Oil & Gas Authority

UKCS Energy Integration

Final report

Contents

Cover image: Windfarm development in Liverpool Bay (Ørsted)

Foreword by Dr Andy Samuel, OGA Chief Executive

Over the past few years, the OGA has increased its focus on the energy transition. The Energy Integration Project began in early 2019 with a £900,000 grant from the Better Regulation Executive's Regulators' Pioneer Fund.

The project purpose was to explore how different offshore energy systems (oil and gas, renewables, hydrogen and carbon capture and storage) could be co-ordinated across the UK Continental Shelf (UKCS) for environmental and efficiency gains, including identifying technical, regulatory and economic hurdles.

Working with the Department for Business, Energy and Industrial Strategy (BEIS), The Crown Estate, Ofgem and others, we published our interim findings in December 2019. This confirmed the technical feasibility of energy integration, providing viable options for helping decarbonise the economy.

Since the project began, the UK became the first major economy to set a target of net zero emissions by 2050; and the OGA began to refresh its core Strategy to integrate net zero and develop benchmarking to track and monitor emissions performance. The focus of this project also progressed to include quantifying how energy integration could contribute to emission reductions.

The results are remarkable. Integration has the potential to make a deep and meaningful impact, with a possible 30% contribution towards the country's overall net zero target, primarily through carbon capture and storage (CCS), and through CCS plus hydrogen.

Adding offshore renewables (wind, wave and tidal) could take that up to 60% of the abatement required in 2050; demonstrating that the UKCS is a critical energy resource. We're working with other regulators, government and industry to ensure this potential is delivered at pace as part of the UK green recovery.

The project has focused on identifying the opportunities and specific barriers the organisations can address, but of course it also sits in the context of wider government policy, such as the work on business models and carbon pricing, which will be important in shaping progress.

For the oil and gas industry, energy integration can help reduce production emissions, as well as accelerate the progress of CCS and hydrogen in support of net zero. These are essential for the sector's 'social licence to operate'. For offshore renewables, there are real opportunities for increased collaboration with oil and gas skills and supply chain for further expansion.

We will continue to work with project partners, industry and others to implement the recommendations and actions set out in this report to accelerate the UKCS net zero potential.

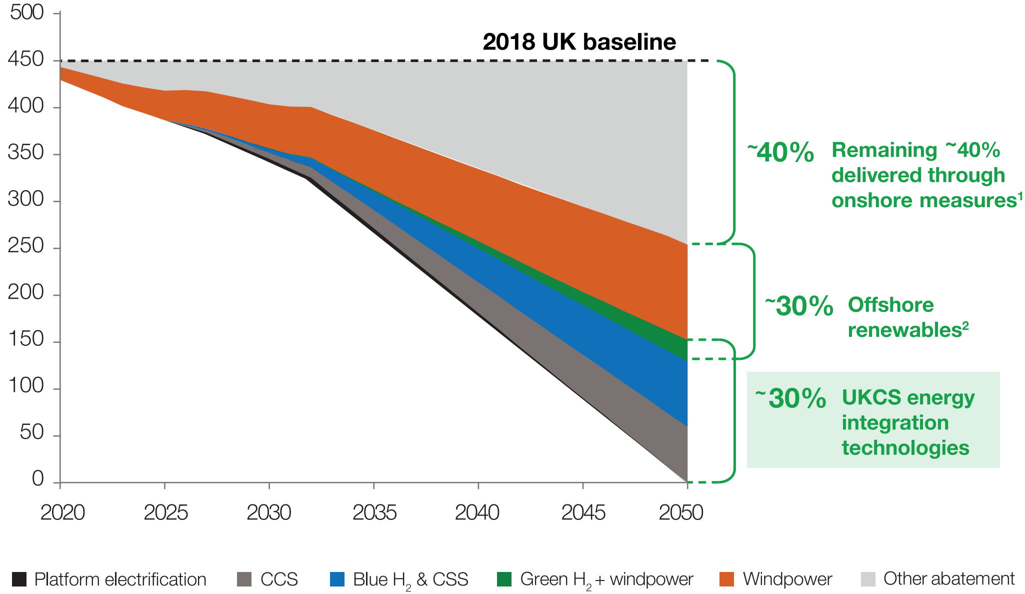
Executive summary

The UKCS is a critical energy resource which could play a significant role in achieving the UK net zero target.

Energy integration technologies (offshore electrification, CCS, blue and green hydrogen) could contribute around **30% of the UK emissions abatement needed.**

In addition, these technologies could **support the expansion of offshore renewables,** which could deliver around a further 30% contribution to the net zero abatement target.

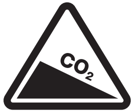
UKCS potential contribution to net zero target



Note: See description of methodology in appendix

[1] Other abatement includes energy efficiency measures

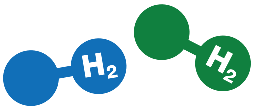
[2] Offshore renewables ~30% contribution would include the amount of electricity used for green hydrogen production



Offshore O&G installations emit ~10MtCO_2e p.a. to generate power (~10% of the UK total energy supply emissions). **Platform electrification** will be key to cutting upstream O&G emissions, and to the industry's social licence to operate.

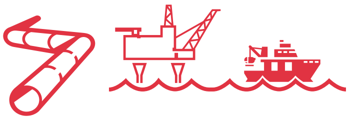
Offshore electrification may unlock the **faster growth of renewables**, expansion of offshore transmission infrastructure, and establishment of floating **windpower technologies** in the UK, contributing to offshore renewables' **75GW capacity ambition** by 2050.

CCS is critical to achieving net zero, **removing over 130MtCO_2** from the UK emissions. The UKCS has enough CO_2 storage capacity to fully support the UK needs and **oil and gas infrastructure** which can be reused.



Blue hydrogen can convert the UK natural gas supply to low-carbon fuel and accelerate the growth of CCS.

Green hydrogen (electrolysis using renewable electricity) will be critical to support the expansion of offshore windpower in the 2030s and beyond.



Oil and gas **infrastructure, capabilities and supply chain** can support energy integration on the UKCS, contributing significantly to offshore renewables expansion and UK net zero.

Combining these technologies into **energy hubs, linked to existing and future onshore net zero clusters**, can accelerate deployment and improve project economics.

Executive summary

Economic findings

- Offshore technologies can provide efficient ways to abate the UK CO_2 emissions, with a broad range of levelised costs per tonne of CO_2 abated (~£10 to ~£100 / tCO_2)
- Costs will not only depend on location and logistics, but also on a number of factors which can be influenced, e.g:
  - Infrastructure availability and access to market
  - Reuse of existing infrastructure (e.g. ~20-30% capex efficiency for selected CCS projects)
  - Technology development (e.g. abating costs of electrolysis/green hydrogen, and floating windpower)

Regulatory findings

- Effective regulations are in place covering individual energy sectors on the UKCS (including oil and gas, and electricity generation and transmission from windpower and other renewables sources)
- As new technologies emerge, regulators are engaged on the further work needed to help unlocking energy integration opportunities, e.g.:
  - Manage new technologies and operations (e.g. CCS and H_2)
  - Support cross-industry collaboration (e.g. O&G and windpower)
  - Accelerate efficiencies (e.g. offshore transmission infrastructure sharing)

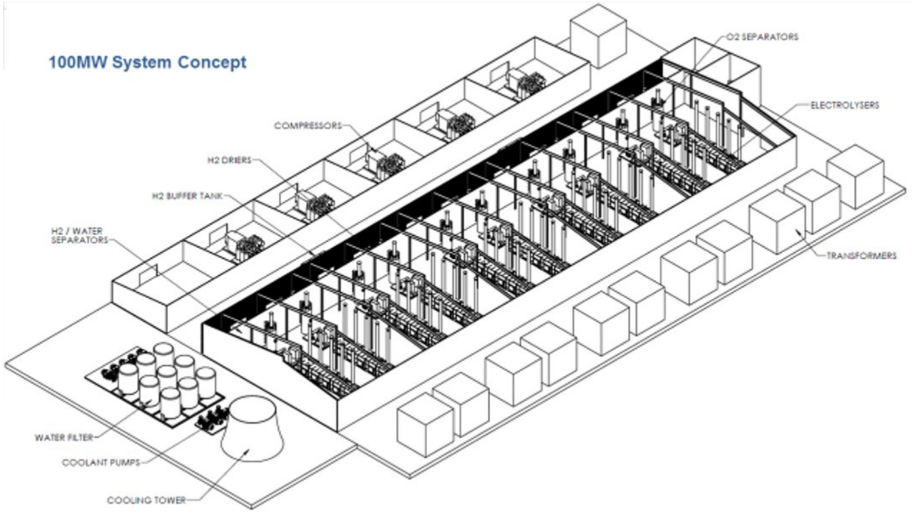
Recommendations and next steps

To realise the vision of the UKCS as a critical enabler for net zero, the project recommends:

- Accelerating and enabling **early energy integration projects**
- Leveraging **oil and gas assets and capabilities,** essential for CCS, preserving existing infrastructure value
- Anticipatory steps to **co-ordinate regulatory processes** for the deployment of UKCS energy integration technologies
- Harnessing the power of **digital and data** to enhance visibility of cross-industry opportunities, accelerating planning and regulatory activities

To take this forward, the OGA with project partners will implement a number of actions, including:

- Accelerate progress on **pioneering projects** to ensure cross-industry opportunities and timely regulatory engagement
- Enhancing **regulatory co-ordination**, to anticipate and address regulatory barriers and/or enablers for CCS, hydrogen and offshore electrification
- Improving **data availability, quality and access** through co-ordinated efforts across government and relevant industries



New generation Proton Exchange Membrane (PEM) electrolyser module enabling larger-scale hydrogen plans (Gigastack project – BEIS, ITM Power, Ørsted, Element Energy)

UKCS Energy Integration Project

Funded by £900k grant from the Better Regulation Executive's Regulators' Pioneer Fund

Led by:

Oil & Gas Authority

in collaboration with:

Department for Business, Energy & Industrial Strategy

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ofgem

- **Engaged widely across industry and regulators**
- **Understood potential of UKCS assets and technologies for net zero, and synergies across the different energy sectors**
- **Identified hurdles (economic, regulatory) and recommend avenues to realise full technologies' value**

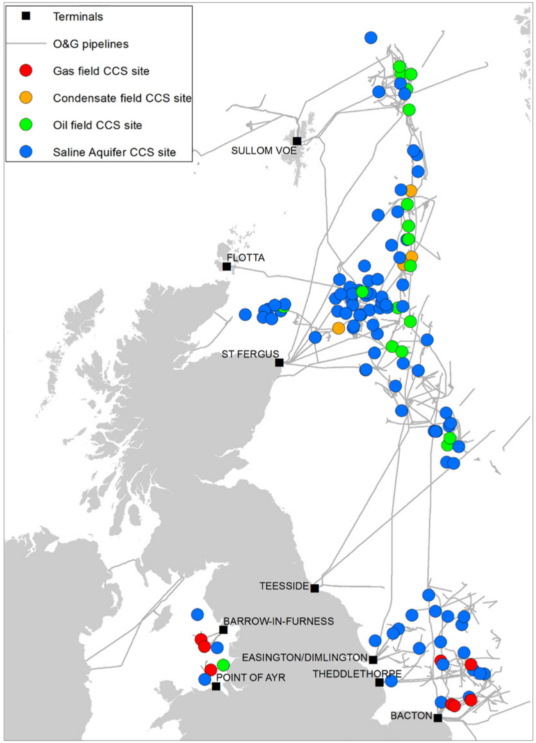
Project timeline

1 **Technical options** 1Q – 2Q 2019 — Lloyd's Register

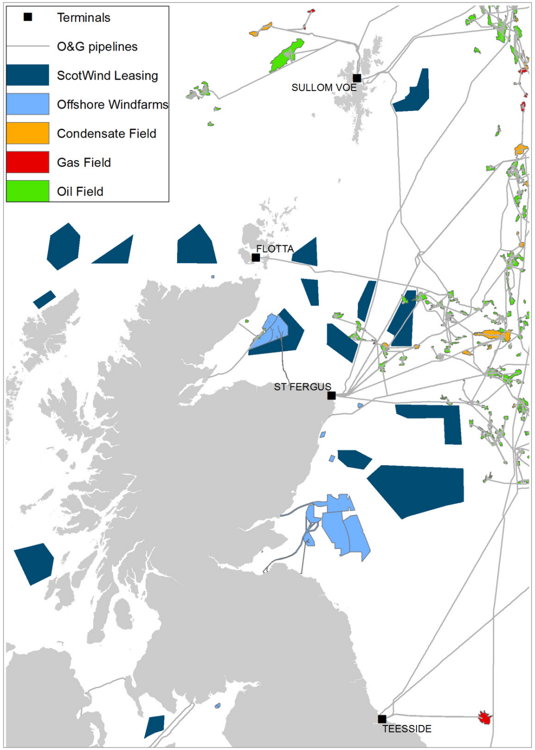
2 **Economic and regulatory assessment** 3Q 2019 – 1Q 2020 — EY

3 **A Phase 3 is proposed to implement recommendations, accelerating UKCS energy integration projects**

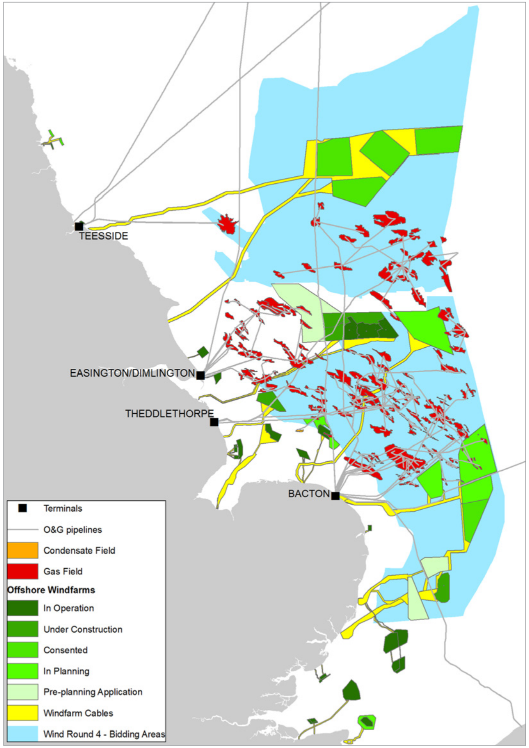
UKCS CO_2 potential stores and O&G infrastructure



ETI and BGS CO2stored.co.uk (2015); BGS and EIP analysis (2019)



Windpower expansion in Scottish waters (Source: CES)

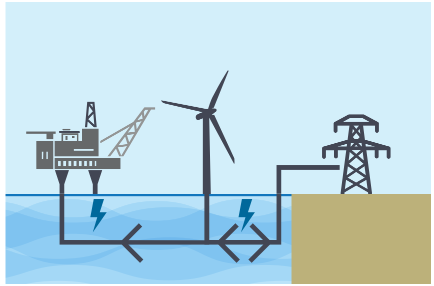


Southern North Sea windpower expansion (Source: TCE)

Energy integration technologies

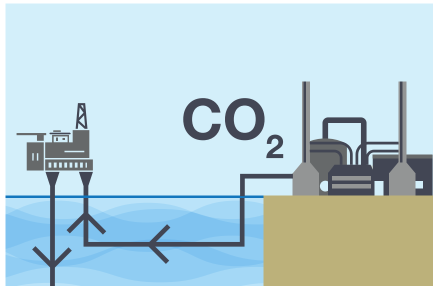
Offshore electrification

UKCS O&G installations required ~21TWh of power in 2018 (~6% of UK generation, equivalent to domestic electricity consumption of a region of the size of Wales)[1]. Generating this power from natural gas or diesel led to emissions of ~10MtCO_2e (~10% of UK energy sector). As power accounts for ~70% of all offshore O&G emissions, replacing thermal generation with power from shore or offshore renewables will be crucial for realising meaningful cuts to the sector's GHG emissions. In addition, the offshore electricity demand and proximity to (future) offshore windfarms could contribute significantly to windpower growth.



Carbon Capture and Storage (CCS)

CCS is considered essential for net zero, by abating emissions from energy and industrial sectors. The CO_2 storage capacity in UKCS reservoirs is estimated at 78Gt, sufficient for hundreds of years of UK CCS needs. The established UK O&G industry is well positioned to redeploy its skills, capabilities and existing infrastructure to accelerate CCS deployment.



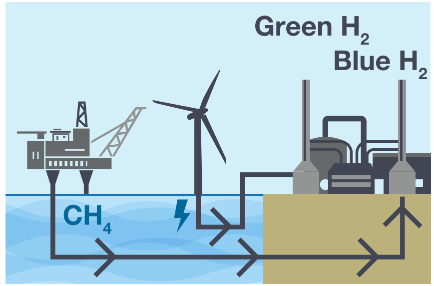
[1] Analysis based on data from BEIS and Office for National Statistics

Hydrogen

Hydrogen is a low-carbon energy source which could replace fossil fuels in power generation, heating and transportation. This project has focused on the potential for UKCS technologies to develop an efficient hydrogen supply to the UK.

Blue hydrogen, from, methane reforming, can be produced from domestic and imported natural gas. Combining this with CCS allows elimination of emissions while leveraging operational and logistical efficiencies from co-location, making this one of the lowest-cost technologies for net zero today.

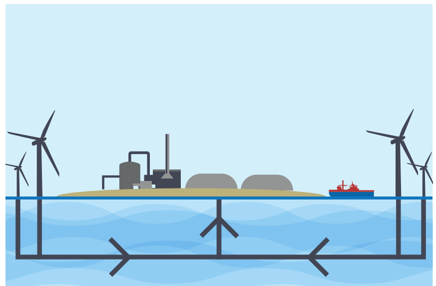
Green hydrogen, produced through electrolysis from renewable energy, will be essential to support offshore windpower growth, addressing issues with power intermittency and long-distance transmission losses (e.g. from the Northern North Sea areas).



Energy hubs

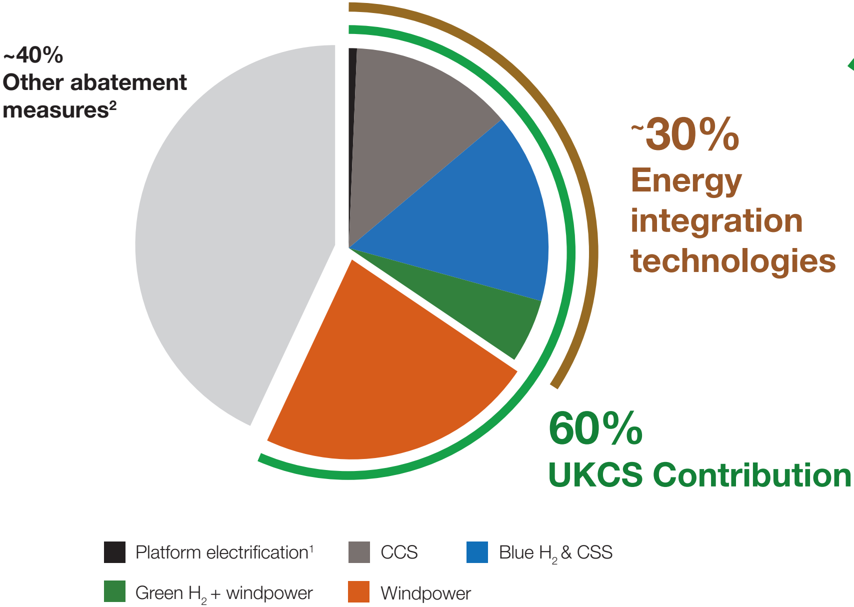
Energy hubs can combine these technologies driving efficiencies through scale and the sharing of site facilities.

Key considerations for energy hubs will be market access, driven by existing (or planned) onshore infrastructure, and access to energy resources (natural gas, renewables and, potentially, CO_2).



UKCS potential contribution to net zero

UKCS net zero emission abatement potential



The UKCS could provide solutions to 60% UK net zero emissions abatement needs. Nearly half of this can be delivered by Energy Integration technologies reviewed in this project.

Technology build-up will vary by UKCS area according to local energy resources, logistics and infrastructure, and access to relevant downstream markets.

Legend – Map on next page →

- O&G platforms
- Offshore cables and ring-mains
- Onshore decarbonisation clusters
- CO_2 storage capacity
- Blue hydrogen reformers
- Windpower expansion
- Green hydrogen electrolyser

Note: See description of methodology in appendix

[1] Impact of O&G platform electrification contribution is shown at peak (mid 2030s)

[2] Other abatement include energy efficiency measures

UKCS energy integration

Northern Scotland and Islands

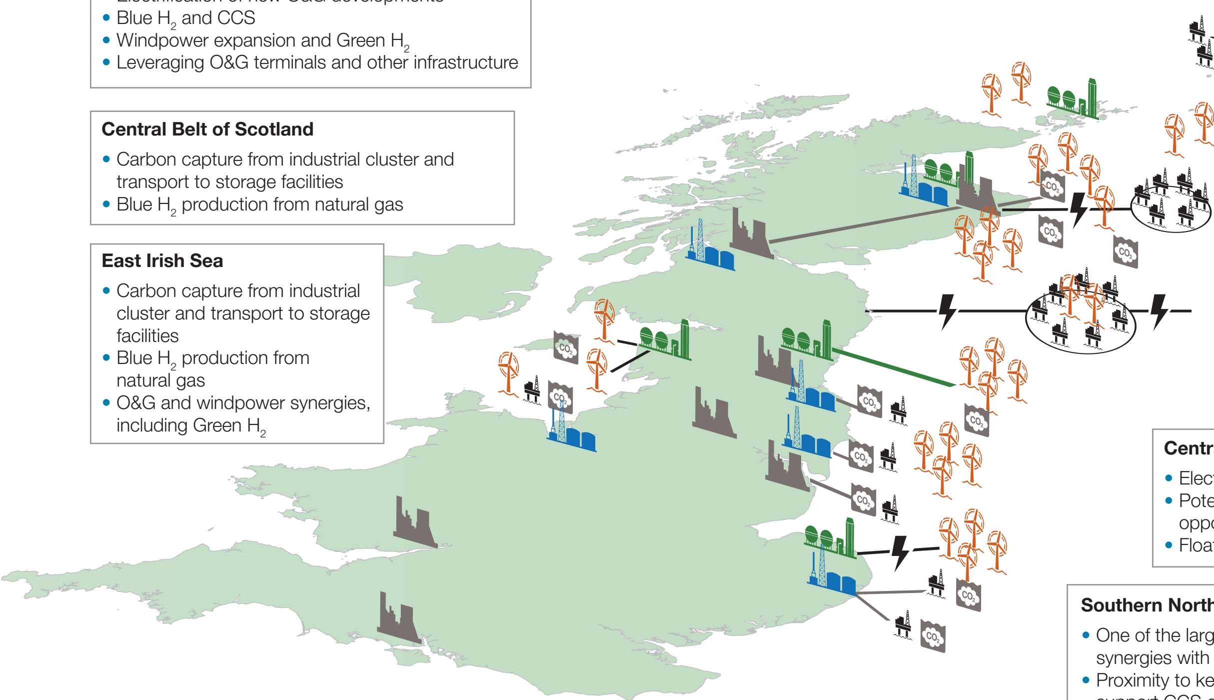
- Electrification of new O&G developments
- Blue H_2 and CCS
- Windpower expansion and Green H_2
- Leveraging O&G terminals and other infrastructure

Central Belt of Scotland

- Carbon capture from industrial cluster and transport to storage facilities
- Blue H_2 production from natural gas

East Irish Sea

- Carbon capture from industrial cluster and transport to storage facilities
- Blue H_2 production from natural gas
- O&G and windpower synergies, including Green H_2



Moray Firth & North East Scotland:

- Electrification of a large O&G province
- Strong windpower expansion driving synergies with O&G and Green H2
- CCS and blue H2 at St Fergus

Central North Sea

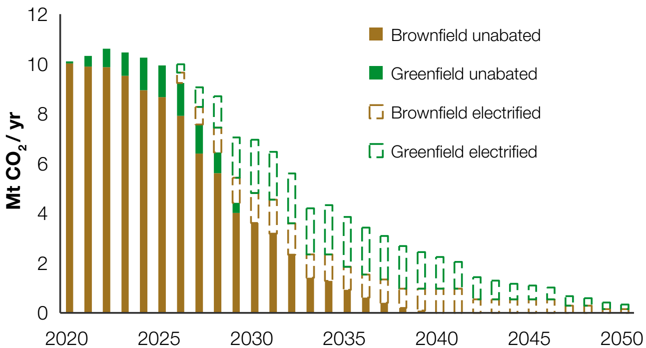
- Electrification of a large O&G province
- Potentially link with interconnector opportunities
- Floating wind deployment potential

Southern North Sea

- One of the largest windpower expansion areas, synergies with O&G include Green H_2
- Proximity to key industrial clusters would support CCS deployment
- UK natural gas production and imports would support Blue H_2

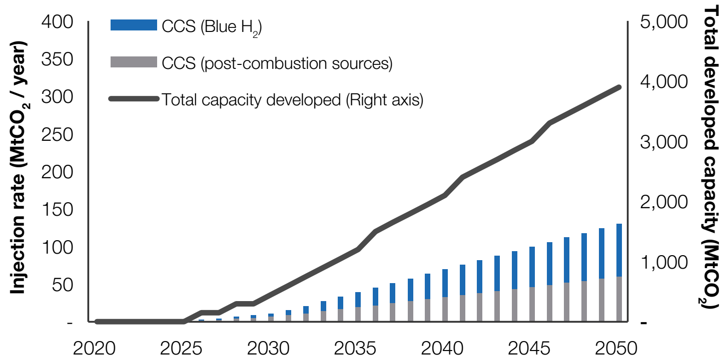
Potential build-up scenarios

Reduction of O&G power emissions by electrification



- Applying electrification to existing assets with >15 yrs of remaining life and 50% of future greenfield projects would lead to 2-3MtCO_2 pa emission reductions
- The resulting power demand would support ~2GW of new offshore windpower capacity
- Industry collaboration and synergies with windpower can reduce costs and accelerate roll-outs
- Project timeline is critical to realise the opportunity

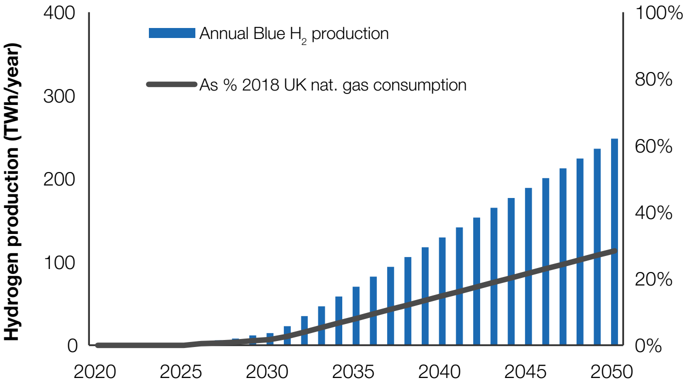
CO_2 injection build-up to support net zero



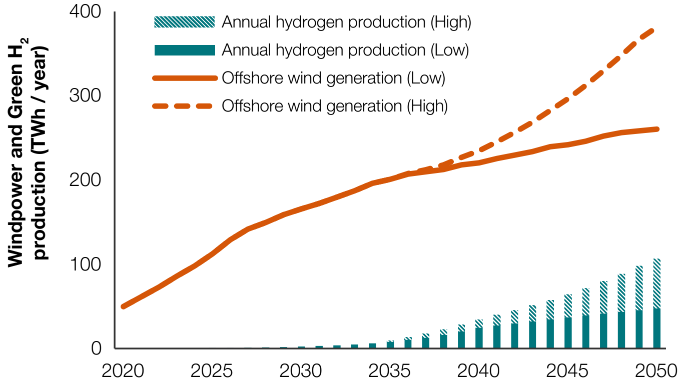
- CCS could contribute to over 130MtCO_2 p.a. of UK net zero by 2050 target
- ~26 CO_2 offshore storage sites would be needed with developed storage capacity of ~3.9 GtCO_2
- To reach this, it would be critical to deliver ~2 pilots by mid-2020s and ~3 commercial projects by 2030
- Accelerating CCS plans is key to secure cost-efficient O&G infrastructure where appropriate

Note: See assumptions and methodology in appendix

Blue hydrogen growth and natural gas decarbonisation



Green hydrogen supporting windpower expansion



- Blue hydrogen can convert UK natural gas supply to low-carbon fuel and support CCS growth
- 250 TWh of H_2 could be generated from natural gas in 2050, replacing nearly 30% of UK natural gas consumption
- 70MtCO_2 p.a.[1] would need to be sequestered, supporting the development of CCS capacity

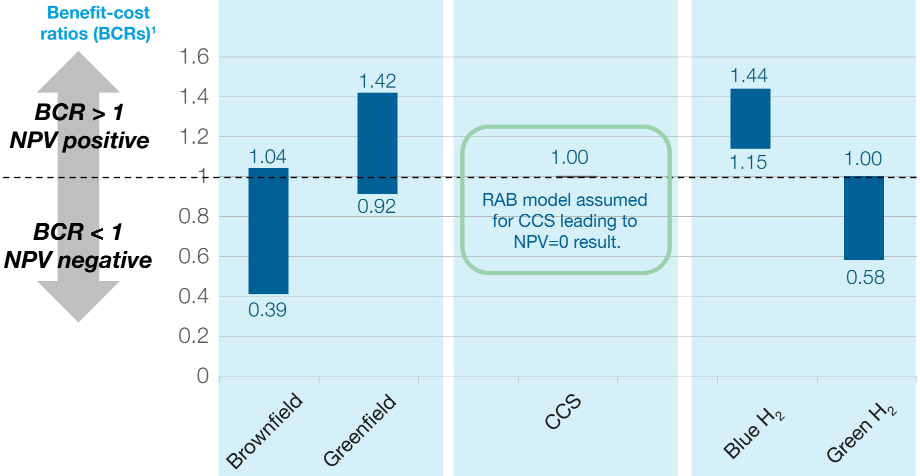
- Offshore windpower will be a key energy source to achieve net zero, with 60-75GW of installed capacity expected by 2050
- Electrolysis could be required to convert a significant portion (25%-40%) of windpower electricity to green hydrogen to mitigate renewables intermittency
- Hydrogen would, at the same time, provide efficient energy transport from distant windfarms

Note: See assumptions and methodology in appendix

[1] These CO_2 volumes are included in the 130 MtCO_2 CCS scenario considered in this study

Economic assessment

Technology	O&G platform electrification		CCS (Transp. & storage)	Hydrogen	
Levelised costs	£23-78/ tCO_2	£6-15/ tCO_2	£12-30/ tCO_2 Levelised cost of transportation and storage (LCOT)	£1.5-2.5/ kgH_2 Excluding CCS costs	£0.44-0.6 /kgH_2 excl electricity; £3.4-3.6 /kgH_2 incl electricity from windpower



Note: See description of methodology in appendix

[1] BCR = ratio between future discounted cash flows and capital investment

Sensitivities

Brownfield electrification

- Economics depend on electricity supply, cost of modifications, and carbon pricing
- Powering solely from the shore would be the highest cost option
- Synergies with offshore windpower could lead to breakeven

Greenfield electrification

- Savings from avoiding generation equipment on the new O&G installations can make greenfield electrification economically viable
- Sourcing power from windfarms improves economics further

CCS

- The project cost of capital (WACC) and uncertainties on Capex and CO2 injection performance could have the largest impact on LCOT
- Reuse of O&G infrastructure can give 20-30% Capex savings

Blue hydrogen

- Combined with CCS, provides a cost effective solution to decarbonise natural gas (BCR >1)
- Economics depend on Capex/process efficiency

Green hydrogen

- Electricity pricing is key factor; assumption of sourcing power from offshore
- Key issues are the electrolyser cost and efficiency – significant improvement is believed possible

Economic findings

Brownfield electrification projects could face high Capex and electricity costs which, however, could be significantly reduced through **synergies with windpower**

Electrification of new assets (greenfield) can add value through Capex savings able to offset power connection cost – **BCR>1 under most circumstances**

O&G electricity demand can **support windpower expansion in new areas**. Sharing of infrastructure can improve project economics for both sectors

T&S[1] costs of ~£12-30/tCO_2 could make **CCS economically attractive** to help decarbonise the UK – **reuse of O&G infrastructure** can lead to 20-30% Capex savings on specific projects

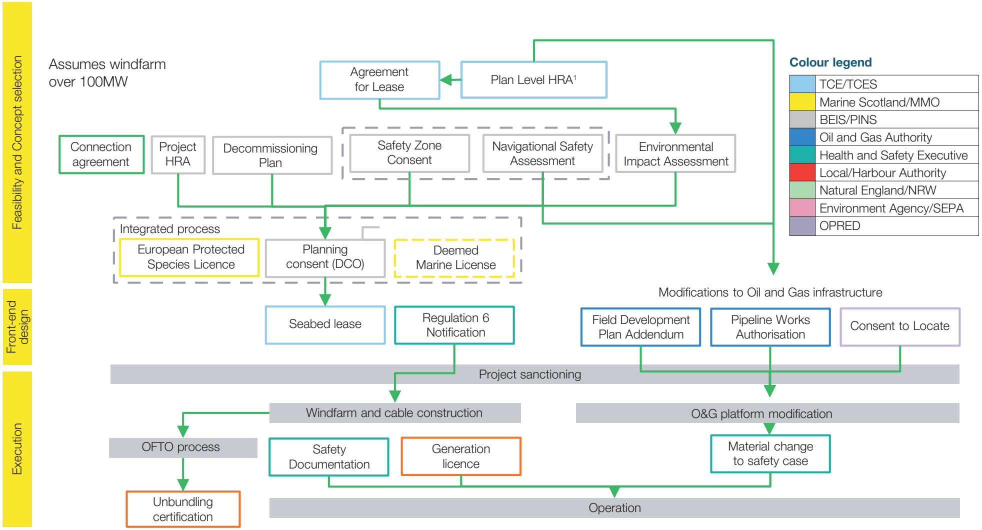
Blue hydrogen is a value-enhancing technology combined with CCS, showing **attractive economics** at today's conditions

Green hydrogen is a key enabler of renewables' growth, addressing energy intermittency and long-distance transmission. Electrolyser cost need to be reduced

[1] Transportation and storage (T&S) scope only

Regulatory assessment

Current regulatory map (indicative - Windpower supply for O&G electrification)



- Regulatory regimes are in place covering the different energy sectors operating on the UKCS
- These have supported successful economic development of multiple UKCS energy sources, in a safe and environmentally sound way
- Energy integration projects would require close cross-regulatory co-ordination, to understand and manage requirements and timeline dependencies optimally
- The map on the left shows the extent of co-ordination required to consent a new windfarm supplying nearby O&G installations
- As energy integration technologies scale-up, further work is advised to address specific value enablers, such as development of CO_2 and H_2, and offshore transmission infrastructure

[1] Habitats Regulations Assessment

Key findings

Opportunity to **clarify regulations and roles** for Energy Integration schemes

Examples

- Offshore O&G electrification falls under the Petroleum Act 1998 as well as renewable legislation (Energy Act 2008)
- Aspects such as seabed leasing over O&G acreage, consenting of shared cables and transformers would need to be clarified upfront
- For H_2 projects, uncertainty over local planning would need to be addressed, as currently no guidance

Consider **adapting guidelines and criteria** to support novel projects

Examples

- Current guidance on sharing network charges only relates to onshore projects, and may need to be extended offshore
- Eligibility of O&G offshore platforms as Energy Intensive Industry (EII) users would require change to current EII guideline

Explore ways to **accelerate timeline** of cross-sector projects

Examples

- The long windfarm development timelines (driven by leasing, planning and consenting) would make joint projects with O&G difficult
- Consenting for initial pilots is often the same as for large projects. Could simplifications be considered for pilots and demonstrators?

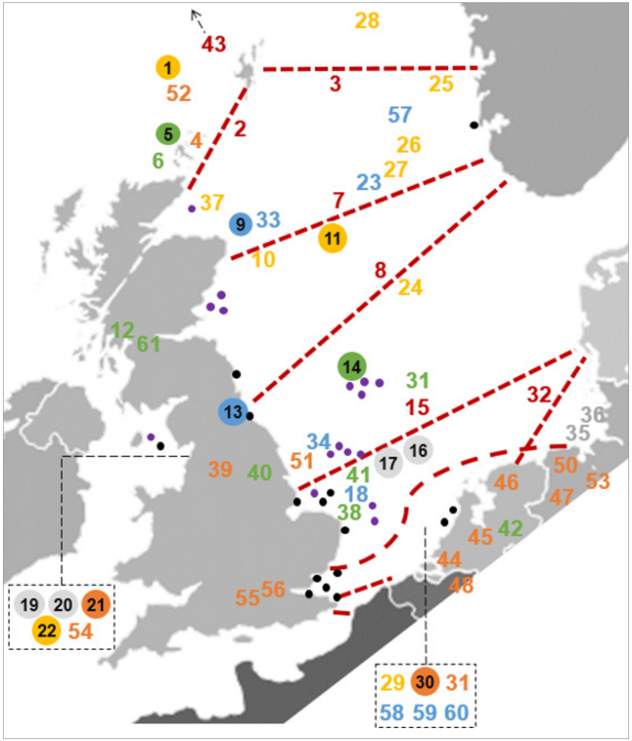
Enhance co-ordination of regulatory **processes, data and interfaces**

Examples

- Environmental assessments for O&G and renewable projects in the same areas of UKCS could have opportunity for greater alignment
- Critical UKCS data (environmental, subsurface and infrastructure) collected by multiple users, could be shared more widely across regulators and industry

Next steps and actions

Action 1: Support energy integration pioneering projects



- Industry has a rich pipeline of energy integration activities in the North Sea (~60 projects, incl. international, see map)
- Building on past work, the project plans to support selected initiatives going forward to demonstrate and accelerate UKCS energy integration:

Help identify key economic hurdles and define approaches to improve project viability

Raise cross-industry awareness and promote engagement to realise synergies

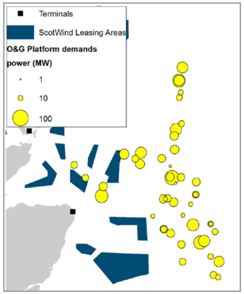
Timely communication with key regulators regarding potential barriers and enablers

Ensure that learnings from individual projects are widely leveraged across industry and government

Project examples

Offshore Electrification in the Central North Sea

- Joint industry and OGA work
- Abate O&G power emissions
- Extend O&G asset lives
- Leverage power demand for faster windpower growth
- Economies of scale (platforms sharing infrastructure)
- Synergies with windpower (supply and transmission cost efficiencies)
- Cross-regulator discussions re planning and market access



O&G platform power demand and ScotWind Leasing areas (CES, OGA)

HyNet – Blue H2 and CCS repurposing O&G infrastructure

- Includes onshore blue H_2 production and distribution, combined with CO_2 capture and storage in a depleted offshore gas field
- Plans to develop local H_2 market
- Currently moving into FEED for a phase 1 development
- Has involved multiple regulators, including BEIS, TCE and OGA

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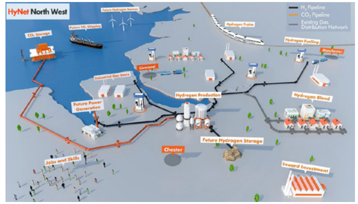


DolpHyn - Integrating Floating Windpower and Green Hydrogen

- Novel concept that combines existing technologies (electrolysis, floating wind turbines, subsea pipelines and risers)
- Integrates energy generation, storage and efficient transport
- Expands the reach of windpower to deep-water and distant regions
- Feasibility conducted (BEIS funding)
- Initial 2MW prototype being planned
- Engaged with OGA and CES and being supported liaising with other regulators

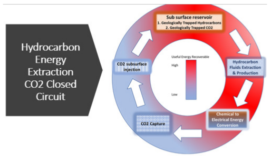
TiGRE SEALS - Low-carbon offshore gas-to-wire with CCS

- Gas-to-wire could help recovering a greater share of UK gas reserves
- Concept combines offshore power gen with CCS to abate emissions
- Electricity cables shared with renewables
- CO_2 injection enhances gas recovery
- Low LCOE for dispatchable power with near zero carbon emissions
- Feasibility study with lead technology suppliers, supported by BEIS
- Currently planning demonstration phase

TiGRE

TiGRE SEALS

Schlumberger



Next steps and actions

Action 2: Enhance regulatory co-ordination

- Support a shared vision of UKCS energy integration potential towards net zero
- Ensure companies establish a timely, open dialogue with relevant regulators regarding energy integration opportunities
- Align regulatory guidance, where possible, co-ordinating response to industry needs
- Proactively identify and, if possible, address potential regulatory barriers (e.g. timeline dependencies across different regulators)
- Promote anticipatory actions on critical enablers (e.g. infrastructure access)
- Facilitate increased linkages across the different offshore energy industries

Offshore electrification[1]

Department for Business, Energy & Industrial Strategy · Oil & Gas Authority · ofgem · marine scotland · Planning Inspectorate · The Crown Estate · Crown Estate Scotland (Oighreachd a' Chrùin Alba) · HSE

Vision: Enable offshore electrification to reduce O&G industry GHG emissions and accelerate offshore windpower growth in the 2020s. Proactively support industries connecting and facilitate joint projects.

CCS and Hydrogen[1]

Department for Business, Energy & Industrial Strategy · Oil & Gas Authority · The Crown Estate · Crown Estate Scotland (Oighreachd a' Chrùin Alba) · ofgem · HSE

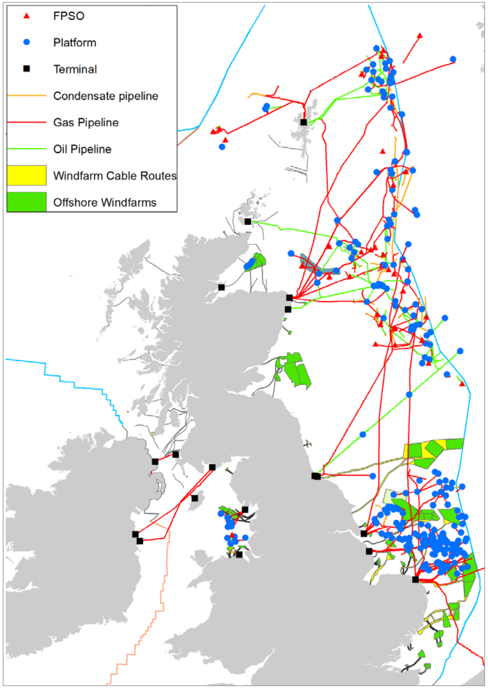
Vision: Provide proactive regulatory support for CCS and hydrogen projects, ensuring guidance to permit the timely execution of pilots and subsequent ramp-up of these novel technologies in the 2020s.

[1] Composition and vision of proposed 'co-ordination groups' yet to be agreed with relevant stakeholders

Action 3: Promote greater data availability and ease of access

- The project collated data on different technologies from multiple government and industry datasets into one place
- Data consolidation helped identify cross-industry opportunities and optimal build-up scenarios
- Potential areas for improvement were also identified (e.g. related to CO_2 stores and infrastructure status)
- Going forward, better Information access is critical to support government and industry decision-making
- Next steps would include plans to enhance data sets, data quality and ease of access, leveraging government systems in place
- Data would support critical industry planning, e.g. for the repurposing of existing O&G infrastructure
- Greater industry data sharing, where possible, would support planning and operational efficiencies

Map of existing UKCS energy infrastructure



OGA Digital Energy Platform and EIP analysis

Biomass domes at Drax Power Station, Yorkshire, on which Bioenergy Carbon Capture and Storage (BECCS) technologies are being piloted (Drax)

Findings by technology

1. Offshore electrification – findings

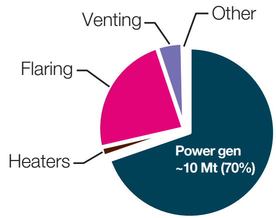
Electrification is an essential response by O&G industry to net zero

- Abate power emissions from O&G platforms (10 $MtCO_2$, 70% of offshore emissions or 10% of total UK energy sector)
- Extend operating life of existing assets and achieve cost efficiencies in the development of new oil and gas fields
- Economics critically depend on electricity and carbon pricing - power from UK shore would be unattractive at current prices
- Joint projects to share infrastructure and sourcing power directly from offshore windfarms can significantly improve economics

Opportunity to accelerate offshore windpower growth

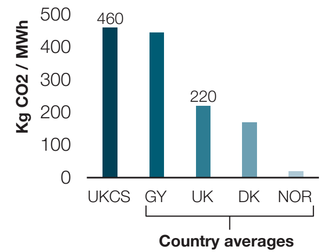
- Large potential growth in offshore windpower (75GW in 2050)
- Expansion in new areas (eg Scottish waters) with favourable wind conditions but water depth and infrastructure challenges
- Energy supply to O&G platforms could represent a commercial opportunity for renewable power developers today
- Co-investing in transmission infrastructure and leveraging O&G deep-water technologies could support growth

UKCS O&G emissions ($14MtCO_2e$)



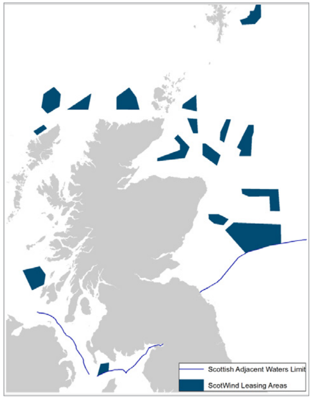
Source: EEMS 2018, EIP

Carbon intensity of power generation



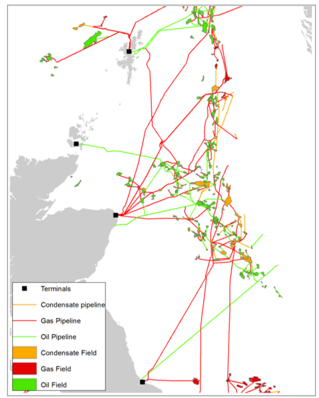
GY – Germany, DK – Denmark, NOR – Norway

ScotWind Leasing expansion



Source: CES

O&G fields and infrastructure



Source: OGA

1. Offshore electrification – recommendations

1: Industry should engage and collaborate on electrification opportunities across energy sectors

- Sourcing electricity for O&G directly from offshore renewables to reduce project lifecycle costs
- Consider hybrid schemes that are Capex-efficient, e.g. partial platform electrification, with gas-to-wire generation capacity to provide power continuity and optimise (or avoid) link to shore
- Engage developers of interconnectors for access to international supply options (e.g. Norway) and sharing of transmission infrastructure
- Investigate wider industry participation (supply chain, and midstream) to improve project economics

2: Government should consider measures to promote investments in offshore electrification, e.g.

- Energy-intensive industry (EII) tariffs exemption for offshore users
- Carbon price on offshore power emissions more in line with onshore
- Enabling sharing of offshore electricity infrastructure and anticipatory investments

3: Enhanced co-ordination among regulators to facilitate cross-industry projects

- Align planning and consenting regimes to support cross-industry developments (O&G and windpower)
- Regulatory co-ordination to expedite industry projects

Enhanced co-ordination in offshore electrification[1]

Vision: Enable offshore electrification to reduce O&G industry GHG emissions and accelerate offshore windpower growth in the 2020s. Proactively support industries connecting and facilitate joint projects.

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[1] Composition and vision of proposed 'co-ordination groups' yet to be agreed with relevant stakeholders

2. Carbon Capture and Storage – findings

CCS is critical to achieve UK net zero, and the UKCS role is key

- 75-175 $MtCO_2$ / year captured and stored by 2050[1], or up to one third of the current UK emission baseline
- 78 $GtCO_2$ potential storage capacity[2] on the UKCS, sufficient for 100s of years of UK demand

Accelerating projects would be needed to achieve expected CCS volumes

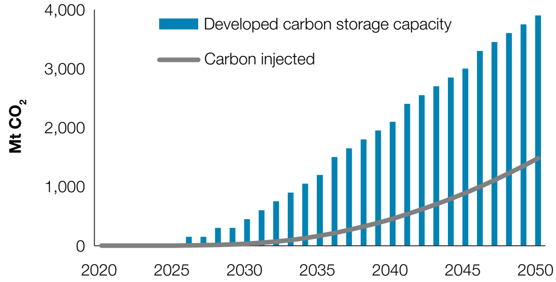
- >2 pilots followed by >2 commercial-scale projects developed by 2030 necessary to provide critical learnings for the subsequent expansion
- 130 $MtCO_2$/yr by 2050 flow rate (central case) would then require ~4 Gt CO_2 storage capacity developed across >20 individual stores[3]

CCS could be economically competitive as emission abatement technology

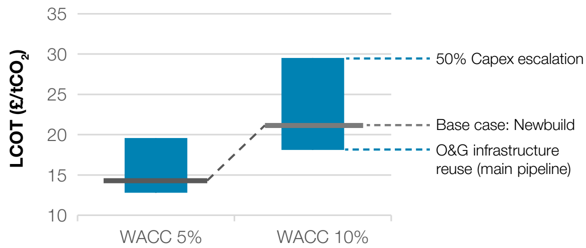
- Levelised transport and storage costs of £12-30/tCO_2 could be attained
- Adding onshore capture costs, CCS is cost-competitive against long-term carbon price forecasts

- Combination with blue-hydrogen can enhance economics and create scalable business models
- Levers to reduce CCS costs include economies of scale (e.g. CCS clusters and hubs) and reuse of O&G infrastructure

Developed CO_2 T&S capacity and cumulative injection (EIP central case[4])



Levelised costs of T&S (£/tCO_2, notional project examples[4])



[1] CCC (2019) 'Net Zero: The UK's contribution to stopping global warming', [2] ETI / BGS co2stored.co.uk
[3] UKCS Energy Integration Project, [4] See note on methodology in appendix

2. Carbon Capture & Storage – recommendations

1. Ensure the timely ramp-up of CCS

- The government has emphasised the importance of CCS to support its Clean Growth Strategy and net zero target, with an aim to deploy the technology at scale during the 2030s
- The government has been providing funding towards CCS technology deployment and the establishment of net zero industrial clusters
- BEIS has been consulting industry and other regulators on critical enablers, including business models, market frameworks and O&G infrastructure reuse policy
- It is key that this good progress and industry engagement are maintained, to ensure CCS pilots and first commercial-scale projects are deployed in the 2020s
- Accelerating initial CCS projects is critical to mature the technology for the subsequent ramp-up in the 2030s
- In addition, this would allow to fully leverage the UK O&G industry expertise, supply chain and existing infrastructure

2. Enhance regulatory co-ordination across CCS and Hydrogen

- Regulatory co-ordination to expedite industry projects
- Align planning and consenting regimes to support cross-industry opportunities (e.g. O&G, CCS and blue H_2)

Enhanced co-ordination on CCS and Hydrogen

Vision: To provide proactive regulatory support to enable/accelerate CCS and hydrogen projects, co-ordinating any work to clarify regulations.

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3. Improve data availability

- Improved access to data (including on subsurface, existing facilities and infrastructure developments) would be critical for both government and industry to develop optimal CCS build-out plans

[1] Composition and vision of proposed 'co-ordination groups' yet to be agreed with relevant stakeholders

3. Hydrogen – findings

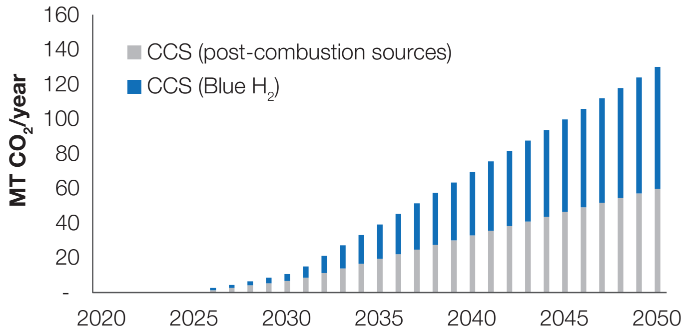
Blue hydrogen could support the faster CCS ramp-up

- 2020s/30s, by leveraging available supply of natural gas and mature technologies
- Provides a zero-carbon fuel (Hydrogen) at cost advantage with conventional power gen when combined with CCS (BCR up to 1.4)
- Leverage oil and gas infrastructure (e.g. terminals) and capabilities
- Would rely on the hydrogen market/sales to absorb CCS cost

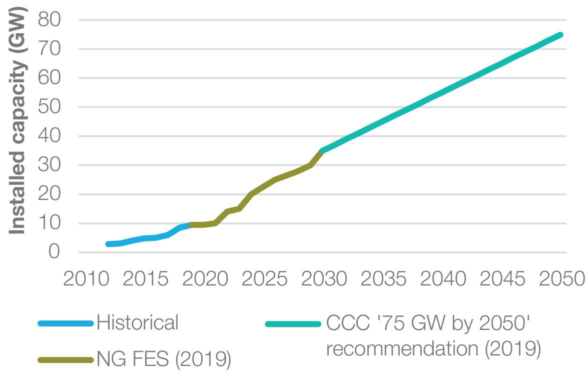
Green hydrogen is a required enabler of large-scale windpower expansion

- Potential to provide efficient energy storage to address power source intermittency on the expected scale (~75GW windpower capacity in 2050)
- Efficient energy transportation solution over the long-distances required
- Due to the high electrolyser costs, green H_2 is not economically attractive today (BCR ~ 0.7) but technology improvements are expected to reduce these costs to achieve project breakeven in this decade

Blue hydrogen contribution to CCS ramp-up (EIP central case)



Potential growth in UK offshore windpower capacity[1]



[1] See note on methodology in appendix

3. Hydrogen - recommendations

1. Continue activities towards development of hydrogen markets

- Local H_2 demand clusters initially identified, include industrial hubs (e.g. Merseyside), and ground transportation (e.g. NE Scotland)
- Ongoing work by BEIS on considering more widespread H_2 distribution and uses (e.g. fuel switching) will be critical to unlock hydrogen growth

2. Focus on Blue Hydrogen key pilot projects / energy hubs

- Blue Hydrogen could accelerate the CCS ramp-up by supporting more scalable business cases
- A faster growth timeline could support more opportunity to reuse O&G assets (eg terminals, pipelines and natural gas resources)

3. Consider further support to hydrogen technologies

- R&D to abate electrolysers' costs and increase their energy efficiency
- Technologies for the transportation and distribution of hydrogen, including converting existing pipeline systems
- Technologies for cost-efficient fuel switching

4. Enhance regulatory co-ordination across CCS and hydrogen

- Regulatory co-ordination to expedite industry projects
- Align planning and consenting regimes to support cross-industry opportunities (e.g. O&G, CCS and blue H_2)

Enhanced co-ordination CCS and Hydrogen[1]

Vision: Provide proactive regulatory support for CCS and hydrogen projects, ensuring guidance to permit the timely execution of pilots and subsequent ramp-up of these novel technologies in the 2020s.

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[1] Composition and vision of proposed 'co-ordination groups' yet to be agreed with relevant stakeholders

Cygnus – a recent UKCS natural gas development (Neptune Energy)

Ørsted's Walney wiindfarm in the Irish Sea (TCE)

Appendix

Appendix

Methodology, assumptions and sources

UK GHG emission profile

- BEIS reported 2018 UK GHG emissions of 451.5 $MtCO_2e$ used as starting point
- Projected GHG emission reductions until 2032 according to the fourth and fifth UK Carbon Budgets
- From 2033, GHG emissions decline linearly to net zero in 2050
- The potential contribution of individual offshore technologies to GHG abatement was modelled according to the methodology below

CCS and Blue Hydrogen outlooks

- BEIS UK CCUS deployment pathway (2018) estimated ca. 130$MtCO_2$ p.a. of negative emissions technologies needed to reach net zero emissions in 2050
- CCC's report Net Zero: The UK's contribution… (2019) estimated up to 175 $MtCO_2$ emissions p.a. to be abated through CCS by 2050, of which 125$MtCO_2$ from Blue-H_2 and combustion sources (power and industrial)
- NG FES Two Degrees case (2019) projects a conversion of 377 TWh of natural gas p.a. (or 28% of UK demand today) to Blue-H_2 by 2050, a process which generates 70$MtCO_2$ p.a. to CCS
- As a result we projected CO_2 injection rate growing to 130 $MtCO_2$ p.a. by 2050, with a 70-60 CO_2 source split between Blue-H_2 and post-combustion capture (power and industrial)
- The rate of growth reflects initial pilot-scale projects deployed in the 2020s, followed by a linear progression of commercial scale plants in the 2030/40s

Methodology, assumptions and sources

Offshore Windpower outlook

- UKCS installed capacity (9.3GW), current project pipeline (4.4GW) and scoping phase (11GW) are sourced from TCE references
- TCE Round 4 documentation (2019) and CES ScotWind Leasing (2020) indicate additional capacity of >7GW and up to 10GW targeted by these rounds, respectively
- BEIS Offshore Windpower Sector Deal (2019) targets 30GW capacity by 2030
- NG FES 'Two Degrees' case (2019) requires offshore windpower generation of 210TWh p.a. by 2050 (or 60GW of installed capacity at 40% load factor)
- CCC Net Zero: The UK's contribution… (2019) indicates the need for 75GW of offshore windpower capacity to achieve net zero

Green Hydrogen outlook

- Our 'Low case' considers NG FES '2 Degree' scenario of 70GW offshore windpower capacity in 2050; applying a 44% load factor, we assumed 25% of electricity would generate 47TWh p.a. of Green-H_2 to mitigate intermittency
- Our 'High case' considers the CCC recommendation of 75GW offshore windpower capacity in 2050; applying a 58% load factor, we assumed 40% of electricity would generate 106TWh p.a. of Green-H_2 to mitigate intermittency

O&G platform electrification

- The BEIS EEMS database indicate 2018 average offshore GHG emissions from power generation (electrical, mechanical and thermal) at ~11 $MTCO_2e$ / year
- In forecasting a forward emission baseline, we considered the impact of asset decommissioning based on OGA's 2018 UKSS projections
- Brownfield electrification: we assumed 14 existing UKCS platforms (largest assets with the longest residual life) will be converted during 2026-2035
- New asset (greenfield) electrification: we assumed 17 greenfield developments (2026-2035) to import electricity avoiding CO_2 power emission

Methodology, assumptions and sources

Economic modelling

- Technologies are compared in terms of BCRs and levelised costs
- Model economics are real and pre-tax
- Offshore projects' scope is discounted at 10% (real)
- Hydrogen onshore processing is discounted at 5% (real)
- Electricity transmission infrastructure is discounted at 2.9% (real, from recent cases)
- For the purpose of estimating CCS T&S projects' economics, we have assumed that CCS project will adopt a regulated business model with typical WACC values (real, pre-tax) of 5% to 10%. Investors' expected returns will be dependent on a range of factors including operational and financial risk, capital structure, incentives and taxation. BEIS is conducting an analysis of CCS potential business models and will provide updates later in 2020

Energy parameters and conversion factors

- UK average power generation emissions 220 KgCO2/MWh (BEIS 2019)
- UK average power emissions excl. renewables 330 KgCO2/MWh (BEIS 2019)
- UKCS offshore power generation emissions 460 KgCO2/MWh (typical OCGT)
- UK offshore windpower commercial load factors 39%-47% (2019 BEIS, DNV GL)
- Hydrogen energy density 39kWh/kg (HHV) and 33kWh/kg (LHV)
- Natural gas energy density 14.5kWh/kg (HHV) and 13.1kWh/kg (LHV)
- Blue Hydrogen (methane reforming) energy efficiency 70-75% (NG FES)
- Green Hydrogen (electrolysis) electricity efficiency 70-80% (Various)

Acronyms and abbreviations

BEIS	Department for Business, Energy and Industrial Strategy
CCC	Committee on Climate Change
CCS	Carbon Capture and Storage
CES	Crown Estate Scotland
CO_2e	Carbon Dioxide equivalent
EIP	Energy Integration Project
GHG	Green-house gases
HC	Hydrocarbon
HHV	High Heating Value = LHV + heat of products' vaporisation
HRA	Habitats Regulations Assessment
LCOT	Levelised Cost of Transport (CCS T&S)
LHV	Low Heating Value
MMO	Marine Management Organisation
NG ESO	National Grid Electricity System Operator
NG FES	National Grid ESO Future Energy Scenarios
NRW	Natural Resources Wales
OCGT	Open Cycle Gas Turbine generator
OGA	Oil and Gas Authority
OPRED	Offshore Petroleum Regulator for Environment and Decommissioning
PEM	Proton Exchange Membrane (electrolysis)
PINS	Planning Inspectorate National Schemes
SEPA	Scottish Environmental Protection Agency
SG	Scottish Government
T&S	Transport and Storage (of CO_2)
TCE[1]	The Crown Estate
tCO_2	Tonnes of Carbon Dioxide
UKCS	UK Continental Shelf
WACC	Weighted averaged cost of capital

[1] The Crown Estate manages the seabed around England, Wales and Northern Ireland and provides leases/licences for offshore energy, marine aggregates and cables and pipelines. It is not a regulator, however, for the purpose of this report, it may be grouped together with regulators

Contact us at:

oga.correspondence@ogauthority.co.uk

OGA Headquarters
AB1 Building
48 Huntly Street
Aberdeen
AB10 1SH

OGA London Office
4th Floor
21 Bloomsbury Street
London
WC1B 3HF

www.linkedin.com/company/oil-and-gas-authority
twitter.com/ogauthority

Oil & Gas Authority

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