Shaping the Future of CCS

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Agenda

- Introduction to Wood
- Emergence of CCS HUBs
- Award winning CO_2 Specification Joint Industrial Project
- Active measurement and control
- Digitally-enabled CCS

The Offshore Achievement Awards (13 March 2025)

We are a world leading consulting and engineering company across energy and materials markets.

160+
year history

c35,000
people

60+
countries

Unlocking solutions to critical challenges. Areas of expertise:

- **Energy Security**
- **Energy Transition**
- **Decarbonisation**
- **Digital Delivery**
- **Circular Economy**

At the heart of Wood's growth strategy

Energy.

Security
- Oil & Gas

Transition
- Hydrogen
- Carbon Capture

Cross-cutting growth drivers
- Decarbonisation
- Digitalisation

Materials.

Raw materials
- Mineral Processing
- Refining & Chemicals

Life sciences
- Pharma

Our track record in CCUS

200+ studies
completed across the globe.

40+ years
experience in this space.

Total portfolio could save
gigatons of CO_2

Helping to deliver one of the **world's largest CCS hubs** in Middle East.

Capturing 95% of CO_2 emissions from industrial facilities on US Gulf Coast.

Designed & built key parts of **CO_2 pipeline network** now operational in UAE.

FEED contractor for **CO_2 and H_2 pipelines** for major UK industrial clusters

Designing **400km CCS pipeline** in Canada to capture emissions from six largest oil sands producers.

Deploying proprietary Wood tool to maintain system integrity on one of the **world's largest CO_2 injection facilities.**

Leading a joint industry partnership (JIP) to **set CO_2 specification guidelines** for effective and economic CCS chains.

Full-chain CCUS

We bring technical and commercial solutions that enable clients to safely capture CO_2, transport and permanently store it, or unlock value by re-using it for alternative purposes.

Capture CO_2 from:

- Power generation
- Industries (e.g. cement, glass, bricks)
- Refineries
- Hydrogen production

Conditioning:

- Compression, dehydration and additional purification
- Temporary storage onsite or direct connection to pipeline

Transportation via:

- Pipeline
- Road
- Ship
- Rail

Store or use:

- Store permanently in geological storage
- Use CO_2 in industry e.g. food products, fire suppression
- Utilise CO_2 for methanol production, methanation, etc.

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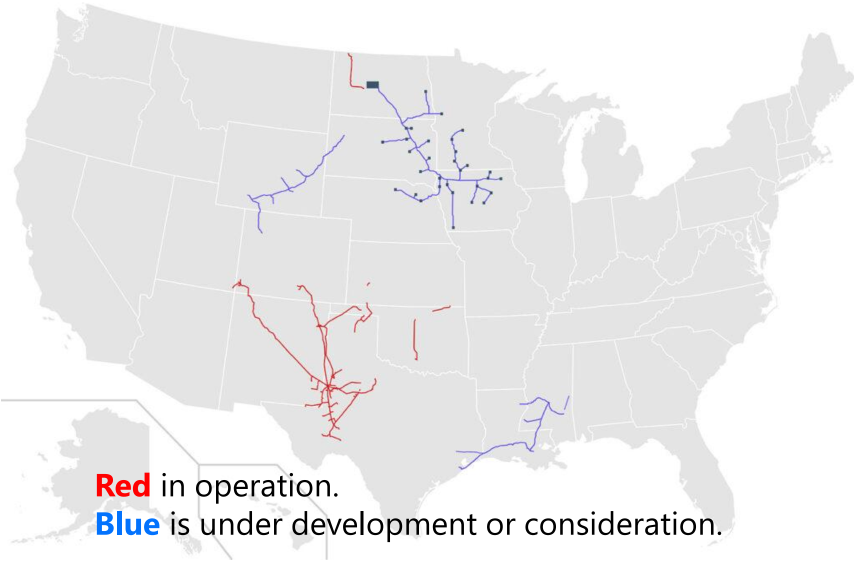
Operating CCS Projects

- Globally, there are around **45 commercial carbon capture facilities in operation**, with a total annual capture capacity >50 MTPA.
- While we're capturing CO_2 at a reasonable volume, there's currently very **limited CO_2 injection for long term sequestration**.
- CCUS projects are often technically **complex**, **expensive,** and require significant **financial incentives** to make the business case stack up.
- **Underperforming projects** (e.g. never reached their target injection rates) considerably outnumbered successful experiences.!
- In America alone, there are >50 CO2 pipelines (>8,000 km/5,000 miles) operated with capacity of 70 MTA. Since 2010, there have been **~70 incidents on CO_2 pipelines** (PHMSA database).
- On positive side, in Norway alone, the Sleipner and Snøhvit facilities have stored close **to 26 MTA of CO2 since 1996**. Northern Lights - 'World's first' cross-border CO2 transport and storage facility is officially open.

Footprint of carbon dioxide pipelines in the US.



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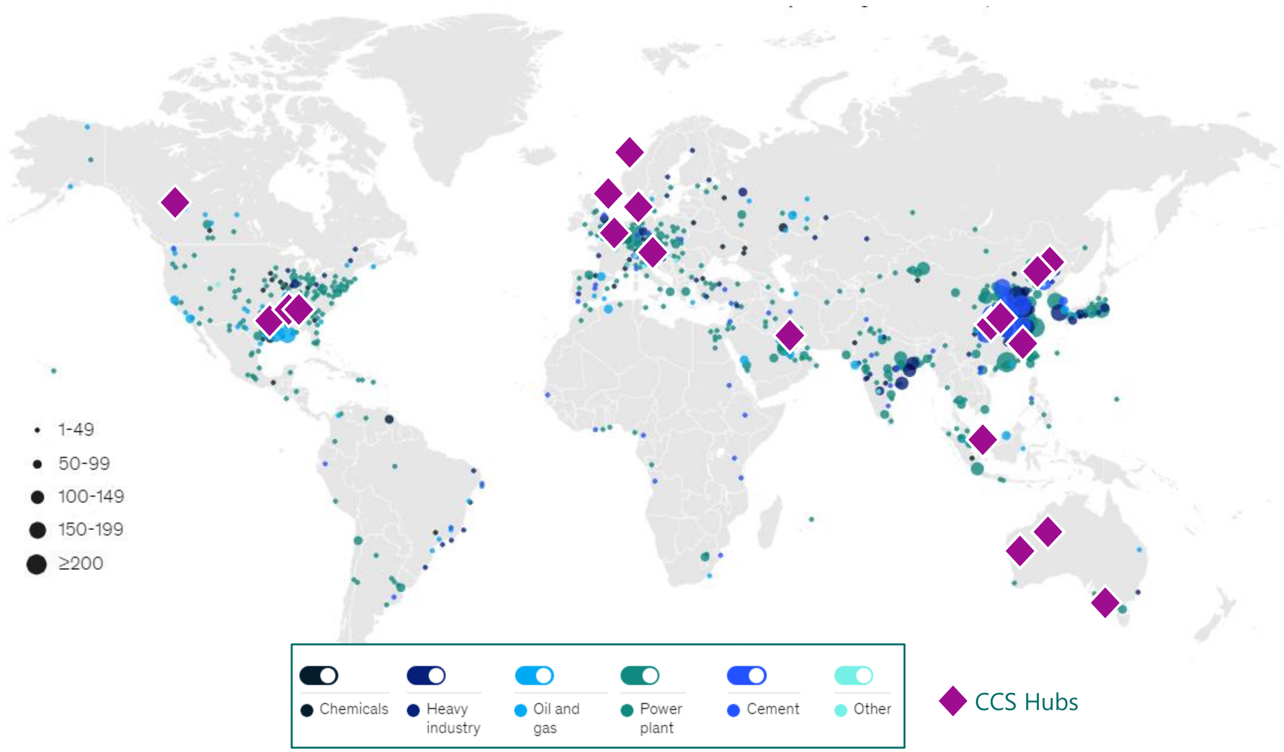
Emergence of CCS hubs

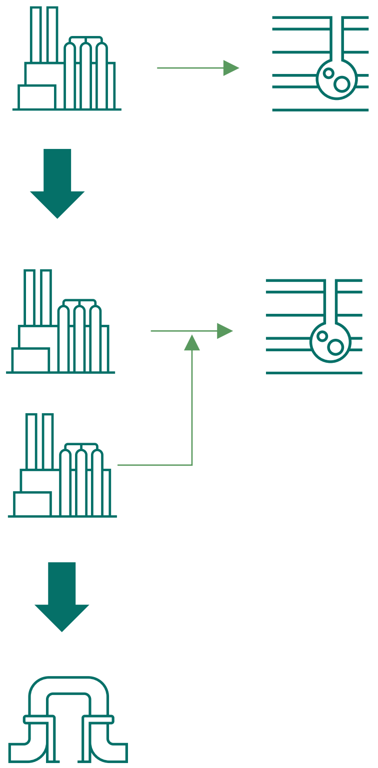
Map of global Emission vs planned CCS HUBs



There are >15 CCUS hubs globally under various stages of development with many more being planned.

Over half of these are in Europe.

Ref. McKinsey 2024



- 'Vertical projects'
- Early 'full-chain' model
- High liabilities
- Single CO_2 source

- Driver for cluster model
- Cost spread
- Economies of scale
- Accessibility
- Incentives
- Varying CO_2 source

- Increase in project scale
- Large transport component
- Value-chain focus
- Specialist skillsets

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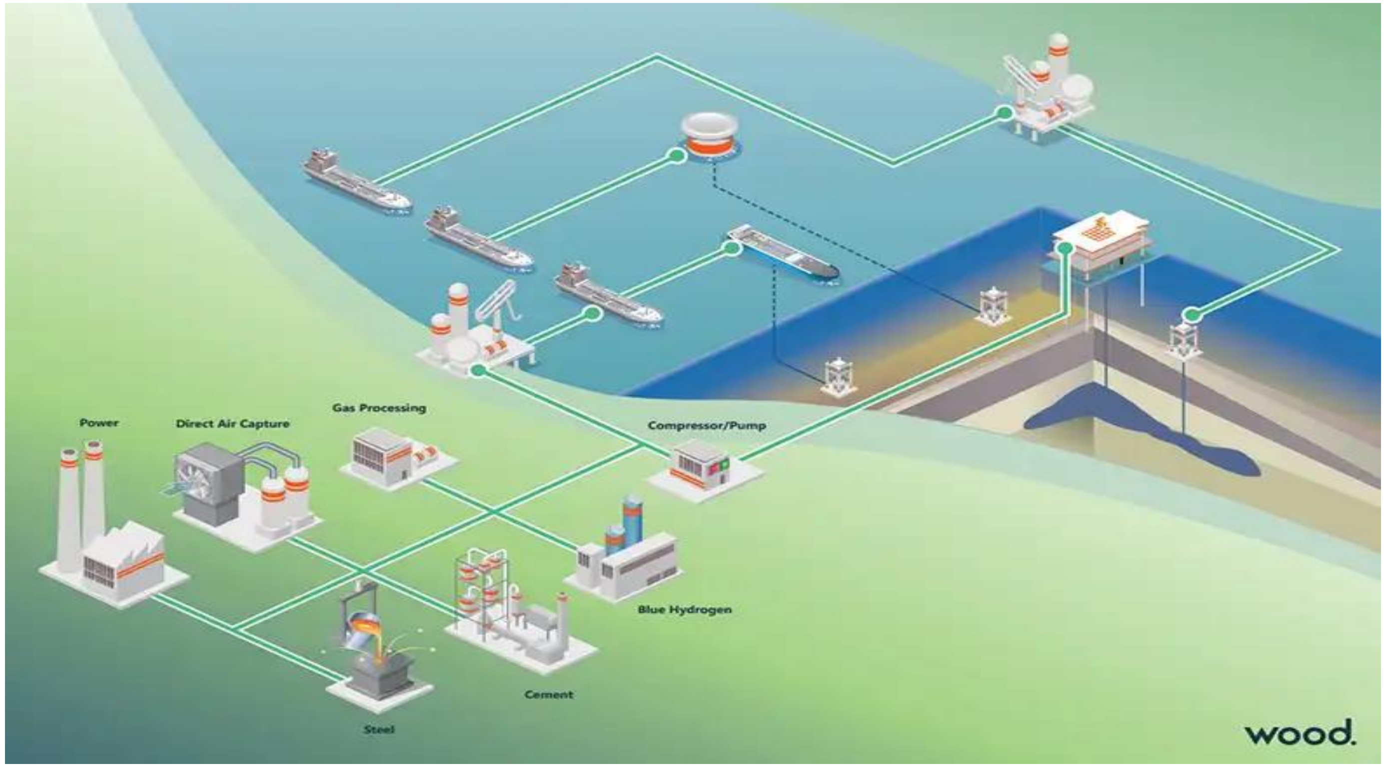
CO_2 Specification in CCUS Chains

Setting CO_2 specification guidelines for CCUS chains

- Wood is leading a Joint Industry Project (JIP) to define an industry accepted set of guidelines to set the CO_2 specification for effective and economic CCS chains.
- This covers different CO_2 sources and transport options and aims to build better understanding on the impact of impurities.

- WP1 – Thermodynamics
- WP2 – Chemical Reactions
- WP3 – Materials & Corrosion
- WP4 – Safety & Environment
- WP5 – Capture & Conditioning
- WP6 – Compression & Pumping
- WP7 – Metering & Sampling
- WP8 – Pipeline Transportation
- WP9 – Ship Transportation
- WP10 – Geological Storage
- WP11 - Economics



JIP Work Packages

Work Package	Scope
WP 1 – Thermodynamics	Review of existing experimental data on CO2 behaviour with impurities and development of a risk-based approach for predicting thermodynamic properties in data gaps. Develop a logic chart for EoS Selection.
WP 2 – Chemical Reactions	Review of chemical reactions and their impact across CCUS chain. Gap analysis on the availability of reliable experimental data and modelling tools and risk-based analysis of impurities impact.
WP 3 – Materials and Corrosion	Review of accuracy of existing corrosion prediction models and assessment of the impact of impurities on material selection and integrity of equipment.
WP 4 – Safety and Environment	Assess the impact of impurities on safety risk and dispersion and review of consequence modelling vs validated data.
WP 5 – CO2 Capture & Conditioning	Impact of impurities on process equipment performance and review of impurity removal and conditioning processes
WP 6 – CO2 Compression & Pumping	Assessing the impact of impurities on optimum compression and pumping philosophy.
WP 7 – CO2 Metering	Review of metering technology and philosophy for CCS based on CO2 phase and impurities composition. Determination of optimum sampling techniques and locations based on the nature of impurities.
WP 8 – Pipeline Transportation	Impact of impurities on pipeline design, operation and integrity (fatigue and fracture control). Address suitability of re-using existing pipelines for CO2 transmission in the presence of different impurities.
WP 9 – Ship Transportation	Review the impact of impurities on ship operations, equipment, fluid behaviour and tank design pressure / temperature.
WP 10 - Geological Storage	Assess impact of impurities on injectivity, reservoir permeability and caprock integrity both near wellbore and deeper in formation. Review the impact of impurities on the re-use of existing depleted gas or saline reservoirs.
WP 11 - Economics	Development of guidelines for economic evaluation and cost estimation with standard approach for calculation carbon abatement.
WP 12 – Guidelines	Consolidation of guidelines from above work packages into a holistic approach for setting the CO2 specification considering the entire CCS chain. Development of a logical workflow diagram to frame the guidelines.
WP 13 – Project Management	Coordination and management of the JIP. Communications with stakeholders and marketing of the JIP.

Active measurement and control

Fluid Sampling and Analysis plays a major role, however the possibility of detecting and shutting off the flow of off-spec CO2 from an emitter can be a challenge.

- Online measurement of key components (CO_2, H_2O, O_2, NO_x, SO_x and H_2S) can be measured at the level of typical threshold from fluid specification
- Even though the measurement is instantaneous, there will a lag of a few mins between gas sampling and measurement at a localist panel.
- The assumption is that analysis will be done offline with manual sampling for the remaining components ; gas sample will be taken to lab to perform analysis. Can take hours if not days to detect an offspec?

"What gets measured gets managed!"

Analyte	Sensor type	Sensitivity	Linear Range	Speed/ Time Resolution	Potential Interferences*
CO	Spectroscopy VUV at 150 nm	<1 ppb	~1 ppb – 100000 ppb	10 ms – 1 sec	
CO	Carbon monoxide electrochemical cell, 3-electrode, O_2> 5% required, -40° to +50° C	1 ppm	3-1000 μmol mol^{-1} (3.4–1145 mg/m^3) ± 3%	≤20 sec (50%), ≤40 sec (90%)	Dimethylamine, HCl, CO, NO, H_2, H_2S, NO_2, SO_2, HCN
NO_x	Spectroscopy Chemiluminescence at 425 nm	1 ppb	<2 – 500 ppb	5 Hz	
NO_x	Oxides of nitrogen electrochemical cell, 3-electrode, O_2> 5% required, -25° to +50° C				
NO_2	Nitrogen dioxide electrochemical cell, 3-electrode, O_2> 5% required, -25° to +50° C				
NO	Nitric oxide electrochemical cell, 3-electrode, O_2> 5% required, -40° to +50° C				
HCOH	Fluorimetric using Hantzsch (acetyl-acetone) reaction				
HCOH	Hydrocarbon electrochemical cell, 3-electrode, -20° to +50° C				
CH_3CHO	Hydrocarbon electrochemical cell, 3-electrode, -20° to +50° C				

NH_3	Ammonia electrochemical cell, 3-electrode, O_2> 5% required, -40° to +50° C	1 ppm	5-500 μmol mol^{-1}, ± 3%	≤50 sec (50%), ≤230 sec (90%)	Dimethylamine, HCl, CO, NO, H_2, H_2S, NO_2, SO_2, HCN
H_2S	Hydrogen sulphide electrochemical cell, 3-electrode, O_2> 5% required, -20° to +50° C	0.1 ppm	0.1-200 μmol mol^{-1} (0.4-164 mg/m^3), ± 3%	50 sec (50%), 360 sec (90%)	NH_3, HCl, CO, NO, H_2, NO_2, SO_2
SO_2	Sulphur dioxide electrochemical cell, 3-electrode, O_2> 5% required, -40° to +50° C	0.2 ppm	0.2-500 μmol mol^{-1} (0.52-1309 mg/m^3), ± 3%	10 sec (50%), 30 sec (90%)	C_2H_2, HCN, C_2H_4, NO, HCl, NO_2
O_2	Oxygen electrochemical cell, 2-electrode, -40° to +50° C	0.05%	0.05-25.0 % v/v, ± 2%	≤10 sec (50%), ≤15 sec (90%)	H_2S, CO_2
Hydro-carbons	Hydrocarbon electrochemical cell, 3-electrode, -20° to +50° C	0.2 ppm	0.5-200 μmol mol^{-1}, ± 3%	30 sec (50%), 150 sec (90%)	CH_3CHO, HCOH, CO, NO_2, SO_2, H_2, NO
H_2	Hydrogen electrochemical cell, 3-electrode, O_2> 5% required, -30° to +55° C	0.02%	0.02-10.0% v/v, ± 2%	≤20 sec (50%), ≤75 sec (90%)	CO, C_2H_2, C_2H_4
HF	Hydrogen fluoride electrochemical cell, 2-electrode, -20° to +50° C	0.2 ppm	0.5-200 μmol mol^{-1} (0.42-167 mg/m^3), ± 3%	50 sec (50%), 360 sec (90%)	NH_3, HCl, NO, H_2S, NO_2, SO_2, HCN
HCl	Hydrogen chloride electrochemical cell, 3-electrode, O_2> 5% required, -20° to +50° C	0.2 ppm	0.5-200 μmol mol^{-1} (0.73-294 mg/m^3), ± 3%	≤50 sec (50%), ≤360 sec (90%)	H_2S, NO, SO_2, NO_2, HCN, CO
HCN	Hydrogen cyanide electrochemical cell, 3-electrode, O_2> 5% required, -20° to +50° C	0.2 ppm	0.5-200 μmol mol^{-1} (0.57-226 mg/m^3), ± 3%	≤10 sec (50%), ≤30 sec (90%)	SO_2, C_2H_2

Digitally-enabled CCS

Wood's Digital twin, **Virtuoso®**, is a field-proven solution for design, asset operations management and optimisation.

Deliverability

Predict and manages CO_2 injection process and monitors operational integrity by tracking the impurities across the network during transient operations and warns against risk of corrosion.

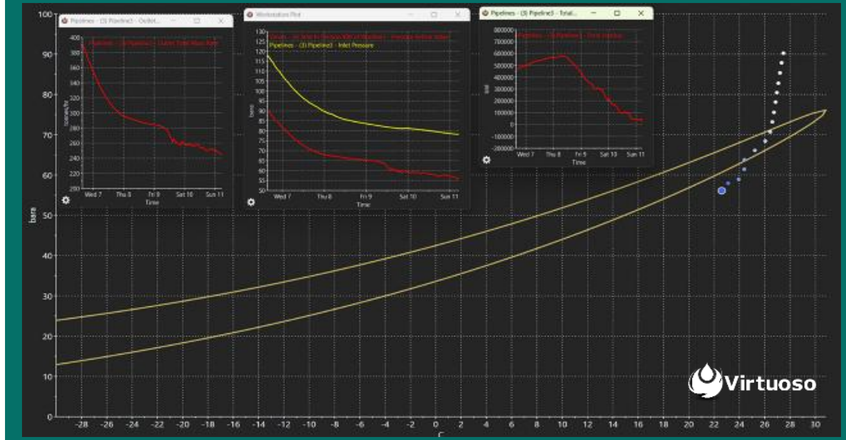
Availability

Online monitoring and offline simulation functionalities to reduce downtime, unplanned operation with real-time alarms for faults, changes, off spec fluid management.

Safety and Efficiency

Efficient handover from design to operation ensures that the CCS network's operation is low-risk, scalable, energy-efficient and sustainable.

Digital solutions are key to managing the complexities that come with designing and operating a CCS hub.



Digitally-enabled CCS in action

Gorgon, Australia

- One of the largest LNG projects on the Western Australia (WA), with and export capacity of 15.6 million tonnes (MT) of liquefied natural gas (LNG) and provides the state with up to 300 terajoules (TJ) of domestic gas daily.
- Utilises the world's largest CCS system designed to capture carbon emissions and aims to **reduce GHG emissions from the Gorgon project by ~40%.**
- **Virtuoso®** was successfully deployed to monitor real-time combined flow of CO_2 from the outlet of compressors to the bottom of the injection wells.

Virtuoso

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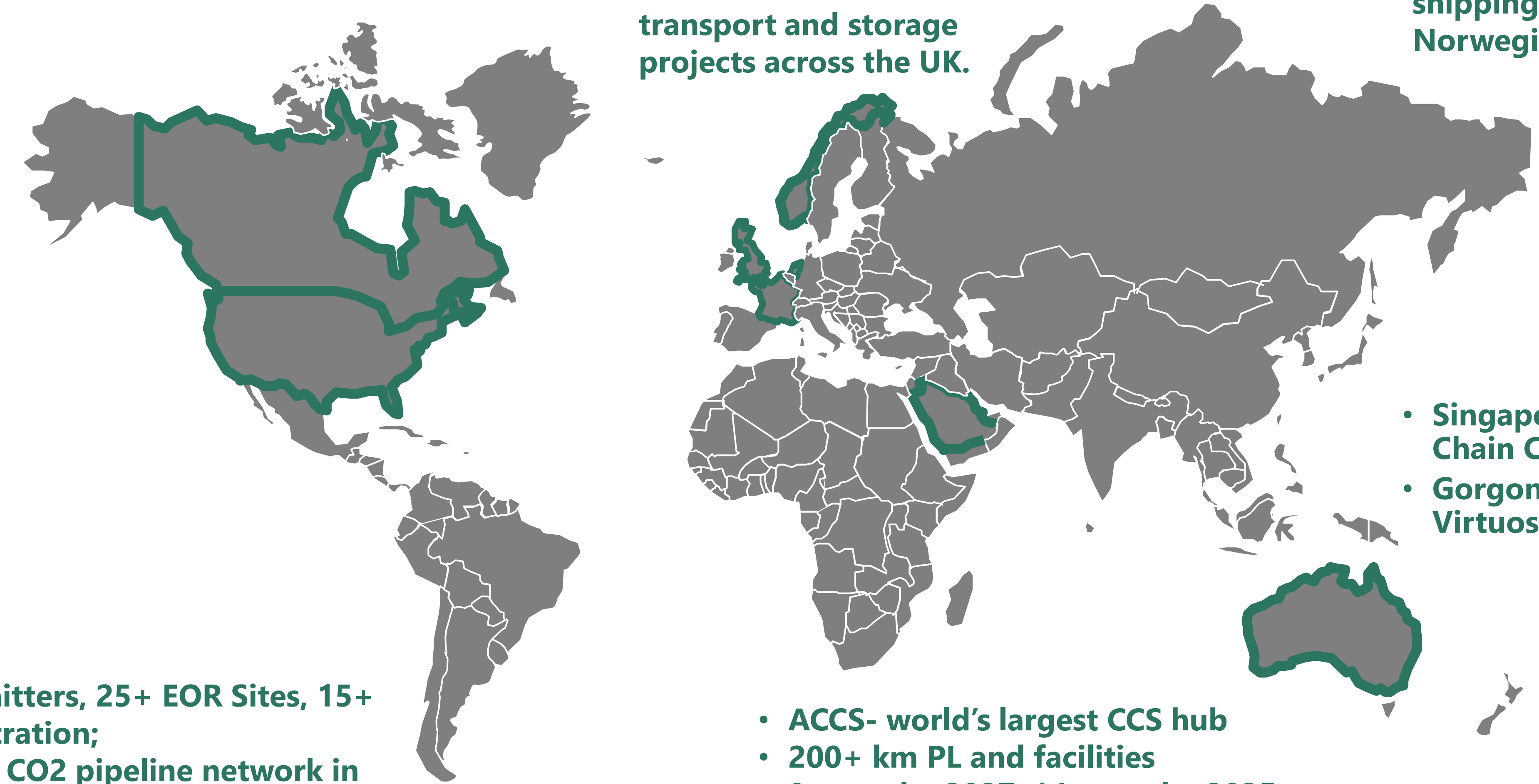
Emerging Global and UK CO2 T&S Expertise

- 400+km PL + hub for oil sands
- 10-12 mtpa by 2030, 40 mtpa by 2050

- Providing feasibility studies, PreFEED, IPMT and FEED services for all the five major onshore and offshore CO2 transport and storage projects across the UK.

- Capture of CO_2 from European hubs
- Transport via pipeline or shipping to offshore Norwegian storage sites.



- Singapore to Australia LCO2 Value Chain Concept
- Gorgon CO2 Digital Process Twin-Virtuoso

- 20+ emitters, 25+ EOR Sites, 15+ sequestration;
- Largest CO2 pipeline network in the US.

- ACCS- world's largest CCS hub
- 200+ km PL and facilities
- 9 mtpa by 2027, 14 mtpa by 2035

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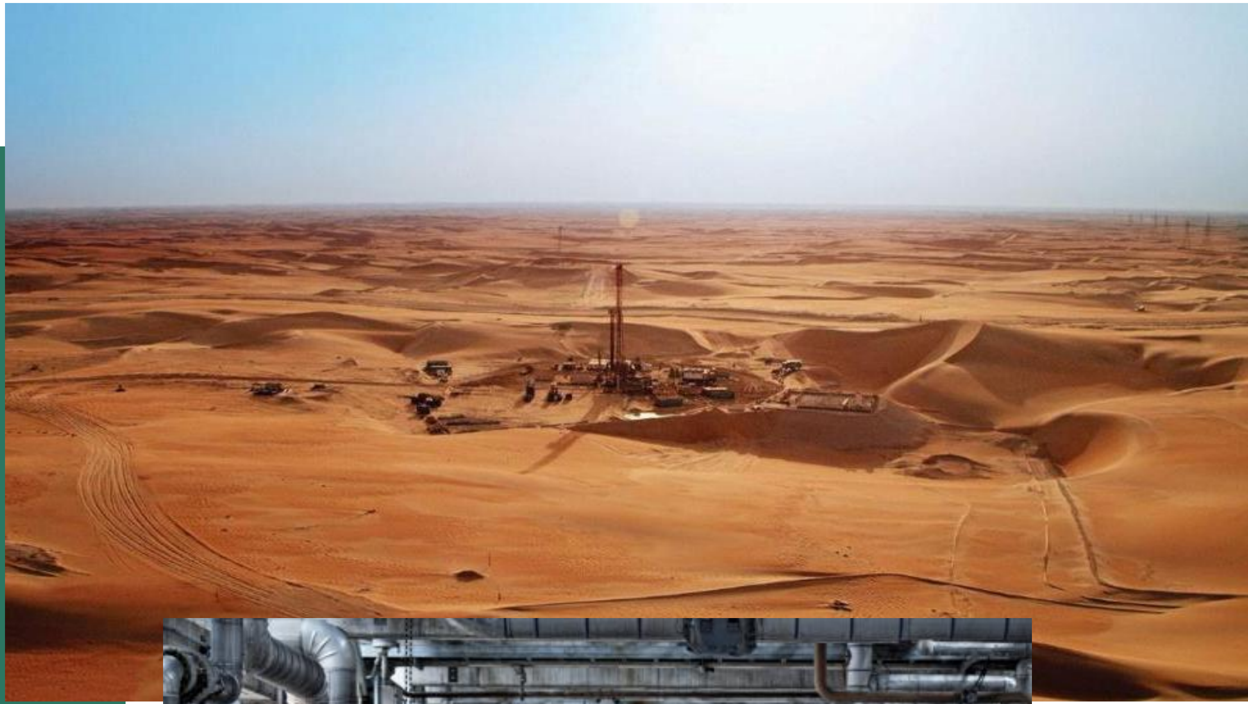
Designing two of the world's largest carbon capture and sequestration hub



Confidential projects:

- Wood designed the greenfield dehydration and compression facilities and the large pipeline network, including >600+km dense-phase CO_2 pipelines for these two projects.
- These projects will remove up to 80m tons per year of CO_2 – this will be sequestrated within onshore geological storage sites.
- These pre-FEEDs, FEEDs were being delivered by 300 engineers from across Wood's global Projects and Consulting teams

Our Reflections

- Wood is committed to supporting local supply chain
- Collaboration is key!
- Wood continues to deliver for major operators and our UK business is positioned for growth.

Contact

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