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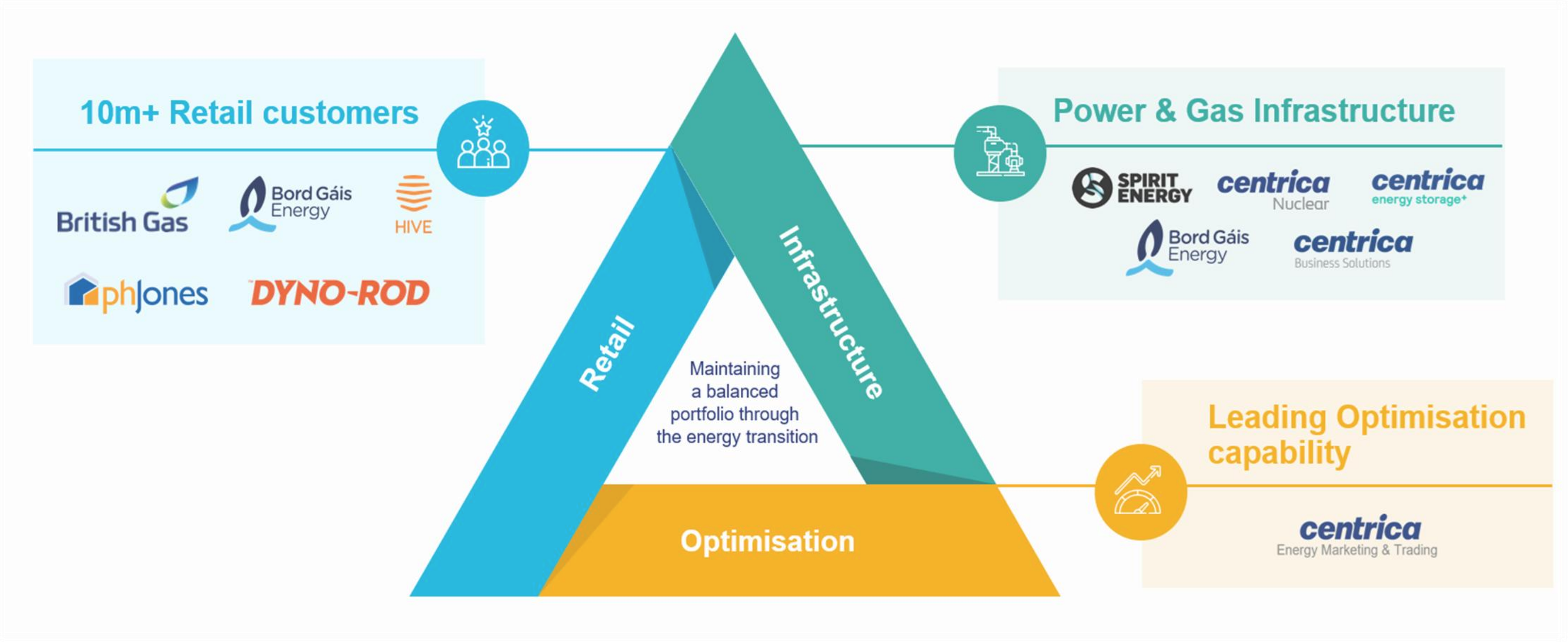
Transforming Rough Storage for the future energy system

HSiC2025: Storing Hydrogen Underground

Chris McClane – Energy Transition Interface Manager

17 April 2025

Energising a greener, fairer future



We are an integrated energy & services business

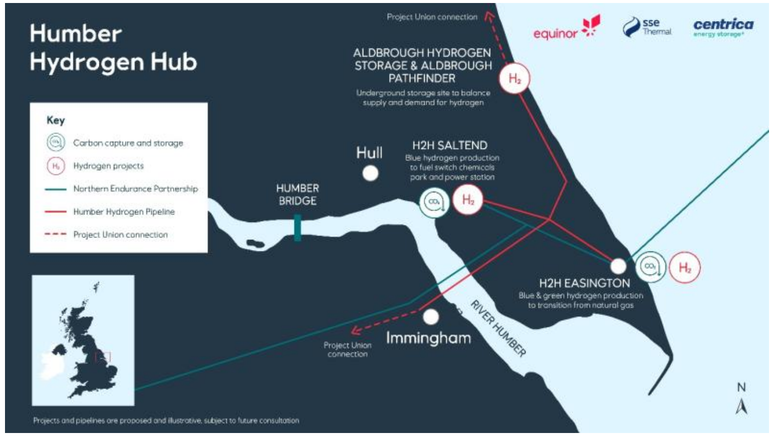
Our hydrogen ambitions (2030's)...

H2 Production

Singleton Birch is a leading Lime supplier. Last week, Centrica has won support from Government via HAR2 Shortlisting to build a **10MW Green hydrogen (Electrolytic) production plant** at the site to blend around 30% into the gas to reduce the emissions. We have ambitions to reach 100% Hydrogen and carbon free lime.

Centrica Energy Storage+ and Equinor propose a GW-scale multi-stage green and blue hydrogen production facility at Easington.

H2 Transport



CES+, Equinor and SSE, propose a **network of hydrogen production, storage, and usage in the Humber, connected by underground pipelines**. These projects form the Humber Hydrogen Hub, supporting sustainable energy solutions in the region.

H2 Storage

Centrica's redevelopment of Rough would significantly increase current natural gas storage capacity in the short-medium term, boosting UK energy security, whilst providing up to **200 billion cubic feet (6 billion cubic meters) of gas or Hydrogen.**

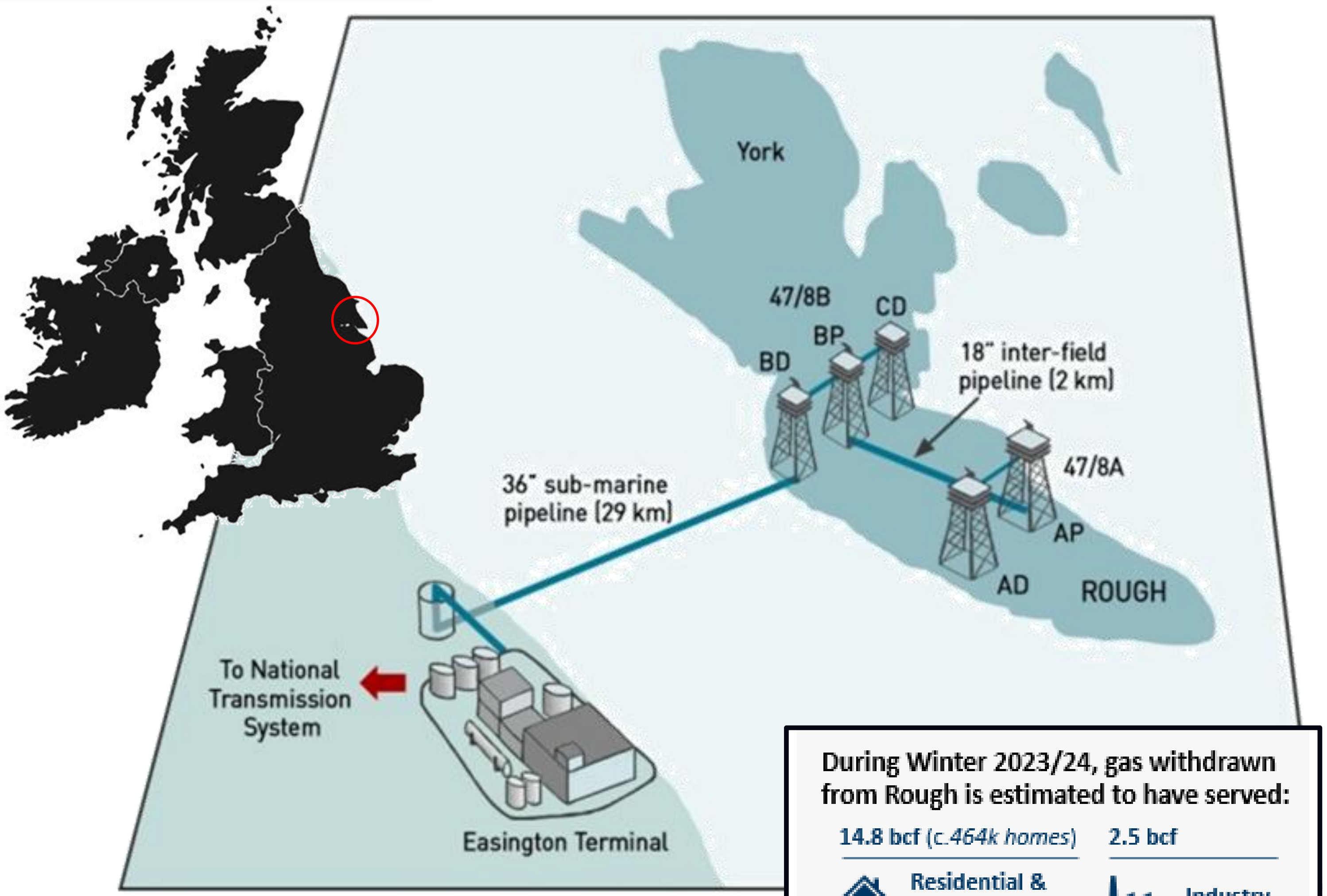
Re-purposing Rough, is expected to be the most cost-efficient option to meet the long-term need for hydrogen storage.

Centrica and partners are developing H2-ready gas storage via the **Kestrel Energy Storage** project in Ireland with a capacity of 1bcm – **10TWh of natural gas** initially, transitioning to **3TWh H2 storage** once market develops

Rough has provided proven gas storage for the UK for over 4 decades

…but its operation has evolved in recent times

- The Rough storage facility is geographically located at the heart of the UK energy system…
- Production commenced in 1975, converted to storage in 1985
- 30 km2 porous rock reservoir, c.3km under seabed
- Up to 200bcf storage (66 LNG Tankers)
- Storage ceased between 2017-2022
- Re-opened for storage in 2022 at reduced capacity (30bcf)
- Rough's future is unclear due to lack of gas storage market support



Capacity in 2025 is 58bcf – still >50% UK's gas storage

During Winter 2023/24, gas withdrawn from Rough is estimated to have served:

14.8 bcf (*c.464k homes*) Residential & Commercial	2.5 bcf Industry
4.6 bcf (*c.400k homes*) Electricity generation	2.8 bcf Exports

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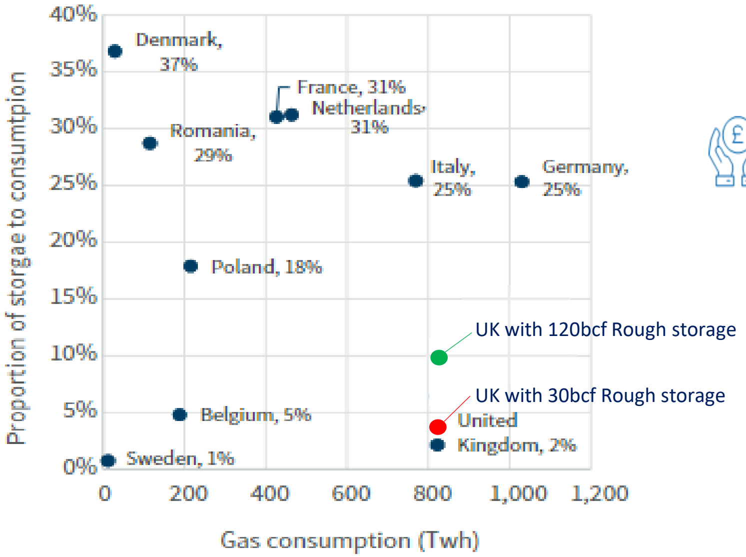
Long Duration Energy Storage in the UK

Low UK gas storage capacity leaves customers exposed to global price changes….



£2.4 bn

Total gas and electricity wholesale cost saving if Rough had been fully operational in Winter 21/22

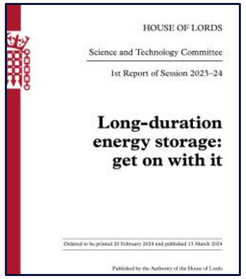
How do you factor in the value of storage in the UK?

- UK has ~**2%** of total gas demand covered by existing operational gas storage
- Other European countries with similar demographics have enough gas storage to meet more than 20% of annual demand

However, the right noises are being made on a national level…

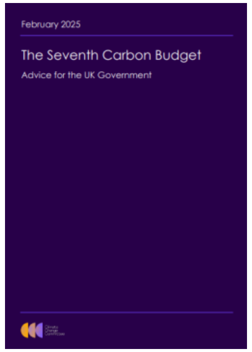
National Infrastructure Committee Report (2023)

- UK Strategic Gas Reserve of 35TWh by 2035
- 8TWh Hydrogen storage available to get to decarbonised energy grid by 2035



House of Lords Science & Technology Committee (2024)

- Decision on Rough is needed by the end of the year
- Supports NIC Report recommendation of strategic gas reserve – vital for energy security
- Set an explicit minimum target for energy storage
- Support no/low-regrets investments for hydrogen



7TH Carbon Budget (2025)

- Balanced Pathway includes 15 GW of dispatchable low-carbon electricity generation by 2040. This includes gas CCS and hydrogen-fired turbines. 38GW by 2050.
- Balanced pathway states **H2 storage need of 3TWh by 2040 rising to 5-9 TWh by 2050** depending on H2P roll out.
- Government should **fast-track low-regret hydrogen infrastructure development**, including networks and storage.

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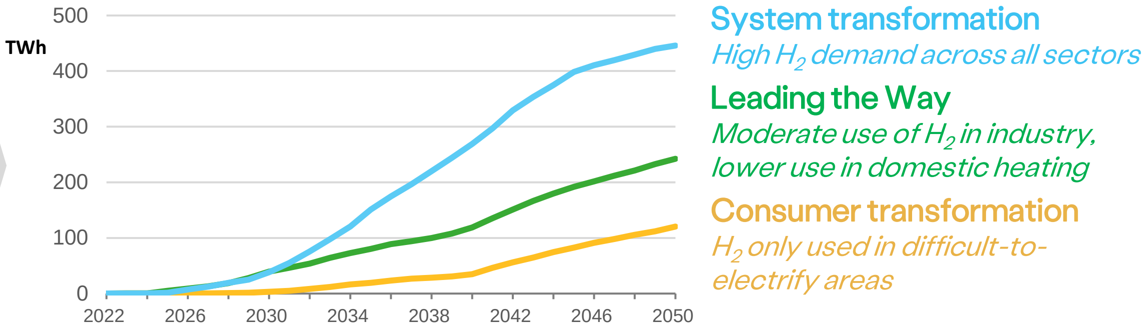
Electrification likely the main route to decarbonisation, hydrogen requirement to support electrification is clear

Hydrogen is expected to have two broad roles in decarbonisation…

- Replace the use of unabated fossil fuels in:
  - Industrial use
  - Transport (air, road, maritime)
  - Domestic use (i.e. heating)
- Support the decarbonisation of the electricity sector

…but projections of how significant a role it plays vary considerably



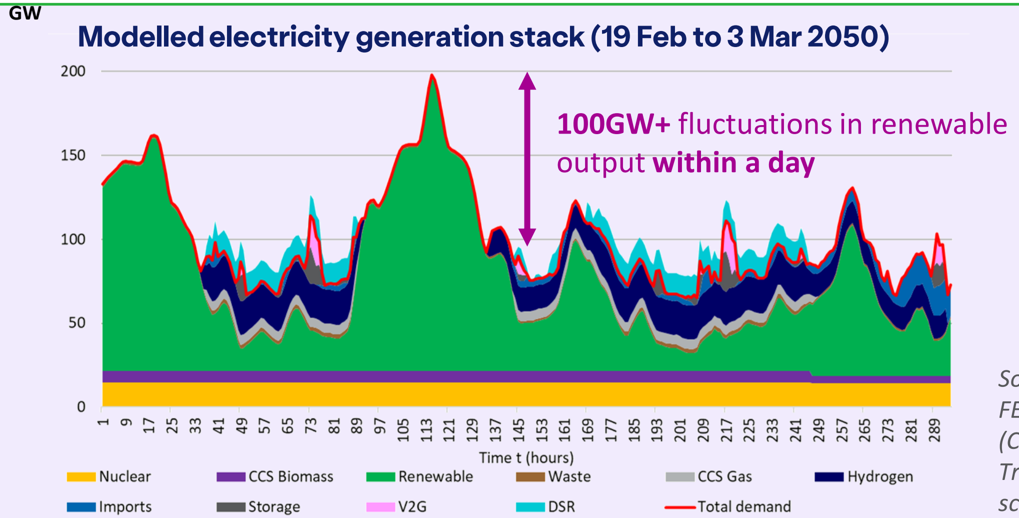
Source: ESO FES 2023

A renewables-dominated electricity sector will be characterised by **highly volatile** supply

When renewable generation is high, excess supply can be used to **produce hydrogen**…

…this hydrogen can be **stored** and subsequently used to **generate electricity** (“hydrogen-to-power”)

The same role cannot be played efficiently by other storage sources (e.g. batteries) for more than a few hours at a time



Sources: NESO FES 2023 (Consumer Transformation scenario).

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Centrica Whole System Model shows the system benefits of H2 T&S deployment…

The hydrogen backbone allows electrolysers to locate at areas with the highest renewable generation…

… reducing the cost of H2 production and relieving electricity network congestion

H2

H_2 storage affects H_2 production in hours with high renewable generation

… storing H_2 in summer periods which in turn improves the economics of increased renewable capacity

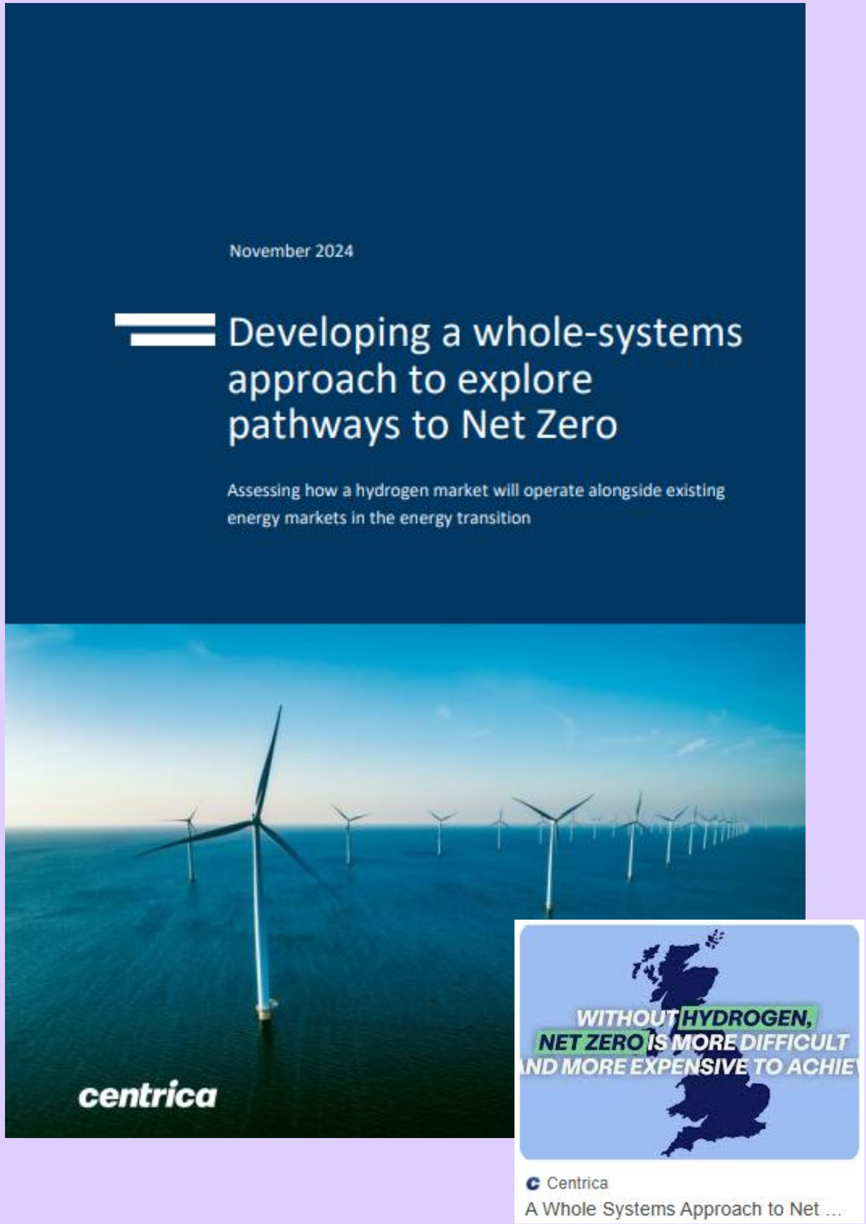
Higher H_2 storage improves the economics of H2-to-power…

… utilising cheaper H_2 during peak power periods, displacing dispatchable thermal generation…

… and increasing GB's security of supply

Reduced hydrogen storage increases wholesale hydrogen and electricity prices, as the lack of hydrogen supply increases system stress, especially in the winter

https://www.centrica.com/sustainability/our-journey-to-net-zero/a-whole-systems-approach/

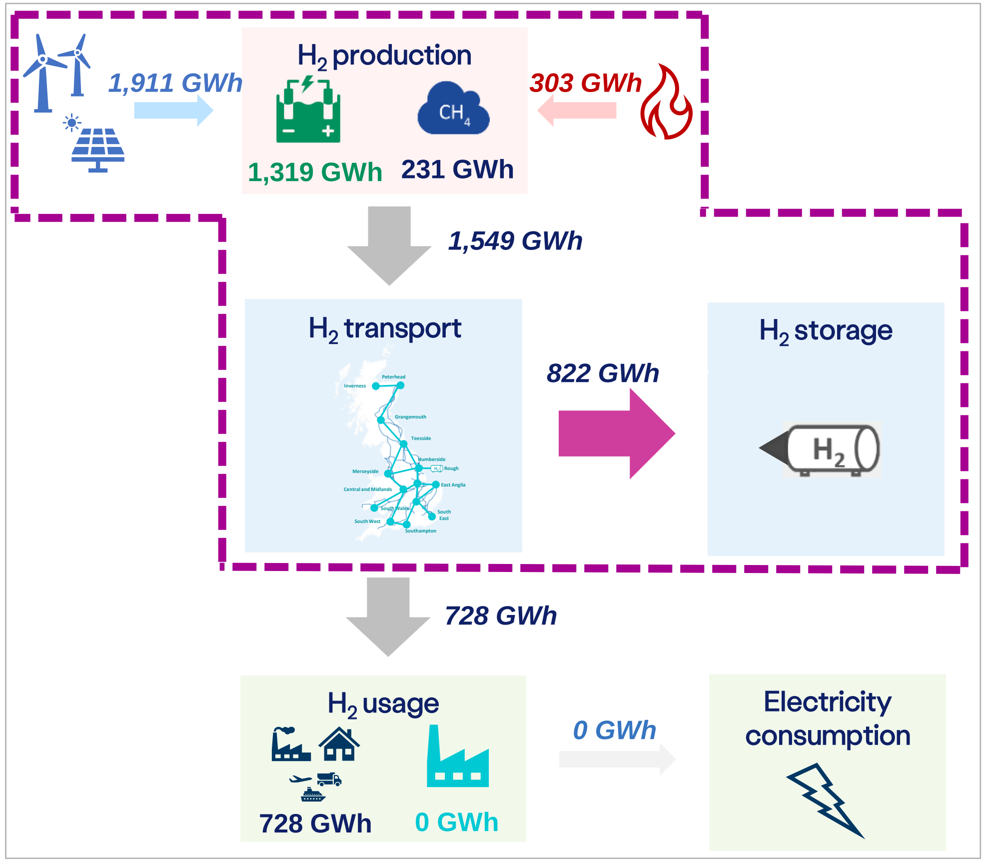


Our results highlight the flexibility provided by storage and transport in different weather conditions – for example, (1) on a windy day in 2050

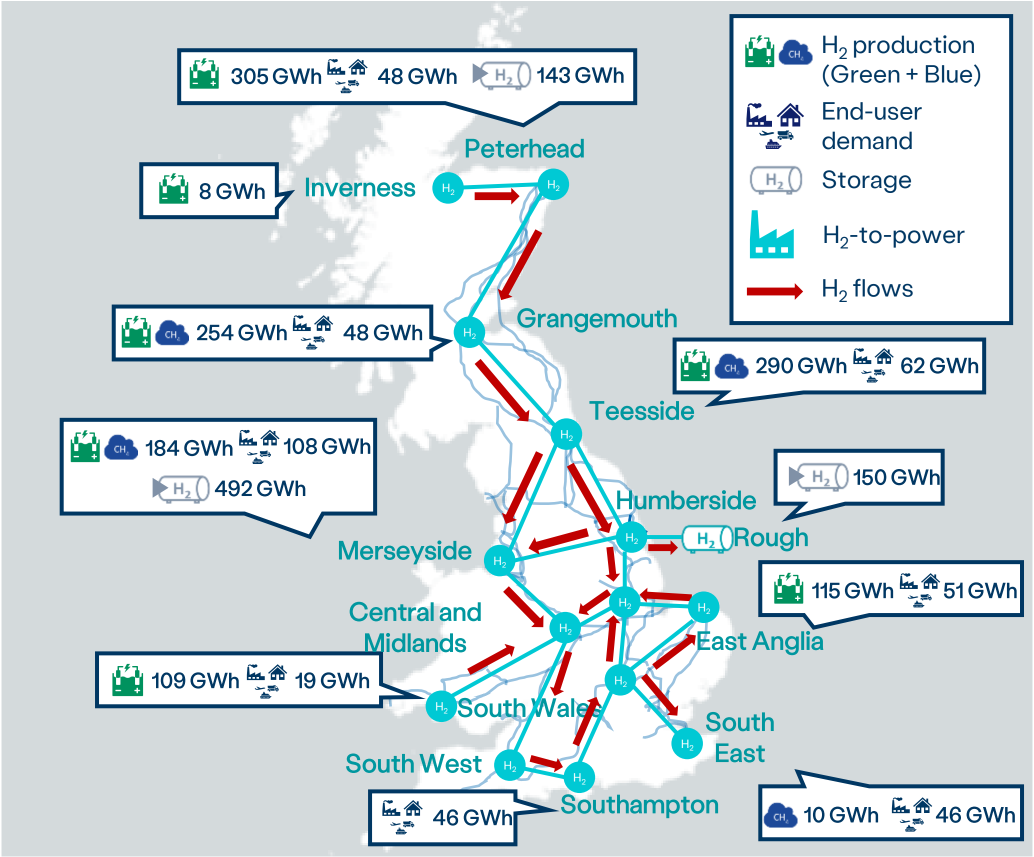
25 Oct 2050

Price	£0/MWh
H_2 Price	£17/MWh

Excess low-cost hydrogen production is stored…



…while networks flow almost exclusively from North to South

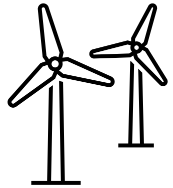


Sources: FTI modelling, Core scenario
Note: To date, we have not accounted for compressor usage and losses but could be included in subsequent modelling runs

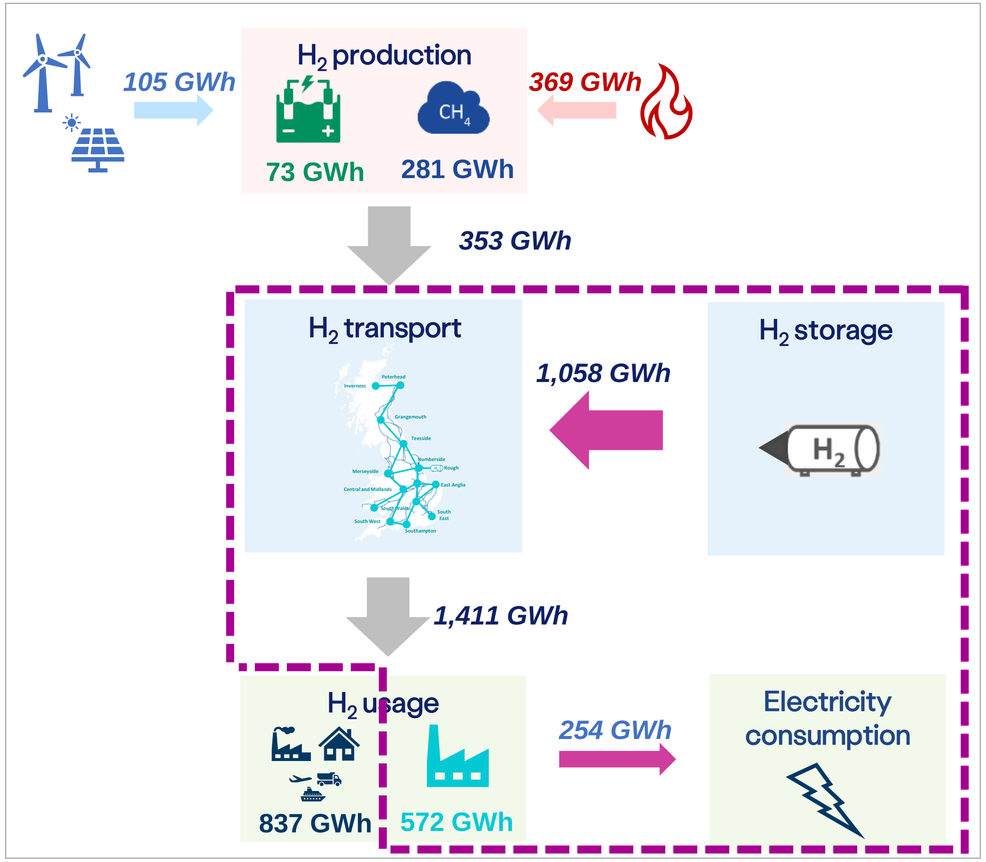
Our results highlight the flexibility provided by storage and transport in different weather conditions – for example, (2) on a low wind day in 2050

8 Nov 2050

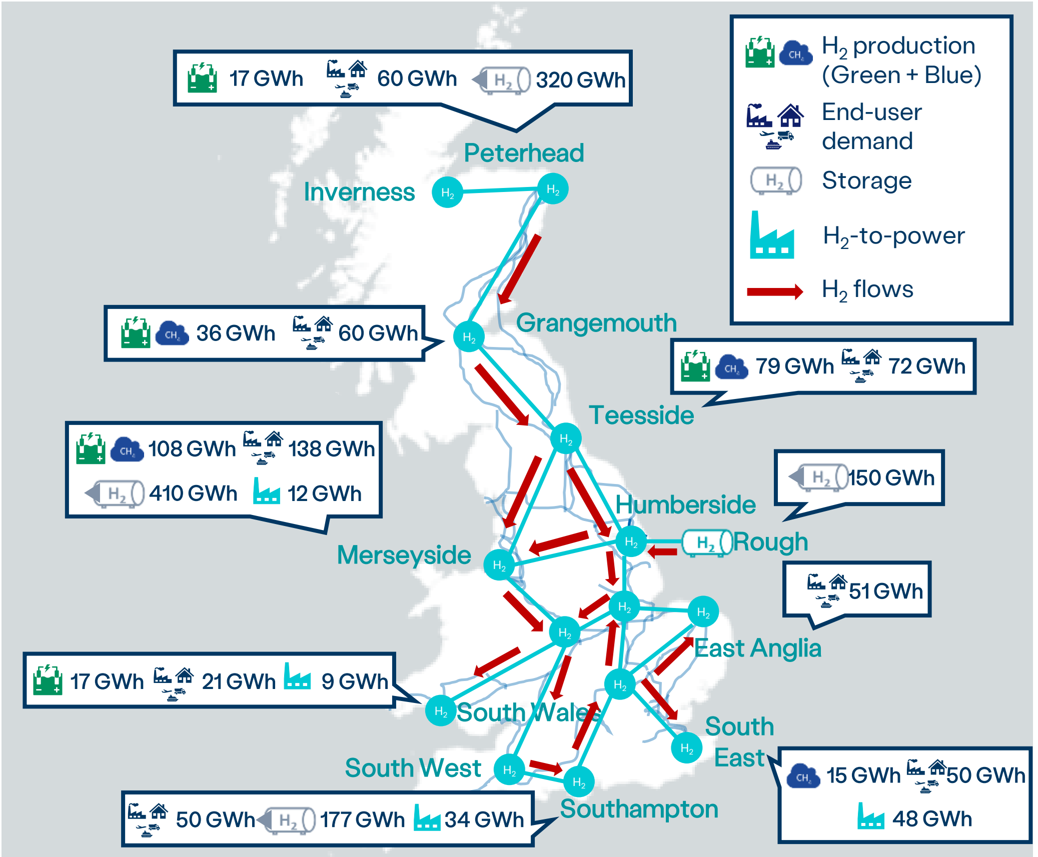
(electricity)	Price	£51/MWh
H_2	Price	£19/MWh



Stored H_2 released to meet both H_2 and electricity demand…



…while some network flows reverse to move H_2 towards generators



Sources: FTI modelling, Core scenario
Note: To date, we have not accounted for compressor usage and losses but could be included in subsequent modelling runs

The strategic location and phased capacity expansion of Rough make it a critical asset in the UK's path to achieving Net Zero by 2050.

16TWh *H2 Capacity*	Rough is a unique asset within UK, a potential to deliver up to 16 TWh of hydrogen storage (equiv. c.160 salt caverns)
3.3 TWh *Phased Build-out*	Capacity can be built in phases to meet market requirements between 2030 to 2050+ This allows Rough to be flexible and adapt to the market, making it a low-risk investment.
>90%	Project FEED is almost complete, and significant supply chain market engagement is progressing
2031	Rough can be operational as a hydrogen store by 2031

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The RougH2 project is a c.£2bn investment in new onshore and offshore infrastructure

A redeveloped Rough will provide scalable H2 Storage **from 1.1bcm/3.2TWh up to 5.4/16TWh**

Wells

- **16 new wells** drilled from central location

Single Jacket Platform

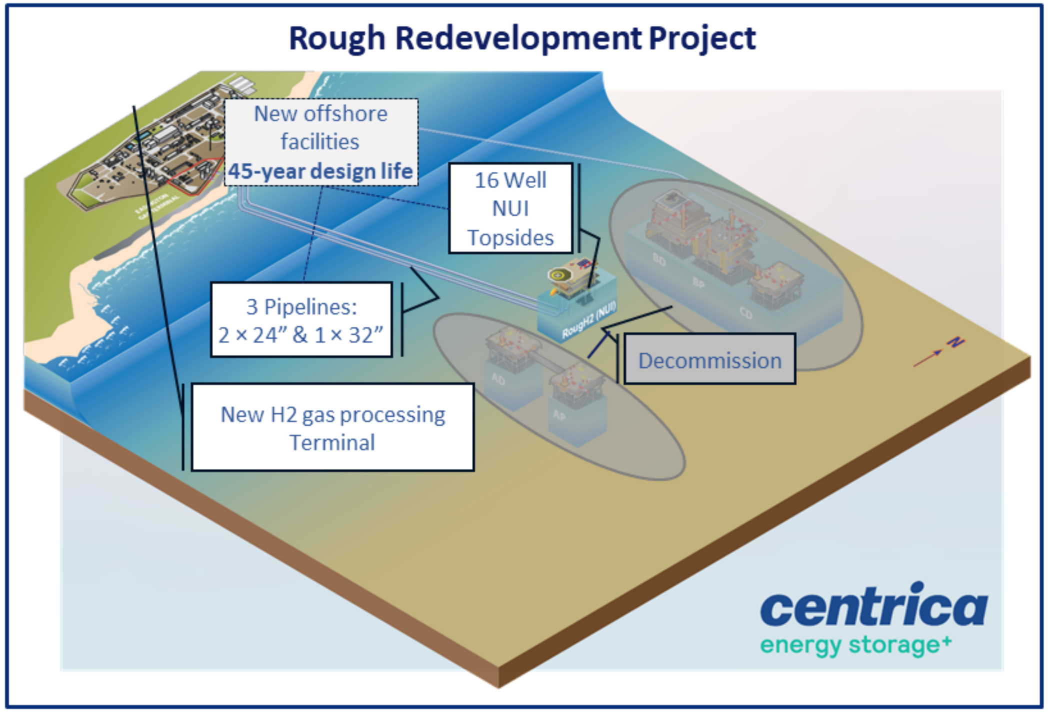
- Minimum Facilities Normally Uninhabited (NUI) Topsides
- Remotely Operated

Subsea Pipelines

- Three new pipelines
- 2 × 24” (for injection/withdrawal)
- 1 × 32” for withdrawal

Easington / Onshore

- New H2 processing Terminal at Easington



4,800	**Jobs** created during construction	**640**	**FTE jobs** sustained for full life span of ~45 years
£930m	**Salaries** paid in the UK	**£1,540m**	**GVA** to the economy during operations

Majority of the impact (80%) expected to be in the North of England
*Socio-Economic Impact Study completed by University of Hull , 2023

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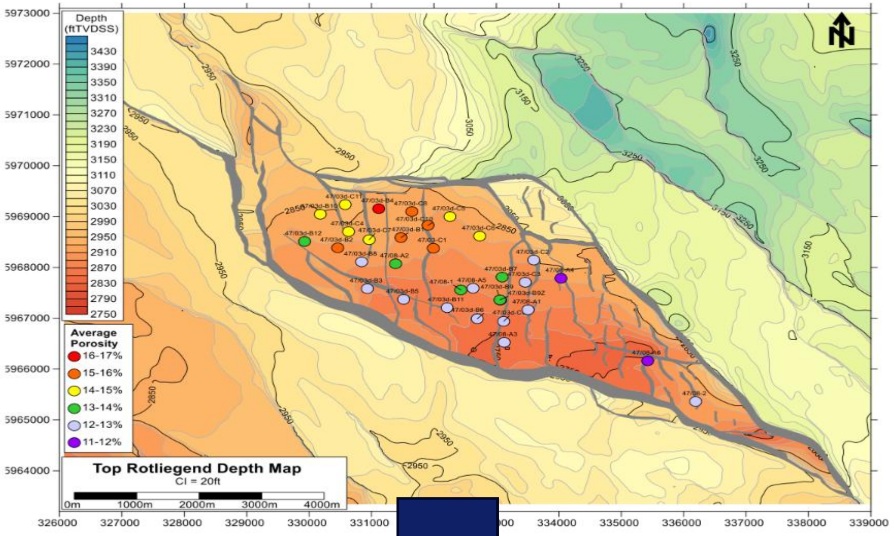
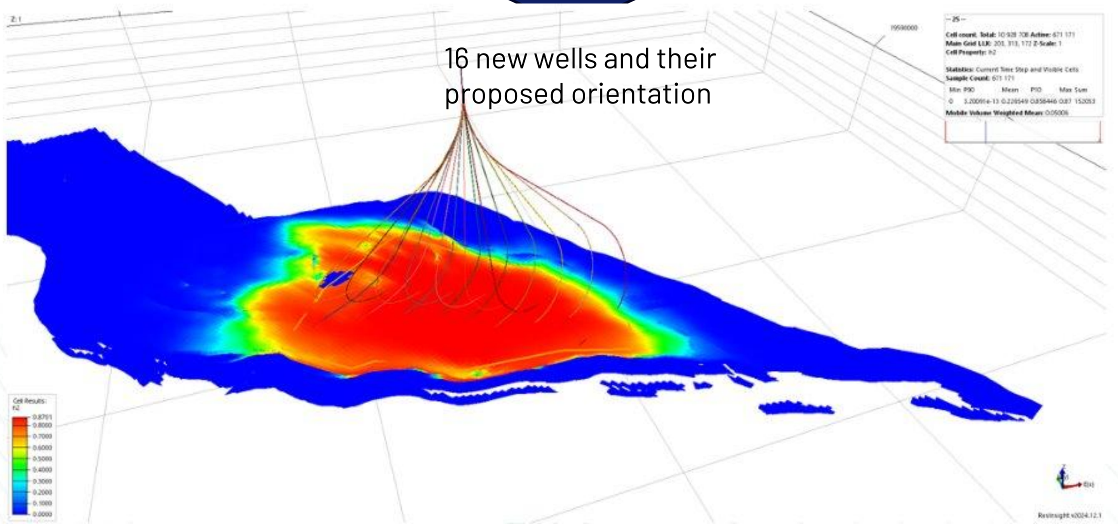
Wells & Subsurface design

30 legacy Rough Well locations



16 new wells and their proposed orientation



Rough's existing wells do not have the integrity for the high reservoir pressures arising from storing 120BCF or 200BCF of working gas.

New Rough multi-compositional 3D model built in CMG GEM. Model was history matched with 30yrs+ data. Well positions optimised for H2 operation and FDP Forecasting completed.

16 wells is optimal both for 120BCF hydrocarbon storage and for future 200BCF H2 storage.

As part of wells 'hydrogen-readiness', looking at embrittlement of high-alloy materials, leakage rates from key valves and swelling impacts on elastomers

EXCEED
slb
DRIL-QUIP

Modelling of CO2 cushion gas also undertaken; however this was 'parked' to allow progression of natural gas and hydrogen at pace

Drill rig quotations received with tendering work ongoing

NOBLE
VALARIS

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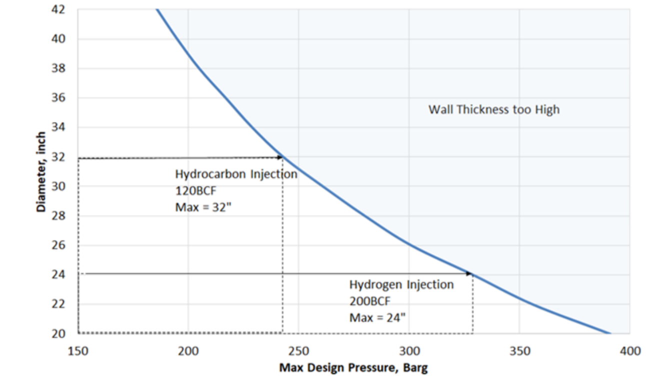
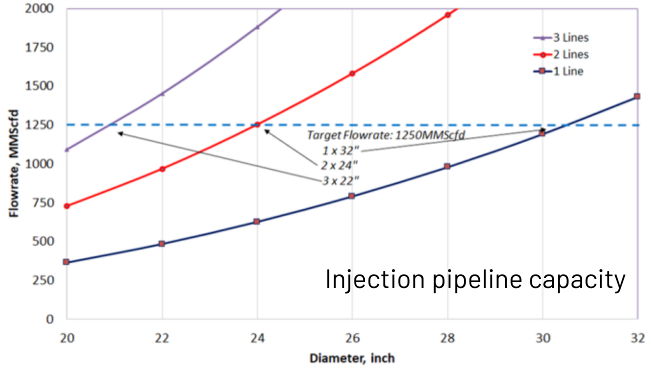
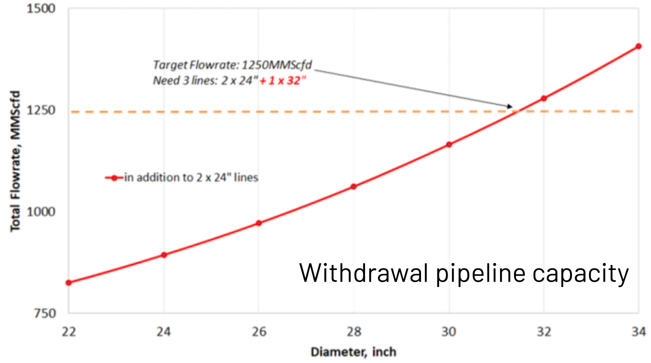
Pipeline Design & Optimisation



24" is maximum allowable pipeline diameter for injection





Compression performed onshore:

- Requires thicker pipelines however,
- Cheaper than compression offshore and thinner walled pipelines
- Design similar to other storage operations

Number of pipelines and wells dependent upon the most onerous case – **hydrogen**. Could be reduced if designed for natural gas only

To achieve H2 working gas volume (WGV) of 200BCF, the injection pipeline design pressure is 330barg, based on max reservoir pressure of 4500psi.

Max injection pipeline size for 330barg, based on manufacturing limitations, is 24", therefore **2 x 24" pipelines are required to inject 200BCF**

Withdrawal is lower pressure, so volumetric flowrate is higher than injection. **Third pipeline is therefore required for withdrawal**.

As withdrawal is lower pressure, size is not limited to 24". **32" was selected to achieve required production rates.**

However, there are **no existing Standards or Guidance on the construction of Offshore pipelines for Hydrogen service**. CES+ with Wood PLC are developing a testing regime to qualify the selected line pipe material for hydrogen service, through a Fracture Mechanic analysis, concentrating on cracking resistance.

What’s next?

The ‘Define’ phase of redevelopment for natural gas storage (FEED) is complete.
FID dependent upon regulatory framework being in place and pace of project has been adjusted based on policy signals

Highly likely that a regulatory model underpinning storage investment will provide multiple investment strategies.

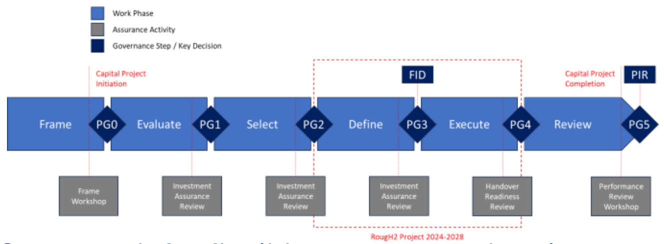
Design of new offshore infrastructure (wells, pipelines, platform) for both NG and H2 is complete.
Tie-in to existing Easington Terminal for natural gas processing and onshore injection compression is complete

Onshore H2 processing Pre-FEED is complete and FEED can be started if policy signals are received.

Government’s Hydrogen Storage Business Model 1st allocation round expected to open in late 2025

Project Structure

Client	centrica energy storage+; centrica
Project Management [Consultancy]	T.EN Technip Energies
Project Delivery (EPCm)	wood.; EXCEED



- PMC approach for flexible resource and project services and experience of ‘mega’-projects
- Project Management Team integrated across CES/PMC/EPCm and Group Functions
- Facilities project delivery through Wood and wells through Exceed Energy.
- Governance being implemented across the project structure.

European demonstrator projects have shown that porous rock technology is viable for large scale hydrogen storage

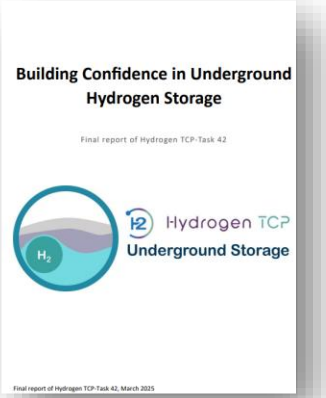
RAG Austria Underground Sun Storage 100% H2 Storage Pilot in depleted gas field now operational

H2 Injection commenced in late 2023, and 1st withdrawal completed in June 2024.

Results were as expected, and compared with lab-scale testing: **No mixing, no H2S, no changes in productivity**

RAG AUSTRIA AG

Note: RAG's USS depleted field site has less favourable geological characteristics than Rough for H2 storage e.g shallow, low temperature, minerology profile etc.



Building Confidence in Underground Hydrogen Storage

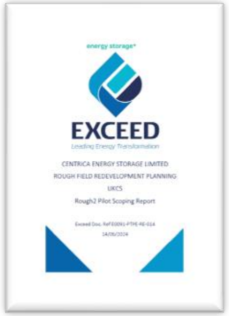
Final report of Hydrogen TCP-Task 42

H2 Hydrogen TCP Underground Storage

Final report of Hydrogen TCP-Task 42, March 2025

IEA-TCP Task42 2024 report "Building Confidence in Underground Hydrogen Storage" published Mar'25

- UHS is technically feasible, and main hurdles are non-technical.
- Remaining technical challenges mostly impact the economics of projects.
- Design and Operation of UGS transferable to UHS
- Confidence Readiness Level (CRL) assessment approach adopted



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EXCEED

Leading Energy Transformation

CENTRICA ENERGY STORAGE LIMITED

ROUGH FIELD REDEVELOPMENT PLANNING

UKCS

Rough2 Pilot Scoping Report

Rough specific hydrogen storage readiness assessment completed by Exceed (SRL 6-7) and independent review ongoing by ARUP

EXCEED

ARUP

Risk of storage integrity and storage performance loss is assessed as low based on site-specific lab scale testing and modelling analysis.

Caprock Diffusion & Geomechanics

When modelled, hydrogen does not reach Rough caprock boundary over 40yr simulated period.
Leakage containment assessment complete. Fracture mechanics complete.
Reservoir seal integrity confirmed

Flow Behaviour

New Rough multi-compositional 3D model built in CMG GEM. Model was history matched with 30yrs+ data. Well positions optimised for operation up to 16TWh max H2 storage case.
Cushion gas optimised for deliverability, and modelling cases completed to maximise H2 Purity on early storage cycles (>90% H2).

Geochemical Reaction

Rough core samples tested in 100% H2 at reservoir equiv. temp/press.
No changes to minerology/gas composition observed (HyUSPRe).

Microbiological Reaction

Rough is paleo-sterile based on reservoir characteristics - high temp and low sulphate concentrations (Thaysen et al, 2023)

RougH2 Summary

Redevelopment will ensure Rough offers **scale** in terms of volume, **flexibility** in terms of turnaround speed and **pace** in terms of withdrawal rates

The final configuration of the site between strategic energy reserve and working gas operations is flexible, and **can be varied in response to government policy preferences**

Rough's **strategic location** enables access to market via planned Humber and national transportation projects, delivering reliable hydrogen supply to industry and the power sector, whilst enabling production of green energy to be optimised.

Technical assessments of Rough's integrity and performance for hydrogen storage have been completed, thus ensuring **confidence** in the transition from proven-gas store to hydrogen store.

Our FEED for the £2bn, 45yr design life infrastructure project is **complete,** with **extensive supply chain engagement and construction planning complete**.

Moving beyond FEED into 'execute' phase will follow positive decision-making from government, allowing Centrica to continue to invest.

Unlocking Our Future...

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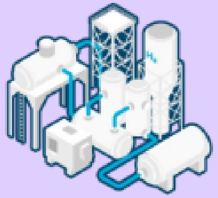
During the 2030s ...



3GW

of hydrogen production

1

hydrogen pipeline connected

>3TWh

of hydrogen storage

...In the UK

Thank you

chris.mcclane@centrica.com