Welcome to today's webinar:

HYDROGEN'S ROLE IN A RAPIDLY EVOLVING NORTH SEA ENERGY SECTOR

Ether Sham

Sr. Process Engineer, NSTA

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Policy Lead for Hydrogen, NSTA

In association with: North Sea Transition Authority, Hydrogen Scotland

"Enabling connections between our members is the most important thing we do."

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Hydrogen's role in a rapidly evolving North Sea energy sector

Hydrogen Scotland

Thierry Berns, Senior Policy Advisor – Hydrogen

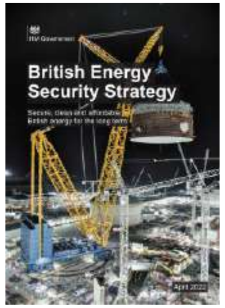
Ether Sham, Senior Process Engineer

02/03/2026

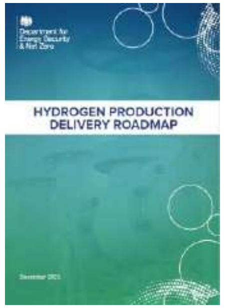
The UK's strategy for hydrogen

Hydrogen can be a key enabler to the energy transition, complementing offshore wind scale up and electrification and providing flexible back-up to intermittent sources.

Government hydrogen targets



British Energy Security Strategy (2022)



Hydrogen Production Delivery Roadmap (2023)

Hydrogen production targets

10GW of low-carbon hydrogen capacity by 2030

- At least half from **Green H_2 (Electrolytic)**
- Remainder from **Blue H_2 (CCUS-enabled)**

Hydrogen allocation targets (financial support)

- up to **1GW** of **Green H_2** by 2025
- up to **6GW** of **Green H_2** by 2030; and
- up to **4GW** of **Blue H_2** by 2030

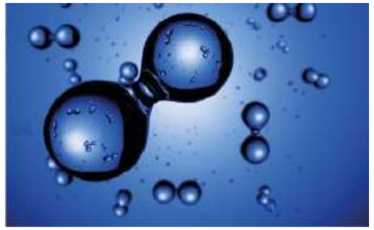
UKCS potential

Production

Low carbon – hydrogen hubs, offshore carbon storage and natural gas feedstock
Electrolytic – coastal location, offshore wind capacity

Infrastructure

Existing pipelines, terminals and skills base can be repurposed saving capital costs and time on permitting



Storage

Short, medium and long duration will be required, including in offshore reservoirs

Hydrogen sector at a glance

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Nascent sector with a growing number of onshore projects and offshore projects being proposed. The types of projects include:

- **Hydrogen production:** from onshore renewables (Green) or CCS-enabled (Blue); from offshore windfarms (Green).

- **Hydrogen storage:** onshore or offshore; in salt caverns, porous rock formations or saline aquifers.

- **Hydrogen pipelines:** to support local (project), regional (industrial hubs), but also national (transmission) and international (interconnector) developments.

- **'Hydrogen ready' terminals and ports:** adapting existing infrastructure to support hydrogen networks

Initial UK emphasis on the development of regional **hydrogen clusters**, which link up hydrogen production and storage with local end-users and associated infrastructure (e.g. CCS network).

Longer term ambition to link up individual hydrogen clusters through a national transmission grid (Project Union).

NSTA – What we do

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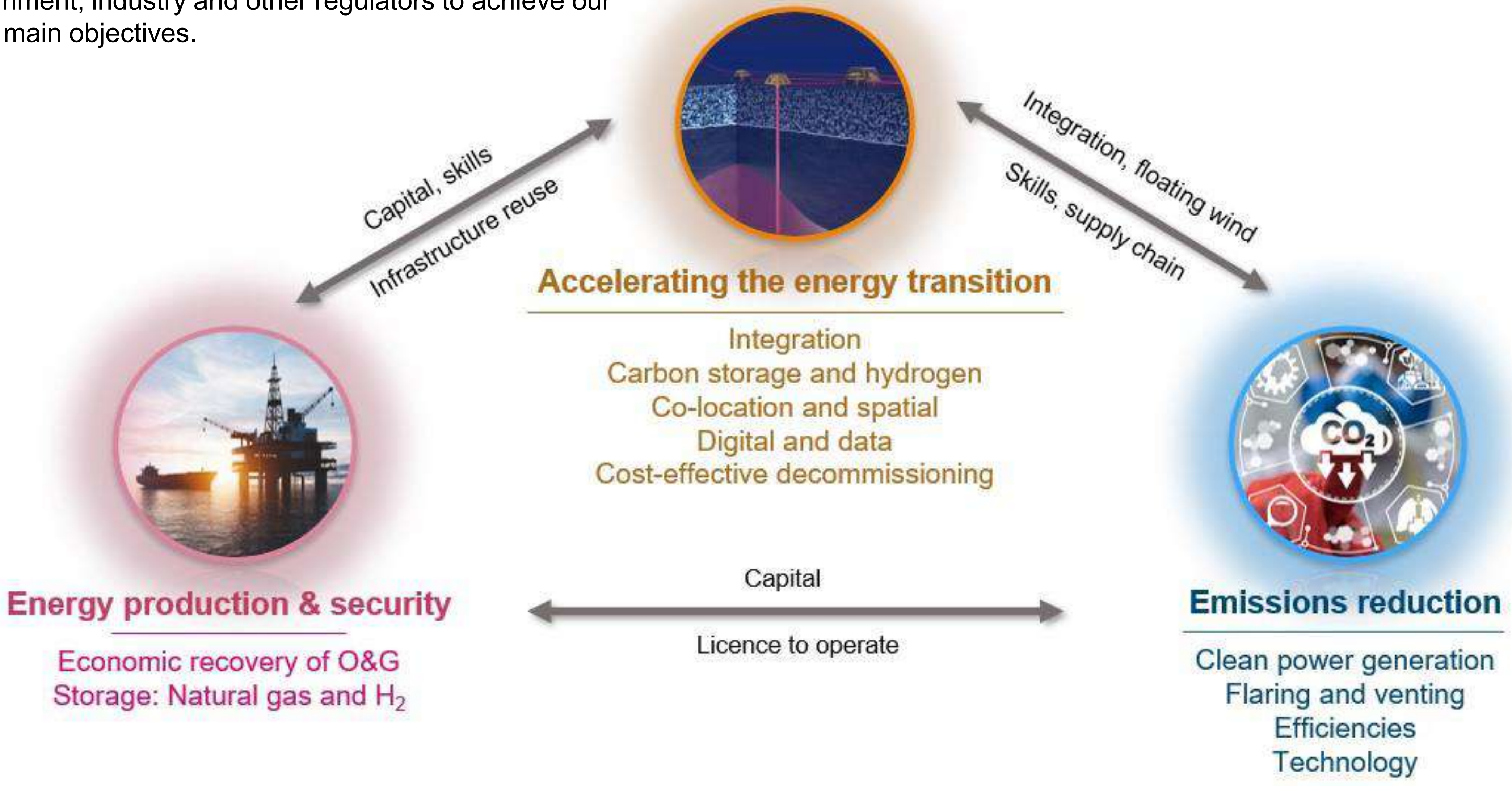
The NSTA regulates and influences the oil, gas, offshore hydrogen and carbon storage industries. We work with government, industry and other regulators to achieve our three main objectives.



North Sea Future Plan

North Sea Transition Authority

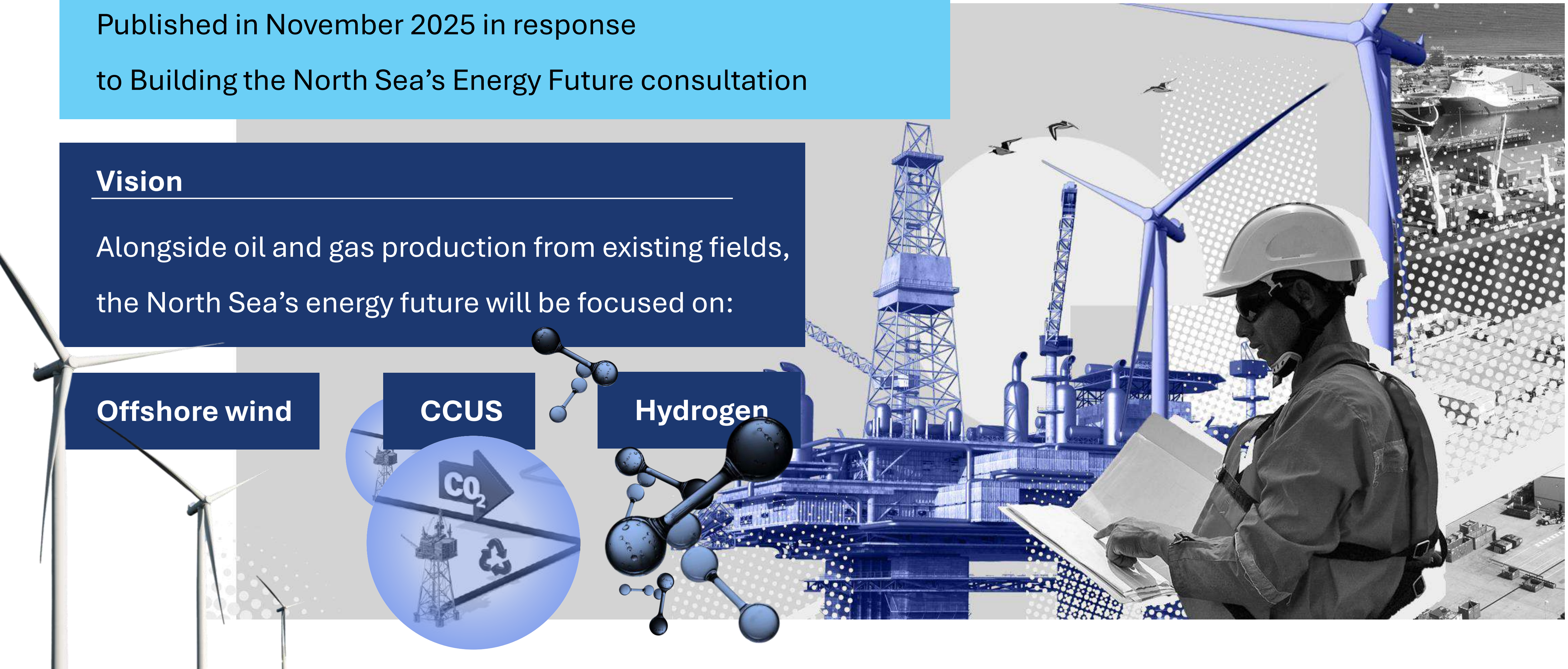
The UK government aims to foster an internationally leading offshore clean energy industry which ensures good, long-term jobs, growth and investment in communities across the North Sea.

Published in November 2025 in response to Building the North Sea's Energy Future consultation

Vision

Alongside oil and gas production from existing fields, the North Sea's energy future will be focused on:

- Offshore wind
- CCUS
- Hydrogen



North Sea Future Plan and the NSTA

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The NSTA will have three primary, balanced objectives applying across our offshore remit.

The new approach reflects the reality of our evolution and increasingly diverse responsibilities.

1 Economic

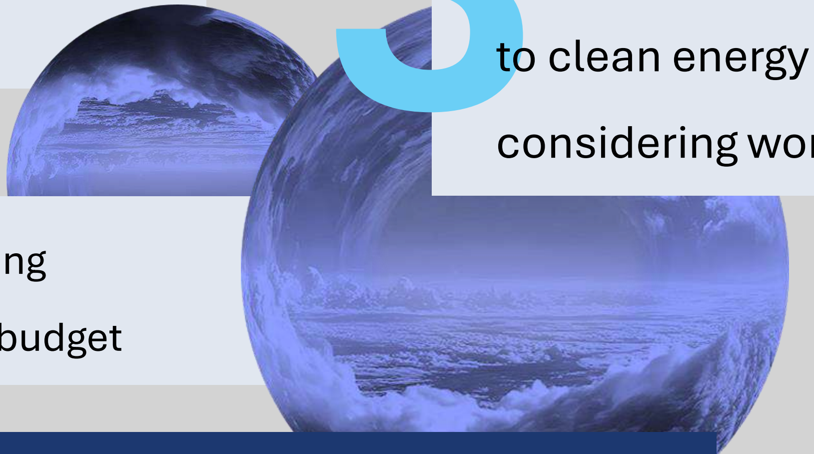
Maximise societal economic value of relevant activity

2 Net zero

Assist the government in meeting the net zero target and carbon budget

3 Transition

Enhance the long-term benefits of the transition to clean energy technologies in the UKCS by considering workers, communities and supply chains



NSTA powers for offshore petroleum will be strengthened and clarified

The plans will be established via an Energy Bill

The NSTA's role on hydrogen

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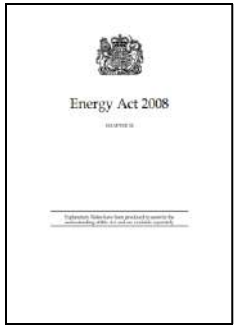
In September 2023, the NSTA became **the licensing** and **consenting authority** for **offshore hydrogen pipelines** and **offshore hydrogen storage**.


Energy Act 2008

Hydrogen storage licences

The NSTA issues hydrogen storage licences and consents under **Chapter 2 of the Energy Act 2008**. These authorise the offshore storage and recovery of hydrogen and associated activities (e.g. exploration for storage).


Petroleum Act 1998

Hydrogen pipeline work authorisations (PWAs)

The NSTA issues Pipeline Work Authorisations under **Part III of the Petroleum Act 1998**. These govern the construction, use and modification of offshore hydrogen pipelines.

The NSTA's approach to offshore regulation

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The development of offshore hydrogen storage and pipeline infrastructure presents opportunities for the UK across each of these three pillars. For example:

Energy production & security

- identifying opportunities to support offshore renewables and mitigate curtailment
- development of inter-seasonal energy storage capacity
- development of hydrogen pipeline infrastructure to support long-distance transmission
- coordination with CCUS developments to support blue hydrogen production

Emissions reduction

- development of offshore hydrogen infrastructure to support Net Zero
- management of flaring and venting activities

Transition

- opportunities for repurposing existing pipelines and terminals

The NSTA's engagement on hydrogen

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Engagement with HMG and regulators

NSTA works closely with government and other regulators

- Supporting government during development of consultation proposals and legislation
- Coordination between key regulators, including in devolved administrations, as offshore regulatory arrangements develop
- Provide technical knowledge to HMG and other regulators to support development of hydrogen policy

Engagement with industry

Support and engagement with first offshore hydrogen projects

- Early engagement with first of a kind offshore hydrogen projects requiring licences/consents from the NSTA
- Critical to understand projects' timelines/requirements to enable the NSTA to best support early development

Engagement with academia

Partner and collaborate with academia to understand ongoing hydrogen research

- Support and learn from academia at the forefront of hydrogen research
- Engage with consultancies to build up technical hydrogen knowledge base
- Collaborate with international regulators to learn best practise and exchange knowledge

The NSTA's engagement on hydrogen

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Engagement with government and regulators

The NSTA works with HMG, devolved administrations and other regulators to support policy development for hydrogen and to deliver a coherent and enabling regulatory framework for offshore hydrogen.

Who does what?

Energy transition including:	
Carbon storage and offshore hydrogen transportation and storage licensing and permitting authority	**NSTA**
UK energy policy, including CCS, hydrogen, renewable energy, legislation	**DESNZ**
Seabed leasing	**The Crown Estate** (England and Wales), **Crown Estate Scotland**
Marine leasing	**Marine Management Organisation (England), Scottish Government, Natural Resources Wales**
Offshore transmission, economic regulator for CCS	**OFGEM**

Oil and gas policy including:	
Overall oil and gas policy, legislation	**DESNZ**
Offshore decommissioning	**DESNZ – OPRED, NSTA, HMT**
Fiscal and taxation	**HMT** (NSTA providing expertise and evidence)
Supply chain and business impact	**DESNZ and NSTA**
Environment	**DESNZ – OPRED**
International relations and trade	**DESNZ, DBT, NSTA, FCDO**

Exploration and production including:	
Offshore, onshore, gas storage and gas unloading licensing Field development plan consents Offshore pipeline works authorisation Infrastructure Commercial matters and changes of control Flaring and venting consents Metering and allocation Production outages Offshore decom efficiency, costs, technology Supply chain action plans Effective net zero assessment Emissions benchmarking	**NSTA**
Offshore decom programme approval, execution and monitoring	**DESNZ – OPRED**
Offshore environmental management and inspection	**DESNZ – OPRED**
Health and safety management	**HSE**
Environmental aspects of onshore regulations	**Environment Agency (England)**

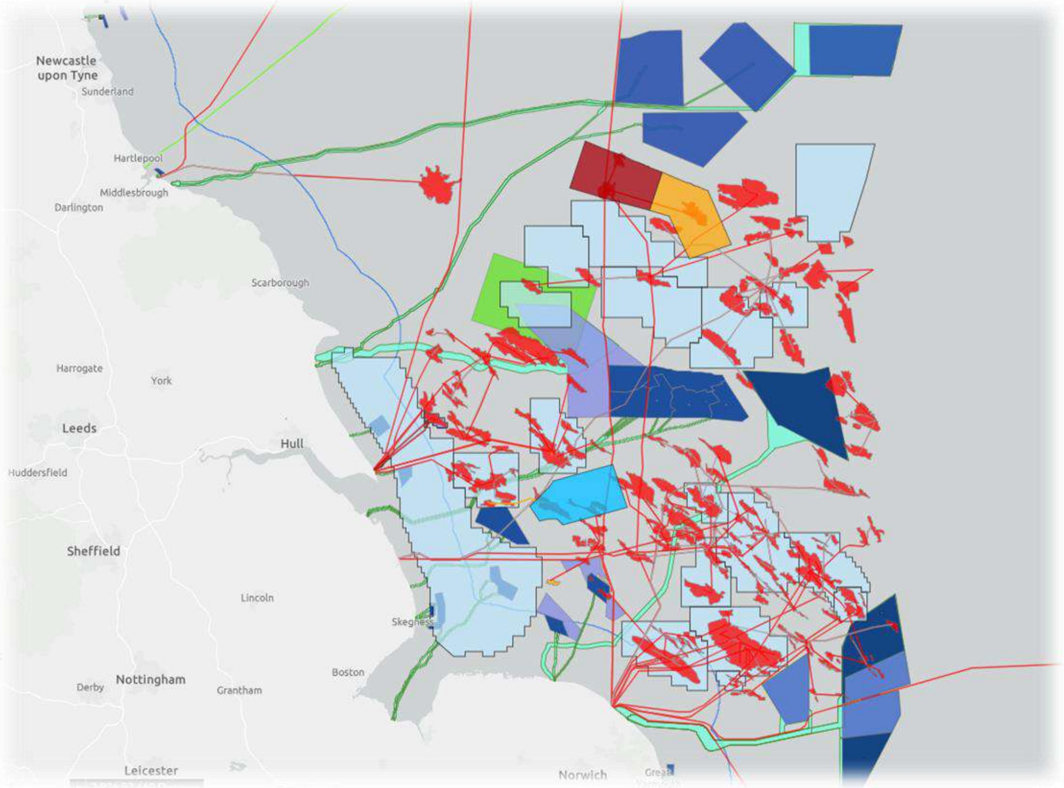
Key:
DESNZ: Department for Energy Security and Net Zero, **OFGEM:** The Office of Gas and Electricity Markets, **HMT:** His Majesty Treasury, **DBT:** Department for Business and Trade, **FCDO:** Foreign, Commonwealth and Development Office **OPRED:** Offshore Petroleum Regulator for Environment and Decommissioning, **HSE:** Health and Safety Executive

Spatial planning and co-location

Collaboration and proactive planning will be required to enable energy and decarbonisation systems to share space in an increasingly busy UKCS, alongside other marine sectors.

The NSTA works with other bodies to drive a co-ordinated approach to managing the seabed, including:

- both crown estates;
- the UK and Scottish governments; and
- the National Energy System Operator.



The NSTA, industry and offshore bodies are using data sharing and novel technologies to spatially optimise current and future projects.

For hydrogen:

- Whole system spatial planning can optimise space and realise synergies (e.g. integration with offshore wind)

- Repurposing existing infrastructure can be an asset to accelerate transition (e.g. repurposed reservoirs, pipelines, platforms and terminals)

International engagement

NSTA works with HMG, counterparts in neighbouring countries, industry and academia to develop a better technical understanding of global developments in the hydrogen sector and to support government policy on regional and bilateral cooperation:

- Engagement with HMG, counterpart states and regulators on the development of policy and regulatory requirements for future hydrogen interconnectors and transboundary assets;
- Engagement with UK and counterpart transmission system operators on the development of domestic hydrogen infrastructure and the potential for future cross-border interconnections;
- Engagement with industry and academia on international hydrogen projects, to develop an understanding of the latest developments in the sector, including for hydrogen production, storage, transmission and use.

Hydrogen – Technical Opportunities

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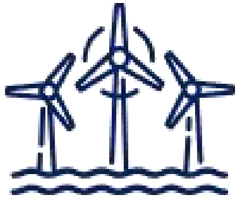
Hydrogen for renewables

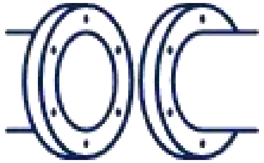


1 Hydrogen as dispatchable form of energy unlocking the full potential of offshore renewables

Storage

2 Hydrogen as solution of choice for long-term energy storage, to address seasonality and curtailments

Infrastructure repurposing



3 Capture full value of O&G legacy infrastructure (pipelines and terminals) for the net zero transition

How do we store H2 underground?

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UK H2 storage options / UK experience

	Onshore	Offshore
Salt Cavern	**Natural gas** • 6 store complexes operating in the UK • Each between 20 and 410 MCM capacity (1 to 10 caverns) **Hydrogen** • 1 cavern complex in Teesside (Sabic) operated ~20 years, now suspended • Two proposals at advanced stage of planning (2 TWh) • Significant international experience.	**Natural gas** • None operating • Project proposal in East Irish Sea, 19 caverns, 700+m depth, 1 BCM capacity **Hydrogen** • None operating • Proposal to convert in East Irish Sea project to hydrogen for 4 TWh capacity
Porous Rock	**Natural gas** • 2 onshore stores operating in the UK (converted depleted fields) • Between 100 and 300 MCM capacity **Hydrogen** • Two UK depleted field proposed • EU commercial pilot operating for 2yrs	**Natural gas** • 1 large offshore store, today 1.5 BCM capacity (but 3 BCM when at peak) • 1 advanced proposal in the East Irish Sea for 1.5 BCM **Hydrogen** • At least two project proposals to convert gas storage fields to hydrogen • Further proposals in the Irish Sea

Tested for both hydrocarbons (HC's) and H2 – FEASIBLE TODAY (green)

Good HC experience and H2 pilot projects ongoing (light green)

HC experience but not H2 (orange)

- 4 key options
  - Salt cavern / porous rock
  - Onshore / offshore
- H2 storage built on the industry experience of natural gas storage (40+ years)
- Can tap into international experience
  - Continental Europe where H2 storage (Caverns and Porous rock) are being piloted
  - US stores in commercial operations for 10-20 years
- UK subsurface has
  - Large salt deposits, onshore and offshore
  - Very large choice of depleted oil and gas fields

UK hydrogen subsurface storage potential

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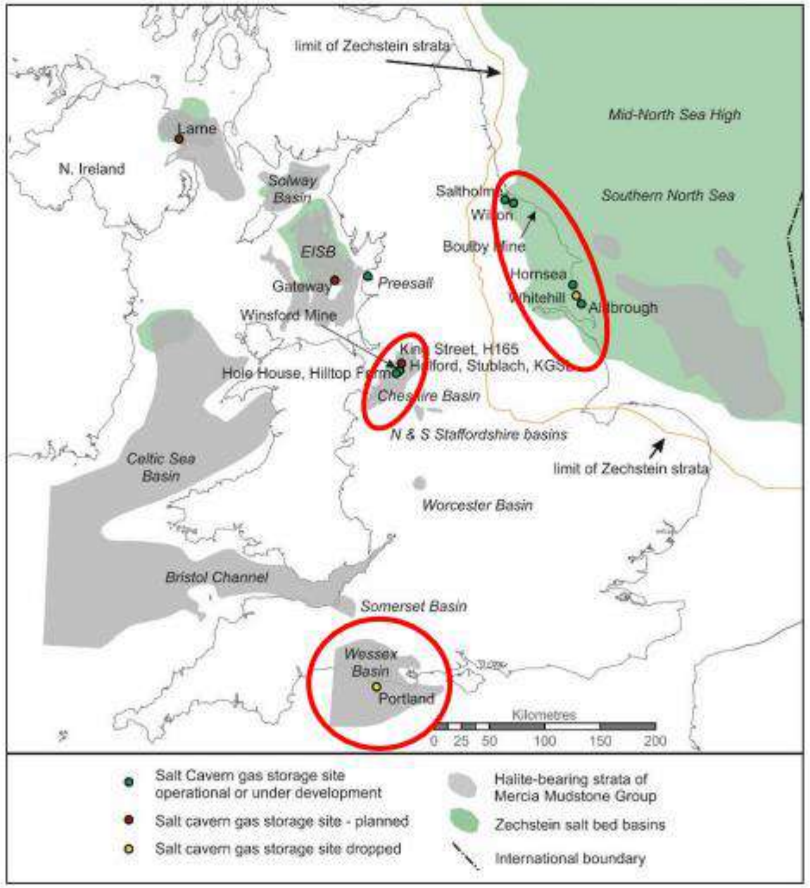
Salt caverns

- Caverns artificially made in subsurface salt formations
- Widely used for natural gas storage
- Flexible access and hydrogen purity
- Medium to large scale (0.1-1 TWh)



H2 storage potential in salt caverns

Onshore

2,150 TWh

49 TWh (NESO FES scenario)

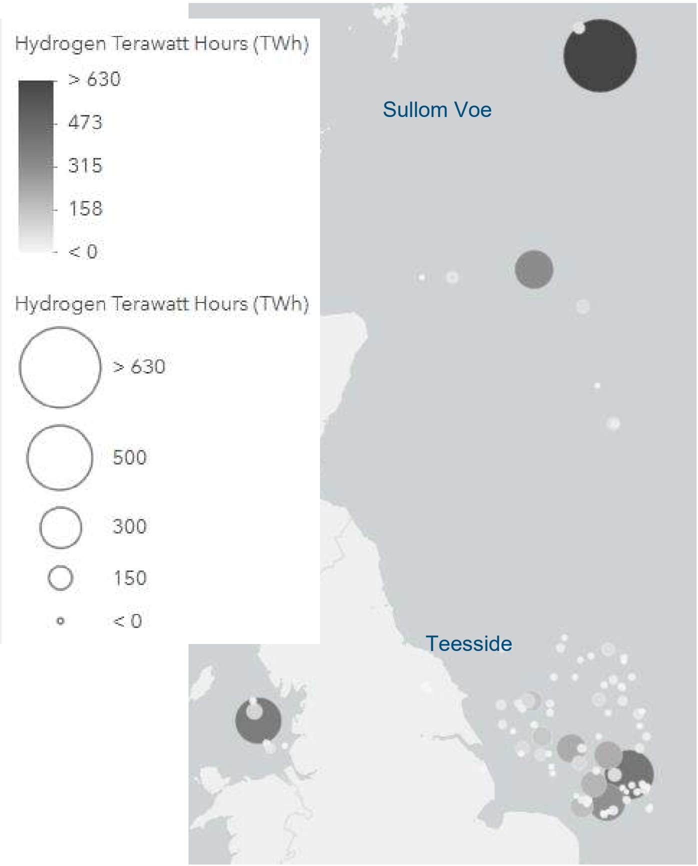
Offshore

292 TWh

49 TWh (NESO FES scenario)

Porous rock (Depleted O&G fields)

- Widely used for natural gas storage
- Allow seasonal stores (1-10 TWh)
- Hydrogen separation/processing after storage



3,455 TWh

49 TWh (NESO FES scenario)

References: BGS, University of Edinburgh, University of Aberdeen

Reference: University of Edinburgh

H2 for seasonal renewable energy storage

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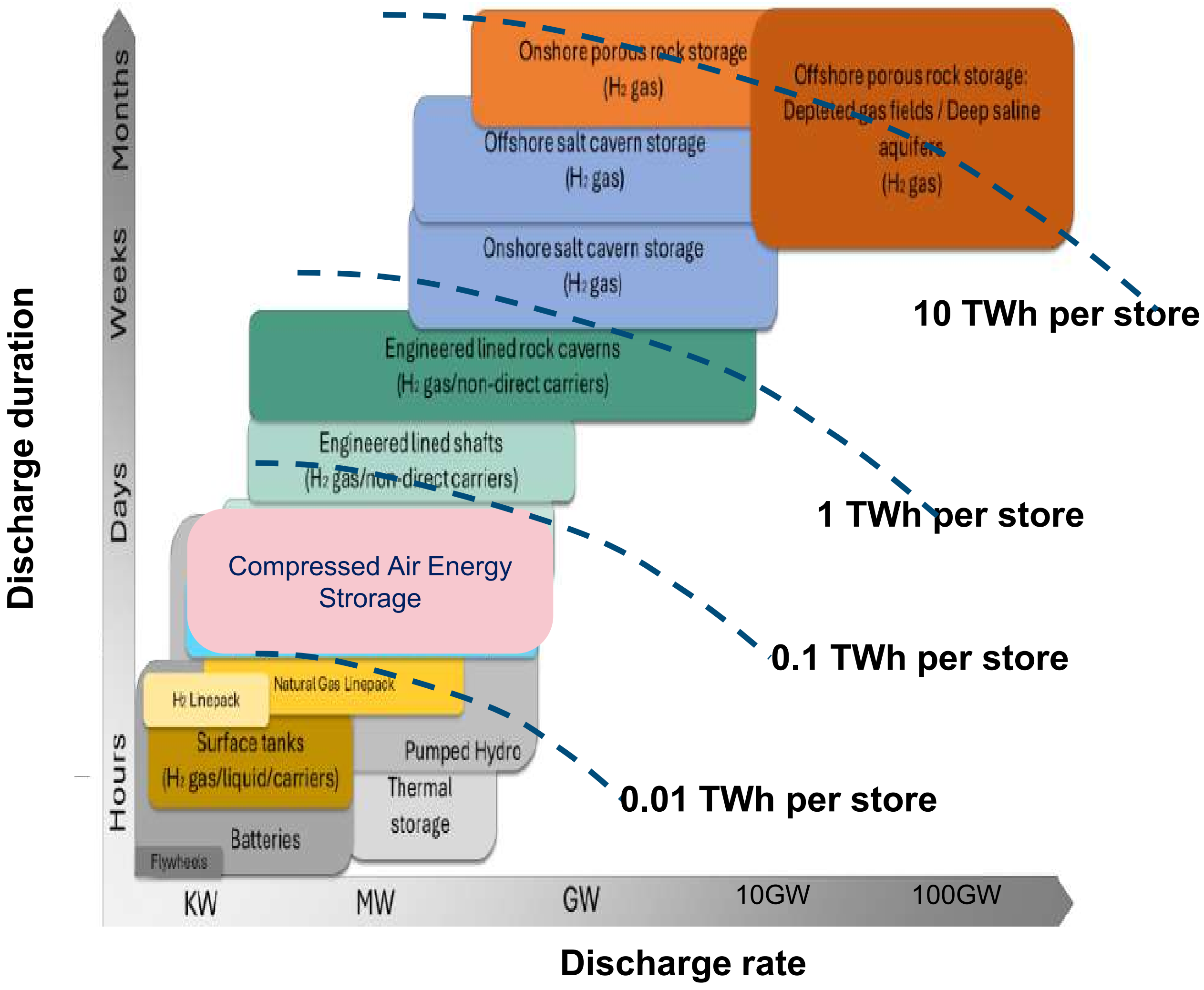
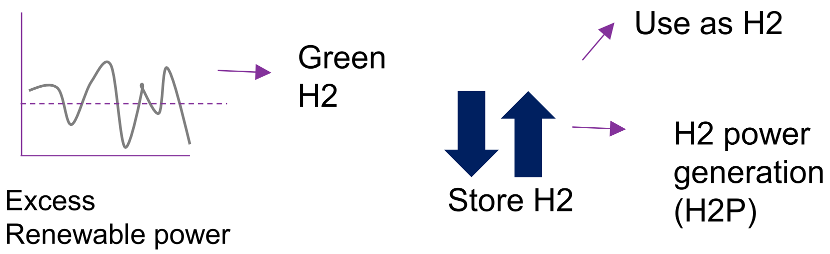
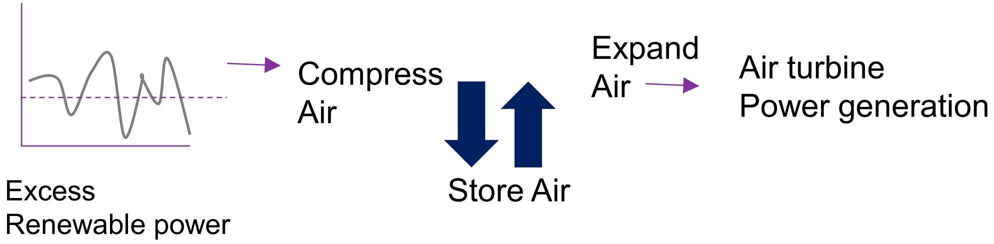
Energy storage capacity (TWh per store)



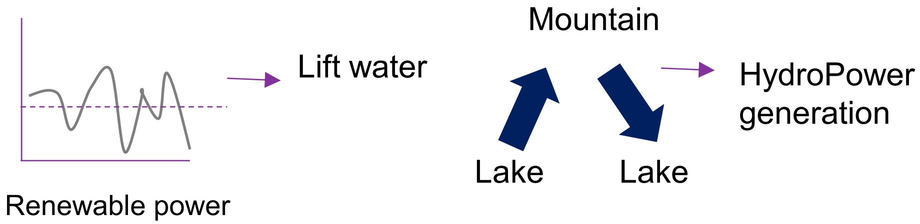
Green Hydrogen (stored underground)



Compressed Air Energy Storage (also Liquid Air)



Pumped Hydro



Batteries will ensure the required grid stability

References:
University of Edinburgh

Example: Offshore wind power Scottish Waters

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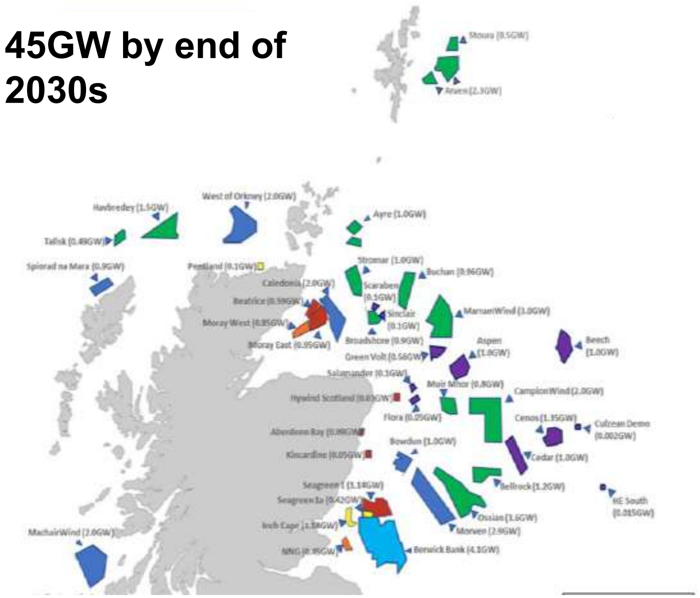
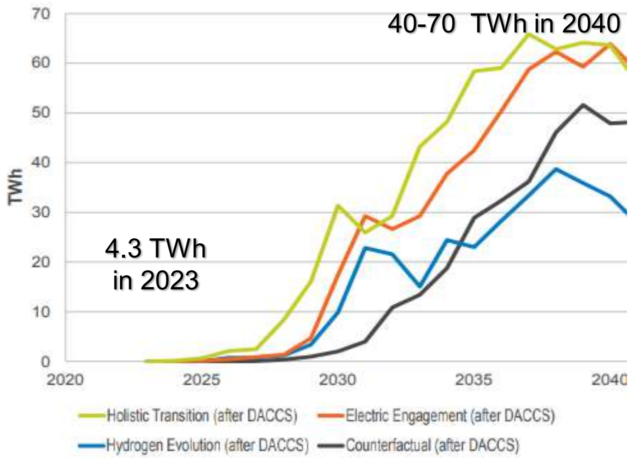
Delivering Scotwind & INTOG

45GW by end of 2030s

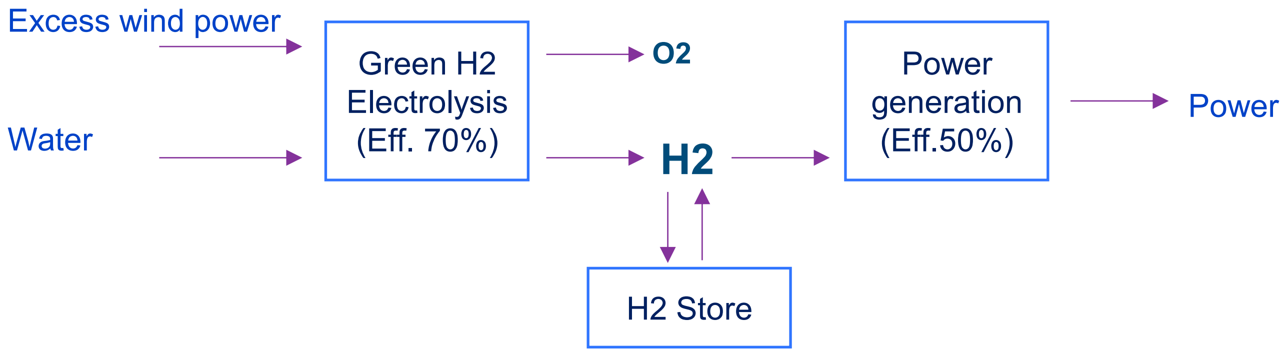


Avoiding wind power curtailments

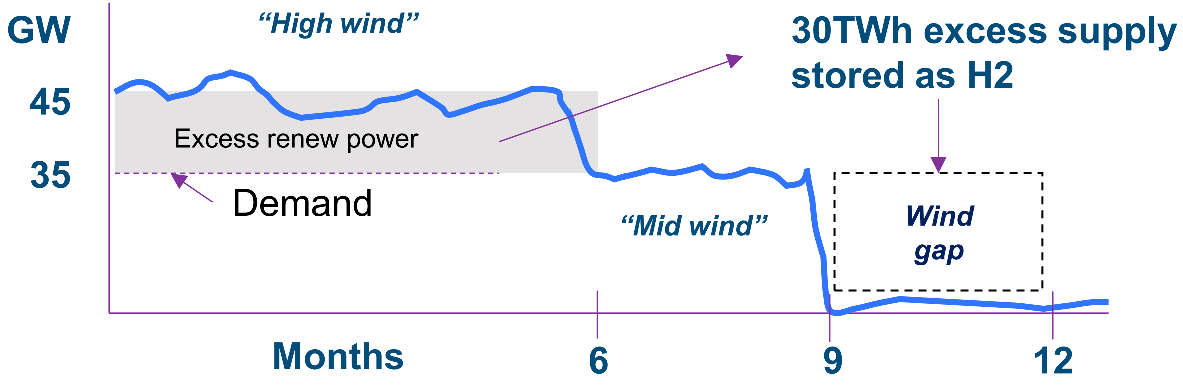


Source: NESO FES 2024, Drax Energy Insights

Hydrogen to Power (H2P)



Idealised wind power generation (Scottish Waters)



- **Also considering inefficiencies, excess wind power could produce 30TWh of storable H2 (20TWh of electricity back to grid) to offset "wind gap" periods**

Infrastructure repurposing for hydrogen

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2025 study with DNV

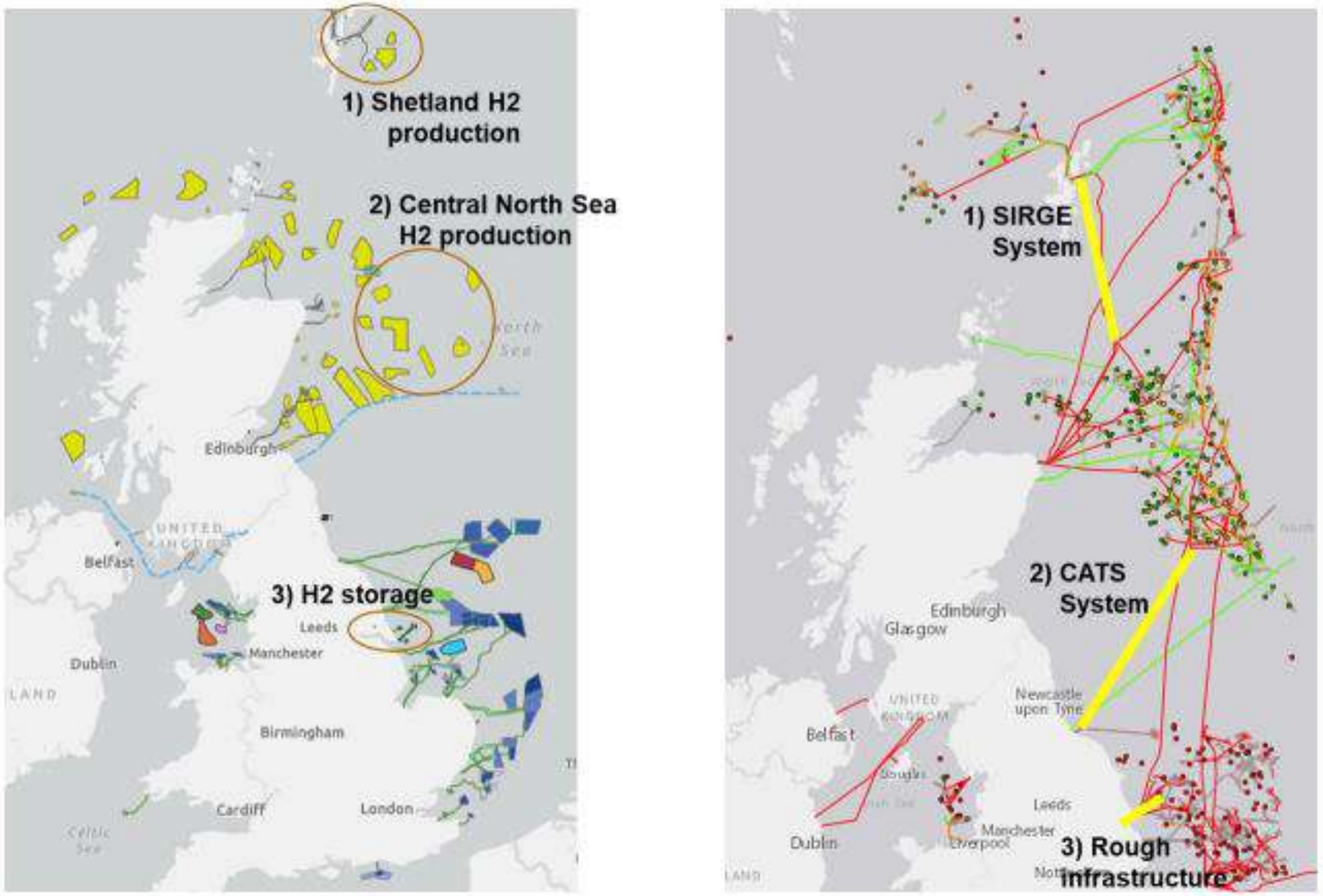


Figure 1 Potential hydrogen production and storage sites in the UK compared to the existing oil and gas infrastructure

Scope and findings

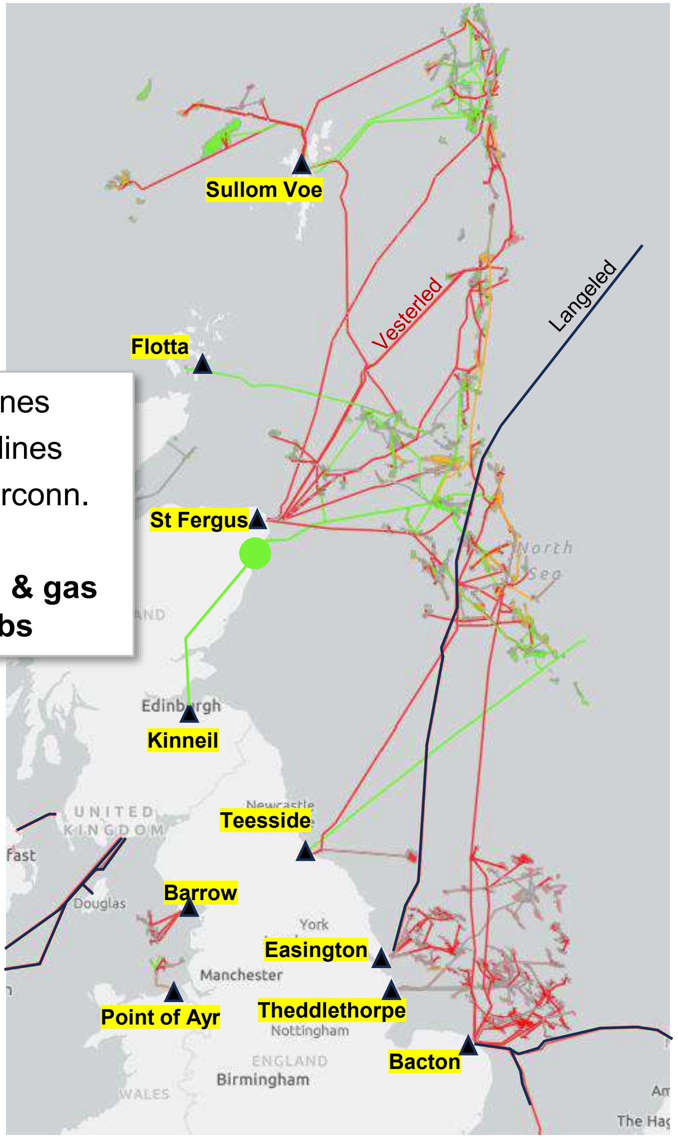
- Understanding if typical UKCS O&G infrastructure may meet technical requirements for repurposing to H2
- Considered three case studies in areas of future H2 interest:
  - Shetland Islands Regional Gas Export (SIRGE) – to transport clean energy from Shetlands
  - Central Area Transmission System (CATS) – H2 using surplus Scotwind developments' power
  - Rough – whether Rough existing facilities could be (partly) reused

Conclusions

- O&G designs and materials are suitable for H2
- However, offshore construction and operating conditions point to greater metal fatigue and integrity risks
- Extensive (and expensive) inspections and assessments needed
- As a result, deratings of maximum operating pressures and flow velocities will be likely
- Question of whether repurposing of specific facilities will make sense

UKCS midstream infrastructure

Offshore pipelines & onshore terminals



Extensive footprint

- ~120 major pipelines creating gathering networks
- In addition, ~800 intra-field flow lines
- Shared infrastructure serving >> fields in catchment areas

- 21 gas & oil onshore terminals in 10 hubs (see map)
- 3000+ acres consented
- 3000+ skilled workforce

Strong integration

- Majority of fields depend on both oil and gas infrastructure
- UK production co-mingled raw-gas imports

Risks

- Rationalisation / decom of key pipelines and terminals
- HC production at risk in 'catchment areas'

UK O&G terminals:

- ***Critical assets for UK's energy security***
- ***Repurposing potential for the energy transition***

More information on terminals' HC operations and their ET transition plans at www.nstauthority.co.uk

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Thank you

Questions?

Facilities

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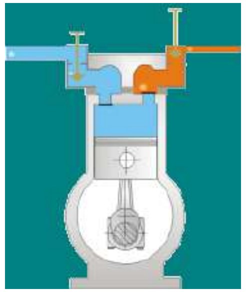
'Compression' and 'Gas processing' stand out for the greater complexity, costs (and R&D) to be fit for purpose for H2 storage

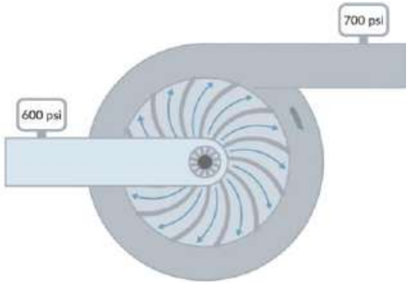
Compression

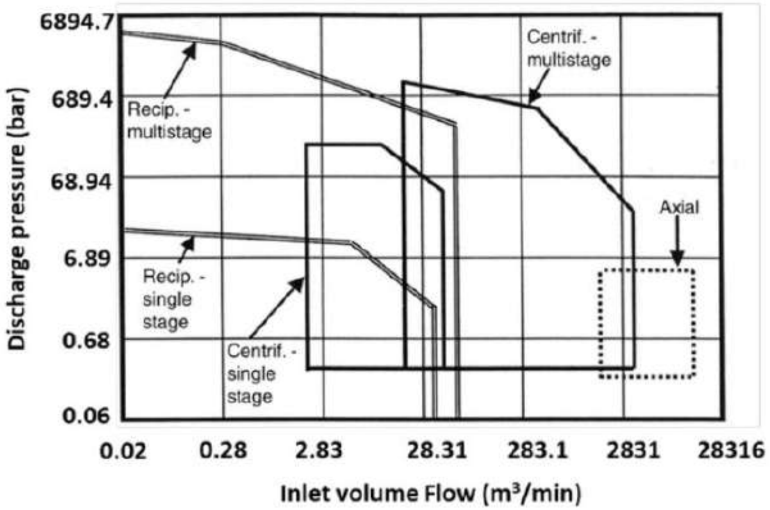
Due to H2 low molecular weight there are significant limitation of centrifugal compressors, and reciprocating (piston) units need to be used

These compressors are expensive and power-hungry. OEMs (Siemens, BakerHughes) are developing enhanced centrifugal compressors for high low/ high pressure H2 service

Reciprocating **Centrifugal**



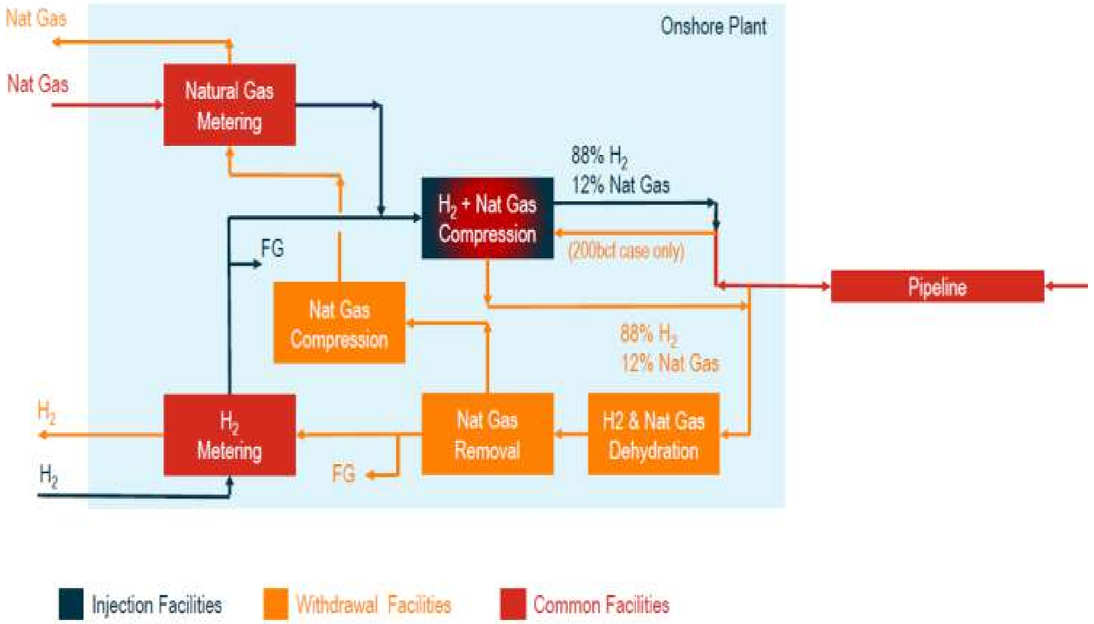




Gas processing

Post processing the H2 from salt caverns should be relatively simple (dehydration, and trace contaminants)

H2 Depleted gas fields, instead, require two entire gas process units: one for H2 conditioning, and one for hydrocarbon processing (either for sale or reinjection)



Hydrocarbon separation will be expensive and energy hungry, unless less strict H2 purity standards are used, eg 95 % H2 purity as opposed to 98 %

This would permit use of more efficient membrane technologies

References:
The Techno-Economics of Hydrogen Compression

Stakeholders engagement – ongoing

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Supply

Department for Energy Security & Net Zero	Green Hydrogen Allocation Round 1	HAR1 successful projects (published December 2023) - GOV.UK (www.gov.uk)
EET Hydrogen	Stanlow blue H2 (Hynet)	EET | Rebranding of Vertex to EET Hydrogen - EET
H2 Teesside	Teesside blue H2 (NEP)	H2Teesside - Project information (planninginspectorate.gov.uk)
equinor	Saltend blue H2 (Humber)	Equinor's H2H Saltend project given major boost as planning permission granted – Equinor

Infrastructure

national gas – **ProjectUnion**
- H2 1,200 km of mostly repurposed gas pipelines
- In first phase, connecting Industrial Decarb. Centres

FutureGrid
- Repurposing for 2%, 5%, 20%, 100% H2 blending
- Proven feasibility for full H2 transmission systems

Scottish Government / Riaghaltas na h-Alba / gov.scot – **Net Zero Technology Centre** (Technology Driving Transition) – **Hydrogen Backbone Link**
- Export
- Connecting into EU markets

Bacton Thames Net Zero – **centrica storage** – **EnQuest** – **kellas midstream**
- **Integrated energy hubs (O&G, H2, CCS, Wind, Storage)**
- Capture synergies to lower H2 supply costs
- Access to infrastructure (short and long term, eg H2 shipping)
- Repurposing of large industrial sites

Storage

nationalgridESO
- 50 TWh of capacity
- That is the equivalent of 5x Rough fields

Heriot Watt University – **IDRIC** – **UK Research and Innovation** – **BGS**
- Researching various parts of the Hydrogen system and economy

The University of Edinburgh – **HyStorPor** – **centrica storage**
- H2 storage criteria
- Screening

equinor – **sse Thermal** – **INEOS** – **Inovyn**
- Ongoing projects (salt caverns)
- Aldborough (North East) and Holford (Cheshire)

Demand

nationalgridESO Future Energy Scenarios
- 35-75GW H2 capacity required by 2050
- Up to 29TWh of hydrogen storage by 2050

national gas – **ProjectUnion**
- Develop a new H2 network
- Repurposing 1,500 to 2,000km of existing assets by early 2030s

SGN – **Cadent** – **Northern Gas Networks** – **Wales&West Utilities**
- Regional Gas Networks
- Stimulating regional demand industrial users (~10 initiatives)
- Opening H2 heating markets and blending

HyNet North West – **Zero Carbon Humber** – **capital hydrogen** – **The Solent Cluster** – **Project Cavendish** – **Net Zero Teesside** – **Hydrogen Valley** – **HumberZero**

Hydrogen storage case studies - summary

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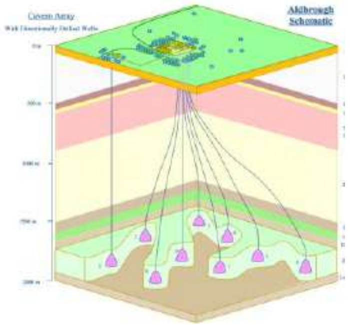
1. Onshore / Salt caverns

Where[1]

[1] Location of suitable salt deposits, plus ability to sell the mineral to local industry

Nine cavern storage site



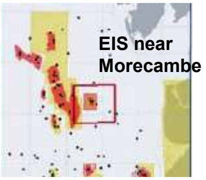
LCOS: Levelised Cost of Storage (WACC 5% is assumed)

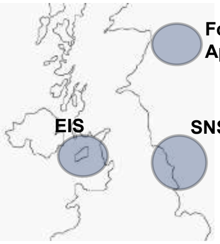
- Largest cost is mining caverns, partly offset by chemicals sales
- Scalable (multiple caverns)
- High H2 purity
- Proximity to clusters
- Short pipelines, simple compression, ~no treatment

Store model output (NSTA)
- Size, working gas: 280 MCM
- Cushion gas: 138 MCM
- Development Capex: £875m
- Working Capital: £41m
- Opex: £49m p.a.
- **LCOS: £ 1.34 /kgH2**

2. Offshore / Salt caverns

Where[2]





[2] Few offshore locations have suitable salt deposits at a reasonable distance from the shore

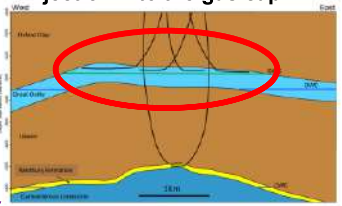
- Cost of mining caverns is larger than onshore
- Greater scalability means unit costs can be lower
- H2 purity and low cushion gas requirements
- Needs to be close to shore to limit rapid Capex and Opex escalation

Store model output (NSTA)
- Size, working gas: 1440 MCM
- Cushion gas: 709 MCM
- Development Capex: £2,226m
- Working Capital: £208m
- Opex: £135m p.a.
- **LCOS: £ 0.71 /kgH2**

3. Onshore / Depleted field

Onshore O&G licences

Humbly Grove case: Injection into the gas cap



Facilities

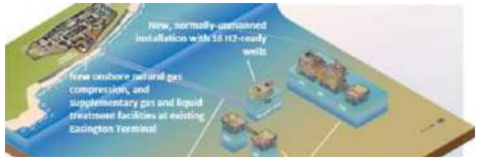
- Larger volumes vs salt cavern, but not down-scalable (tied to field size)
- High cushion gas costs
- Low H2 purity
- Processing equipment complexity, footprint and cost
- Needs infrastructure to transport produced hydrocarbons

Store model output (NSTA)
- Size, working gas: 279 MCM
- Cushion gas: 326 MCM
- Development Capex: £202m
- Working Capital: £95m
- Opex: £49m p.a.
- **LCOS: £ 1.37 /kgH2**

4. Offshore / Depleted field

Choice of depleted fields constrained by distance to sources/users (Rough 29km is the upper end)

Rough current footprint



Full redevelopment modelled: migrating all operations to shore (but still very expensive)

- Very large capacity but not down-scalable (tied to the field size)
- Very high cushion gas costs
- Low H2 purity
- Highest processing costs, need to sell or reinject hydrocarbons
- Moderate distances (10-30km) from shoreline more economically feasible

Store model output (NSTA)
- Size, working gas: 3300 MCM
- Cushion gas: 3850 MCM
- Development Capex: £1,393m
- Working Capital: £1,129m
- Opex: £92m p.a.
- **LCOS: £ 0.39 /kgH2**

Summary: Hydrogen storage case studies

North Sea Transition Authority

	Aldbrough	Gateway	Humbly Grove	Rough
Location	Onshore	Offshore	Onshore	Offshore
Geology	Salt Cavern (9 caverns)	Salt Cavern (20 caverns)	Depleted oil reservoir	Depleted gas reservoir
Working gas capacity (MCM)	280	1440	279	3300
Cushion gas capacity (MCM)	138	709	326	3850
Total number of Wells	9	20	8	16
Flow rate (MCM/D)	27	46	8.5	46
Time to fill/empty store (D)	15	35	35	90
No. of full cycles per annum (# turns)	3	3	2	2
Development Capital costs (£m)	875	2226	202	1393
Working capital costs (£m)	41	208	95	1129
Operation costs (£m pa)	49	135	49	92
Levelised Cost of Storage (£/kgH2)	1.34	0.71	1.37	0.39
Levelised Cost of Storage (£/CM)	0.11	0.06	0.11	0.03

- Levelised cost of storage (LCOS) decreases as storage is moved offshore from onshore.
- The development capital costs for both onshore and offshore depleted reservoirs is lower than their salt cavern counterparts but they also have higher working capital costs.
- Note: the initial process designs have been engineered to meet operating requirements but have not been optimised which could result in a reduction in costs.

Q&A:

HYDROGEN'S ROLE IN A RAPIDLY EVOLVING NORTH SEA ENERGY SECTOR

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North Sea Transition Authority

Hydrogen Scotland

Thank you

for joining us

today!