national gas transmission

H_2 Backbone Insights Report

national gas transmission

Outline

national gas transmission

Introduction

national gas transmission

Hydrogen Backbone Insights Overview

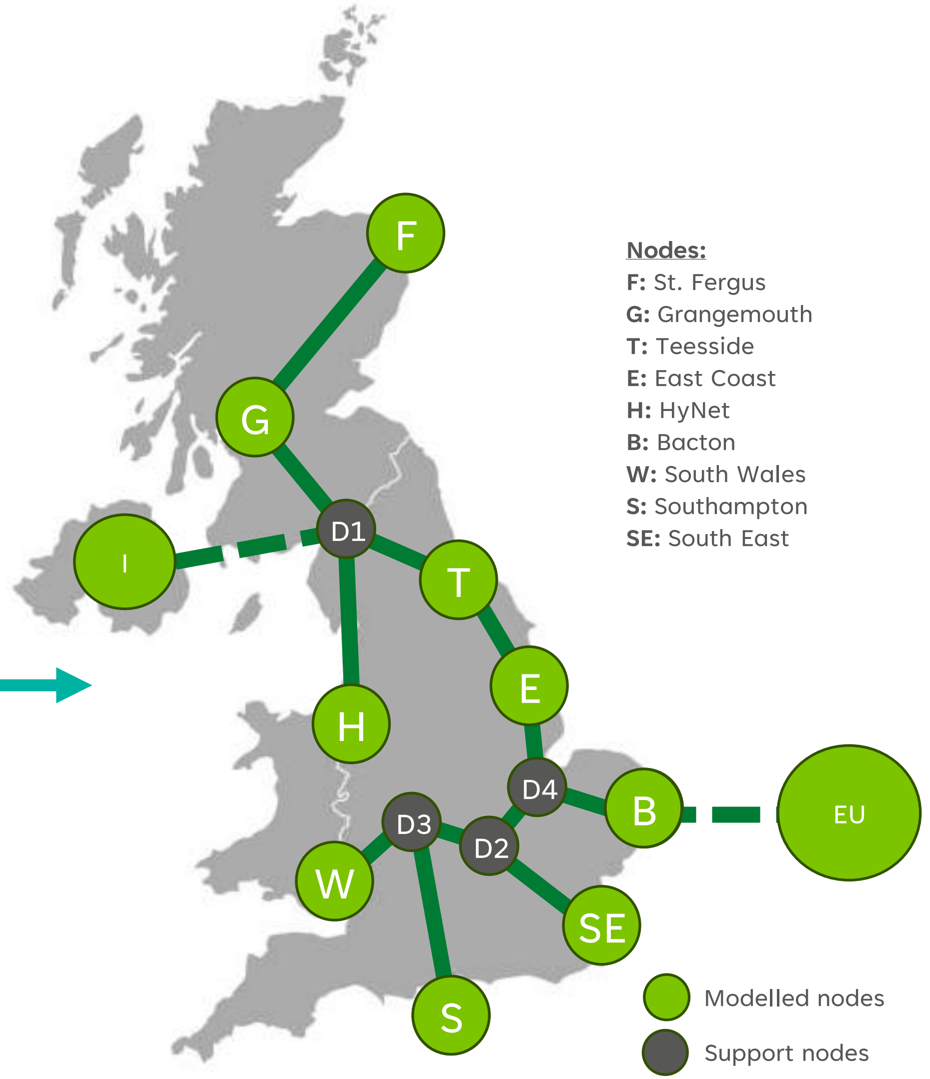
The hydrogen backbone review develops credible and independently modelled pathways, to test the economic case of a Hydrogen Backbone in the UK.

The objectives of the work focus on:

1. **Whole System Review:** Development of an independent view on what scenarios would need to come true for a hydrogen backbone to be economically justified.
2. **Economic case:** The economic case tests under which conditions the economic case for the backbone becomes compelling. Each segment of the backbone is assessed (e.g., St Fergus to Teesside, Humber, combined) and what needs to happen to justify the investment.
3. **NESO Planning Engagement:** For engagement with NESO on their planning, including SSEP, CSNP, and potentially RESP, the modelling of the hydrogen backbone enables greater insights on the need for H_2 infrastructure.

Hydrogen Backbone Configuration

- The modelling of the backbone is configured to a **geographical scope made of 11 sub-regions to provide granularity to the analysis.**
- The 9 onshore sub-regions have been determined based on the proposed path of the Hydrogen Backbone.
- Two neighbouring regions provide insight into the export potential to Europe and Ireland.



Whole System Model Methodology

national gas transmission

Whole Systems Model Methodology – Full Backbone

General Model Configuration

- The study uses a PLEXOS model to simulate the flow rates across the proposed H_2 Backbone **in 6 different scenarios**.
- The scenarios are using FES 2025 as a base for electricity and methane projections, but the hydrogen forecasts are adjusted (demand, supply, export), and the ‘turning points’ are tested.
- The model is configured to a **geographical scope made of 11 sub-regions to provide granularity to the analysis.** The 9 onshore sub-regions have been determined based on the proposed path of the H_2 Backbone. Two neighbouring regions will provide insight into the export potential to Europe and Ireland.

Configuration to H_2 Backbone Economic Case

11x Geographic Scope:

- 9x onshore nodes
- 2x neighbouring region

5x Model Years:

2030, 2035, 2040, 2045, and 2050

7x Rep. day:

Spring | Summer | Fall | Winter | Winter / Summer Peak | Winter Peak & No wind

6x Scenarios:
To account for six H2 demand categories

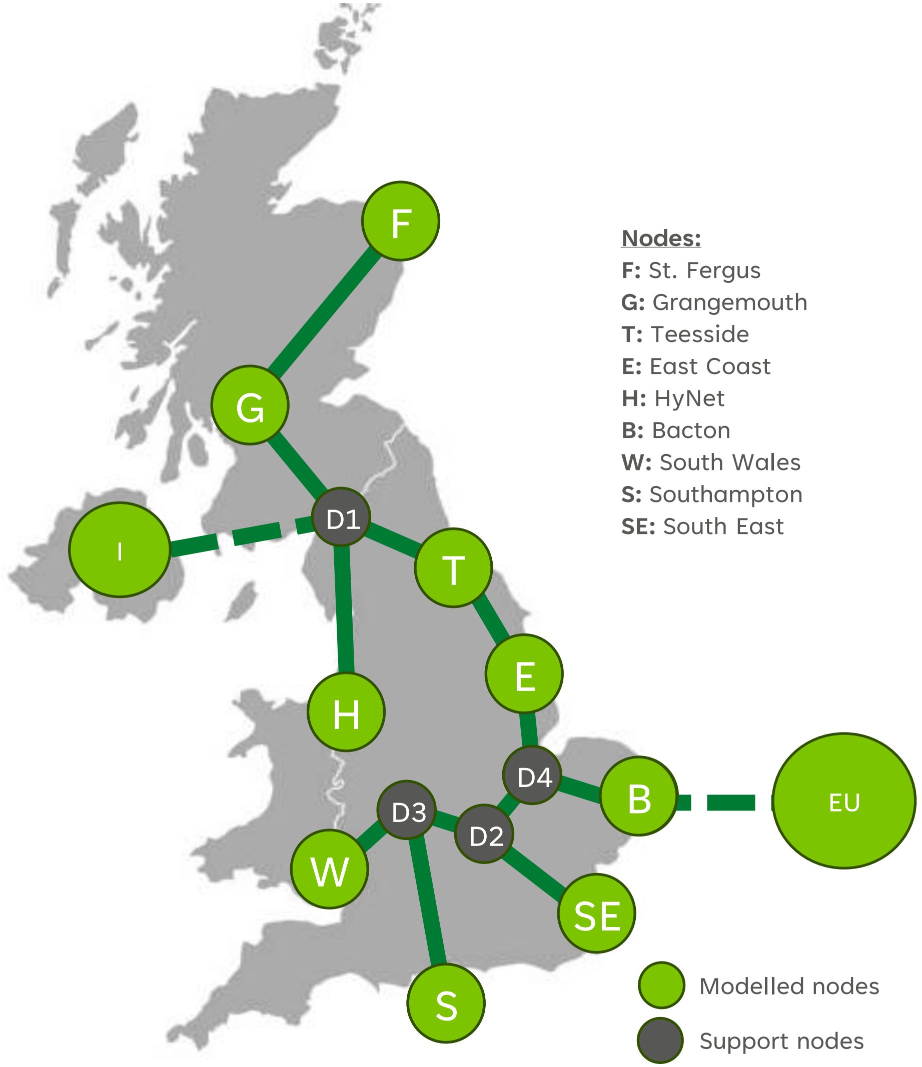
2x Energy Carrier:

Hydrogen

Power

Hourly Timestep:

24h



Nodes:
F: St. Fergus
G: Grangemouth
T: Teesside
E: East Coast
H: HyNet
B: Bacton
W: South Wales
S: Southampton
SE: South East

Modelled nodes

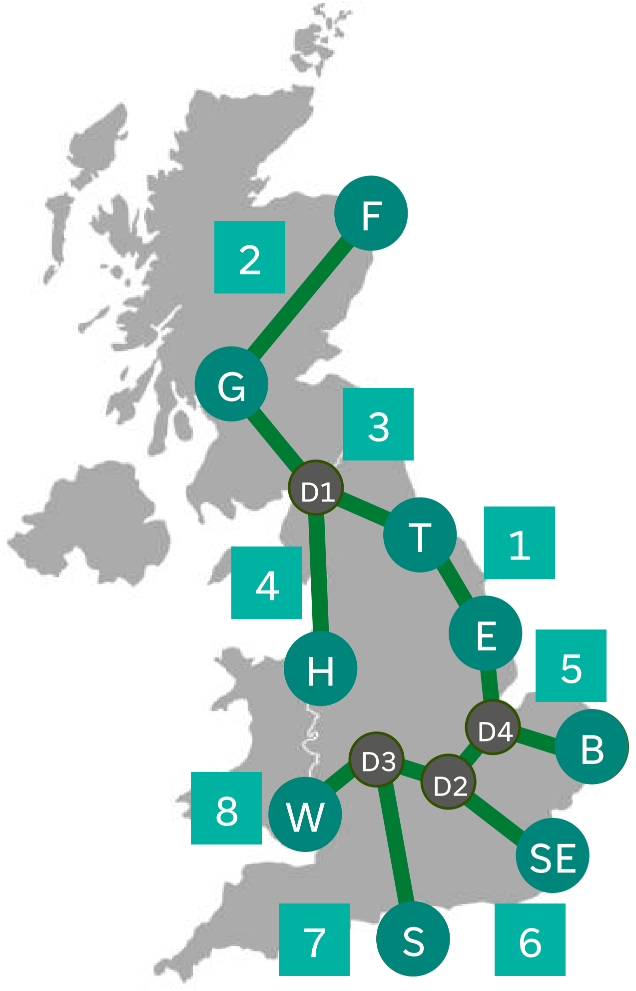
Support nodes

PLEXOS Modelling Configuration – Lean Backbone

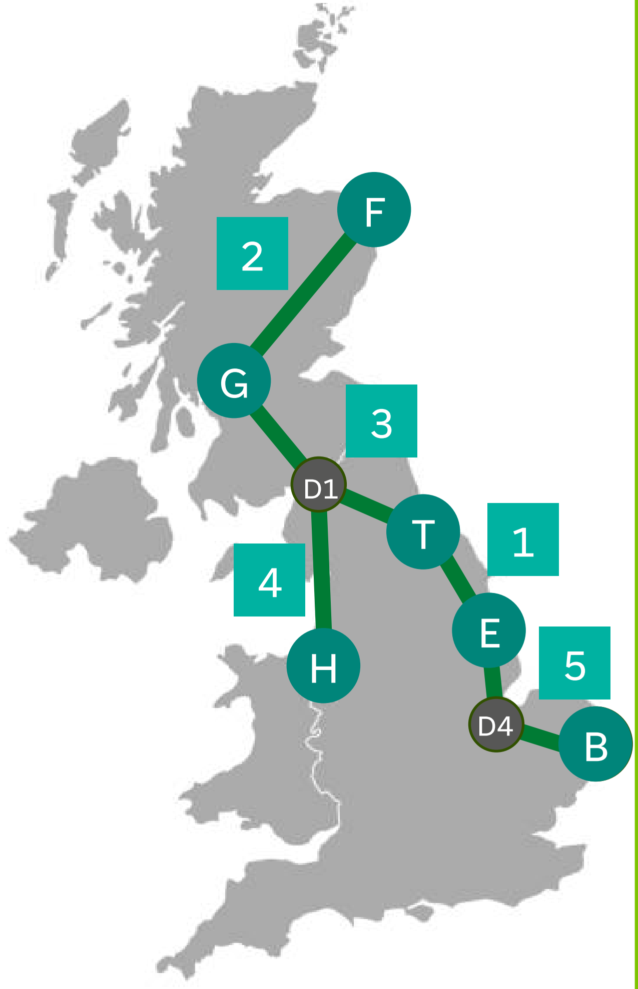
Lean Backbone Configuration

- In addition to the analysis of the full backbone, the analysis looked at a lean backbone configuration for comparison. The lean backbone omitted certain legs to test the impact on financial metrics.
- For the lean model, legs 5, 6, and 7 were removed. This creates a configuration in which no hydrogen pipeline connection is made to W, S and SE.
- The selected legs for the lean backbone align with areas where FEED funding and advanced development are already progressing, ensuring consistency with ongoing investment and reducing delivery risk.
- The selected legs also cover regions with the highest projected hydrogen demand and established industrial clusters, enabling early impact and strong utilisation of the backbone.

Full Backbone

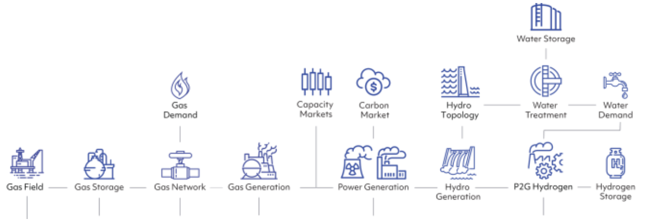


Lean Backbone



PLEXOS Model Overview

PLEXOS is widely recognised as the **most accurate and reliable whole system energy market modelling** software in Europe and the UK.



PLEXOS is also used in the UK by....

NESO National Energy System Operator ofgem nationalgrid

and many others...

Category	Description	Benefits

High temporal granularity	• Higher temporal granularity:
	  • Higher level of sampled days in the capacity expansion
	  • Hourly resolution in the dispatch model
		• Ensures generation, storage, and transmission capacity built out in capacity expansion are in line with system needs
		• Provides more detail insights into operational outputs

Detailed operational characteristics	• Higher level of operational characteristics included to more accurately represent the energy system	• Greater pipeline modelling accuracy and insights (flow rates, linepack, and utilisation) • Greater representation of gas and hydrogen storage (injection and withdrawal rates), and role of pipeline in supporting energy system flexibility.

Dispatch modelling	• Medium-term and short-term modelling (dispatch modelling):
	  • Hourly modelling of the system
	  • Allows modelling higher level of granularity of operational parameters
		• Ensures capacity build out in the capacity expansion is sufficient for the hourly dispatch of the system
		• Provides more detailed operational outputs (generation, hourly prices, etc.)

Automated sampled days technique	• Automated selection of sampled days using built-in customisable algorithms in PLEXOS	• Automated sampling allows for sample days to be selected based on different input parameters (e.g., load, RES profiles) & to be easily tested to ensure the sampled days are adequately representative

<u>**Resulting in...**</u>

Accurate outputs that can be directly used by NGT for hydrogen infrastructure planning and regulatory submission

Greater credibility in engagement with Ofgem, NESO (who use PLEXOS) and other external stakeholders

PLEXOS Model Overview

Overall Approach

- This study uses Energy Exemplar's PLEXOS model to simulate the decarbonisation, expansion, and hourly optimisation of the electricity and gas system from 2035 to 2050.
- The model is configured to a geographical scope made up of Great Britain and its sub-regions, and its neighbouring regions i.e. Northern Ireland/Ireland and a simplified version of the remainder of Europe, modelling an integrated electricity and hydrogen system.
- PLEXOS has been adapted to the characteristics of Great Britain's gas and electricity system and optimises across electricity and hydrogen supply and transmission infrastructure.
- The analysis models different scenarios of how electricity and gas supply and infrastructure can meet energy demand. This includes identifying what investments in electricity and hydrogen supply capacity and infrastructure are required, where and when those investments will be needed.
- Methane as an energy carrier is not being modelled, pipeline repurposing costs and considerations are provided exogenously by NGT.

Modelling Configuration

- **Geographic Scope**: 2 Scottish sub-regions + 6 English sub-regions + 1 Welsh sub-region + 2 neighbouring regions (including simplified remainder of Europe).
- **Energy carriers**: Electricity and hydrogen
- **Simulation timeframe**: 2030 (base), 2035, 2040, 2045 & 2050
- **Intra-annual temporal resolution**: 1 week per month for the capacity expansion & 8760 hours for the dispatch

Integrated Energy System Modelling

- PLEXOS is an integrated capacity expansion and dispatch optimisation model used to identify the lowest-cost pathway to a decarbonised energy system.
- The analysis *solves* the expansion and decarbonisation of the electricity and hydrogen system by investing in new supply and transmissions infrastructure over time (e.g., onshore wind, offshore wind, solar, electrolysers, hydrogen pipeline, transmission lines, etc.).
- As a "whole of system" model, the cross-sector energy conversion interactions between electricity and hydrogen are an integral part of the analysis (e.g., electrolysers driving increased electricity demand, hydrogen gas turbines driving increased hydrogen demand)
- The analysis also models the use of transmission interconnections across regions (e.g., power lines and pipelines) and storage assets (e.g., gas and electricity storage) to balance supply and demand.
- The analysis's nodal configuration – whether sub-regions within the core geographical scope or with neighbouring regions – defines whether electricity and gas interconnections exist across regions.
- Each node is treated as a "copper plate" of demand and supply meaning there is no sub-nodal granularity of transmission or distribution infrastructure behind each node. In other words, the analysis focuses on the interaction of supply and transmission infrastructure *across* nodes and not *within* nodes.

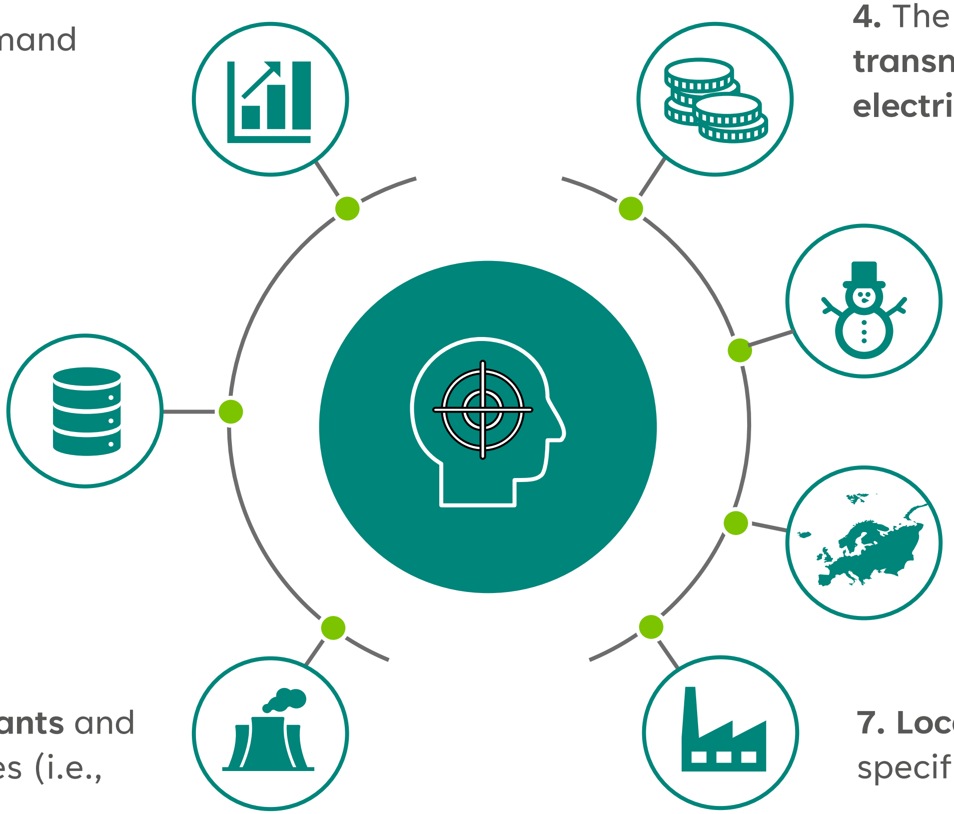
Key parameters for the PLEXOS Model

Several key parameters for the PLEXOS model have been summarised below, with further detail in the following slides for how certain parameters have been approached in the model.

1. The **volume of future hydrogen demand** across Great Britain

2. The **location of underground hydrogen storage** in Great Britain

3. The **location of hydrogen power plants** and the capacity of other flexibility sources (i.e., power CCUS, biomass and nuclear)



4. The **costs of** both electricity and hydrogen **transmission assets** and **physical constraint on electricity transmission network buildout**

5. The conceptual definition of the **winter & summer peak periods**

6. Interconnectivity with continental Europe and volume of hydrogen demand in neighbouring markets

7. Location of hydrogen production and specifically the blue hydrogen clusters

Underground Hydrogen Storage Location

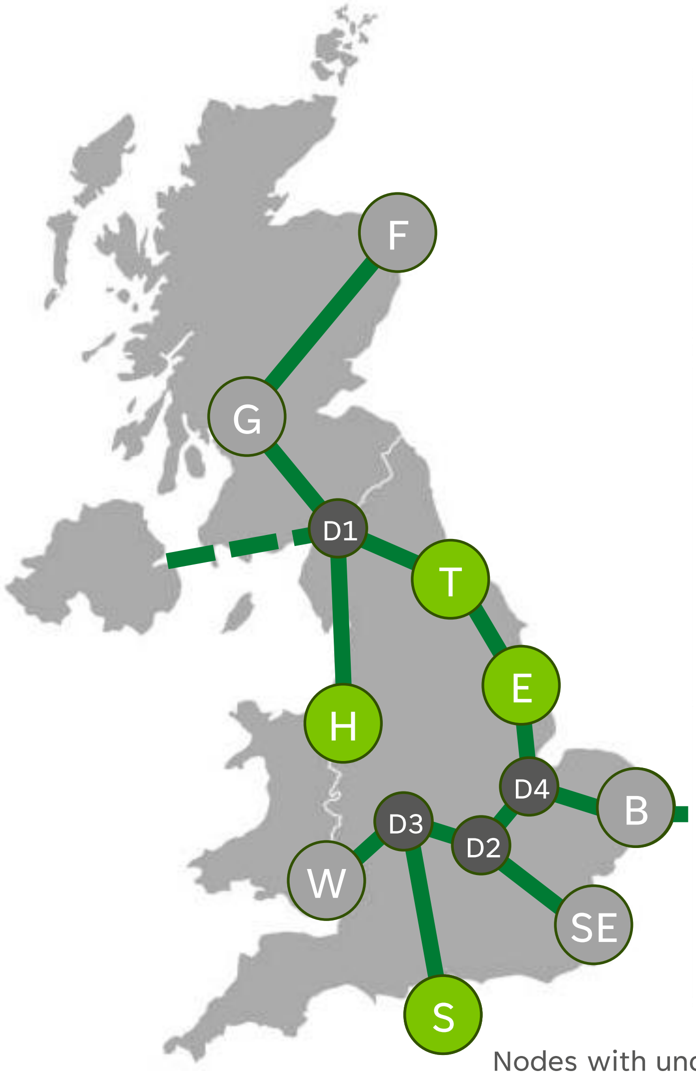
The location of underground hydrogen storage in Great Britain is based on known geological location

Gas storage potential is concentrated in a few regions across Great Britain

While other form of gas storage facilities exist (i.e., aquifers, above ground, depleted O&G fields) salt cavern provide both scale and high cycling rates.

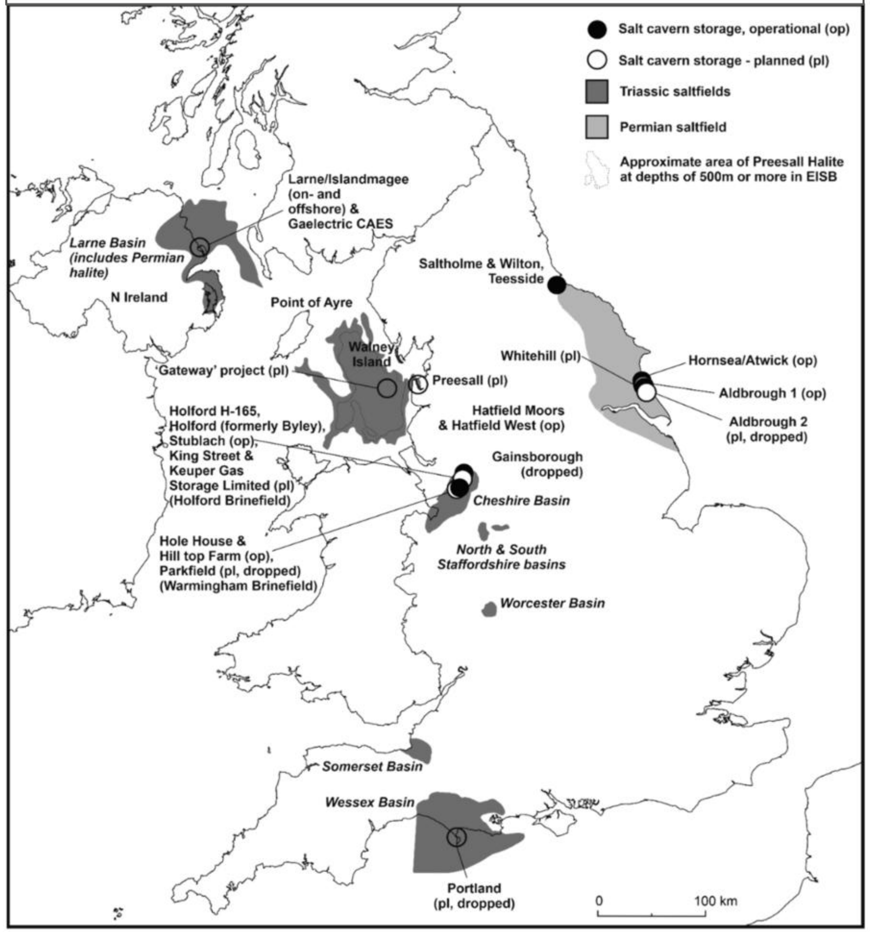
All existing onshore gas storage facilities are located in the North East and North West of England, particularly around the Cheshire Basin.

We consider that future hydrogen storage facility will most likely be developed around known salt fields. This includes Cheshire, the North East and the Wessex Bassin. As such, we expect hydrogen storage capacity in the H, E, T and S nodes.



Nodes with underground hydrogen storage enabled:

The potential for underground gas storage in salt caverns in the UK



British Geological Survey, Link

Hydrogen Power Plants

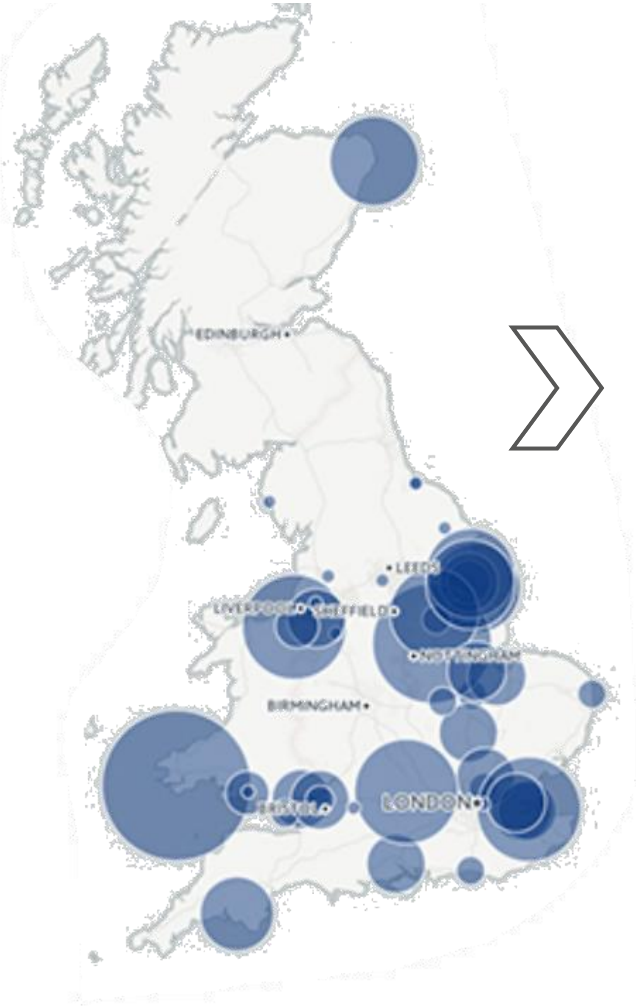
The location of hydrogen power plants is estimated based on the current nat. gas power plant distribution

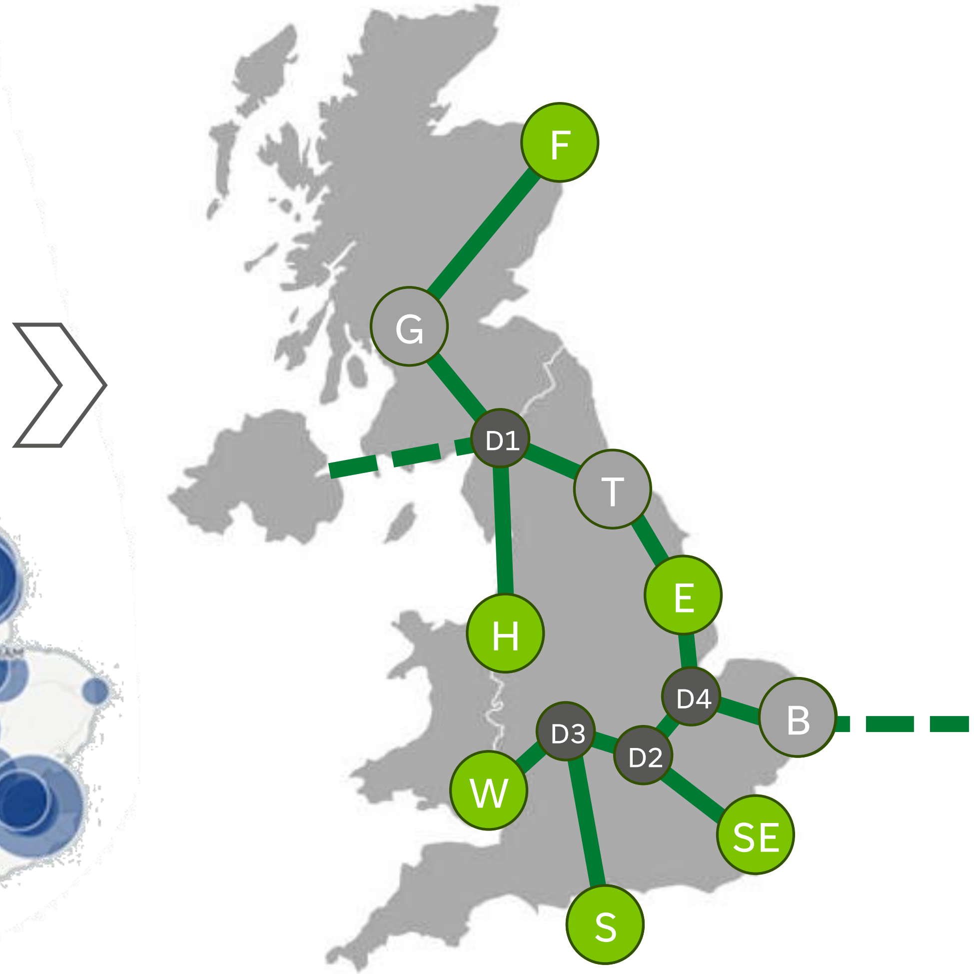
Hydrogen power plants are unlikely to be developed greenfield.

Instead, they are likely going to be located where existing natural fired generation plants are located

As such, hydrogen power plants are allowed in regions which currently host natural gas power plants.

This includes all regions except the Grangemouth, Teesside and Bacton.





Nodes with hydrogen for power generation enabled:

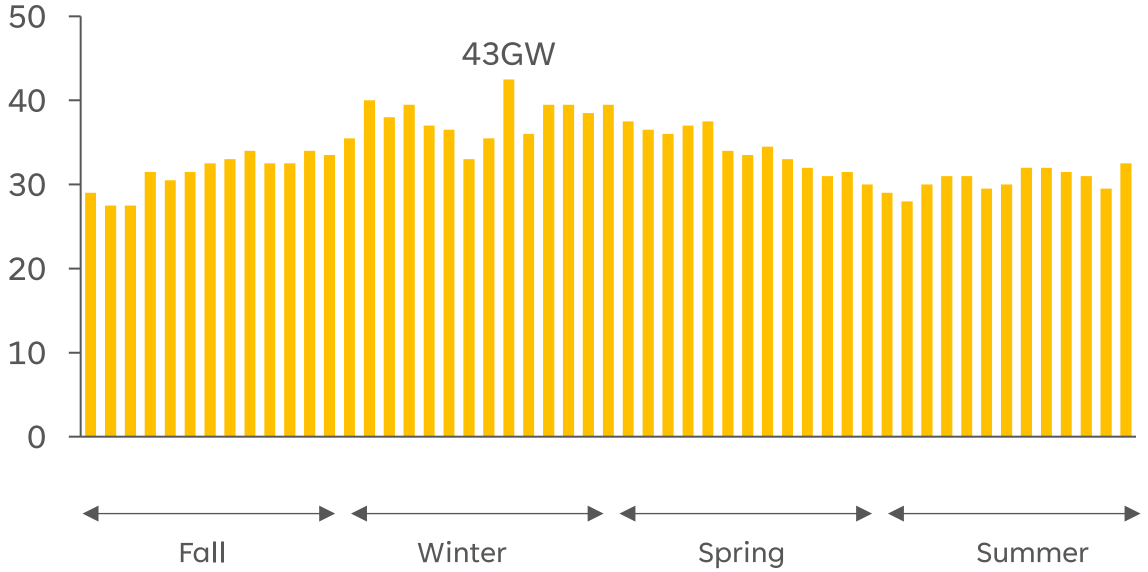
Peak Demand

Today, energy peak demand is driven by winter residential heat - it will likely remain so in the future

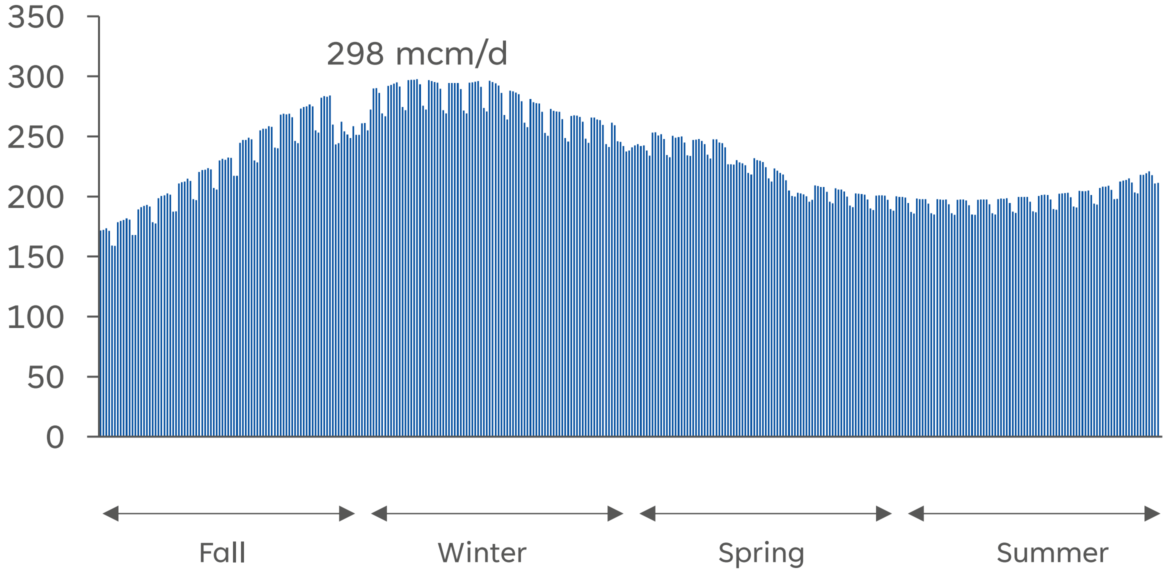
Energy peak demand in Great Britain is today driven by residential heat demand, more likely to happen during winter months. This is very likely to remain the case in the future despite an increase in cooling-related energy demand during summer months.

Peak power and gas demand is and will likely remain in winter.

Weekly electricity peak demand in GB in 2024, GW*



Daily natural gas demand in GB in 2024, mcm/d*



***Note:** The following is not used for modelling and serves only illustrative purposes. Source: OFGEM

Location of hydrogen production

We include blue hydrogen projects with relatively higher likelihood to realisation, recognising uncertainty

While production of green hydrogen is optimised through the model, blue hydrogen capacity location is defined as an input assumption

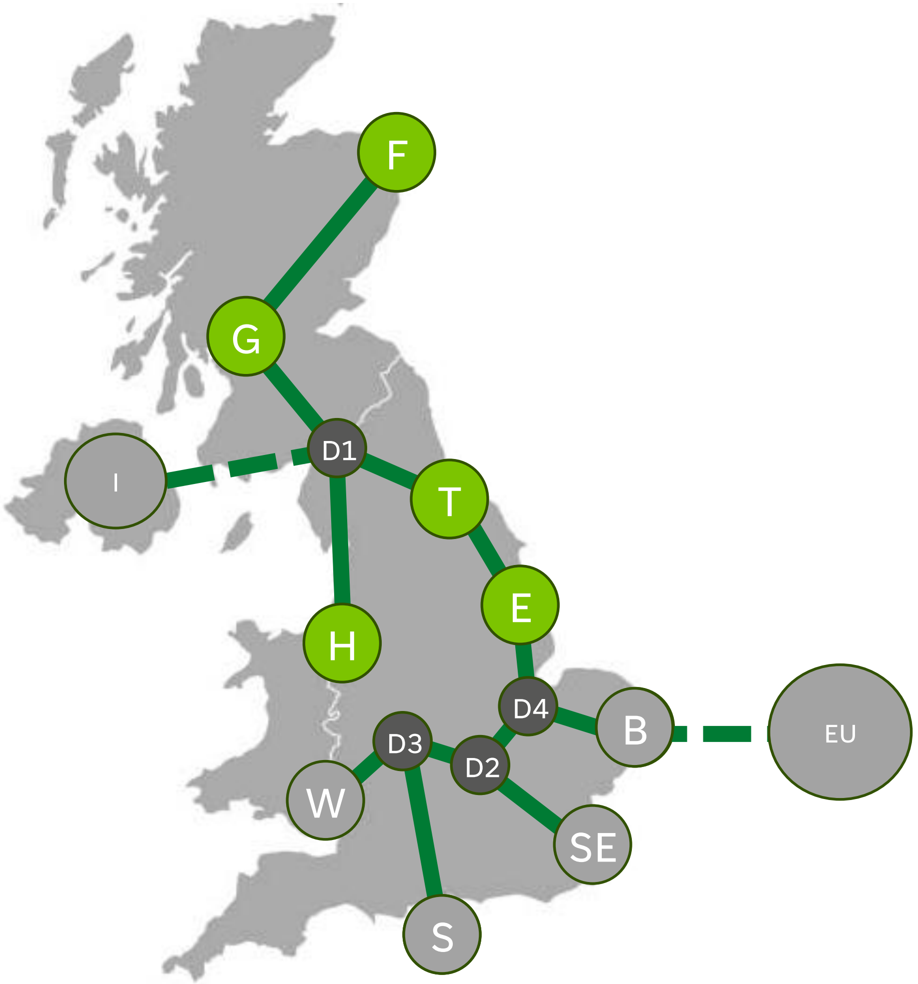
Blue hydrogen supply location is defined as an assumptions due to inherent infrastructure constraints needed for carbon capture & storage, and the inherent uncertainty of CCS technology.

We decided to include all blue hydrogen projects currently in FEED or construction in the UK. This represent 10 projects according to Hydrogen UK.

Most projects are located in:

- **Teesside:** H2Teesside (1,200 MW), H2NorthEast (1,065 MW), and Teesside Hydrogen (150 MW).
- **Humber:** Humber Saltend (1,800 MW), Humber Hydrogen Hub (800 MW), and Humber H2ub (720 MW).
- **HyNet:** HyNet Hydrogen HPP1 (combined capacity of 4,000 MW).

Additional contributions come from Scotland with project Acorn Hydrogen phase 1 in St Fergus (200 MW) and INEOS Grangemouth Hydrogen (600 MW).

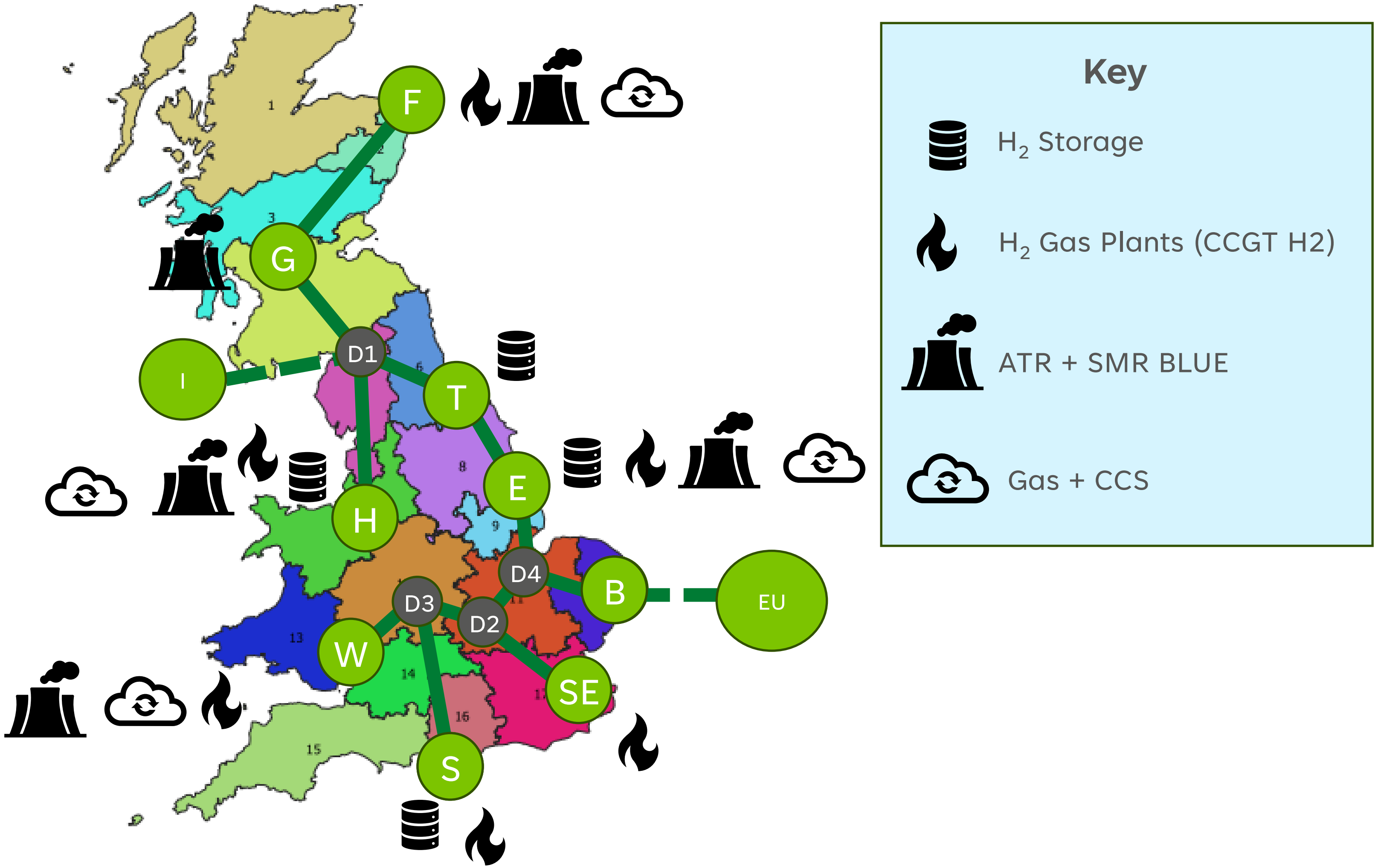


PLEXOS Model Configuration

The location of nodes & assets for the PLEXOS Model reflects real world infrastructure and expectations

The location of assets in the PLEXOS model have been informed by real world infrastructure and expectations

Under the PLEXOS model capacity expansion, the location of these assets provide the model with the boundaries within which to optimise the solution.



Scenario Development and Regionalisation

national gas transmission

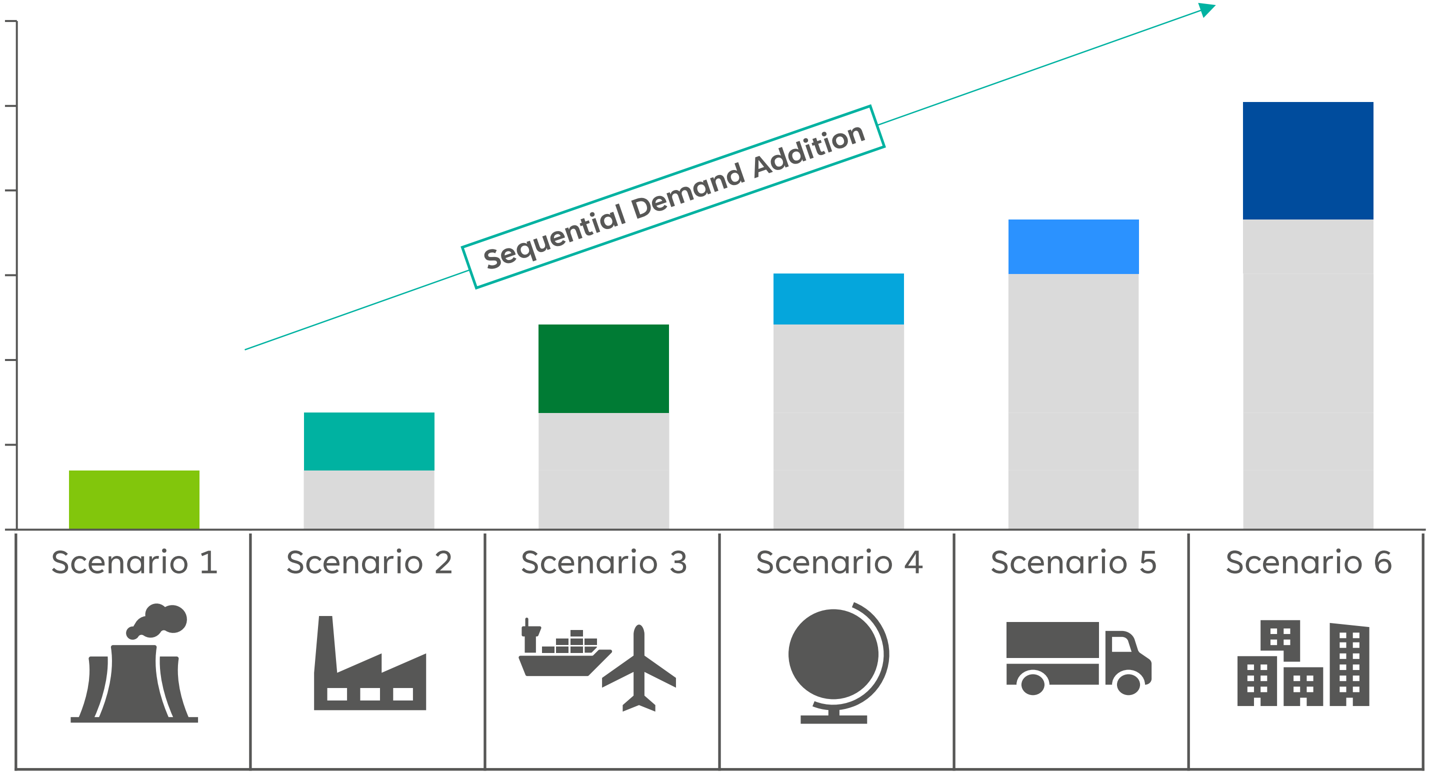
H_2 Demand Scenarios Overview

- To create future hydrogen demand scenarios, we use a **layered approach that builds cumulative demand across sectors** from 2030 to 2050. Each of the six scenarios begins with **power generation as the base case**, reflecting its fundamental role in the future energy system.
- To build up the other scenarios, we **sequentially add demand** from other sectors.

Scenarios

1. Power Generation
2. Industrial & Commercial (I&C)
3. Aviation & Shipping (A&S)
4. Exports
5. Road Transport
6. Residential Heating

Cumulative 2050 H2 demand in GB, TWh



H_2 Demand - Scenario 1 Power Generation

Scenario 1 establishes the foundational hydrogen demand for power generation developed by the PLEXOS modelling

Scenarios

1 **Power Generation**

2 Industrial & Commercial (I&C)

3 Aviation & Shipping (A&S)

4 Exports

5 Road Transport

6 Residential Heating

Drivers and Rationale

- Hydrogen plays a key role in providing electricity generation capacity to support grid stability. In the model horizon, hydrogen supports the UK's peak electricity demand at times of low renewables generation.
- Hydrogen for power generation as first scenario given the high likelihood of hydrogen for power generation.

Regional Implications

- Hydrogen power plants are unlikely to be developed greenfield. They will likely be **located where existing natural fired generation plants are located.**
- In the model, hydrogen power plants can be developed across **all nodes except Grangemouth, Teesside and Bacton.**

Backbone Impact

- Hydrogen for power generation provides a base hydrogen demand for the support of the backbone investment case.
- The PLEXOS modelling highlights power generation demand at times of peak electricity demand.

H_2 Demand - Scenario 2 Industrial & Commercial

Scenario 2 adds hydrogen demand from industrial and commercial sectors, creating strong regional hubs in industrial clusters and driving significant emissions reduction

Scenarios

1 Power Generation

2 **Industrial & Commercial (I&C)**

3 Aviation & Shipping (A&S)

4 Exports

5 Road Transport

6 Residential Heating

Drivers and Rationale

- **Industrial customers represent a high likelihood customer for hydrogen**, with industrial clusters ready for hydrogen adoption. For industries in hard-to-abate sectors, hydrogen offers a path for emissions reduction.
- NESO's **Holistic Transition & Hydrogen Evolution Future Energy Scenarios support early industrial decarbonization with hydrogen.**

Regional Implications

- For industrial and commercial demand, the **key focus is on industrial clusters**: Teesside, Humber, Merseyside.
- Industrial clusters create strong localized demand hubs.

Backbone Impact

- Focus of industrial demand within the central nodes of the backbone, with more limited demand spread across the southern nodes of the backbone.

H_2 Demand - Scenario 3 Aviation & Shipping

Scenario 3 introduces hydrogen demand for e-fuels in aviation and shipping, expanding demand towards coastal and airport regions in line with FES 2025 assumptions

Scenarios

1 Power Generation

2 Industrial & Commercial (I&C)

3 **Aviation & Shipping (A&S)**

4 Exports

5 Road Transport

6 Residential Heating

Drivers and Rationale

- Aviation and Shipping hydrogen demand uptake driven by international decarbonization pressures, with a strategic importance for hard-to-abate sectors.
- Across all of NESO's Future Energy Scenarios assumptions are made for e-fuels in aviation and shipping.

Regional Implications

- Aviation demand is largely concentrated among the ammonia production plants, which are **Stanlow Energy Hub, Teesside SAF cluster and East Coast**.
- Shipping demand is distributed across five main ports and their corresponding nodes – **Teesside, Immingham (East Coast), Felixstowe (South-East) and Milford Haven (Wales).**

Backbone Impact

- Hydrogen demand for aviation and shipping is concentrated predominantly on the East Cost at nodes T&E.

H_2 Demand - Scenario 4 Exports

Scenario 4 incorporates hydrogen exports (and imports) to Ireland and continental Europe, positioning the UK as a strategic energy supplier and requiring links from Bacton and Scotland

Scenarios

1 Power Generation

2 Industrial & Commercial (I&C)

3 Aviation & Shipping (A&S)

4 Exports

5 Road Transport

6 Residential Heating

Drivers and Rationale

- European demand could to position the UK with a strategic energy role to operate as a hydrogen exporter to continental Europe.
- The UK is expected to be a net importer from Ireland given Irish Government targets to develop offshore wind.

Regional Implications

- Hydrogen flows are modelled through interconnectors connecting **Bacton to Continental Europe**, and **Scotland to Northern Ireland.**
- European hydrogen demand has an impact on the southern nodes of the backbone, where significant hydrogen demand across the UK-Europe interconnector.

Backbone Impact

- Interconnection to Europe increases the backbone's strategic importance for trade.

H_2 Demand - Scenario 5 Road Transport

Scenario 5 includes hydrogen demand for heavy-duty road transport, introducing dispersed demand

Scenarios

1 Power Generation

2 Industrial & Commercial (I&C)

3 Aviation & Shipping (A&S)

4 Exports

5 Road Transport

6 Residential Heating

Drivers and Rationale

- Hydrogen demand for heavy-duty transport identified as a possible future hydrogen use case.
- NESO's **Hydrogen Evolution Future Energy Scenario** supports hydrogen for freight decarbonization.

Regional Implications

- Hydrogen demand for road transport spread relatively evenly with some additional demand in high demand freight regions.

Backbone Impact

- Dispersed nature of hydrogen demand for road transport brings additional flows across a range of nodes.

H_2 Demand - Scenario 6 Residential Heating

Scenario 6 completes the stack of hydrogen demand by adding hydrogen for residential heating, requiring highest level of hydrogen backbone flows

Scenarios

1 Power Generation

2 Industrial & Commercial (I&C)

3 Aviation & Shipping (A&S)

4 Exports

5 Road Transport

6 **Residential Heating**

Drivers and Rationale

- Hydrogen for heating in the UK will be driven by policy ambition for whole-system decarbonization, but it is the aspect of demand that represents the highest uncertainty.
- NESO's **Hydrogen Evolution Future Energy Scenario** includes hydrogen for heating in some homes.

Regional Implications

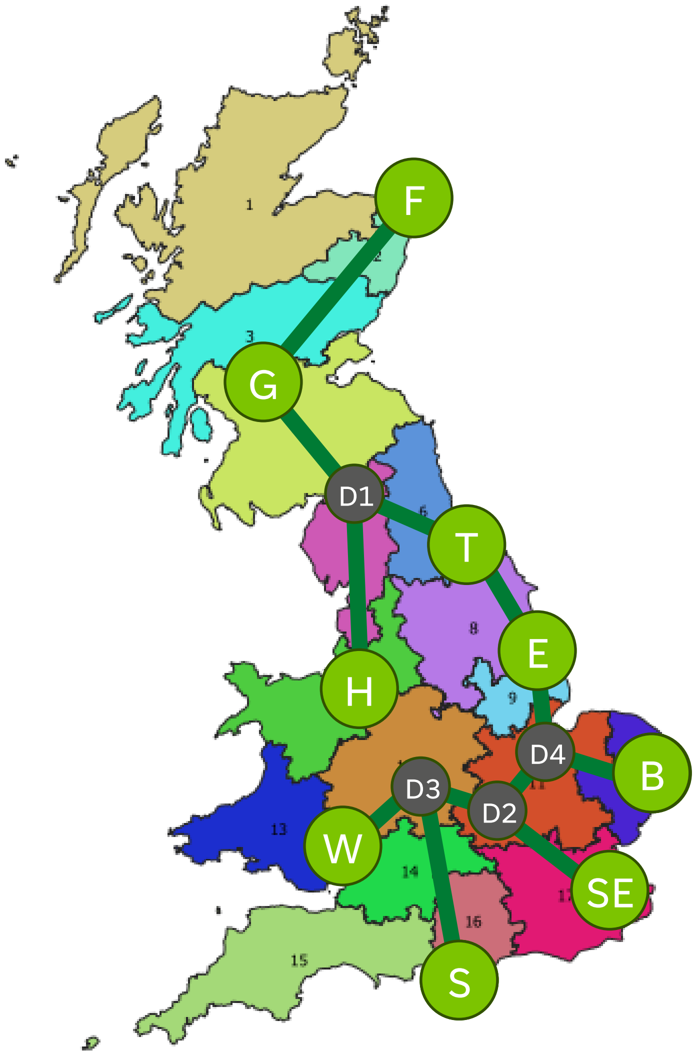
- Hydrogen demand for residential heating driven by customer density, with concentration of demand in the South East and Manchester region.

Backbone Impact

- Focus of residential heading across densely populated nodes brings additional demand to certain legs of the backbone.

Regionalisation – Electricity Demand

Demand is regionalised using NESO's economic zone framework focusing on entry and exit points



NESO's 17-zone framework is applied to structure the model's electricity transmission, ensuring alignment and consistency with national network planning. Transmission boundaries follow ETYS Critical Boundaries, which provide a realistic representation of flow constraints. Within this framework, hydrogen backbone nodes are placed in the relevant electricity zones to align closely with industrial cluster demand. PtX assets are located to connect the Hydrogen and Electricity carriers.

Zones & Nodes	Assumptions
• Zone 2 – St. Fergus (F) • Zone 4 – Grangemouth (G) • Zone 6 – Teesside (T) • Zone 8 – East Coast (E) • Zone 12 – Bacton (B) • Zone 17 – Southeast (SE) • Zone 16 – South/Southampton (S) • Zone 13 – South Wales (W) • Zone 7 – Manchester/Hynet (H)	• Remaining zones: local supply meets local demand • Not capturing 100% of GB Hydrogen demand unless more entry/exit points are added • ETYS Critical Boundaries define transmission constraints

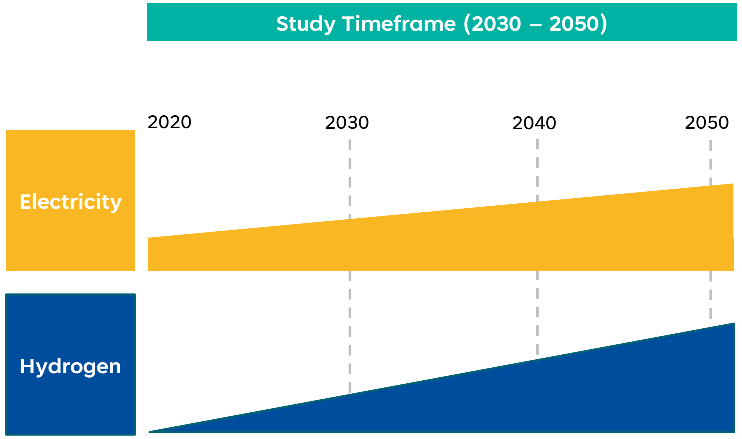
Regionalisation - Demand & Supply

The approach to scenario development accounts for both hydrogen and electricity demand & supply

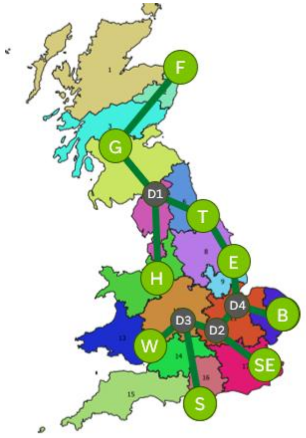
Energy Demand

The modelling disaggregated hydrogen and electricity demand from the six custom scenarios across each of the UK's 9 regions.

- **Hydrogen**: The model uses data for a sector-specific approach, using FES and other secondary resources, to disaggregate hydrogen demand across regions.
- **Electricity:** The model uses a regional distribution of electricity demand using GSP-level FES results and apply the distribution to the total electricity demand across six custom scenarios



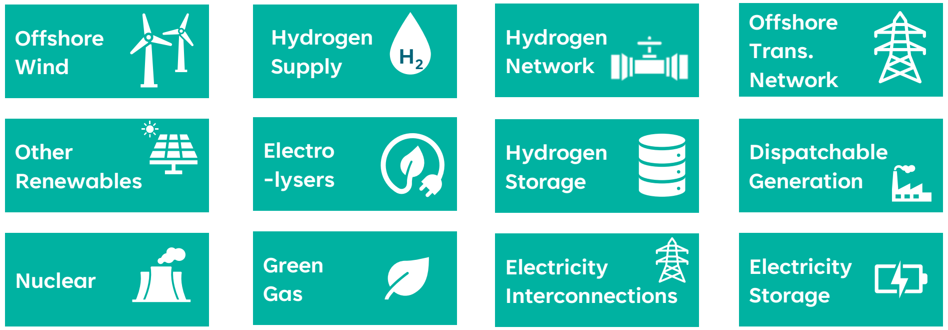
17 zones – 9 regions



1. GSP = Grid Supply Point.

Energy Supply and Infrastructure

- Energy supply resources and infrastructure options include electricity and gas supply resources like offshore and onshore wind, solar, nuclear, or electrolysers, as well as infrastructure options like on/offshore hydrogen and electricity transmission infrastructure.
- In some cases, the approach is to align with assumptions from the FES and, thus, adopt exogenous inputs into the analysis. While for others, the approach is to remain agnostic and endogenously model technologies / options / decisions.



Hydrogen Demand Regionalisation (1/2)

AVIATION & SHIPPING

Aviation: regionalisation using the ammonia production cluster demand data from UK SAF Industry Report - Department for Transport and documentation of respective facilities.

Shipping: regionalisation using the data on the ports with highest number of industrial bases (UKRI) and vessel traffic volumes.

General Approach

Region's share of H2 for Aviation & Shipping (%)

✖

Aviation & Shipping demand by scenario (TWh)

Sources

- **Shipping:** Historical Freight tonnage traffic. Department for Transport, (2024), industries & refineries - UKRI
- **Aviation:** UK SAF Industry Report - Department for Transport (2023).
- **Hydrogen Demand:** Results from FES 2025 scenarios (common across 3)

INDUSTRY & COMMERCIAL

Regionalisation using the cluster demand data from the CCC UK industry report up to the total demand outlined in the report (73.3 TWh)

For FES scenario with higher 2050 H2 demand than the one outlined in the report, the remaining demand is distributed evenly across all regions.

General Approach

Region's share of H2 for I&C (%)

✖

I&C H2 demand by scenario (TWh)

Sources

- **H2 demand shares:** Element Energy, Net Zero Industrial Pathways (NZIP) model (Balanced Scenario)
- **Hydrogen Demand:** Results from FES 2025 Holistic Transition scenario

Hydrogen Demand Regionalisation (2/2)

ROAD TRANSPORT

Regionalisation based on DfT historical statistics on licensed vehicles.

General Approach

Region's share of H2 for road transport (%)

×

Road transport H2 demand by scenario (TWh)

Sources

- **Road transport**: Historical Vehicle Licensing Statistics. Department for Transport, (2024).
- **Hydrogen Demand**: Results from FES 2025 Hydrogen Evolution scenario

HEATING

Regionalisation based on heating equipment stock forecasts from the FES Regional Heating Model (with results available at the Local Authority level) aggregated up to individual regions.

General Approach

Region's share of H2 for heating equipment (%)

×

Building H2 demand by scenario (TWh)

Sources

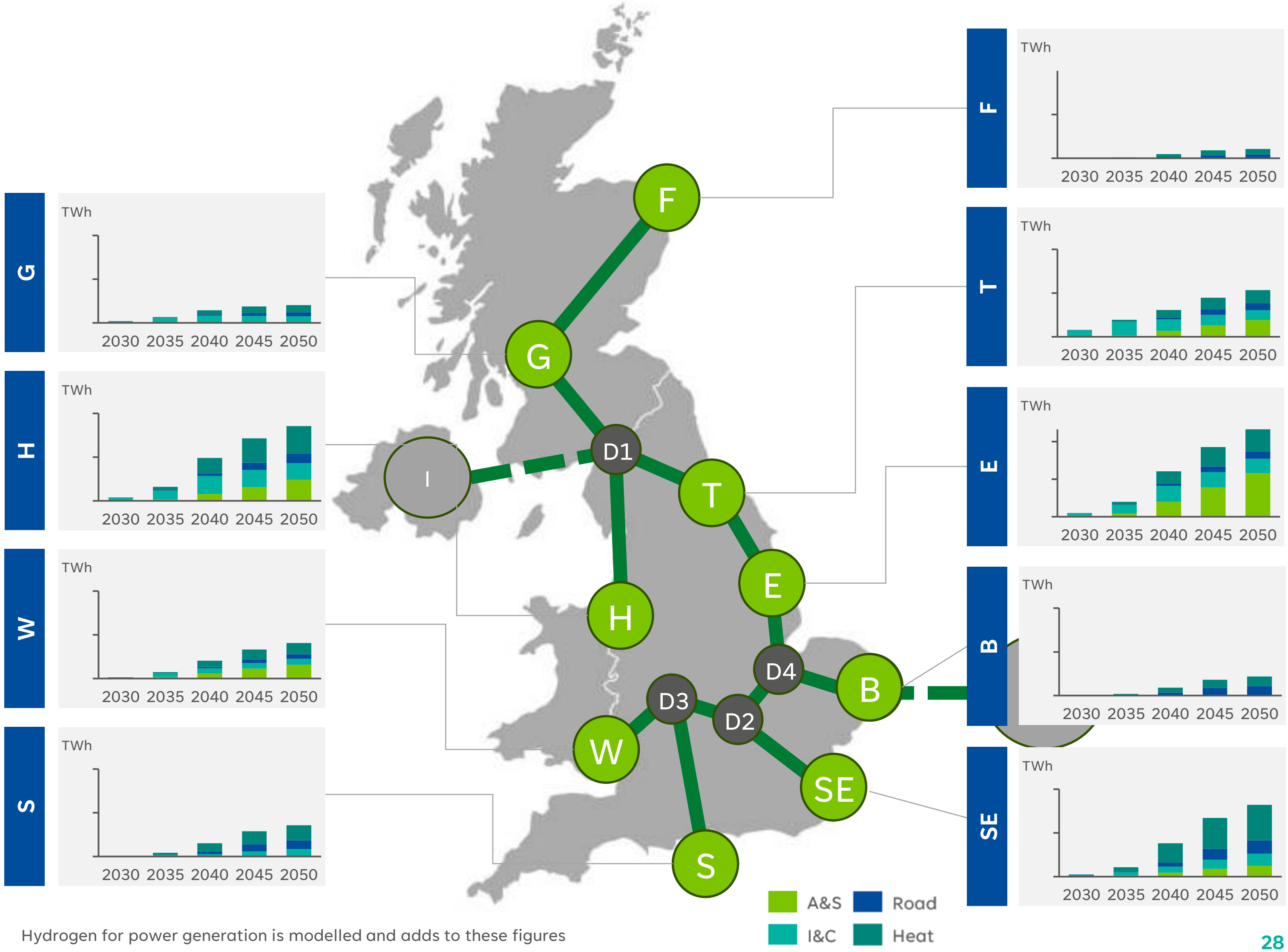
- **H2 equipment shares**: FES Regional Heating Model (2021)
- **Hydrogen Demand**: Results from FES 2025 Hydrogen Evolution scenario

Hydrogen demand by region 2030-2050

Hydrogen Demand

- **Hydrogen for buildings (heating) accounts for the largest share of demand** compared to other demand sectors.
- The **East Coast, HyNet and Southeast nodes** have the largest shares of hydrogen demand across all regions due to industrial clusters, ammonia production plants as well as large ports.
- **The St. Fergus and Bacton nodes have the lowest hydrogen figures** due to a low industrial and transport sector demand.

Note: The hydrogen demand figures only represent end-use, customer demand. Hydrogen for power generation is endogenously modelled and adds to these figures



Hydrogen for power generation is modelled and adds to these figures

Financial Model Methodology & Findings

Hydrogen Backbone Economic Assessment

Simplified representation of Project Union

WHY Study the Hydrogen Backbone	**National Gas needs to establish a strong economic justification for its future network expansion**, focusing on cost reduction opportunities and prioritisation. This is particularly important in anticipation of future regulatory funding request to Ofgem and as NESO develops future gas network planning capabilities.
WHAT The financial analysis aims to achieve	• **Understand the economic case of the full backbone and lean backbone**, as well as each of the main legs which constitutes it the backbone, under various scenarios. • **Evaluate future tariffs needed for each leg of the hydrogen backbone** to be profitable, as well as wider GVA benefits.

How we took a three-step modelling approach to deliver analysis aims:

Full Backbone Analysis

The full backbone analysis establishes the upper bound of infrastructure investment and demonstrates conditions under which the entire network becomes viable.

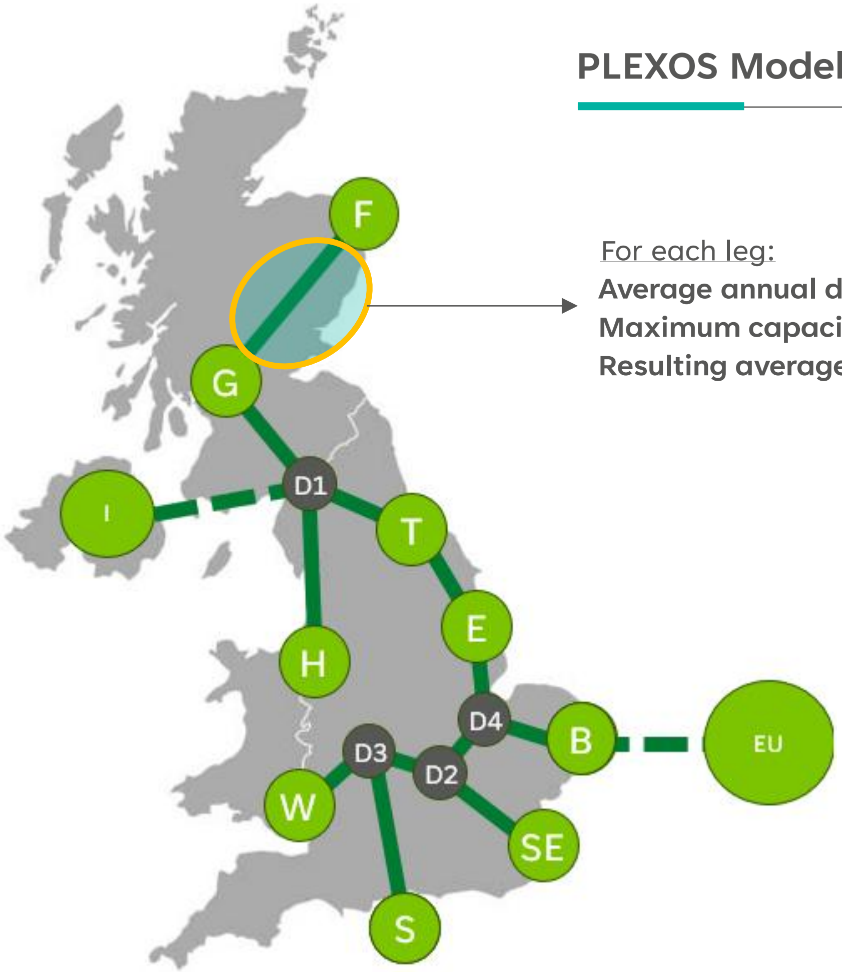
Granular Leg Analysis

The granular leg analysis aims to determine the legs to deliver the highest economic performance. The lean backbone is essentially a subset of the full backbone, optimised for cost-effectiveness.

Lean Backbone Analysis

The lean backbone aims to assess whether a smaller network can deliver most strategic benefits with strong economic performance while identifying the minimum infrastructure and tariff structures needed for positive NPV under realistic scenarios.

The methodology evaluates the financial performance of the backbone legs under multiple scenarios



PLEXOS Modelling

For each leg:
Average annual daily volume
Maximum capacity booking
Resulting average utilisation

Financial assessment

Direct financials:

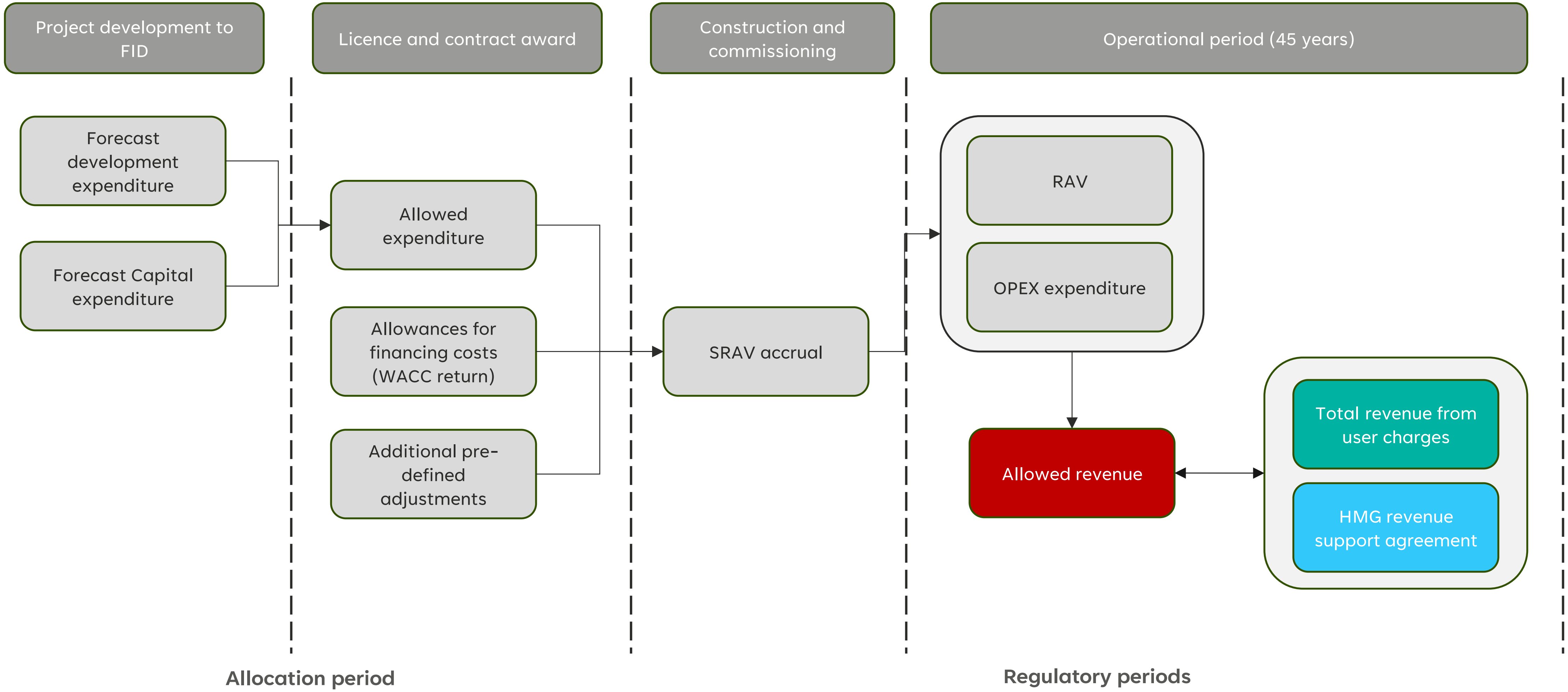
- PLEXOS results on pipeline flow have been translated to financial metrics in line with the current natural gas regime tariff charging methodology.
- For simplicity, we have assumed charges are done on volume flows per annum (instead of capacity and commodity charging).

Estimate gross value add:

- Assesses wider societal benefits like a reduction in system balancing costs and jobs creation.
- Assesses emission valuation
- The GVA benefits are used for a qualitative assessment of the value for money of the hydrogen backbone.

RAV financial model approach

The analysis is aligned with the latest Hydrogen Transport Business Model thinking, feeding in key Project Union specifics such as reopener funding for the first three legs of the backbone.



*A **revenue gap** is total allowed revenue minus total actual revenue over the life of a project. **This assumes that actual revenue above allowed revenue can be claimed by NG.***

Economic assessment parameters and sensitivities

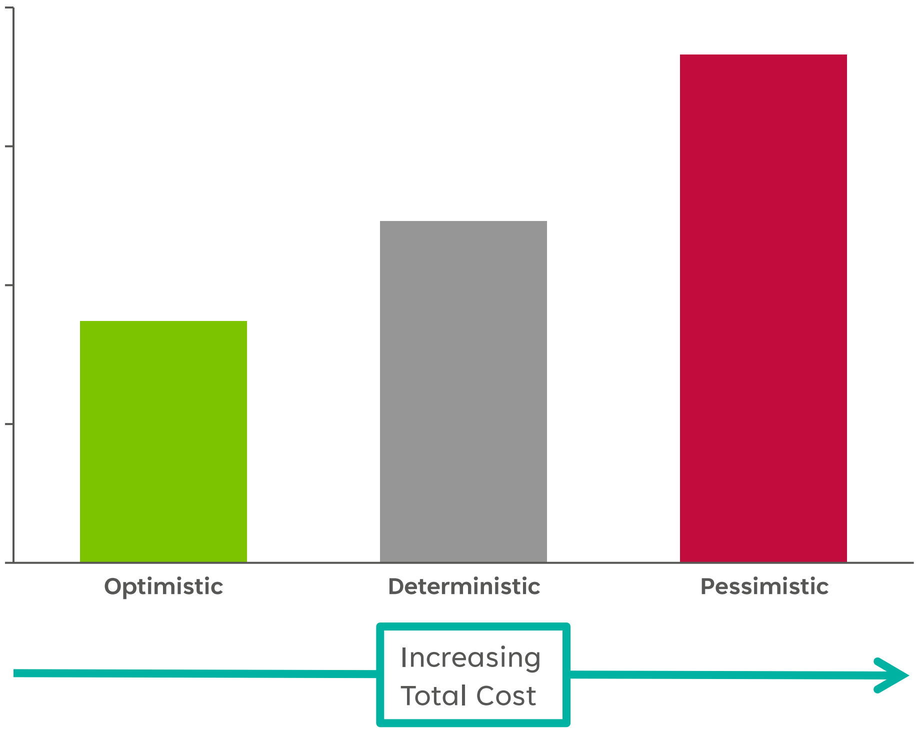
The assessment tested the economic case of the hydrogen backbone across six cumulative scenarios…

Increasing Hydrogen Demand

1. Power Generation
2. Industrial & Commercial (I&C)
3. Aviation & Shipping (A&S)
4. Exports
5. Road Transport
6. Residential Heating

And three scenarios of total costs (TOTEX) for the hydrogen backbone development…

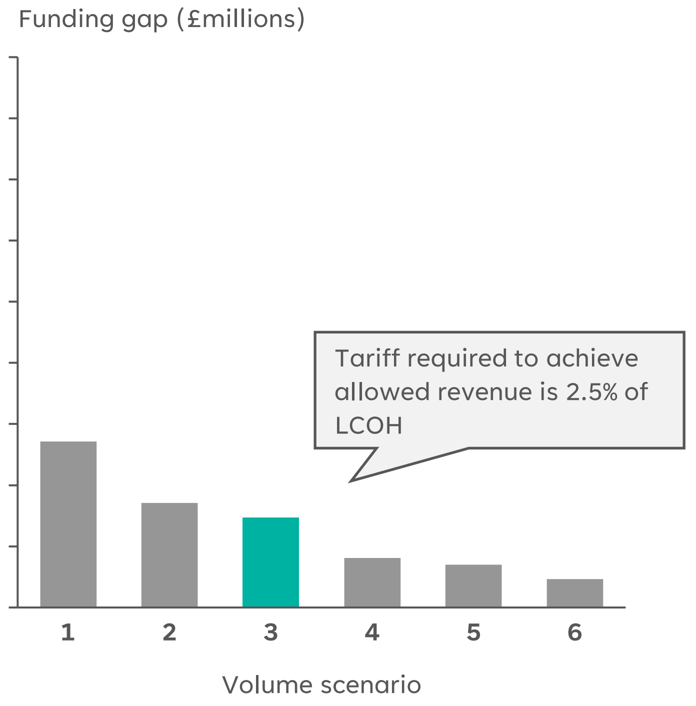
TOTEX estimates



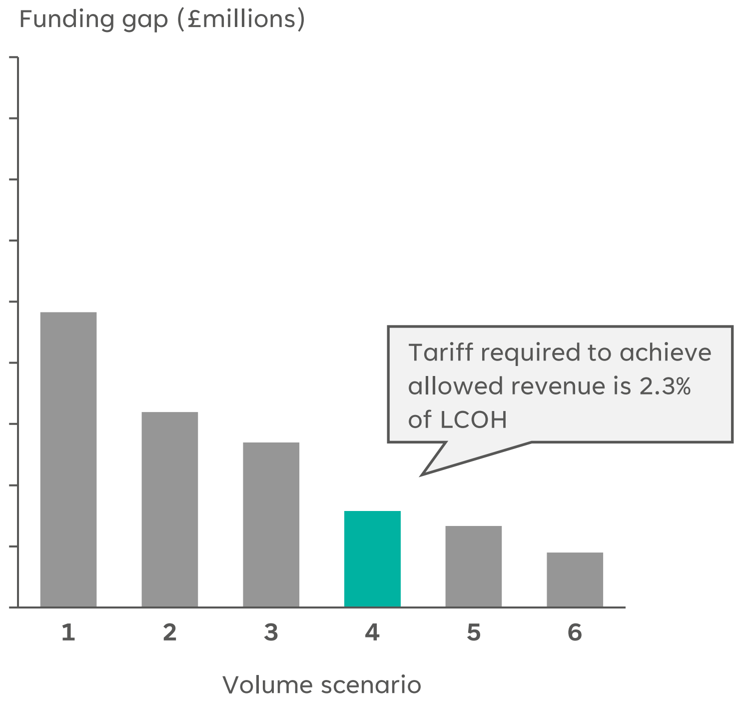
Funding gap

I&C, export and domestic heating hydrogen demand represents key step-changes in strengthening the commercial case for developing the full hydrogen backbone. Scenario 4, where export volume is added to I&C, Power, and Aviation & Shipping demand is a key tipping point where customers may be able to absorb tariffs that recover allowed revenue without the need for substantial government support.

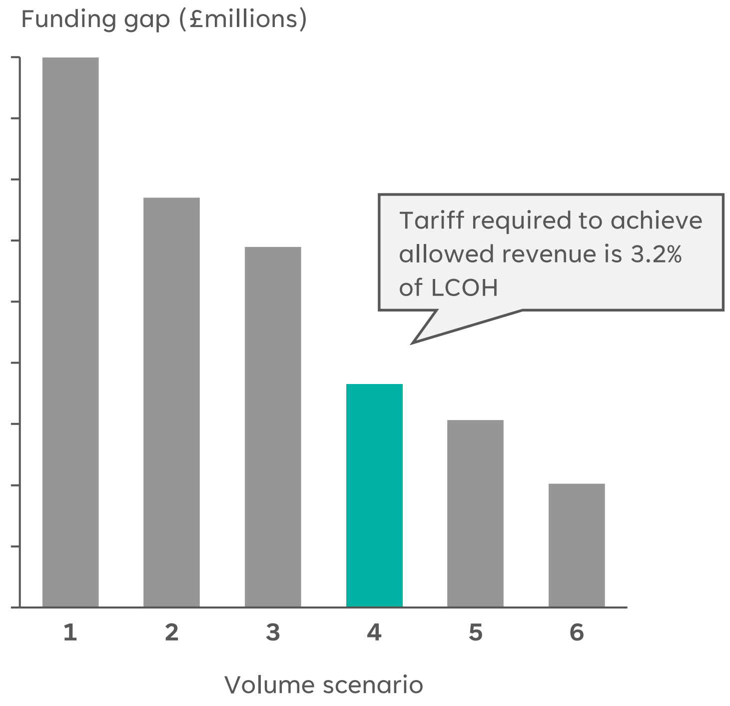
Optimistic Case



Deterministic Case



Pessimistic Case

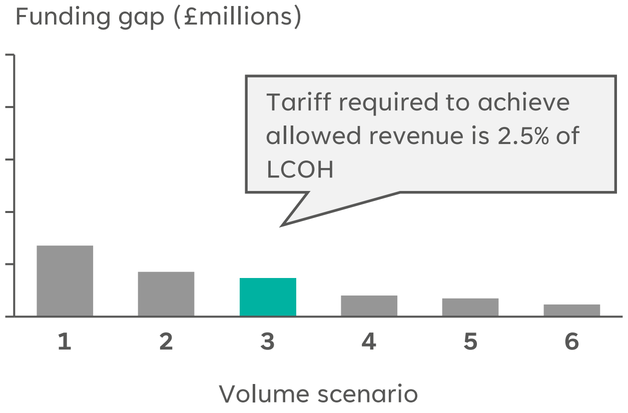


Lean vs Full backbone | funding gap

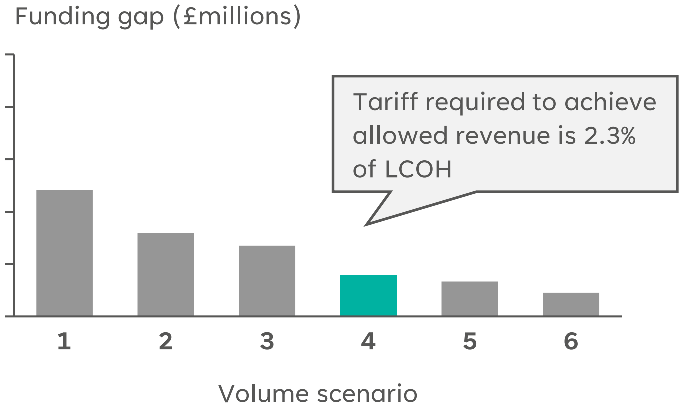
A lean backbone can be defined by taking the sequence of backbone legs that represent the best value for money (legs 1 to 5). Developing new hydrogen scenarios for the lean backbone and running a comparative economic assessment shows financial performance can be optimised to reduce funding gaps across all volume and CAPEX scenarios.

FULL backbone

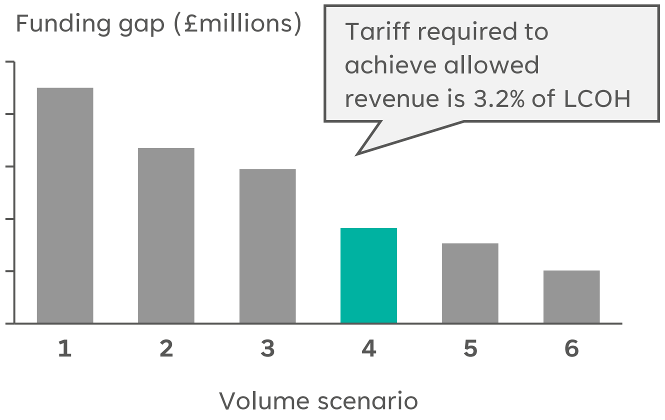
Optimistic Case



Deterministic Case

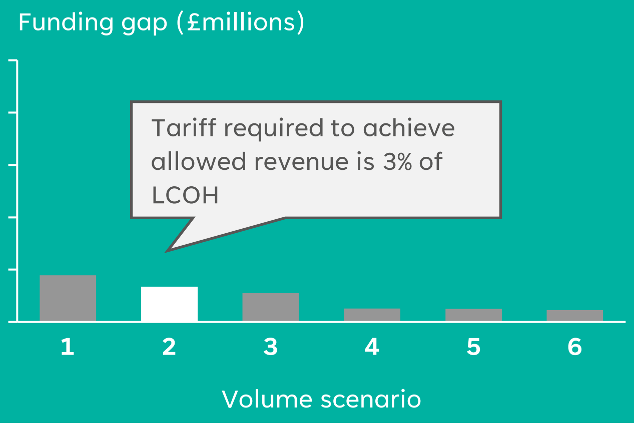


Pessimistic Case

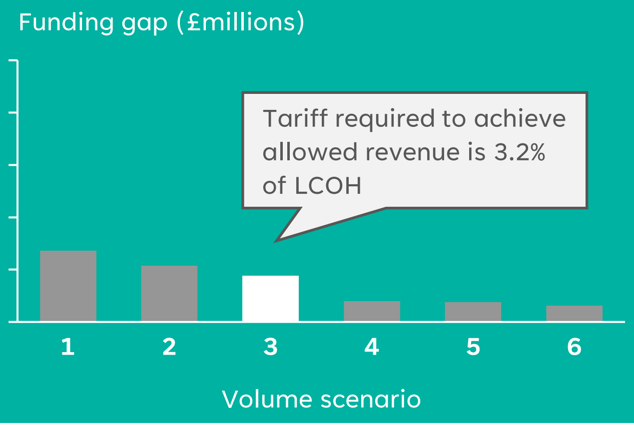


LEAN backbone

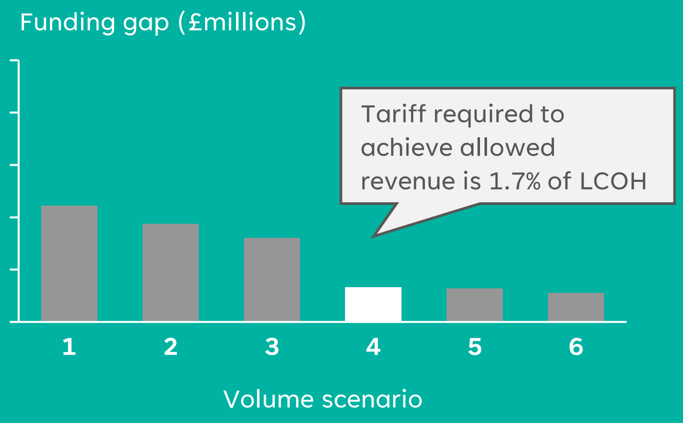
Optimistic Case



Deterministic Case



Pessimistic Case



Wider benefits Calculation

To offset the expected funding gap from generating new infrastructure in a new market, there are several additional benefits that need to be factored into the overall assessment of the project's net benefits. The factors that were monetised as part of the broader cost-benefit assessment are outlined below.

	Creating jobs	Decarbonising energy consumers	Reducing system balancing costs	Gross value add (GVA)
Definition	Employment impacts are expressed in terms of the number of jobs supported by Deployment Projects. A 'supported' job includes those that are created, safeguarded, and displaced.	The emissions abatement contribution of developing midstream infrastructure to displace natural gas with hydrogen usage.	The monetised benefit of cutting balancing costs by reducing electricity network curtailment, supporting renewable integration.	GVA captures the value chains contribution to the economy. GVA only includes the value of additional output generated by the value chain, excluding the value of any intermediate inputs used in the production of goods and services (i.e., final demand)
Methodology	▪ Job creation expectations per KM of pipeline built are derived by leveraging Track 1 and Track 2 H_2 pipeline job estimates. ▪ This was determined for construction and operation phases, and for both direct and indirect jobs sustained.	▪ Assumed an emission abatement factor for every molecule of natural gas displaced by H_2 to determine a kg CO2 saving. ▪ Multiplied by DESNZ Green Book carbon price to determine a £ per kg CO2 saving. ▪ Multiplied by 6% to represent the midstream contribution (in line with WTP assumptions)	▪ Value of curtailment taken as an average of the past decade. ▪ Curtailment reduction volumes were generated through PLEXOS.	▪ GVA creation expectations per KM of pipeline built and CAPEX spend are derived by leveraging Track 1 and Track 2 H_2 pipeline GVA estimates. ▪ This was determined for construction and operation phases, and for both direct and indirect GVA benefits.
Sources	Track 1 and 2 cluster H_2 pipeline job figures.	DESNZ Green Book, CCC Net Zero Scenarios.	ESO Balancing Cost Reports, BEIS Curtailment Studies.	Track 1 and 2 cluster H_2 pipeline GVA figures.

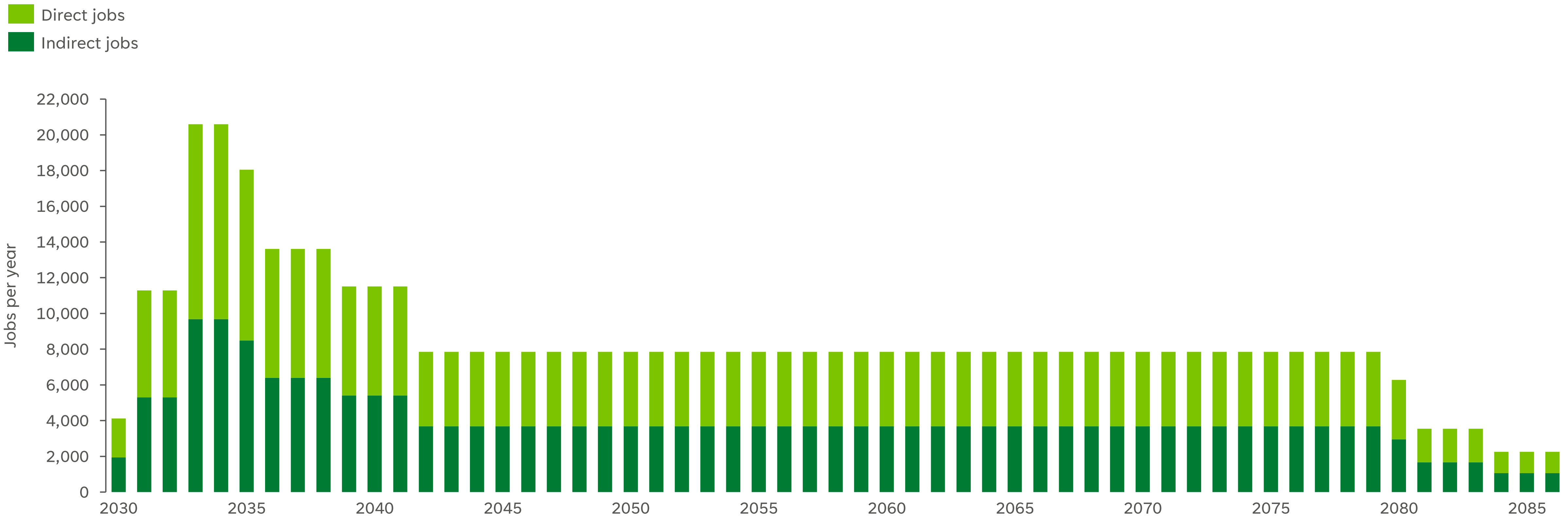
Full Backbone Societal Value Added

Monetisation of emission abatement, curtailment reduction, Direct and Indirect GVA shows positive net benefits across all scenarios. However, the "real system" benefits of emissions abatement and curtailment reduction close the funding gap from scenario 4 onwards in a deterministic CAPEX scenario.

Assumptions: Attributable share of benefits to the backbone based on the relative costs of hydrogen transportation to the LCOH (~6%); Value of emission based on DESNZ Green Book; Value of curtailment taken as an average of the past decade (£63/MWh).

Jobs sustained per year

As expected, the largest number of jobs sustained are during the construction phase of the H_2 backbone, with a peak in 2034. Average jobs sustained are close to 8k per year, with jobs focused on the operational period given the window of time covered. Note, this does not consider back-office operational synergies of whole network operation and is instead a sum of "leg-by-leg" jobs sustained.



Assumptions: Attributable share of benefits to the backbone based on the relative costs of hydrogen transportation to the LCOH (~6%); Value of emission based on DESNZ Green Book; Value of curtailment taken as an average of the past decade (£63/MWh).

national gas transmission