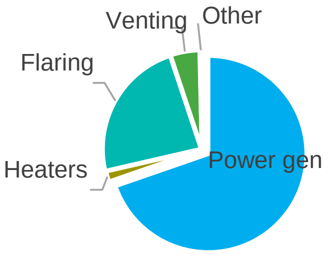
1. Offshore electrification

Offshore electrification – context

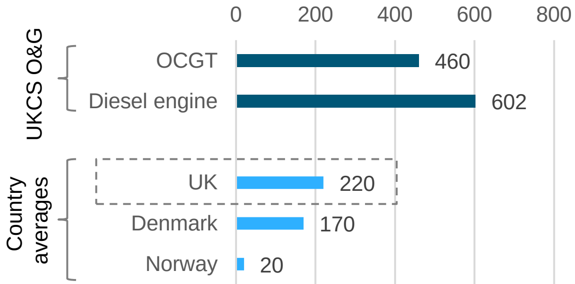
Oil & Gas Authority

Offshore O&G emissions (14MtCO_2e)

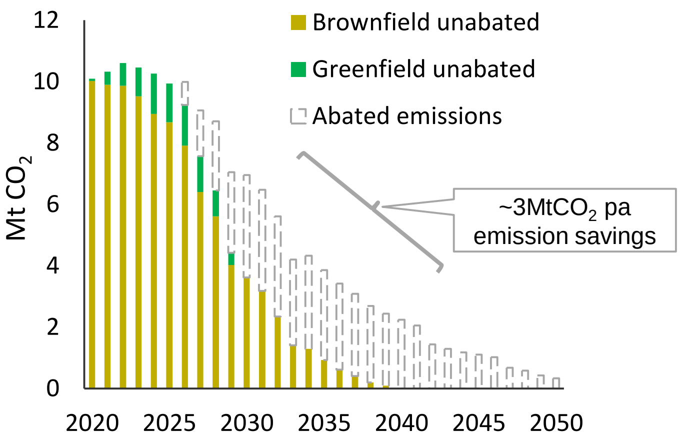


Source: EEMS 2018, EIP

Carbon intensity of power generation (kgCO_2/MWh)



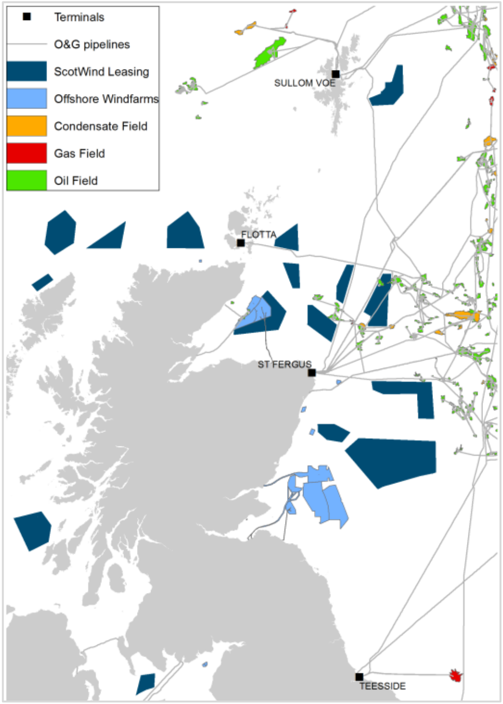
Potential emission reduction from electrification



North Sea Transiton Deal - committment

- 2025: -10% GHG emissions
- 2027: -25%
- 2030: -30%
- 2050: Net zero

Windpower expansion in Scottish waters



CES data and OGA Digital Platform

Cross-sector synergies

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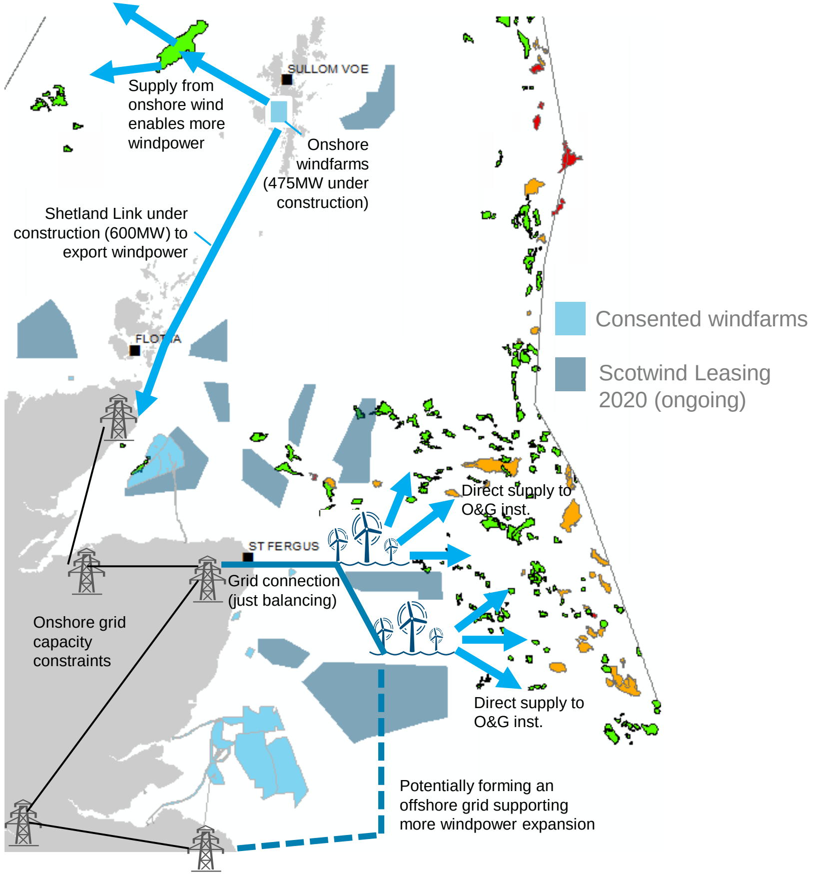
O&G operations and Windpower expansion (Scotland)



Offshore windpower and electricity transmission

- Strong windpower growth targeted: 40GW by 2030, 75GW by 2050 (projected)
- Move to deep waters: floating wind 1 GW by 2030
- Expansion in Scottish waters: transmission bottlenecks, onshore grid capacity constraints slowing down new windfarms until mid 2030's
- Electrification of oil and gas installations: 2GW power demand available today (~1.5GW in CNS, ~0.5GW in Shetland)
- Can support 3-4GW windpower capacity developments by supplying directly to offshore installations (*demand cables*) avoiding burden on onshore grid
- Additional O&G investment in offshore transmission could create an offshore grid lasting beyond O&G operations to debottleneck onshore capacity

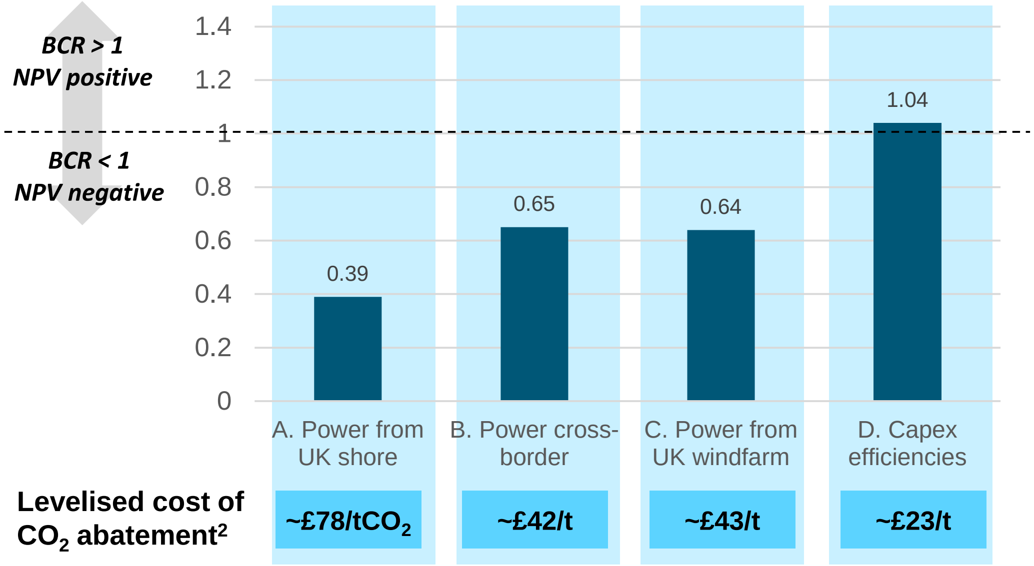
Hydrogen

- Risk of curtailment of renewable power generation as significant capacity is added from intermittent sources (e.g. windpower) in the 2030's
- Cost of electricity transmission from production areas to demand centres increases due to longer distance and cable inefficiencies
- Hydrogen can represent an efficient energy transportation & storage solution to address these two challenges
- Additional benefit from a gradual and cost-effective conversion of large energy users compared to electrification (industrial processes, domestic heating)
- O&G industry's capabilities and infrastructure can support the ramping up of cost-efficient hydrogen supply that the UK will need

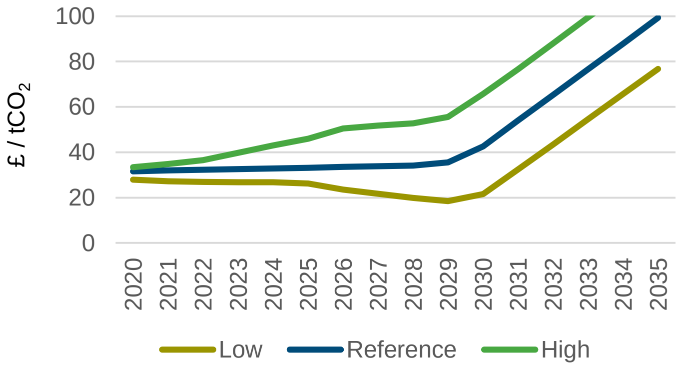
Electrification schemes (economics)

Oil & Gas Authority

Benefit-cost ratios[1]



Carbon prices projections[3]
(Electricity supply sector, inclusive of EU ETS and UK CPS)



3) BEIS Updated Energy & Emissions Projection - Annex M (May 2019)

Enablers

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Technical

- Floating wind – approach cost parity with ‘fixed bottom’
- Long distance transmission infrastructure (eg HVDC, reducing costs)
- Brownfield modifications
- Hydrogen as viable alternative? To reduce brownfield changes and mitigate grid constraints
- Systems not connected to shore (power continuity)

Regulatory / Economic

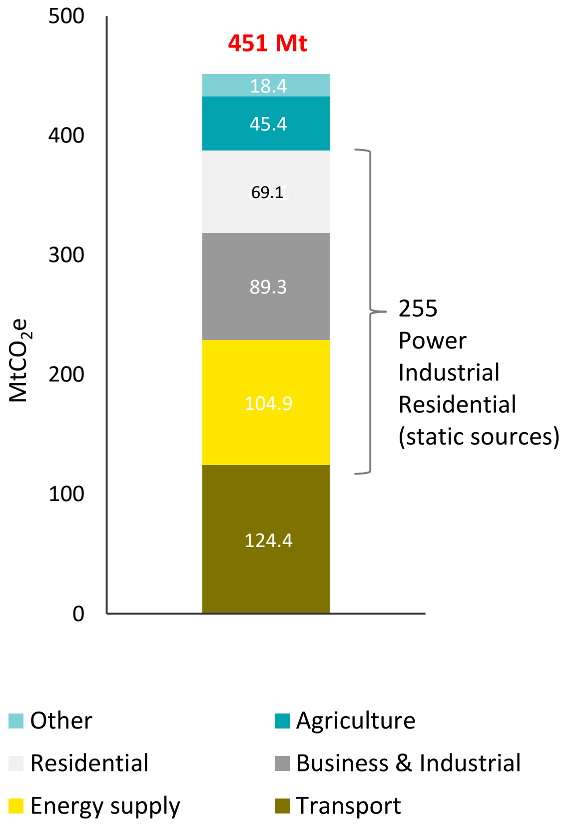
- Aligning windpower projects (consenting and planning) with O&G needs
- Debottleneck onshore grid capacity
- Commercial – aggregate power buying
- Funding / financing

2. Carbon capture and storage

CCS will be critical for net zero

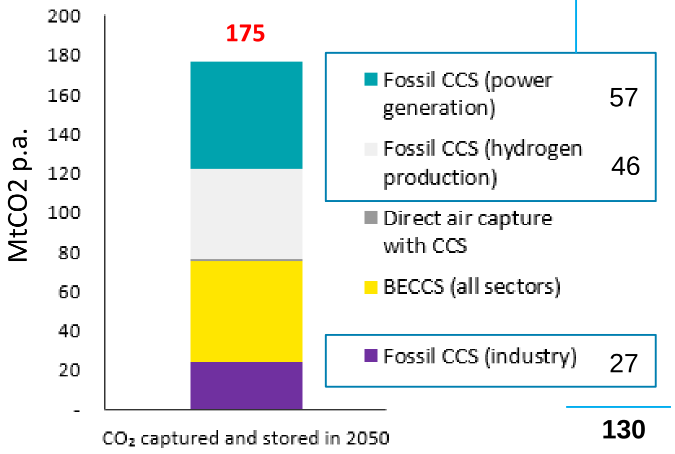
Oil & Gas Authority

UK CO_2e emissions (2018)

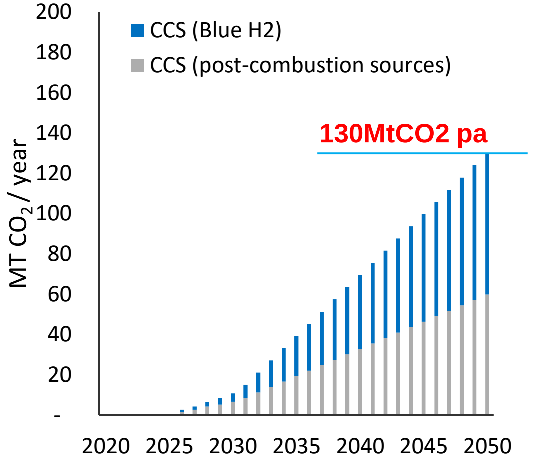


Fossil fuels continue to remain important

CO_2 captured and stored in 2050 (CCC prediction, up to 175mTpa)



UKCS CO_2 injection rates (EIP scenario)



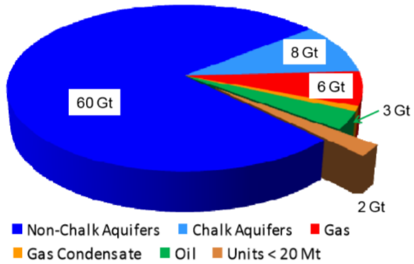
Committee on Climate Change (2019) 'Net Zero: The UK's contribution to stopping global warming' (high case shown)

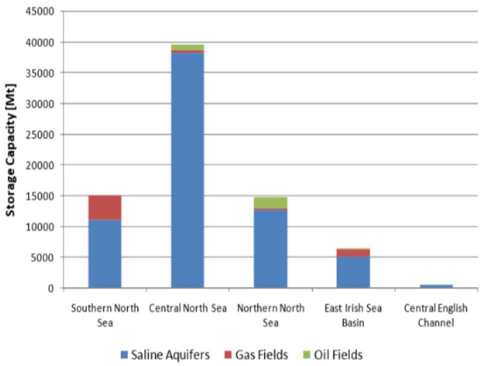
BECCS = Bio-Energy with CCS

Where can the CO_2 be permanently stored

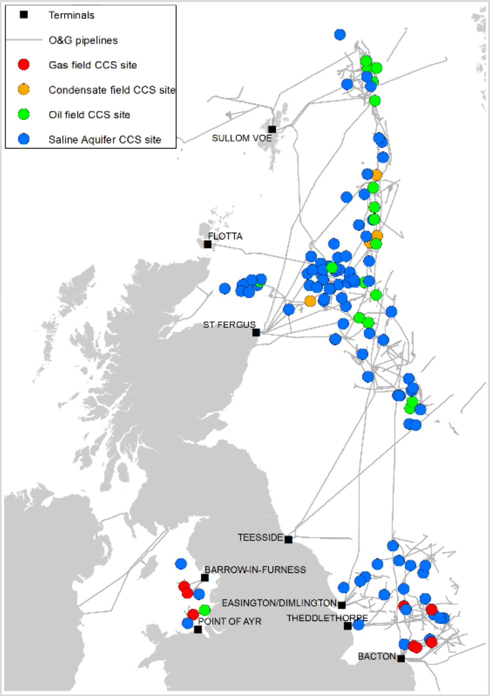
The UKCS is estimated to hold ~78Gt of potential CO_2 storage capacity, in over 560 subsurface stores[1]. This capacity could potentially cover UK needs for 100s of years. However more work is needed to understand the effective UKCS CO2 storage potential.

UKCS CO_2 potential storage capacity[1]





Store locations and O&G infrastructure



Main considerations for CO2 storage appraisal

Elements	Main criteria
Reservoir (All)	• Trapping mechanism • Seal competence • Store capacity • Injectability • Geomechanical effects • Geochemical compatibility
Reservoir (O&G repurposing)	• All of the above • Reservoir conditions at abandonment • Damage to seal formation as a result of O&G production • Formation damage which may affect injectability
Wells (P&A)	• P&A methodology • CO_2 resistant barriers • Verification • Long-term monitoring
Wells (Repurposing)	• Well trajectory • Casing and cementing • Side-tracking and re-completion options

1) ETI, BGS, et al. UK Storage Appraisal Project (2011)

BGS CO2stored.co.uk, and BGS/EIP analysis

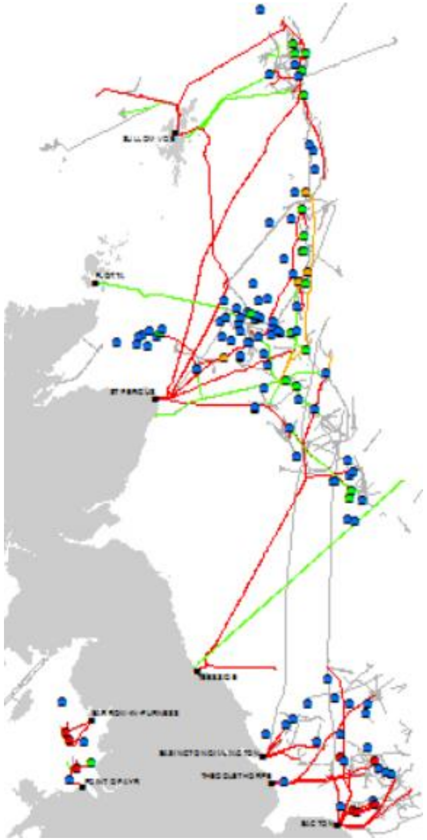
EIP analysis

2) Axhurst, M, et al. Steps to achieve storage readiness for CO_2 source clusters; GHGT-14 Conference (2018)

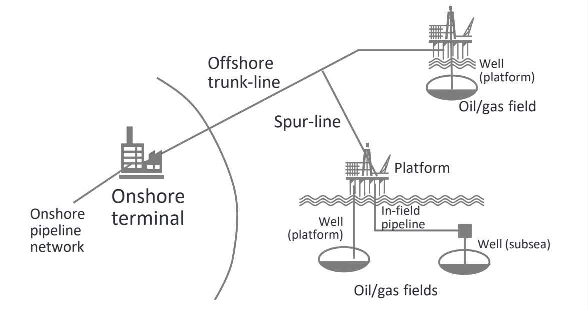
Can O&G infrastructure be reused

Oil & Gas Authority

Oil & Gas pipelines with landfall (red, green, amber)



Oil & Gas infrastructure



Trunklines and spurlines (ca. 100 on UKCS) connecting offshore platforms with terminals; transporting separated, pre-conditioned hydrocarbons; better candidates for reuse:

- Location (connecting terminals to main CO_2 storage areas)
- Larger diameters and higher design pressures
- Having transported less corrosive fluids
- Having had better corrosion prevention, monitoring and inspections

Intra-field pipelines (ca. 1000 on UKCS) 'tie-in' nearby fields to main platforms. Less suitable for reuse for lack of above characteristics.

Platforms can be considered for reuse. CCS platform would be low-Opex, normally unmanned well-head installations, in particular if the original wells can also be repurposed.

Other subsea equipment, specifically designed for O&G wells control and fluid handling, very difficult to retrofit for CO_2 injection.

EIP Phase 2 analysis

Criteria for repurposing and reuse

Elements	Assessment criteria
Pipelines	**Design parameters** Original design compatible with CO_2 transport, and/or modifications are possible
	Flow assurance Pipeline operations to ensure CO_2 is maintained in the same phase and free water not formed
	Internal corrosion Depending on the pipeline material and assurance against water condensation, verify that sufficient corrosion allowance is in place
	External corrosion Integrity of external coatings (where exposed), absence of damage (eg trawlers), cathodic protection for intended operational life
	Installation and seabed conditions Verify pipeline stability (including seabed loads, free spans, and buckling) due to the greater CO2 fluid density and different temperature profiles
	Other components Compatibility of other pipeline components with CO_2, including spools, risers, valves, pigging

EIP Phase 2 analysis

Initial ramp-up driven by industrial clusters

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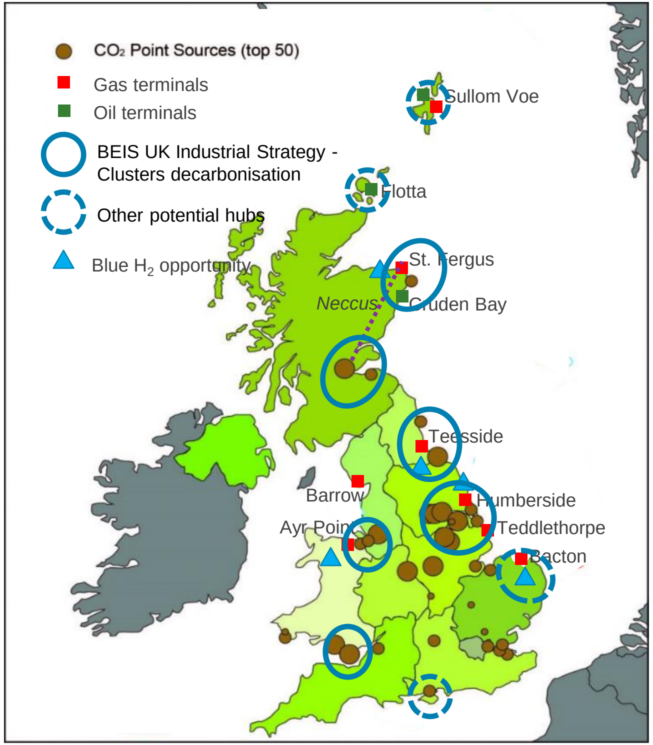
UK industrial clusters and largest CO_2 sources



CO_2 point sources (ETI)

CCS / blue hydrogen potential ramp up (OGA analysis - 2020)

Clusters(1) / Hubs	CCS	Blue H_2	Green H_2	Potential CCS volumes (MTCO2 / year)				Opportunity
				2025	2030	2040	2050	
Sullom Voe								Windpower growth green H2
Flotta								Windpower growth green H2
St Fergus Grangemouth				1	2.5			Acorn and other projects to include blue H2 and NECCUS
Teesside				1	2.5			Teesside Net Zero decarbonisation incl blue H2
Humber-side/ H21 Leeds				1	2.5	?		Zero Carbon Humber (incl.H21 20MtCO2/yr)
Bacton								Blue H2 from SNS and gas imports + green H2 from wind
Merseyside-Ayr Point				1	2.5			HyNet blue Hydrogen and CCS from industrial sources
South Wales								CCS industrial decarbonisation and green H2 from wind
MtCO2 / yr (EIP outlook)				**4**	**10**			

1) UK Industrial Strategy and Industrial Cluster Mission (BEIS, see appendix for references), CCS and blue hydrogen potential (EIP analysis)

Enablers

Oil & Gas Authority

Technical

- CO_2 storage exploration
- Development: wells, processing, transportation
- Existing infrastructure: repurposing assessment, brownfield modifications
- Subsurface management and monitoring
- Infrastructure monitoring and remote operations
- …

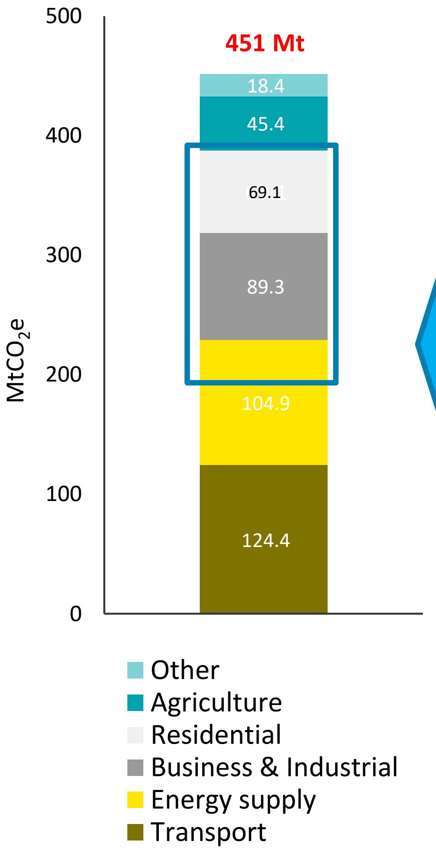
Regulatory / Economic

- Government support
- Drive cost down to commerciality (scale, learning)
- Onshore CO_2 capture infrastructure
- Planning of other CO_2 sources eg Blue H_2
- O&G industry capabilities and supply chain, ensure timely transition
- …

3. Hydrogen

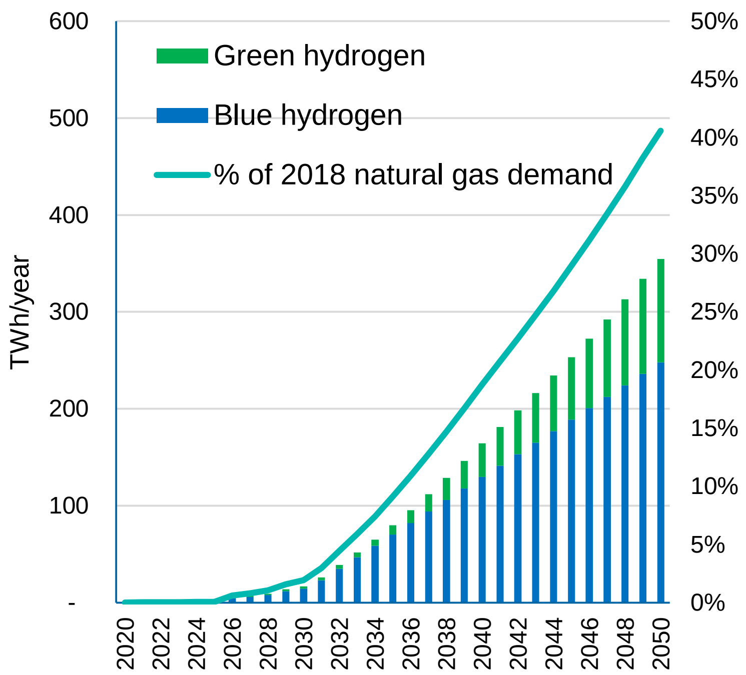
Importance for decarbonisation

UK CO_2e emissions (2018)



- Hydrogen can be an efficient way to deliver low-carbon energy to a large share of energy users
- Delivered as gas
- Pure or gas blending
- Can accelerate transition (eg does not require previous "electrification" of uses)

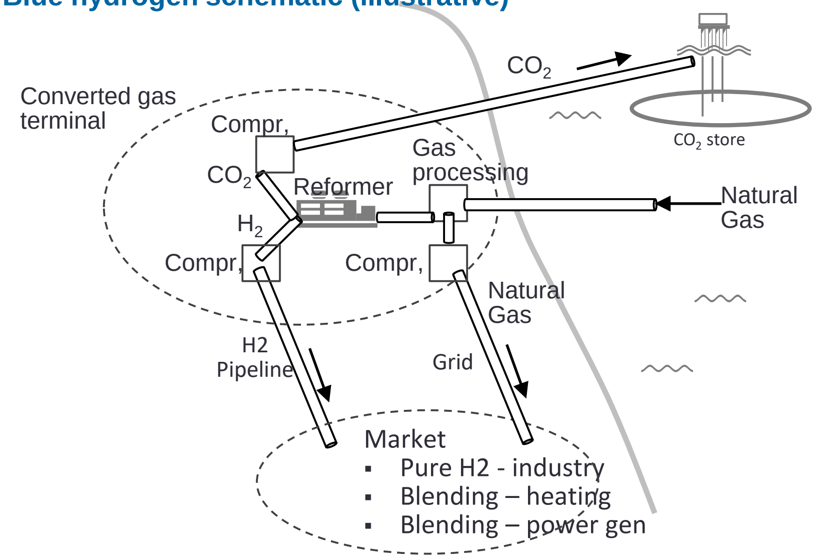
Hydrogen growth scenarios



Hydrogen supply – Blue

Oil & Gas Authority

Blue hydrogen schematic (illustrative)



Steam methane reforming plant

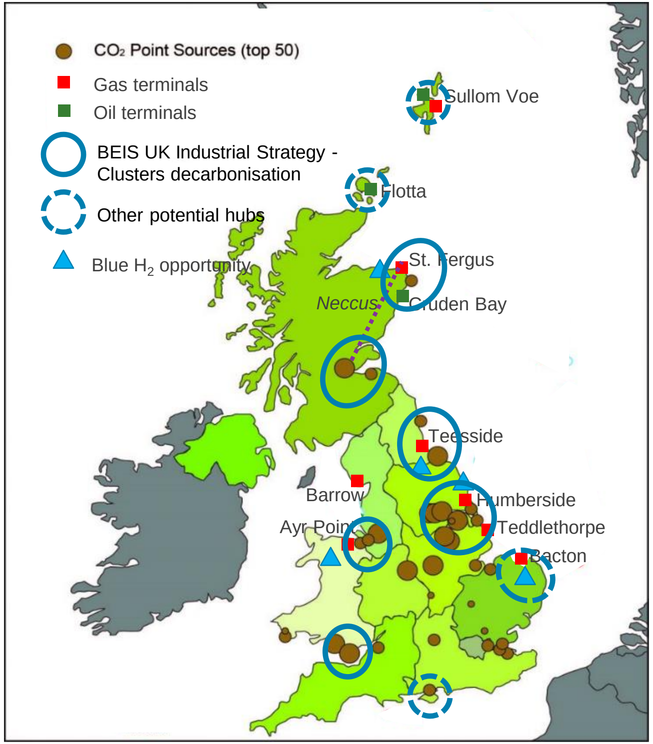
Blue hydrogen economics (illustrative)	
Characteristics	Methane reformer Capacity: 200MW th (output) Efficiency: 75% Natural gas consumption 19.5T/h (8.41Bcf/y) H2 production 6T/h (1.75 TWh/yr) CO2 capture 51T/h (0.45 MTCO2 pa)
Capex	Equipment £130m Fabrication 78 Installation 20 Project costs 45 Total Capex £203m
Opex	Fixed £11m/yr Variable 27 Natural gas 62
H_2 levelised cost	**2.66 £/Kg plus** **0.17 £/Kg offshore CO2 T&S @ £20/tCO2** **2.83 £/Kg (85 £/MWh)**

Breakeven with electricity wholesale price (5p/kWh, 2020): £1.68/KgH_2

Next steps: leverage low natural gas prices, deploy existing technology (reforming), repurposing O&G infrastructure, support growth of onshore H_2 demand,

Blue hydrogen ramp up

UK industrial clusters and largest CO_2 sources



CO_2 point sources (ETI)

CCS / blue hydrogen potential ramp up

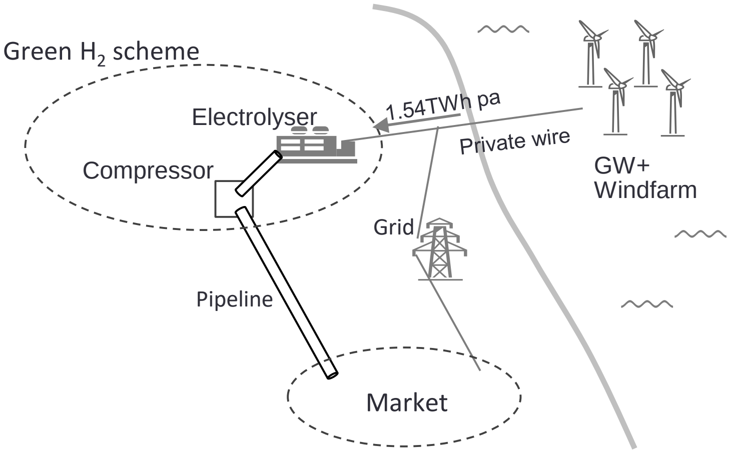
Clusters and Hubs	CCS	Blue H_2	CCS / blue hydrogen development potential
St Fergus - Grangemouth			*Acorn* project. CCS from BlueH2 and combustion sources. NECCUS link from Grangemouth (4.3MtCO_2/yr)
Teesside			*Net zero Teesside* decarbonisation including blue H_2. Teesside industrial cluster emissions (3.1MtCO_2 p.a.)
Humberside			*Zero Carbon Humber* (12.4 MtCO_2/yr) includes Blue H2, BECCS and links with H21 project ources (20MtCO_2/yr)
Bacton			Potential Blue H2 from SNS gas and interconnector imports. Green H2 from large expected windpower exp.
Merseyside			HyNet Blue Hydrogen (volumes TBD) and additional CCS from industrial sources (2.6 MtCO_2/yr)
South Wales			Large industrial cluster with 8.2 MtCO2/yr emissions, CO_2 could be transported by ship to storage sites
Southampton			Industrial cluster with 2.6 MtCO2/yr emissions, CO_2 could be transported by ship to storage sites

1) UK Industrial Strategy and Industrial Cluster Mission (BEIS, see appendix for references), CCS and blue hydrogen potential (EIP analysis)

Hydrogen supply – Green

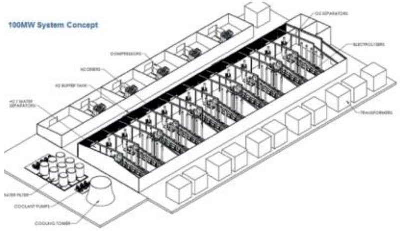
Oil & Gas Authority

Green hydrogen schematic (illustrative)



New technology proton exchange membrane (PEM)

Gigc-scale electrolysis plant (concept)



Green hydrogen (electrolysis) economics (illustrative)	
Characteristics	Onshore electrolyser Capacity: 250MW (£2m/MW) H_2 conversion efficiency: 70-80% Project life: 31 yrs
Capex	Electrolyser £129m (£0.52m/MW) H2 compressor £38m (£1.15/KgH_2yr) <u>Ancillaries £333m (2x equipment)</u> Total Capex £500m
Operational	Operational hours: 8,760 / yr H_2 output (net): 1.54 TWh/yr H_2 output (net): 39.5 kt/yr Electricity consumption: 2.19 TWh/yr Electricity price: 53 £/MWh (landed from windfarm at cost) H_2 compression: 12% of H_2 gross output Opex: £16.7 / yr
H_2 levelised cost	**0.63 £/Kg (excl. electricity)** **3.60 £/Kg (incl. electricity)**

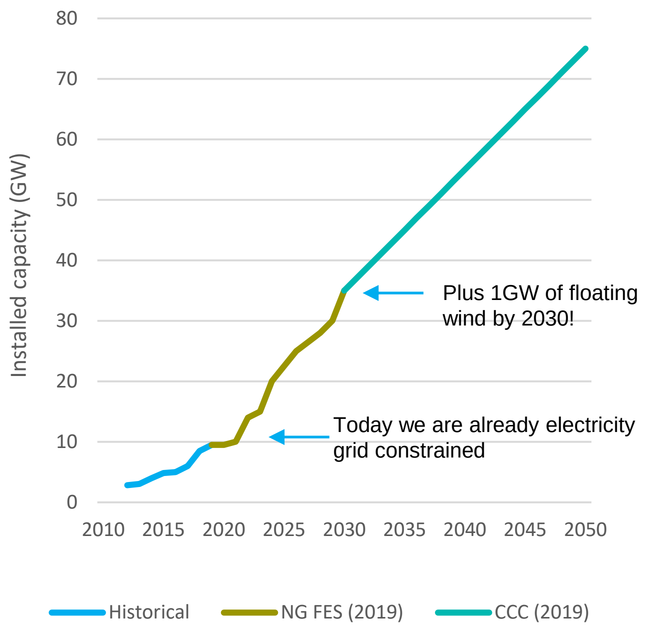
Breakeven with electricity wholesale price (5p/kWh, 2020): £1.68/KgH_2

<u>Next steps</u>: Debottleneck windpower growth, leveraging ultra-low renewable electricity prices (oversupply), invest technology development (electrolyser cost reduction)

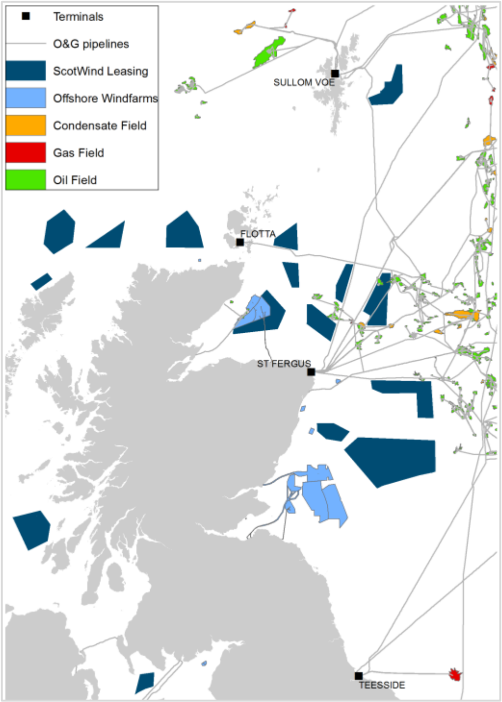
Green H2 unlocks power transmission and storage

Oil & Gas Authority

Targeted growth in UK offshore windpower capacity



Expansion in more distant regions
Eg recent Scotwind Leasing areas (2020)



- Converting renewable electricity to hydrogen…
- Can provide efficient transportation / buffering and storage
- Can give access to extensive natural gas distribution (eg via blending)
- Can open export market for zero carbon energy (H2 exports by pipelines to Europe and ships)

Enablers

Oil & Gas Authority

Technical

- H2 transportation and onshore usage
- Electrolysis
- Offshore hydrogen generation (several themes)
- …

Regulatory / Economic

- Government support
- Energy transmission strategy
- Ramping up hydrogen demand (industrial, households)
- …