chain will require a starting point with sufficient production capabilities, storage capacity, network connectivity, and concentrated demand.

Production

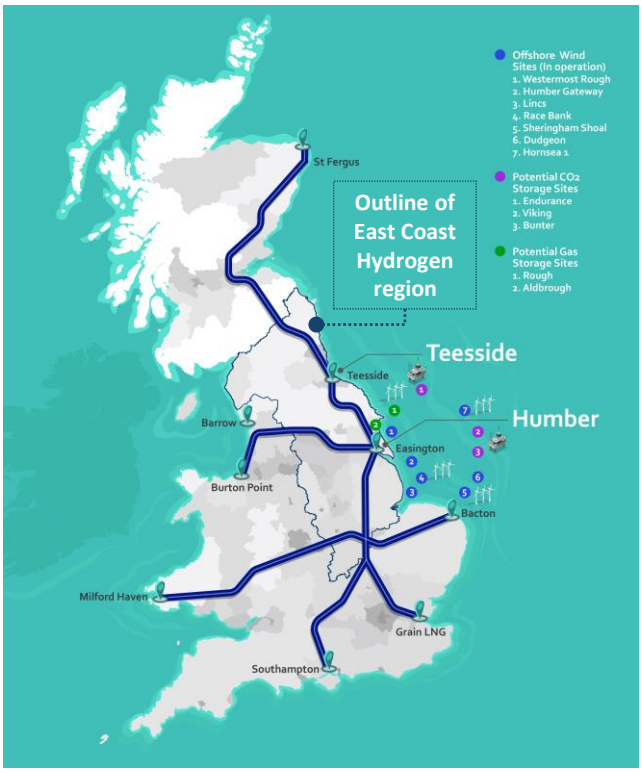
- **Over 7GW of hydrogen production capacity is in the pipeline in the East Coast Region by 2030,** which represents **over 140% of Government target by 2030**[1] with potential to increase further.
- The proximity to disused offshore oil & gas fields makes the region ideal for industrial decarbonisation and low-carbon blue hydrogen production.
- Access to **offshore wind farms** on the coast of the region position the East Coast perfectly for future green hydrogen production, with **3.4GW of wind capacity already online and a pipeline of over 10GW which have agreed connection dates** [2].

Storage

- The East Coast's access to **salt caverns such as Aldborough** and other large-scale hydrogen storage options make it the logical choice for anchoring a national hydrogen supply chain.
- **Rough is under review to resume its role** as a gas storage facility with potential to store hydrogen.
- **Salt caverns across the region and depleted gas field in the Southern North Sea** are well located to support the storage of hydrogen produced in the East Coast Hydrogen region.

Demand

- **20% of the UK's domestic, industrial and commercial gas usage is in the East Coast Hydrogen region**[3].
- **The Teesside and Humber clusters represent up to 50% of the total industrial cluster** emissions representing a large concentrated source of hydrogen demand and decarbonisation potential[4].



Key figures:

Over 7GW of hydrogen production capacity by 2030

20% of UK's domestic, commercial and industrial gas demand

bp

"The development of a safe and reliable hydrogen distribution network is critical to scale up hydrogen production, and bp is delighted to be working in partnership on the East Coast Hydrogen programme. An important part of bp's strategy is to deliver low carbon hydrogen to our customers, including on Teesside where it will help the region to decarbonise, and the push to get to Net Zero." *Matt Williamson, VP Hydrogen*

1. ICIS, 2021. & Company Announcements, 2021.
2. RenewablesUK,"Offshore Wind Project Timelines' 2021.
3. BEIS, "UK Energy in Brief 2021," 2021. *Demand includes Industrial, Commercial, Domestic and Energy Services demand*
4. BEIS, "Clean Growth Grand Challenge: Industrial Clusters Mission.", 2021

The East Coast's existing hydrogen production ambitions and ideal location make it the logical anchor for a national hydrogen supply chain

2.3) Industrial decarbonisation

East Coast Hydrogen

Hydrogen will play a prominent role in decarbonising the industrial and commercial sector by providing a low-carbon feedstock for industrial processes and commercial heat.

Hydrogen's role

- **The chemicals and oil refining industries** require hydrogen as a feedstock for a number of processes (e.g. Ammonia production) which are currently mainly supplied with grey hydrogen.
- A number of other industries such as the **glass, ceramic, cement, and iron/steel** manufacturing require high temperature heat which can be provided by low-carbon hydrogen.

East Coast Cluster

- The East Coast Cluster is a combination of the Humber and Teesside industrial clusters **accounting for up to 50% of the UK's industrial cluster emissions and 3.7% of the UK's total greenhouse gas emissions**[1].
- The cluster will **aid the decarbonisation of the Zero Carbon Humber and Humber Zero programmes** which contain a number of assets that are looking to convert to hydrogen such as Triton Power's Saltend Combined Heat & Power (CHP) plant in the Humber.
- **Decarbonising the cluster has the potential to create over 25,000 green jobs per year between 2023 and 2050**[2]. The cluster has had a successful Track 1 bid and is scheduled to be online by 2025.

Expanding industrial decarbonisation

- Expanding the CCUS infrastructure to surrounding industrial clusters with large hydrogen production facilities such as **V Net Zero and DelpHYnus** offers the opportunity to expand blue hydrogen production on the East Coast in the late 2020s.
- There are over **39,000 industrial and commercial gas connected sites from the Teesside and Humber clusters out to the East Midlands**.
- As hydrogen production scales up in the East Coast it gives the opportunity to **provide other industrial areas across the Midlands with fair access to low-carbon hydrogen**.

Key figures:

The East Coast Cluster is up to 50% of the UK's industrial cluster emissions

Over 39,000 industrial and commercial gas connected sites from the Teesside and Humber clusters out to the East Midlands

DelpHYnus

"Connecting the East Coast Hydrogen programme with the proposed DelpHYnus blue hydrogen supply at Theddlethorpe through the Humber and Teesside areas constitutes a critical strategic step in creating a competitive market for hydrogen."
Pierre Girard, Director of New Energy

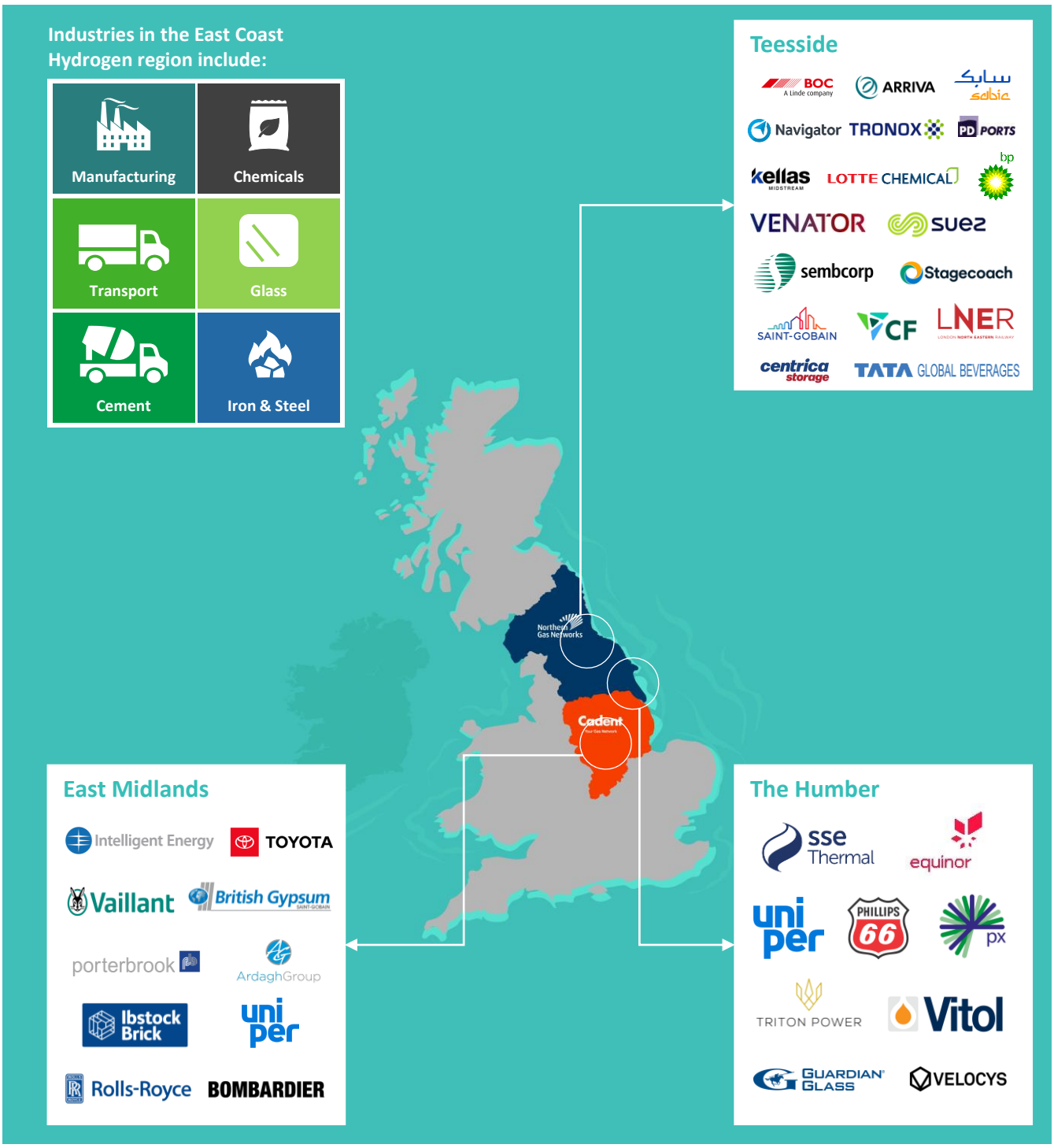
1. BEIS, "Clean Growth Grand Challenge: Industrial Clusters Mission," 2021.
2. National Grid, "New East Coast Cluster could decarbonise up to half of the UK's industrial cluster emissions", 2021

The industrial sector will be a significant and growing source of low carbon hydrogen demand in the future and critical to the achievement of Net Zero

2.4) East Coast industry

East Coast Hydrogen

The East Coast region covers two of the largest industrial clusters and extends into the major manufacturing and production hubs of the East Midlands covering a broad range of sectors.



Major industrial players across a range of industries in the East Coast have a credible pathway towards the decarbonisation of their operations through the use of low carbon hydrogen

2.5) Domestic hydrogen heating

East Coast Hydrogen

Up to 57% of the current housing stock in the UK have limiting factors to installing electric heat pumps[1]. Hydrogen will have a key role to play in providing low-carbon heat to many types of these homes in the UK.

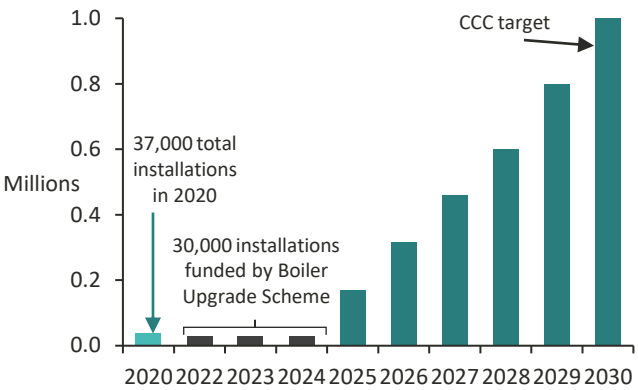
Future of residential heating

- A range of low carbon heating options will be required to be delivered at scale in order to achieve the decarbonisation of the UK's housing stock required for Net Zero.
- **Resistive electrical heating, heat pumps, heat networks and hydrogen boilers** are all likely to play a role in a Net Zero housing stock dependent on the suitability of properties to accommodate the solutions with Government expecting heat pump installation to ramp significantly in the mid 2020s.
- **At current rates of heat pump installation (37,000 in 2020) is behind schedule to meet emission reduction targets and the Government's Ten Point Plan's target of installing 600,000 heat pumps by 2028 [2,3].**

Hydrogen's role

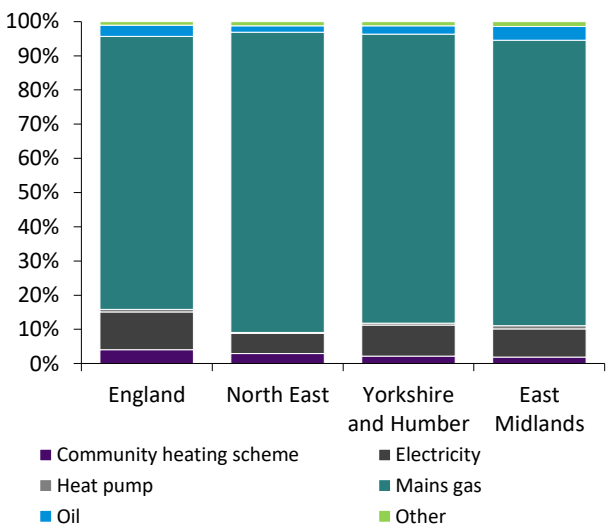
- **Up to 17 million homes in the UK may not have the space required for a heat pump and a hot water tank [1].** Hydrogen may need to play a role in these urban environments where the gas-based heating infrastructure already exists.
- Deployment of hydrogen-ready boilers may be crucial in meeting the International Energy Agency's (IEA) target of phasing out the sale of fossil fuel-based boilers by 2025 to stay on-track to meet global climate targets [4] where other heating solutions are less suitable.
- **Around 90% of the existing housing stock in the East Coast region is connected to the gas network[5]. Electric heat pumps will not be a suitable replacement for all, and hydrogen will have a role to play to partly or fully decarbonise heating in these homes.**

Heat pump installation targets



Source: BEIS

Type of Central Heating Used in the UK



Source: ONS

Key figures:

30,000 heat pumps per year subsidised by Government's boiler upgrade scheme from 2022 to 2024

90% of homes in the East Coast Hydrogen region connected to the gas grid

1. Energy & Utilities Alliance, "Decarbonising heat in buildings: Putting consumers first", 2021
2. HM Government, "Energy White Paper: Powering Our Net Zero Future," 2020.
3. HM Government, "Heat and Building Strategy," 2021.
4. IEA, "Net Zero by 2050: A Roadmap for the Global Energy Sector," 2021.
5. Office for National Statistics, 2020.

Hydrogen will have a key role to play in decarbonising heating in many UK homes where heat pumps or other low carbon heating solutions are not suitable

2.6) Domestic hydrogen heating trials

East Coast Hydrogen

The UK Government will make a strategic decision on hydrogen in domestic heating and cooking in 2026 with ongoing trials seeking to prove the use case for hydrogen in residential heating.

Safety

- A 20% volume hydrogen blend can be utilised and distributed safely within the existing gas network, with no disruptive changes for consumers. **HyDeploy 2 is gathering evidence to support a Nationwide roll out to homes by blending in to the public network to 668 in the village of Winlanton**.
- The **Hy4Heat** programme conducted tests at the **Spadeadam** site and found that with small adaptations to the gas piping to homes, 100% hydrogen can be as safe as the current natural gas system in homes[1].
- Projects under the H21 Programme also conducted tests at the **Spadeadam and Buxton test sites to demonstrate the safety and necessary changes required to convert the gas network to 100% hydrogen**.

Consumer Experience

- **The HyDeploy project has demonstrated an unchanged consumer experience through blending of 20% hydrogen by volume in the gas grid** without any changes required to appliances.
- Gas appliance manufacturers have developed 100% hydrogen ready appliances with **Worcester Bosch, Vaillant, Baxi and Ideal committing delivering hydrogen-ready boilers at no greater cost than natural gas equivalents**.
- **The Hydrogen Homes Project** has developed 2 homes which are currently on display with **boilers, hobs, cookers, and fires that utilise 100% hydrogen** which show that hydrogen can be easily used in the same way as current natural gas.
- **Government ambitions for a Hydrogen Village scale trial by 2025** represent the next step to demonstrating potential for wide-scale deployment of hydrogen heating.

Spadeadam

Image Credit: NGN

Hydrogen Homes

Image Credit: NGN

Domestic Hydrogen Heating Trials

H21 · Hydrogen Home · Hy4Heat · HyDeploy

Domestic hydrogen heating trial sites:

1. Gateshead (Hydrogen Homes)
2. Winlanton (HyDeploy 2)
3. Spadeadam (H21, Hy4Heat)
4. Buxton (H21)

Key figures:

668 properties on a 20% hydrogen blend in Winlanton

2 Homes operating on a 100% hydrogen supply

1. Hy4Heat, BEIS, "WP7 – Safety Assessment: Conclusions Report," 2021.

Domestic heating trials are demonstrating the safe, ease-of-use, and reliability of hydrogen in homes in preparation for the UK Government's strategic decision on hydrogen for heat in 2026

2.7) Why the East Coast Hydrogen region?

East Coast Hydrogen

The East Coast Hydrogen region represents an opportunity to kickstart a UK hydrogen economy owing to an abundance of natural resources suitable for hydrogen production and storage, as well as a significant potential to decarbonise industrial, commercial and domestic activity.

01 Interconnectivity

20%
UK's domestic, industrial and commercial gas usage is in the East Coast Hydrogen region[1]

6+
Accessible offshore CO_2 (Endurance, Bunter, Cygnus and Viking), and gas (Rough and Aldbrough) storage sites

3.4GW
Operational and 10GW+ pipeline of offshore wind capacity landing on East Coast[2]

02 Industrial decarbonisation

Up to 50%
UK's total industrial cluster greenhouse gas emissions accounted for by East Coast Cluster[3]

39,000+
Industrial and commercial gas customers connected sites from clusters out to the East Midlands

Late 2020s
DelpHYnus and V Net Zero industrial cluster bids with potential deployment date

03 Domestic decarbonisation

~6 million
Households connected to the gas grid across Cadent Eastern region and entire NGN network

5+
Multiple domestic hydrogen heating trials providing domestic conversion feasibility

75%+
Cadent Eastern and NGN networks are ready to transport hydrogen

1. BEIS, "UK Energy in Brief 2021," 2021. *Industrial and Commercial demand includes Industrial, Commercial and Energy Services demand*;
2. Renewables UK, 2021
3. East Coast Cluster, 2021;

03

What is East Coast Hydrogen and what are the benefits?

3.1) East Coast Hydrogen outline

East Coast Hydrogen

East Coast Hydrogen is an ambitious 15 year mega infrastructure programme aiming to decarbonise the most carbon-intensive sectors in the UK through the provision of low-carbon hydrogen.

01 Interconnectivity

Over 7GW
Current planned hydrogen production by 2030 in the East Coast Hydrogen region

~800km
Total repurposed and dedicated new-build hydrogen national and local transmission pipelines

~10TWh
Planned hydrogen storage capacity in the East Coast Hydrogen region

02 Industrial decarbonisation

Up to 39,000
Commercial and industrial sites supplied with low carbon heating and process fuel

Up to 24%
Annual UK industrial and commercial gas demand decarbonised by East Coast Hydrogen

Up to 11MtCO$_2$
Annual avoided commercial and industrial emissions by fuel switching from gas to hydrogen

03 Domestic decarbonisation

Up to 4.4 million
Domestic properties switched to a low carbon heating solution

Up to 17%
Annual UK domestic gas demand decarbonised by East Coast Hydrogen

Up to 9MtCO$_2$
Annual avoided domestic emissions from switching to a hydrogen gas supply

3.2) Overview of East Coast Hydrogen

East Coast Hydrogen

The Humber and Teesside industrial clusters will be connected using existing NTS infrastructure with expansion into the Cadent East and NGN regions through new-build LTS infrastructure, which will provide a continued supply of natural gas and seamless conversion to hydrogen.

Hydrogen Production Zones

- The successful Phase 1 East Coast Cluster submission, expected to come online in 2025, is composed of CO_2 transportation connecting blue hydrogen production plants and major industrial users across **Humber** and **Teesside** to the offshore Endurance CO_2 store.
- The East Coast region contains the DelpHYnus and V Net Zero cluster bids at **Theddlethorpe** with associated blue hydrogen projects that are likely to participate in the Phase 2 Cluster selection process.
- Green hydrogen production is also expected to be deployed in the **East Midlands Freeport** zone.

Local Transmission System

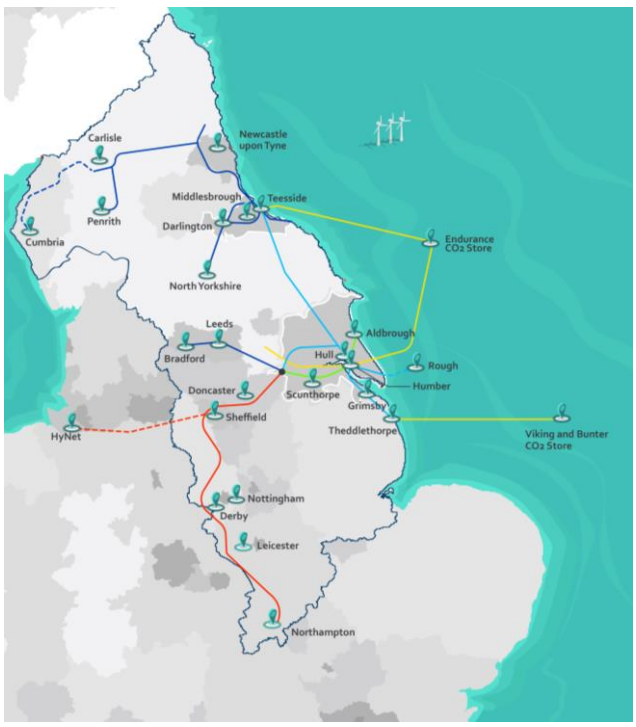
Cadent Your Gas Network

- **A 241km new-build Hydrogen LTS will serve the Cadent East region beginning in North East Lincolnshire and ending in Northampton** with further expansion opportunities across the Midlands.
- The pipeline will have the potential to serve **large industrial users & properties across South Yorkshire, Derbyshire, Northamptonshire Lincolnshire and Nottinghamshire with 78% of local Cadent Eastern networks already ready to carry hydrogen**.

Local Transmission System

Northern Gas Networks

- **A 396km new-build Hydrogen LTS will service the NGN region capturing over 95% of existing gas demand in the region**, with separate pipelines emerging from the Teesside and Humber clusters.
- The pipelines will have the potential to capture **large industrial users across Yorkshire, Tyneside and Cumbria with 76% of NGN networks already ready to carry hydrogen**.



Navigator

"For more than four decades on Teesside, Navigator has developed assets to safely and efficiently import export, store and blend chemicals and energy carriers. Navigator is excited to support East Coast Hydrogen and develop safe, flexible, and responsive infrastructure solutions to enable the decarbonisation of heat and transport."
Jason Hornsby, CEO, Navigator Terminals

National Transmission System

nationalgrid

- As part of East Coast Hydrogen, up to **200km of the NTS will be converted** to allow for the transportation of hydrogen, forming a key leg in Project Union's 'hydrogen backbone' across the UK and acting as a blueprint for conversion.
- **Feeder 6 running from the Teesside to the Humber region** will be the key enabler for the connection of the industrial clusters.

Legend

East Coast Hydrogen initial Scope

Future Expansion Opportunities

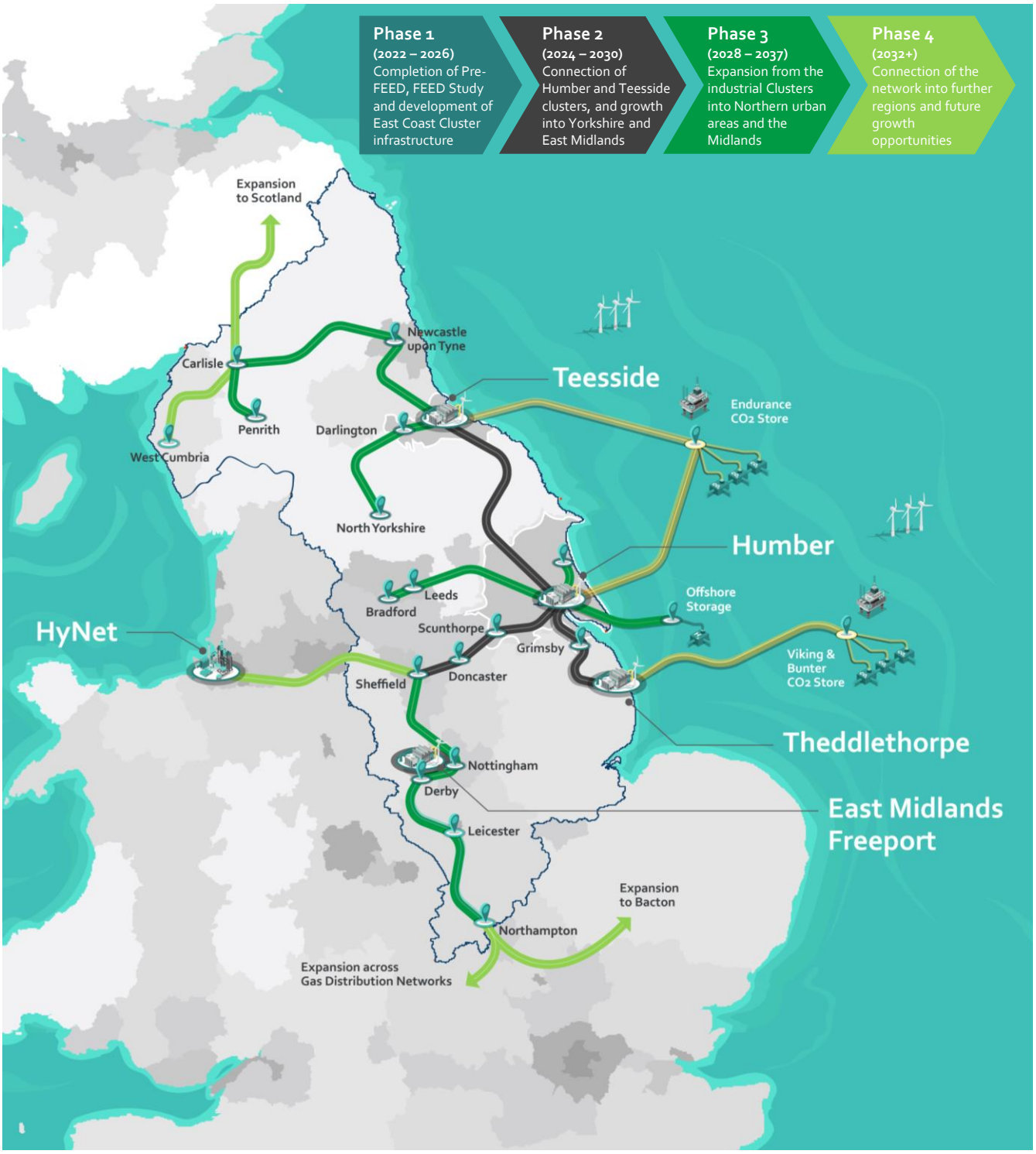
National Grid Hydrogen NTS | NGN Hydrogen LTS | Cadent Hydrogen LTS | Zero Carbon Humber Hydrogen Pipeline | Carbon Dioxide Pipeline

East Coast Hydrogen will connect hydrogen production zones with demand across the UK through repurposing existing infrastructure and building new Local Transmission Systems

3.3) Timeline of East Coast Hydrogen

East Coast Hydrogen

East Coast Hydrogen will re-purpose and develop new hydrogen infrastructure over 4 phases, enabling over 7GW of publicly announced hydrogen production projects by 2030 to export their hydrogen across the region up to 39,000 larger users of gas and up to 4.4 million homes.



East Coast Hydrogen's programme will expand across the region through discrete phases, connecting to hydrogen production, storage and end users as they come online

3.4) Hydrogen value chain

East Coast Hydrogen

East Coast Hydrogen will connect 7.37GW of announced hydrogen production projects by 2030 and potential hydrogen storage facilities across the East Coast Hydrogen region.

Hydrogen Production

	Project	Technology type	Location	Key Stakeholders	Year online	Capacity (MW)
1	**H2H Saltend**	Blue hydrogen	Saltend	equinor, sse	2026/27	600
2	**Keadby**	Blue hydrogen	Keadby	equinor, sse	Late 2020s	1,200
3	**H2Teesside**	Blue hydrogen	Teesside	bp	2027	500 (2027) 1,000 (2030)
4	**DelpHYnus**	Blue hydrogen	Theddlethorpe	Neptune Energy	By 2030	1,200
5	**Humber Zero**	Blue hydrogen	Killingholme	VPI, Phillips 66	Late 2020s	767
6	**H2NorthEast**	Blue hydrogen	Teesside	Kellas Midstream	2027	1,000
7	**Killingholme**	Blue hydrogen	Killingholme	uniper	Mid 2020s	720
8	**Gigastack (Phase 2)**	Green hydrogen	Killingholme	Ørsted, Phillips 66, ITM Power	Mid 2020s	100
9	**Protium**	Green hydrogen	Teesside		2026	40
10	**Killingholme**	Green hydrogen	Killingholme	uniper	Mid 2020s	100
11	**H2Green**	Green hydrogen	Teesside	bp	2030	500
12	**Knapton**	Turquoise hydrogen	East Knapton (Yorkshire)	Third Energy, Northern Gas Networks	2023/24	50
13	**Waste Gas to Hydrogen**	Turquoise hydrogen	Near Immingham		2023+	100

Hydrogen Storage

Project		Technology type	Location	Key Stakeholders	Year online	Capacity (GWh)
1	**Rough**	Depleted gas field	Easington	centrica storage	Late 2020s	Up to 10,000
2	**Aldbrough**	Salt caverns	Aldborough	equinor, sse	2028	320+

Key figures:

Over 7GW of announced hydrogen production by 2030

Potential storage of 10TWh+ equivalent to over a week's residential gas demand in the UK

A pipeline of projects to be delivered by 2030 equivalent to over 140% of the Government's 5GW 2030 hydrogen production target has been announced in the East Coast Hydrogen region

Project location may be indicative and not representative of the true location.

3.5) Industrial & commercial decarbonisation impact

East Coast Hydrogen

The East Coast Hydrogen region has access to a substantial portion of the UK's industrial and commercial energy use. Replacing this current natural gas demand with hydrogen will have a significant decarbonisation impact.

Industrial & Commercial reach

- There are over **7,000 industrial sites**[1] in the East Coast Hydrogen region. These sites cover a range of industrial sectors such as **steel, cement, glass, and chemicals production along with manufacturing and CHP plants**.
- **High temperature industrial processes such as glass and steel production are an ideal candidate for fuel switching to hydrogen** whilst low temperature processes are more likely to electrify.
- The region also has access to up to **32,000 commercial customers**.

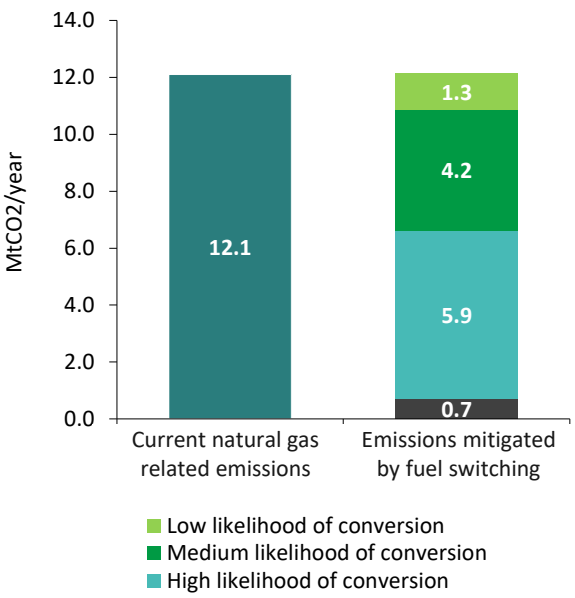
Energy demand

- Industrial and commercial sites in the East Coast region make up **66.1TWh**[1] **of natural gas demand per year** accounting for **24% of the UK's total industrial and commercial gas demand**[2].
- Likelihood of future hydrogen demand of industrial and commercial sites has been assessed based on analysis of gas usage suitability for alternative decarbonisation pathways such as electrification and CCS and company announcements.

Decarbonisation impact

- With the replacement of the gas energy demand of the industrial and commercial sites with blue hydrogen produced via ATR expected from early deployments, direct emissions from **industrial and commercial gas demand can be reduced by up to 94%***.
- Residual emissions from blue hydrogen will be replaced as green hydrogen production comes online.
- There is potential for emission saving of **11.4 $MtCO_2$/year,** equivalent to **17% of the UK's total industrial and commercial emissions if all potential sites are converted**.
- **52% of industrial and commercial gas usage in the region has been assessed to be highly likely to switch to hydrogen, equivalent to a saving of 5.9$MtCO_2$/year**.

Potential annual industrial & commercial direct emissions avoided through fuel switching



Case study: Triton Power's Saltend Combined Heat & Power (CHP)

- **Triton Power** is working with project partners **Equinor and Mitsubishi Power** to develop the **1,200 MW Saltend CHP plant.**
- The site can play a crucial role in the Humber hydrogen economy by helping to decarbonise the Saltend Chemicals Park through the **provision of low carbon heat and power for large industrial emitters**, in addition to the provision of low-carbon electricity to the wholesale electricity market through the **combustion of clean hydrogen**.

Image Credit: Hull Daily Mail

1. Cadent, NGN, 2021.; 2. BEIS, "UK Energy in Brief 2021," 2021. *Industrial and Commercial demand includes Industrial, Commercial and Energy Services demand*; 3. BEIS, "2020 UK greenhouse gas emissions, provisional figures," 2021.; 4. NibleFins, "Average CO_2 emissions per car in the UK," 2021.

Hydrogen has the opportunity to decarbonise a significant proportion of industrial processes and commercial heat across the East Coast Hydrogen region

3.6) Residential decarbonisation impact

East Coast Hydrogen

The East Coast Hydrogen region connects a large percentage of England's homes to the gas network and the provision of hydrogen would enable the seamless decarbonisation of homes.

Residential reach

- The East Coast Hydrogen region covers almost **66% of Cadent Eastern region's domestic connections and over 95% of NGN's domestic connections**.
- In total, there are almost **4.4 million homes connected to the NGN and Cadent distribution networks** along the East Coast Hydrogen route.
- This represents energy demand of **51.6TWh per year, or 17% of the total annual domestic natural gas demand in the UK** [2].

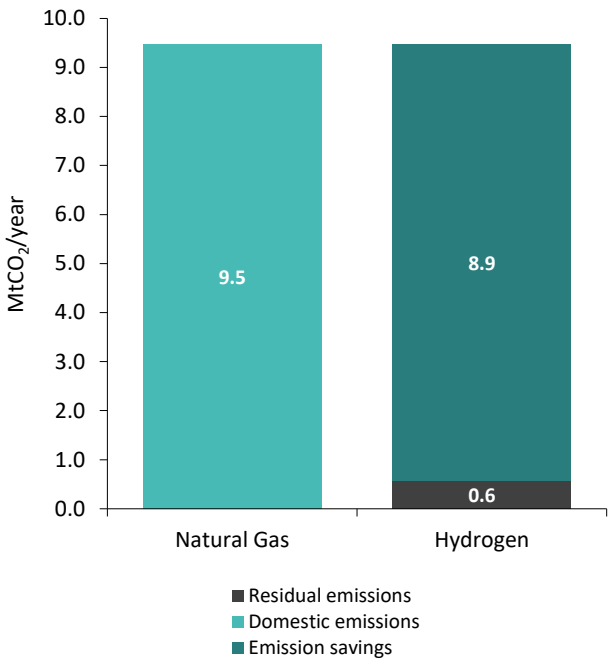
Impact

- The impact of fuel switching of residential heating to hydrogen in the East Coast Hydrogen region **is highly dependent on the consumer's choice of domestic heating technology**.
- By replacing total current domestic natural gas demand in the region with a blue hydrogen supply as expected in early years of the programme, there is potential to **reduce domestic direct emissions by 8.9 $MtCO_2$/year equating to 13% of the UK's total annual residential emissions**[3] .
- Residual emissions of 0.6$MtCO_2$ could be mitigated as green hydrogen production scales up in the later periods to 100% of the network's hydrogen supply.

Connecting beyond

- Over **50,000 properties in the East Coast Hydrogen region that are off-grid** will have the potential to connect to a low-carbon heating supply, working to alleviate fuel and heat poverty, in line with a net zero future[4].
- The East Coast Hydrogen region is also well positioned with the potential to expand the hydrogen distribution network further into **Cadent's Eastern Region in the Midlands as well as linking with the West Midlands and the HyNet programme on the West Coast**.

Domestic emissions in the East Coast Hydrogen region avoided through fuel switching



Key figures:

4.4 million gas connected properties

13% of total UK residential emissions

West Yorkshire Combined Authority

"West Yorkshire has ambitious plans to decarbonise by 2038, but we need the right net zero infrastructure to get there. The East Coast Hydrogen programme provides the critical infrastructure needed to support the decarbonisation of public transport, business and industries and create green, high skilled jobs across the region."
Tracy Brabin, Mayor of West Yorkshire

1. HCLG, "Dwelling Stock Estimates," 2020.; 2. BEIS, "UK Energy in Brief 2021," 2021.; 3. BEIS, "2020 UK greenhouse gas emissions, provisional figures," 2021. 4. ONS, 2019.; 5. NibleFins, "Average CO_2 emissions per car in the UK," 2021.

East Coast Hydrogen presents the opportunity to decarbonise up to 4.4 million homes providing a green light for hydrogen utilisation in the HMG strategic heat decision in 2026

3.7) Energy system resilience

East Coast Hydrogen

With the growing contribution of intermittent renewable power in the UK's electricity generation mix, sufficient storage capacity will be required to balance future energy supply and demand.

The necessity of Hydrogen energy storage

- Energy demand is seasonal, with **peaks during winter and troughs during summer.** To ensure enough energy is available to meet peak demand whilst avoiding generation overcapacity during low demand, **sufficient energy storage is required**.
- Without hydrogen storage, around **500-600GW** of installed wind capacity would be required to supply the UK power demand, compared to **140-190GW** of wind with around **140TWh** of hydrogen storage.[1]

East Coast storage

- **Geological salt deposits across the East Coast region and depleted oil and gas reservoirs off the East Coast** provide a significant opportunity for large-scale hydrogen storage.
- Conversion of existing salt caverns or creation of new purpose-built caverns at **Aldbrough** presents a great opportunity for storage of hydrogen produced in the Humber region.
- Potential repurposing of the **Rough gas storage facility** and other disused oil and gas wells to accommodate hydrogen could play a key role in delivering inter-seasonal gas storage.

A resilient future energy system

- Gas storage infrastructure already exists in the form of line pack in the gas network for **short-term storage**, or large **inter-seasonal storage** facilities.
- This **existing gas storage infrastructure can be adapted with few upgrades to accommodate hydrogen** although performance is impacted with higher hydrogen content in the gas grid.
- The future Net Zero energy system will rely on hydrogen storage to balance energy production and demand and integration with the power system.

Case study: Rough gas storage facility

Background

- Rough is located off the Yorkshire coast and has previously held 70% of the UK's gas storage capacity.
- At peak operation, the facility could store up to 41TWh of gas supply to provide inter-seasonal storage for the UK[1].
- The site was closed in 2017 at the end of its design life.

Hydrogen at Rough

- With the growing need for hydrogen storage, **Rough is being explored as a potential large-scale hydrogen storage site**.
- The location is **ideally placed near to the East Coast of the UK** to play a role in the growing hydrogen economy in the region.
- The facility can **provide up to 10TWh of low-carbon hydrogen storage** as part of a balanced national hydrogen storage supply.

Image Credit: Centrica

centrica storage

"Rough is the 'goldilocks' of storage and is perfectly suited to provide scalable and flexible green energy storage. Once an icon of the fossil fuel age, redevelopment of Rough to provide resilience to the UK energy system provides a unique and world leading opportunity to kick start the hydrogen economy."
Martin Scargill, Managing Director, Centrica Storage

1. Gas Goes Green, "A System for All Seasons," 2021.

Hydrogen plays a key role in power system balancing in all of National Grid's Net Zero Future Energy Scenarios and storage facilities would play a key role in inter-seasonal balancing

3.8) Expansion opportunities

East Coast Hydrogen

The East Coast Hydrogen programme is ideally placed to expand a hydrogen network to other industrial clusters, distribution networks, the freight transport sector, and regional industry.

Track 1 clusters

- **HyNet on the West Coast at Merseyside** has been selected as a Track-1 industrial decarbonisation site alongside the **East Coast Cluster.**
- The proximity of the clusters presents the opportunity to connect them via a hydrogen pipeline in the near future. This will provide the **benefits of flexible off-taking and security of hydrogen supply** for both sites.

Expansion to GB gas distribution networks

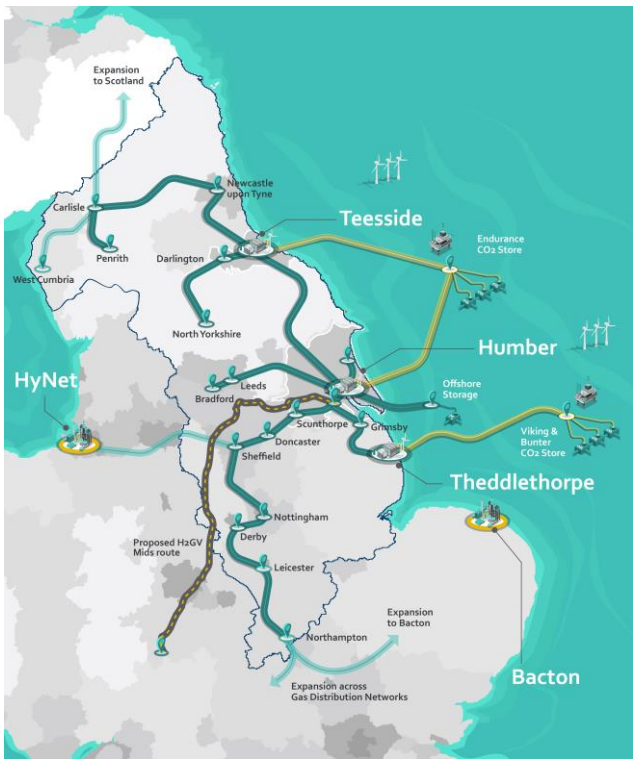
- As the demand for hydrogen grows, there will significant opportunity to connect hydrogen supply to millions more homes, businesses, and industries by **expanding further into Cadent's infrastructure, and partnering with other distribution networks, Wales & West Utilities and Scotia Gas Networks** to advance Great Britain's hydrogen backbone.
- As **additional hydrogen clusters develop such as the Bacton project in East Anglia**, there will be more opportunity to grow the distribution network by linking sources of hydrogen supply.

Hydrogen transportation

- Freight transport hubs in the UK Midlands including **Immingham and East Midlands Airport** present an important opportunity for developing hydrogen networks in freight decarbonisation.
- With up to **3,000 trucks leaving the Immingham port per day,** the East Midlands are ideally placed to pilot and roll-out hydrogen refuelling networks, with the **H2GV Mids Consortium** exploring this opportunity.

Regional Industry

- Industrial sites in **Cumbria** and further into **the North and Midlands** will form important sites of hydrogen demand.
- **Overall, all industrial clusters across Great Britain will need to be decarbonised in order to meet net zero emission targets.** The East Coast is ideally placed to facilitate the expansion of a UK-wide hydrogen network.



Case study: H2GV Mids

- H2GVMids is a **feasibility study for a hydrogen fuelled HGV demonstration project** led by EDF and the Energy Research Accelerator and funded by HM Government.
- The study will create a **plan for the optimal distribution of hydrogen refuelling stations** and is considering a route that includes key transport hubs at the Humber and East Midlands Freeport sites.
- Cadent's work on the **purification of pipeline transported hydrogen, and the synergies between the proposed local transmission routes and transport hubs**, could enable a re-purposed gas network to serve re-fuelling stations for HGVs.

ERA Energy Research Accelerator | Midlands Engine | EDF | cenex

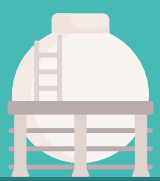
East Coast Hydrogen will act as a blueprint for regional network conversion to hydrogen, supporting the broader ambitions of Project Union and a decarbonised gas grid

3.9) Contribution to the UK

East Coast Hydrogen

The East Coast Hydrogen programme will play a significant role in achieving HMG targets from 'The Ten point plan for a green industrial revolution' across job creation, hydrogen production, decarbonisation and emission targets, and investment.

Hydrogen production



- **Over 7GW of Hydrogen production is planned to come online in the East Coast region by 2030** fulfilling all of the UK Government's 2030 target of 5GW, plus an additional 2GW+.
- There is future ambition to connect with 5GW of hydrogen production scheduled to **come online by 2030 in the HyNet industrial cluster**.
- The **CCUS infrastructure developing as part of the V Net Zero & DelpHYnus projects** in the East Coast will facilitate further growth of low-carbon hydrogen production.
- **Green hydrogen production is expected to be deployed in the East Midlands Freeport** area with confirmation of Hydrogen Business Models.

Jobs & local economy

- **East Coast Cluster will deliver 9,000 jobs at peak in 2026** in relation to hydrogen which would satisfy 100% of HMG's target of 9000 hydrogen jobs by 2030[1].
- Derbyshire and Nottinghamshire have the opportunity to support a minimum of **800 new jobs in the hydrogen supply chain by 2030[2]**.
- The UK North Sea could deliver **£20bn a year in GVA by 2050 from offshore wind and hydrogen leading to a net increase of 40,000 jobs[2]**.
- Through the project partners, East Coast Hydrogen will develop and maintain a **skilled green workforce building on extensive capabilities** across the gas supply chain.

Decarbonisation

- East Coast Hydrogen has the opportunity to contribute to the decarbonisation of **over 39,000 industrial sites with gas consumption emissions equivalent to 17% of the UK's total industrial and commercial emissions**.
- East Coast Hydrogen has the opportunity to reduce total UK emissions by up to 20 $MtCO_2$/year **equating to up to 6% of the UK's total annual emissions[3]**.
- Rapid decarbonisation of hard to abate industrial processes and residential heat as part of East Coast Hydrogen will play a **key role in achieving Carbon Budget 6 objectives**.

Investment

- **Over £850 million investment will be required** for the conversion and construction of new transmission pipeline infrastructure**. (See page 49 for breakdown)**
- Investment in a Net Zero compliant gas grid **will safeguard continued supply chain spend in the gas industry within the East Coast totalling over £1bn in 2020**.
- The East Coast Hydrogen programme will **unlock the opportunity for large industrial users** across the Cadent Eastern and NGN regions to invest in fuel switching to hydrogen with the prospect of a **reliable hydrogen supply via the gas grid**.

1. East Coast Cluster, 2021; 2. Arup, "Establishing a Hydrogen Economy in Derby", 2021; 3. BEIS, "Energy & Emissions Projections", 2021

East Coast Hydrogen has the opportunity to drive the delivery of the UK Government's key priorities with ability to hit nationwide hydrogen production and hydrogen job target alone

04

How will we deliver East Coast Hydrogen?

4.1) Overall programme roadmap

East Coast Hydrogen

East Coast Hydrogen is a 15+ year mega-programme that will be carried out in multiple, discrete phases to decarbonise industrial processes and domestic heating in the East Coast region.

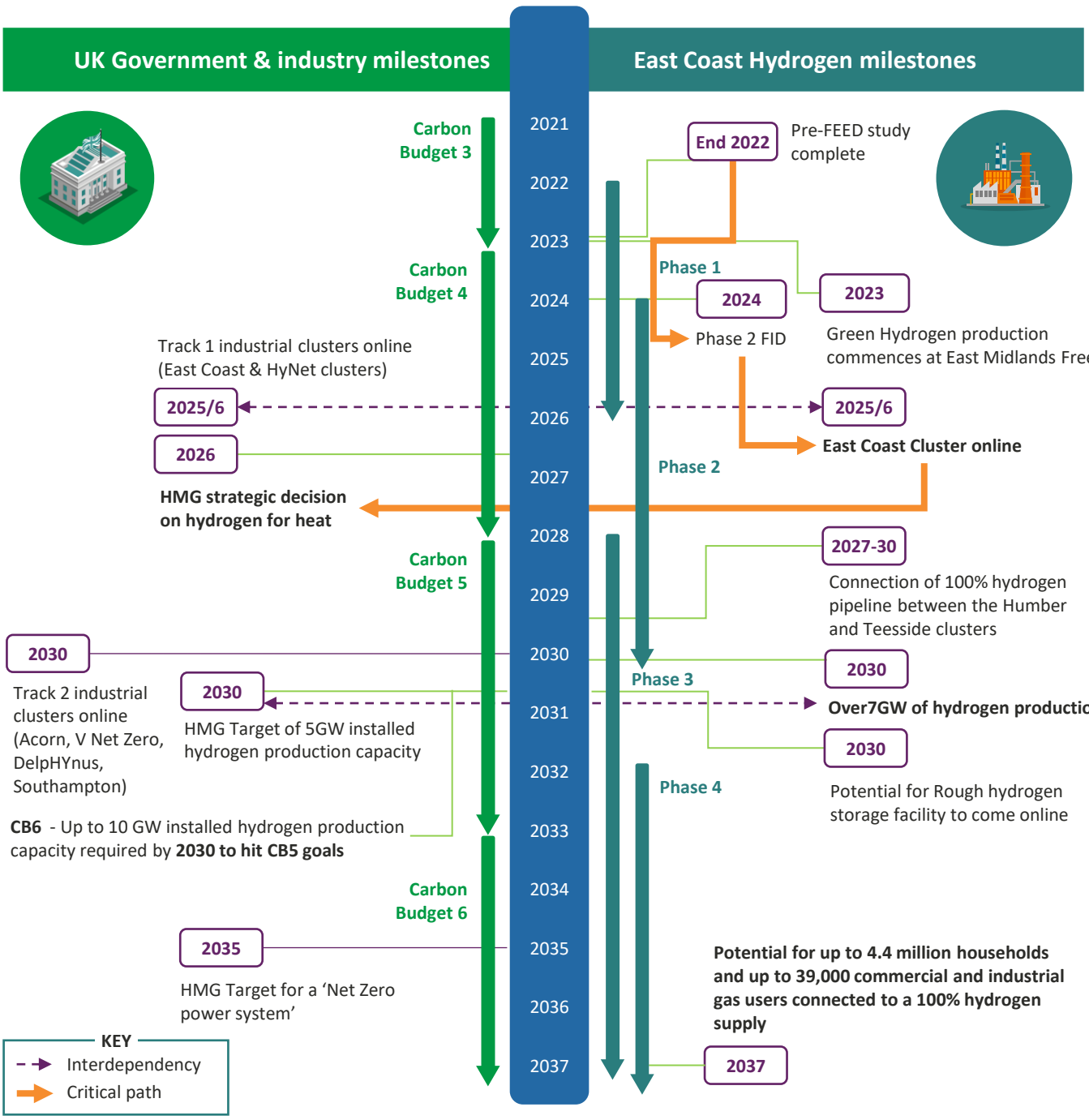
	Feasibility Study Definition of the strategic business case for East Coast Hydrogen	**Phase 1 (2022 – 2026)** Completion of Pre-FEED, FEED Study and development of East Coast Cluster infrastructure	**Phase 2 (2024 – 2030)** Connection of Humber and Teesside clusters, and growth into Yorkshire and East Midlands	**Phase 3 (2028 – 2037)** Expansion from the industrial Clusters into Northern urban areas and the Midlands	**Phase 4 (2032+)** Connection of the network into further regions and future growth opportunities
Objectives	• Lay out strategic business case and decarbonisation potential of the programme.	• Conduct detailed design and assessment of technical feasibility of the programme.	• Connect Humber and Tees clusters through the NTS and expand into Yorkshire. • Growth of local network in East Midlands Freeport Zone.	• Expand the project into Northern urban areas and the Midlands. • Connection of South Yorkshire to East Midlands Freeport Zone.	• Expand further across NGN and Cadent East's networks and connect to neighbouring projects.
Overview	*This Feasibility Study*	• Phase 1 will involve the Pre-FEED and FEED studies for East Coast Hydrogen to complete detailed design of and confirm technical feasibility of the programme. • Simultaneously, during this period, East Coast Cluster infrastructure will be deployed, enabling blue hydrogen production in the Humber and Teesside to come online. • The results and learnings from the existing hydrogen projects in the East Coast Hydrogen region will be harnessed for East Coast Hydrogen. • Green hydrogen production starts in East Midlands Freeport Zone.	• Phase 2 will see the connection of the Humber and Teesside clusters through the repurposing of the Humber-Tees leg of the National Transmission System to carry 100% hydrogen, enabling the transportation of hydrogen between clusters. • Connection of over 5GW of hydrogen production across Humber and Teesside, will enable the programme to expand through the Local Transmission System (LTS) into the nearby Yorkshire urban areas. • Growth of local network connecting green hydrogen production to industrial and transport users in East Midlands Freeport Zone.	• Phase 3 will see the potential connection of the additional industrial clusters, DelpHYnus and V Net Zero to the programme. • The programme will expand north through NGN's LTS into Newcastle upon Tyne and west towards Cumbria passing through Carlisle and Penrith. • Network will grow north and south from the East Midlands Freeport Zone, connecting to South Yorkshire, Leicestershire and Northamptonshire.	• Phase 4 will seek to further expand the programme through Cadent's Eastern region with the potential connection with the HyNet industrial cluster in Merseyside. • Connection with HyNet has potential to connect 10GW+ of announced hydrogen production capacity across based in the industrial clusters. • Furthermore, the programme will expand through the Midlands, with potential to link with hydrogen production at Bacton, as well as through the NGN region towards West Cumbria.
Outcomes	• Initial routing outline. • Value chain assessment. • Stakeholder consortium.	• Detailed project roadmap. • Technical appraisal.	• Dedicated hydrogen pipeline between Humber and Tees. • Project expansion into Yorkshire.	• Connection of Nottinghamshire and Derbyshire. • Connection of Northern urban areas. • Connection to Northamptonshire.	• Connection to neighbouring projects (HyNet). • Connection to Bacton and other Cadent Eastern locations.

The East Coast Hydrogen Feasibility Report is the first stage in a long journey and connection timelines may differ following further investigations within the pre-FEED stage

4.2) Key programme milestones

East Coast Hydrogen

Several key milestones must be met across the hydrogen value chain in order to deliver the programme's decarbonisation and resilience targets. The CCC and UK Government have recognised the importance of hydrogen in meeting Net Zero, and East Coast Hydrogen's milestones will deliver on these targets.

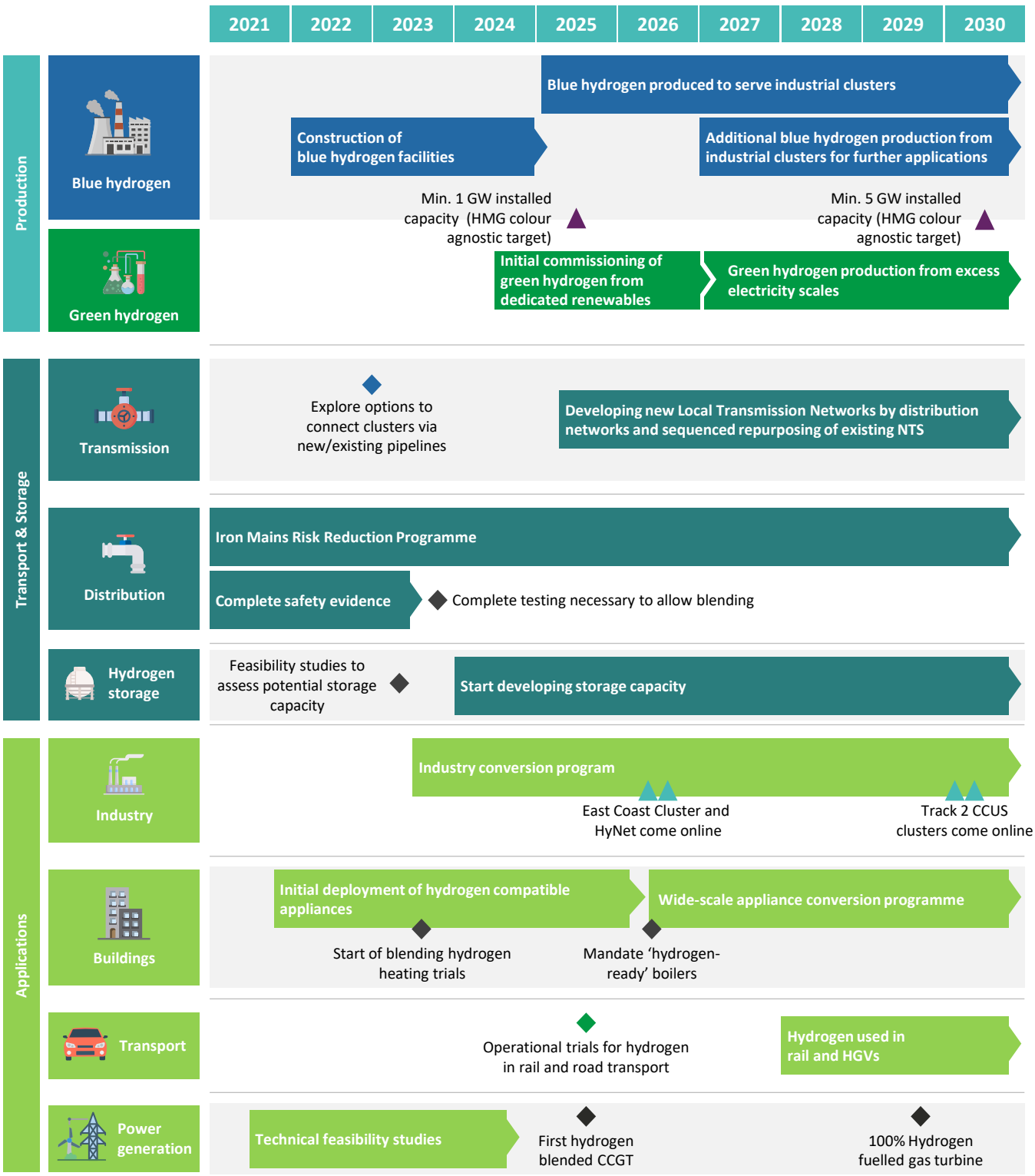


The CCC have recognised the requirement of hydrogen to hit Carbon Budget targets and East Coast Hydrogen stands ready to deliver on the UK Government's decarbonisation objectives

4.3) Hydrogen economy development

East Coast Hydrogen

East Coast Hydrogen looks to facilitate the growth of a UK-wide hydrogen economy by meeting development targets across the hydrogen supply chain.



East Coast Hydrogen will deploy in tandem with the acceleration of the development of the hydrogen economy in the mid 2020s

4.4) Stakeholder engagement

East Coast Hydrogen

Stakeholder engagement across the hydrogen value chain is essential. Each will have key inputs and requirements for the programme as the East Coast Hydrogen programme advances.

Stakeholder Group	Detail	What does East Coast Hydrogen need from the group?	What do stakeholders need from East Coast Hydrogen?
Cross-value chain	• Participants involved in multiple stages of the hydrogen value chain.	• Identification for hydrogen value chain synergies. • Ability to connect on identified opportunities.	• Timing for 100% hydrogen ready pipelines. • Ability to deliver to identified end users.
Upstream	• Stakeholders involved in the production and supply of hydrogen.	• Planned hydrogen production volumes. • Ability to feed into the East Coast Hydrogen programme. • Expected commissioning dates.	• Proximity of planned hydrogen production plants to feeders into the East Coast Hydrogen programme. • Timing for 100% hydrogen ready pipelines.
Midstream	• Stakeholders responsible for the transportation and storage of hydrogen.	• Timing for readiness to distribute hydrogen. • Location and capacity of private networks.	• Timing for the 100% hydrogen ready pipelines. • Required infrastructure to feed hydrogen into network / storage site.
Downstream	• Hydrogen end-users including industrial (including power generation), commercial, and domestic stakeholders.	• Feasibility and readiness for fuel switching to hydrogen • Timing of fuel switching to hydrogen. • Potential hydrogen demand volumes.	• Proven safety case for hydrogen for specified end uses. • Timing for connection to 100% hydrogen ready pipeline.
Local stakeholders	• Sub-regional and local governments, elected mayors, and LEPs.	• Confirmation of alignment with local decarbonisation ambition.	• Timing of the consumer conversion to 100% hydrogen. • Proven safety case for hydrogen for specified end uses. • Economic feasibility of 100% hydrogen usage.

The key requirements for East Coast Hydrogen and stakeholders across the value chain have been identified to ensure alignment as the programme progresses

4.5) East Coast Hydrogen stakeholders (1/2)

East Coast Hydrogen

30 stakeholders across the hydrogen supply chain with 7 public and local authorities have shown overwhelming support for the East Coast Hydrogen programme. Each have committed to contribute in their respective value chain segment.

Organisation		Value chain segment	Location	Commitment
BOC	BOC	Upstream	Teesside	BOC are a leading producer of hydrogen in the UK and are **committed to exploring cross value chain integration with East Coast Hydrogen across production facilities, distribution and storage.**
bp	BP	Cross-value chain	Teesside	BP are committed to deploying hydrogen infrastructure across the UK and have agreed **to explore the potential for the H2Teesside to feed into the programme.**
CATCH	CATCH	Local stakeholders	The Humber	CATCH are an industry led partnership supporting energy, engineering and renewables industries in Yorkshire and Humber and **have committed to highlighting East Coast Hydrogen to local industrial stakeholders.**
centrica storage	Centrica Storage	Midstream	The Humber offshore	Centrica Storage are investing in hydrogen storage and have **committed to working with East Coast Hydrogen on the foundations for a hydrogen economy and explore investment into the Rough gas storage facility.**
CPH2	Clean Power Hydrogen	Upstream	East Midlands	Clean Power Hydrogen are a green hydrogen producer that are committed to **exploring the potential to create jobs in the East Coast Hydrogen region through deployment of their technology.**
DelpHYnus	DelpHYnus	Cross-value chain	Theddlethorpe	DelpHYnus is a industrial cluster project at Theddlethorpe that will **explore the potential to feed hydrogen from up to 2GW of blue hydrogen production at Theddlethorpe.**
East Coast Cluster	East Coast Cluster	Cross-value chain	Humber and Teesside	East Coast Cluster is one of the announced Track 1 Cluster projects that recognises the benefits of East Coast Hydrogen **with potential for access to the CO_2 infrastructure part of the East Coast Cluster.**
Eco Energy World	Eco Energy World (EEW)	Upstream	Multiple locations	Eco Energy World are a global developer of utility scale solar PV projects that have **committed to exploring the potential to feed in hydrogen produced on-site of planned projects into East Coast Hydrogen.**
Enertek International	Enertek	Downstream	The Humber	Enertek is the UK's leading engineering consultancy for hydrogen appliance development and have committed to **offering technical expertise on hydrogen appliances, hydrogen combustion, and safe deployment.**
EQUANS	EQUANS	Cross-value chain	Multiple locations	EQUANS is a leading services business focused on the energy, digital and industrial transitions and **have committed to support the identification of optimal industrial and heat use cases and explore the role of green hydrogen production.**
equinor	Equinor	Cross-value chain	Saltend, Keadby	Equinor are a leading cross-value chain developer in the hydrogen space and have **committed to developing 1.8 GW of blue hydrogen production hydrogen in the Humber by 2030.**
Greater Lincolnshire	Greater Lincolnshire LEP	Local stakeholders	Lincolnshire, East Midlands	Greater Lincolnshire LEP are a business led partnership in the Greater Lincolnshire **area committed to highlighting East Coast Hydrogen to local stakeholders** that may have an interest of benefit from the programme.
HiiROC	HiiROC	Upstream	The Humber	Hiiroc are a innovative hydrogen producer that have committed to **exploring the ability to build zero emission hydrogen production in the area and investing in assembly and testing facilities.**
VPI	Humber Zero / VPI	Cross-value chain	The Humber	Humber Zero is an industry led project in the Humber that have **committed to developing a large-scale CCUS and hydrogen production project at the Immingham industrial site to produce up to 1 GW of hydrogen.**

28 of the 30 stakeholders who have committed Letters of Support have approved to show their logos above.

4.6) East Coast Hydrogen stakeholders (2/2)

East Coast Hydrogen

30 stakeholders across the hydrogen supply chain with 7 public and local authorities have shown overwhelming support for the East Coast Hydrogen programme. Each have committed to contribute in their respective value chain segment.

Organisation		Value chain segment	Location	Commitment
ITM POWER	ITM Power	Upstream	The Humber, East Midlands	ITM Power are a leading electrolyser producer and have committed to **optimising the business case for electrolyser deployment and to meet demand for UK electrolysers in the East Coast Hydrogen region**.
kellas MIDSTREAM	Kellas Midstream	Cross-value chain	Teesside	Kellas are a independent energy infrastructure company that owns and operates midstream infrastructure that have **committed to developing 1 GW of blue hydrogen production in the East Coast Hydrogen region.**
MIDLANDS ENGINE	Midlands Engine	Local stakeholders	Midlands	Midlands Engine are an organisation bringing together public sector partners and businesses in the Midlands that **have committed to working with East Coast Hydrogen to deliver hydrogen solutions.**
Navigator	Navigator Terminals	Midstream	Teesside	Navigator are a leading bulk liquid storage provider that have committed to **assisting with specialist storage and handling expertise and advising on access to critical infrastructure in the East Coast Hydrogen region.**
North East Local Enterprise Partnership	NE LEP	Local Stakeholders	Teesside	North East LEP is a local enterprise partnership that have committed to **align the development of the programme with wider strategies, networks, and partnership's which the North East LEP is involved in.**
D2N2	Nottinghamshire and Derbyshire LEP (D2N2)	Local stakeholders	Nottinghamshire, Derbyshire	D2N2 are a local enterprise partnership serving Derbyshire and Nottinghamshire that have committed to **promoting East Coast Hydrogen to local industrial stakeholders** that may benefit from hydrogen.
SIEMENS energy	Siemens Energy	Cross-value chain	Multiple locations	**Siemens Energy is an energy technology company and leader in the transition to Net Zero who** will support East Coast Hydrogen across the hydrogen value chain including electrolysers, compression and gas turbines.
sembcorp	Sembcorp	Downstream	Teesside	Sembcorp is a leading integrated energy business that has committed to **feeding in implications of emerging decarbonisation plans and sharing information on hydrogen storage in its salt cavern sites** in the East Coast Hydrogen region.
TEES VALLEY COMBINED AUTHORITY	Tees Valley Combined Authority	Local stakeholders	Teesside	TVCA is the combined authority for the Tees Valley area and have committed to driving economic growth in the area and **providing input to East Coast Hydrogen on hydrogen opportunities.**
TOYOTA MANUFACTURING UK	Toyota	Downstream	East Midlands	Toyota are a large automobile manufacturer with operations in the Midlands who have **committed to exploring the potential for East Coast Hydrogen to supply hydrogen for Toyota's operations subject to feasibility.**
TRITON POWER	Triton Power	Downstream	The Humber	Triton are a leading UK power generator that have **committed to work with East Coast Hydrogen to deploy the first hydrogen fueled gas turbine in the UK in the Humber.**
uniper	Uniper	Upstream	Humber and East Midlands	Uniper are a leading energy company that are committing to **assessing how Uniper's blue and green hydrogen development plans at Killingholme can feed into the East Coast Hydrogen project.**
Vaillant	Vaillant	Downstream	East Midlands	Vaillant are a leading boiler manufacturer committed to **providing early trial hydrogen appliances for demonstration projects and ensure support for the extended village and town trials.**
West Yorkshire Combined Authority	West Yorkshire Combined Authority (WYCA)	Local stakeholders	West Yorkshire	WYCA are the combined authority for West Yorkshire that have **committed to ensuring strategic priorities are recognised by, and support the objectives of East Coast Hydrogen by providing local policy advice.**

4.7) Pre-FEED study overview

East Coast Hydrogen

The pre-FEED study commencing in Q1 2022 will work to deliver high-level outcomes across eight workstreams. These will cover all aspects of the programme from supply chain management and stakeholder engagement to regulation and policy management.

Bringing Hydrogen to You

As East Coast Hydrogen enters the pre-FEED phase the work will be directed by a combined vision.

	Repurposing & existing assets	Consumer transition planning	Capital projects & planning	Regulatory & policy	Contracts & commercial	Technical & system integration	Deployment strategy	Stakeholder engagement
Key activities	• Articulate project infrastructure requirements. • Study existing distribution and storage assets. • Establish optimum transmission and distribution routing and costing. • Manage the overall safety plan. • Incorporate existing evidence base developed across gas industry.	• Develop and implement a consumer engagement strategy. • Work to ensure the availability of hydrogen-ready appliances and accredited installers. • Build the consumer transition strategy and engage local consumer groups. • Identify and support vulnerable customers.	• Set out proposed project plan deliverables. • Determine funding requirements for each project. • Lead on construction and project delivery. • Complete detailed programme plan and determine the critical path. • Engage cross-industry partners.	• Develop a regulatory plan. • Develop a financing plan. • Coordinate regulatory interactions with UK Government. • Manage interface with regulatory components of the overall programme. • Determine the impacts of UK policy decisions on the plan and support UK Government with evidence.	• Initiate procurement strategy. • Identify key delivery partners. • Lead on commercial negotiations. • Develop robust commercial framework. • Work to develop commercial market confidence in hydrogen. • Engage supply chain in early stage project assessments.	• Advance the strategic modelling of the gas network infrastructure. • Build on existing studies to understand system balancing. • Initiate engineering and design of integration with existing assets. • Identify and manage potential technical risks of the widespread use of new technologies.	• Develop a plan and timetable for the scope of work for subsequent stages of the project. • Organise responsibilities and liabilities. • Identify and work to mitigate overall project risks. • Agree the operating model between the project partners and responsibilities for capability development.	• Manage the overall stakeholder engagement approach. • Support stakeholders with concerns. • Gather stakeholder engagement evidence. • Implement a public engagement strategy through targeted communicatio-ns with industrial and local stakeholders.
Deliverables	• Repurposing strategy. • Conversion routing strategy. • Safety case and asset management plan.	• Consumer engagement strategy. • Appliance installation timeline and logistics plan. • Customer transition plan.	• Record of current and planned infrastructure assets. • Project delivery timeline.	• Regulatory plan. • Financing and funding mechanism plan. • Policy timeline and interaction plan.	• Commercial contracts. • Delivery partner plan. • Supply chain strategy.	• Asset integration strategy and plan. • Modelling of East Coast Hydrogen infrastructure. • Initial design overviews.	• Deployment strategy. • Project timeline. • Project risk register. • Operating model and responsibility matrix.	• Stakeholder engagement strategy. • Customer evidence base and public communicati-ons. • Stakeholder plan.
Owner	**The identified workstreams will be delivered by the agreed operating model on page 51**							

The Pre-FEED work covered by the workstreams above will enable East Coast Hydrogen to proceed to commencing the FEED Study from 2023 onwards

4.8) Regulatory engagement

East Coast Hydrogen

East Coast Hydrogen will continue to engage with Ofgem through the delivery of the Phases to ensure alignment with and delivery of Ofgem's key objectives.

- **Under a co-ordinated programme of work, NGN, National Grid and Cadent will ensure the efficient delivery of the workstreams for East Coast Hydrogen** by focusing on delivery projects in line with the network's natural strengths.
- NGN, National Grid and Cadent will **continue to manage their own engagements and requirements for funding for future gas projects** with Ofgem.
- The **four Phases of the programme have been structured to maintain optionality during the programme** to deliver segments that are viewed as delivering the greatest value to consumers for the decarbonisation potential of the programme.

Initial estimates based on preliminary analysis indicate the total cost of East Coast Hydrogen transmission pipeline at £863m

Pipeline	Length (km)	Cost (£m/km)	Total cost (£m)
Repurposed National Transmission System pipeline	200	0.34 [1]	**67**
New-build Local Transmission System pipeline	637	1.25 [2]	**796**

East Coast Hydrogen aims to repurpose where possible including the existing NTS which is ~20% to repurpose versus the cost of new build and it is understood that this is similar for lower pressure asset repurposing

East Coast Hydrogen extends the useful life of the assets which in turn will maintain the Regulated Asset Value of the gas networks which otherwise would undergo a phased depreciation and risk prior investments

Investment in East Coast Hydrogen could be delivered through funding models such as the Regulated Asset Base which is used today for operating gas assets and could be extended to capital infrastructure projects

East Coast Hydrogen aims to align with Ofgem's key strategic objectives:

Consumer

- East Coast Hydrogen offers the opportunity to decarbonise heat for industrial users and domestic users alike with **a low disruption conversion pathway ensuring that consumers are off-supply for an intended maximum of 12 hours**.
- The infrastructure developed will ensure that the networks are **developed and ready for domestic use when the hydrogen heat policy strategic decision is made by UK Government in 2026**.
- East Coast Hydrogen will **incorporate the learnings from the suite of projects including the Hy4Heat programme and HyDeploy 2 exploring the customer experience of hydrogen**.

Cost

- East Coast Hydrogen will **deliver repurposing of Great Britain's world-leading gas infrastructure where possible** to ensure cost-effectiveness, with new build capacity deployed to maintain system resilience and reduce off-supply time for consumers where this is not achievable.
- East Coast Hydrogen will **integrate and build on the existing portfolio of hydrogen projects (H21, HyDeploy 1&2, Hydrogen Home, Hy4Heat and other NIA projects)** to deliver value for money to the consumer from the programme.

Decarbonisation

- East Coast Hydrogen will **act as a blueprint for the wider decarbonisation of the gas industry, enabled by Project Union**, through cross-network conversion of existing assets and provide investor confidence in the hydrogen opportunity in Great Britain.
- East Coast Hydrogen will **stimulate the transition of the gas industry to a Net Zero future and decarbonise a large proportion of the UK's industry and homes**.

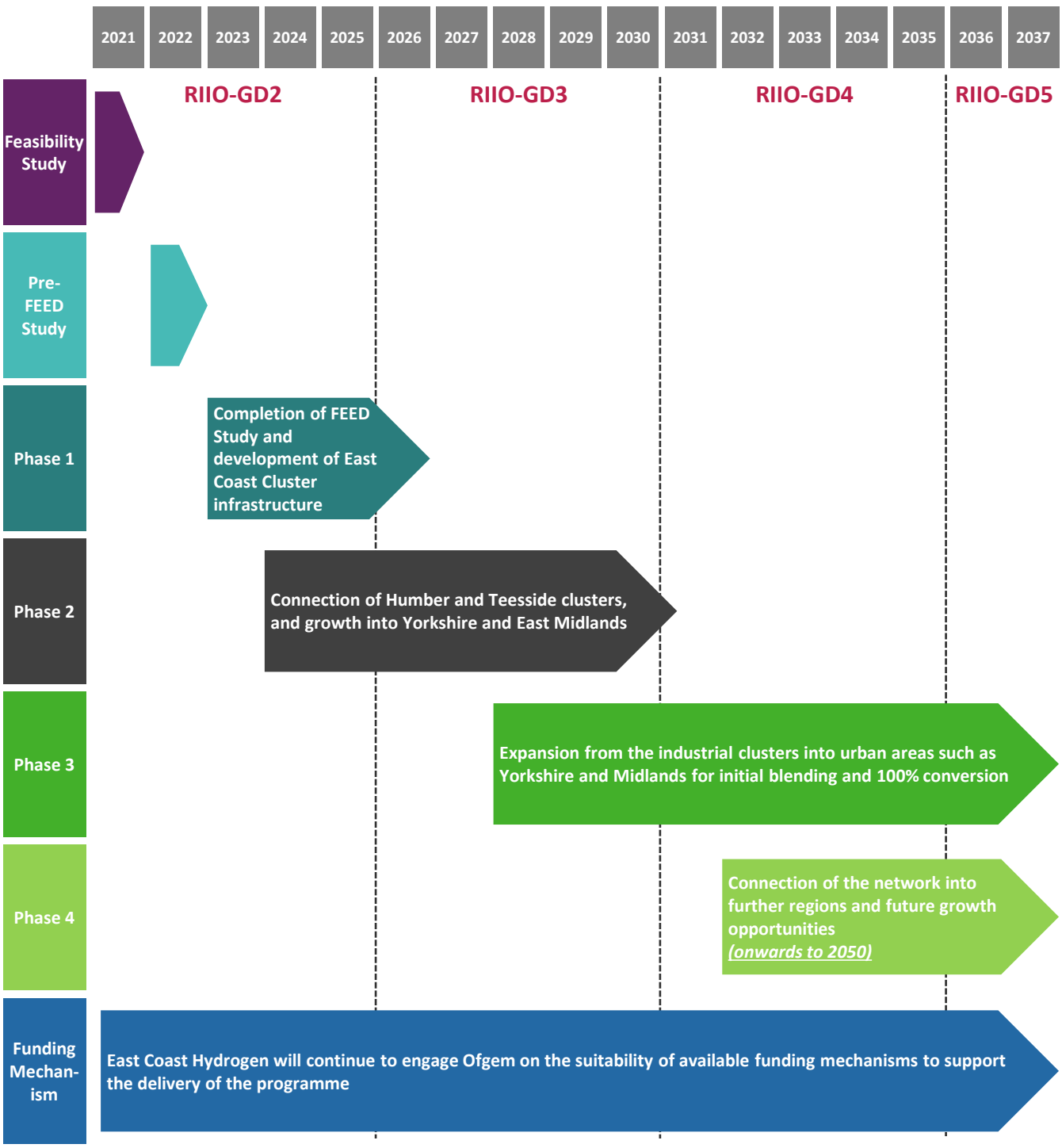
1. Gas for Climate, "European Hydrogen Backbone", 2020.;
2. NGN, 2021.

Decarbonisation of up to 4.4 million households and up to 39,000 industrial and commercial gas users could cost ~£13 per household per year*

*£863m cost allocated across 4.4 million households over 15 years, which does not account for investor returns or the time value of money.

4.9) Indicative delivery timeline

The East Coast Hydrogen programme has proposed the following indicative timeline for the delivery of the phases of the programme to enable a sustainable deployment of infrastructure.



East Coast Hydrogen has been structured in 4 distinct phases which will interact individually with network price control periods to ensure plans optimise alignment with existing operations

4.10) Next steps

East Coast Hydrogen

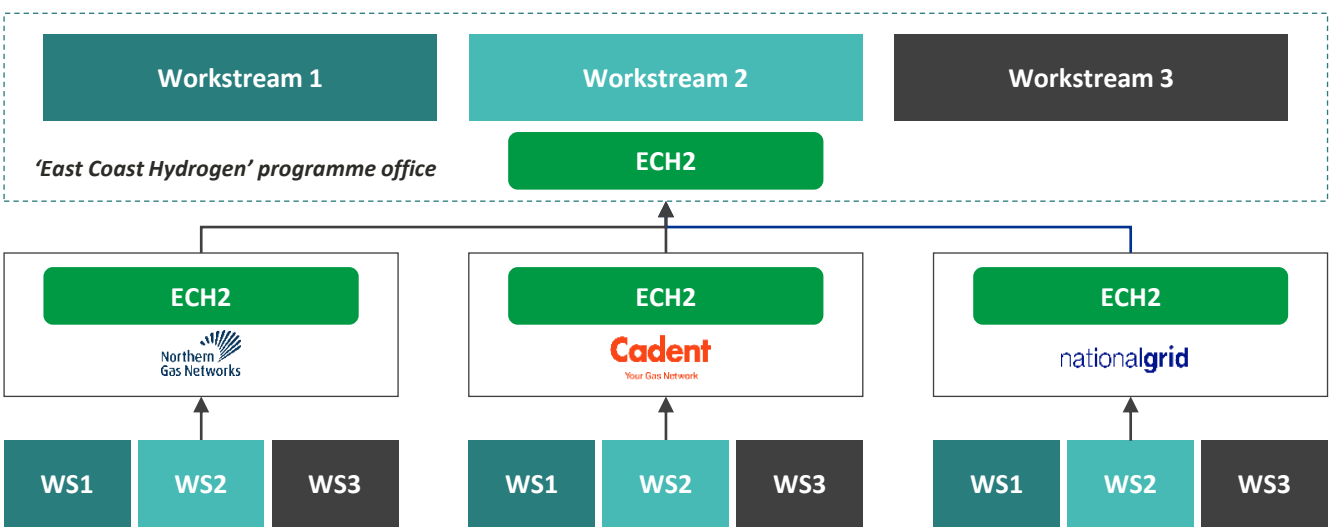
East Coast Hydrogen has outlined the key next steps, with an intensified focus on engaging with stakeholders as the programme progresses towards deployment.

East Coast Hydrogen will commence the pre-FEED Study in Q1 2022

01	02	03
		
Interconnectivity	**Industrial decarbonisation**	**Domestic decarbonisation**
East Coast Hydrogen will align with East Coast Cluster and Project Union in the early 2020s to ensure co-ordinated deployment of hydrogen infrastructure	East Coast Hydrogen will establish an Industrial Hydrogen Users Group (IHUG) in early 2022 and support industry across the region to assess conversion feasibility	East Coast Hydrogen will engage in 2022 with consumer groups on domestic conversion to ensure consumers are ready for the UK Government's decision

NGN, Cadent and National Grid, as they enter 2022, will continue to deliver workstreams within their organization building on organisational capabilities and existing innovation programmes. The networks will collaborate on workstreams through an East Coast Hydrogen programme to ensure alignment and efficient programme delivery.

The programme office will continue the important work of external stakeholder engagement, such as the Stakeholder Consortium, IHUG, consumer groups and other special interest groups. As this programme evolves there will be the organisational flexibility to bring on new partners and the supply chain to support delivery.



The East Coast Hydrogen programme partners stand ready to begin Phase 1 of the programme from the start of 2022 to drive the decarbonisation of industry, transport and heating

4.11) Macro assumptions and requirements

East Coast Hydrogen

Planning for a large-scale infrastructure programme involving new technologies and system changes will require several baseline assumptions. Responsibility and actions should be assigned to ensure these assumptions hold true.

Key assumption	Responsibility	Action required
Strategic decision on the potential for hydrogen for domestic heating is made by 2026.	BEIS	BEIS will need to continue projects such as Hydrogen Village to gather evidence to make an informed, timely decision on the future of hydrogen for heating.
A residual natural gas supply will remain in place for system resilience.	NGN, Cadent, National Grid	The East Coast Hydrogen programme partners will set out a detailed technical plan for maintaining residual natural gas supply as part of pre-FEED workstreams.
There will be sufficient hydrogen production to realise East Coast Hydrogen's full ambition.	Hydrogen producers	Liaise with hydrogen producers in the East Coast Hydrogen region on their future plans to deploy hydrogen production facilities.
Blending of hydrogen in the gas grid up to a 20% hydrogen mix is permitted in 2023	BEIS and the Health & Safety Executive (HSE)	BEIS and HSE will need to approve the use of blending in the gas grid.
New-build LTS will be sequenced in line with National Transmission System (NTS) conversion timelines.	NGN, Cadent, National Grid	The East Coast Hydrogen programme partners will maintain dialogue with Project Union on sequencing conversion of NTS and construction of new LTS.
Households will only be off-supply for their gas for up to 12 hours during the conversion of their gas supply to 100% hydrogen.	NGN & Cadent	NGN and Cadent will ensure a robust delivery plan to support the 12 hour target implementation and consumer is engaged throughout.
Ofgem will regulate hydrogen infrastructure in a timely manner to ensure deployment of hydrogen infrastructure in line with the programme timeline.	Ofgem	Ofgem to bring forward regulation to support timely deployment of converted & new build hydrogen infrastructure.
Hydrogen producers are willing to export their hydrogen via the East Coast Hydrogen programme.	NGN, Cadent, National Grid	The East Coast Hydrogen programme partners will engage with hydrogen producers in the East Coast region on transportation plans for their hydrogen.
Hydrogen-ready boilers will be mandated by 2026	BEIS	Ensure timely consultation and mandate for hydrogen-ready boilers to ensure consumer readiness for hydrogen.
Hydrogen storage becomes a regulated asset	BEIS	Ensure timely decision on investment models for hydrogen storage

The successful deployment and expansion of the East Coast Hydrogen programme is contingent on key assumptions delivered through industry and Government partnership

Glossary

East Coast Hydrogen

ALK	Alkaline Electrolysis
ATR	Autothermal Reforming
BEIS	Department for Business, Energy and Industrial Strategy
CB	Carbon Budget
CB6	Carbon Budget 6
CCC	Climate Change Committee
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilisation, and Storage
CHP	Combined Heat & Power
FES	Future Energy Scenarios
GDN	Gas Distribution Network
GHG	Greenhouse Gas
GW	Gigawatt
HGV	Heavy Goods Vehicle
HMG	Her Majesty's Government
HSE	Health & Safety Executive
IEA	International Energy Agency
IMRRP	Iron Mains Risk Reduction Programme
LTS	Local Transmission System
Mt	Megatonnes (million tonnes)
$MtCO_2$	Megatonnes of CO_2
NGN	Northern Gas Networks
NTS	National Transmission System
PEM	Proton Exchange Membrane
RIIO-GD	Cost mechanism for GDNs within a defined price control period
SMR	Steam Methane Reforming
SOE	Solid Oxide Electrolysis
TWh	Terawatt-hour

Bibliography

East Coast Hydrogen

Arup, "Establishing a Hydrogen Economy in Derby", 2021

BEIS, “2020 UK greenhouse gas emissions, provisional figures”, 2021

BEIS, “Clean Growth Grand Challenge: Industrial Clusters Mission.”, 2021

BEIS, “Consultation on a UK Low Carbon Hydrogen Standard”, 2021

BEIS, “UK Energy in Brief 2021”, 2021

BEIS, “Energy and Emissions Projections” 2019, 2020

CCC, "The Sixth Carbon Budget: The UK’s path to Net Zero", 2020

East Coast Cluster, 2021

Energy & Utilities Alliance, “Decarbonising heat in buildings: Putting Consumers First”, 2021

Energy Networks Association, 2021

Gas for Climate, “European Hydrogen Backbone”, 2020

Gas Goes Green, “A System for All Seasons”, 2021

Gorski et al., “Carbon intensity of blue hydrogen production”, 2021

HCLG, “Dwelling Stock Estimates”, 2020

HM Government, “Energy White Paper: Powering Our Net Zero Future”, 2020

HM Government, “Heat and Building Strategy”, 2021

HM Government, “UK Hydrogen Strategy”, 2021

Howarth, Robert W., and Mark Z. Jacobson. "How green is blue hydrogen?”, 2021

Hy4Heat, BEIS, “WP7 – Safety Assessment: Conclusions Report”, 2021

ICIS, 2021. & Company Announcements, 2021

IEA, “Net Zero by 2050: A Roadmap for the Global Energy Sector”, 2021

IEA, “The Future of Hydrogen”, 2019

National Grid ESO, “Future Energy Senarios”, 2021

National Grid, “New East Coast Cluster could decarbonise up to half of the UK’s industrial cluster emissions”, 2021

NibleFins, “Average CO_2 emissions per car in the UK”, 2021

Office for National Statistics, 2020

RenewablesUK, ”Offshore Wind Project Timelines”, 2021

East Coast Hydrogen