Northern Gas Networks

East Coast Hydrogen - Pre-FEED Study

Production Study Report

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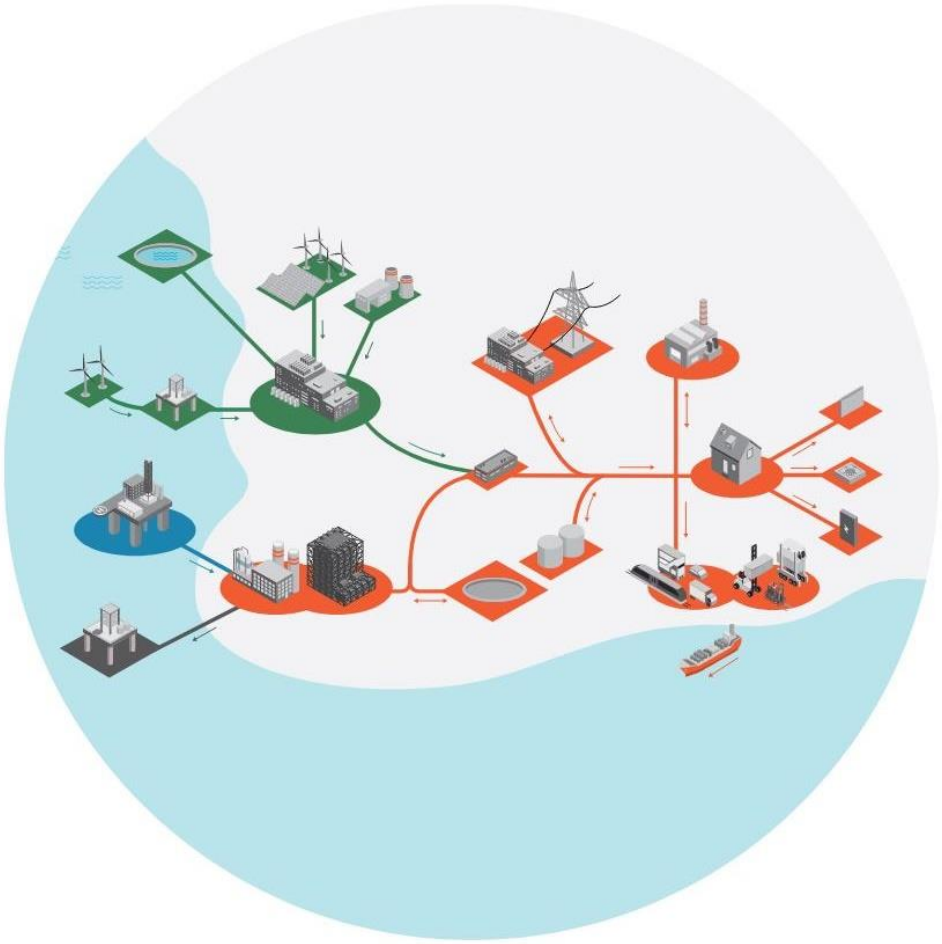

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1. Introduction

Northern Gas Networks (NGN) are the company responsible for distributing gas to homes and businesses across the north of England, an area covering West, East & North Yorkshire, the North East and Northern Cumbria.

East Coast Hydrogen (ECH) provides a solution to connect these industrial clusters with other supply points, such as the East Midlands Hydrogen Innovation Zone, and export hydrogen production across the North of England enabling the seamless conversion of businesses and homes to 100% hydrogen where it is best deployed.

This collaborative programme between Northern Gas Networks, Cadent Gas and National Gas Transmission (NGGT) represents an opportunity for the Government and the private sector to work together in delivering on the ambitious decarbonisation targets. ECH has the potential to connect over 7GW of hydrogen production by 2030, significantly contributing to the UK Government's 10GW by 2030 target in a single region.

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

ECH is a 15-year programme that will be carried out in multiple discrete phases to decarbonise industrial processes and domestic heating in the East Coast region. Proposed phases can be seen below:

Phase 1 - (2022 2026) - Completion of Pre-FEED, FEED Study and development of East Coast Cluster infrastructure

Phase 2 - (2024 2030) - Connection of Humber and Teesside clusters, and growth into Yorkshire and East Midlands

Phase 3 - (2028 2037) - Expansion from the industrial Clusters into Northern urban areas and the Midlands

Phase 4 - (2032+) - Connection of the network into further regions and future growth opportunities

NGN will look to trigger the Net Zero and Small Projects (NZASP) Reopener to undertake the subsequent phase i.e., FEED study.

Arup have been commissioned by NGN to undertake a Pre-FEED study to support the Net Zero and Small Projects (NZASP) Reopener and subsequent project phases e.g., FEED study.

2. Purpose of Document

The purpose of this document is to describe the data collection and processing stages which have been undertaken to provide the hydrogen production modelling inputs for the East Coast Hydrogen project. This document also outlines the assumptions which have been made up to the stage of issue, which are also captured in the project assumptions register.

This document was produced in the early stages of the Pre-FEED project, to inform the development of the network. Revision B captures updates which have developed throughout the Pre-FEED stage.

The information relating to the production is correct at the date of issue of this document. However, it is expected that this information will be continually refined during this project due to the fast-moving nature of the industry and upon further engagement with potential hydrogen producers.

3. Data Analysis

Production projects for both green and blue hydrogen within the East Coast region have been investigated building on the key hydrogen production projects provided in the Pre-FEED Scope of Services document [1] as listed below:

Teesside

- H2 North East, Kellas, 1000 MW
- H2 Teesside, BP, 1000 MW
- HyGreen Teesside, BP, 500 MWe
- Protium Teesside, 40 MWe
- Tees Green Hydrogen, EDF, 500 MWe

The Humber

- H2H Saltend Project, Equinor, 600 MW
- H2H Production 2 Project, Equinor, 1200 MW

Data from NGN's third-party stakeholder files was used in conjunction with the project Business Development Tracker to add further detail to the hydrogen production projects, enabling a detailed forecast of hydrogen production to be constructed.

A literature review has been completed on hydrogen production in the East Coast region with sources including press releases and Bloomberg NEF [2], a leading provider of primary research and analysis on the trends driving the transition to a lower-carbon economy. This has enabled the identification of additional hydrogen production projects in the region for inclusion in forecasting.

Refer to Appendix A.1 of this document for a summary of the hydrogen production locations.

All identified projects have been broken down into phases where applicable to enable a more granular forecast of potential hydrogen production to be developed. Forecasts have been considered in the greater context of the UK governments targets to produce 10GW of low carbon hydrogen by 2030.

In addition to this, the Department for Energy Security & Net Zero (DESNZ) Hydrogen Allocation Rounds are continuing, with HAR2 undergoing assessment in 2024. These will likely result in additional production sites which could be considered for connection to the ECH network in the FEED stage of the project.

4. Methodology

Initially all hydrogen production projects in the East Coast Region were identified. A detailed picture of each project was then developed utilising the information from the literature review which was compared and supplemented with the NGN Business Tracker communication notes, enabling the identification of phasing, operational start dates and plant capacities. Appendix A.1 includes a summary of the direct communications between NGN and hydrogen producers in the east coast region with a narrative for operational start date assumptions.

It has been assumed that for all green hydrogen electrolysis projects the power values have been provided as electrolysis input power (MWe) unless otherwise stated. These have been converted to MW H_2 (HHV) production capacity utilising a system specific consumption figure for MWe/kg H_2 based on an average value for a range of electrolysers technologies from number of global electrolyser manufacturers including Nel, Cummins, ITM Power and Siemens. The electrolyser efficiency utilised is approximately 71% efficiency. As information on specific technologies utilised for projects becomes available more specific efficiencies could be applied.

Plant availability and load factors take into account the actual hydrogen production expected from the facilities against the maximum any facility is capable of producing. These have been applied in the forecasting to ensure a realistic hydrogen production capacity is determined. Table 1 includes a summary of the plant load factors applied for green and blue hydrogen production facilities based on engineering judgement. It is assumed that the plant load factor remains constant from year 2 onwards and that production remains at maximum capacity.

Table 1: Plant availability assumptions for green and blue hydrogen producers

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

4.1 Key assumptions

A number of key assumptions have been made to enable forecasting of hydrogen production as detailed below:

- All projects will go ahead as planned at the time of forecasting (this is being monitored and updated as more information becomes available)
- 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 H_2 (HHV) production capacity at approximately 71% efficiency based on industry data
- Operations commence as stated in public literature unless otherwise stated in direct communications with NGN
- Hydrogen production outside of the Yorkshire, Humber and Teesside regions is not included in hydrogen production forecast
- Plant availability and load factors have been applied as included in Table 1
- All hydrogen produced will be available to the wider network as no public literature includes information on specific offtake agreements and the potential for distribution through the NGN network has received letters of support from producers

5. Results

5.1 Hydrogen Production Forecast

Table 2 includes a list of the identified planned production facilities within the East Coast region ordered by the date that operations are expected to commence. The original projects identified in the scope of services document are included along with additional projects in the region. A map of the ECH region including the locations of the projects is included in Appendix A.1. Details of the projects have been determined with consideration of online literature and NGN direct communications with a summary of these included in Appendices A.2 and A.3.

Table 2: Planned hydrogen production facilities in the East Coast Region

Organisation	Project Name	Location	Type	Plant Capacity H2 MW (HHV) [1]	Potential Supply per year (TWh) [2]	Year online	Notes
BP	HyGreen Phase 1	Teesside	Green	42	0.317	2025	
Protium	Tees Valley Net Zero	Teesside	Green	12	0.09	2025	
Protium	Tees Valley Net Zero phase 2	Teesside	Green	36	0.272	2025	
Phillips 66	Gigastack Hydrogen Production	Humber	Green	71	0.528	2025	Paused
SSE Thermal/ Equinor	Aldbrough Hydrogen Pathfinder	Humber	Green	35	0.262	2025	
Hygen	Bradford Low Carbon Hydrogen	West Yorkshire	Green	25	0.184	2025	HAR1
Equinor	H2H Saltend	Humber	Blue	600	4.494	2027	
BP	H2teesside Phase 1	Teesside	Blue	500	3.745	2027	CCUS track 1
Kellas Midstream	H2NorthEast Phase 1	Teesside	Blue	355	2.659	2027	
EDF	Tees Green Hydrogen	Teesside	Green	353	2.640	2027	HAR1
Equinor	H2H Production 2	Humber	Blue	1200	8.988	2028	
BP	H2teesside Phase 2	Teesside	Blue	500	3.745	2030	
Kellas Midstream	H2NorthEast Phase 2	Teesside	Blue	645	4.831	2030	
BP	HyGreen Phase 2	Teesside	Green	310	2.323	2030	
Equinor	*Equinor Green Hydrogen*	Humber	Green	846	6.337	2030	
Meld	Saltend Green	Humber	Green	71	0.528	2028	

Notes
1. Plant capacity for green hydrogen projects has been calculated using the provided MWe figures in literature
2. Potential supply has been calculated using the maximum forecasted plant availability

These results have been plotted showing the forecast for hydrogen production from January 2025 to January 2032 after which all identified low carbon hydrogen production projects will be fully operational. The hydrogen production forecast graphs are shown below in Figure 1 and Figure 2.

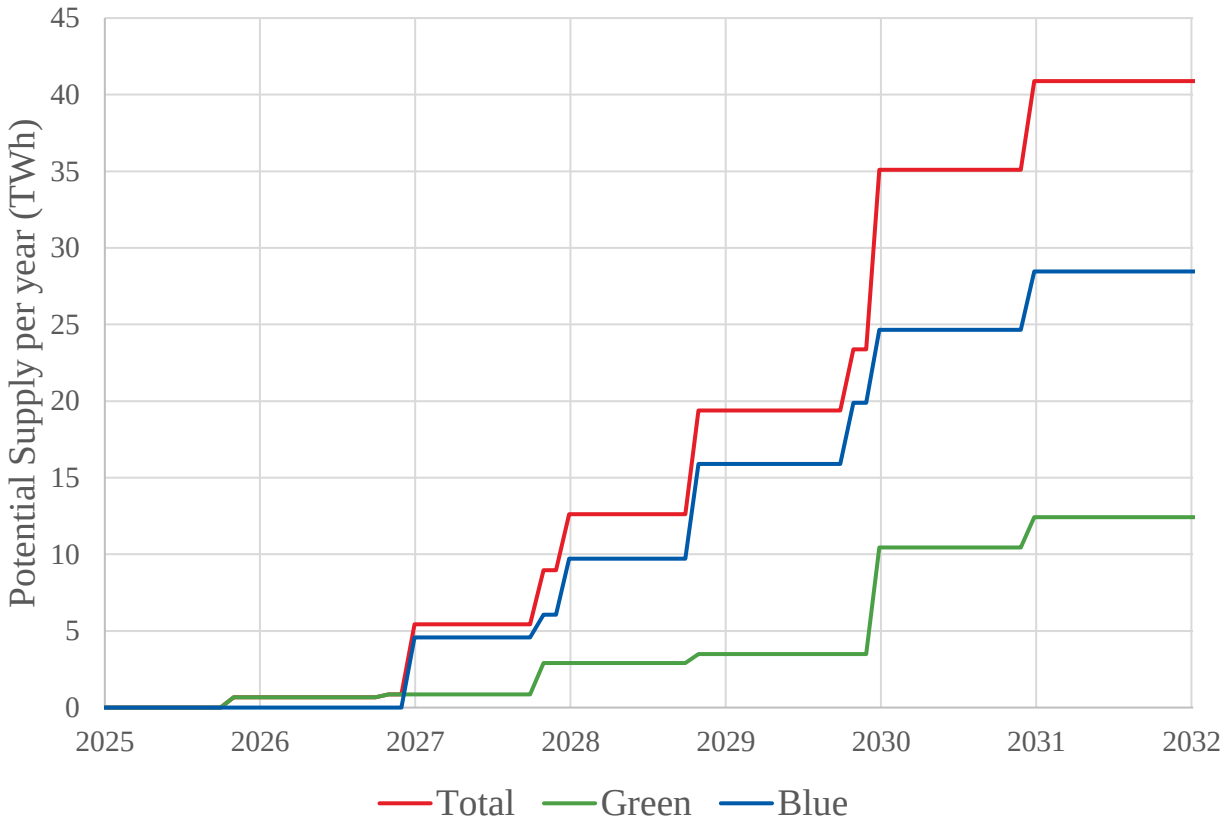


Figure 1: Hydrogen production profile for Teesside and Humber broken down into green and blue hydrogen technologies from 2025-2032

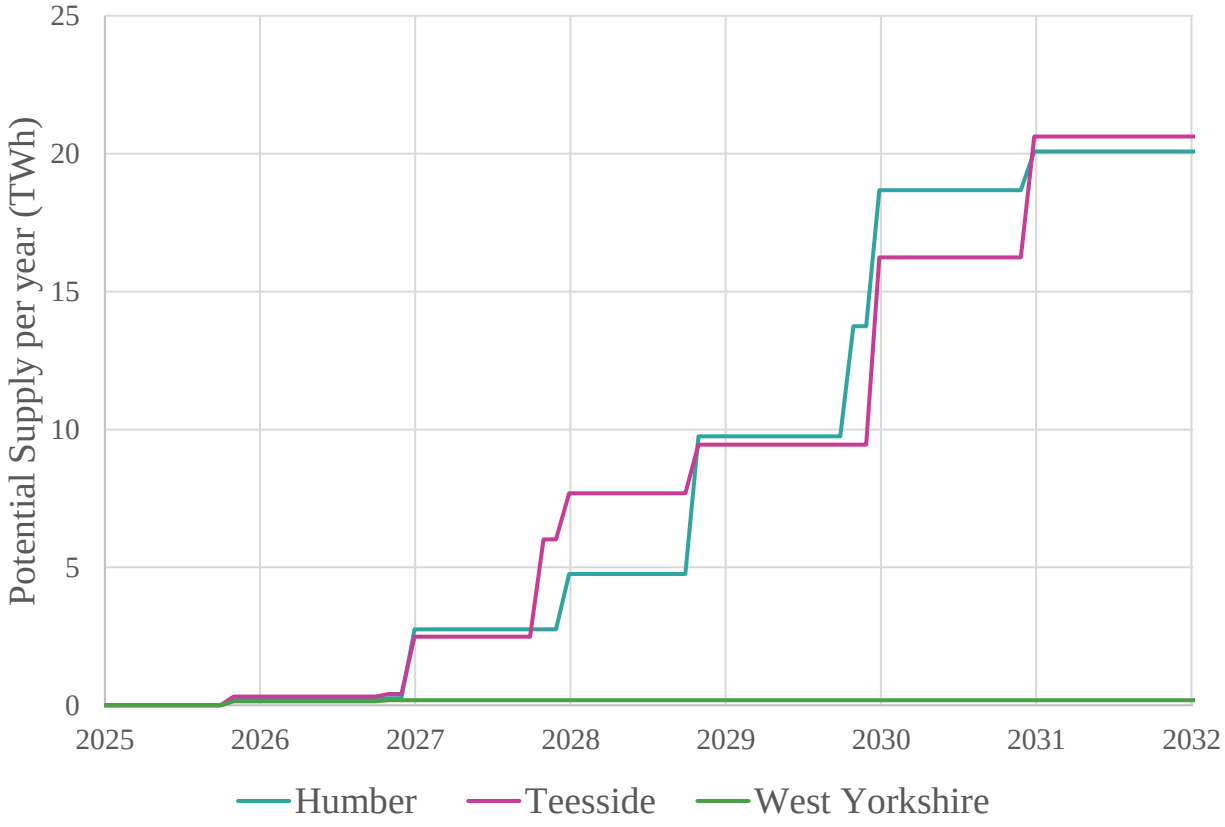


Figure 2: Hydrogen production profile broken down into the location of production facilities from 2025-2032

Figure 3 below includes a summary of potential hydrogen supply per year from the beginning of 2028 and 2032. This shows that by 2032 there will be 41TWh produced per year of which 30% will be made up of green hydrogen. Projects planned to become operational after this period have not yet been identified so no additional supply is currently forecasted in 2037 however this is being monitored.

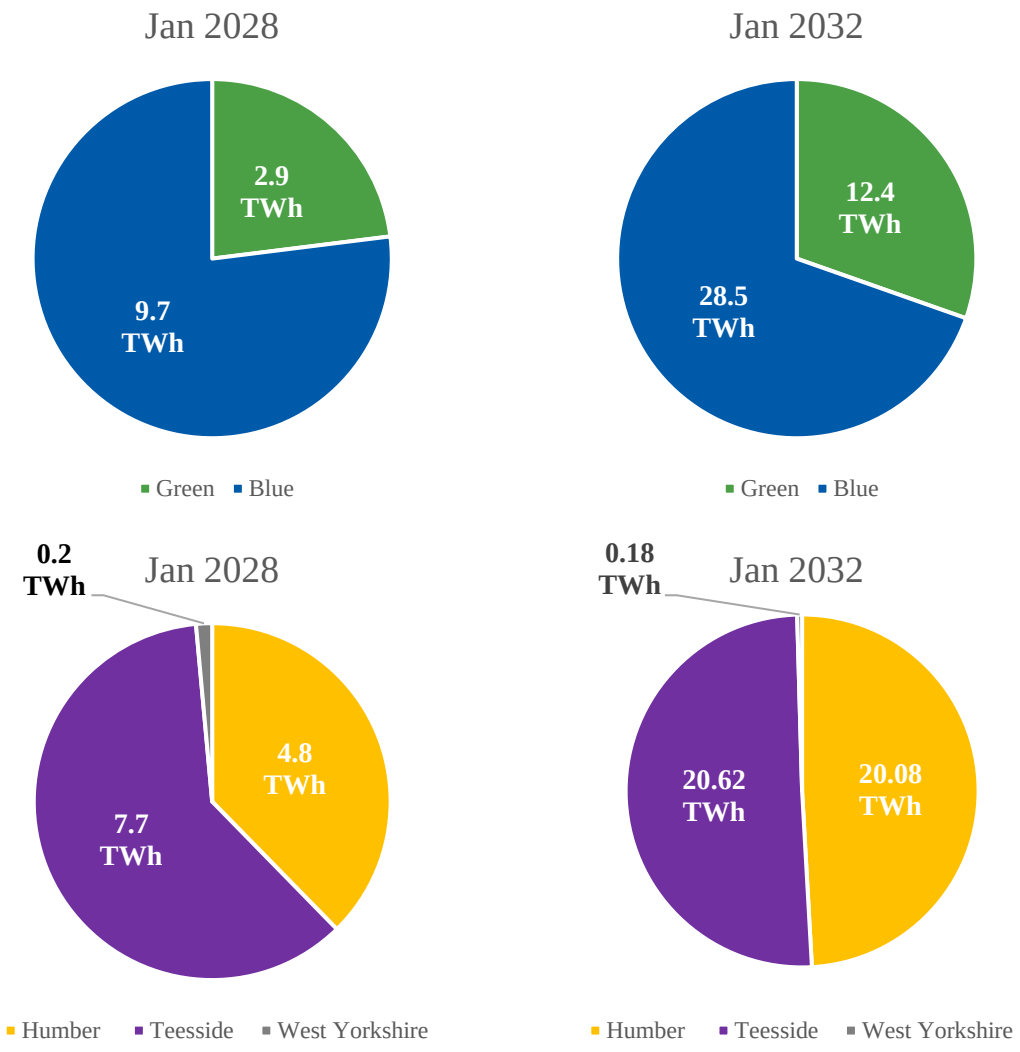
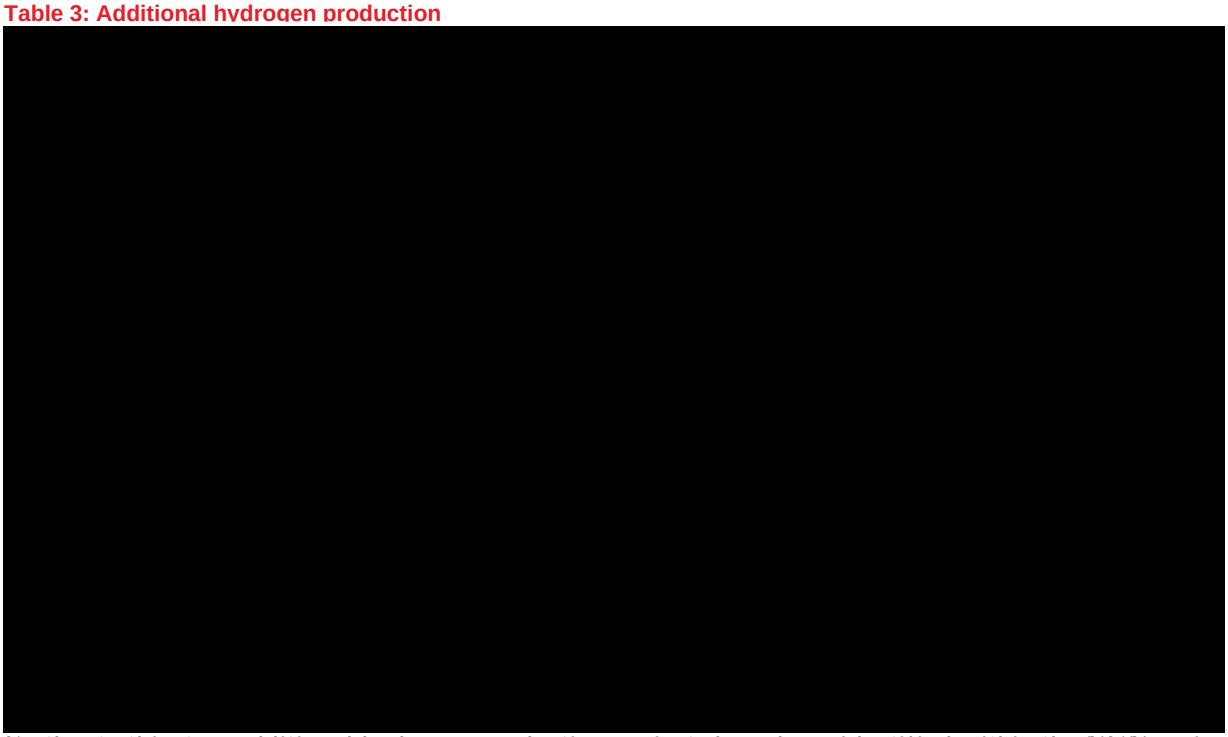


Figure 3: Potential hydrogen supply pie chart for the beginning of 2028 and 2032

5.2 Other Hydrogen Production

Throughout the pre-FEED, stakeholder engagement has been ongoing and multiple potential hydrogen producers have been engaged. This has identified projects which are in relative infancy and have not been publicly announced, these have not been included in the reported demand figures, but show the strong pipeline of production which is planned, even without the certainty of a transport network. These can be seen in the table below.

Table 3: Additional hydrogen production



Further to this, two additional hydrogen production projects have been identified within the NGN region, but outside of ECH scope, these are included in the Table 4. These facilities are a large distance from the main industrial clusters of Teesside and Humberside and are not at a large scale by comparison to projects in those clusters, they have not been considered as part of the main forecast. However, this does supplement the need for a network which connects these other areas of production to generate growth in the market.

Table 4: Summary of other hydrogen production in NGN regions of coverage

Organisation	Project Name	Location	Type	Plant Capacity H2 MW (HHV) [1]	Potential Supply per year (TWh) [2]	Year Online
Carlton Power	Barrow Green Hydrogen	Cumbria	Green	25	0.185	Nov-25
Lhyfe	Lhyfe Wallsend	North Tyneside	Green	20	0.123	TBC

Notes

1. Plant capacity for green hydrogen projects has been calculated using the provided MWe figures provided in literature
2. Potential supply has been calculated using the maximum forecasted plant availability

There is a further strong pipeline of low carbon hydrogen production facilities which have been identified through market engagement. One of the key drivers for this is the DESNZ Hydrogen production delivery road map and associated funding rounds which are driving the development of the market. The below table shows the ambitions of DESNZ in the future Hydrogen Allocation Rounds.

Table 5: DESNZ Hydrogen allocation round ambitions

	HAR 2	HAR 3	HAR 4	HAR 5	HAR 6	HAR 7
HAR launch	2023	2025	2026	2027	2028	2029
Contract Award	2025	2026	2027	2028	2029	2030
Capacity target	Up to 875MW	Up to 750 MW	Up to 750 MW	TBA	TBA	TBA
Delivery Years	31/03/2026 – 31/03/2029	31/03/2027 – 31/03/2030	31/03/2028 – 31/03/2031	TBA	TBA	TBA

5.3 Opportunities and Risks

There are a number of risks affecting the production and supply to NGN of hydrogen including hydrogen availability and government funding decisions.

The amount of available hydrogen to the wider network is not fully understood. Many of the identified projects are in communication with local offtakers already and are planning private hydrogen pipelines to transport the hydrogen to potential users. NGN has contacted many of the producers and there is a definite interest shown in working with NGN to distribute the hydrogen but until clear plans are in place these producers will likely progress with their own private pipelines.

Many of the projects identified have been shortlisted for government funding through DESNZ with funding decisions potentially affecting the likelihood of projects developing. On the 30th March 2023 the government issued an update for both blue and green hydrogen funding decisions. The government announced the shortlisted electrolytic hydrogen projects [3] which included five green hydrogen projects in the North East and Yorkshire and are detailed in Table 6. The shortlist did not include the Protium Teesside project or the Uniper Humber hydrogen project which may cause changes to the planned production, timelines and completion of these projects. Press releases should be monitored to determine the effects of this.

In December 2023 the successful projects were announced [4], with only two of the shortlisted five projects in the ECH region being successful. The unsuccessful schemes have not yet indicated that without the support from HAR1 they will not proceed. There is however a risk that these schemes were reliant on HAR funding for financial viability and may not progress without it in the timescales stated or at all.

Table 6: Net-zero hydrogen fund shortlisted electrolytic hydrogen projects in the North East and Yorkshire regions from HAR1

Project Name	Lead Developer	Location	Successful
Aldbrough Hydrogen Pathfinder	SSE Thermal	Yorkshire	No
Bradford Low Carbon Hydrogen	Hygen	Yorkshire	Yes
Gigastack	Phillips 66	North East	No
HyGreen Teesside	BP Alternative Energy Investments	North East	No
Tees Green Hydrogen	EDF Renewables Hydrogen	North East	Yes

For blue hydrogen projects the government announced the shortlist for track 1 phase 2 CCUS, hydrogen and ICC projects [5] which included bpH2Teesside in the selected hydrogen projects for the East Coast Cluster. Equinor H2H Saltend was not included on the shortlist for track 1 which may cause changes to the planned production and timeline of the project. H2NorthEast was successful in securing project development support as part of the governments net zero hydrogen fund [6].

The announcement [5] noted the planned launch of a process later in 2024 to enable further expansion of the Track-1 clusters, beyond the initial deployment, identifying and selecting projects for HyNet and East Coast Cluster (including the Humber) as they become viable to be operational by 2030. The process aims to identify projects that could be potential alternatives to any of the initial Track- 1 projects, if any are unable to agree contracts within the criteria and timelines required. This should be monitored to determine the effects on forecast hydrogen production in the ECH region.

In addition, the announcement noted the planned launch of Track-2 to identify 2 additional clusters contributing to the governments ambition to capture 20-30 Mt CO2 per year across the economy by 2030.

In the December 2023 Hydrogen Production Delivery Road map, the government announced their intention to launch a process to further expand Track-1 clusters beyond the initial deployment to fill the available storage and network capacity [7].

6. References

[1] NGN, Pre-FEED Scope of Services for East Coast Hydrogen Specification for Pre-FEED, Rev 02, 28 Oct 2022.

[2] BloombergNEF, BloombergNEF (bnef.com), Accessed 17 Feb 2023.

[3] Department for Energy, Security & Net Zero, Hydrogen Business Model / Net Zero Hydrogen Fund: shortlisted projects allocation round 2022, 30 March 2023.

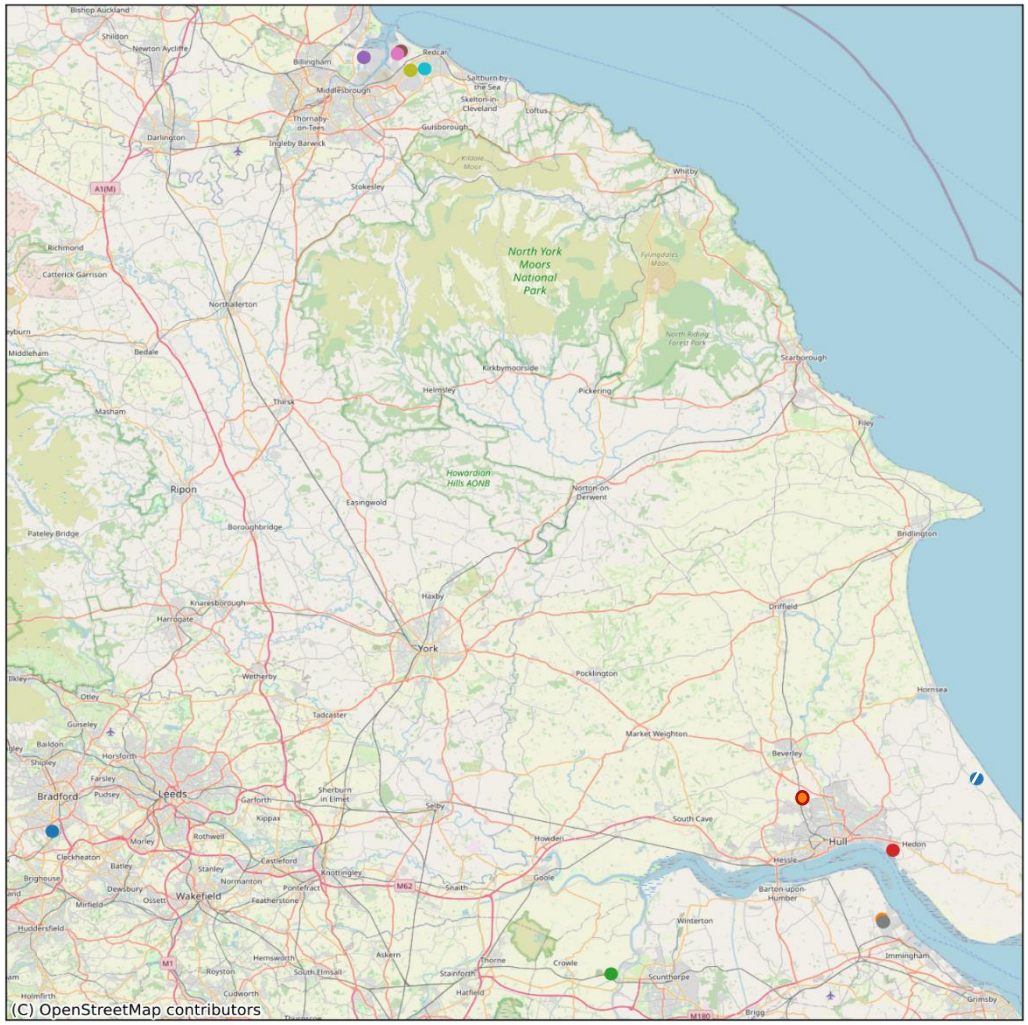
[4] Department for Energy, Security & Net Zero, Hydrogen Production Business Model / Net Zero Hydrogen Fund: HAR1 successful projects, 14 December 2024.

[5] Department for Energy, Security & Net Zero, Cluster sequencing Phase-2: shortlisted projects (power CCUS, hydrogen and ICC), August 2022, 30 March 2023.

[6] Department for Energy Security & Net Zero, Net Zero Hydrogen Fund strands 1 and 2: summaries of successful applicants round 1 (April 2022) competition, 30 March 2023.

[7] Department for Energy Security & Net Zero, Hydrogen Production Delivery Roadmap, December 2023.

A.1 Hydrogen Production Locations



- BP Hygreen
- Protium Teesside
- Element Energy Gigastack
- Uniper Humber Hydrogen
- SSE/Equinor Aldbrough Hydrogen Pathfinder
- Hygen Bradford Low Carbon Hydrogen
- Equinor H2H Saltend
- Equinor H2H Production 2
- BP H2Teesside
- Kellas H2NorthEast
- EDF Tees Green Hydrogen
- Uniper H2ub
- Equinor Green Hydrogen

Figure 4: Hydrogen production project locations in the ECH region

A.2 Direct Communications and Literature Review

Table 7: Summary of direct communications and literature review for each of the major known producers identified by NGN

Project	Communications Summary	Literature Review	Year Online Assumption
H2H Saltend Project, Equinor, 600MW	[redacted]	Stated operational date of 2026-2027.	Start date of January 2027.
H2H Production 2 Project, Equinor, 1200 MW		Stated that the facility could be by operational by 2028.	Start date of November 2028
H2 North East, Kellas, 1000MW		Stated 1GW of low carbon hydrogen by 2030. Phase 1 start date stated as by 2027	Start date for phase 1 of November 2027 with phase 2 starting in January 2030.
H2 Teesside, BP, 1000MW		Phase 1 could begin production in 2027 or earlier with additional capacity to be deployed by 2030.	Start date for phase 1 of January 2027 with phase 2 starting in January 2030.

Project	Communications Summary	Literature Review	Year Online Assumption
HyGreen Teesside, BP, 500MWe	[redacted]	Targets 60MWe of 'green' hydrogen production by 2025 and could deliver up to 500Mwe (megawatt electrical input) of hydrogen production by 2030.	Phase 1 operational in November 2025 and phase 2 in January 2030.
Protium Teesside, 40MWe		The 70MWe site will be developed in two phases, the first aims to be operational by quarter 3 of 2025.	Phase 1 operational in November 2025 and phase 2 in January 2030.
Tees Green Hydrogen, EDF, 500MWe		The project will support ambitions to reach carbon neutrality across our Tees-based operations by 2027.	Start date of November 2027.

Project	Communications Summary	Literature Review	Year Online Assumption
Meld - Goole	[redacted]	N/A	TBC
SSE Ferrybridge Phase 1&2			2027-31, 2034
RWE – Green horizons			2027, 2030

A.3 Hydrogen Production Table and References

Table 8: Hydrogen production table for the East Coast Region including online literature references

Organisation	Project Name	Location	Type	Reference
BP	HyGreen Phase 1	Teesside	Green	https://www.bp.com/en_gb/united-kingdom/home/where-we-operate/reimagining-teesside/hygreenteesside.html
Protium	Protium Teesside Phase 1	Teesside	Green - PEM	https://protium.green/news/protium-s-flagship-tees-valley-net-zero-hydrogen-project-expands-to-nearly-70mw-capacity/
Phillips 66	Gigastack Hydrogen Production	Humber	Green	https://gigastack.co.uk/about/
SSE Thermal/ Equinor	Aldbrough Hydrogen Pathfinder	Humber	Green	https://www.ssethermal.com/news-and-views/2023/08/uk-government-advances-sse-thermal-s-green-hydrogen-project/
Hygen	Bradford Low Carbon Hydrogen	West Yorkshire	Green	https://ryzehydrogen.com/2023/03/30/bradford-hydrogen-production-facility-shortlisted-for-government-funding/
Equinor	H2H Saltend	Humber	Blue	https://www.equinor.com/news/20220812-h2h-saltend-selected
BP	H2teesside Phase 1	Teesside	Blue	https://www.bp.com/en_gb/united-kingdom/home/where-we-operate/reimagining-teesside/h2teesside/about-h2teesside.html https://www.bp.com/en_gb/united-kingdom/home/news/press-releases/bp-plans-uk-s-largest-hydrogen-project.html
Kellas Midstream	H2NorthEast Phase 1	Teesside	Blue	https://www.kellasmidstream.com/net-zero/hydrogen
EDF	Tees Green Hydrogen	Teesside	Green	https://www.edf-re.uk/media-centre/new-green-hydrogen-project-by-edf-renewables-uk-and-hynamics-comes-to-teesside/
Equinor	H2H Production 2	Humber	Blue	https://www.equinor.com/news/uk/20220622-hydrogen-production
BP	H2teesside Phase 2	Teesside	Blue	https://www.bp.com/en_gb/united-kingdom/home/news/press-releases/bp-plans-uk-s-largest-hydrogen-project.html
Kellas Midstream	H2NorthEast Phase 2	Teesside	Blue	https://www.kellasmidstream.com/net-zero/hydrogen
Protium	Protium Teeside Phase 2	Teesside	Green - PEM	https://protium.green/news/protium-s-flagship-tees-valley-net-zero-hydrogen-project-expands-to-nearly-70mw-capacity/
BP	HyGreen Phase 2	Teesside	Green	https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-plans-major-green-hydrogen-project-in-teesside.html
Equinor	Equinor Green Hydrogen	Humber	Green	Confirmed to NGN at ECH integration meeting of internal approval for 1.2GWe green H2 plant. Assumed Jan-2030 operational start date.