East Coast Hydrogen

East Coast Hydrogen Delivery Plan

November 2023

Northern Gas Networks

Cadent
Your Gas Network

national gas

Disclaimer

This report provides a strategic outline for delivery of the East Coast Hydrogen (ECH_2) Programme and the opportunities and benefits it can bring. It builds upon the information published in the 2021 ECH_2 Feasibility Report and findings of Cadent, National Gas and Northern Gas Networks (NGN) Pre-FEED studies. [1]

Certain companies included within this report have provided Letters of Support to ECH_2. These Letters of Support are non-legally binding documents indicating early stage strategic support for the high level ambitions of the programme.

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External sources of data and analysis used within the report are cited and a complete list of sources used can be found in the Bibliography. Any data or analysis used in the report without specific citation to an external source is based on analysis conducted by Cadent, National Gas and NGN:

- Analysis of the current and potential future network configuration and capacities is based on the networks' own data.
- Analysis of the future system user's needs (forecasts of hydrogen demand, production, storage) is based on primary data collected directly from current and future network users for the purposes of supporting the development of the ECH_2 Programme.

Key assumptions used in analysis of the data and information presented within this report, along with a summary of the approach to primary data collection, can be found in Appendix 1: Methodology.

All data and information presented within this report should be considered a snapshot in time and subject to change. Due to the early-stage nature of many of third party projects referenced in the report, the plans for infrastructure developments are subject to change. The analysis and data outputs are based on the most recently available information from the networks and third parties, and are also subject to change.

ECH_2 reserves the right to continue to develop and amend pipeline routing options 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 to be refined during FEED and other future stages of the Programme. They also remain subject to relevant regulatory oversight and approvals.

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Foreword

According to the Climate Change Committee, low-carbon hydrogen will play a critical role in enabling the UK to meet its Net-Zero target by 2050. [2] Complementing electrification and carbon capture, utilisation and storage (CCUS), hydrogen provides an alternative decarbonisation solution for hard-to-abate industrial processes, which account for 16% of the UK's total carbon emissions. Hydrogen also provides a decarbonisation solution for heavier forms of transport like aviation and shipping, and has the potential to play an important role in delivering low carbon-dispatchable power.

Recognising the important role of hydrogen in our future energy system, UK Government has set an ambitious target of deploying 10 GW of low-carbon hydrogen production by 2030, with at least half of this total coming from Green Hydrogen. The National Infrastructure Commission (NIC) has also recognised the important role of hydrogen and called for the development of a core network of hydrogen pipelines by 2035. [3] The East Coast region will be vital to achieving this national ambition. The region is host to two of the UK's largest industrial centres, as well as two of the proposed CCUS clusters - East Coast Cluster and Viking – and is home to 8 hydrogen projects that were shortlisted for bilateral negotiations in multiple UK Government funding rounds (accounting for ~30% of successful production projects).

The Combined Authorities and the Local Enterprise Partnerships (LEPs) in the East Coast region are crucial partners in the UK reaching its Net-Zero goals, driving local plans to decarbonise and supporting businesses and communities to upskill to enable the low-carbon economy to grow.

We are fully supportive of the UK Government's ambitions for hydrogen and have reflected this in the commitments we have made within our local energy plans:

- Power emissions in the **Derby and Nottingham** areas will be reduced by transitioning coal-fired power stations at Ratcliffe-on-Soar and High Marham to produce energy from low-carbon technologies like hydrogen. Increasingly high-voltage power lines will import renewable electricity which can be used to make Green Hydrogen. This hydrogen will then be used to decarbonise aviation, and manufacturing.
- **Greater Lincolnshire** has plans to reduce emissions in the area by supporting the early adoption of hydrogen technologies, and strengthening local industrial productivity through the delivery of low-cost, low-carbon energy. The area will be home to several hydrogen production sites in the South Humber, and is home to an important access point to the Viking CCUS store. Low-carbon hydrogen will be vital to decarbonising the steel industry and power generation in Scunthorpe, as well as chemicals and building materials production in Immingham. [4]
- **Tees Valley** aims to be the world's first Net-Zero industrial cluster by 2040 along with the Humber region, with hydrogen acting as the centrepiece for achieving this. The region will produce more than 50% of the UK's hydrogen, and is home to the UK's first Hydrogen Transport Hub. [5]
- Leading by example **West Yorkshire** is aiming to be Net-Zero by 2038, with low-carbon hydrogen being a potential solution to achieving significant emission reductions in hard-to-decarbonise sectors such as heavy industry. The use case and value proposition of hydrogen to reduce emissions in those hard-to-decarbonise sectors in West Yorkshire is currently being assessed and modelled. [6]

ECH_2 will play a critical role in the development of a regional hydrogen market, providing the opportunity to connect up to 11 GW of hydrogen production capacity by 2030 (exceeding the UK Government's 10 GW by 2030 target in a single region) and up to 4 TWh of hydrogen storage by 2030. By providing the network infrastructure needed to transport low-carbon hydrogen, the Programme will connect producers and storage providers to a range of customers, who expect to need over 63 TWh/year of low-carbon hydrogen to decarbonise their operations and save up to 12 $MtCO_2$/year by 2037.

This Programme puts the East Coast region at the heart of the UK's industrial decarbonisation agenda, creating world leading hydrogen hubs in places like Teesside, the Humber region and East Midlands. This will support green jobs, skills and competitive supply chains levelling up the economy by bringing new investment, and preserving the industrial and commercial (I&C) value of the Midlands and North East.

We are proud to support this important initiative and look forward to witnessing the exciting developments yet to come in future phases of the ECH_2 Programme.

Lord Houchen
Major of Tees Valley

Chris Rowell
Chair of North East and Yorkshire Net Zero Hub

Ruth Carver
CEO of Greater Lincolnshire LEP

Tracy Brabin
Mayor of West Yorkshire

Will Morlidge
CEO of D2N2 Local Enterprise Partnership

Executive Summary

Executive Summary

ECH_2 is a 15-year programme which will play a critical role in creating a UK hydrogen economy and decarbonising a range of sectors in line with UK Government targets.

The UK Government has identified low-carbon hydrogen as a key solution for decarbonising the UK economy and has set ambitious targets for the deployment of hydrogen production. The National Infrastructure Commissions' second National Infrastructure Assessment has recommended the development of a core network of hydrogen pipelines by no later than 2035. [3]

ECH_2 was established by NGN, Cadent and National Gas with the objective of identifying and ultimately delivering the network infrastructure required to support the deployment of low-carbon hydrogen, facilitating the decarbonisation strategies of energy generators and users in the East Coast region. A Feasibility Study launched in December 2021, established the case for the Programme and set out the roadmap for completing further investigation and design of the infrastructure required. The Programme will provide a blueprint for deployment of low-carbon hydrogen and provide a starting point for the development of the core network that the UK needs to achieve its decarbonisation goals. [1]

The Programme is being developed in close collaboration with network users, local authorities and national policy makers to ensure that the Networks are ready to provide the infrastructure required to facilitate decarbonisation plans of energy users and support the development of a low-carbon hydrogen economy in the East Coast region. 122 stakeholders across the energy value chain – from existing large industrial energy users, to power stations and to universities – have shown overwhelming support for ECH_2.

This Delivery Plan provides an update on the progress made since the Feasibility Study. It provides a detailed overview of the emerging hydrogen economy in the East Coast region and aims to provide UK Government and industry, visibility of the networks' plans. This supports UK Government's work on hydrogen and provides stakeholders with more certainty on the availability of infrastructure to help them progress business decisions.

This report sets out:

1) The progress made by ECH_2 since the Feasibility Study (Chapter 1)
2) Details of system users' decarbonisation plans with respect to hydrogen (Chapter 2)
3) Details of the initial infrastructure routing options based on system users' plans (Chapter 3)
4) Updated assessment of the benefits unlocked by ECH_2 (Chapter 4)
5) Next steps and enabling actions needed to successfully deliver the Programme (Chapter 5)

Progress since the Feasibility Study launch

Since the Feasibility Study was launched in December 2021, UK Government and wider industry have achieved significant progress in developing plans for a hydrogen economy across the UK.

Government progress

- **British Energy Security Strategy** was published setting out how Great Britain will accelerate homegrown power for greater energy independence [7]
- **Jet Zero Strategy** was established to develop a roadmap to achieving Net-Zero aviation by 2050 [8]
- **Minded to position on Hydrogen T&S Infrastructure** has been published [9]
- **Powering Up Britain** plan was created to set out how the UK Government will enhance the country's energy security, seize the economic opportunities of the transition, and deliver on Net-Zero commitments [10]
- 17 projects have been announced for the **first hydrogen electrolytic allocation round** (HAR1) [11]
- **UK Hydrogen Strategy** was updated to set out the approach to developing a thriving low-carbon hydrogen sector in the UK [12]
- **Energy Bill** provisioned energy production and security and the regulation of the energy market
- **UK-German hydrogen cooperation partnership** announced aiming to accelerate innovation and deployment
- **Hydrogen blending consultation** launched seeking views in the case and options for implementation [13]
- Response published on creating a **UK Low Carbon Hydrogen Certification Scheme** [86]
- Response published on **revenue support regulations for the Hydrogen Production and Industrial Carbon Capture Business Models** [87]

ECH_2 Programme actions

- World first **100% hydrogen programme** completed in Teesside as part of the H21 initiative to test the use of 100% hydrogen in an existing gas distribution network
- NGN has opened **a Hydrogen Hub in Redcar** to give customers the opportunity to learn more about hydrogen for heating
- **Project Union's Feasibility Stage Re-opener** was submitted, as part of the RIIO-2 price control
- **H2NorthEast, Uniper Humber Hub Blue Project, bpH2Teeside and H2H Saltend** passed the eligibility criteria for Phase-2 of the government's cluster sequencing process
- **East Midlands Hydrogen**, a large scale inland hydrogen cluster, has been launched
- **The Viking CCUS cluster has been selected as part of the Track-2 UK Government cluster sequencing process**
- **Successful demonstration of HyDeploy**, providing vital evidence to support the safety case for blending up to 20% hydrogen into the grid across the UK and supporting UK Government's 2023 blending decision.

ECH_2 Programme achievements

- 5 external stakeholder events have been held, helping to ensure alignment of the ECH_2 infrastructure programme with stakeholders' needs. Since December 2021, **the number of Consortium Members increased from 37 to 122.**
- **Primary and secondary data gathered and analysed** from key stakeholders in relation to 367 planned and potential production, demand and storage sites across the East Coast region.
- Networks' **Pre-FEED Studies will be completed by the end of 2023** and provide greater understanding of the technical feasibility of the Programme, as well as routing design and potential routing options.
- **Ongoing regulatory engagement** to ensure alignment of the programme with regulatory requirements, and develop the evidence base required to allow consideration of funding requirements for the next stage of work of FEED.
- **This Delivery Plan has been prepared** to demonstrate the Programme's needs case and engage key stakeholders and decision makers in ECH_2.

ECH_2 is evolving in line with UK Government decisions and industry initiatives. Since the Feasibility Study, the Programme has made significant progress in defining the scope and scale of hydrogen infrastructure that may be required in the East Coast region.

The role of hydrogen in decarbonising the East Coast

The detail and ambition of the hydrogen plans set out by existing customers, prospective hydrogen producers and storage developers have advanced since the Feasibility Study.

Demand

Over 63 TWh/year
identified I&C, power and aviation hydrogen demand by 2037*

44%
annual I&C and power natural gas demand potentially switched to hydrogen

Up to 12 $MtCO_2$/year
avoided I&C, power, and aviation emissions helping the UK to achieve its 6th Carbon budget**

Production

Up to 83 TWh/year
current planned hydrogen production by 2037 in the East Coast region

4.4 GW
Green Hydrogen capacity is planned by 2030, meeting 88% of the UK Government targets

22 projects
provided primary data and forecasts to support network development

Storage

4 large scale sites
connected across North Humber and Teesside

Over 19%
of the UK's storage requirements (56 TWh) will be met by 2050 within the region[39]

10.7 TWh
storage to be deployed by 2050

Momentum and ambition across demand, production and storage has grown since the Feasibility Study

Demand forecasts have been refined through primary user data and further secondary analysis

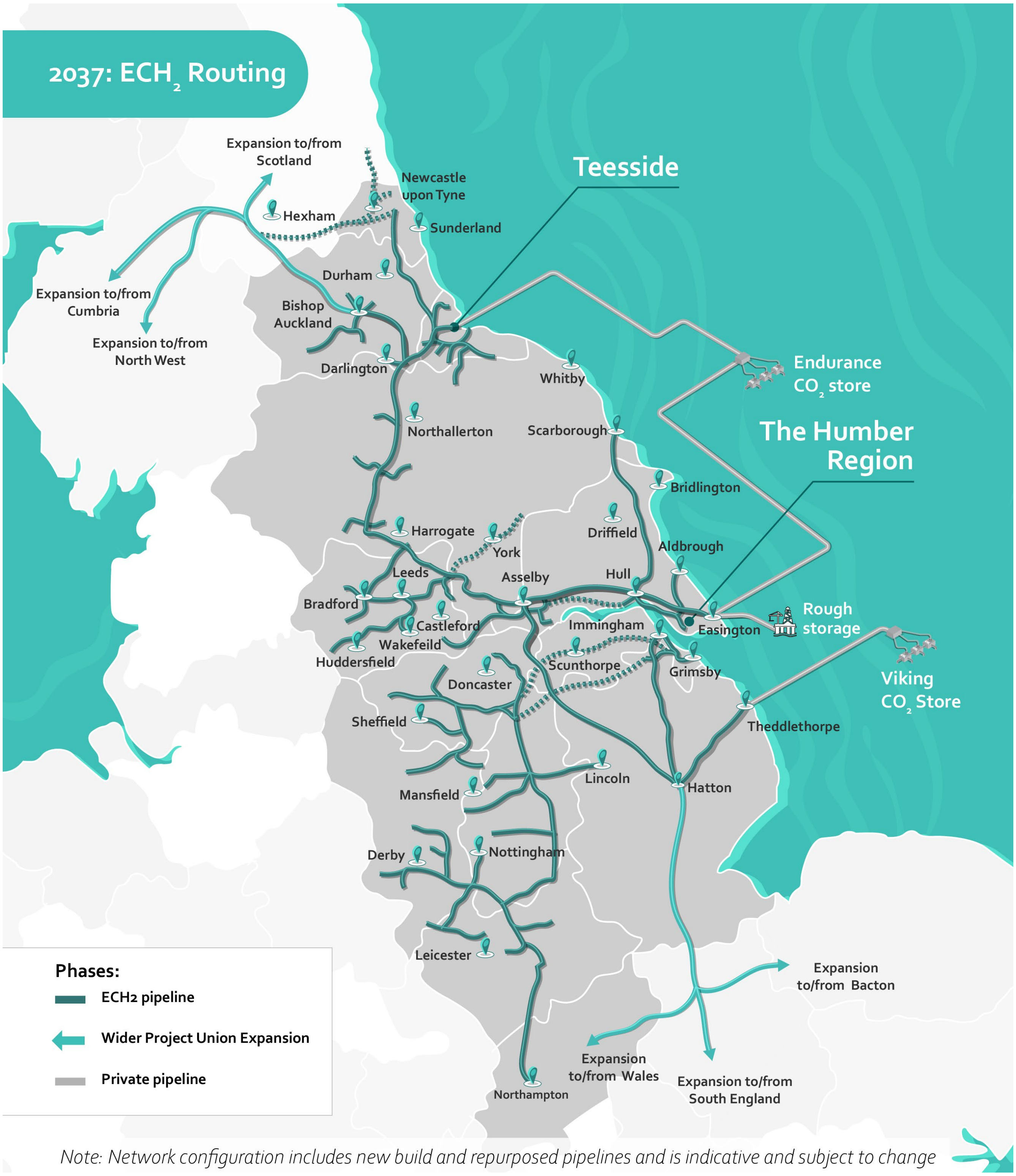
4.5 GW
of additional production capacity under development

Up to 0.7 TWh
of additional storage capacity under development in onshore salt caverns

**Total hydrogen demand includes (23.1 TWh) I&C demand, (34.5 TWh) power demand, (5.6 TWh) transport demand.*
*** Total decarbonisation potential from switching to low-carbon hydrogen includes (4.1 $MtCO_2$) I&C, (6.2 $MtCO_2$) power, and (1.4 $MtCO_2$) transport emissions.*

Initial options for routing of ECH_2 hydrogen infrastructure

We have conducted a comprehensive analysis of the hydrogen infrastructure required for the East Coast region based on the data provided by the Programme's stakeholders about their own plans. Initial routing options efficiently connect supply and demand through a mixture of repurposed and new build pipelines.



Note: Network configuration includes new build and repurposed pipelines and is indicative and subject to change

The routing options presented will be carried forward to the next phase of the Programme for further analysis through Front End Engineering Design (FEED). We will continuously optimise routing to ensure that Programme plans continue to align with both evolving UK Government policy and achieving value for money.

Unlocking the benefits of hydrogen for the East Coast Region

The ultimate goal of ECH_2 is to deliver the hydrogen transport infrastructure required to achieve the UK Government and industrial decarbonisation ambitions. Progressing to FEED now is critical to ensure deployment in time to unlock benefit and achieve 2030 and 2050 targets.

UK Government's commitments	• ECH_2 will be necessary for the UK Government's Net-Zero ambitions by enabling the scale up of a hydrogen economy • The Programme informs future policy and investment decisions by showcasing how development and deployment challenges can be overcome	**11.6 GW** Of planned hydrogen production capacity can potentially be connected within the region	**8** Projects selected through the NZHF, HAR1, and Cluster Sequencing can be supported by ECH_2
Decarbonisation of the East Coast region	• ECH_2 will help I&C, power and transport enterprises within the East Coast region to decarbonise their operations • The East Coast region is home to multiple pilots and research projects that require hydrogen infrastructure to test decarbonisation opportunities across a variety of sectors	**58 TWh** Natural gas could be converted to hydrogen by 2037*	**up to 12 $MtCO_2$/year** Abated across I&C, power and transport sectors**
Hydrogen value chain development	• ECH_2 supports value chain development and growth of a hydrogen market through its Consortium Group • The Programme is based on hydrogen forecasts received directly from users, providing certainty on the volume and timing of need	**122** Number of stakeholders across the value chain who support ECH_2	**53** Customers who provided primary hydrogen forecasts
Wider system benefits	• ECH_2 can help to provide whole system resilience and flexibility providing access to storage and reducing curtailment via Green Hydrogen facilities. • The programme additionally supports regional jobs and economic growth, potentially safeguarding £208bn/year GVA (based on 2021 figures) by avoiding business closures and providing an additional £27bn GVA and across the North East, East Midlands, Yorkshire and Humber region up to 2050.	**21GW** offshore wind capacity is due online by 2030 with **17** Green Hydrogen facilities expected	**£27bn GVA** and **360k jobs** through the development of a full hydrogen value chain ***

ECH_2 will unlock a number of benefits from deploying hydrogen in the East Coast region, however further work is needed to confirm locations and timing for delivering this infrastructure. This in-depth analysis will be carried out during the FEED phase.

** Total natural gas (58 TWh) to switch to low-carbon hydrogen excludes aviation sector transport demand because it is additional that comes from aviation turbine fuel, not natural gas.*
*** Total decarbonisation potential from switching to low-carbon hydrogen includes (4.1 $MtCO_2$) I&C, (6.2 $MtCO_2$) power, and (1.4 $MtCO_2$) transport emissions.*
**** Independent analysis, completed by PWC on behalf of Cadent. See pp 81 for more information on economic benefits.*

Delivering the ECH_2 Programme

To successfully deliver ECH_2 and capture the anticipated benefits across the region, a number of enabling actions are needed. Progressing these now is essential not just to ECH_2 but to the core network of hydrogen pipelines needed nationally by 2035.

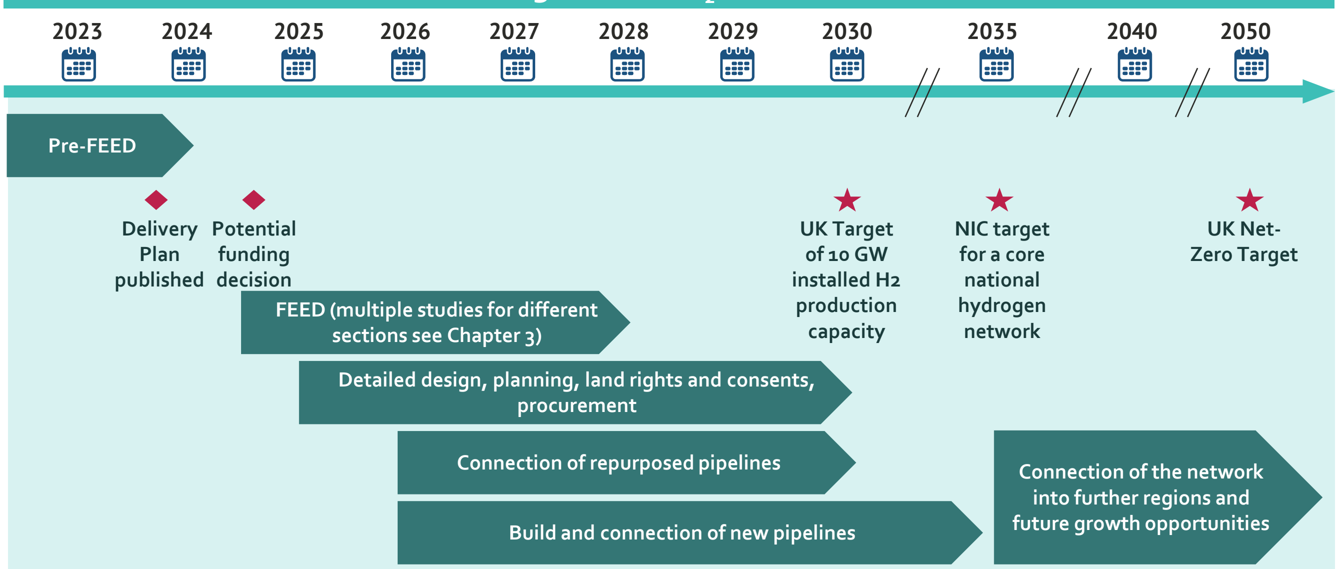
UK Government and wider industry actions

- ☐ Make a decision on hydrogen blending
- ☐ Finalise T&S Business Models that provide the right incentives for investment
- ☐ Make a decision on the role of hydrogen in residential heating
- ☐ Assess technical requirements for safe hydrogen transportation
- ☐ Establish standardised procedure for hydrogen safety case approval
- ☐ Support the development of hydrogen storage facilities
- ☐ Support development of hydrogen offtake agreements
- ☐ Engage with different stakeholders to understand and better support the need for hydrogen in specific businesses
- ☐ Ensure HSE & Ofgem have enabling mandates and sufficient resource to undertake all necessary licensing activities (e.g. safety case, economic license)
- ☐ Support projects through further rounds of the cluster sequencing and hydrogen allocation process aiding them achieve CAPEX or DEVEX support.

ECH_2 Programme actions

- ☐ Provide evidence to the UK Government and regulators through trials and technical assessment results to support policy decisions
- ☐ Ensure sufficient engagement with Ofgem & DESNZ to share key Programme insights and be aware of any policy changes
- ☐ Engage with potential customers and provide them input to support decisions on their own hydrogen and decarbonisation plans
- ☐ Conduct Consortium activities to continue to ensure alignment of ECH_2 with stakeholder plans
- ☐ Ensure that the Programme meets the requirements of hydrogen users, production and storage facilities
- ☐ Ensure optionality to adapt the routing design to an evolving environment
- ☐ Engage with cross supply-chain stakeholders, ensuring resourcing and procurement risks are addressed
- ☐ Support initiatives which unlock further investment into the wider hydrogen economy and stakeholders decarbonisation plans

High level ECH_2 timeline



To ensure the progress of ECH_2 and the development of a hydrogen economy in the East Coast region and across the UK, continued momentum and commitment from Programme Partners, the UK Government and wider industry is required.

01

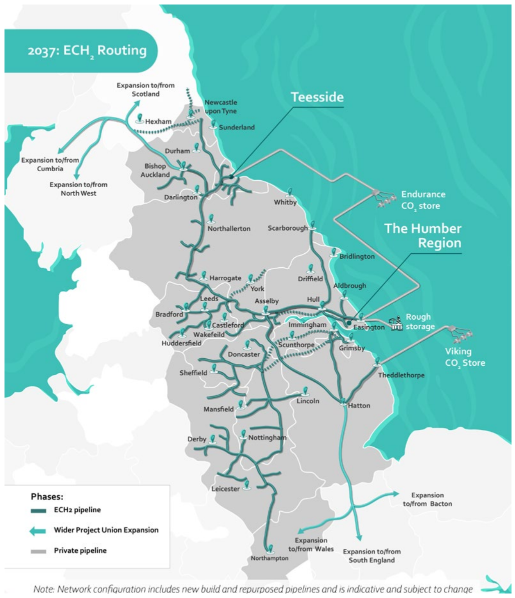
Introduction to East Coast Hydrogen

Overview of East Coast Hydrogen and its main objectives

ECH_2 is a large scale hydrogen infrastructure project that will connect production, storage and demand in the East Coast region. The aim is to facilitate the decarbonisation plans of energy users in the region by proving the infrastructure needed to support a hydrogen economy.

Connect supply and demand

- The East Coast region hosts concentrated industrial energy demand, significant gas storage and offshore wind power, making it an obvious location to produce low-carbon hydrogen. By providing critical midstream hydrogen infrastructure, the Programme can enable widespread decarbonisation benefits through fuel switching from fossil fuels.
- Through its Consortium Group, ECH_2 has identified up to 83 TWh of annual hydrogen production and over 63 TWh of annual I&C, power and transport hydrogen demand, potentially materialising over the next 15 years.*
- It is essential that a clear plan for the transportation of hydrogen is developed to provide certainty for those at both ends of the value chain looking to make investments.
- ECH_2 will connect hydrogen production projects with demand sites, enabling large scale use in I&C and power, and potentially, transportation and residential sectors.



Note: Network configuration includes new build and repurposed pipelines and is indicative and subject to change

Decarbonise multiple sectors

- This Programme could help reduce up to 7% of the UK's total I&C annual carbon emissions across hard-to-abate industries through switching to low-carbon hydrogen (see pp 71).
- In the power sector, there is a potential to save 6MtCO_2/year, equivalent of over 12% of the UK's total emissions from the power industry see pp 72).
- ECH_2 also provides the opportunity for hydrogen to play a crucial role in achieving Net-Zero in heavy transport applications and in residential heat, subject to the UK Government decisions.

Support delivery of UK Government targets

- ECH_2 will be an enabler for UK Government hydrogen production targets (10 GW of by 2030); Net-Zero targets; target for a Net-Zero power system by 2035; the NIC's hydrogen infrastructure target; and private sector investment (see pp 64-66).
- The Programme is aligned with development of the East Coast Cluster, providing transmission infrastructure in both the Teesside and Humber region. It also supports development of 8 projects shortlisted through the NZHF and HAR1, and the CCUS clusters within the region.

Provide UK energy system resilience and flexibility

- If the UK is to decarbonise multiple sectors through electrification, it will largely depend on intermittent renewable power to achieve this. Backup flexible generation, supported by seasonal storage and hydrogen networks connecting to hydrogen storage facilities, will be required to maintain system resilience and security of supply.
- ECH_2 can deliver this by connecting large scale CCUS-enabled hydrogen production with demand across the region, including the supply of hydrogen-fuelled gas turbines that will provide low-carbon, dispatchable power to the electricity system.

Catalyse wider system benefits

- ECH_2 will provide value for money by repurposing parts of the existing network instead of building a separate hydrogen network; utilising assets that customers have already funded and avoiding potential future decommissioning costs.
- By facilitating sharing of market knowledge between energy users through Consortium events and the ECH_2 website, the Programme helps users to make investment decisions.
- ECH_2 will support the growth of the local economy, levelling up the region by providing businesses with a low-carbon option to decarbonise. This has the potential to avoid UK industrial exits, create new hydrogen jobs and transition the existing skilled workforce, and build capabilities throughout the supply-chain.

See chapter 2 on the 'Vision of the East Coast' to find the figures on hydrogen demand, storage and production.

The East Coast Hydrogen Programme Partners

ECH_2 is delivered by three of the UK's gas networks. Each of the Partners has their own goals for the hydrogen sector based on the needs of their own customers. The Programme reflects their shared vision, setting the blueprint for cross-network initiatives in the transition to hydrogen.

Cadent
Your Gas Network

About: Cadent is the UK's largest gas distribution network, managing a network of more than 130,000km of pipes which transport natural gas throughout the North West, West Midlands, East Midlands, South Yorkshire, East of England and North London.

Purpose : Cadent is committed to delivering Net-Zero, which means finding a way to transition all consumers away from the methane in its network today and to clean alternatives like hydrogen. They are delivering this by leading the UK's work on developing the infrastructure and evidence case necessary to realise this.

Objectives for ECH_2: Supporting the local hydrogen economy by connecting large scale hydrogen producers with industry, hospitals, airports and power generators in towns and dispersed sites.

For Cadent, East Coast Hydrogen presents a unique opportunity to drastically reduce fossil fuel use for our biggest industrial customers in the East Midlands and South Yorkshire. Many of the large industrial and power sector stakeholders that we have engaged with informed us that they have limited alternative options to decarbonise their operations, other than hydrogen. This makes it vitally important that we are able to bring them low carbon hydrogen in a timely manner to allow them to decarbonise operations and keep their companies thriving in the region, supporting the local economy, providing high-value jobs and manufacturing low-carbon goods for the UK and export around the world.

Steve Fraser, Cadent CEO

Northern Gas Networks

About: NGN maintain more than 37,000km of gas pipes, covering large cities like Newcastle, Sunderland, Leeds, York, Hull, and Bradford and rural areas such as North Yorkshire and Cumbria.

Purpose: Assessing the suitability of the gas network to transport 100% hydrogen and proving that the gas network can safely transport a hydrogen blend through HyDeploy. In addition, NGN is working on research into how hydrogen can be used for heating.

Objectives for ECH_2: ECH_2 presents an opportunity to scale the experience to date into a broader deployment across East Coast region, including homes, commercial and industrial users.

Our East Coast Hydrogen delivery plan is absolutely critical to maintaining and building a thriving regional economy, whilst hitting our Net-Zero target. It demonstrates how we can decarbonise industry initially in Teesside, West Yorkshire and the Humber, by bringing hydrogen to the majority of our largest users, many of which are simply unable to function without an alternative to today's natural gas. A thriving industrial economy is essential to our region, creating good quality local jobs and prosperity for the community and attracting inward investment.

Mark Horsley, NGN CEO

national gas

About : National Gas is the backbone of Britain's energy system today and will play a leading role in the transition to a clean energy future that works for every home and business.

Purpose: National Gas through Project Union aims to develop a hydrogen 'backbone' by connecting Industrial Clusters and strategic hydrogen production sites, with storage and demand across the UK.

Objectives for ECH_2: Connection of the largest Industrial Clusters in the UK, Humber region and Teesside, to prove the case for hydrogen transportation at scale, whilst connecting these clusters with production, storage and demand points.

Our teams at National Gas are preparing to convert our national network to hydrogen, and we have a concentration of key assets in the East Coast Hydrogen area. We are excited about our role in the vanguard of a Net-Zero future, while still ensuring the continued dependability of natural gas transmission to support Britain through the energy transition. Indeed, it is this dependability of our networks which enables us to make these decisions and deliver the innovation we need. Every project is eventually part of a customer bill - and that is why it is so critical to adapt the networks we have already paid for, as well as building targeted, efficient new components. East Coast Hydrogen provides this balance, driving economic growth while securing thousands of jobs and creating thousands of new ones in the process.

Jon Butterworth, National Gas CEO

The Programme is guided and supported by our stakeholders

The Consortium Group is central to the delivery of ECH_2. It allows the Programme to be tailored to the needs of the region's energy users. 122 stakeholders across the entire value chain have provided information about their hydrogen plans and/or letters of support for ECH_2 development.

The Hydrogen Industry Value-Chain

Cross-value chain Participants

VPI, Statera, SSE Thermal, Equans, Centrica Storage, Siemens Energy, East Coast Cluster, Kellas Midstream, Equinor, bp

Hydrogen Production

BOC (A Member of The Linde Group), ITM Power, Chinook Hydrogen, CPH2, RWE, Carlton Power, Eco Energy World, Uniper, HyMarnham Power, Phillips 66, HiiROC, H2V, ecOnergy

Demand

Navigator, Liberty, Sembcorp, Samworth Brothers, Forterra, Aggregate Industries, Guardian Glass, Triton Power, Velocys, inVivo • Soufflet, Vaillant, NHS England, Nestlé, Knauf, Toyota, West Burton Energy, PepsiCo, Ardagh Glass Packaging, Beatson Clark, Premier Foods, Sofidel, University of Sheffield, Lenzing, Carlsberg Marston's Brewing Company, Cranswick plc, University of Nottingham, British Sugar, Solenis, 2 Sisters Food Group, Boots, Rolls-Royce, Alstom, Mercia Power Response, Singleton Birch, Saint-Gobain, Loughborough University, Enertek International, Naylor, MAG East Midlands Airport, Syngenta, British Glass, Hanson (Heidelberg Cement Group), H+H, Molson Coors Beverage Company

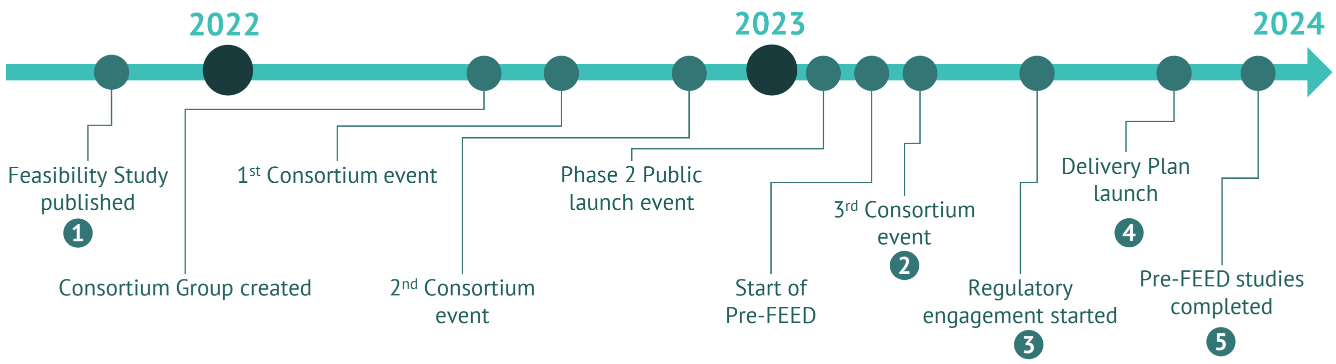
Local Stakeholders

Tees Valley, West Yorkshire Combined Authority / Tracy Brabin Mayor of West Yorkshire, CATCH, D2N2, Midlands Engine, East Midlands Development Company, Greater Lincolnshire Local Enterprise Partnership

Key Programme milestones

ECH_2 has significantly progressed since the Feasibility Study was published in December 2021. This Delivery Plan builds on the previous work to show the development of the Programme partners' low carbon networks.

Key project milestones



Key Programme achievements

1 Feasibility Study completion

The Feasibility Study established the strategic vision and opportunity for ECH_2.

2 Consortium Group growth

The Partners work closely with hydrogen off-takers, producers and storage providers. The number of members in the ECH_2 Consortium is now 122, including representation from a variety of sectors including the NHS and educational bodies, demonstrating the level of demand for a hydrogen economy in the region.

3 Progress on regulatory engagement

The Partners have commenced Re-opener engagement, one of the key milestones in obtaining funding for the Programme. The 'needs case', being the most critical part of the submission, has been presented to Ofgem and DESNZ, helping to maintain the Programme's alignment with the UK Government's strategy.

4 Delivery Plan

This Delivery Plan represents the culmination of the Pre-FEED phase of the Programme. It has summarised the findings of the Pre-FEEDs and presents the ECH_2 needs case, including the benefits that could accrue to various stakeholders, and a detailed plan for further Programme development.

5 Pre-FEED completion (end 2023)

As part of the Pre-FEEDs, the Partners will complete a technical feasibility assessment of the Programme, identifying route design options and indicate which pipelines could be repurposed and where new assets are needed.

Programme Partners' accomplishments supporting the project

Development of East Midlands Hydrogen [14]

Cadent with partners, including D2N2, Uniper, Toyota, Midlands Engine, and East Midlands Freeport, demonstrated the existence of more than 10 TWh of distribution connected hydrogen demand in this sub-cluster of ECH_2, and 650 MW of forecast localised hydrogen production. This has demonstrated the need for a localised hydrogen network and boosted investor confidence.

NGN Village trial in Redcar [15]

Subject to a decision from DESNZ later this year, NGN will support the development of the UK's first hydrogen village in the East Coast region with a large scale trial to be carried out in Redcar, Teesside by 2026. The trial will collect critical evidence to inform the UK Government's decision on hydrogen's role in decarbonising residential heating.

Successful submission of Project Union Feasibility Re-opener [16]

Section 1 of Project Union forms part of ECH_2 acting as a blueprint for the rollout of a UK hydrogen backbone, and supporting the development of a wider energy system. The progression of Project Union, delivered by National Gas, supports the development of the Programme.

Introduction to the Delivery Plan

This Delivery Plan provides an update on progress since the ECH_2 Feasibility Study. It presents more detailed insights on the decarbonisation plans of energy users in the East Coast region and defines the next steps needed to deliver the Programme.

Delivery Plan

Purpose of the Delivery Plan

1. **Demonstrate alignment and collaboration** between Cadent, NGN and National Gas hydrogen plans for the East Coast region.
2. **Support timely decision** making by UK Government and Ofgem to enable ECH_2 and the UK's wider hydrogen ambitions.
3. **Provide confidence to regional stakeholders,** including hydrogen users, producers and storage asset owners, on the direction of travel for hydrogen network infrastructure, allowing them to further invest in hydrogen plans.
4. **Engage key stakeholders and decision makers in ECH_2** to galvanise support for the need to develop plans for hydrogen infrastructure in a timely manner.

Structure of the Delivery Plan

Goals	Chapter	Details
Set out the **vision and need for ECH_2** by demonstrating the scale of expected hydrogen demand, supply, and storage within the region.	Chapter 2 (pp 19-46)	1. Demonstrate how the need for hydrogen infrastructure is being driven by system users and their plans for Net-Zero. 2. Present high level timeline for ECH_2 and show how these map to the needs of system users and other transmission and distribution projects.
Align detailed work of individual network Pre-FEEDs to **present a holistic approach** to delivery by providing clarity on the **'what', 'when', 'where', 'how'** of network development.	Chapter 3 (pp 47-60)	1. Present an updated and more detailed overview of ECH_2 critical path and deployment timeline. 2. Outline high level routing options and assumptions. 3. Summarise key themes and findings of Pre-FEED studies.
Building on the ECH_2 Feasibility Study, **reinforce the opportunity and benefits** of the Programme and why it is **critical to achieving Net-Zero** targets.	Chapter 4 (pp 61-84)	1. Demonstrate ECH_2 opportunities and benefits accross jobs and local economy, industrial, and residential decarbonisation, system resilience. 2. Showcase support for the Programme across the value-chain. 3. Highlight the impact and consequences of failing to deliver ECH_2 on UK Government targets.
Identify **key enabling actions** across UK Government, regulators, industry, and networks **to make ECH_2 a reality.**	Chapter 5 (pp 85-90)	1. Summarise actions, identifying an owner, and timeline to achieve ECH_2 Programme. 2. Identify any dependencies and risks that could impact ECH_2 delivery. 3. Illustrate the scale of investment required for the Programme delivery.

02

A vision for hydrogen in the East Coast region

Key statistics provided by the East Coast Hydrogen Consortium Group

Existing users of the gas transportation network, prospective hydrogen producers, and hydrogen storage developers have informed us about their decarbonisation plans with respect to hydrogen. Here, we summarise the demand for ECH_2 based on their feedback.

01 Demand

Over 63 TWh/year

Identified potential hydrogen demand by 2037 for industrial, commercial, power and aviation companies looking to decarbonise their operations*

45%

Of total forecast hydrogen I&C and power demand is in the Humber and Teesside Industrial Clusters. The remaining 55% of demand will come from Yorkshire and the East Midlands

64 Power Sites

Make up 55% of total announced hydrogen demand by 2037

02 Production

Over 83 TWh/year

Current planned hydrogen production by 2037 in the East Coast region

Rise in green

The East Coast region could meet 88% of the UK's target for 5 GW of Green Hydrogen by 2030

Up to 30%

Of all projects down selected for funding negotiations with UK Government are located within the East Coast region

03 Storage

Over 19%

of the UK's storage requirements (56 TWh) will be met by 2050 with Rough accounting for 10 TWh [39]

UK's Largest Permian Saltfield

Huge potential for salt cavern development in the region for hydrogen storage

Up to 4 TWh

Announced storage within the East Coast region by 2037 to provide system resilience and flexibility

*Total hydrogen demand includes (23.1 TWh) I&C demand, (34.5 TWh) power demand, (5.6 TWh) transport demand.

Hydrogen demand, production and storage in the East Coast region

The East Coast region is an ideal location to kickstart the UK hydrogen economy, due to a high concentration of industrial, commercial (I&C) and power demand, a pipeline of hydrogen production, and advantageous geological conditions for storage.

Hydrogen Demand

Using stakeholder data, **over 63 TWh/year of I&C, power, and transport hydrogen demand is identified within the region by 2037.**

Hydrogen demand has the potential to grow at an annual rate of 27% between 2028 to 2037. A trend that is anticipated to increase as the UK Government and industries push forward with their decarbonisation strategies, the Hydrogen Business Model is established, and further certainty on the construction of a network which increases the feasibility and attractiveness of switching to hydrogen for potential users.

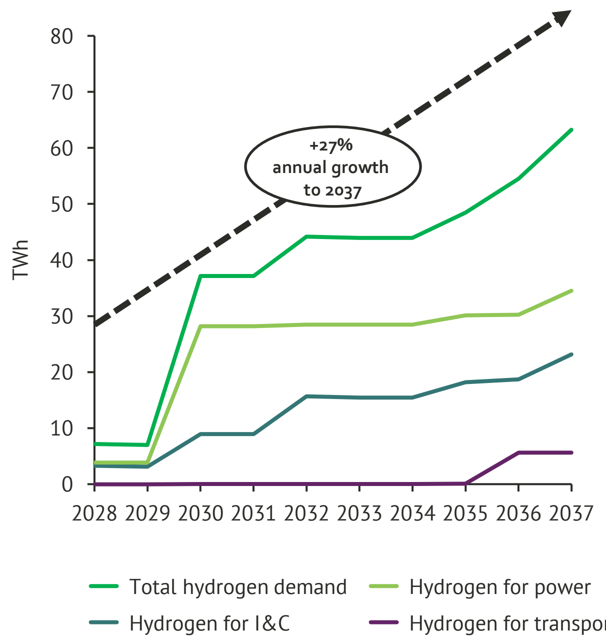
55% of total identified hydrogen demand lies within power, with 64 sites making up the largest share of total hydrogen demand.

There are 9 classified key I&C sectors within the East Coast region with **270 sites demanding a combined 23.1 TWh/year of hydrogen by 2037, with 41% of demand coming from the chemical sector.**

A single potential user in the aviation sector has provided a hydrogen forecast for 5.6 GWh/year hydrogen for zero-emission aircraft, plus ground and aircraft power units.

Residential demand within towns and wider regions have not been factored into demand calculations used for core network configurations.* However, optionality must be maintained within any strategy pending UK Government's decision on hydrogen for heat in 2026, potentially resulting in a large increase in total demand.

Identified potential annual I&C and power hydrogen demand between 2028 to 2037 (based on primary forecasts from industry)



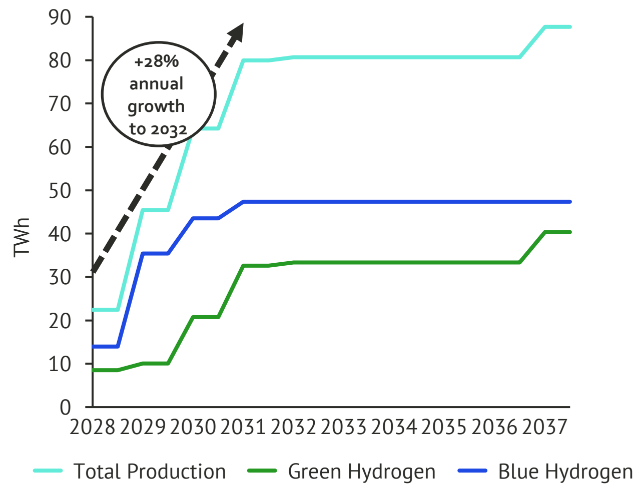
Hydrogen Production

The East Coast region is central to meeting the UK's hydrogen production targets**, with over 83 TWh/year of potential hydrogen production to be available by 2037** to decarbonise Industrial Clusters and wider region.[17]

The majority of hydrogen produced in the mid-term will be Blue Hydrogen (from Steam Methane Reforming (SMR) or Autothermal reforming (ATR)), **but Green Hydrogen** (produced by electrolysis) **will reach near-parity by the late 2030's** thanks to an abundance of offshore wind power potential located in close proximity to the East Coast region.

There is a large pipeline of hydrogen production capacity, but according to producer surveys 52% is still in the pre-planning stage of development. To unlock a rapid scale up of production between 2025 to 2032**,** clarity on support from the UK Government will be required.

Announced annual hydrogen production between 2025 to 2037



Hydrogen Storage

High levels of long-term storage will be essential for the UK to provide energy security, system resilience and flexibility without unabated natural gas in a grid powered by renewables.

ECH_2 can meet over 19% of the UK's storage requirements of 56 TWh as outlined in National Grid System Transformation scenario by 2050. [18]

Key figures on storage

Up to 4 TWh of potential hydrogen storage by 2037

East Coast region holds the largest Permian saltfield in the UK for salt cavern development

Note: See methodology section to understand the assumptions and data used in assessing hydrogen demand, production and storage.

** In the case of Scunthorpe, Cadent have accounted for town demand in pipeline sizing. See chapter 3 for more information.*

The need for integrated hydrogen midstream infrastructure

ECH_2 will be critical to the development of a regional hydrogen market by connecting a large number of producers with consumers in the region and eventually to the wider market.

Connecting production with demand

A large amount of hydrogen production and demand is expected to be commissioned at pace, with up to 83 TWh of annual production, and 63 TWh of annual demand by 2037.

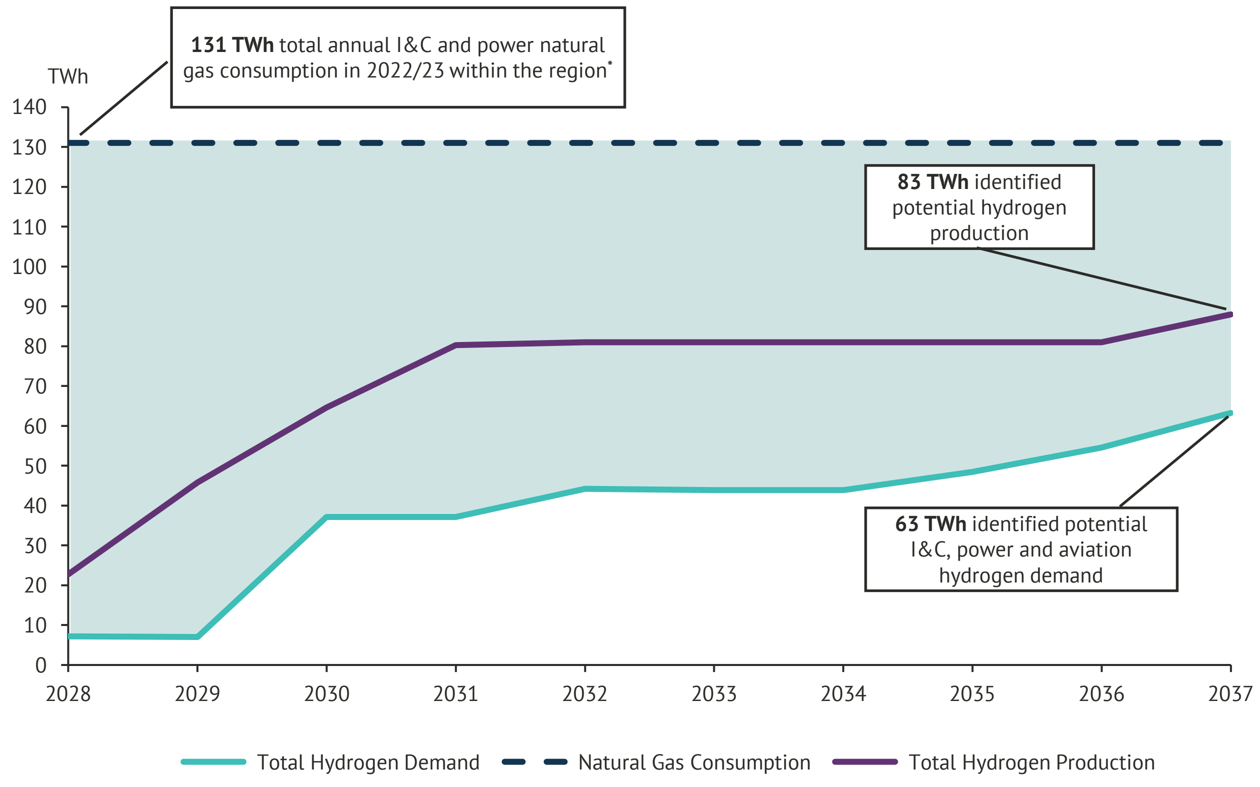
To transform the nascent and fragmented hydrogen market into a more integrated and competitive end state, **hydrogen transport and storage infrastructure needs to be developed in anticipation of the volumes of demand and production materialising in the coming years.** Planning for the network infrastructure now will send clearer signals to the market on the future structure of the hydrogen market. This will provide greater certainty for both hydrogen producers and consumers in centres of supply and demand, supporting investment in an integrated energy system that works alongside electricity and natural gas. This integration across the value chain is essential to the UK's overall energy supply, making it more secure and resilient.

By 2037, ECH_2 will be required to connect over 63 TWh/year of projected demand with hydrogen production, roughly 48% of total natural gas supplied to I&C and power sectors in 2022/23. It is expected that natural gas demand will decrease due to the uptake of hydrogen, electrification and other alternative energies**. It is anticipated that hydrogen demand will continue to rise as low-carbon hydrogen becomes more accessible, commercially viable, and scalable**, giving businesses the confidence to invest in the equipment required to switch from natural gas. [17]

Additionally, the majority of hydrogen production that is announced within the region is planning to come online before 2031. Growth is anticipated to continue increasing as the nascent hydrogen market transforms and it is proven to be economically viable with sufficient infrastructure available to transport and store hydrogen at scale.

There is potential for hydrogen production in the region to outstrip demand, this could provide ECH_2 with a opportunity to distribute, or export, excess hydrogen across the UK through Project Union's network. The significant scale up in hydrogen supply and demand will require an integrated hydrogen transport network to enable a stable supply of energy to the businesses and customers that depend on it.

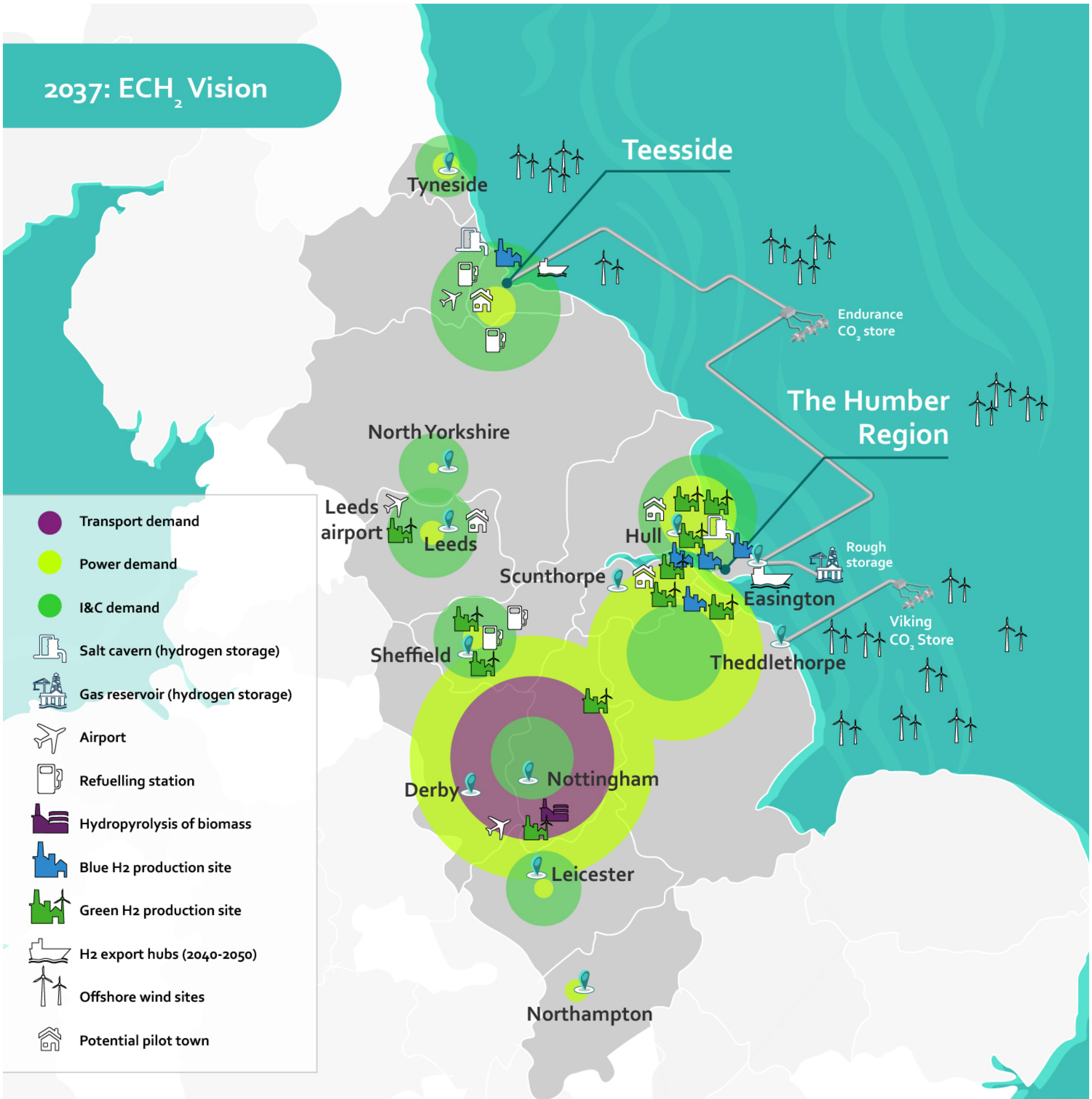
Total potential annual I&C, power and aviation hydrogen *demand and production within the East Coast region (2028 to 2037)*



Note: Total natural gas consumption is indicative of the scale of natural gas to fuel switch or abate, not a forecast over time.

A vision for hydrogen in the East Coast region

Our vision of a hydrogen economy in the East Coast region by 2037 is based on the decarbonisation plans of our stakeholders and has been shaped by our Consortium Members.



Note: Routing and location of demand and supply is indicative and will be confirmed as programme progresses. Sites shown on this map are compiled from information provided by potential customers, supplemented by secondary sources. Project locations are the approximate relative location and may not be complete or accurate. The location of Pilot Towns have not been decided and the icons represented on the map indicate the region under consideration.

ECH_2 provides a solution to efficiently connect planned centres of hydrogen production, demand and storage; balancing the network and managing misalignment between supply and demand through a safe and regulated distribution system.

Image Source: Uniper

2.1

Hydrogen demand

Industrial and commercial hydrogen demand profile

The East Coast region is home to a variety of I&C organisations, many of which are actively seeking to decarbonise their operations by switching to low-carbon hydrogen to achieve Net-Zero compliance.

Methodology for assessing potential hydrogen demand from I&C and power customers

424 Top natural gas consuming sites investigated within the East Coast region

191 Demand sites expected to switch to hydrogen based on a set of assumptions

156 Demand sites confirmed to switch to hydrogen based on forecasts

53 Customers who have provided hydrogen forecasts for multiple sites

Cadent	National Gas	NGN
Received primary data from **146 top gas consuming sites** in the East Midlands network, including potential hydrogen consumption over time and future decarbonisation plans.	Received primary data from **10 sites which directly connect to the National Gas network in the region** on current natural gas demand, future decarbonisation plans and potential hydrogen demand.	Secondary data has been collected from **the top 200 natural gas customers** and a set of assumptions have been applied to ascertain the future demand for hydrogen at 191 of the sites identified.

Potential future hydrogen I&C demand profile

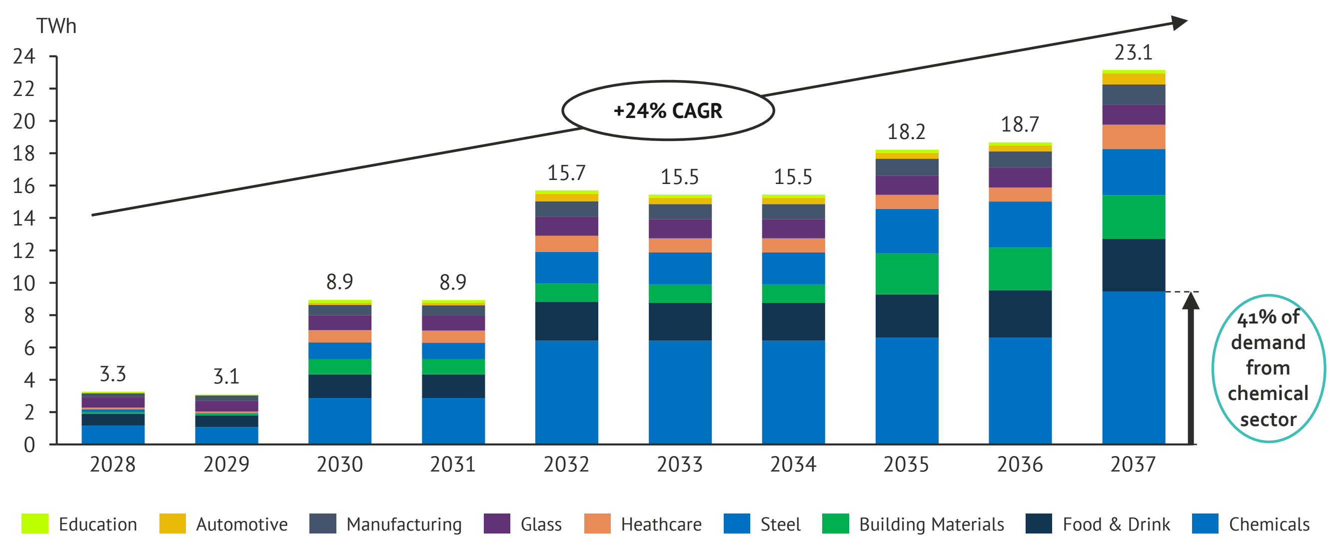
There are **7 energy intensive industrial sectors and 2 key commercial sectors within the East Coast region with 270 sites potentially requiring 23.1 TWh/year of hydrogen by 2037** to decarbonise their operations and reach Net-Zero targets.

On average I&C hydrogen demand will increase annually by 24% between 2028 to 2037. **We expect this growth to continue as I&C hydrogen-ready assets are deployed at scale, transport and storage infrastructure gets developed**, and the potential rising price of emissions allowances in the UK ETS.

Due to increasingly stringent regulatory restrictions and Net-Zero targets being enforced on heavy emitting industries, hydrogen demand has the potential to increase by 187% between 2029 and 2030 with 184 sites looking to transition away from natural gas. A transport network will need to be ready in time to support this scale up and ensure that these sites can access hydrogen.

The **chemical sector is expected to consume the largest amount of hydrogen within the East Coast region,** making up 41% of total I&C demand in 2037, requiring 9.4 TWh of hydrogen.

Total announced I&C demand for hydrogen by large users between 2028 to 2037 [19]



Note: See methodology section to understand the assumptions and data used in assessing I&C hydrogen demand.

Role of hydrogen in decarbonising industrial and commercial sectors

While there are multiple routes to decarbonisation in different sectors of the economy, the availability of low-carbon hydrogen is essential for the decarbonisation of hard-to-abate industrial operations.

Each industrial sector is faced with a different set of challenges and options

While some sectors have multiple options to cost effectively decarbonise, others have fewer and are more dependent on the availability of hydrogen. Factors influencing this include:

1. **Technical feasibility of alternatives** such as space constraints, technology maturity, readiness and scalability (which often vary on specific site level basis)
2. **Industrial dependency on natural gas as feedstock**, or for high temperature thermal processes making it hard-to-abate
3. **Cost effectiveness of using alternative fuels**, or capital investment cycles to refit/convert industrial equipment.

Technologies are constantly evolving, and we need to be mindful that preferred solutions may change over time.

Using feedback from stakeholders, we have considered potential sector reliance on hydrogen-based on todays availability and cost of technologies, as well as:

- → Sector decarbonisation commitments collected from industry associations or UK Government reports.
- → Industrial dependency on natural gas, e.g. feasibility and cost effectiveness of implementing alternative technology.
- → Companies' strategic priorities on decarbonizing collected through primary data and secondary resources.

Other	Biogas or efficiency gains	✓	Technically feasible
(icon)	CCUS	✓✓	Technically and economically feasible
(icon)	Electrification	✓✓✓	Considered potentially optimal solution
(icon)	Hydrogen		

Image Source: SSE Thermal

Sector	Identified hydrogen demand	Sector commitments	Potential technologies to decarbonise industrial process that uses natural gas				Comments by key sector player
					CO_2	Other	
Chemicals	9.44 TWh	Chemical Industries Association stated Net-Zero target by 2050. [20]	✓	✓✓✓	✓✓	✓	"We have processes that are not practical to decarbonise without hydrogen." **Tronox**
Food & Drink	3.28 TWh	UK Food & Drink Federation Net-Zero target by 2040. [21]	✓✓	✓✓		✓	"Hydrogen is a potentially very real option for our decarbonisation." British Sugar
Steel	2.85 TWh	Pledged to reduce emissions by 2035, committing to using hydrogen and CCUS. [22]	✓✓	✓✓✓	✓✓		"Hydrogen is a replacement for Natural Gas; it is critical for our industrial Process." LIBERTY
Building Materials	2.69 TWh	Cement and construction materials to reach Net-Zero by 2050. [23]	✓✓	✓✓✓	✓✓	✓	"We are looking at a 20% blend with the intention to move to 100% hydrogen in the future." FORTERRA
Healthcare	1.52 TWh	NHS has a Net-Zero target by 2040. [24]	✓✓	✓		✓	"Hydrogen is a key decarbonisation technology that a number of NHS Trusts will seek to utilise where technically and commercially viable "* NHS
Glass	1.24 TWh	British Glass association pledge Net-Zero target by 2050. [25]	✓✓	✓✓✓	✓		"Hydrogen is above all a new solution to decarbonise our industrial processes that are unsuited to conventional solutions." SAINT-GOBAIN
Manufacturing	1.24 TWh	Net-Zero aim by 2050 and ambition to reduce emissions by 2035. [26]	✓✓	✓✓	✓	✓	"Hydrogen could replace natural gas as the main fuel for our lime kilns." Singleton Birch
Automotive Manufacturing	0.68 TWh	Many OEMs are setting ambitious cross-value chain decarbonisation targets by 2040. [27]	✓✓	✓✓		✓	"We see hydrogen generated from renewable sources as an important component in achieving decarbonisation." TOYOTA
Education	0.20 TWh	UK's education sector targeted to be Net-Zero target by 2030. [28]	✓✓	✓		✓	"Green Hydrogen presents an opportunity to use a carbon free fuel for heating." University of Nottingham UK | CHINA | MALAYSIA

Note: This is a qualitative view of the potential reliance of industrial sectors on hydrogen for decarbonisation. This is based on information provided by ECH$_2$ stakeholders and consortium members, as well as secondary case studies. It considers not only the economic potential of alternative solutions but also practical considerations for implementation (such as availability of space for carbon capture facilities). As technologies continue to evolve this view will change over time.

Industrial and commercial demand centres

I&C hydrogen demand is expected to be spread across nine demand centres, with 45% of demand located outside of core Industrial Clusters being developed within Yorkshire and the East Midlands.

Demand centre

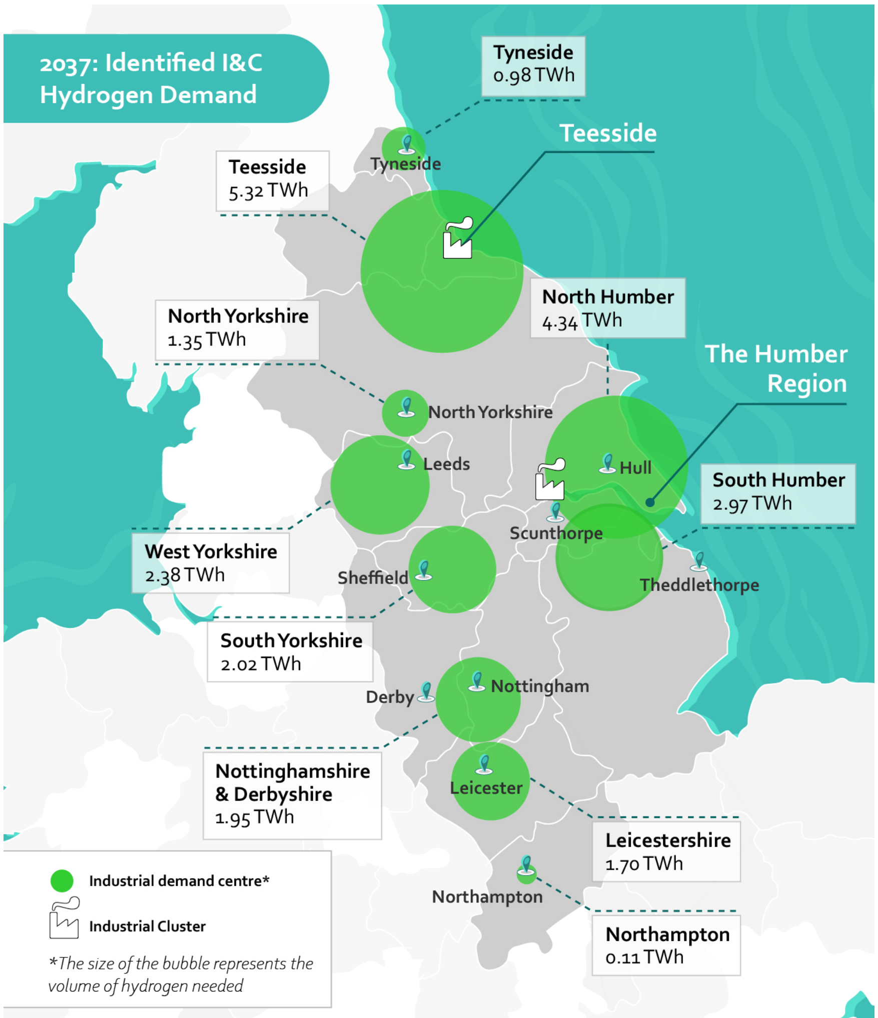
It is anticipated that the networks will build out from areas of large scale production in the Track-1 Industrial Clusters and Freeports within the Humber region, Teesside, and East Midlands. The ambition will then be to connect demand locally and expand regionally to meet the UK Government's targets to reduce industrial emissions by two-thirds by 2035.

23.1 TWh/year of hydrogen demand is spread throughout the East Coast region, with **key centres of demand in the Humber region (32%), Teesside (23%,), Yorkshire and East Midlands (33%)**. Pipeline infrastructure is required to connect assets within clusters but also to connect those clusters to the wider region.

Despite the concentration of demand within these centres, the sites are geographically dispersed. The main difficulty in switching to hydrogen, as indicated by customers, is the lack of infrastructure that will connect all 270 sites with producers and storage facilities.

1.1 TWh/year hydrogen demand is on the border of the East Coast region in Northampton and Tyneside. ECH$_2$ will look to reach these customers by constructing, or repurposing, pipeline infrastructure in later phases subject to market maturity and early network development.

This also applies to a further 128 GWh/year, of commercial and industrial demand (1 site) which is located outside of the demand centres identified on the map.



Note: Demand cluster locations are only the approximate relative location of multiple demand sites. Sites shown on this map are compiled from information provided by potential customers, supplemented by secondary sources.

Nottingham & Derbyshire
33 sites
33% of demand is from **Food & Drink** and **Building Materials** sector

South Humber
12 sites
51% of demand is from **Chemical** sector

North Humber
33 sites
79% of demand is from **Chemical** sector

West Yorkshire
47 sites
30% of demand is from **Chemicals**, 23% from **Glass** sector

South Yorkshire
21 sites
64% of demand is from **Steel** sector

Leicestershire
25 sites
51% of demand is from **Building Materials**, 32% from **Food & Drink**

Teesside
43 sites
66% of demand is from **Chemicals**, 15% from **Steel** sector

North Yorkshire
30 sites
80% of demand is from **Food & Drink** sector

Tyneside
22 sites
31% of demand is from **Healthcare**, 20% from **Chemicals sector**

Northampton
3 sites
54% od demand is from **Food & Drink**, 42% from the **Healthcare** sector

Note: See methodology section to understand the assumptions and data used in assessing I&C hydrogen demand.

Risk of industrial exits

Industrial processes, jobs and investment could move abroad if decarbonisation targets are enforced without hydrogen being widely available for companies with limited alternatives

When collecting data from our industrial customers, we have gained vital insight into the need for hydrogen and the potential consequences if it is not readily available.

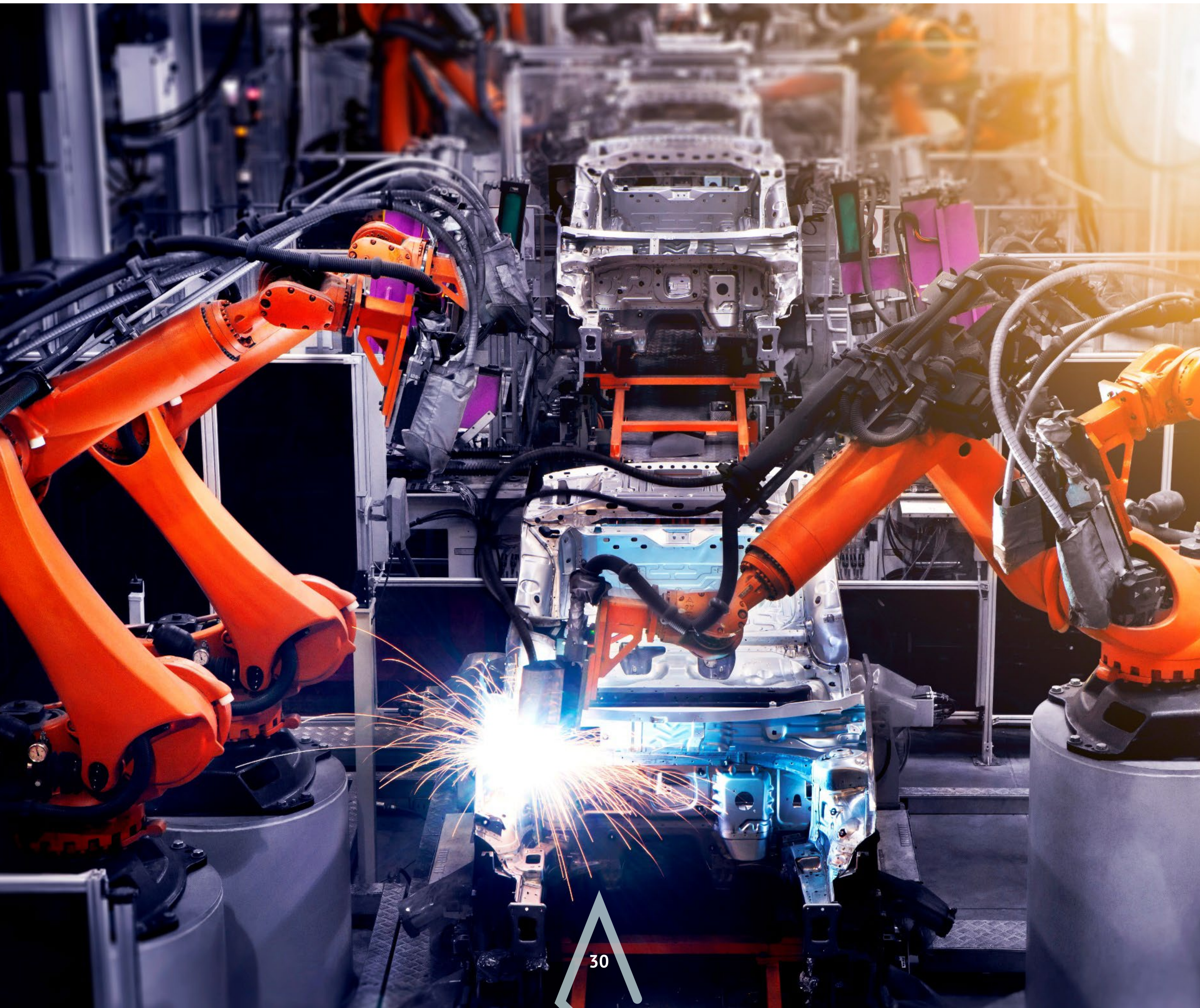
Hydrogen is critical to many industrial customers in achieving their decarbonisation strategy, with many companies hailing it as the only option to decarbonise certain elements of their operations.

Without access to hydrogen at scale, these industrials will fail to decarbonise which either jeopardises the UK's Net-Zero ambitions, or risks driving industrial processes abroad. This will result in a loss to investment and jobs, whilst increasing our energy and industrial dependence on other countries.

"Hydrogen is a lifeline [for organisations] that have no way else to get to Net-Zero"

"We have manufacturing processes that cannot be electrified unless we gain significant investment"

"There are so many variables to factor [when considering relocating operations] … but if all operations close in the East Midlands 300 jobs would be affected"



Industrial and commercial case studies

Large industrial players in the East Coast region see switching to hydrogen as a route to decarbonisation. The current lack of hydrogen infrastructure and certainty of supply are barriers to investment.

Case study: British Sugar

British Sugar is the leading producer of sugar for the British and Irish food and beverage markets. The company has set a goal of reducing its carbon footprint by 30% by 2030.

"For full decarbonisation, availability of renewable sources of energy in dispersed industrial locations, with sufficient supply capacity and distribution is going to be critical, and specifically decarbonisation of heat will be the most significant challenge as we move towards Net-Zero." – *Phillip McNaughton, Head of Decarbonisation.*

Case study: Wienerberger Ltd

"Availability of timely alternatives to natural gas, at scale, and with a price that will allow us, with some optimisation of our processes, to continue to manufacture building products that are viable for our customers is the main challenge for the company in decarbonising operations." – *Keith Jackson, Head of Thermal Process & Projects.*

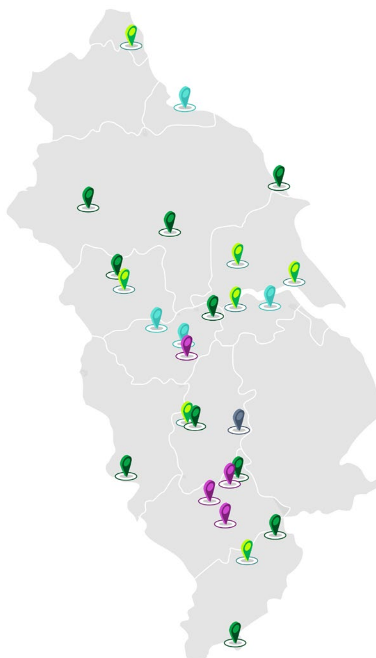
Wienerberger is currently exploring a range of energy efficiency and decarbonisation options across the whole product lifecycle, with electrification and hydrogen key solutions for reducing dependency on natural gas.

Case study: Liberty Steel

Liberty Steel needs around one million tonnes of hydrogen by 2035 to reduce emissions across its operations.

"One of the key barriers to widespread adoption of hydrogen is the lack of network infrastructure which connects producers with users." - *Ed Heath-Whyte, Head of Environment and Sustainability.*

Liberty Steel is exploring the feasibility of end-to-end Green Hydrogen production, transport and end use as part of the Sheffield-based HYDESS project. If successful, the project can be rolled out nationally.



Case study: Hanson

Hanson UK is a leading supplier of heavy building materials to the construction industry. With these industries requiring high levels of energy, Hanson is working on sustainable low-carbon building materials and solutions for the future.

Hydrogen is seen as a solution for reducing carbon emissions whilst maintaining productivity, but scale, cost and integration with the wider production plants are all key challenges.

"Hydrogen is critical for industrial decarbonisation. The challenge with hydrogen is generating it affordably and at the scale we need. That's where we see pipeline connection to future hydrogen infrastructure as a decent solution." - *Elliot Wellbelove, Carbon Innovation Manager.*

Case study: Aggregate Industries

Asphalt production requires significant amounts of high temperature heat that cannot be provided through electrification. Decarbonisation therefore requires large volumes of an alternative low-carbon fuel.

"The supply of hydrogen in a cost effective manner can only be delivered through pipeline infrastructure such as ECH_2. This project is critical to driving forward the use of hydrogen within energy intensive and hard-to-decarbonise industries across the East Midlands." - *Luke Olly, Energy & Carbon Manager.*

Note: All quotes and case studies have been provided by the named companies.

Industrial and commercial case studies (cont.)

Case study: University of Nottingham

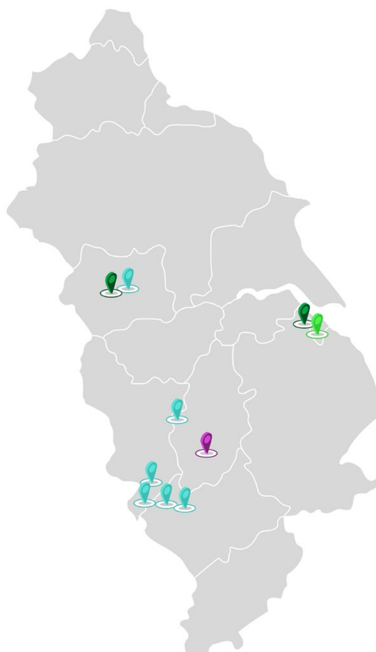
"One of the biggest challenges for the University is decarbonising the way it heats buildings and water. The University can use hydrogen to decarbonise the existing heating system infrastructure without the need for extensive capital investment and disruption." *- Andy Nolan, Development and Sustainability Director.*

The University of Nottingham has a strong and varied hydrogen research portfolio, focusing on hydrogen storage and utilisation. The University currently generates its own hydrogen through electrolysis, but having a pipeline supply could allow the University to explore new opportunities.

Case study: Solenis UK

For Solenis, a manufacturer of specialty chemicals, the biggest challenge in decarbonising its operations is the availability of Green Hydrogen in sufficient quantity and at a commercially competitive cost.

"Hydrogen connectivity and availability will be a critical step in sustaining Foundation Industry manufacturers such as Solenis on our journey to Net-Zero. ECH_2 promises to deliver this capability and will be a key factor in creating a vibrant, green manufacturing sector in northern England" - *Kevin Fitzgerald, Operational Excellence Manager.*



Case study: Lenzing Fibres

Due to a large heat requirement, full electrification is not currently a financially viable option for decarbonising Lenzing's operations.

The company is investigating alternative decarbonisation pathways. Lenzing's main focus is to understand how hydrogen will fit into its road map, what technologies are available and will be available in the future, and when hydrogen will be available in sufficient quantities at a price that is financially viable.

"ECH_2 can help support our strategy by laying out more specific plans with accurate timelines and therefore more accurate indications of when hydrogen will be available and at what cost." - *Rob Payne, Plant Improvement Manager.*

Case study: Forterra

Forterra is one of the UK's leading manufacturers of building products. The company employs circa 1,800 staff across 17 manufacturing facilities, 10 lying in the East Coast region.

Forterra has a target of 33% and 80% CO_2 reduction by 2030 in clay and concrete productions respectively. If Forterra switched its plants within the East Coast region to 100% low-carbon hydrogen, 22% of its total emissions can be avoided, enabling 20% reduction in CO_2 emissions by 2030.

Forterra can decarbonise 50% of its total industrial process emissions through alternative technologies such as electrification, energy efficiency and carbon capture, but the remaining 50% come from thermal processes which use natural gas. These emissions need to be decarbonised through low-carbon hydrogen.

"Almost 50% of the carbon emissions generated by Forterra can be attributed to the use of natural gas. If the UK wants to achieve the Net-Zero target, we believe cost-competitive, grid-connected hydrogen will be essential. We are fully committed to ensuring all Forterra manufacturing facilities are hydrogen-ready." - *David Manley, Head of Sustainability.*

Note: All quotes and case studies have been provided by the named companies.

Hydrogen demand in the power sector

The East Coast region is home to a significant proportion of the UK's existing natural gas-fired power generation capacity. Operators of these facilities have expressed a desire to convert to hydrogen to decarbonise operations.

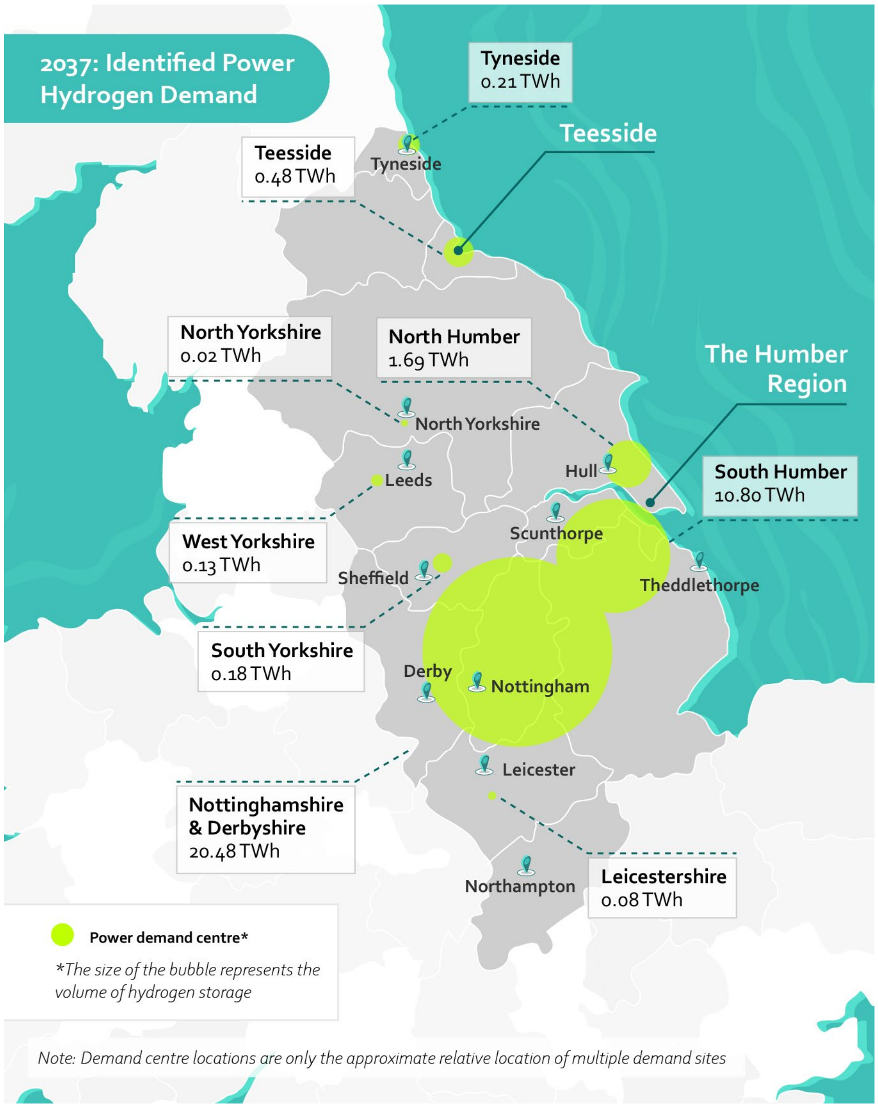
Power demand

38.5% of the UK electricity was generated from natural gas in 2022. Hydrogen-fuelled power stations offer a low, or zero carbon, flexible alternative that can make use of the UK's existing gas infrastructure to provide a resilient and flexible energy system. [29]

64 power sites make up 55% of total potential hydrogen demand in 2037. This emphasises the critical role of hydrogen fuelled power (and gas with post-combustion CCUS) in supporting the ambitions to deliver decarbonisation targets through electrification and having a Net-Zero power system by 2035. [30]

South Humber and Nottinghamshire & Derbyshire represent the two largest power demand centres in the region, potentially requiring over 31 TWh/year of hydrogen by 2037. A cost effective way to meet this demand is via a hydrogen transmission and distribution network that delivers low-carbon hydrogen from key production centres across the region, most notably in the Humber region and Teesside to a range of sites including ex-coal-fired power station sites. [31]

Based on forecasts received from power companies, **Project Union will play an important role in meeting this demand by transporting hydrogen across the region and offering direct connections to large users.**



Consortium Members - Power

Mercia, Statera, VPI, West Burton Energy, Sembcorp, SSE Thermal, Triton Power

Nottinghamshire & Derbyshire

29 power sites

59% of total Power demand

Teesside

5 power sites

1% of total Power demand

South Humber

7 power sites

31% of total Power demand

North Humber

3 power sites

5% of total Power demand

Note: See methodology section to understand the assumptions and data used in assessing hydrogen demand in the power sector.

Hydrogen power case studies

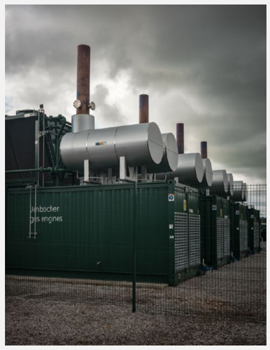
Case studies from our Consortium Members show the demand for stable hydrogen supply, at scale, for power in the East Coast region.

Case study: West Burton Energy

West Burton is committed to decarbonising its power stations so it can continue to provide flexible and efficient energy to the grid. It is currently exploring how it can convert its Combined Cycle Gas Turbines (CCGT) to run on a blend of hydrogen and natural gas.

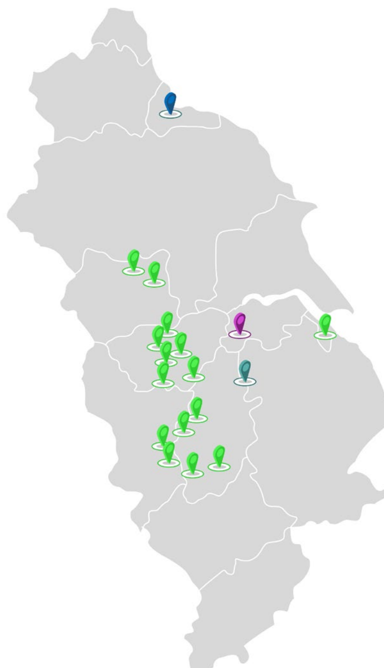
"ECH_2 could support the West Burton decarbonisation strategy by enabling the development of the critical infrastructure needed to supply hydrogen at scale to the West Burton plant." - *Heather Wilkinson, Growth and Strategy Manager.*

Case study: Mercia Power Response



Mercia Power Response, a key provider of flexible power response services to the UK grid, is currently looking at the feasibility of changing assets to use hydrogen. One of the biggest challenges for the company is ensuring that there is a reliable hydrogen supply to give the business the confidence to switch to hydrogen.

"It is very exciting to be a part of ECH_2 as it helps us to ensure the future of our business by establishing a clear, reliable and secure hydrogen supply in the Midlands for power generation." - *Courtney Depala, Research and Development Director.*



Case study: Statera

Statera is developing a combination of green hydrogen production, hydrogen storage and hydrogen fuelled thermal generation projects to provide energy storage and dispatchable generation and support the further growth of intermittent renewable energy sources.

"ECH_2 is critical to our objectives as it will enable us to connect our existing thermal generation projects in both Teesside and the Humber region, as well as others in development, to both hydrogen production and storage to enable their transition to a low-carbon fuel source" -Charlie Hill, Hydrogen Director

Case study: Keadby Hydrogen Power Station

SSE Thermal and Equinor are developing Keadby Hydrogen Power Station, which would have a peak demand of 1,800 MW of hydrogen, producing zero carbon emissions at the point of combustion. It would be the world's first major 100% hydrogen-fired power station, securing at scale demand for hydrogen in the region for decades to come. With appropriate policy mechanisms in place, Keadby Hydrogen could come online before the end of the decade.

In order to bring forward hydrogen to power projects, a hydrogen network will be essential. That is why ECH_2 has an important role to play in the development of a thriving hydrogen economy in the region, allowing sites to connect with a wider network carrying the fuel to centres of demand. That will be vital not only for Keadby Hydrogen but also for other hydrogen to power projects in the Humber and beyond.

Note: All quotes and case studies have been provided by the named companies.

Hydrogen demand in the transport sector

The East Coast region is home to major ports and airports that are investigating the role of low carbon hydrogen in decarbonising their operations.

Transport projects

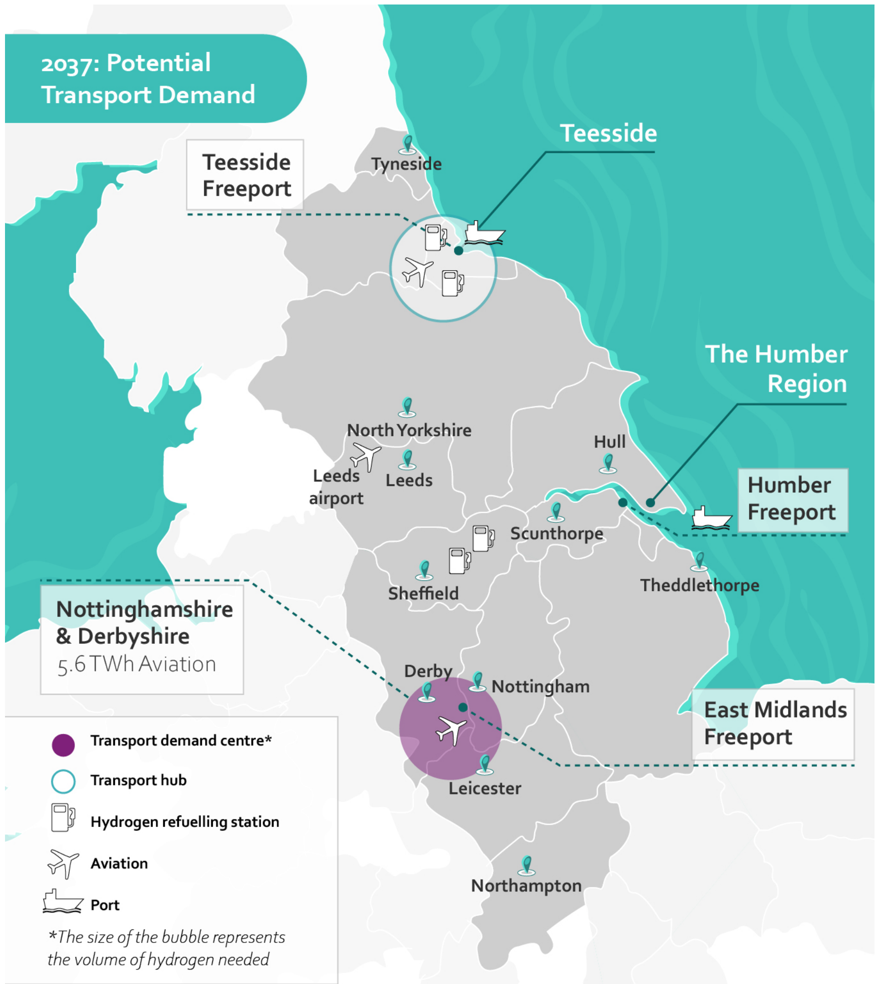
Low-carbon hydrogen is expected to play a role in decarbonising heavier transport applications (HGVs), aviation, and shipping, where energy density requirements, infrastructure constraints, and re-fuelling times favour hydrogen-based fuels. [12 32]

According to the UK Government's 'Hydrogen Transportation and Storage Infrastructure' report, **hydrogen demand for domestic transport could reach up to 21 TWh/year by 2035.** However, there is **uncertainty about the scale and growth of hydrogen demand in transportation**, with the question of which decarbonisation technology will dominate, and the timing of infrastructure rollout, making it difficult to forecast at scale. [33 34]

That said ECH_2 has obtained **a forecast from East Midlands Airport of 5.6 TWh/year hydrogen** for zero-emission vehicles and ground and aircraft power units. More customers are expected to convert operations and technology to hydrogen as the market and policy environment evolves for this case. The region is also home to Altalto a commercial scale waste-to-jet-fuel facility being built in Immingham by Velocys.

In the East Coast region, **there are numerous hydrogen transport projects funded by the UK Government** to either drive innovation in carbon neutral transport technology or to demonstrate the technology on a large scale in the 'real world'. [12]

- **Road:** Several cities and local authorities in the Yorkshire and Nottingham region have received funding to deploy zero-emission buses, including hydrogen, under the ZEBRA Programme. [35]
- **Marine:** 40 marine hydrogen projects have been funded under the three strands of the Clean Maritime Demonstration Competition (CMDC), many in the region, such as Project Mayflower which aims to supply 20 MW of Green Hydrogen to the Port of Immingham. [12 36]
- **Aviation**: £55.8m will be available to support SAF projects across the UK through to construction. In addition, funding will be provided to the ULEMCo project at Teesside Airport to produce hydrogen-fuelled ground vehicles. [12 37]



Note: Map only includes publicly announced hydrogen transport projects, with demand forecasts based on data received from potential customers. Project locations are the approximate relative location and may not be complete or accurate.

Key figures on transport

1 Transport Hub - Tees Valley is the UK first transport hub, receiving £20m to encourage the growth and development of hydrogen in transport. [38]

4 Hydrogen re-fuelling stations – Between 2027 and 2032 multiple refueling stations will be developed across Teesside and South Yorkshire. [39 40]

2 Ports - Immingham Port and Tees Valley are major freight transport hubs investigating the role of hydrogen for the port operations and shipping. [41 42]

3 Airports - East Midlands, Teesside International and Leeds airports, have stated their intentions to use hydrogen to decarbonise part of their airport operations. [43 44]

Note: Potential hydrogen demand for transport has only been quantified within this report where specific sites provided primary data for hydrogen forecasts.

Hydrogen demand in towns

Some I&C and power demand comes from within towns. Studies are ongoing to determine the technical feasibility of deploying hydrogen to decarbonise these operations.

Connecting I&C and power in towns

As networks start to invest in repurposing or building new pipelines to reach large I&C customers across the region, it is possible to build in the optionality to convert the existing gas distribution network to enable the transportation of low-carbon hydrogen to towns. This could be a solution for decarbonising additional hard-to-abate industries, commercial buildings, homes that are hard-to electrify and hospitals.

Profile of pilot town conversions

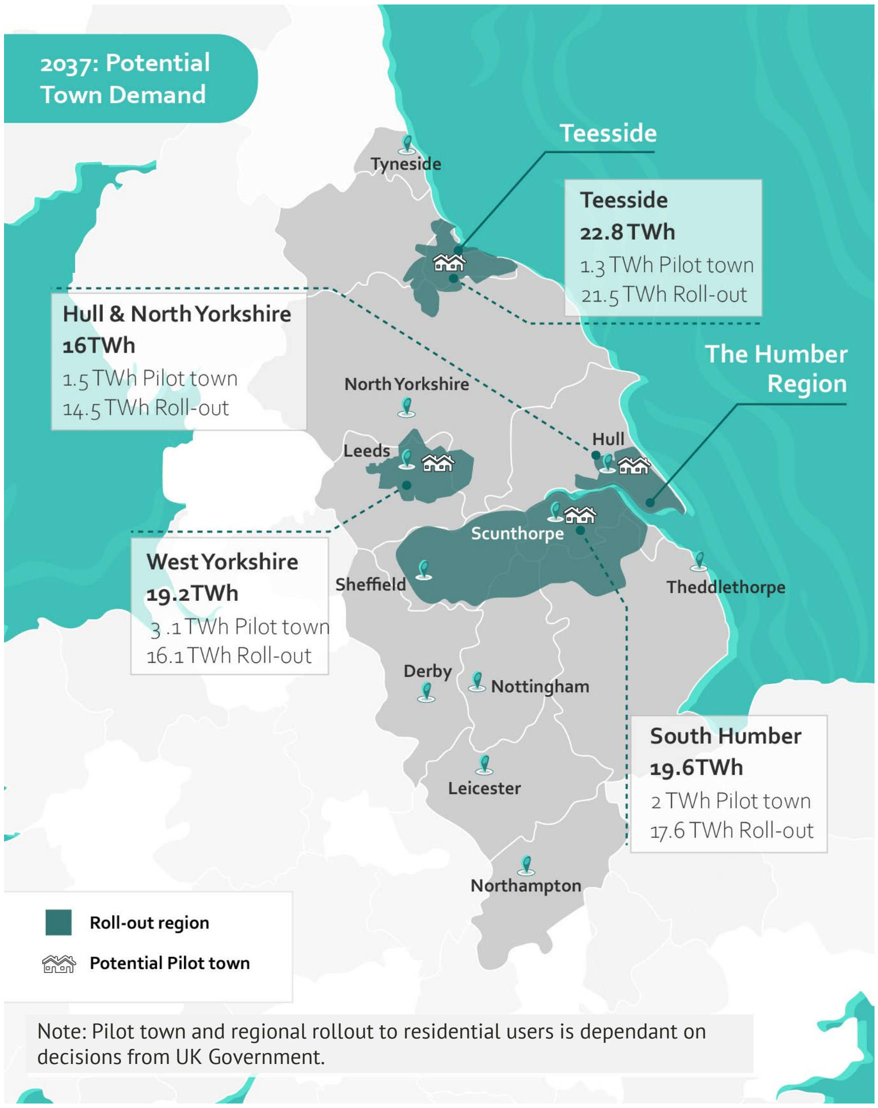
In 2025, the UK Government announced plans for a series of hydrogen pilot towns, inviting gas networks to put forward potential locations.

Four of the potential locations identified are within the ECH_2 region in Scunthorpe, Hull, West Yorkshire, and Teesside.

These towns are considered options due to their proximity to hydrogen production and demand centres, which host a wide range of I&C customers. In Scunthorpe and West Yorkshire, over half of identified hydrogen demand is from I&C and power customers.

Of the 7.8 TWh/year of hydrogen demand identified in the pilot towns, ECH_2 expects to connect to 57% of demand by 2030, irrespective of the UK Government's decision on hydrogen for heat. Transitioning the network to supply hydrogen to key customers including the NHS, food & drink manufacturers, chemical and steel producers, and power generators.

Whilst residential demand has not been factored into ECH_2 routing options at this stage, it is important that ECH_2 plans are developed in line with any town pilots and networks are ready to unlock opportunities for over 100k homes that choose to take advantage of hydrogen for heat from 2026 (pending decision by UK Government).



Scunthorpe Pilot Town

61% of demand is required for 131 industrial, 517 commercial sites and 1 power site

58,154 properties could be decarbonised via hydrogen

West Yorkshire Pilot Town

66% of demand is required for 84 industrial and 182 commercial sites

15,396 properties could be decarbonised via hydrogen

Teesside Pilot Town

21% of demand is required for 14 industrial, 182 commercial sites and 1 power site

15,341 residential sites could be decarbonised via hydrogen

Hull Pilot Town

25% of demand is required for 40 industrial and 178 commercial sites

18,398 residential sites could be decarbonised via hydrogen

Note: See methodology section to understand the assumptions and data used in assessing hydrogen demand in towns.

2.2

Hydrogen Production

Hydrogen production

The UK Government has developed business models that support investment in hydrogen production to help achieve its ambition of delivering 10 GW of low-carbon hydrogen production capacity by 2030.

Types of low-carbon hydrogen production methods

Technology group	Characteristics	Estimated construction period	2030 hydrogen production GHG emissions ranges [45]
Blue	• Created by Steam Methane Reforming (SMR) or Autothermal Reforming (ATR) plants which separate hydrogen from natural gas with the **addition of carbon capture and storage (CCS) technology** to capture and store the carbon dioxide produced by the process.	3-4 years	*ATR with CCS:* 16 gCO_2e/MJ *SMR with CCS:* 21.4 gCO_2e/MJ
Green	• **Created through electrolysis**. Clean electricity from the power grid or surplus renewable energy sources is delivered to electrolysers to split water into its components of hydrogen and oxygen, emitting zero carbon dioxide in the process. • Various types of electrolysers can be used in producing Green Hydrogen such as Alkaline electrolysis (ALK), Proton-exchange membrane (PEM), and solid oxide electrolysis (SOE).	1 – 3 years	*Grid electrolysis:* 78.4 gCO_2e/MJ *Renewable electrolysis:* 0.1 gCO_2e/MJ
Pyrolysis	• Created through the **thermal decomposition of naturally occurring methane** in biomass or organic materials. There are several techniques (fast pyrolysis or hydropyrolysis) which separates methane into hydrogen and solid carbon (carbon black), which can then be captured and stored with low GHG emissions.	Not modelled, but expected 2 years	Not modelled
White	• **Known as natural hydrogen**, created from geological hydrogen found in underground deposits and extracted through fracking. • While the concept of white hydrogen is promising, the practicality of commercial scale extraction and utilisation is still being examined.	Not modelled	Not modelled
Other	• While it is expected that Blue and Green Hydrogen will play a dominant role initially, there are other low-carbon hydrogen production techniques (such as pink or yellow hydrogen) with a potential role to play in ECH_2		

There are multiple funding and revenue support schemes to kickstart hydrogen production within the UK

CAPEX & DEVEX Support

The Net-Zero Hydrogen Fund (NZHF), worth up to £240m, funds the development and deployment of new low-carbon hydrogen production to de-risk investment and reduce lifetime costs.

NZHF: Strand 1

Provides DEVEX support for FEED and post-FEED activities

NZHF: Strand 2

Provides CAPEX support for projects that do not require revenue support HPBM

NZHF: Strand 3

Provides CAPEX for projects requiring an HPBM and sit outside Track-2 Cluster Sequencing Process

NZHF: Strand 4

Provides CAPEX for CCUS enabled projects that require HPBM and are in Track-2 Cluster Sequencing Process

Revenue Support

Hydrogen Production Business Models (HPBM) will support selected electrolytic and CCUS enabled hydrogen producers, by paying them a premium, calculated as the difference between a Strike Price and a Reference Price.

HAR 1 & 2

First electrolytic hydrogen allocation round (HAR1) will award contracts for green production up to 250 MW. HAR2 will award contracts up to 750 MW.

CCUS Cluster Sequencing

Track-1 and 2 Cluster Sequencing Process allows CCUS enabled hydrogen projects to progress to contract negotiations.

Note: Grey hydrogen is the most common form of hydrogen produced today and is generated from methane. ECH_2 is focused on developing infrastructure for low-carbon hydrogen, which does not include grey.

Hydrogen production profile

There is strong pipeline of hydrogen production assets in the East Coast region, with enough planned capacity to meet the UK Government's 2030 ambition.

Methodology for assessing production capacity

ECH_2 has collected primary quantitative and qualitative data from 22 announced production projects. The majority of these projects have provided Letters of Support for ECH_2 and engaged heavily with the gas networks to inform the development of their Pre-FEED and FEED studies.

Secondary data has been collected on 3 announced production projects within the region. **A set of assumptions have been applied** to calculate the identified annual hydrogen production shown in the methodology section (see pp 97).

The East Coast's hydrogen pipeline could meet the UK total target in 2030

In 2022 the UK Government doubled it's **ambition for low-carbon hydrogen production capacity to 10 GW by 2030, with at least half of this coming from electrolytic hydrogen.** [40]

The **East Coast region has up to 11.6 GW of planned hydrogen capacity by 2037, making up 58% of the UK's total announced capacity which stand at just over 20 GW. The East Cost region is therefore** vital for the government to meet the UK's hydrogen production targets. [46]

The East Coast region has seen an **increase in Green Hydrogen development projects** with some projects procuring Power Purchase Agreements (PPAs) and having direct supply agreements with offshore wind farms. By 2030, 88% of the UK Government target of 5 GW of Green Hydrogen could be provided within the East Coast region alone.

Blue Hydrogen projects remain a significant part of the overall mix, accounting for 54% of total production capacity by 2037.

Majority of hydrogen production is in the early stages of development*

Whilst the East Coast region has a large pipeline of hydrogen production, **52% (6 GW) of potential capacity is still in the Pre-planning stage of development.**

With the aid of multiple UK Government funding schemes, 2.8 GW of potential hydrogen capacity has progressed to the design and engineering phase of development. [46]

A further 2.4 GW, made up of nine projects, are preparing for FID having gained more revenue certainty by signing Memorandums of Understanding (MoU) or preliminary contracts with off-takers, and/or progressing through to low-carbon hydrogen negotiations with the UK Government.

Policy and regulatory decisions must not be delayed if the UK is to achieve its 2025 and 2030 ambitions.

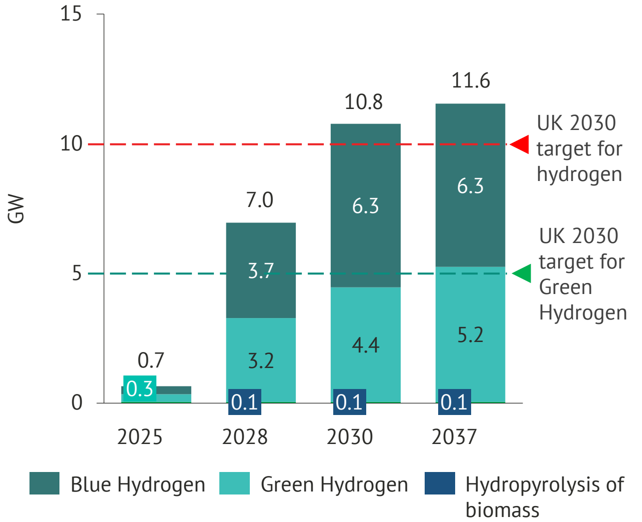
Key figures on production

22 projects have provided hydrogen production forecasts as primary data

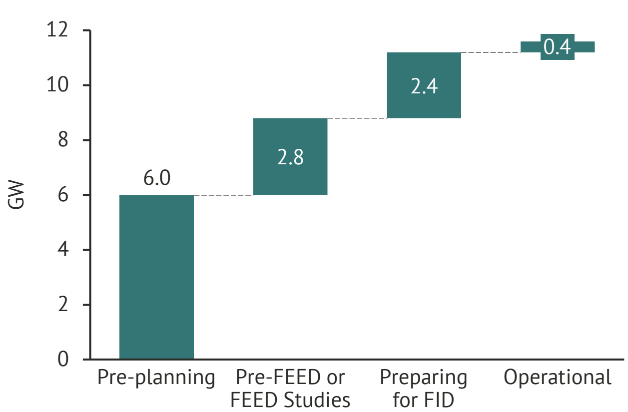
4.4 GW of Green Hydrogen is planned for 2030

58% of UK pipeline of hydrogen production is based in region

Total potential hydrogen capacity within the East Coast region between 2025 and 2037



Status of development for the hydrogen production projects within the East Coast region in 2023*



Note: See methodology section to understand the assumptions and data used in assessing hydrogen production.

** The status of hydrogen production projects has been collected through discussions with developers and supplemented by secondary sources. The information provided is a snapshot of the stage of development for each project as of 08/2023 and may not include the latest project updates or market information.*

Hydrogen production hubs

There are five production centres in the East Coast region, with 25 hydrogen production projects of which 8 have secured funding from the UK Government.

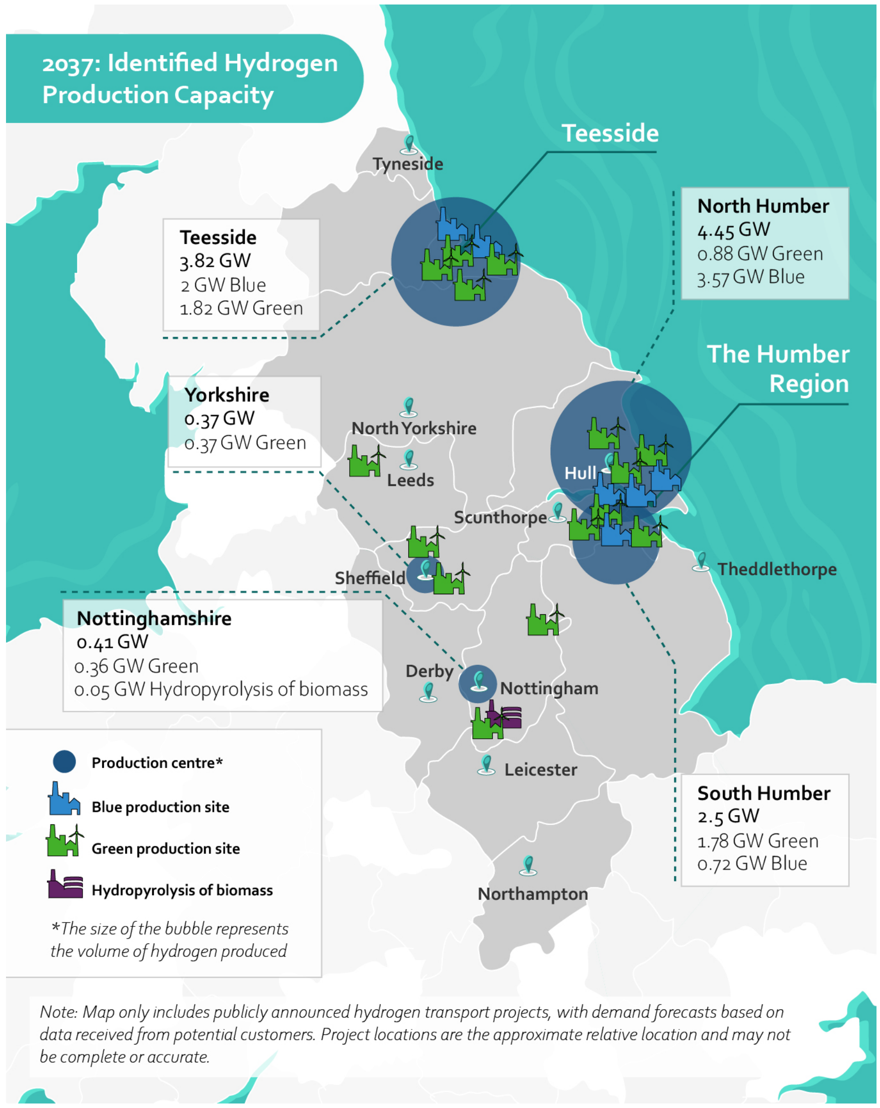
Production centres

There are five production hubs within the East Coast region with 11.6 GW of announced hydrogen capacity by 2037.

Eight projects in the East Coast region have been successful in the UK Government funding allocations, supporting 1 GW of Blue and Green Hydrogen under the HAR1, CCUS Cluster Sequencing and NZHF strand 1 and 2, demonstrating the role the region can play in kick-starting the UK hydrogen economy. [46]

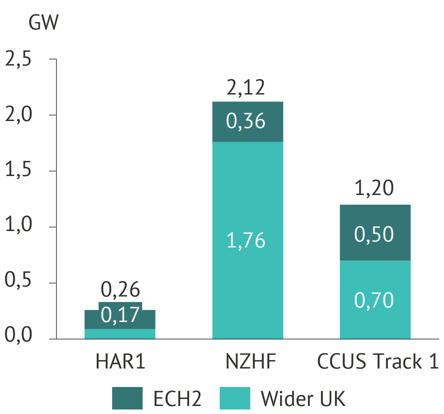
bpH2Teesside is selected as one of two Blue Hydrogen projects moving forward under Track-1 of CCUS enabled hydrogen projects, with the Humber being selected for Track-1 expansion and Viking selected for Track-2 creating further possibilities for Blue Hydrogen facilities within the region. [46 47]

Five projects were shortlisted under the first HAR1 in the East Coast region, totalling to 169 MW. [46 48]



Note: Map only includes publicly announced hydrogen transport projects, with demand forecasts based on data received from potential customers. Project locations are the approximate relative location and may not be complete or accurate.

Total hydrogen capacity allocated through UK Government funding schemes**



ECH_2 will play a vital role in connecting 25 production facilities with end-users*

8 projects selected through the NZHF, HAR1, and Cluster sequencing that can be supported by ECH_2

Teesside

7 production sites*

Blue Hydrogen will be primarily produced in Teesside, aided by the UK Governments Track-1 announcement

North Humber

6 production sites

Majority of **Blue Hydrogen** will be produced in the North Humber from 4 production facilities

South Humber

5 production sites*

Majority of **Green Hydrogen** will be produced in South Humber with some sites **using PPA's**

Yorkshire

4 production sites*

Only Green Hydrogen has been announced, there is an ambition for further capacity expansion

Nottinghamshire

3 production sites

One Hydropyrolysis of biomass plant is being considered, using waste to make hydrogen

** Three confidential production projects have not been included within the map, but have been included within total production figures.*
*** Note that 0.26 GW Wider UK capacity entering HAR1 negotiations with UK Government will be reduced to 0.25 GW through final negotiations.*

Hydrogen production sites

ECH_2 has support from 15 prospective hydrogen producers within the region, many of which would be dependent on connecting into a network for flexibility and resilience.

Case study: Uniper

The Humber H2ub® project is a proposed large scale, low-carbon hydrogen production facility at Uniper's Killingholme site, being delivered by Uniper in partnership with Shell. The project is expected to be operational later this decade.

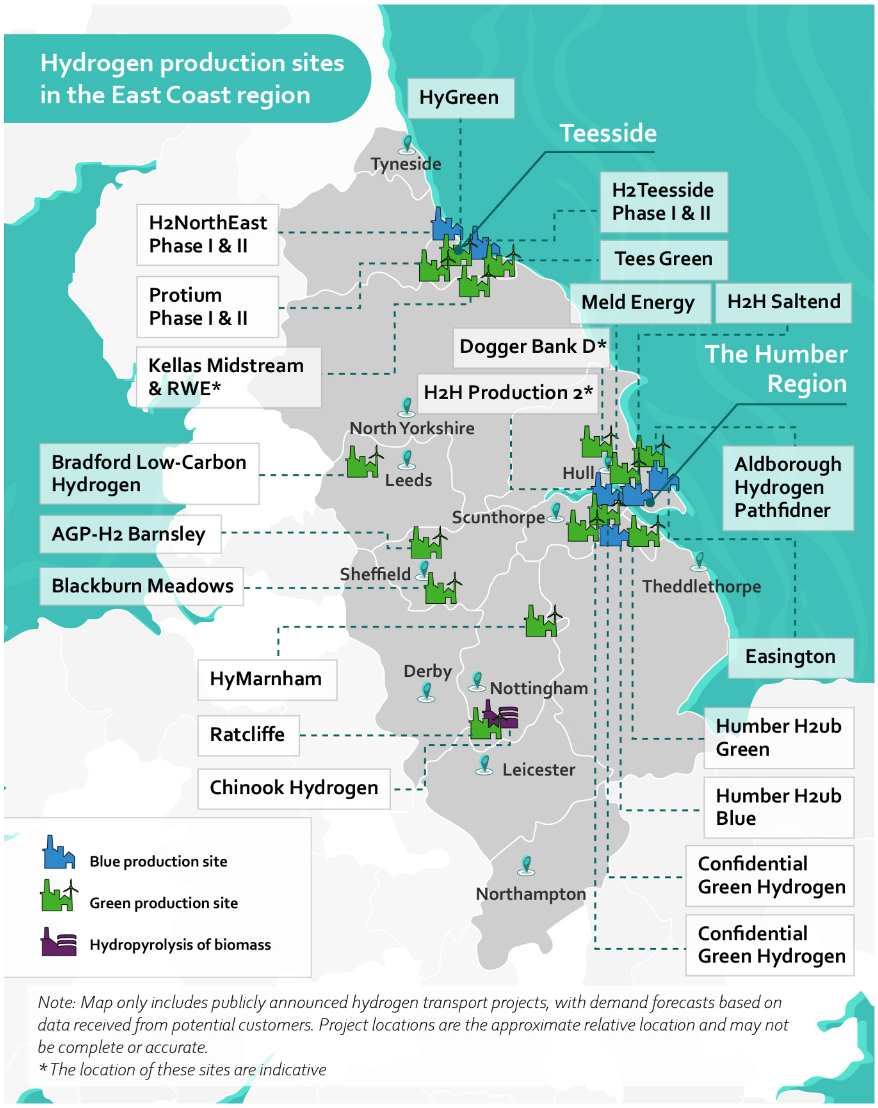
With plans for low-carbon hydrogen production capability with a capacity of up to 720 MW, the Humber H2ub® could contribute to the UK Government production target of delivering 10 GW of hydrogen by 2030.

Case study: Equinor

Part of Zero Carbon Humber, H2H Saltend will be led by Equinor. By using Humber's unique geography to deploy and grow hydrogen and CCS, this will help to deliver one of the world's first large low-carbon Industrial Clusters by 2040.

A first-of-a-kind 600 MW Blue Hydrogen production plant will enable fuel switching at scale by 2026/7, providing 6% of the UK's hydrogen production target.

"ECH_2 can enable early developing Hydrogen Transport and Storage Infrastructure, as well as both CCS enabled and electrolytic hydrogen production to be connected to the wider East Coast region, thereby consolidating and aggregating demand and accelerating the development of the Hydrogen Economy" - *Ian Livingston, Project Manager.*



Note: Map only includes publicly announced hydrogen transport projects, with demand forecasts based on data received from potential customers. Project locations are the approximate relative location and may not be complete or accurate.
** The location of these sites are indicative*

Case study: Kellas Midstream

As part of the East Coast Cluster, Kellas is developing H2NorthEast, a major project that will deliver over 1 GW of low-carbon hydrogen to industrial users across Teesside. As one of the first Blue Hydrogen production facilities in Teesside, Phase 1 of the project will deliver 355 MW of hydrogen, with plans to scale up to full capacity by 2030.

Utilising synergies with the existing CATS terminal and connection to the Northern Endurance Partnership CO_2 pipeline and store, H2NorthEast will deliver hydrogen at lower cost, cutting emissions whilst also promoting regional growth - contributing an additional £200-300m to the local economy and creating hundreds of new jobs

Hydrogen production developers rely on business model support from UK Government to provide the long-term certainty required to make final investment decisions. Continued support for the hydrogen business models is needed to ensure that the production capacity materialises; and to ensuring that low carbon hydrogen is available to support industrial decarbonisation.

Note: All quotes and case studies have been provided by the named companies.

2.3

Hydrogen storage

Hydrogen storage

The East Coast region is home to a diverse development pipeline of potential hydrogen storage – this will be critical to delivering a resilient energy system.

The need for hydrogen storage

Hydrogen storage is required in almost every independent third party Net-Zero scenario for the UK. Hydrogen storage capacity will be required for:[49,50]

1. **Grid balancing** by storing excess electricity as hydrogen to then use as power or gas in peak energy periods
2. **Energy security** through the ability to store energy as hydrogen at scale and across seasons improves energy security
3. **Support development** of an efficient tradable hydrogen market
4. **Provide sufficient resilience to customers** above single direct connections to give offtakers confidence in switching

Whilst storage has a crucial role to play in ensuring a resilient and efficient system, there are barriers to deployment, including: [51,33]

1. Demand uncertainty around the location, capacity and type of storage infrastructure that will be required
2. High investment cost requirements and long lead times
3. Absence of a clear and consistent long-term policy
4. Uncertainty regarding the commercial business case

The UK Government is working with industry to support further R&D and to design a business model by 2025 to unlock UK hydrogen storage potential and promote investment in large scale storage.

Technology group	Characteristics	Discharge duration	Suitability	Capacity [52,53]
Disused oil & gas fields	Underground solution where sites of former oil and gas assets are repurposed.	Inter-seasonal	Although an attractive option, we are still at early stages of technology readiness and there are geographical constraints due to the fixed location of these geological assets.	High
Salt cavern	Underground solution where mined cavities created in salt-strata.	Intra and Inter-day	Can potentially offer storage of large volumes of compressed hydrogen but has geographical constraints due to geological requirements. To date hydrogen is stored in geological formations in the UK.	Medium
Surface storage	Large above ground fabricated containers, either stationary or mobile. Hydrogen can be held in solid-state storage or liquefied at -253°C in cryogenic vessels for storage.	Intra-day	Suited for short-term grid services. Requires considerable space and requires specialist equipment, expertise and certification to manage safely. Constant cooling is necessary when storing liquefied hydrogen.	Low
Line-pack	The transmission and distribution networks increase within-pipe gas pressures to accommodate more hydrogen.	Intra-day	Line-pack has a role to play in managing flexibility of the hydrogen system. This is crucial to manage variability in production and demand. It can also play a role in managing intermittent renewables by providing offtake for Green Hydrogen.	Low

Methodology for assessing storage capacity

ECH₂ has collected primary quantitative and qualitative data from eight announced storage projects. This includes four off-site storage facilities that are co-located with production projects. All of these projects are at early stages of development, and are looking to secure funding or gain planning permission.

Secondary analysis has identified eight existing and planned natural gas storage sites within the region, which are assumed to hold the potential to convert to hydrogen.

Primary storage data

4 Storage sites have **confirmed their intention to store hydrogen and provided forecasts**

4 Hydrogen production sites have **confirmed their intension to build on-site storage**

Secondary storage data

5 Existing or planned natural gas storage sites are located in the region with an **assumed potential to convert to H2**

Note: See methodology section to understand the assumptions and data used in assessing hydrogen storage.

Hydrogen storage within the East Coast region

The East Coast region is well placed geologically for hydrogen storage, with high availability of existing natural gas reservoirs and salt caverns. ECH$_2$ can connect up to 19% of the UK's 2050 estimated hydrogen storage requirements.

Storage capacity

The East Coast region has a large **availability of existing gas reservoirs and potential for salt cavern development for hydrogen storage**, with the largest Permian saltfield in the UK lying between Humber and Teesside. [50]

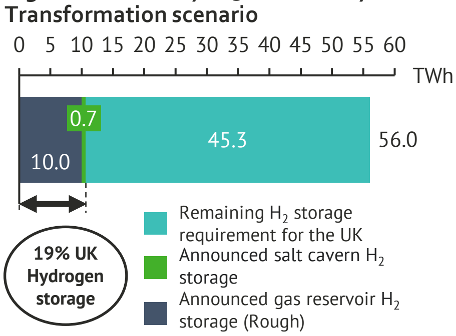
There is a pipeline of up to 0.7 TWh of announced salt cavern storage by 2037, with 3.3 TWh expected from Rough by 2030 and a further 10 TWh by 2050.

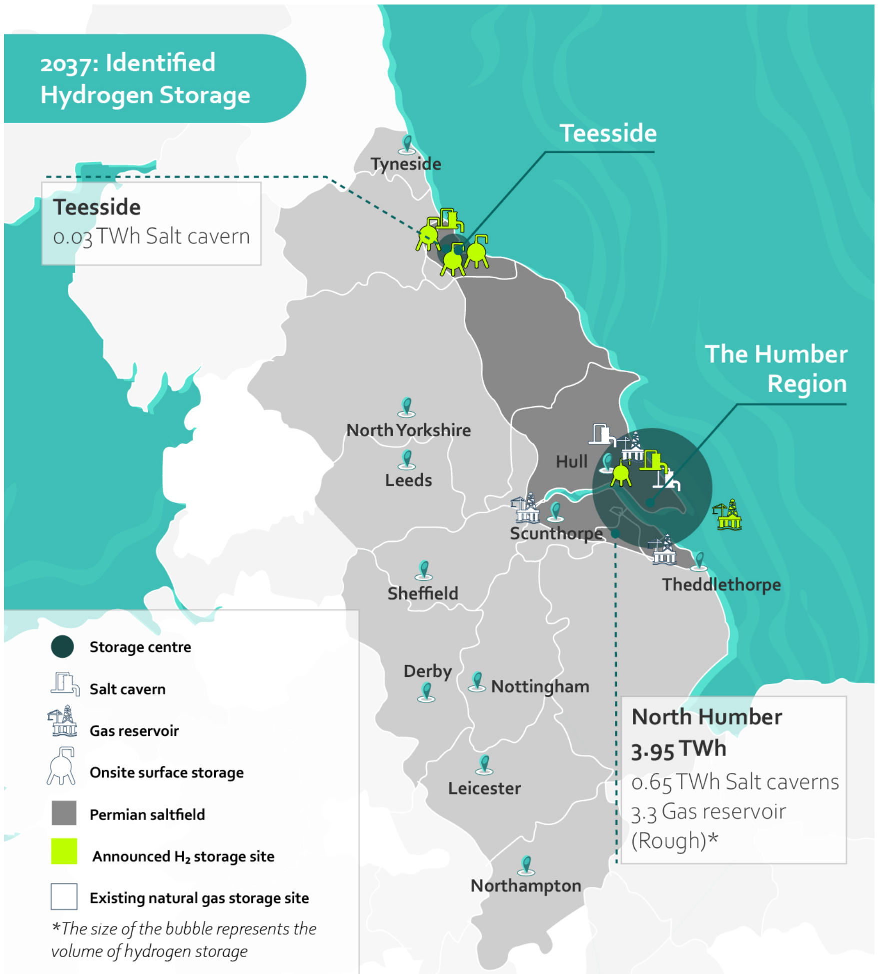
In addition to this, the East Coast region has the potential to unlock further hydrogen storage through the conversion of five existing and planned natural gas storage sites.

Early hydrogen production projects will rely on on-site storage solutions, however this is not a suitable long-term solution. Under National Grid's System Transformation scenario 56 TWh of hydrogen storage will be required by 2050 to enable the UK's energy system to achieve Net-Zero through the integration of hydrogen. [49]

ECH$_2$ can address these needs by connecting up to 19% of the UK's 2050 storage requirements to producers and demand centres in the region.

Storage requirement the East Coast region can meet by 2050 under a System Transformation scenario





Note: Map only includes publicly announced hydrogen transport projects, with demand forecasts based on data received from potential customers. Project locations are the approximate relative location and may not be complete or accurate.
** Rough hydrogen storage that will be operational by 2037, further 10 TWh is expected by 2050*

North Humber

3 storage sites

Under development with **Rough gas reservoir set to be a strategic connection site**

Teesside

1 storage sites

Under development with **multiple production facilities looking to build on-site storage**

Large scale hydrogen storage projects within the East Coast region

Location	Project	Type	Location	Developer	Year online	Capacity
North Humber	Aldborough	Salt Cavern	Hornsea	SSE & Equinor	2028	0.32 TWh
	Rough	Gas Reservoir	North Sea	Centrica	2030-2050	10 TWh
	Confidential	Salt Cavern	-	-	-	0.33 TWh
Teesside	Saltholme	Salt Cavern	Teesside	SABIC	2025	0.03 TWh

Note: See methodology section to understand the assumptions and data used in assessing hydrogen storage. One confidential storage project is not included within the map, but has been included in total storage figures.

Announced hydrogen storage

Hydrogen storage developers in the region are supporters of the ECH_2 and its objectives.

Case study: Rough

Centrica has been working to re-open Rough off the Yorkshire coast, which resumed storing natural gas again in October 2022, providing half of the UK's total gas storage.

Rough's unique geological and geographical advantages position it well to support a growing hydrogen economy and with no insurmountable technical barriers to conversion, it could store 10 TWh of hydrogen, 94% of announced storage capacity, making it one of the world's largest hydrogen stores.

"Our long-term aim remains to **turn the Rough field into the world's biggest natural gas and hydrogen storage facility**, bolstering the UK's energy security, delivering a Net-Zero electricity system by 2035, decarbonising the UK's Industrial Clusters, such as the Humber region by 2040, and helping the UK economy by returning to being a net exporter of energy" - *Chris O'Shea, Centrica CEO.*

Note: Project locations are the approximate relative location and may not be complete or accurate.

Case study: Aldbrough

Aldbrough Hydrogen Storage facility is looking to **convert existing natural gas storage in salt caverns.**

It is expected to be in operation by early 2028, subject to positive policy developments and consents being given, with an initial **capacity of at least 320 GWh**, which is enough to power over 860 hydrogen buses a year.

This project offers future storage opportunities for **hydrogen produced at multiple sites across the Humber cluster**, with close proximity to Hornsea 2 offshore wind providing renewable power for Green Hydrogen.

Note: All quotes and case studies have been provided by the named companies.

03

East Coast Hydrogen Delivery Plan

East Coast Hydrogen routing overview

This chapter outlines initial network configurations for ECH2, reflecting on supply and demand as identified through Pre-FEED. These options will be further refined during FEED to create an integrated hydrogen transmission and distribution system capable of meeting user needs.

Connects 61.9 TWh/year I&C and power hydrogen demand by 2037

Connects up to 83 TWh/year potential hydrogen production by 2037

Connects up to 4 TWh potential hydrogen storage capacity by 2037

The total length of the network will be approximately 1,840 km

770 km of existing natural gas pipeline could be repurposed

Saves up to 12 MtCO₂/year by 2037

Connects large demand centres in Teesside, Humber and the East Midlands

Note: Total annual hydrogen demand, production and storage shown above is representative of what the initial network design aims to connect by 2037, not the total potential in the region.

Existing network design and future optionality

In outlining routing, the networks have incorporated optionality to ensure the future hydrogen system can evolve to meet changing policy and user needs over the coming years.

Existing network design

The UK's existing gas network is split into different transportation systems and pressure tiers. The country is served by the National Transmission System (NTS). This is the backbone of natural gas transportation throughout the country and is owned and operated by National Gas.

At a regional and local level, natural gas is distributed by Gas Distribution Networks (GDNs), such as NGN and Cadent. The GDNs build, own, operate and maintain the distribution systems which are broken into two main tiers:

1. Local Transmission System (LTS): a high pressure network responsible for the transport of gas within a region.
2. Distribution network: a medium and low pressure system responsible for distributing gas around cities, towns and villages.

ECH_2 will focus on converting and expanding the high and medium pressure network – with Cadent and NGN enabling hydrogen supply to large I&C and Power users, potential town trials and future transport demand.

National Gas will focus on repurposing the NTS between the Humber and Teesside clusters, Theddlethorpe, and other large production and storage locations in the region and beyond. This will ensure wider system resilience and flexibility.

Need for optionality

To satisfy network design principles and ensure the future hydrogen transmission and distribution system can be adapted to changing circumstances and policies, optionality must be incorporated into routing design. The preferred pipeline routes, whether repurposed or new build, will be developed during the next stage of ECH_2, and will depend on a number of factors, including:

Customer Connection Optionality
Where a customer has options on which network to connect to, a collaborative approach will be adopted, taking account of customer preferences. This may impact preferred routes.

Natural gas security of supply
Decisions on when, where and how the network is converted will need to take account of maintaining natural gas network resilience.

NTS repurposing decisions
NGN's routing strategy is designed around specific National Gas pipelines, a change to National Gas pipeline conversion strategy will impact NGN's preferred routing.

Cost-benefit analysis
Routing, and decisions on repurposing vs new build, will evolve as CBAs are refined with preferred routes maximising value for money.

Environmental & planning constraints
Routes may be adjusted following environmental and land survey findings. Extended consenting timelines could impact route prioritisation and which users are connected when.

Storage volumes & timing
Decisions on storage locations will impact routing, with a need to connect capacity into the hydrogen network to ensure resilience.

Demand volumes & timing
Demand volumes and timings will evolve as the project develops, requiring adjustments to phasing plans.

2026 decision on residential heat
UK Government's decision may alter options with routes potentially adjusted slightly to include pilot towns and a wider regional rollout.

Network design principles

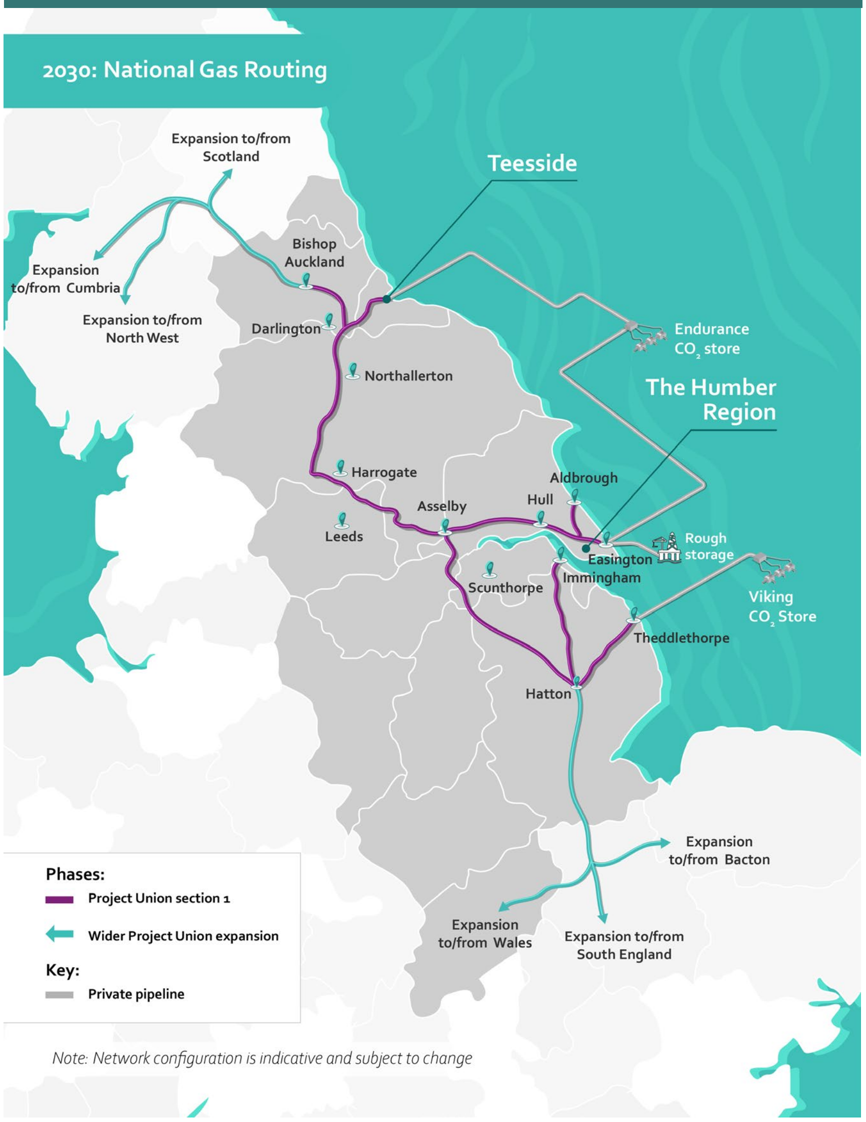
The initial routing options are guided by design principles which ensure that the design options align with the overall Programme objectives as well as the networks' duties and obligations.

Reliability	• **Ensuring all routing options are capable of connecting sufficient production to the system**, building in optionality to enable sites to connect into the network as they reach maturity • **Integrate with private pipelines** to increase capacity and efficiency, improve reliability and reduce costs • **Maintain flow assurance** across both the natural gas and hydrogen systems throughout the transition
System flexibility	• Ensure routing enables **connection with planned hydrogen storage facilities**, providing critical system flexibility and resilience • Account for customers' on-site storage plans and the impact that storage availability and requirements could have on design options • Building a high pressure backbone which allows cheaper and easier medium pressure connections as demand evolves
Minimal disruption	• Routing should **avoid impacting on environmentally sensitive** and heavily populated areas • **Existing sites should be considered** for development before new land rights are secured • Construction approaches should consider the use of trenchless technologies, where cost effective and technically viable
Cost effective	• **Both repurposing and new build solutions should be considered, with the best value option that meets the technical requirements being selected** • Demand should be carefully considered to avoid oversizing, whilst also providing future growth opportunities • Environmental and socio-economic considerations should also be factored in, ensuring the network is not just cost effective but adds overall value • Subject to the above considerations, pipeline length and layout will then be optimised to the most cost effective route
Optionality	• **Routing and phasing requires optionality**, creating flexibility in how network objectives can be met given uncertainty around policy, pipeline design (new build vs repurposed), final routing of each network, third party commercial decisions (users, producers, land owners and storage providers) etc.
Safety	• Selected routes must **ensure a safe and secure environment for network employees, system users and the general public** during the construction and over the assets operational life – this includes the pipeline and Above Ground Installations (AGIs)
I&C and power led	• **Design network to meet I&C and power demand**, providing optionality to connect future residential heat and transport demand • Identify cornerstone customers of the network to determine the scale and geography of phasing

National Gas routing and phasing

The National Gas route focuses on connecting the Humber-Tees Industrial Clusters and other large production and storage locations in the region and beyond, ensuring that demand from the GDNs and its directly connected customers can be supplied with hydrogen from production centres or storage facilities.

National Gas initial routing options and phasing



Key Information

Connects 27 TWh/year of power hydrogen demand and 1.3 TW year industrial demand through direct connects by 2030 increasing to 31.1 TWh/year and 1.4 TWh/year by 2037

Supports NGN to connect 11.4 TWh by 2030 and 12 TWh/year of hydrogen demand by 2037

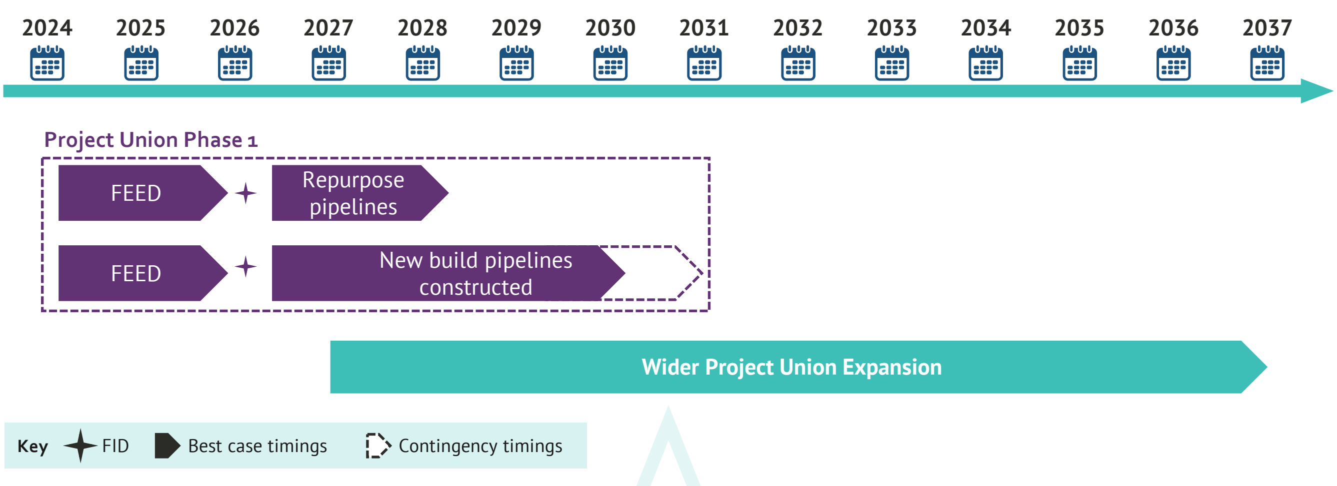
Provides storage options for Cadent via connections at Scunthorpe and Immingham

Connects over 3.6 TWh potential hydrogen storage capacity from Rough Gas Reservoir and Aldbrough by 2030

Up to 330 km of existing natural gas pipeline has the potential to be repurposed. If pipelines cannot be repurposed, new build pipelines options will be assessed

Saves up to 5 $MtCO_2$/year through fuel switching from natural gas by 2030 and 6 $MtCO_2$/year by 2037

This is the first section of Project Union, a nationwide hydrogen transmission network



National Gas routing and phasing strategy

The first section of Project Union will create a hydrogen transmission pipeline within the East Coast region, creating a national 'backbone' for Cadent and NGN to connect to, scaling up storage and production hubs across the UK.

National Gas approach to defining its routing and phasing options

Through its routing and phasing strategy National Gas has **prioritised the repurposing of existing infrastructure**, exploring how current transmission pipelines can be converted to 100% hydrogen to meet regional, and eventually, national demand. New pipelines are only considered where existing assets cannot be used due to technical, economic or locational factors and will be subject to detailed assessment of routing options to ensure environmental impacts are minimised, as well as the relevant consents obtained.

In identifying routing options, National Gas first mapped system users, considering not just their location but also their future hydrogen capacity, grid connection status, and strategic importance to the wider UK hydrogen landscape. As a result, National Gas has **focused on the Humber-Tees Industrial Clusters, production centres in Lincolnshire and North Humber, and storage at Rough**. Other strategic sites have been prioritised based on high density of industrial users, the presence of proposed hydrogen projects, and GDN hydrogen network plans.

After identifying anchor projects, National Gas evaluated network requirements, modelling not just the operation of a future hydrogen network but also the impact of routing options on the existing natural gas network. This enabled repurposed and new build options to be identified that would effectively integrate supply and demand within the East Coast region, and then nationally, whilst also ensuring the continued safe and stable operation of the NTS.

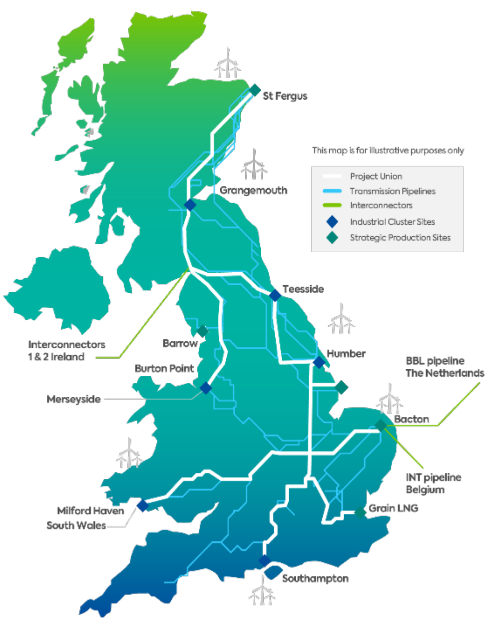
National Gas have also worked closely with Cadent and NGN to ensure routing options and phasing are complementary, enabling the whole region to be interconnected.

As a next step, **all options will be subject to engagement with statutory bodies and local communities**.

Key assumptions used in the network assessment

1. Modelling based on National Grid's FES System Transformation scenario.
2. Off-takers will transition to 100% hydrogen (confirmed through stakeholder engagement).
3. Pipelines can be repurposed from a technical standpoint (material, asset, integrity etc). This will be confirmed in the FEED study.
4. The GDN hydrogen demand is included as a potential offtake connection point within the network design.

Project Union map



Section 1 of Project Union

Project Union will deliver a hydrogen transmission backbone for the UK linking strategic hydrogen production sites, with storage and demand.

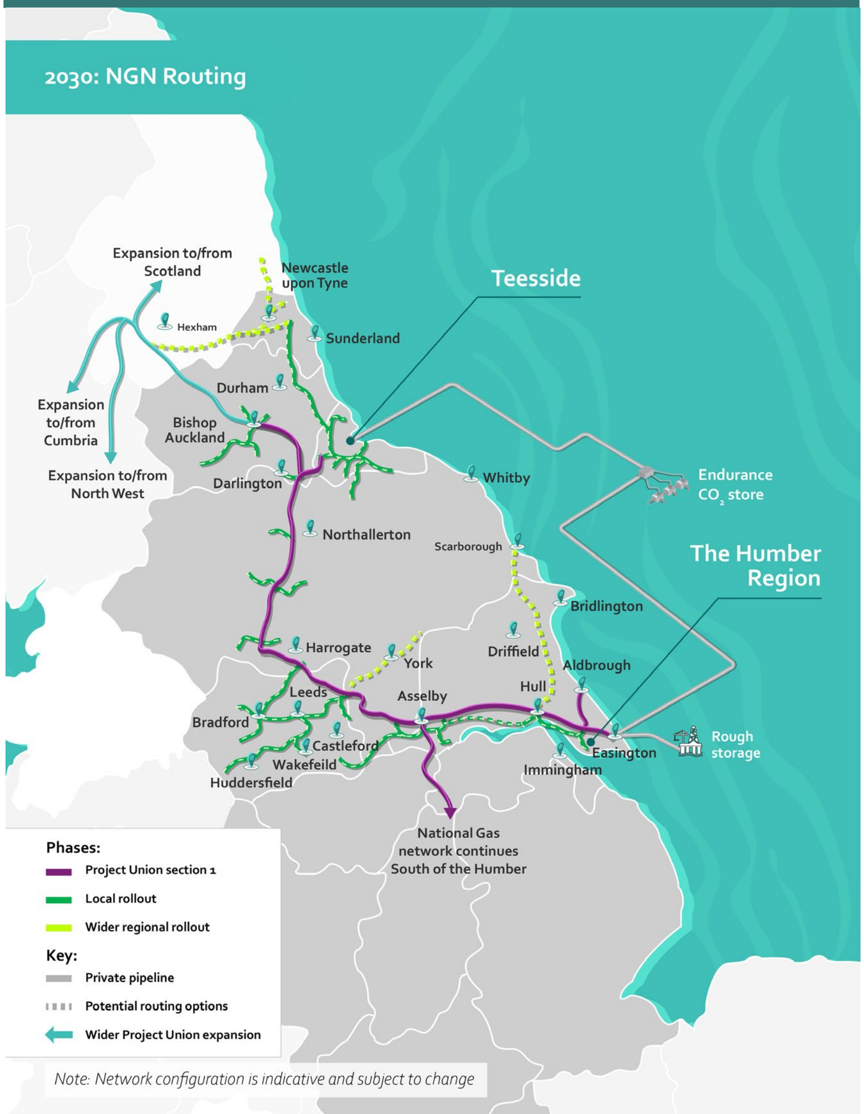
The development of this transmission system will require a starting point with sufficient low-carbon production capabilities, storage capacity, network connectivity and concentrated demand. The East Coast region fulfils these requirements, centralising concentrated industrial sites, large scale gas storage and offshore wind capacity. **The first phase of Project Union is therefore the connection of the Humber region, Teesside and Theddlethorpe.** With further expansion to other Industrial Clusters planned throughout the 2030's.

By taking a phased approach to repurposing existing assets, up to 25% of the UK's current natural gas transmission pipelines could be converted to hydrogen, alongside the integration of new pipeline as necessary. This ensures a cost effective transition whilst maintaining resilience of the UK energy system and operability of the natural gas network.

NGN routing and phasing

NGN's routing focuses on connecting production, storage and demand around the Teesside and North Humber Industrial Clusters, then extending wider into Leeds, Newcastle-upon-Tyne, and Scarborough.

NGN initial routing options and phasing



Key Information

Connects 12.6 TWh/year I&C and Power hydrogen demand by 2037

Multiple connection points into the National Transmission pipeline providing access to storage at Aldbrough and Rough

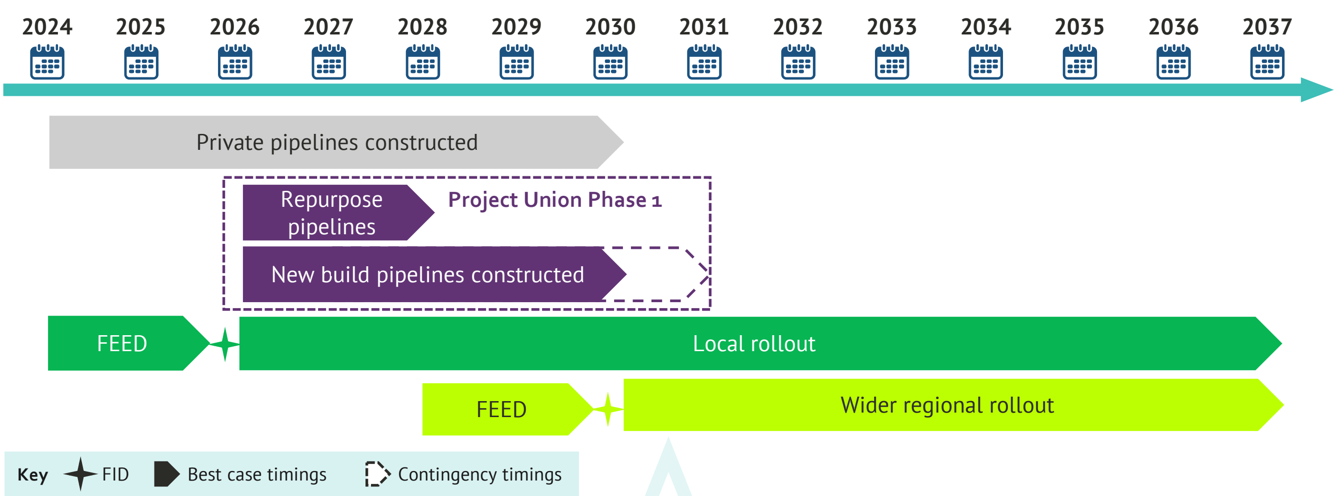
The total length of the network will be 950 km

Up to 440 km of existing natural gas pipeline will be repurposed

Saves over 2 $MtCO_2$/year through fuel switching from natural gas by 2037

Enables nearly 50% of total regional I&C and power natural gas demand to switch to hydrogen by 2037

Integrates with bp and Kellas pipelines in Teesside providing wider network security and resilience



NGN routing and phasing strategy

The NGN network integrates with National Gas and private hydrogen networks to deploy locally before extending regionally. In addition, it focuses on repurposing existing assets to limit costs and network redundancy.

NGN approach to defining it's routing and phasing options

NGN's approach to routing and phasing considers how hydrogen can be delivered to the network's top 200 natural gas customers, with detailed modelling used to identify requirements across Yorkshire, Teesside, and County Durham. Given the location of key centres of production, storage and demand, NGN's routing options have been **designed to complement National Gas's plans for the Hydrogen NTS between Teesside, Asselby and Easington.**

Network requirements have been identified based on the following:

1. ***I&C and power offtake points:*** Assuming a 100% switch to hydrogen NGN used primary and secondary data to model the ability of large users to transition to hydrogen, anchoring infrastructure around those with high requirements. Consideration was also given to clusters of industrial sites where a number of potential hydrogen users in close proximity could be supplied using common infrastructure.
2. ***Supply points (spurs):*** Using primary data from potential producers and storage facilities, NGN modelled future capacities and resulting connection requirements (including integration with private pipelines).
3. ***Towns:*** Residential demand within pilot town locations has been considered as an optional load. In the first instance routes have been prioritised to meet I&C and power demand, but subject to UK Government decisions can also satisfy residential needs with limited impact on costs and network design.

Pipeline routes has been selected based on user demand, ease of connection, ease of conversion, safety, flow assurance, and environmental concerns. In addition, NGN has optimised routing to prioritise pipeline repurposing and keep new build to a minimum.

Whilst routing options consider how hydrogen can be delivered to the top natural gas customers and towns, subject to policy decisions, **connection phasing ultimately depends on confirmation from these users that they will transition to hydrogen when it is made available**. During FEED, NGN will engage directly with customers to confirm assumed demand.

Delivering a regional rollout

- **Phase 1** *(2028)* – By 2028, NGN aims to connect 60 large I&C customers in the Humber and Teesside regions, **suppling up to 5 TWh/year of low-carbon hydrogen**
- **Phase 2** *(2030)* - By 2030, NGN will extend to 80 large I&C customers and three pilot towns, supplying **11.4 TWh/year of low-carbon hydrogen**
- **Phase 3** *(2037)* - Further integration with the Hydrogen NTS developed under Project Union will **enable NGN to supply 12.6 TWh/year** to 108 I&C customers across Yorkshire, Teesside and Scarborough
- **Phase 4** *(2037+)* - **Expansion beyond ECH_2 will be prioritised** based on user demand and government decisions on hydrogen for heat, **connecting to demand in Tyneside and Cumbria**

Repurposing the GDN network

The UK's natural gas use and supply requirements has evolved over time, creating an opportunity to repurpose existing infrastructure in some areas to transport low-carbon hydrogen at a third of the new build cost, without impacting current natural gas customers.

46% of NGN's proposed hydrogen network **can be repurposed from existing assets** for low-carbon hydrogen between Teesside and the Humber region, **saving in building and construction costs.**

To assess the feasibility of repurposing existing pipeline, assessments have been undertaken on both the energy capacity of the repurposed line and any existing lines which will be required to uptake additional natural gas flow.

In order to repurpose the existing pipeline, **legislation and regulatory frameworks, such as the Gas Safety (Management) Regulations 1996, need to be amended** to accommodate the conveyance of hydrogen.

Integrating the GDN with private pipelines within the region

Central to the NGN design strategy and approach is its collaboration between private hydrogen networks and the Hydrogen NTS, ensuring duplication of pipelines is avoided and wider UK hydrogen network resilience and flexibility is maintained.

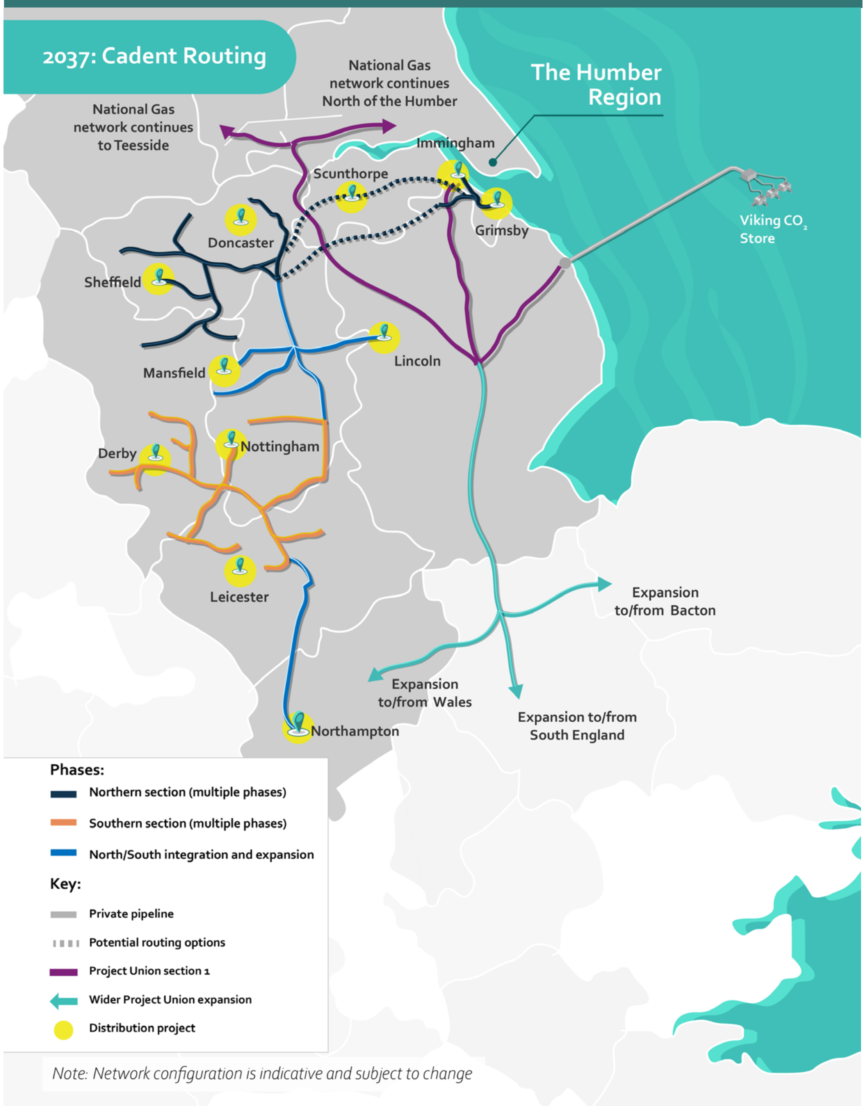
NGN is working closely with bp and Kellas to integrate the private lines being developed as part of HyGreen and H2NorthEast in Teesside, with routing plans under ECH_2.

Integration enables expansion of infrastructure beyond that built under the hydrogen production business models, securing new revenue streams for producers and enabling them to scale up faster. Not only does this provide users with greater certainty of supply but also provides greater efficiency, cost savings and resilience for the wider hydrogen transmission network.

Cadent routing and phasing

Cadent's routing focuses on connecting production in the East Midlands, South Humber and South Yorkshire with local industrial and commercial users, connecting these sub-regions over time to provide resilience.

Cadent initial routing options and phasing



Key Information

Connects 16.7 TWh/year I&C and power hydrogen demand by 2037

Phase 1 North will build approximately 130 km of new pipeline

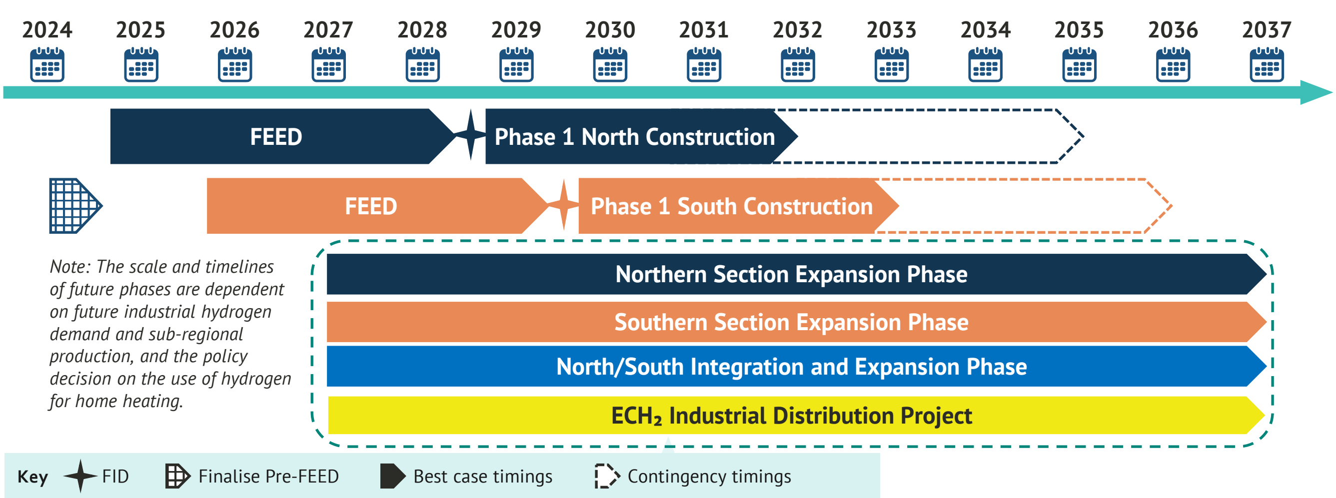
Phase 1 South will build approximately 140 km of new pipeline

The total length of the network will be approximately 560 km

Saves over 3 $MtCO_2$/year through fuel switching from natural gas by 2037

Enables 74% of total regional industrial natural gas demand to switch to hydrogen by 2037

Potential storage capacity will be connected through integration with the Hydrogen NTS



Note: The scale and timelines of future phases are dependent on future industrial hydrogen demand and sub-regional production, and the policy decision on the use of hydrogen for home heating.

Cadent routing and phasing strategy

The Cadent network initially focuses on delivering hydrogen within two distinct regions given the urgency and density of demand, and the location of production.

Cadent approach to defining its routing and phasing options

Cadent's approach to routing and phasing is **demand-led, using primary data forecasts from 170 top natural gas consuming sites to identify hydrogen network requirements.** In particular requirements have been identified beyond the Humber Industrial Cluster, with 16.7 TWh of industrial, commercial and power demand located across the East Midlands, South Yorkshire and South Humber region.

Through in-depth discussions with cornerstone industrial users, and robust forecasts taking account of each site's decarbonisation plan, the speed of transition their equipment to hydrogen and interest in blending, Cadent is confident in the needs case for the network and the real benefits it can unlock.

Pipeline options have been identified based on their ability to efficiently and cost effectively deliver hydrogen, whilst avoiding all key constraints and minimising impact to the surrounding areas and resilience of the existing natural gas network.

In contrast to NGN, the National Gas network within Cadent's area does not go through key industrial demand locations. To meet need across South Yorkshire, Nottinghamshire, Derbyshire and Lincolnshire a new hydrogen transmission pipeline is needed. This means new build pipelines have been considered in the first instance, with multiple route corridors taken into FEED for refinement ahead of selecting preferred routes. **Options for repurposing the existing local transmission network will be further developed in FEED,** considering the most suitable engineering and economic solution to meet need.

By 2030, the UK Government plan to pilot a full town conversion to hydrogen. Given the need for the pilot to be within reach of existing hydrogen production, storage and network infrastructure there are limited options, with Scunthorpe as one of those options. Based on construction timings, and the need to meet I&C demand within Scunthorpe, Cadent have included full town demand of Scunthorpe in pipeline sizing requirements. This maintains optionality, enabling the pipeline to carry sufficient hydrogen to meet existing planned demand and future potential residential demand, with limited impact on costs.

In preparation for a wider rollout, **Cadent have undertaken a sensitivity analysis, identifying the impact of including residential demand on pipeline diameter and pressure.** This will allow decision making on pipeline sizing at the start of FEED, with engagement from Ofgem and DESNZ.

Phasing of construction

The network is initially anchored in two separate locations covering the North and South of Cadent's distribution area:

- **North: South Humber to South Yorkshire** (target construction 2028 – 2031)
- **South: East Midlands (Nottinghamshire, Derbyshire and northern Leicestershire**) (target construction 2029 – 2032)

The development of the network in the South will depend on the outcomes of a finalised Pre-FEED study conducted in Q2 2024. Importantly this will include a transient flow analysis which will ensure an isolated hydrogen network with no access to storage can operate efficiently and with resilience.

From 2030 Cadent will begin work to connect the North and South sections, and further expansion into towns and to users not able to connect as part of Phase 1. The routing for the expansions will be prioritised based on customer need and government decisions on hydrogen for heat.

Timings for construction

The 3-year best case construction timings presented rely on detailed design, construction contractor (or partner) procurement and long lead item procurement - such as steel pipe, valves and pressure reduction equipment - running in parallel to the consenting process. To enable this, **certainty is needed from government on strategic planning and the Hydrogen Transport and Storage Business Models.**

Adopting an accelerated programme will mean the benefits of ECH_2 can be realised sooner, supporting not just UK Hydrogen targets but enabling key industrial sectors to decarbonise in line with Carbon Budget 6 and the trajectory set for achieving Net-Zero by 2050.

If these activities do not run concurrently, over 2 years will be added to delivery timelines, meaning the first users will not be connected until the early 2030s.

ECH_2 Industrial Distribution Project

The ECH_2 Industrial Distribution Project will run in parallel to the build out of the main network. Its aim is to increase the 'reach' of the transmission pipeline through additional networks and spurs, enabling hydrogen to be delivered into towns or to more remote users. The plan is to repurpose the existing natural gas network where possible, only building new pipelines to bridge gaps. Cadent are also exploring the potential to utilise 'dis-used' assets in some regions. Early investigations are expected to begin next year with the re-purposing and new build connection work starting as soon as is practically feasible alongside the main new build phases.

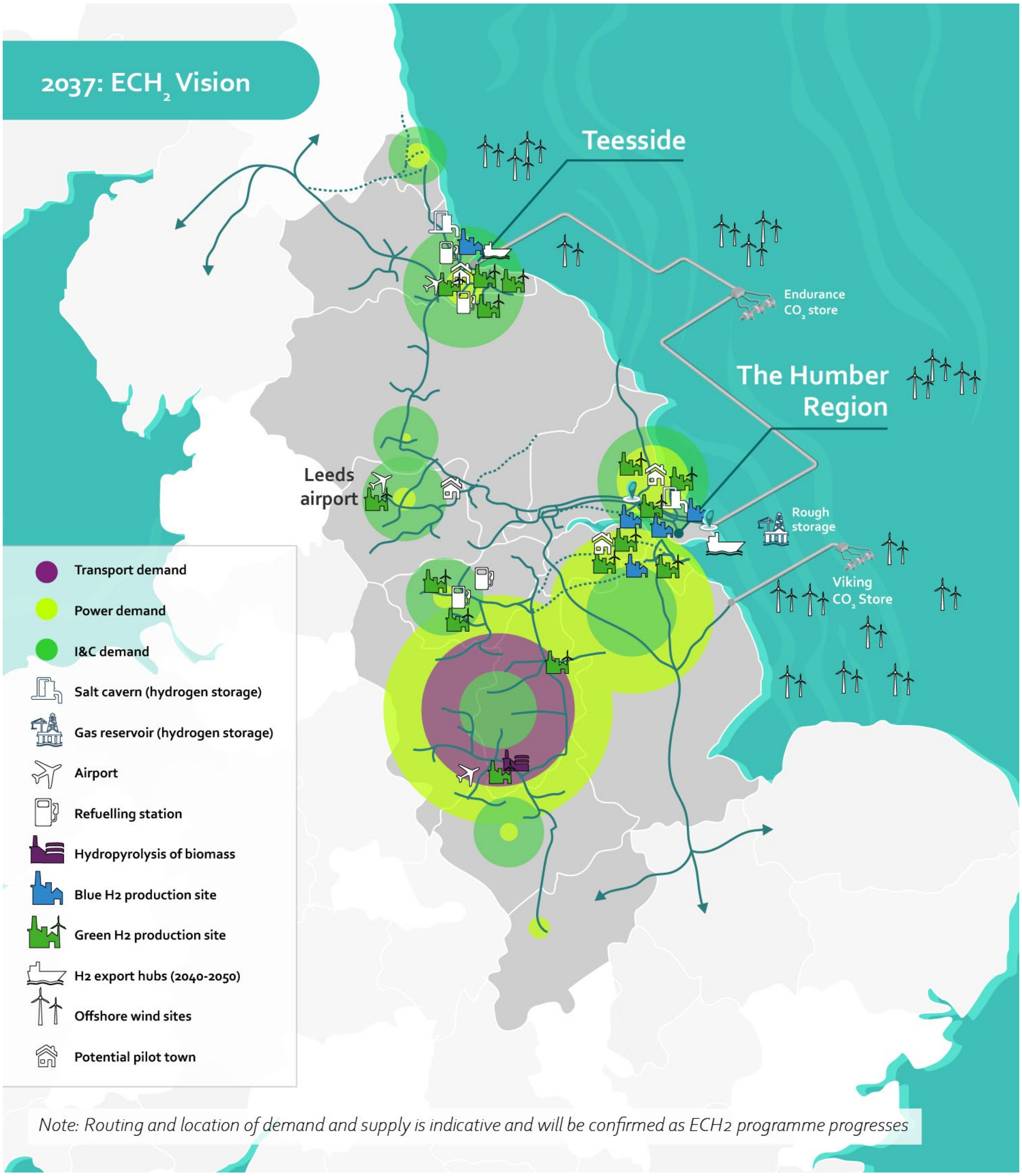
ECH_2 Programme Roadmap

ECH_2 is a long-term project that will be carried out in multiple, discrete phases to decarbonise industrial processes and potentially residential heating in the East Coast region. This Delivery Plan marks a significant milestone within Phase 2 – as the networks complete the Pre-FEEDs.

	Phase 1 Feasibility Study (2021) Definition of the strategic business case for ECH_2	**Phase 2 (2022 – 2028)** Completion of Delivery Plan, Pre-FEED, FEED Study and development of East Coast Cluster infrastructure	**Phase 3 (2026 – 2030)** Hydrogen transmission system development and initial hydrogen distribution system	**Phase 4 (2028 – 2037)** Expansion from the Industrial Clusters into northern urban areas and the Midlands	**Phase 5 (2037+)** Connection of the network into further regions and future growth opportunities
Objectives	• Concept development of ECH_2 • Validate the hydrogen market and strategic benefits of a transmission and distribution network	• Lay out the strategic business case for the Programme • Conduct detailed design and assessment of technical feasibility of the Programme	• Connect Humber and Teesside clusters through the repurposed NTS • Build a local network in East Midlands Freeport Zone, South Humber region and Teesside cluster	• Expand the project across Yorkshire's urban areas and the Midlands • Connection of the North and South Humber region to East Midlands Freeport Zone	• Expand further across NGN and Cadent networks • Connection into neighbouring projects
Overview	• Establish the design concept and strategic objectives of the Programme • Demonstrate customer support, establishing a Consortium Group of participants from across the value chain • Identify the scale and location of potential hydrogen 'hubs' to which a network can connect	• Complete Pre-FEED and FEED studies for ECH_2, finalising feasibility and detailed design of the Programme • Demonstrate the needs case and benefits of the Programme within a public facing Delivery Plan • Conduct detailed engineering and technical assessments such as flow assurance, final routing design, options analysis, and environmental surveys • Undertake economic analysis to ensure that the proposed network delivers value for money • Private hydrogen networks to be built within the region	• Connection of Industrial Clusters within the Humber region and Teesside through repurposing of the Humber-Tees leg of the NTS, enabling the transportation of hydrogen between clusters • NGN will develop off the Hydrogen NTS, connecting to large I&C customers in Teesside and West Yorkshire and building into private pipelines from production sites • Cadent will develop the network within North (South Humber to Sheffield) and South (Nottingham and Derbyshire), connecting Green Hydrogen production facilities in the Midlands with industrial and transport centres	• Connection of North and South Humber, bridging the gap between NGN and Cadent regions through the Hydrogen NTS. • NGN will develop off the NTS 'Hydrogen Backbone' in West Yorkshire, connecting to production and storage centres in Hull and Scarborough. • Cadent's local transmission network will seek to connect South Yorkshire and the Humber with the East Midlands, and add second stage expansion in all regions. • The networks will seek to connect to private pipelines and projects such as the Viking CCUS cluster, BP's HyGreen and Kellas' H2NorthEast.	• Further expansion of the Programme nationally through subsequent sections of Project Union • Expansion through Cadent's Eastern region with potential connection into the HyNet industrial cluster in Merseyside • Expansion North through NGN's network into Newcastle-upon-Tyne and west towards Cumbria passing through Carlisle and Penrith
Outcomes	• Feasibility report • Initial routing outline • Value chain assessment • Stakeholder Consortium Group	• Delivery Plan • Pre-FEED and FEED studies • Detailed routing options • Cost Benefit Analysis (CBA)	• Dedicated hydrogen pipeline within, and between, the Humber region and Teesside • Connection into Teesside and West Yorkshire • Connection into Cadent North and South regions	• North/South connection of Derbyshire and Nottinghamshire with Yorkshire • Connection to storage and production in Scarborough, Hull and Easington • Connection into Northamptonshire	• Connection to neighbouring projects (e.g. HyNet) • Connection into Bacton and other Cadent Eastern locations • Connection into Cumbria and Tyneside

Connecting supply, demand and storage with a transport network

The below map provides a snapshot of what the regional hydrogen economy could look like by 2037 if ECH_2 is delivered as envisaged. This is indicative and subject to ongoing testing of requirements with stakeholders and future UK Government policy decisions.



Sites shown on this map are compiled from information provided by potential customers, supplemented by secondary sources. Project locations are the approximate relative location and may not be complete or accurate. The location of Pilot Towns have not been decided and the icons represented on the map indicate the region under consideration. Confidential storage and production facilities are not included within the map

Transitioning into FEED Studies

As ECH_2 progresses into FEED studies, the networks' routing options and phasing strategy will be further developed, alongside technical requirements and costing work to prepare for construction.

	Key activities	Key deliverables
Data collection & analysis	• Review changes in demand, production, and storage data since completion of Pre-FEED • Backcheck route option selection and basis of design	• Early-FEED reports confirming need
Design surveys, assessments & investigations	• Complete multiple intrusive and non-intrusive investigations to assess impacts of new build network on surrounding environment, infrastructure and land	• Geological and hydrological reports • Environmental impact reports (noise, visual, biodiversity) • Routing options report for new pipeline sections • Preapplication consultation
Flow assurance	• Analyse transient flow across a range of scenarios including ramp up and ramp down capabilities of other networks, production and storage facilities and customer demand	• Flow assurance report
Route selection & design	• Refine routing options, identify preferred repurposed/new build routes • Complete mechanical, electrical and civils design of pipelines and AGIs, including materials selection and key long lead procurement items • Reproposed network modelling, including redistribution of existing natural gas supply	• Pipeline route selection reports • Design specifications • Equipment specifications • Pipeline modelling reports • Various engineering discipline reports
Land acquisition, licenses & planning	• Review existing licenses, land agreements and consents to identify new or additional requirements • Identify land requirements and prepare for acquisition • Develop and complete all required consenting activities to enable, if required, a DCO submission to the Planning Inspectorate, including needs case, public consultation, draft order, environmental statement, land plans etc.	• Land acquisition strategy • New or updated licences and consents • DCO application (as required)
Programme Plan	• Develop a detailed delivery timeline, including key milestones up to FID and beyond to the start of construction/repurposing • Update ECH_2 Programme Management Plan to enable progress, costs and risks of subsequent phases to be monitored	• Programme timeline • Detailed Programme Management Plan
Cost estimates	• Estimate the total Programme costs (DEVEX, CAPEX, and OPEX) through to delivery • Refine CBAs, demonstrating costs and benefits of individual routes but also the programme as a whole	• Cost estimate report • Detailed CBA
Supply-chain, resourcing & procurement	• Review and evaluate supply-chain, resourcing and procurement risks • Identify mitigation measures to provide confidence that the programme can deliver to quality and time	• Supply-chain strategy • Procurement plan • Resourcing strategy
Stakeholder feedback & consultations	• Engage statutory bodies and local communities • Engage system users through the Consortium Group to collect feedback on pipeline route • Consulting public stakeholders on the design and construction process ensuring broader public needs are met through the project	• Consortium events • Public consultations • Public Engagement events


Hydro
HYDROG

04

Defining the ECH_2 Opportunity

Defining the East Coast Hydrogen opportunity

ECH_2 aims to be the foundation upon which the East Coast region builds out its hydrogen economy; delivering decarbonisation, resilience, energy security, and green economic growth.

1. Delivers UK Government commitments

ECH_2 aligns to the UK's wider ambition of delivering growth through a leading low-carbon hydrogen economy by:

- → **Tackling the low-carbon energy needs of the UK's largest Industrial Clusters,** connecting hydrogen supply with demand
- → **Aiding sectors and customers to achieve their decarbonisation commitments,** supporting the UK Net-Zero ambitions by 2050

2. Creates a pathway to decarbonise the East Coast region

Natural gas is a primary energy source in the East Coast region with industrial, commercial and residential customers consuming over 200 TWh, 30% of the UK's total gas usage in 2022/23, making the Programme essential to regional decarbonisation: [17] [54]

- → **Saving up to 7% of UK total I&C annual emissions** across hard-to-abate industries through switching to low-carbon hydrogen, abating over 10.2 $MtCO_2$/year (see pp 70-72).
- → **Enabling the conversion of four potential pilot towns to low-carbon hydrogen** which could see over 100k residential sites decarbonising their heating by the early 2030s (see pp 74).
- → **Supporting multiple transport pilots and research projects within the region**, investigating the potential for hydrogen to decarbonise aviation maritime and road transport decarbonisation (see pp 73).

3. Supports hydrogen value chain development

- → **Connecting demand with supply,** utilising the gas networks' customer relationships to grow the nascent hydrogen market.
- → **Collecting cross value chain support from 122 stakeholders** by joining the Consortium Group and providing hydrogen forecasts or/and letters of support.

4. Catalyses wider system benefits

- → Connecting 17 Green Hydrogen production facilities with 64 power sites, and 4 storage sites in the region to **balance future energy supply and demand and ensure energy system resilience. ***
- → **Supporting the continued growth of local and regional economies** by maintaining the current skilled workforce in manufacturing, transitioning its industry to low-carbon hydrogen.
- → Leveraging the decarbonisation benefits of the two CCUS Clusters selected within the East Coast region by **connecting large scale Blue Hydrogen production with demand**.
- → **Expansion into other proposed UK's hydrogen network,** supporting the broader ambitions of other UK Programmes, such as Project Union, HyNet and Hydrogen Valley, to decarbonise the gas grid.

** See chapter 3 on the 'Vision of the East Coast' to find the figures on hydrogen demand, storage and production*

Image Source: Centrica Storage, Rough

D2N2 Derby Derbyshire Nottingham Nottinghamshire

"We need a hydrogen pipeline network in Nottinghamshire and Derbyshire to allow our aviation, power generation and manufacturing companies access to low carbon hydrogen – without this, many of them cannot decarbonise as they have no other viable options. This will not only protect jobs in the region, but will also create tens of thousands of new jobs within the hydrogen supply-chain."
 - *Will Morlidge, CEO.*

4.1

Delivers on the UK Government commitments

UK policy landscape

The UK Government is strengthening its policies and commitments in building a world leading hydrogen economy to deliver on its Net-Zero target by 2050.

The evolution of the UK hydrogen policy landscape

The UK Government has not wavered in its **ambition to develop a global leading low-carbon hydrogen economy** since the 'Ten Point Plan for a Green Industrial Revolution' in 2020.

Low-carbon hydrogen is cited in multiple papers as critical to the transition to Net-Zero, and **ECH_2 will play a role** in decarbonising our industrial heartlands, delivering energy resilience, and driving sustainable national growth.

East Coast Hydrogen alignment with UK policy

ECH_2 will support the UK Government policy and Net-Zero ambitions – enabling green job creation, emissions reduction, energy system resilience and the integration of power and gas value chains.

How ECH_2 aligns to the key UK Government policy and public commitments

Policy commitments		How ECH_2 will support
10 Point Plan for a Green Industrial Revolution *Nov, 2020*	Driving growth in low-carbon hydrogen with an initial production target of 5 GW (now increased to 10 GW) of low-carbon hydrogen by 2030 Develop Industrial 'SuperPlaces' as hubs for renewable development	✓ Enable the transition to a large, mature, and competitive hydrogen market by connecting up to 11.6 GW of hydrogen supply with demand by 2030* ✓ Facilitate the decarbonisation of two of the UK's largest industrial centres, Teesside and Humber region ✓ Enable the creation of new inland hydrogen super places such as East Midlands Hydrogen
Industrial Decarbonisation Strategy *July, 2021*	Reduce industrial emissions by at least two-thirds by 2035 and 90% by 2050 Capture 3 $MtCO_2e$ per year through Carbon Capture, Usage and Storage (CCUS) by 2030 Switch 20 TWh per year of fossil fuel to low-carbon fuels in 2030	✓ Support I&C sites within and outside of the clusters to decarbonise through a phased and customer driven pipeline routing strategy ✓ Connect Blue Hydrogen facilities within the East Coast Cluster and Viking CCUS clusters ✓ Enable 8.9 TWh I&C demand to fuel switch from natural gas to hydrogen in 2030 (see pp 71)
Net-Zero Strategy: Build Back Greener *April, 2021*	All electricity generation to be decarbonised by 2035 60% reduction in natural gas demand versus 2020 levels	✓ Enable decarbonisation of 12% of the UK's electricity from natural gas, helping to abate over 6 $MtCO_2$/year within the East Coast region (see pp 72) ✓ Provide a network to help fuel switch 58 TWh of natural gas demand in 2037 (see pp 70)

* See chapter 3 on the 'Vision of the East Coast' to find the figures on hydrogen demand, storage and production

East Coast Hydrogen alignment with UK policy (cont.)

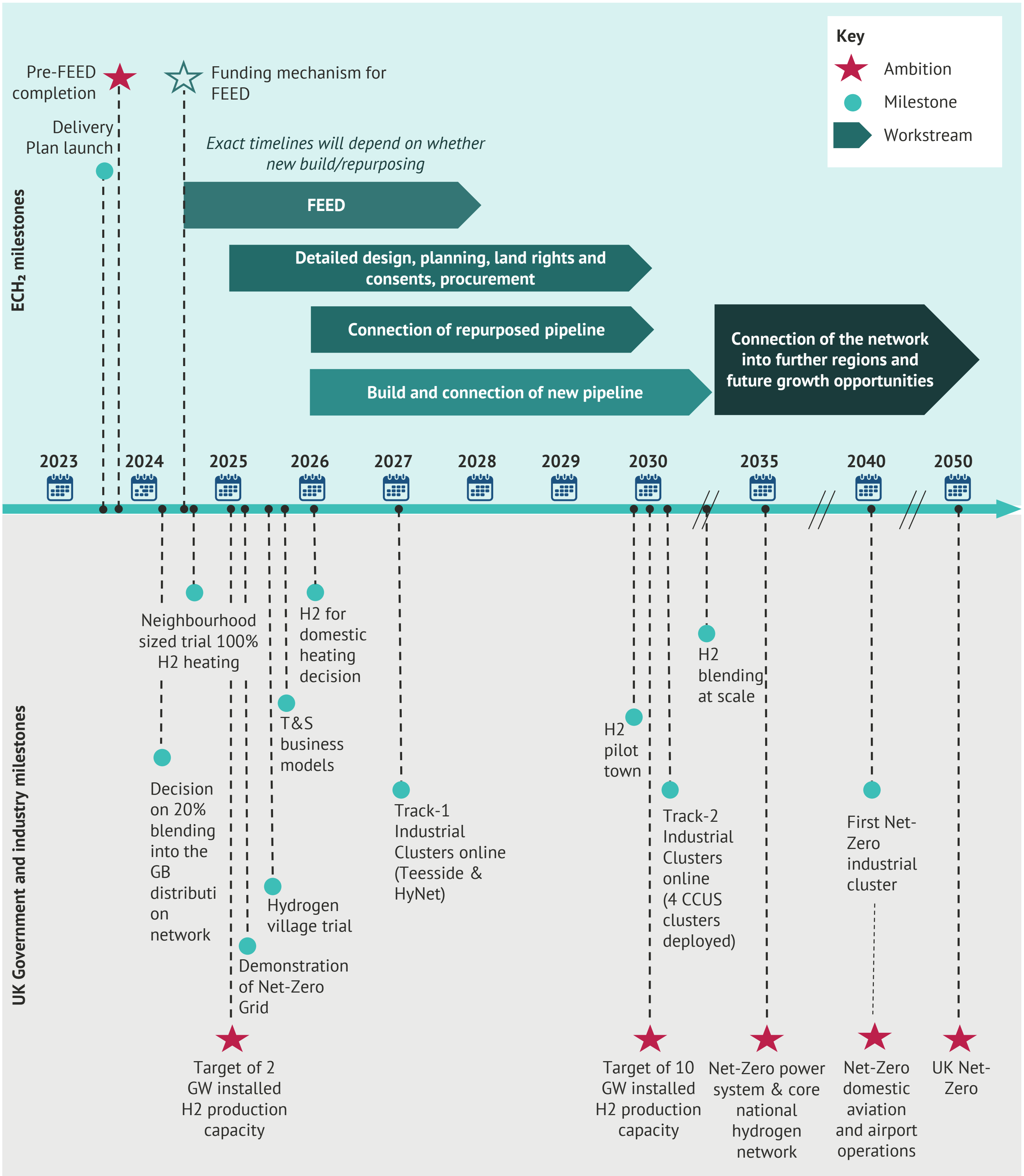
Policy commitments		How ECH_2 will support
Decarbonising Transport: A Better Greener Britain *August, 2021*	Investment of £3m in 2021 to establish the UK's first multi-modal hydrogen transport hub in Tees Valley All new vehicles must be fully zero-emission by 2040, including buses and heavy goods vehicles (HGV)	✓ Facilitates distribution of hydrogen capacity to supply future transport demand and supports development of integrated transport hubs ✓ Enables 5.6 GWh potential supply of low-carbon hydrogen fuel to decarbonise East Midlands Airport*
Heat and Building Strategy *October, 2021*	Expected policy decision on the role of hydrogen in decarbonising heat by 2026 Supporting industry to deliver a 100% hydrogen heating neighbourhood trial by 2024, a village trial by 2025, and town trial by 2030	✓ Provide optionality in all pipeline routing and design engineering options to account for potential future demand from towns with high I&C and power demand ✓ Integrated hydrogen network which connects with town pilots realizing wider system benefits (see pp 74)
British Energy Security Strategy *April, 2022*	10 GW of hydrogen production by 2030, with at least half of this total coming from Green Hydrogen 1 GW of electrolytic hydrogen is in construction or operational by 2025	✓ Potential to connect over 10 GW of hydrogen capacity by 2030 within the region, with 4.4 GW coming from 17 Green Hydrogen facilities* ✓ Provide low-carbon hydrogen to 64 power sites within the region, providing flexible power generation and plugging the gap of intermittent renewable electricity *
Powering up Britain *April, 2023*	15 projects selected to develop with the £240 m Net-Zero Hydrogen Fund (NZHF) Select two CCUS enabled hydrogen projects for the Track-1 clusters 20 projects announced for the first hydrogen electrolytic allocation round (HAR1)	✓ Support the development of 7 projects selected through the NZHF and HAR1 within the region * ✓ Align with development of the East Coast Cluster to provide transmission infrastructure in both Teesside and Humber region, connecting low-carbon hydrogen supply, demand and storage
Hydrogen Transport and Storage Infrastructure: Minded to Positions *August, 2023*	Initial focus for hydrogen transport will be large scale pipeline infrastructure transporting hydrogen as a gas Design a new business models for hydrogen transport and storage infrastructure by 2025 using a RAB mechanism to encourage investment	✓ Strategically plan a coordinated and phased hydrogen transportation network, delivering hydrogen as gas to customers ✓ Stimulate private sector investment by ensuring a transport system that is ready to connect supply with demand
Energy Bill *Nov, 2023*	Creation of Future System Operator, taking on the role of strategically planning the energy system with appropriate legislated power Enable business models to be brought forward to provide investors with long-term revenue certainty	✓ Inform the FSO on how to build out hydrogen assets within the region, utilising networks' customer relationships and insights on volume and timing of demand and production ✓ Provide investor confidence with plans to develop a transmission network ensuring security of hydrogen supply and demand

It is critical that the UK develop a hydrogen transportation infrastructure that enables the growth of a mature and competitive hydrogen economy by diversifying energy supply, encouraging hydrogen producers into the future market, and enabling end-users to fuel switch to hydrogen.

* *See chapter 2 on the 'Vision of the East Coast' to find the figures on hydrogen demand, storage and production*

ECH_2 will support ongoing policy decisions

In addition to developing infrastructure that supports UK Government's ambitions, ECH_2 will provide insights into potential costs and challenges of developing hydrogen infrastructure that will inform future policy and investment decisions.



ECH_2 is aligned with the UK Government priorities and industry strategies and will help to assess the hydrogen evidence base to inform government policy decisions on the future role of hydrogen.

Note: UK Government timings are indicative and subject to change

4.2

Creates a pathway to decarbonise the East Coast region

The identified decarbonisation potential of building out ECH_2

The East Coast region accounts for up to 30% of the UK industrial, commercial and residential natural gas usage. Analysis suggests that by 2037, over 57 TWh of natural gas will fuel switch to low-carbon hydrogen, abating over 10 $MtCO_2$/year.*

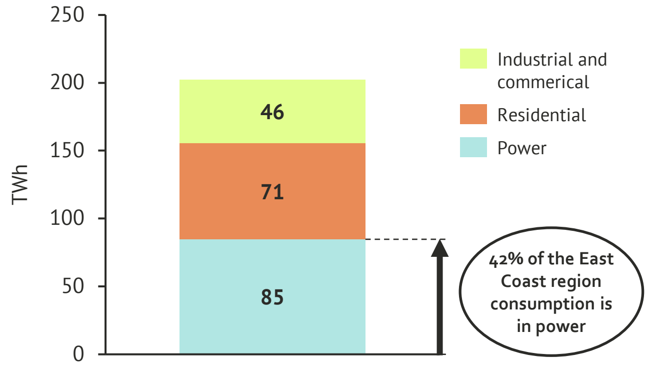
Energy consumption in the East Coast region

Natural Gas is a primary energy source in the East Coast region consuming a total of around 200 TWh, accounting for up to 26% of the UK's total natural gas usage in 2022/23. [55 56]

42% (85 TWh) of the East Coast region's natural gas demand is used for power generation in 2022/23, responsible for over 15 $MtCO_2$/year emissions. [17 55]

The I&C sectors consume 23% of the region's natural gas demand, supplying energy to disperse I&C gas connected sites, highlighting the opportunity to decarbonise multiple sectors and reduce the UK's dependency on natural gas. [17]

Final natural gas consumption in the East Coast region by end use in 2022/23



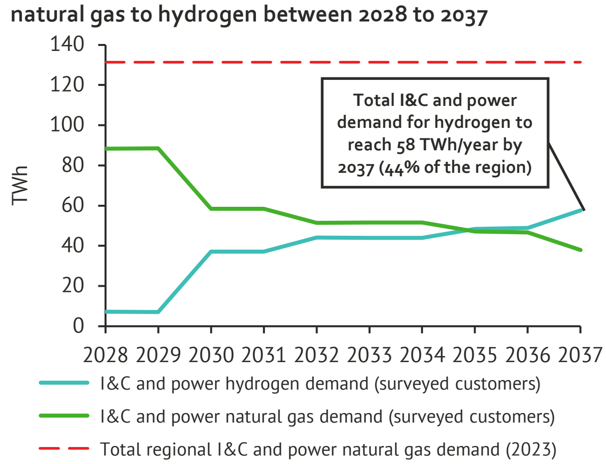
Fuel switching in the East Coast region

We collected primary and secondary data from >300 of the top I&C and power sites.

Based on the plans set out by our stakeholders, we estimate that at least **44% of the region's total I&C and power sector demand (58 TWh) could fuel switch from natural gas to low-carbon hydrogen by 2037*.** This reflects the plans of just those stakeholders we surveyed and investigated. The true potential may be higher.

This would enable the UK to transition large energy users and sectors away from natural gas if a repurposed, or new build pipeline infrastructure, is developed to supply hydrogen to multiple disparate sites.

Potential annual I&C and power demand switching from natural gas to hydrogen between 2028 to 2037



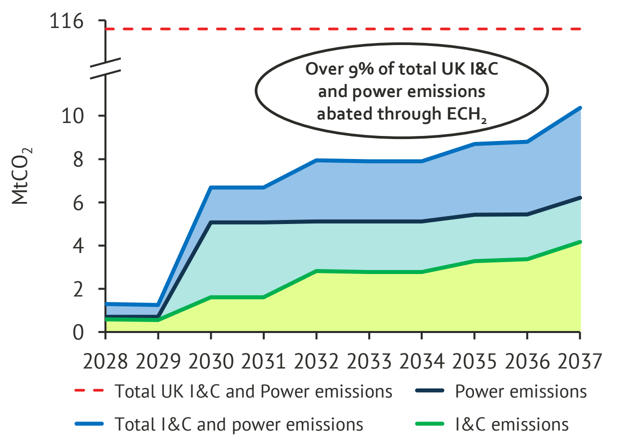
Potential decarbonisation impact

The UK Government has a good opportunity within the East Coast region to provide multiple sectors with an avenue to decarbonise their operations, utilising existing gas infrastructure to supply low-carbon hydrogen to high energy consumers.

Using I&C and power customers' hydrogen forecasts, there is the **potential to save over 10 $MtCO_2$/year by 2037. This is equivalent to abating over 9% of the UK's total I&C and power emissions.****

As ECH_2 is developed, further customers could be connected to the network and thereby greater carbon savings could be achieved once a viable and cost effective alternative is available to transition away from natural gas.

% of total potential UK I&C and power emissions to be abated by switching to hydrogen within the East Coast region***



A hydrogen midstream will be essential in achieving the UK Net-Zero targets, enabling I&C and power customers to decarbonise their operations.

** Total natural gas (58 TWh) to switch to low-carbon hydrogen excludes aviation demand because it is additional demand that comes from aviation turbine fuel, not natural gas.*
*** Total decarbonisation potential from switching to low-carbon hydrogen includes (4.1 MtCO2) for I&C and (6.2 MtCO2) for power, and excludes (1.4 MtCO2) transport.*
**** Total UK I&C and power emissions is indicative of the scale of CO_2 to abate, not a forecast over time.*

The opportunity to decarbonise industry and commercial

Our analysis indicates 50% of the East Coast region's total I&C gas consumption could switch to low-carbon hydrogen by 2037, abating over 4 $MtCO_2$/year.

Total I&C decarbonisation potential

The East Coast region has multiple dispersed I&C gas connected sites, from the Teesside and Humber clusters down to the East Midlands. In 2022 these customers consumed over 46 TWh of natural gas, emitting over 8 $MtCO_2$/year, [1 17] which is 13% of total UK emissions from I&C (62 $MtCO_2$/year). [55 56]

Given the high density of I&C demand within the East Coast region **providing an integrated hydrogen transport pipeline could enable 33% of the total UK I&C natural gas demand** to switch to low-carbon hydrogen.

Key figures for the East Coast region:

Over 4.2 $MtCO_2$/year	I&C emissions to be abated by switching to low-carbon hydrogen
Up to 50%	I&C sector in the East Coast region could switch from natural gas to hydrogen before 2037
Up to 7%	Total UK I&C annual emissions to be abated through switching to low-carbon hydrogen by 2037

I&C fuel switching within the region

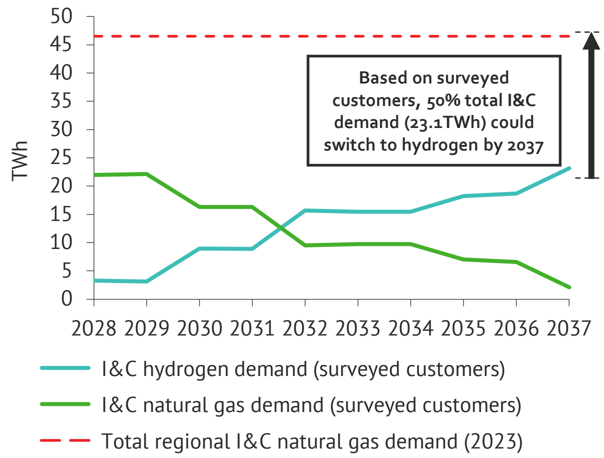
Based on primary and secondary data collected from **over 270 of the East Coast region's top I&C sites, 50% of the East Coast region total I&C sector is estimated to fuel switch from natural gas to hydrogen by 2037.**

Based on the customers surveyed, we may see I&C demand for hydrogen surpass demand for unabated natural gas as early as 2032.

This would tackle the decarbonisation of two of the UK's largest Industrial Clusters and aid the UK in its plans for meeting the 2050 Net-Zero target.

However, fuel switching by 2037 will only be possible for most I&C customers if a transport network is ready and available to connect supply and demand.

Potential annual I&C demand switching from natural gas to hydrogen between 2028 to 2037



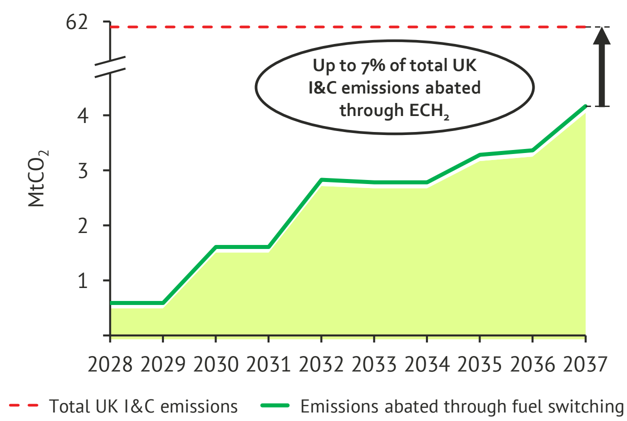
Potential I&C decarbonisation impact

The East Coast region has two of the largest Industrial Clusters within the UK. Last year, the region emitted over 8 $MtCO_2$/year within the I&C sector by consuming natural gas, making it the logical place to start in decarbonising I&C activity and building up the hydrogen economy.

Through fuel switching the I&C sector from natural gas, **there is the potential to save up to 50% of the East Coast region emissions** by reducing over 4 $MtCO_2$/year by 2037, equivalent of up to 7% of the UK's total I&C emissions.

There is potential for further carbon savings as residual emissions from Blue Hydrogen are replaced with over 5 GW of Green Hydrogen projected to come online by 2037 (see pp 36).

% of total potential UK I&C emissions to be abated by switching to hydrogen within the East Coast region*



ECH_2 can help deliver the benefits of switching 23.1 TWh of natural gas usage to low-carbon hydrogen by 2037, abating up to 7% of total UK I&C emissions.

Note: See methodology section to understand the assumptions and data used in assessing I&C demand and decarbonisation.
** Total UK I&C emissions is indicative of the scale of CO_2 to abate, not a forecast over time.*

The opportunity to decarbonise power

The UK Government has set the ambition of having a zero carbon power grid by 2035. The East Coast region has the potential to fuel switch over 34 TWh of natural gas based power generation to hydrogen, abating over 12% of total UK power emissions.

Total power decarbonisation potential

The UK Government faces a major challenge to abate emissions from **gas-fired power plants** by 2035, which **generate 40% of the UK's electricity and emit up to 54 $MtCO_2$/year** whilst meeting an expected increase in electricity demand. [30 55 56]

The two main technologies which can be used to produce low-carbon, dispatchable thermal power generation to balance supply and demand are retrofitting power plants with CCUS, or replacing natural gas with hydrogen. **The East Coast region consumes up to 85 TWh of natural gas for power**, providing an opportunity to abate over 15 $MtCO_2$/year. [17]

However, there is uncertainty over future efficiencies and costs related to using hydrogen as a source of dispatchable power meaning that the precise future balance and direction of low-carbon power generation remains unclear with clarity needed quickly.

Key figures for the East Coast region:

6.2 $MtCO_2$/year	Annual power emissions to be abated by switching to low-carbon hydrogen
Up to 41%	Power sector in the East Coast region could switch from natural gas to hydrogen before 2037
Up to 12%	UK total annual power emissions to be abated from switching to low-carbon hydrogen

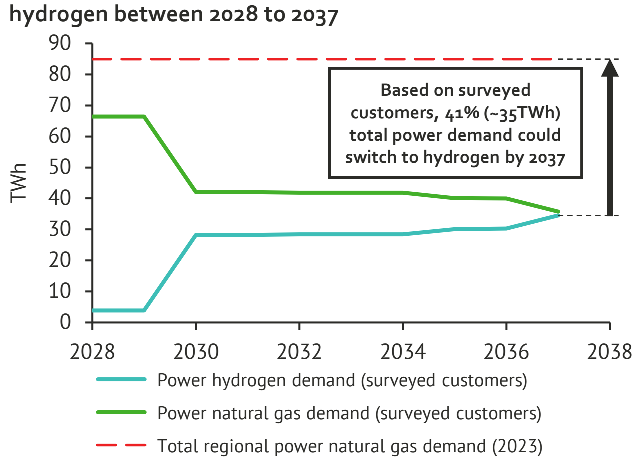
Power fuel switching within region

Multiple power generators have provided **34.5 TWh in hydrogen demand forecasts** anticipating the future role and demand for hydrogen to generate low-carbon electricity.*

41% of the East Coast region total power sector could switch from natural gas to hydrogen by 2037, with 64 power sites needing to be connected to a hydrogen network to offer a reliable and flexible low-carbon dispatchable power within the East Coast region.

Due to uncertainties around the use of hydrogen as input for low-carbon thermal generation, it is impossible to say if more sites will adopt the technology before 2040 and when the sector will achieve low-carbon fuel switching.

Potential annual power demand switching from natural gas to hydrogen between 2028 to 2037



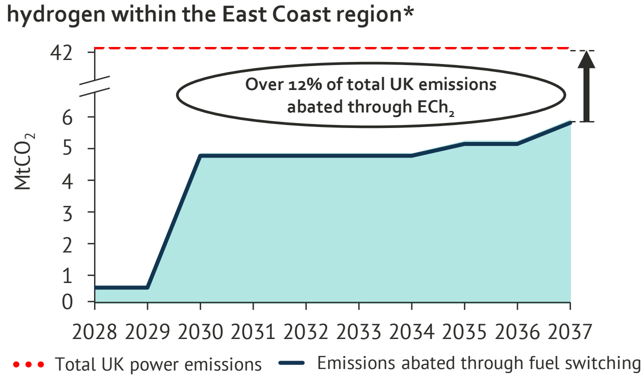
Potential power decarbonisation impact in the East Coast region

The East Coast region emits over 15 $MtCO_2$/year through power generation using natural gas making it a potentially attractive location for the UK to start decarbonising power activity and planning wider system flexibility. [17]

Using the hydrogen forecasts collected from power generators, **there is a potential for emissions saving over 6 $MtCO_2$/year, equivalent of over 12% of the UK's total power emissions.** [49]

ECH_2 will be vital to ensure low-carbon hydrogen is supplied to these power generators to provide a low-carbon alternative to meet the UK ambitious 2035 Net-Zero target.

% of total UK power emissions abated by switching to hydrogen within the East Coast region*



There is an opportunity to decarbonise 6 $MtCO_2$/year in power emissions by 2037 within the East Coast region if the UK Government provides certainty in the strategic direction for low-carbon hydrogen in dispatchable power generation and if the ECH_2 network is built.

Note: See methodology section to understand the assumptions and data used in assessing power demand and decarbonisation
** Total UK power emissions is indicative of the scale of CO_2 to abate, not a forecast over time*

The wider opportunity to decarbonise transport

Low-carbon hydrogen will play a role in decarbonising heavier transport applications, where longer ranges are necessary, or as a feedstock in developing fuels for aviation and shipping.

Transport decarbonisation potential

Transport is the UK's largest carbon emitting sector **accounting for 27% of the UK's total GHG emissions**, where 1,300-1,800 $MtCO_2e$ could be saved between 2020 to 2050 by transitioning away from fossil fuels. [33]

Low-carbon hydrogen is an energy solution for harder to electrify transport where alternative solutions are either unavailable or difficult to implement, such as Heavy Goods Vehicles (HGVs), long-haul aviation and international shipping.

The East Coast region is home to multiple pilots and research projects to demonstrate the potential transport decarbonisation with the first multi-modal hydrogen transport hub in Teesside and pilot projects for freight transport hubs in the UK Midlands.

Key figures for the East Coast region:

Up to 1.4 $MtCO_2$/year	Annual avoided aviation emissions by switching one airport to low-carbon hydrogen in the East Coast region
At least 4	Hydrogen Re-fuelling Stations to be built within the East Coast region
Largest Port (by tonnage)	Immingham handles ~46 million tonnes of cargo every year and is a gateway for trade across the UK and beyond

Road Transport

The UK Government recognises the **importance of hydrogen in decarbonising heavier road transport applications (HGVs)** which make up 19% of domestic transport emissions (18.6 $MtCO_2e$/year), and little progress has been made on cutting emissions to date. [57]

The Department for Transport (DfT) is set to define hydrogen's role in decarbonising road transport with a zero-emission HGV infrastructure strategy being published in 2024. Furthermore, DfT is exploring hydrogen in clean transport technologies, funding five hydrogen-fuelled road projects, including to develop zero-emission emergency service vehicles.

At least 4 hydrogen re-fuelling stations are expected to be built in the East Coast region by 2027. According to UK H2 Mobility consortium of industrials, initial focus will be on the infrastructure in metropolitan areas and the major routes, progressing to nationwide coverage by 2030. [34 58]

Aviation

The UK's Jet Zero Strategy has set out a **Net-Zero target by 2050 with a Net-Zero target in domestic flights and airports in England by 2040** which will help to reduce sector emissions by 40%. An energy transition will include commercialization of SAF, with 2030 the target to replace 10% of jet fuel with SAF. [8]

Hydrogen offers a viable alternative offering a **100% reduction in lifetime CO_2 emissions and no tailpipe CO_2 relative to kerosene.** As well as up to £178bn/year by 2050 and 60,000 jobs. [8] SAF production could require 0.6-3 TWh of low-carbon hydrogen, increasing to 5-20 TWh depending on the final mandate. [59]

Beyond the UK Government, companies are setting Net-Zero targets. Manchester Airports Group (MAG) owns the East Midlands airport, a leading UK airport by number of aircraft movements in the East Coast region. By switching to hydrogen, a total estimate of 1.4 $MtCO_2$/year from aircraft serving East Midlands airport could be abated based on current commitments. [60]

Maritime

The maritime sector accounts for 5% of UK emissions. UK Government is committed to reach Net-Zero in maritime by 2050. **The indirect use of Green Hydrogen**, i.e. for the subsequent production of e-fuels or ammonia, **will be critical for the decarbonisation of international shipping** and reaching the UK targets. [61]

Based on responses received from the Consultation on domestic maritime decarbonisation, hydrogen is viewed as a clean and safe fuel for 78% respondents. [62]

Immingham is home to the UK's largest port by tonnage, accounting for up to 46 million tonnes of cargo annually. Located in the Humber Industrial Cluster this location presents a unique opportunity to pilot and rollout a maritime hydrogen decarbonisation model. [63]

> "Increasingly the aviation industry sees hydrogen as a key component of its decarbonisation strategy. As the operator of East Midlands Airport we are therefore considering how best to ensure that low-carbon hydrogen is available in the future for airlines operating at the airport." - *Miles Pattison, External Affairs.*

MAG East Midlands Airport

ECH_2 has the potential to play a crucial role in achieving Net-Zero in heavy transport applications by delivering hydrogen to transport hubs and supporting transport pilot trials

Note: See methodology section to understand the assumptions and data used in assessing transport demand and decarbonisation for East Midlands Airport

The wider opportunity to decarbonise residential heating

ECH_2 could enable over 100,000 homes to decarbonise within four potential UK Government pilot towns. There are further carbon savings, up to 16% of the total UK residential emissions, through conversion of wider rollout regions, should the UK Government wish to pursue hydrogen for heating.

Residential decarbonisation potential

In 2022, up to 20% of the UK's total energy demand was for residential heating, emitting over 56 $MtCO_2$/year.* The scale of the residential decarbonisation challenge is unprecedented, the UK will have to decarbonise around 22 million homes that rely on natural gas for heat and hot water. [55 56 64]

In total, Cadent and NGN distribution **networks connect up to 4.4 million homes in the East Coast region, supplying 71 TWh of natural gas in 2022,** or 28% of the total annual residential natural gas demand in the UK. [1 17]

Over 50,000 properties in the East Coast region are off-grid, with the majority using either heating oil or LPG, providing further opportunities for ECH_2 to expand its network in the future to decarbonise these hard-to-reach homes and alleviate fuel and heat poverty, in line with a Net-Zero future. [1]

Key figures for the East Coast region:

Over 70 TWh	Total potential UK annual residential natural gas demand that could be switched to hydrogen within the East Coast region
Over 100,000	Residential properties within the four potential UK Government pilot towns that could switch from natural gas to low-carbon hydrogen before 2030
Up to 16 %	UK residential emissions are located within the UK Government pilot towns and wider rollout regions

Pilot towns within the East Coast region

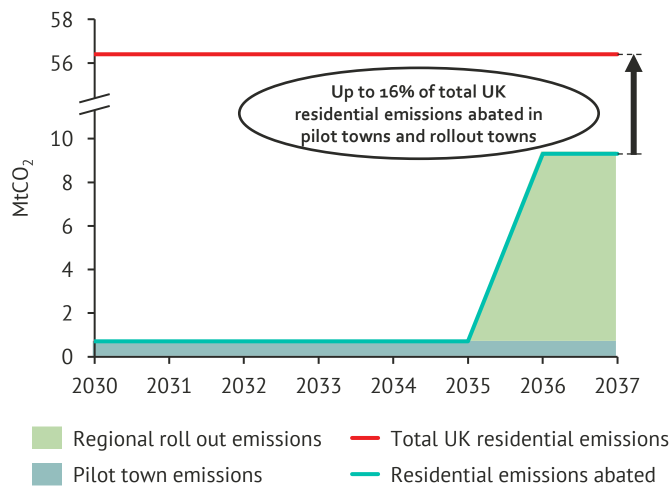
Within the East Coast region, **investigations are underway to examine the possibility to convert four pilot towns through the UK Government programme to low-carbon hydrogen** which could see over 100,000 residential properties in Scunthorpe, West Yorkshire, Hull, and Teesside decarbonised by 2030 (see pp 36).

There is up to 4 TWh/year of potential residential hydrogen demand within these pilot towns, providing the potential to abate up to 1 $MtCO_2$/year in 2030 by switching natural gas to low-carbon hydrogen.**

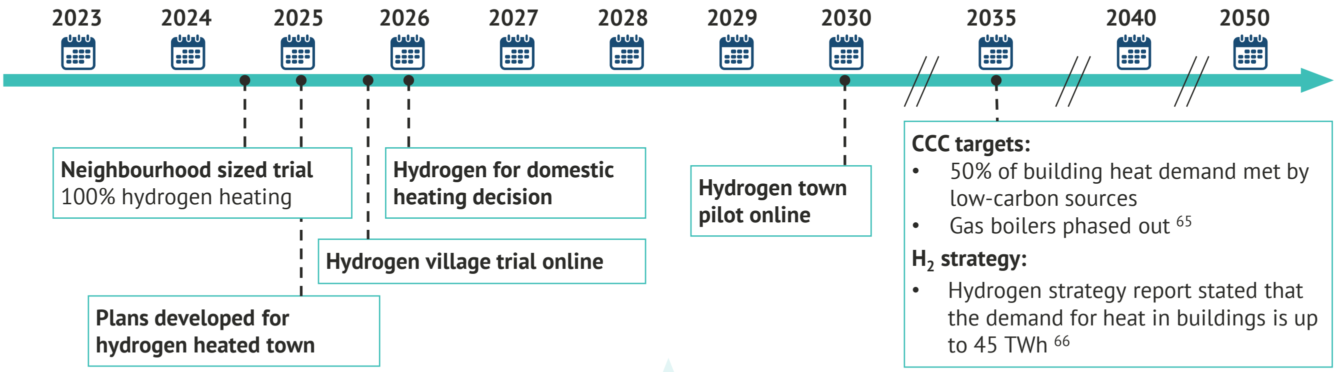
By 2037 this could be scaled to include 17 wider rollout towns, abating over 9 $MtCO_2$/year of residential emissions, or 16% of the UK total residential emissions. **

Using hydrogen as a tool to enable these residential emissions savings will be dependant on the UK Government's decision for hydrogen for heat in 2026.

% of total UK residential emissions abated by switching to hydrogen within the East Coast region*



Announced UK Government heating policy decision timeline



Note: See methodology section to understand the assumptions and data used in calculating residential demand and decarbonisation.
** Total UK residential emissions is indicative of the scale of CO_2 to abate, not a forecast over time.*

4.3

Supports hydrogen value chain development

East Coast Hydrogen is facilitating the creation of a hydrogen economy

ECH_2 is using its Consortium Group to facilitate the creation of a hydrogen economy in the East Coast region, providing a blueprint for other regions to follow.

Benefits	How will ECH_2 achieve these benefits?	
A blueprint for future hydrogen transport infrastructure	• Act as a blueprint for regional network conversion to hydrogen, **supporting the broader ambitions to create a UK wide hydrogen network and a UK hydrogen economy** • Inform the UK Future System Operator (FSO) on how to build out hydrogen assets to develop a mature, well-functioning hydrogen market through the **lessons learned in the strategic network planning that the East Coast region** will help inform	Inform future or existing hydrogen projects
Achieve value for money for both supply and demand stakeholders	• Repurpose existing infrastructure to **achieve cost savings**, whilst ensuring wider energy system functionality is maintained as the industrial hubs decarbonise • Undertake strategic planning and routing of the network to **minimise disruption and maximise gains on connecting supply with multiple demand users** • Alleviate wider system constraints by ensuring the transport network is ready to connect supply with demand • Share the knowledge with stakeholders to **create efficiencies** for subsequent projects and next phases of the ECH_2 programme.	Preferred routing options are based on forecast demand and cost effectiveness
Inform industrial decarbonisation strategies and allow hard to abate sectors to decarbonise	• **Facilitate customer and market knowledge** through Consortium events and the ECH_2 website on the latest developments within the hydrogen landscape • Utilise networks' relationships with I&C users to provide clarity on their options to decarbonise using low-carbon hydrogen • Capitalise on the networks' platform with the UK Government to help funnel **key messaging from industry on barriers and challenges to achieving decarbonisation**	 ECH_2 website has been launched
Facilitate hydrogen offtake agreements with industrial users	• Capitalise on the Consortium Group to **connect over 100 upstream/cross-value chain providers with down stream users** • Utilise the networks' knowledge and relationships with large I&C users and hydrogen providers within the region to foster credible partnerships • **Share valuable insights on the region's hydrogen demand, production and storage forecasts** through Consortium updates and reports helping inform offtake agreements • Further develop offtake agreements to include 3rd party intermediaries such as a network owner/operator	122 Consortium Members
Ensure timely fuel switching from carbon intensive demand	• **Collect and utilise hydrogen forecasts directly from industrial users to coordinate the phasing and construction** of the networks' hydrogen pipelines to ensure transport infrastructure is available when demand and supply comes online • **Prioritise connection** with known or confirmed future hydrogen production facilities with large scale credible hydrogen customers	424 Sites have been investigated within the East Coast region

ECH_2 can support the UK Government to strategically build out hydrogen transport infrastructure, utilising the Gas Networks' customer relationships to grow the nascent hydrogen market.

East Coast Hydrogen is facilitating benefits across the value-chain

ECH_2's Consortium Group consists of producers, off-takers and transport and storage developers. The Programme provides a combined strategic vision for stakeholders in the East Coast region to facilitate cross-value chain benefits.

Hydrogen value chain	Detail	Key challenges and risks for stakeholders	Benefits for stakeholders from ECH_2
Cross-value chain	• Stakeholders involved in multiple segments of the hydrogen value chain	• Uncertainty on costs and benefits • Public acceptance - lack of understanding and education around benefits of hydrogen • Limited certainty of offtake and supply	• Provide information on the benefits of hydrogen through Feasibility Study • Provide greater clarity on potential routes and associated costs during Pre-FEED and FEED phase • Be a conduit back to UK Government to support industry's voice
Production	• Stakeholders focused on the production and supply of hydrogen	• Limited certainty of offtake • Public acceptance - lack of understanding and education around benefits of hydrogen • Lack of infrastructure to connect the production with demand centres	• Build a realistic picture of hydrogen demand to 2035 within the East Coast region • Enable early development of hydrogen transport and storage infrastructure • Create a directory of experts
Transportation & Storage	• Stakeholders responsible for the transportation and storage of hydrogen, incl. public gas grid, storage network and private hydrogen network	• Uncertainty on costs and benefits • Limited infrastructure readiness to transport 100% hydrogen • Regulatory limitations on current % hydrogen blending capacity	• Provide greater clarity on potential routes and associated costs during Feasibility phase • Prove the viability of repurposing assets • Determine a transition plan to low-carbon hydrogen, incl. blending
Demand	• Hydrogen end-users including industrial, commercial, power and domestic stakeholders	• Lack of infrastructure to support testing at scale • Limited certainty of supply • The supply of hydrogen in a cost effective manner	• As part of Programme, networks will continue to work with customers, providing insights on potential routes and expertise on hydrogen benefits to help them to make investment decisions • The project will establish a connection to production facilities to secure Hydrogen supply

ECH_2 will also support local stakeholders, including sub-regional and local governments, elected mayors and LEPs, by providing more clarity on consumer usage of hydrogen, incl. safety measures and economic feasibility of 100% hydrogen usage, so local authorities can plan for and achieve their decarbonisation ambitions.

Source: British Sugar

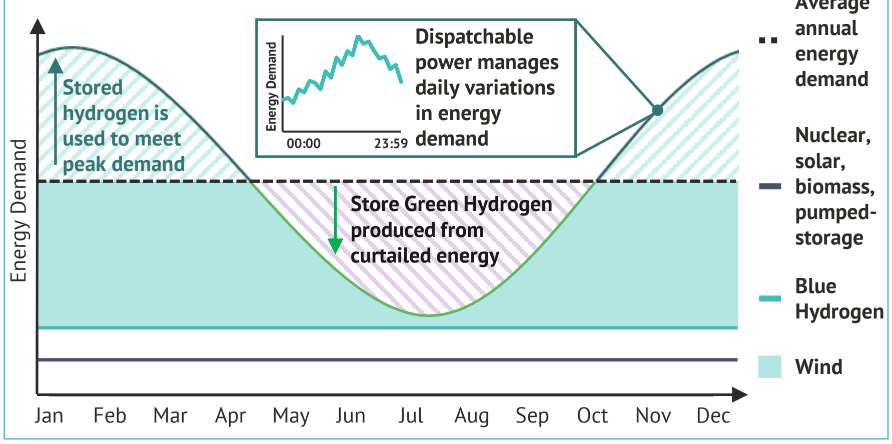
4.4

Catalyses wider system benefits

Whole energy system resilience and flexibility

The penetration of intermittent renewables in UK's electricity mix is rising, creating challenges in balancing supply with demand. Hydrogen-fuelled electricity generation with hydrogen storage can help support a resilient energy system.

Future Energy demand in a resilience and flexible system (Illustrative) [67]



Energy demand is inherently variable with the gas and electricity grids working to ensure resilience and flexibility in the UK's energy supply.

The growing contribution of intermittent renewable power and additional electricity demand will create challenges in balancing supply and demand.

To ensure flexibility and resilience are maintained, renewables will need to be complemented by other flexible low-carbon technologies such as hydrogen-fired power generation, hydrogen storage and line-pack. Each providing whole system flexibility across different time-frames.

Hydrogen can provide significant flexibility benefits

Low-carbon source of dispatchable power

In a highly renewable electricity system, hydrogen power can help to manage:

- **System stability** by providing ancillary services that renewables can't solely provide, such as inertia or voltage control
- **System resilience and adequacy** by providing low-carbon, flexible generation capacity to meet peak demand
- **System cost** by providing a network balancing solution that is cheaper than electricity storage

The East Coast region has 64 power generation sites considering hydrogen who recognise the need for developing low-carbon, dispatchable power.*

Reduce curtailment

In a decarbonised electricity system with a high penetration of renewables, challenges arise from the intermittency of wind and solar, causing supply, in some periods, to be significantly higher than demand. This can result in curtailment of generation.

Utilising excess **power to produce Green Hydrogen can reduce curtailment** costs by acting as a flexible source of power demand. This hydrogen can then be stored (in dedicated stores or line-pack) for times when demand is higher, or renewable generation is lower.

The **East Coast region could develop 21GW of offshore wind energy capacity** making it a strategic location to develop electrolysers to ease local constraints and reduce incurred curtailment costs. [69]

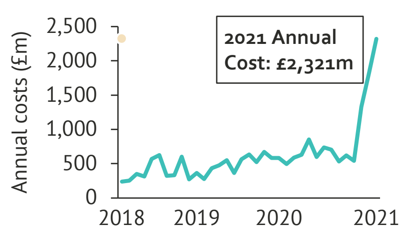
Offers seasonal energy storage

Molecules (gas) are easier and cheaper to transport and store in large volumes, for long durations, than electrons (power). **Hydrogen is currently the best option for seasonal energy storage in a decarbonised UK energy system.** [50]

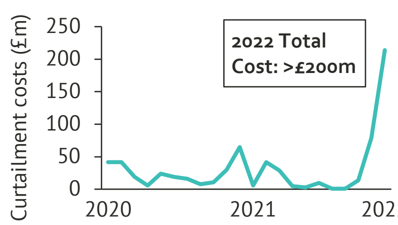
Hydrogen can enable the storage of excess renewable energy from the summer months, when demand is low, to utilise in the winter months, when demand is high.

The UK has a high potential storage capacity in salt caverns and disused oil and gas fields to meet the seasonal variation in demand, with the **East Coast region having the potential for more than 10 TWh of storage capacity by 2050.***

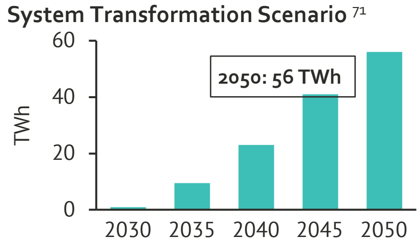
Annual balancing costs in the UK power system [68]



Monthly curtailment costs in the UK [70]



Hydrogen storage requirement in a System Transformation Scenario [71]



ECH_2 can play a key role in providing whole energy system resilience and flexibility by connecting to hydrogen-fuelled power stations, long-term storage facilities and Green Hydrogen production facilities.

** See chapter 3 on the 'Vision of the East Coast' to find the figures on hydrogen storage and power generation.*

Regional jobs and economic growth in the East Coast region

The East Coast region is an important economic region within the UK with large capabilities in manufacturing goods and services. To secure regional green growth and jobs, investment in infrastructure is required.

Economic importance of the East Coast region

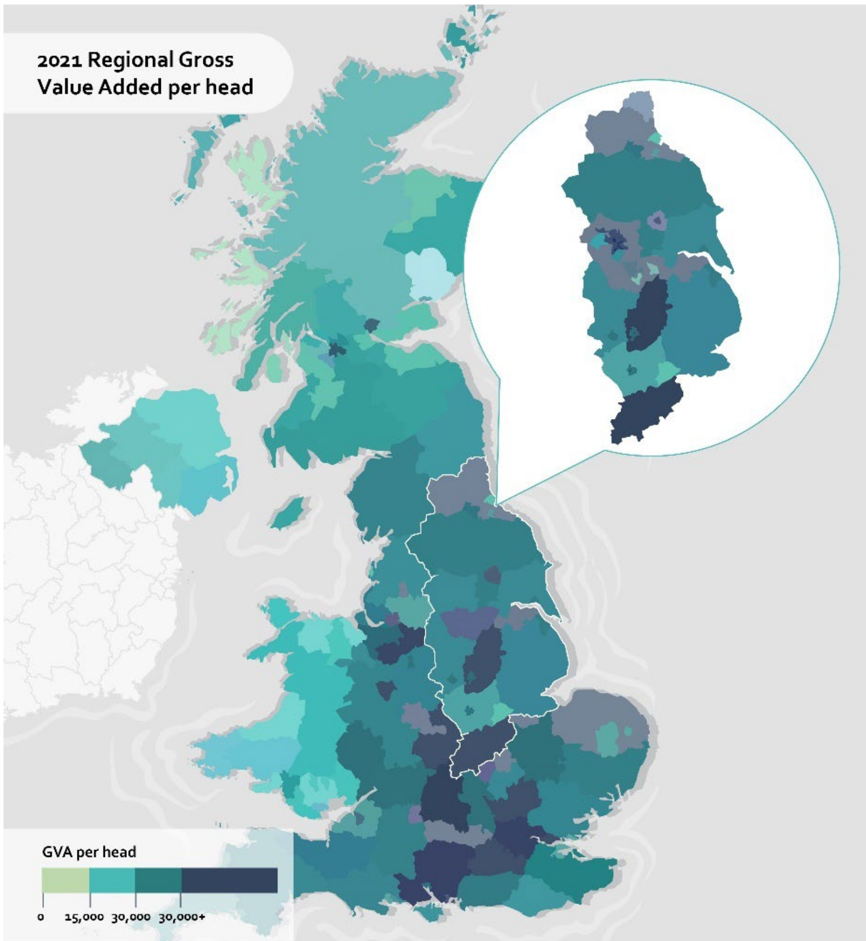
The East Coast region is an important industrial heartland within the UK, **contributing £308.2bn a year in Gross Value Added (GVA).** *

Given the region's significance, it is important to safeguard jobs, the local economy and industrial operations as the UK navigates a 'green industrial revolution'.

Based on data from the Office of National Statistics (2021), Nottingham has the highest GVA per head in the East Coast region at £33.6k, followed by York and West Northamptonshire at £33k per year, illustrating the economic importance of these areas. *

The East Coast region is well placed to grow green jobs, skills and competitive supply chains, levelling up the economy through the green growth agenda.

Independent analysis, completed by PWC on behalf of Cadent, estimates that the development of a full hydrogen value chain could provide **an additional £27bn GVA and 360k jobs across the North East, East Midlands, Yorkshire and Humber region in the period up to 2050.** The East Coast Cluster alone will deliver 9,000 jobs at its peak in 2026. [26]



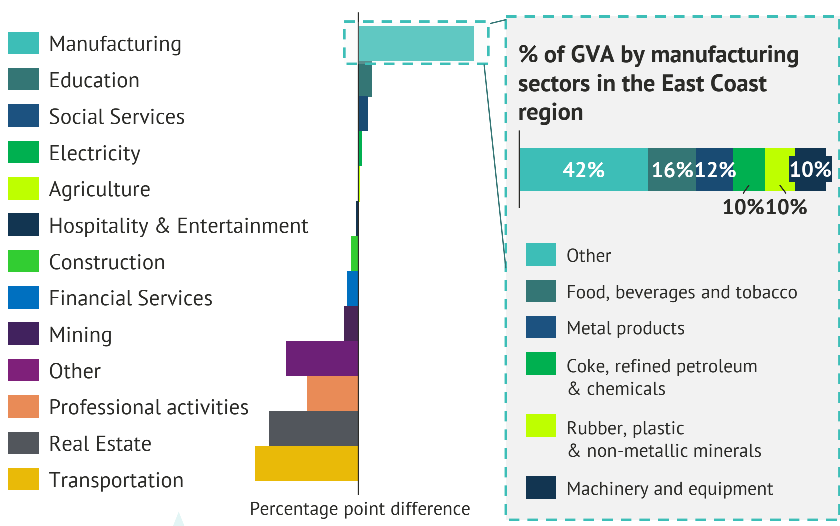
Manufacturing is an important economic sector for the East Coast region*

Manufacturing is the largest sector within the East Coast region, generating £48.5bn for the UK in 2021. Food Beverages and Metal Products were the highest earning sectors, producing £13.6bn, up to 14% of the manufacturing sector. Subsequently aligning to industries which are forecasting the need for 6.1 TWh of low-carbon hydrogen by 2037 (see pp 26).

Manufacturing companies need to ensure a smooth transition to a low-carbon alternative, whilst maintaining market competitiveness.

If the infrastructure to support the transition of these hard-to-abate sectors is not developed the region runs a risk of seeing jobs and investment move either out of the region or abroad, putting the local economy at risk.

GVA by broad industry sector: East Coast region vs UK (excl. London)*



** Data was collected from the Office of National Statistics (ONS) dataset titled 'Regional gross value added (balanced) per head and income components. The latest available data for 2021 was used to calculate the regional GVA per head across the UK and the GVA by industry at current basic prices.*

Enhanced benefits of a decarbonised industrial cluster

The region is host to two of the proposed CCUS transport and storage facilities, East Coast Cluster and Viking. ECH_2 can help maximise the benefits to the region, by connecting large scale CCUS enabled hydrogen production with demand across the East Coast region.

The UK Industrial Clusters

The UK Government's Industrial Decarbonisation Strategy identified 6 Industrial Clusters which emit a combined total of over 64 $MtCO_2$ / year in 2021.*

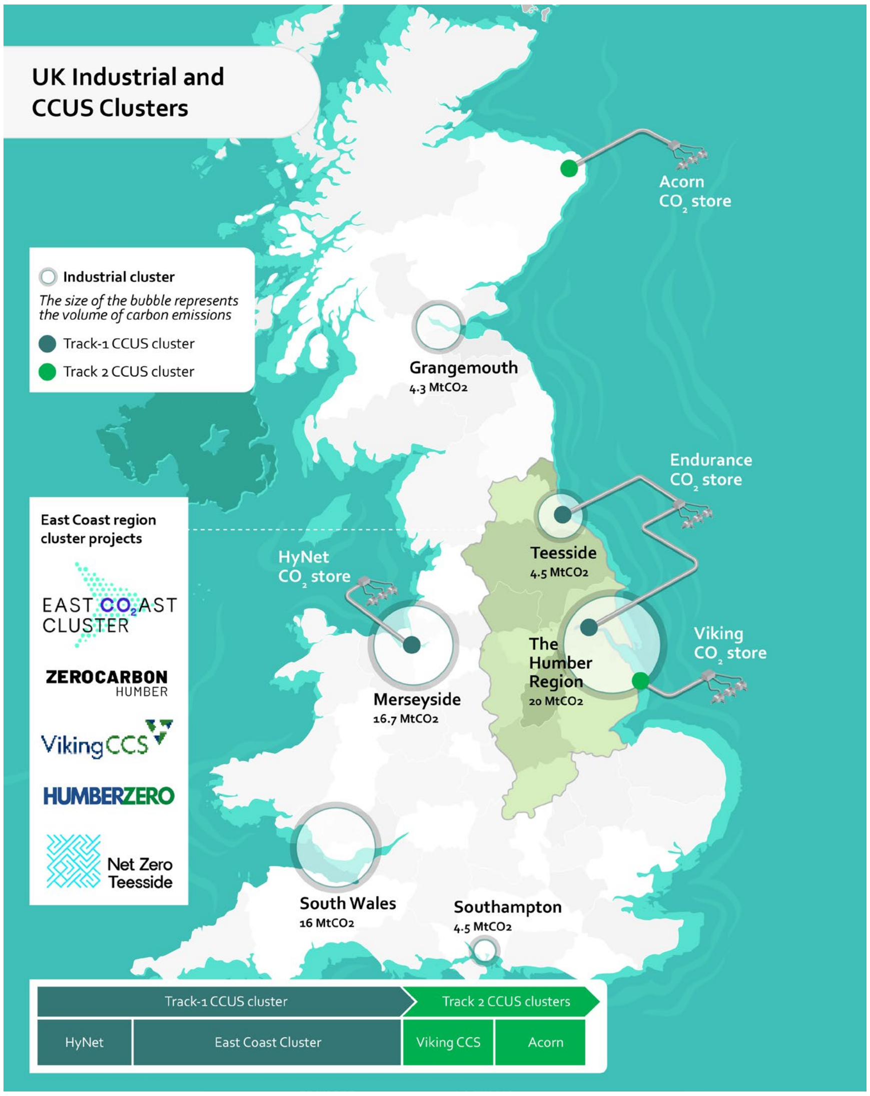
The UK Government aims to have 4 CCUS clusters online by 2030, to capture and store 20 -30 $MtCO_2$/year. This will enable the wider rollout of Blue Hydrogen. [72] [73]

Two out of the four CCUS clusters selected in the Track-1 and 2 sequencing process are based in the East Coast region.

Connecting the Industrial Clusters

An integrated hydrogen transport network can help to enhance the benefits of the East Coast Cluster and Viking by connecting eight Blue Hydrogen production sites with multiple I&C gas connected sites from the Teesside and Humber Industrial Clusters to the East Midlands (see pp 29, 40).

As hydrogen production scales up in the East Coast region, it opens the opportunity to provide other industrial areas across the Midlands with fair access to hydrogen, realising the wider UK ambition of levelling up and reinvigorating our industrial heartlands. [74]



Realising the industrial cluster benefits by having an integrated hydrogen transport network to connect the three selected CCUS clusters

1. Teesside	2. Humber	3. Viking
• **Largest chemical complex** in the UK [75] • Produces **50% of the UK commercially available hydrogen**, with ambitions to become the "UK Hydrogen Valley" [76]	• **Largest industrial decarbonisation opportunity** in the UK [77] • **£15bn private investment available** for Humber-based energy transition [78]	• **High capture and storage potential cluster**, with up to 11 MTPA by 2030 and over 12MTPA by 2034 [79] • Harbour Energy **obtained a CO_2 storage license, storing up to 10 $MtCO_2$/year** [80]

Benefits in connecting the CCUS clusters

Interlink hydrogen production from two CO_2 storage projects realising wider system benefits	**Enable the decarbonisation of up to 36% of the UK industrial cluster emissions,** accounting for up to 4% of the UK total green house gas emissions.	Support the growth of the local economy by **creating over 25,000 green jobs** per year between 2023-2050 [80]

* *$MtCO_2$ for each cluster estimated from each industrial cluster's website and supplemented with the UK Governments 2021 'Clean Growth Grand Challenge: Industrial Clusters mission' infographic*

Contribution to the wider hydrogen economy

ECH_2 complements and enhances the hydrogen projects within the region, supporting the interconnection of different users to facilitate a resilient hydrogen economy across not just the East Coast region but also the UK as a whole.

Note: Project locations are the approximate relative location and may not be complete or accurate.

OYSTER Project (Grimsby Port)

Location: Grimsby

Details: The OYSTER project aims to develop a combined wind turbine and electrolyser system to advance the technologies needed for future offshore hydrogen production. [81]

How ECH_2 aligns: ECH_2 can connect future hydrogen production with demand points within and beyond the region to facilitate greater use of renewable energy and deployment of Green Hydrogen.

Northern Endurance Partnership

Location: Teesside

Details: CO_2 transportation and storage company which will deliver the onshore and offshore infrastructure needed to capture carbon from a range of emitters across Teesside and the Humber region, and transport to the offshore Endurance store. [84]

How ECH_2 aligns: ECH_2 provides a viable opportunity for industrial decarbonisation in the region, linking Blue Hydrogen producers with users.

Viking

Location: Humber Region and North Sea

Details: Viking is developing a CO_2 store in the North Sea, connecting CCUS in the Humber region via Immingham and an existing gas terminal in Theddlethorpe. The 55km Viking CCS pipeline will transport up to 10 $MtCO_2$/year. [82]

How ECH_2 aligns: ECH_2 will support the scale up of the wider value chain connecting large industrial emitters and users in the region who are looking to deploy both CCUS and low-carbon hydrogen.

Zero Carbon Humber Project

Location: Humber region

Details: Zero Carbon Humber brings together multiple industrial and power generation partners to develop shared hydrogen infrastructure in the Humber region. [78]

How ECH_2 aligns: ECH_2 will help Humber infrastructure to expand further by connecting hydrogen production and storage in Humber region with businesses and industries outside of cluster to support their hydrogen trials and investment decisions respectively.

H2 Village

Location: Redcar, Teesside

Details: Dependant on the UK Government decision, by 2025 a large scale trial will see 1000-2000 properties converted to 100% hydrogen for heating and hot water. The final decision is expected to be made by the end of 2023.

How ECH_2 aligns: If a positive decision is taken on hydrogen for heat, ECH_2 can provide the infrastructure to provide a wider roll-out of hydrogen to homes across the region.

Net-Zero Teesside

Location: Teesside

Details: Net-Zero Teesside is a full chain CCUS project that will provide a CO_2 capture network to transport the captured CO_2 and CCGT that will have an electrical output of up to 860 MW of low-carbon electricity. [76]

How ECH_2 aligns: ECH_2 supports the programme by providing hydrogen supplies, allowing Teesside industries to have a choice of approach to decarbonising their operations.

East Midlands Hydrogen

Location: Nottinghamshire, Derbyshire and Northern Leicestershire

Details: East Midlands Hydrogen, pioneering the UK's largest inland hydrogen cluster, is established to commercialise and deliver a hydrogen ecosystem. [14]

How ECH_2 aligns: East Midlands Hydrogen's pipeline routing will be designed as part of ECH_2. ECH_2 will also ensure connection of this 'sub-regional cluster' to storage in the North, enabling greater resilience and expansion opportunities.

Hydrogen Valley

Location: West Midlands and East of England

Details: The Hydrogen Valley project connects costal hydrogen hubs with landlocked industries looking for decarbonisation solutions. The project is also at the heart of the UK's strategic road networks providing opportunities to test and scale re-fuelling technologies. [85]

How ECH_2 aligns: As demand in the region scales ECH_2 will provide access to additional low-carbon hydrogen production and storage.

Tees Valley Hydrogen Transport Hub

Location: Teesside

Details: Tees Valley Hydrogen Transport Hub will foster collaboration across UK Government, academia and industry to explore the benefits of using hydrogen in various transport models such as trains, cars and freight. [83]

How ECH_2 aligns: The ECH_2 network will deliver hydrogen to pilot projects and hydrogen re-fuelling stations to test hydrogen for transport and then inform policy makers on the outcomes to enable critical decisions.

Project Union

Location: UK wide

Details: Project Union will deliver a "first-of-a-kind" hydrogen transmission backbone for the UK. The c. 2,000km hydrogen backbone will link hydrogen production sites, including Industrial Clusters with demand and storage. [16]

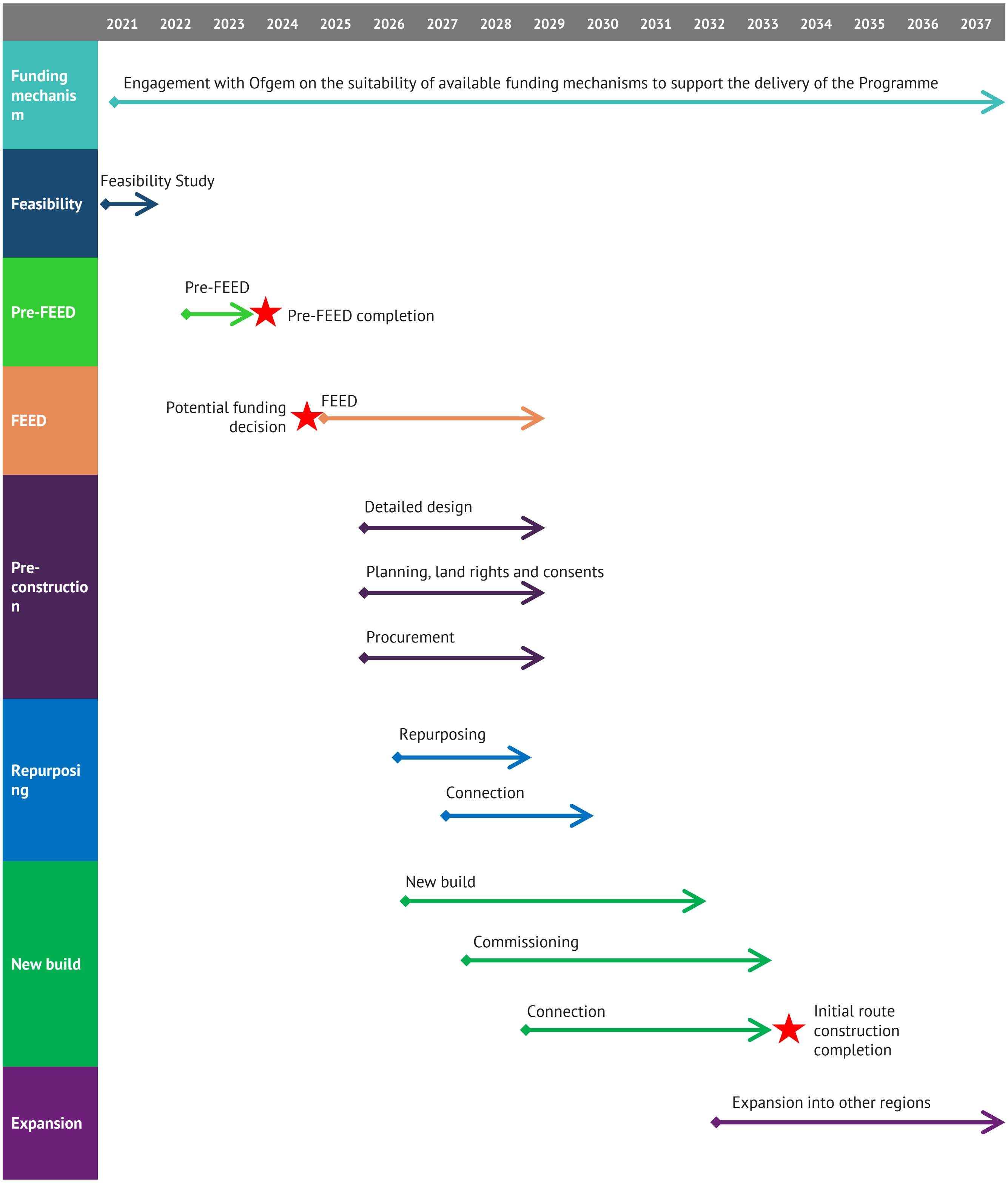
How ECH_2 aligns: Stage one of Project Union is being designed as part of ECH_2, supporting the connection of consumers outside of Industrial Clusters and enabling options for cost effective hydrogen transport options to be scaled nationally.

05

Programme dependencies and enabling actions

Programme timeline

The ECH_2 Programme has been scoped as a 15-year project from feasibility through to commissioning of new build and repurposed pipelines within the region and expansion to connect the East Coast with other regions of the UK. The below is an indicative programme timeline, please see Chapter 3 for more detail.



The staged delivery approach of ECH_2 allows the Programme to take into account market and customers' needs as they evolve over time and ensures optionality in how hydrogen infrastructure is deployed in the region – so that it is deployed where and when it is needed.

Note: These timelines are indicative and could be subject to change as the programme progresses through FEED.

Programme dependencies and critical enabling actions

To support the delivery of ECH_2 across the multiple phases of the Programme, there are critical enabling actions that require the involvement of the UK Government, regulators (Ofgem and HSE) and networks. These actions will not only unlock the benefits of ECH_2 but also UK wide hydrogen ambitions.

	Key dependency	How does this affect the project	Risks for ECH_2	Critical enabling actions	Responsibility
Policy & Regulatory	**Blending decision 2023**	This decision will give more clarity on the potential of blending hydrogen to provide firm, high-volume offtake for producers.	• Lack of initial hydrogen supply if blending will not be allowed	**Providing evidence** to the UK Government and regulator **on the feasibility of blending through the trials and insights from technical assessment** to support blending decision.	• Networks • Other Transmission System Operators
	Hydrogen T&S Business Models 2025	The new business models will establish the principles of UK Government's support for hydrogen T&S projects. It is critical that the new business models provide the right incentives for investment.	• The project delivery timeline being extended due to the delay in the announcement of a new business model • Networks' costs go up due insufficient incentives	The engagement with the UK Government, regulator and system operators to ensure ECH_2 provides evidence **to support the development of the T&S Business Models**.	• Networks • Ofgem • DESNZ
	Hydrogen for Heat Policy decision in 2026	Although ECH_2 demand is not based on heat demand, a positive decision on hydrogen for heat will allow the project to be scaled up.	• Decisions can better be taken on pipe sizes and routes now to support a more cost-effective residental rollout	**Providing evidence** to the UK Government and regulator at an early stage of the FEED to enable joint decision making on pipe sizing.	• Networks
	Safety Case: approval	A decision on the safety case is currently outstanding, and a date for approval has not yet been defined. This process is critical to the deployment of hydrogen infrastructure.	• Added costs due to additional research needed • The project delivery timeline being extended due to insufficient approval procedure	**Sufficient engagement with DESNZ and HSE** to be aware of any changes to procedures.	• Networks • DESNZ • HSE • FutureGrid

Similarly, in the next stage of the ECH_2 Programme, the networks, industry and statutory bodies will need to continue to collaborate on addressing technical constraints, developing commercial frameworks and engaging stakeholders.

	Key dependency	How does this affect the project	Risks for ECH_2	Critical enabling actions	Responsibility
Technical	**Storage capacity**	Lack of sufficient storage can result in improper energy balance during peak consumption.	• Loss of security of supply • Slowdown in the transition to hydrogen	The UK Government and industry players need to work together to **assess the storage capacity needs and support policy development** that will support hydrogen storage projects.	• Ofgem • DESNZ • Storage providers
Technical	**Safety Case: technical standards**	There are no defined technical standards for hydrogen transmission and distribution pipeline design, and the timings for their establishment is currently uncertain.	• Added costs due to additional research needed • Project delivery timeline being extended	**Engaging with HSE and collaborating with projects assessing technical requirements for the safe transport of hydrogen** to ensure knowledge sharing.	• HSE
Commercial	**Offtake agreements**	Offtake agreements need to be developed to ensure cost efficiency of hydrogen production projects and support their deployment.	• Project delays and unsuitable pipeline sizing due to uncertainty around production volumes and deployment timing	**Engaging with potential hydrogen users and providing them evidence** needed to support the decision to switch to hydrogen. Ensure timelines are met for HAR1, HAR2 and beyond to enable the identified production to materialise.	• Networks • Hydrogen users • Hydrogen producers • DESNZ
Commercial	**Project reaching FID**	Mechanism to unlock capital is needed to ensure project can be delivered.	• Projects delays • Missing opportunity to realise all the benefits	Provide the **evidence needed to de-risk investment decisions** and present **strong needs case**.	• Networks • Ofgem • DESNZ
Stakeholders	**Public acceptance**	Public acceptance drives demand for hydrogen. Public support for hydrogen projects will allow the hydrogen economy to develop.	• Networks' costs go up due to the lack of demand and insufficient external investments	**Engaging with potential hydrogen users** to ensure that ECH_2 meets their needs, **conducting Consortium activities** to develop understanding of the expected use of hydrogen in the future energy system and raising awareness of the Programme.	• Networks • Other Transmission System Operators • Ofgem • DESNZ
Stakeholders	**Users' hydrogen forecast plans**	Network users' demand may not materialise as forecasted, resulting in under-utilisation of assets or insufficient capacity to connect all customers.	• The pipeline design might become unsuitable for customers' needs • Potential benefits will not be realised	Continued engagement with potential system users and **refreshing primary data collection at appropriate stages of the Programme** to ensure that pipeline design meets customers' needs. Maintaining optionality within routing and phasing.	• Networks • Hydrogen producers • Hydrogen users • Storage providers

The next phase of ECH_2 could not only provide the detailed analysis needed for the hydrogen infrastructure deployment, but also the evidence base that is important for further development of the hydrogen economy in the UK. The support of the UK Government and regulators are therefore required to move this Programme forward

ECH_2: a look ahead

ECH_2 will build on the progress made, progressing the assessment of hydrogen infrastructure routing options to the FEED stage. The Programme will continue to provide vital insights into how hydrogen distribution can be delivered, enabling widespread benefits for industry and the environment.

Managing ongoing uncertainty for the Programme

If hydrogen is to play its full potential role in the future energy system, and if the ambitions of the UK Government's Hydrogen Strategy are to be realised, it is critical that the necessary midstream infrastructure is developed in a timely manner. Whilst there has been progress across the value-chain, including T&S business model development, the expansion of Industrial Clusters, progression of large scale hydrogen technology and consumer trials, there is still a lot of uncertainty across the supply-chain that is preventing investment decisions from being made.

Over the coming stages of work, ECH_2 will continue to collaborate with industry and government stakeholders to deliver the actions outlined above, to support decision making and reduce uncertainty for the Programme and critical hydrogen projects more widely.

Policy and regulation	The UK Government has set ambitious hydrogen targets complemented by a strategy for policy change and pro-active development by industry, however the lack of a clear regulatory framework impacts the drive for consistent and sustained investment in hydrogen at pace.
Technical constraints	The supply chains essential to the hydrogen economy are new and still evolving, with a variety of approaches and technologies being explored globally. Additionally, work is still ongoing to define safety and technical standards for storage and distribution.
Commercial framework	One of the biggest challenges for the nascent UK hydrogen industry is the cost of producing low-carbon hydrogen compared to alternatives. Defining new business models is critical for growth of the hydrogen economy.
Stakeholder engagement	Although customers in the region understand the benefits of hydrogen, the wider public has limited awareness of hydrogen as a low-carbon energy source and is unfamiliar with its expected use. Additionally, uncertainty around when and how hydrogen will be supplied make it difficult for customers to commit to transition.

Next steps for the Programme

The completion of Pre-FEED studies, which has provided detailed insights on hydrogen demand, technical feasibility of the Programme, and routing options, makes the networks ready to progress to the next stage of work. Namely the FEED, which will provide more detailed analysis of commercial, construction and engineering requirements, and allow continued engagement with stakeholders to keep potential hydrogen demand up to date and ensure permitting from relevant authorities.

The FEED will form the basis of preparations for infrastructure delivery from summer 2024, contingent on government decisions and access to funding.

Cadent, NGN and National Gas are currently engaging with Ofgem to secure FEED funding through the Net-Zero Pre-construction Work and Small Net-Zero Projects Re-opener (NZASP). This Delivery Plan, which provides details on the Programme needs case, benefits, and opportunities as well as a detailed Programme development plan, will feed into the Re-opener, supporting Ofgem's decision making. Subject to agreement with Ofgem the networks expect to **submit the ECH_2 Re-opener in Q1 2024.**

As ECH_2 progresses through Phase 2 of the 15-year Programme, the Partners are committed to continuing to work with network users, the UK Government and Ofgem to further develop the Programme, to ensure **ECH_2 can unlock hydrogen ambitions and realise decarbonisation across multiple sectors.**

The Programme Partners will now further assess the identified routing options through the FEED. We will provide a further update on the preferred routing options once that work is complete; taking into account UK Government policy decisions and users' needs.

Glossary

AGI	Above Ground (hydrogen) Infrastructure
ALK	Alkaline Electrolysis
ATR	Autothermal Reforming
CAPEX	Capital expenditure
CB	Carbon Budget
CB6	Carbon Budget 6
CBA	Cost-Benefit Analysis
CCC	Climate Change Committee
CCGT	Combined Cycle Gas Turbines
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilisation and Storage
CHP	Combined Heat & Power
CMDC	Clean Maritime Demonstration Competition
Consortium Group	Natural gas users, potential hydrogen users, hydrogen producers and storage developers and local authorities that provided information about their hydrogen plans and/or letters of support for ECH_2 development
DCO	Development Consent Order
DESNZ	Department for Energy Security and Net-Zero
DEVEX	Development expenditure
East Coast region	Area covering Teesside, North Yorkshire, West Yorkshire, Humberside, South Yorkshire, Lincolnshire, Nottinghamshire, Derbyshire, Leicestershire
ECH_2	East Coast Hydrogen Programme
FEED	Front End Engineering Design
FES	Future Energy Scenarios
FID	Final Investment Decision
FSO	Future System Operator
GDN	Gas Distribution Network
GHG	Greenhouse Gas
GVA	Gross Value Added
GWh	Gigawatt-hour
HAR1/HAR2	First and Second Hydrogen Electrolytic Allocation Round
HGV	Heavy Goods Vehicle
HMG	His Majesty's Government
HSE	Health & Safety Executive
IEA	International Energy Agency
IMRRP	Iron Mains Risk Reduction Programme
I&C	Industrial and Commercial
LEP	Local Enterprise Partnerships
LPG	Liquefied Petroleum Gas
LTS	Local Transmission System
MoU	Memorandums of Understanding
Mt	Megatonnes (million tonnes)
$MtCO_2$	Megatonnes of CO_2
NGN	Northern Gas Networks
NIC	National Infrastructure Commission
NHS	National Health Service
NTS	National Transmission System
NZHF	Net-Zero Hydrogen Fund
OPEX	Operating expense
PEM	Proton-Exchange Membrane
PPA	Power Purchase Agreement
Pre-FEED	Preliminary Front-End Engineering Design
Programme Partners	National Gas, Cadent and NGN
RIIO-GD	Cost mechanism for GDNs within a defined price control period
SMR	Steam Methane Reforming
SOE	Solid Oxide Electrolysis
TWh	Terawatt-hour
T&S	Transport & Storage
UKETS	The UK Emissions Trading Scheme

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Appendix: Methodology | hydrogen demand

Hydrogen demand methodology

This report has drawn upon data from National Gas, Cadent and NGN to assess the potential future demand for hydrogen (TWh) within the region from I&C, power, transport and residential customers.

To establish the potential demand for hydrogen, the networks have focused on collecting primary data on large I&C and power natural gas users who may convert to hydrogen, as well as potential new hydrogen users. Domestic and transport demand has been modelled using mainly secondary data.

This section outlines each networks data collection approach, analysis of the data and any assumptions used to estimate demand.

I&C and power hydrogen demand data collection

Cadent	National Gas	NGN
Cadent requested data from the top 180+ natural gas consuming sites across North East Lincolnshire and Nottingham. 146 sites confirmed an intention to switch from natural gas to hydrogen providing forecasts. These forecasts include: • Potential hydrogen demand over time in 2030, 2035, and 2035+, • Current natural gas demand for 2022/2023, • Site location(s), • Site business operation, • Ability to blend or fuel switch to 100% hydrogen, • Decarbonisation plans.	National Gas undertook a UK wide data collection exercise to help inform the network design of Project Union. This included all large industrial and power customers that connect directly to the NTS. Forecasts from 10 directly connected customers within the East Coast region were received. These forecasts include: • Potential hydrogen demand over time in 2025, 2028, 2030 and 2037. • Current and future expected natural gas demand for 2022/2023, 2025, 2028, 2030, and 2037. • Site location, • Site business operation, • Decarbonisation plans.	NGN developed forecasts on the potential demand for hydrogen-based on the top 200 natural gas customers across North & Central Yorkshire, North of England & East Coast Yorkshire. Secondary data was collected for all the top 200 natural gas sites operated by identified customers, including: • 2022/23 annual natural gas consumption (Xoserve), • industrial sector, • location, • site specific plans which impact future demand, • site potential for accepting a hydrogen blend, • site plans for electrification or other alternative energy supply. Based on the above, NGN identify 191 sites for further investigation, collecting primary data to forecast potential hydrogen demand out to 2037. NGN also collected qualitative information from these 191 sites, including on (i) Net-Zero or sustainability plans, (ii) specific projects/initiatives underway, (iii) type of natural gas burning technologies used, and (iv) capability/appetite to accept hydrogen.

Additional hydrogen demand

Transport demand

Potential hydrogen demand for transport has only been quantified within this report where specific sites provided primary data for hydrogen forecasts (eg East Midlands Airports). For illustrative purposes, maps within the report include a number of publicly announced hydrogen for transport initiatives which may also become users of hydrogen network's users in future.

Residential demand

Residential demand is not included in the total hydrogen demand analysis. Residential demand is quantified separately to illustrate the potential impact on ECH_2 in the event UK Government determines that hydrogen will have a role in residential heat. We have assumed a 100% switch of residential natural gas users to hydrogen throughout this document in order to illustrate the maximum scenario. In future planning for pilot towns and working with the electricity distribution network operators, this assumption will be refined for each town to account for expected electrification of residential heat on a location by location basis.

Town demand

Town Pilot demand is not included in the total hydrogen demand analysis. Town Pilot demand is based on expected residential demand within the identified pilot areas (based on same approach as above). It also includes I&C and Power demand from sites that provided data and are located within the pilot areas.

Sector demand and location analysis

Demand data is presented in 10 'hydrogen demand clusters' within the East Coast region based on the location (post code) of sites. Any demand outside of the ECH_2 catchment area, such as Cumbria, Northumberland and Barrick upon Tweed, is not included in the analysis.

Demand data is presented in four categories: (i) Industrial & Commercial (I&C), (ii) Power, (iii) Transport, and (iv) Residential. Within I&C, data has been presented in 9 sub-sectors.

Appendix: Methodology | hydrogen demand continued

Demand sector definitions

Industrial demand	High energy end-users which are directly involved in manufacturing or producing services or goods. The major industrial sectors included within this report are divided into; Glass, Chemicals, Food & Drink, Steel, Manufacturing, Automotive Manufacturing, and Building Materials.
Commercial demand	End-users which engage in all commerce-providing services within the business, public, social, healthcare and educational sectors.
Power demand	End-users that generate power from natural gas and export to the electricty grid, including large scale power generators and flex or standby generators
Transport demand	End-users which use natural gas for transport activities including freight (HGVs), aviation, maritime, passenger transport (car, buses, trains).
Residential demand	End user is an individual or household that uses energy at domestic premises for their own personal domestic purposes, rather than for business or commercial purposes.
Steel sector	A network user that produces, manufactures, and processes steel.
Automotive sector	A network user that designs, produces and manufactures motor vehicles including cars, light trucks, and commercial vehicles.
Glass sector	A network user that designs, produces and manufactures various types of glass and glass products including sheet glass, optical glass, glass fibre, household glassware, and glass used in various fields such as construction, lighting and electronics.
Building materials sector	A network user that produces or manufactures building materials for industrial, rural, marine and other types of construction including gravel, cement, timber, stone & tiles, bricks & blocks, mortar, plaster board, plastic, aggregates, asphalt, concrete, lime, metal and building products.
Chemicals sector	A network user that produces, manufactures or converts materials into organic and inorganic chemicals and their derivatives, including industrial chemicals, ceramic products, petrochemicals, agrochemicals & fertilizers, polymers and fragrances.
Manufacturing sector	A network user that produces and manufacture large scale products from raw materials, involving clothing, computers, consumer electronics, electrical equipment, furniture, heavy machinery, ships, and tools.
Food & drink sector	A network customer that produces, manufactures, and packages food and drink products from raw food agricultural commodities and semi-processed food products.
Education sector	A network user that provides educational services, including public and non-profit, or for profit institutions such as schools, community colleges, and universities.
Healthcare sector	A network user that provides healthcare services, including public and non-profit, or for profit institutions such as trusts, hospitals, and clinics.

Additional hydrogen demand assumptions

1. Natural gas consumption (based on Xoserve data) is assumed to be reflective of total energy requirement in MWh
2. No partial switching, off-takers will transition to 100% hydrogen (confirmed through stakeholder engagement).
3. Potential I&C and power hydrogen demand from private pipelines to producers, within Teesside region only, has been included within total hydrogen demand calculations.
4. Charts present hydrogen demand coming on-stream at the dates provided, no additional profiling has been applied.

Appendix: Methodology | hydrogen production

Hydrogen production methodology

Hydrogen production capacity (GW) and annual supply (TWh) has been estimated based on primary and secondary data collected for 25 production sites across the East Coast region.

Hydrogen production data collection

Primary data	Secondary data
Hydrogen production forecasts have been collected from 22 hydrogen projects. These forecasts include: • Potential hydrogen supply (TWh or kg) over time in 2030, 2035, and 2037+, • Site location, • Technology type, • Year online, • Plant capacity (GW), • Status of development, • Probability of funding (if applicable), • Private hydrogen network designs (if applicable), • On-site hydrogen storage capacity (if applicable), • If Green Hydrogen, the renewable energy source.	Three hydrogen production sites have been identified through desktop research. These sites are included in the total production capacity analysis based on data and assumptions gathered from: Press releases, UK Government funding allocations (HAR1, NZHF, or CCUS cluster sequencing) and BloombergNEF. Data on these sites is in the process of being confirmed with primary hydrogen forecasts through ongoing network engagement.

Hydrogen production assumptions

1. All hydrogen produced will be available to the wider network, despite specific offtake agreements, private pipelines, and which network connects as it is assumed that each of the networks will connect into these pipelines in the future for wider resilience and flexibility options.
2. Assumed that production commences at the beginning of the year online for all projects listed.
3. The UK Government's Lower Heating Value (LHV) of hydrogen (KWh) is 33.4 kg/H2
4. All projects will go ahead as planned at the time of forecasting (this is being monitored and updated as more information becomes available)
5. For all Green Hydrogen electrolysis projects, it is assumed that power values have been provided as electrolysis input power (MWe) unless otherwise stated. These have been converted to MW H2 (LHV) production capacity at approximately 71% efficiency based on industry data.
6. It is assumed that the plant load factor remains constant from year 2 onwards and that production remains at maximum nameplate capacity (see table below]).
7. Due to differing production dates between the networks, production is kept constant between the yearly data points provided. No linear increase or assumption has been made.
8. Operations commence as stated in public literature unless otherwise stated in direct communications with the gas networks/developers.

Production load factors and availability assumptions

Green Hydrogen			
Year of Operation	**Year 1**	**Year 2**	**Year 3**
Availability	0.95	0.95	0.95
Load Factor	0.70	0.90	0.90
Plant Load Factor	0.67	0.86	0.86
Blue Hydrogen			
Year of Operation	**Year 1**	**Year 2**	**Year 3**
Availability	0.95	0.95	0.95
Load Factor	0.50	0.90	0.90
Plant Load Factor	0.48	0.86	0.86

Appendix: Methodology | storage

Hydrogen storage methodology

Primary data has been collected from all announced or operational hydrogen storage projects within the region. A literature review has been completed on all current or potential natural gas storage sites, demonstrating the region's potential hydrogen storage availability and requirements to meet the future necessities of future hydrogen transmission and distribution system.

Hydrogen storage data collection

Announced hydrogen storage	Current or potential natural gas storage sites
Announced hydrogen storage forecasts have been collected from four storage providers operating within the East Coast region. These forecasts include: • Potential storage capacity (kg, nmcm or GWh), • Technology type, • Year online, • Site location, • Injection and withdrawal rate (nmcm/h) and pressure required (barg), • Possibility to store blended hydrogen or 100% hydrogen. • Information on development status, risks, potential growth in storage capacity over time.	Data on additional natural gas storge sites has been collected via a literature review on the current natural gas storage and potential natural gas storage capacity in the UK. This is based on: • National Gas' '*2022 Gas Ten Year Statement*', • North Sea Energy's '*Project Atlas*', and • Atkin's '*Hydrogen Cavern Storage – WS10 & WS11*' report.

Hydrogen storage data analysis

Storage capacity

Potential hydrogen storage capacity has been estimated based on primary data gathered by the networks from the sites. The total energy capacity for each site was estimated on the basis of the volumetric capacities stated. Throughout our analysis we have assumed a Lower Heating Value (LHV) of 33.4kg/H_2.

On-site storage capacity collected from production sites has not been included within the total potential capacity figures for ECH_2, as facilities will be used mainly by the individual producer and not for wider energy network balancing.

Additional potential hydrogen storage (eg from potential to convert existing and planned natural gas) has not been quantified for the purposes of this report.

Total hydrogen storage requirements

Total potential UK hydrogen storage requirements are based on the System Transformation scenario from National Grid's '*Future Energy Scenarios 2022*' report.

Hydrogen storage assumptions

1. The Hydrogen NTS will connect into the majority of announced storage sites to provide national energy system resilience through Project Union. It is then assumed that the GDN's will connect into the NTS pipelines in the future for wider flexibility options.

2. It is assumed that storage commences at the beginning of the year each of the projects comes online.

3. The UK Government's Lower Heating Value (LHV) of hydrogen (KWh) is 33.4 kg/H2

4. The capacity of natural gas storage sites are indicative of the potential for future hydrogen storage capacity, but are not assumed as actual hydrogen storage capacity.

Appendix: Methodology | decarbonisation & fuel switching

Decarbonisation methodology

Decarbonisation data analysis

The Delivery Plan outlines the total I&C and power decarbonisation potential from switching from natural gas to low-carbon hydrogen.

The same carbon intensity factor for natural gas is used for all demand sites, except transport, where the carbon intensity value used is for aviation turbine fuel as the data relates to East Midlands Airport only.

The abated $MtCO_2$ is estimated by applying the carbon intensity values outlined in the assumptions to the stated potential hydrogen demand over time between 2028 to 2037. Total forecast hydrogen demand (TWh) within the I&C and power sectors is estimated based on Cadent and National Gas primary and NGN secondary data (see pp 26).

Potential abated emissions is compared against the UK's total provisional emissions for 2022 as stated in the UK Government DUKEs dataset.

Residential decarbonisation has been estimated using the same methodology and assumptions to showcase the potential emissions to be abated within the pilot towns and wider rollout region. These figures are not included to the total decarbonisation calculation as it is still uncertain and dependant on the UK Government's decision on hydrogen for heat.

Decarbonisation assumptions

1. The potential abated $C0_2$ emissions from the identified demand sites will be considered as Scope 1 (direct) emissions from natural gas or aviation turbine fuel combustion
2. The UK Government's emissions factor for natural gas: 0.18 kg $C0_2e$ per kWh
3. Hydrogen is displacing natural gas through fuel switching
4. The UK emissions factor for aviation turbine fuel: 0.25 kg $C0_2e$ per kWh
5. For new hydrogen demand, it is assumed this has come from an increase in production not from other processes which have fuel switched
6. To calculate the UK total I&C sector emissions, we have only taken data from the 'Business' sector emissions in the UK Governments 'Provisional emissions for 2022' dataset

Fuel switching potential

Fuel switching data analysis

The Delivery Plan has estimated the potential volume of I&C and power natural gas demand that could switch to low-carbon hydrogen between 2028 and 2037.

Total forecast hydrogen demand (TWh) within I&C and power sectors is estimated based on Cadent and National Gas primary and NGN secondary data (see pp 26). The fuel switching potential is set against the sum of all the potential hydrogen sites current natural gas consumption for 2022/2023. Note, the natural gas demand of the user/site is based on a moment in time and reflects demand when forecasts were shared, it does not include any assumptions on future energy demand profile.

The transport and residential sector hydrogen demand fuel switching potential has not been estimated due to the uncertainty surrounding future hydrogen demand.

Furthermore, the site level fuel switching potential has been set against the wider regions natural gas demand to calculate the scale of which ECH_2 can help fuel switch the I&C and power sectors. The networks own data has been used to calculate the total natural gas demand for 2022/2023, split by residential, power, industrial, commercial sectors, for the entire East Coast region.

Hydrogen fuel switching assumptions

1. It is assumed that 100% of natural gas consumption will switch to low-carbon hydrogen.
2. The potential for a future increase or decrease in each sites natural gas demand due to energy efficiencies, site closures or a change in activity is not factored into the calculation.
3. It is assumed that no new processes will be implemented to require hydrogen. New hydrogen demand is assumed to derive from production increase in same processes.
4. 2022/2023 total natural gas consumption is indicative of the scale of natural gas to fuel switch or abate, not a forecast over time.

East Coast Hydrogen