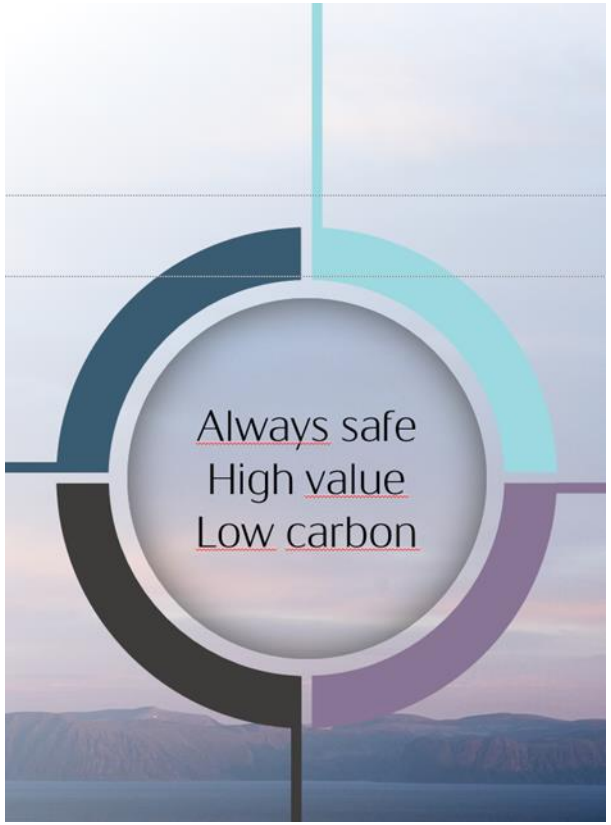
Carbon Capture solutions and demonstrations

ETN Workshop, Berlin, October 13, 2022

Olaf Brekke, Advisor Rotating Equipment

Outline

- Strategy and ambitions
- CO_2 transportation and storage
- Post-combustion CCS projects
- Summary



Shaping the future of energy

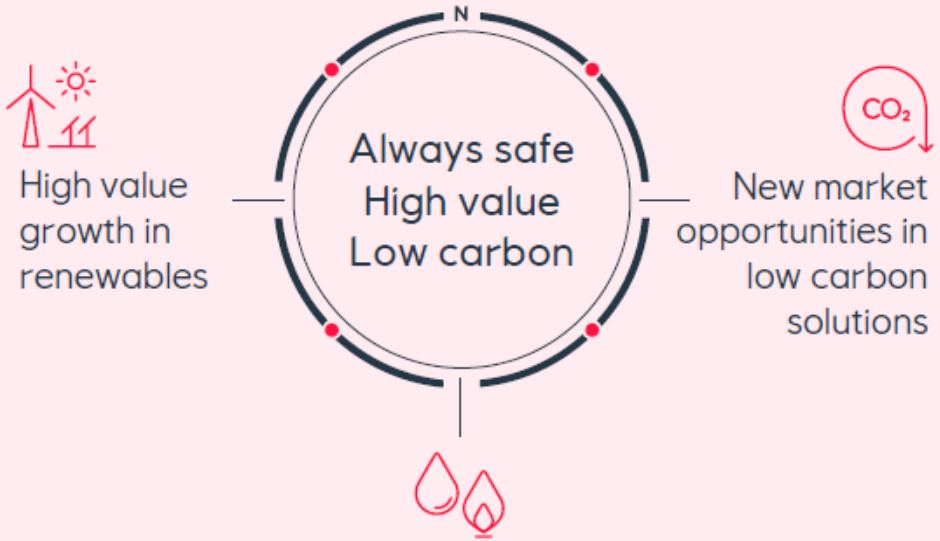
A leading company in the energy transition

Turning natural resources into energy for people, and progress for society

Why we are changing

- Creating value through the energy transition
- Net-zero ambition gives new industry opportunities
- Technology excellence and innovation define winners
- Market dynamics set margins under pressure

Accelerating our transition



How we will get there - together

- Safe and secure operations
- Guided by our values
- Building on competencies and our experience
- Together as one team – engaging partners and society

LOW CARBON SOLUTIONS

A leader in carbon management and clean hydrogen

NCS basin master within CO_2 transport and storage

15-30 MILLION TONNES PER ANNUM

CO_2 transport and storage capacity by 2035

Equinor share

Becoming a major European supplier of hydrogen

3-5 MAJOR INDUSTRIAL CLUSTERS

Clean hydrogen projects by 2035

Developing Northern Lights - Europe's first third party source CO_2 storage

5 MILLION TONNES PER ANNUM

CO_2 storage capacity phase 1 and 2

100% basis

[Equinor Capital Markets Day, June 2021]

Net-zero ambition backed by action

Advantaged upstream position

- <8 kg CO_2 per boe by 2025 and ~6 kg CO_2 per boe by 2030[1]
- Carbon neutral Equinor global operations by 2030[2]

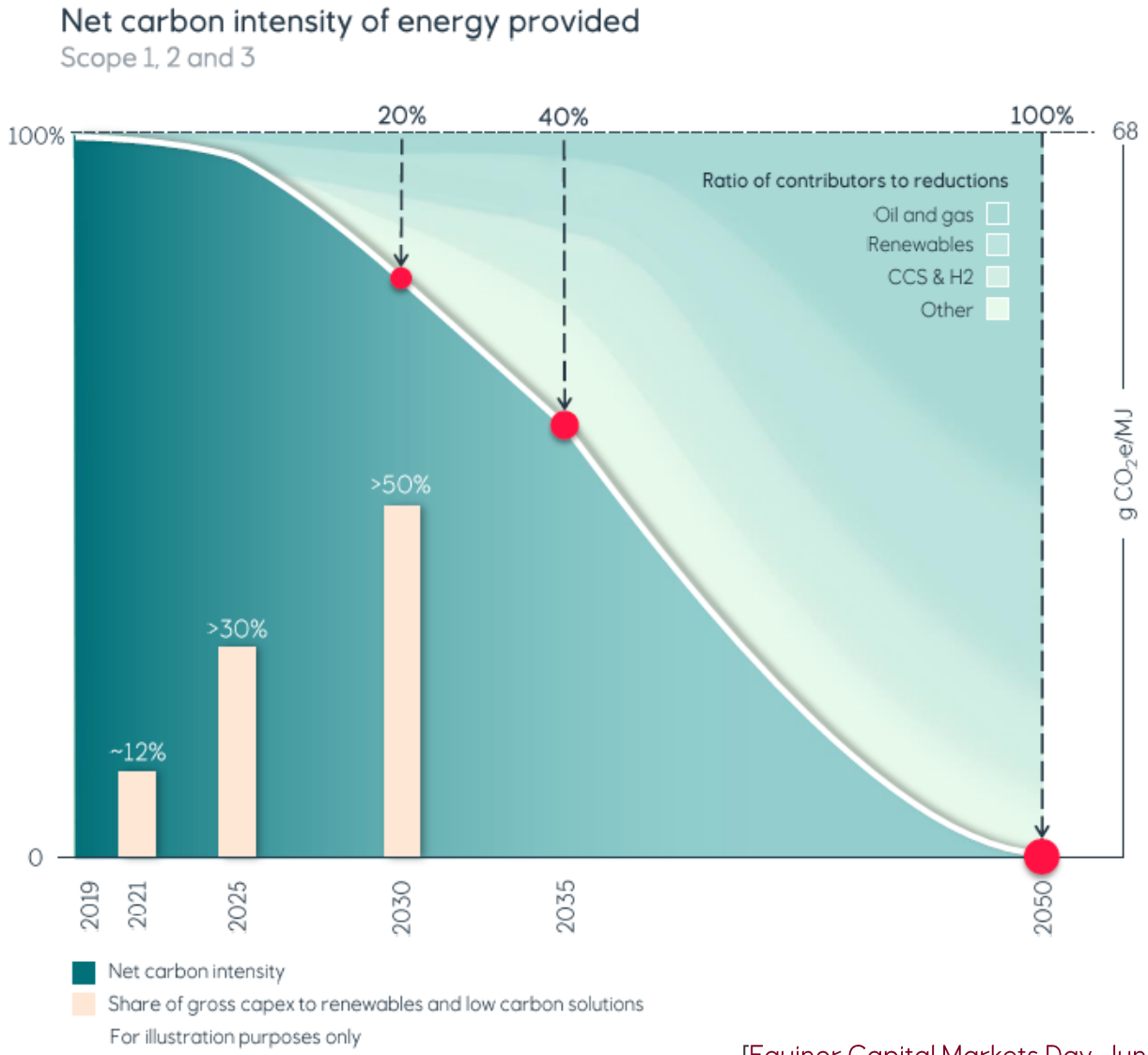
Accelerating renewables

- 12-16 GW installed capacity by 2030[3]

Scaling up CCS and hydrogen

- 15-30 million tonnes CO_2 storage per year by 2035[3]
- 3-5 major industrial clusters for clean hydrogen projects by 2035

1. Upstream intensity, scope 1 CO_2 emissions, Equinor operated, 100% basis
2. Scope 1 and 2 GHG emissions. Remaining emissions will be compensated through quota trading mechanisms and offsets.
3. Equinor share

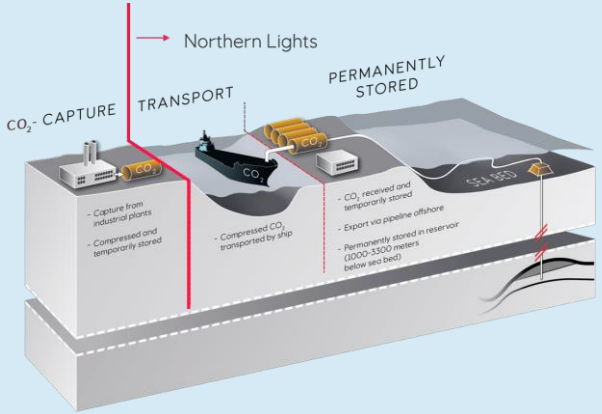


[Equinor Capital Markets Day, June 2021]

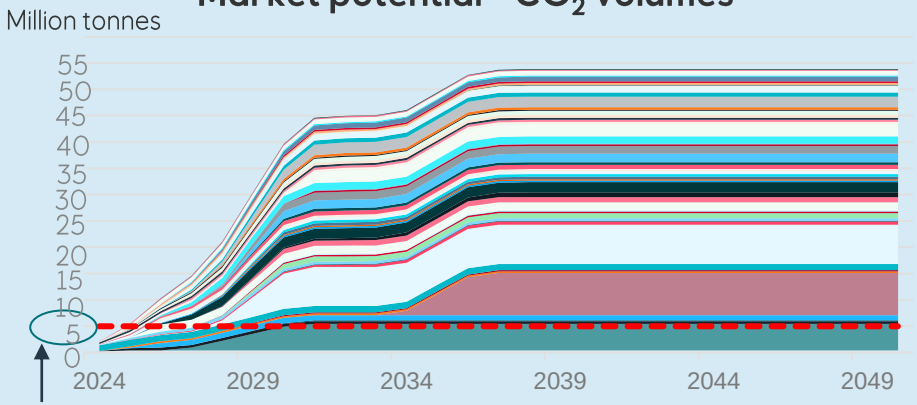
Emission reductions is driving demand for CO_2 transport and storage
- enabler for 'blue' hydrogen production

CO_2 transportation & storage

Lower barrier for industry to capture CO_2



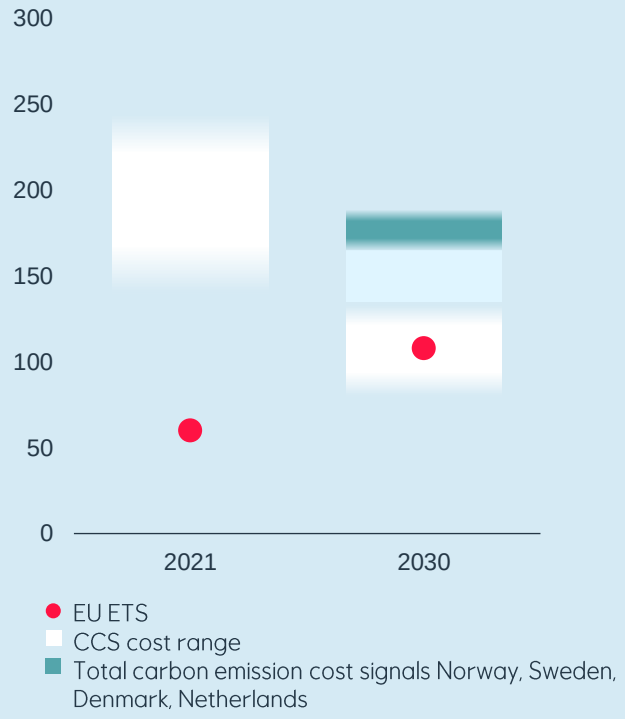
Market potential - CO_2 volumes



Northern Lights pipeline capacity

CCS cost vs. carbon emission costs

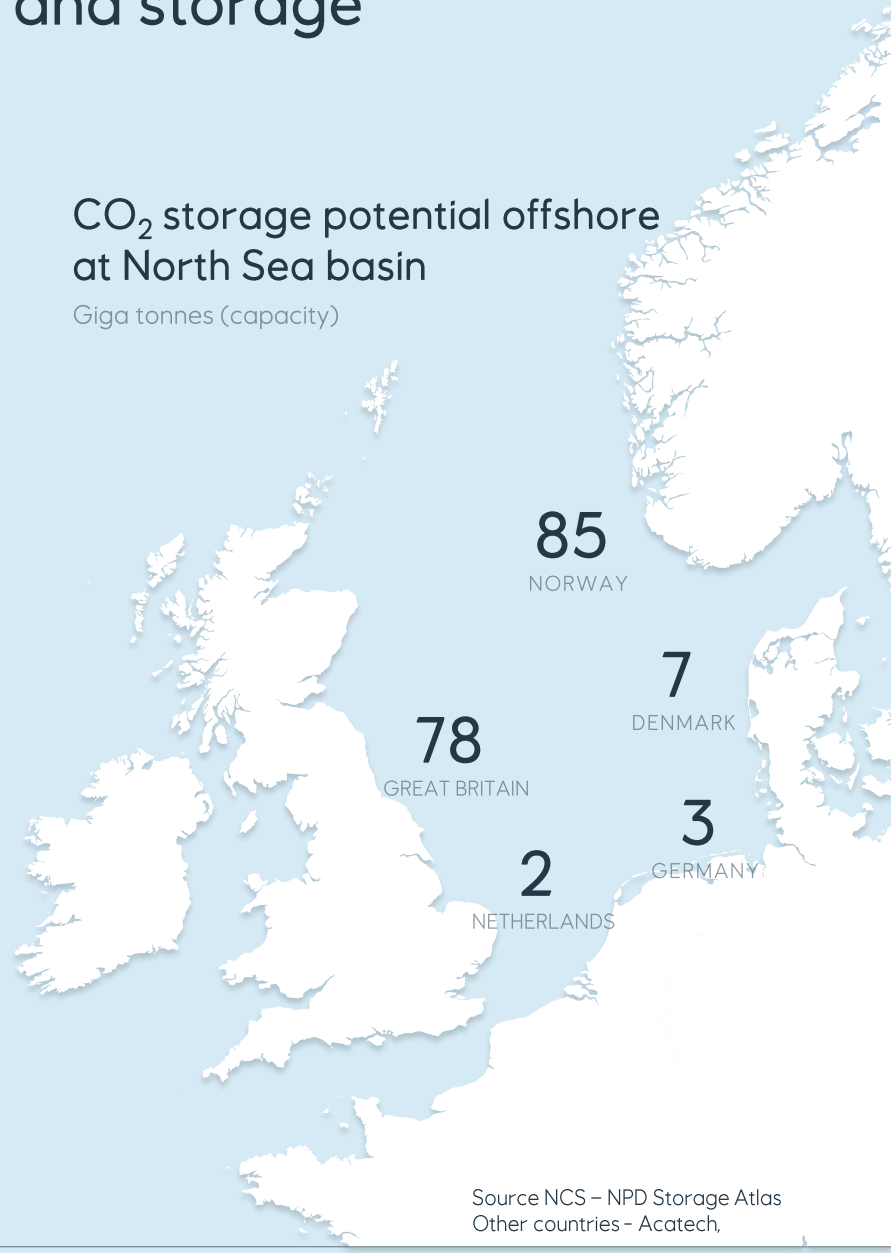
EUR per tonne



CCS cost: various sources including Equinor, Northern Lights and IEA.
EU ETS projections from BloombergNEF March 2021

CO_2 storage potential offshore at North Sea basin

Giga tonnes (capacity)



Source NCS – NPD Storage Atlas
Other countries - Acatech,

Equinor's CO_2 Storage, Hydrogen and Post Combustion CCS Portfolio

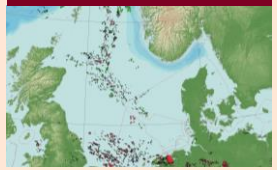
Transport & Storage (T&S)

2024>

Northern Lights

- CCS for industry
- Transport of CO2 by ship
- Open/ flexible

North Sea Basin



- In-house general screening
- Saline and depleted fields

2026

Northern Endurance Partnership

- Pipeline transport
- Storage for Humber and Teesside
- Potential scale-up opportunities identified

2029

Tri-State

- Supply hydrogen and collect CO_2 in a large US industrial area
- Offer geological CO_2 storage for industrial decarbonization

Polaris

- Storage solution for Barents Blue
- Offshore off-loading concept

Blue/green H2 and low carbon power

2025

Hydrogen Norway

- Liquid hydrogen for maritime
- Integration with existing onshore plants
- H2/Ammonia – Barents Blue

2026

Zero Carbon Humber

- Hydrogen for industry/power

Post-combustion portfolio

CCGT with CCS for industry

- Net Zero Teeside
- SSE Peterhead
- SSE Keadby 3

2027/28

NW Europe

- Hydrogen for industry (H2morrow steel)
- Hydrogen to power/industry (Magnum)
- Flexible back-up for intermittent renewable
- Market based H2 approach

2028

H2BE

- Hydrogen for hard-to-abate industry in Ghent /Antwerp cluster (steel, ammonia, chemicals, refinery)

2027

NortH2

2028

AquaSector

Progressing where advanced CCS/H2 policies | Require large CO_2 storage capacity

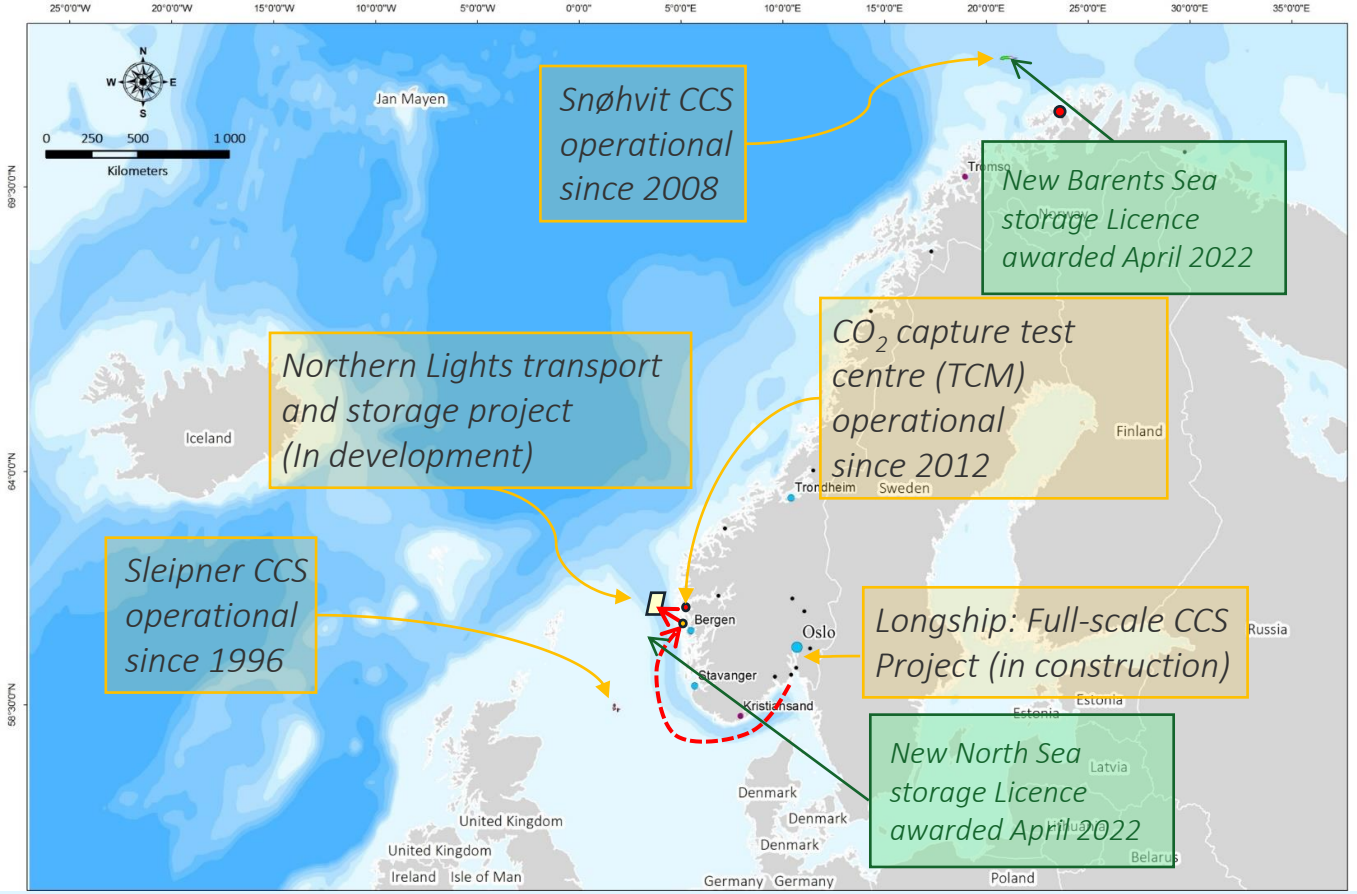
CCS in Norway

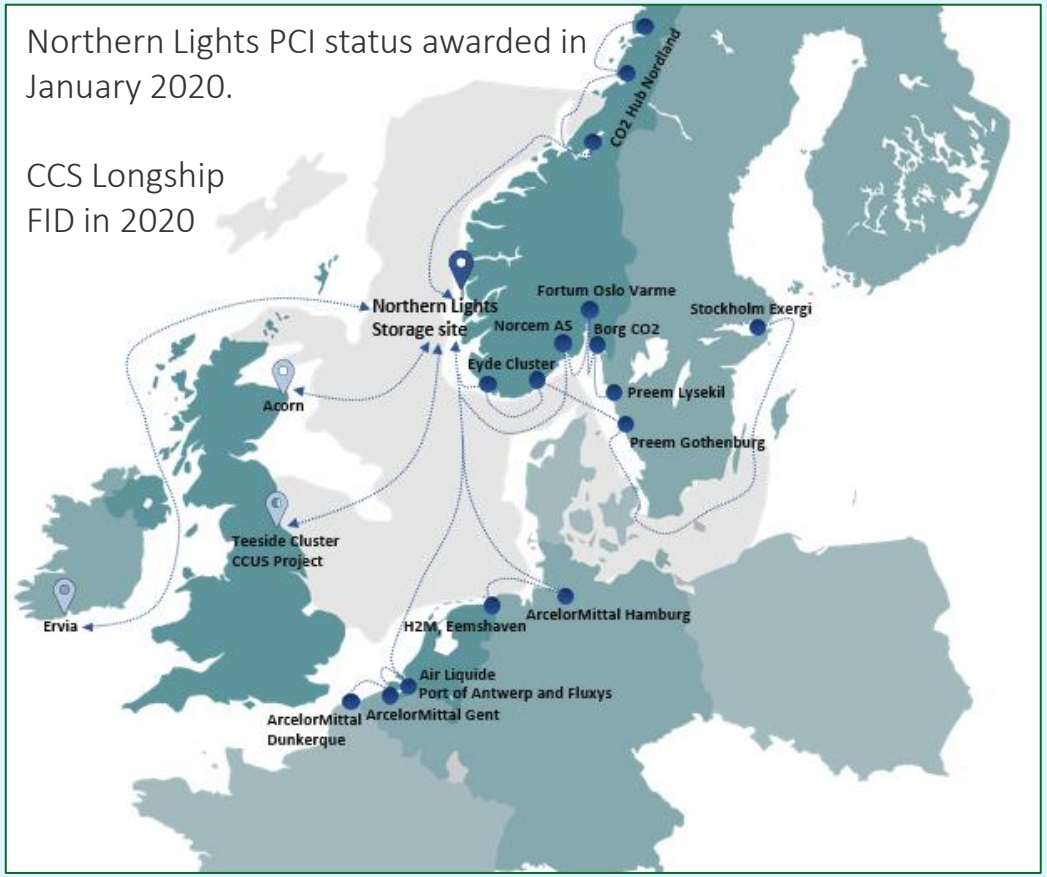
Building on experience

- 25 years of operations
- >26 Mt CO_2 stored

Supporting decarbonization

- Open storage concept
- Incipient CCS hub





Northern Lights

World's first third-party CO_2 storage

1.5 MTPA

CO_2 volumes phase 1

100% share

5 MTPA

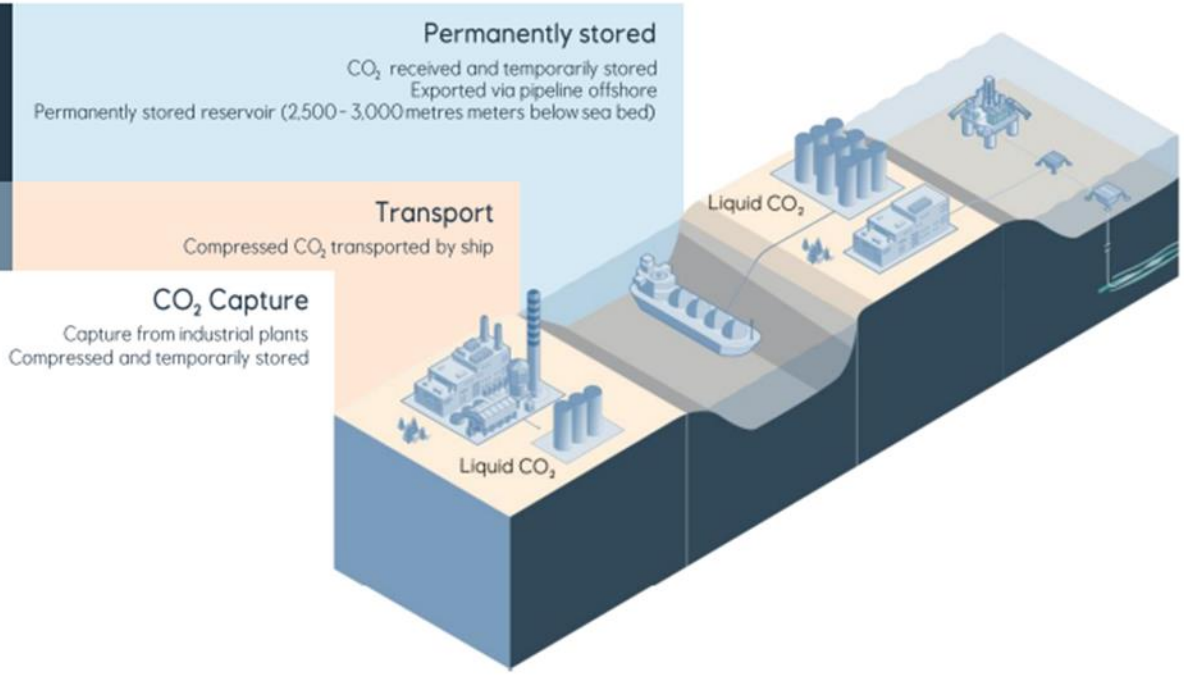
CO_2 volumes including phase 2

100% share

2024
Start-up, phase 1

2025-27
Start-up, phase 2

- Large scale CO_2 transportation and storage on NCS
- Interest from > 50 potential customers
- Joint venture with Total and Shell
- Funding from Norwegian government
- Capture sites eligible for EU innovation funding



[Equinor Capital Markets Day, June 2021]

Northern Lights and Yara sign first cross-border CO2 transport and storage deal in 'major milestone' for decarbonising Europe

CARBON CAPTURE USAGE & STORAGE

August 29, 2022, by Ajsa Habibic

Northern Lights and Yara sign first cross-border CO2 transport and storage deal in 'major milestone' for decarbonising Europe - Offshore Energy (offshore-energy.biz)

Equinor and Fluxys unveil plans for CO2 pipeline from Belgium to Norwegian offshore CCS

Equinor and Fluxys are working on plans for a pipeline to shift captured CO2 from Belgium to storage sites off Norway.

Equinor and Fluxys unveil plans for CO2 pipeline from Belgium to Norwegian offshore CCS | Upstream Online

PIPELINES

North Sea pipeline to transport CO2 from Germany to storage sites in Norway

Equinor and Wintershall Dea will collaborate on a new carbon capture and storage (CCS) development in Norway and Germany.

Aug. 30, 2022

https://www.offshore-mag.com/pipelines/article/14281987/north-sea-pipeline-to-transport-co2-from-germany-to-storage-sites-in-norway

BP leads heavy-hitters in 'Endurance' CO2 storage funding bid in UK

Consortium also with Eni, Equinor, Total, Shell and National Grid aims to kick-start infrastructure to capture emissions from Teesside and Humberside industrial decarbonisation projects

https://www.upstreamonline.com/energy-transition/bp-leads-heavy-hitters-in-endurance-co2-storage-funding-bid-in-uk/2-1-899907

Important step to decarbonise Europe

August 29th, 2022

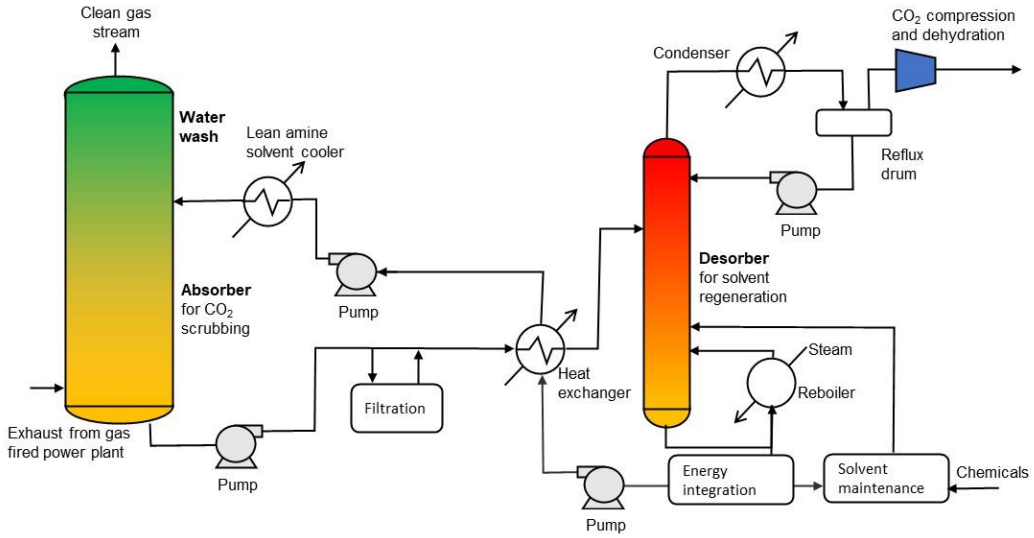
The Northern Lights site at Øygarden near Bergen.
(Photo: Rikard Wilson / Equinor ASA)

https://www.equinor.com/news/20220829-important-step-to-decarbonise-europe

- Northern Lights JV signs the world's first commercial agreement on cross border CO_2 transportation and storage with Yara
- 800 000 tonnes of CO_2 per year
- Stored 2600 meters under the seabed

CO_2 capture for dispatchable power generation is experimentally verified

- Post-combustion CO_2 capture plants can operate flexibly and follow dynamics of gas fired Combined Cycle Gas Turbine (CCGT)
- Demands:
  - Frequent start-up and shut-down events
  - Shorter start and stop times
  - High CO_2 capture rate overall
  - Higher ramp rates and lower minimum load
- All these aspects have been tested at Technology Centre Mongstad (TCM) which:
  - Is world's largest demonstration of CO_2 capture
  - Has tested many commercial suppliers
  - Is owned by Gassnova, Equinor, Shell and TotalEnergies
- Transient tests documented in various academic papers and reports (e.g.: ref. [1-4])



CCS for flexible dispatchable power generation is being commercialized[1] in the UK

- CCGT power stations with post-combustion carbon capture
- Developed as part of the Cluster Sequencing Process initiated by the Department for Business, Energy and Industry Strategy (BEIS).

Examples:

- East Coast Cluster:
  - Keadby 3 Carbon Capture Power Station
  - Net Zero Teesside Power (NZT Power)
- Scottish Cluster:
  - Peterhead Carbon Capture Power Station

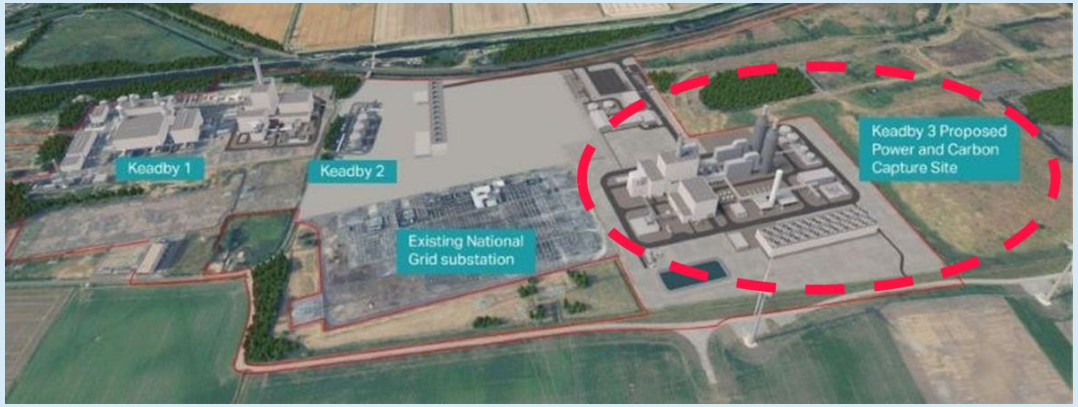
- BEIS has also awarded grant funding to the R&D project FOCUSS – Flexibly Operated Capture using Solvent Storage, [6]

Typical impression of two 1X1 H-Class CCGT with post-combustion carbon capture, Adapted from [5]

1 Subject to final investment decision

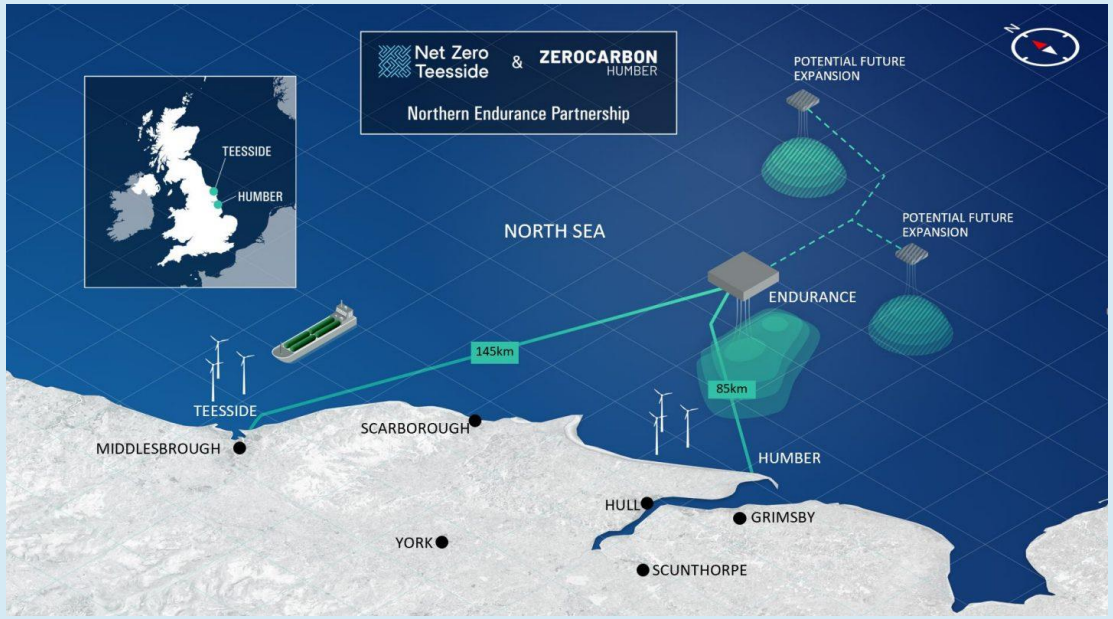
Keadby 3 Carbon Capture Power Station

- CCGT power station with carbon capture
- Up to 910 MW of flexible dispatchable power
- Partners: SSE Thermal and Equinor
- FEED awarded June 2022 to a consortium of: Aker Solutions, Siemens Energy and Doosan Babcock, with Aker Carbon Capture supporting on the carbon capture technology



Adapted from [7] and [8]

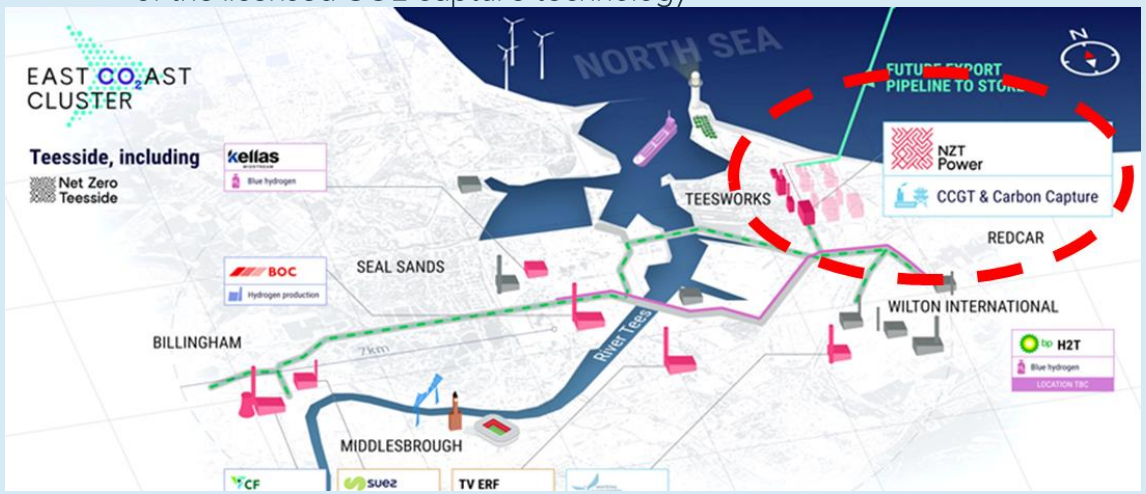
- Transport and Storage planned to be provided by the Northern Endurance Partnership
- Partners: bp, Eni, Equinor, National Grid, Shell and Total



Adapted from [9] and [10]

Net Zero Teesside Power (NZT Power)

- CCGT power station with carbon capture
- Up to 860 MW of flexible dispatchable power
- Partners: bp and Equinor
- FEED awarded Dec 2021 to two consortiums:
  - Technip Energies and General Electric consortium: including Shell as a subcontractor for the provision of the licensed Cansolv CO2 capture technology and Balfour Beatty as the nominated construction partner
  - Aker Solutions, Doosan Babcock, and Siemens Energy consortium: including Aker Carbon Capture as a subcontractor for the provision of the licensed CO2 capture technology



Adapted from [11] and [12]

- Transport and Storage planned to be provided by the Northern Endurance Partnership
- Partners: bp, Eni, Equinor, National Grid, Shell and Total

Adapted from [9] and [10]

Peterhead Carbon Capture Power Station

- CCGT power station with carbon capture
- Up to 910 MW of flexible dispatchable power
- Partners: SSE Thermal and Equinor
- FEED awarded July 2022 to a consortium of: Mitsubishi Heavy Industries Group, Worley and Técnicas Reunidas

Adapted from [13], [14] and [15]

- Transport and Storage planned to be provided by the Acorn project
- Industry partners: Storegga, Shell, Harbour Energy and NSMP

Adapted from [16]

Summary

- Northern Lights, the world's first third-party CO_2 storage, is under construction and start up is scheduled for 2024.
- The Northern Lights JV has signed the world's first commercial agreement on cross border CO_2 transportation and storage.
- We aim to scale up CCS and provide a CO_2 storage capacity of 15-30 million tonnes per year by 2035[1].
- CO_2 capture for dispatchable power generation is experimentally verified at Technology Centre Mongstad (TCM).
- CCS for flexible dispatchable power generation is being commercialized in the UK[2].

1 Equinor share 2 Subject to final investment decision

References (accessed October 8-9, 2022)

[1] Scale-Up and Transient Operation of CO2 Capture Plants at CO2 Technology Centre Mongstad | Abu Dhabi International Petroleum Exhibition and Conference | OnePetro

[2] Dynamic operation and modelling of amine-based CO2 capture at pilot scale – ScienceDirect

[3] Dynamic Process Model Validation and Control of the Amine Plant at CO2 Technology Centre Mongstad

[4] Demonstrating flexible operation of the Technology Centre Mongstad (TCM) CO2 capture plant

[5] Start-up and Shut-down times of power CCUS facilities (publishing.service.gov.uk)

[6] Carbon Capture, Usage and Storage (CCUS) Innovation 2.0 competition: Call 1 successful projects - GOV.UK (www.gov.uk)

[7] https://www.ssethermal.com/flexible-generation/development/keadby-3-carbon-capture/

[8] https://www.sse.com/news-and-views/2022/06/major-contract-for-keadby-3-carbon-capture-power-station/

[9] https://www.bp.com/en/global/corporate/news-and-insights/reimagining-energy/northern-endurance-partnership-to-develop-offshore-ccus-infrastructure.html

[10] https://www.netzeroteesside.co.uk/northern-endurance-partnership/

[11] https://www.netzeroteesside.co.uk/project//

[12] https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-and-partners-award-first-engineering-contracts-advancing-major-uk-power-and-carbon-capture-projects.html

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[15] https://www.sse.com/news-and-views/2022/03/peterhead-takes-major-step-towards-low-carbon-power-as-planning-application-submitted//

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Carbon Capture solutions and demonstrations

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