MAHON, R. and OLUYEMI, G. 2024. From sands to solutions: the role of sand management in carbon capture and storage projects to enable the energy transition. Presented at the 10th Sand Management Network Euroforum 2024, 27-28 November 2024, Aberdeen, UK.

From sands to solutions: the role of sand management in carbon capture and storage projects to enable the energy transition.

MAHON, R. and OLUYEMI, G.

2024

From Sands to Solutions: The Role of Sand Management in Carbon Capture and Storage Projects to Enable the Energy Transition

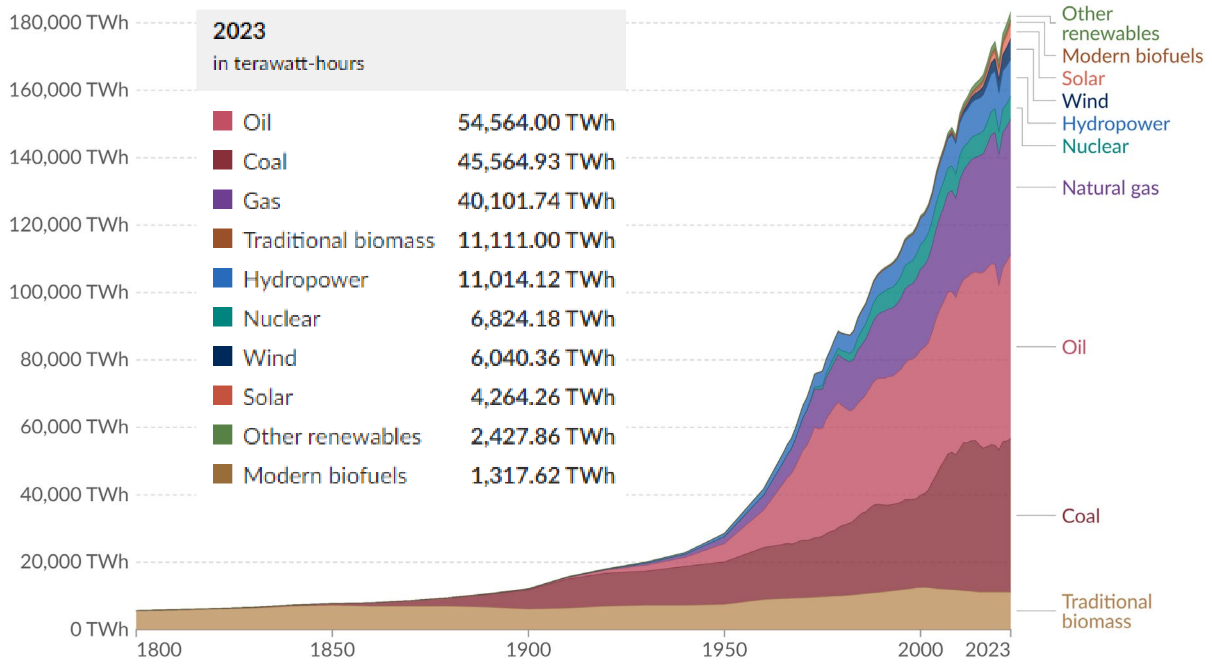
Dr Ruissein Mahon & Dr Gbenga Oluyemi

Outline

- Energy landscape
- GHG emissions
- Energy transition
- CCS
- Case studies
- Opportunities
- Key takeaways
- Future direction

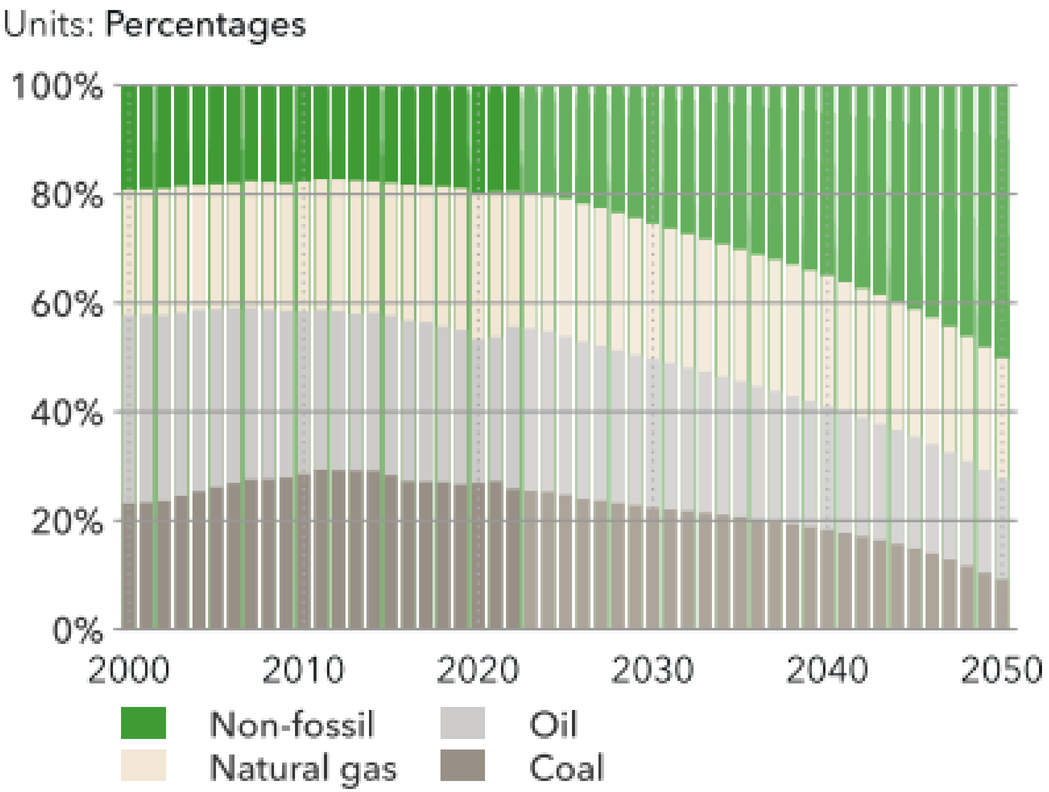
Global Energy Landscape

- Oil is the largest contributor to the energy supply since surpassing coal in 1964.
- Over the last decade, the share of oil in the primary energy supply has been ~30%.
- Renewable power generation is gaining momentum.
- China recorded the highest level of renewable installations in 2023 as the entire world in 2022.
- Overall, wind and solar generation rose rapidly (+10% and +25%, respectively) to reach 15% of the G20 power mix.



Global primary energy consumption by source (Our World in Data, 2024)

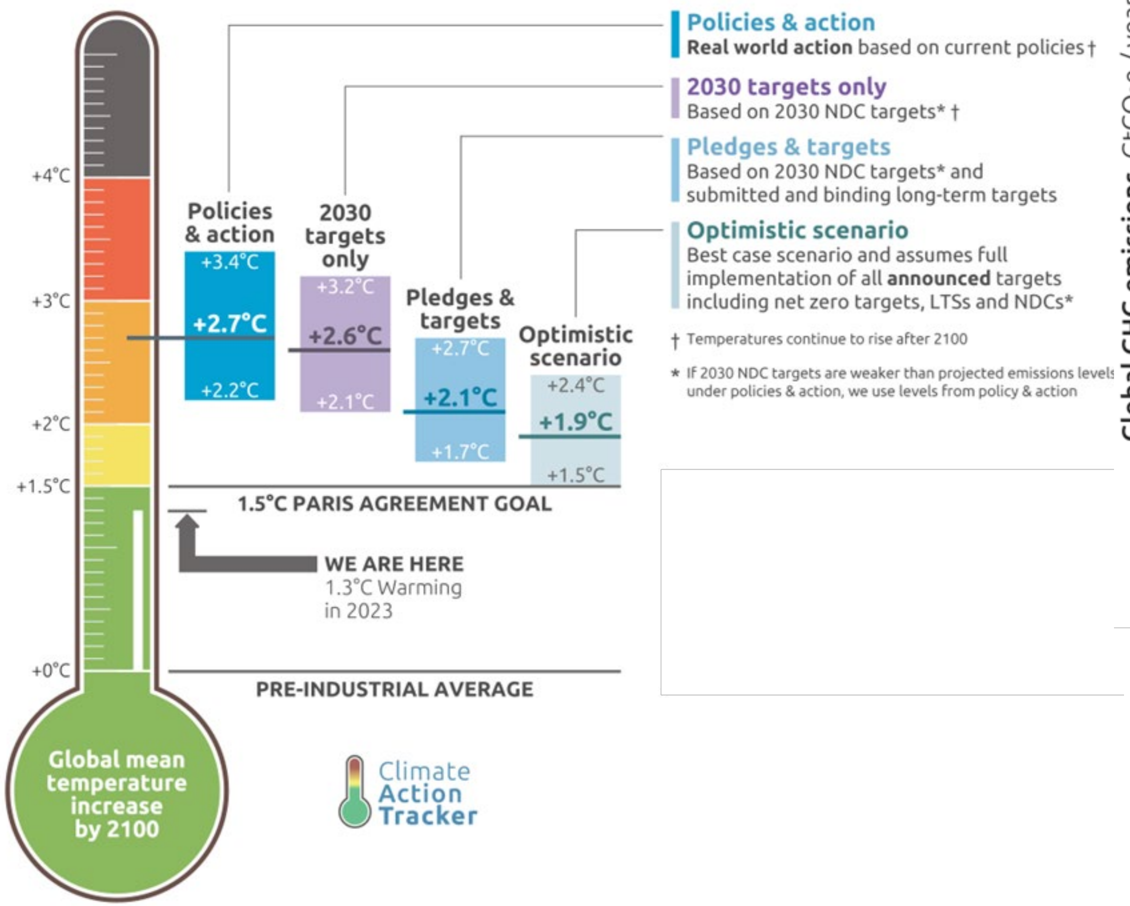
Global Energy Landscape

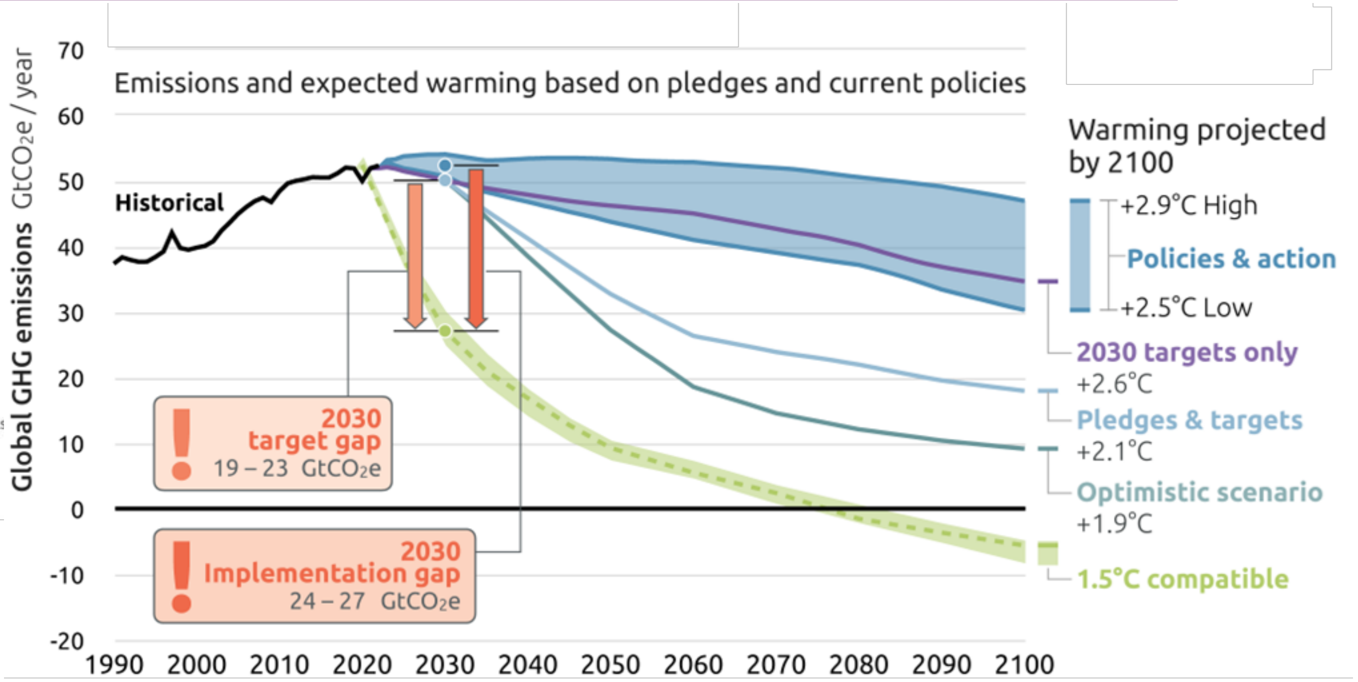


Fossil versus non-fossil in primary energy supply (DNV, 2024)

- Gradual phase-down of fossil fuels.
- Natural gas maintains a high share of the primary energy supply mix throughout the forecast period.
- Although renewables are already competitive with fossil-fired electricity, it will be many years before low- and zero-carbon energy sources dislodge fossil fuels from the broader energy system.
- Share of fossil fuels will shrink by more than one percentage point per year to 50% by mid-century.

Global GHG Emissions





Emissions pathways to 2100 (Climate Action Tracker, 2024)

IPCC Special Report on 1.5 °C shows that steep emissions reductions are urgent, but feasible.

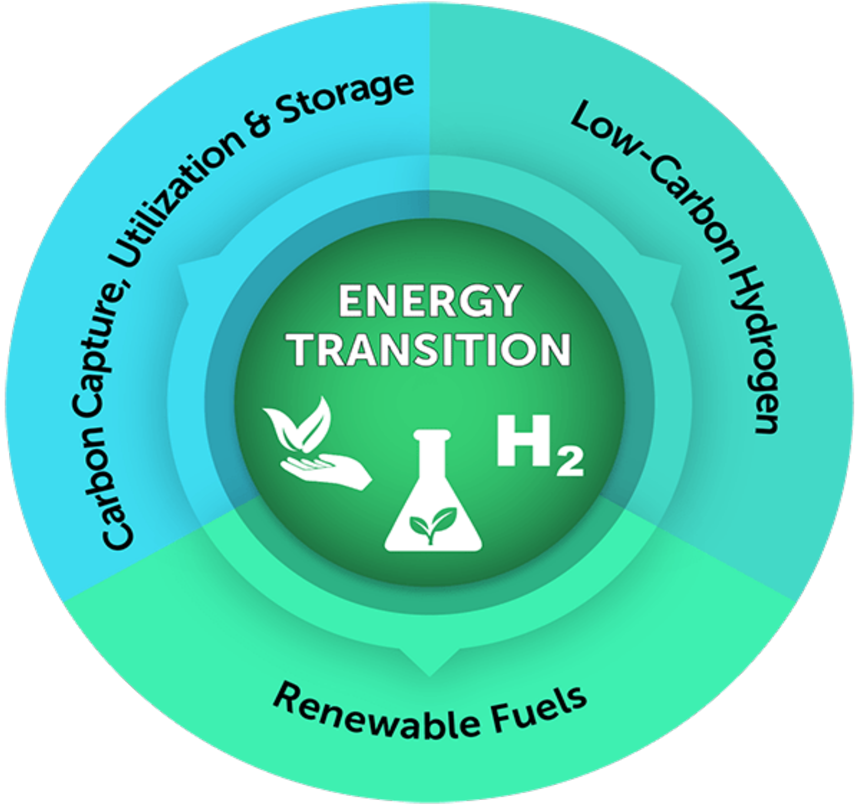
Warming projects: Global temperature increase by 2100 (Climate Action Tracker, 2024)

Energy Transition

- Energy system changes are required to achieve GHG emission targets
- Climate technologies and decarbonisation tools required to accelerate the move towards net zero energy system

Global markets

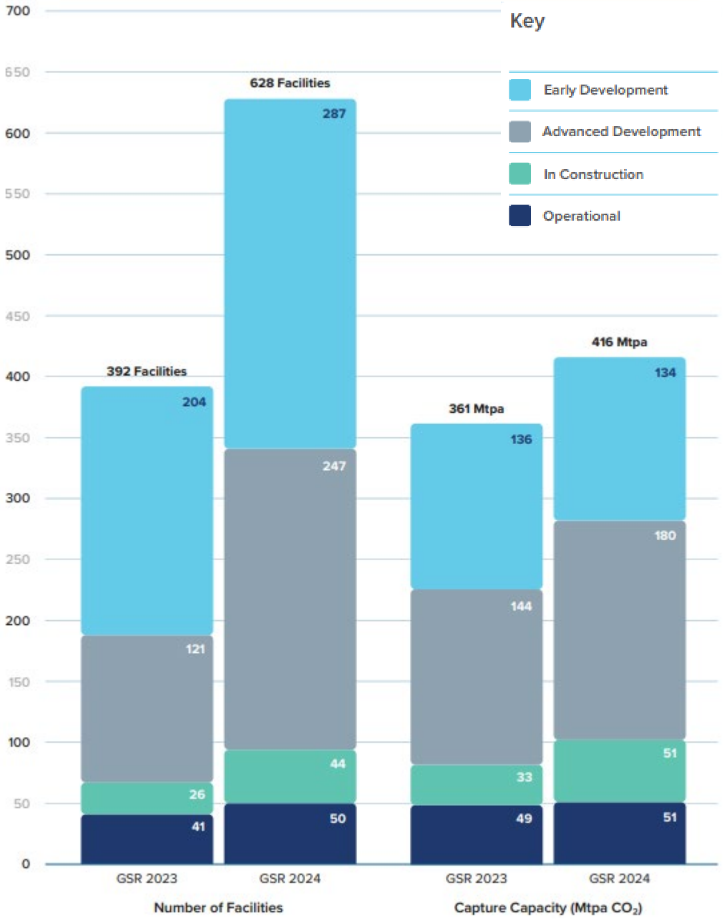
- **Geothermal[1]:** USD 70.14 billion, expected to grow to USD 117.02 billion by 2032
- **Hydrogen[1]:** USD 176.74 billion, expected to expand to USD 278.26 billion by 2032
- **Carbon Capture and Storage[1]:** USD 3.54 billion, expected to grow to USD 14.51 billion by 2032



Tools to facilitate the energy transition (DistributionNOW, 2023)

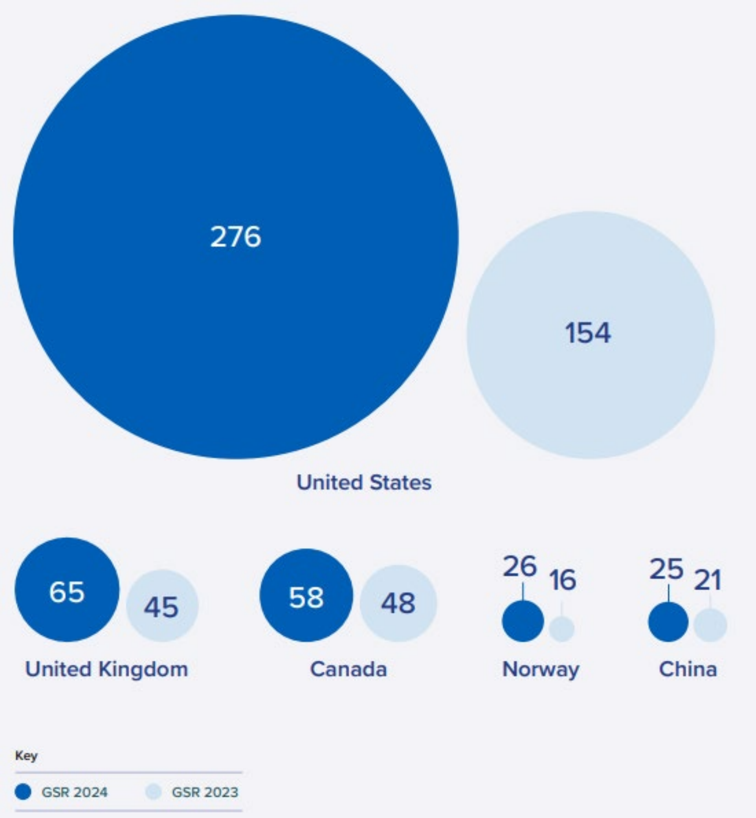
[1] According to Fortune Business Insights 2024

Carbon Capture and Storage



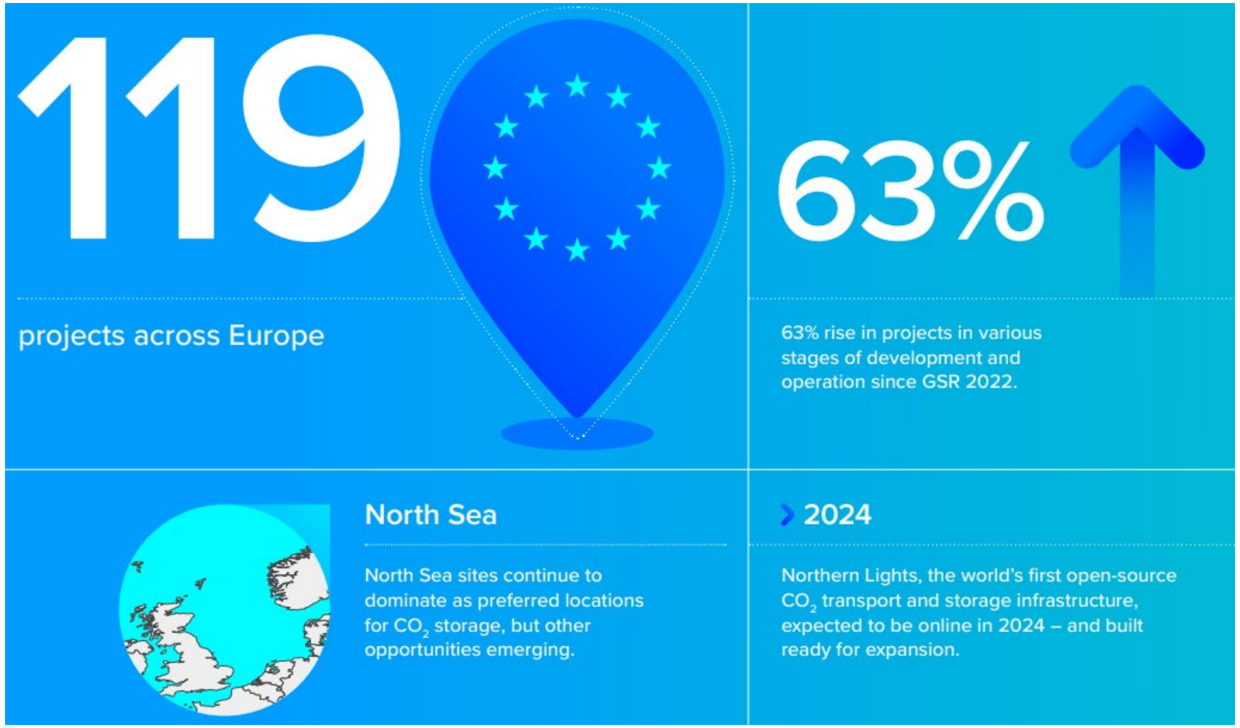
Commercial CCS facilities by number and total capture capacity (Global CCS Institute, 2024)

- Important role in decarbonising hard-to-abate (electrify) industries and the power sector.
- Facilitates the production of low-emissions hydrogen and ammonia.
- Supports a Paris Agreement aligned transition — or any transition that results in warming close to 2°C.
- **Characterised by complex rock-fluid interactions.**



Top 5 countries with CCS projects in 2024 v 2023 (Global CCS Institute, 2024)

Europe & UK CCS Projects

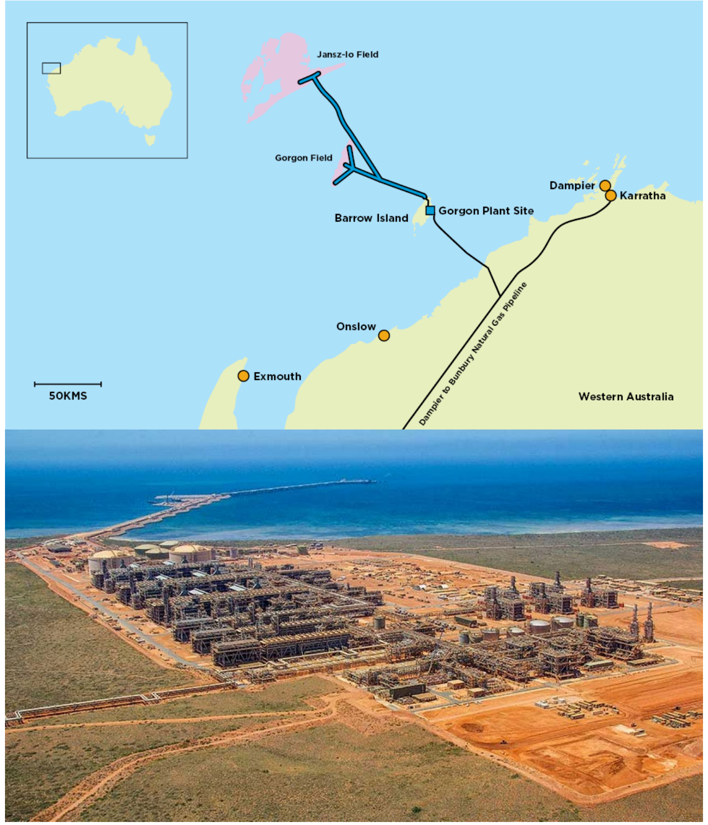


Regional overview of Europe and the UK 2022/23 (Global CCS Institute, 2023)

Regional overview of Europe and the UK 2023/24 (Global CCS Institute, 2024)

ETS price of €100 per tonne of CO_2 in Feb 2023, contributed to an improved CCS business case.
Across Europe there are 5 projects in operation, with 10 in construction.

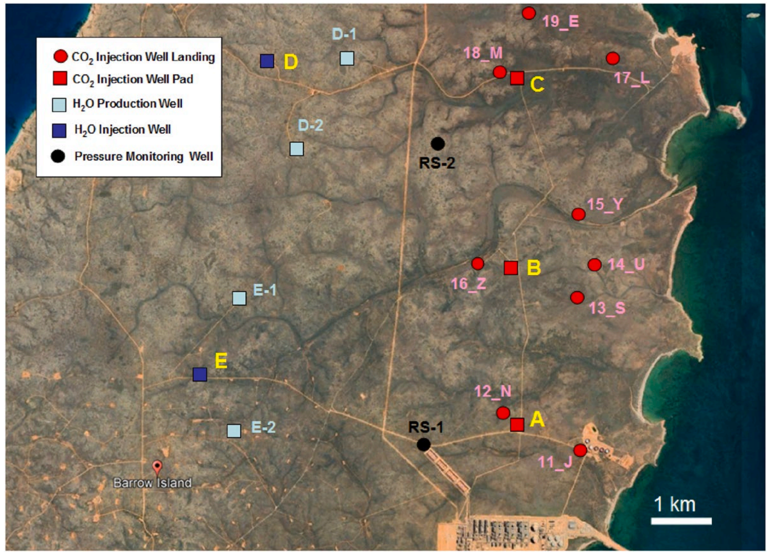
Case Study: Gorgon, Australia



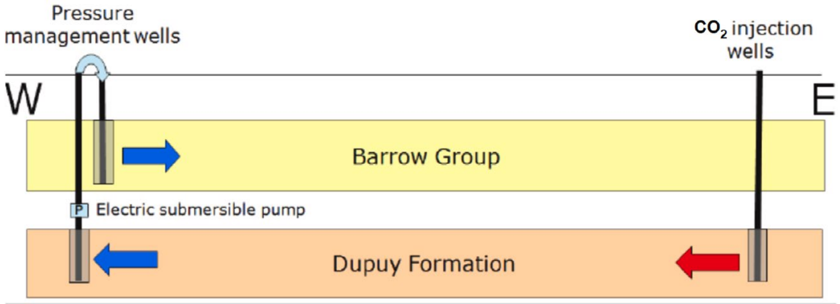
Location of Gorgon CCS project and facility (Chevron Australia, 2024)

- **World's largest CCS project,** aiming to sequester 2 Tcf CO_2 (~0.1 Gt) over the 40-year project life.
- Gorgon CO_2 injection is part of the wider Gorgon LNG development project offshore Western Australia.
- Nominal maximum capacity of 4 Mtpa accounting for 40% of the capacity of all CCS projects.
- Received $60 million from the Australian government as part of the Low Emissions Technology Demonstration Fund.
- Revised target for the first five-year period was about 10.1 MT, **failing to meet its target by about 50%.**
- Capital expenditure escalated to ~USD $3.1 billion.

Case Study: Gorgon, Australia



17 well arrangement employed for reservoir management system of the Gorgon CCS project (Weijermars, 2024)

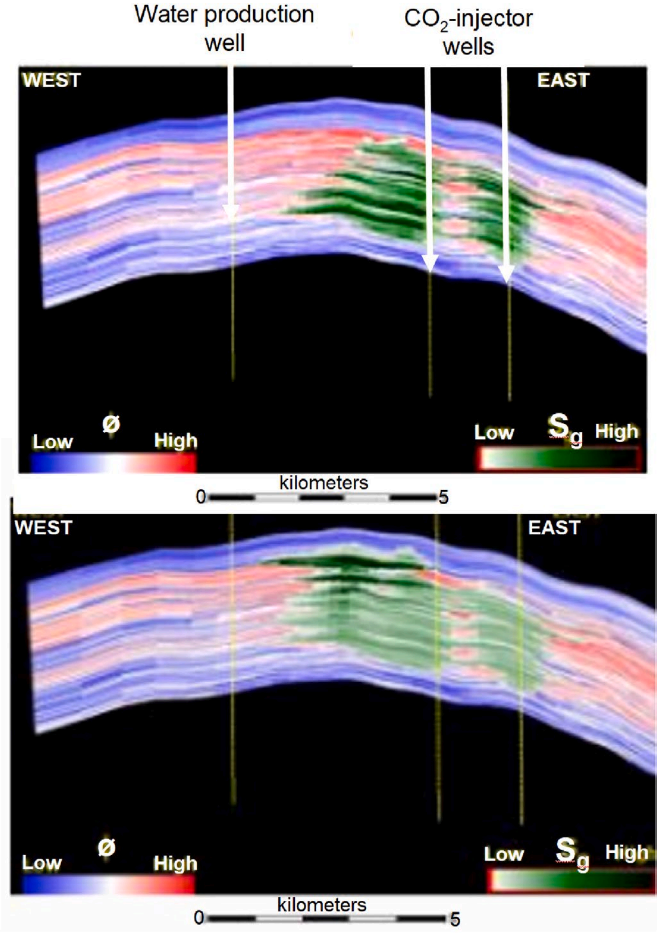


Design principle for the Gorgon CCS project (Weijermars, 2024)

- **Operational problems:**
  1. Sand clogging of all wells.
  2. Pressure increases that neared the failure strength of the Basal Barrow Group Shale cap-rock sealing the injection zone.
  3. Water-block in the CO_2-injection wells due to premature water condensation from the raw CO_2-gas supply.
- Wells had poor sand control, which damaged submersible pumps in the water production wells and further delayed restarting the CO_2-sequestration in 2021.
- After 3 to 4 years of injection, injection rates reduced resulting in the project delivering one-third of the planned injection capacity.

“Gorgon a poster-child for CCS shortcomings”

Case Study: Gorgon, Australia



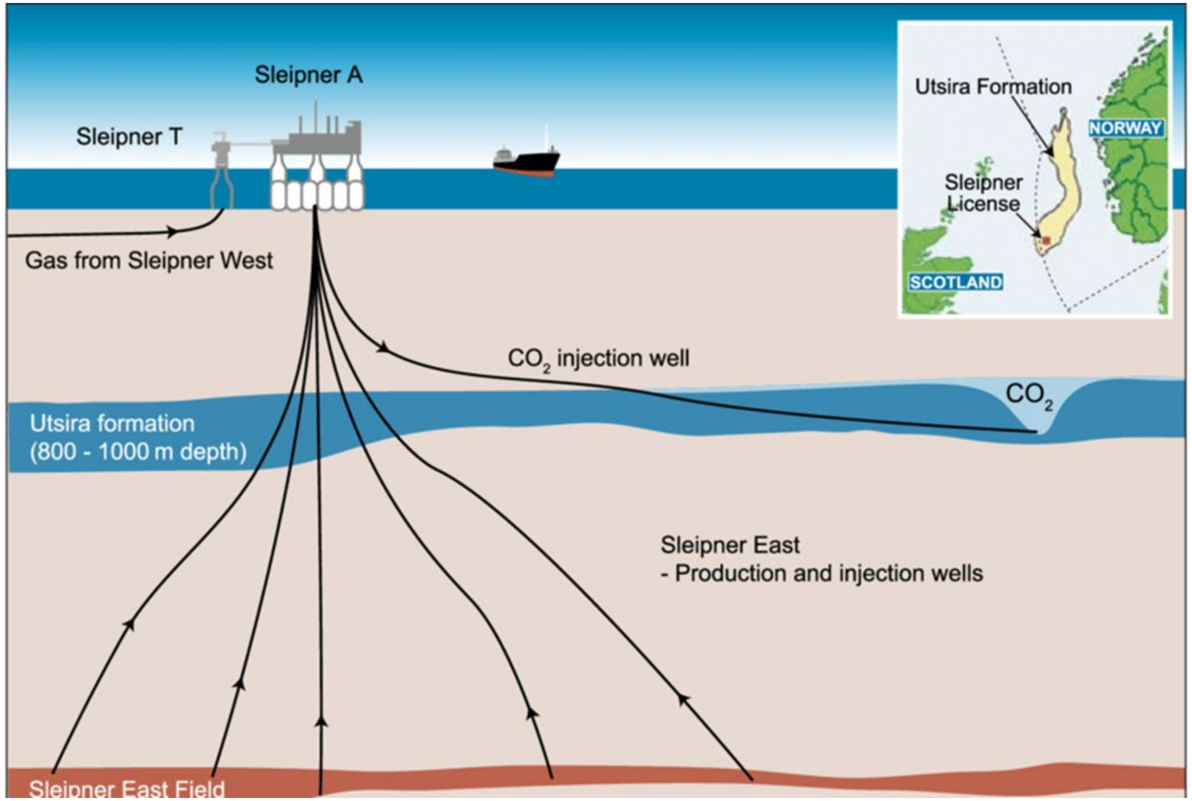
Cheveron's simulation of CO_2-plume migration paths (Weijermars, 2024)

- Announced plans for the recompletion of all of the wells, to stabilise the sand control issues.
- Sidetrack all 9 CO_2-injection wells and re-equip them with gravel packs and active control sanding systems.
- 4 water-production wells, which are used to take water out of the Dupuy Formation (where Gorgon CO_2 is stored), will be sidetracked.
- Water re-injection wells will be increased from 2 to 4 and will be sidetracked to inject water in a reservoir located above the Dupuy formation.

Re-engineered well completions to solve the sand control and pressure management issues

Case Study: Sleipner, Norway

- **First large-scale** CCS project to become operational in Europe and **longest-running** CCS project in the world.
- **Regulatory frameworks:** EU Directive, London Protocol (amended), and OSPAR Convention.
- **Stringent emission regulations:** Combination of the CO_2 tax and levied climate quota.
- **Operational issues:** Initial injection problems due to sand influx, and faster CO_2 migration, into a previously unidentified shallow layer in unexpectedly large quantities.

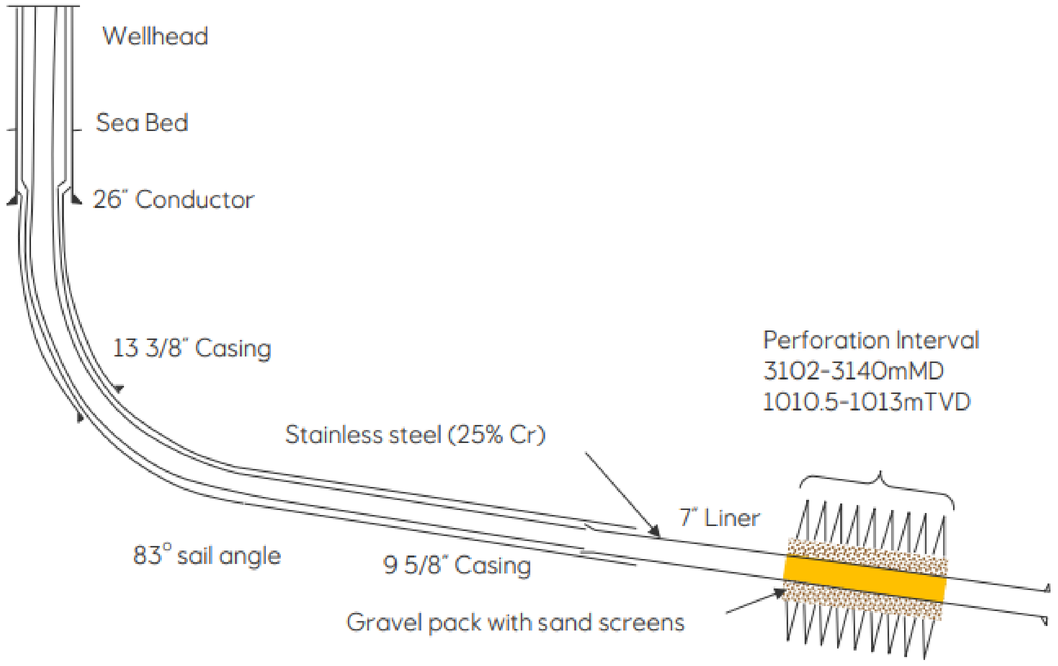


CO_2 injection in the Utsira Formation at Sleipner (Solomon, 2007)

Case Study: Sleipner, Norway

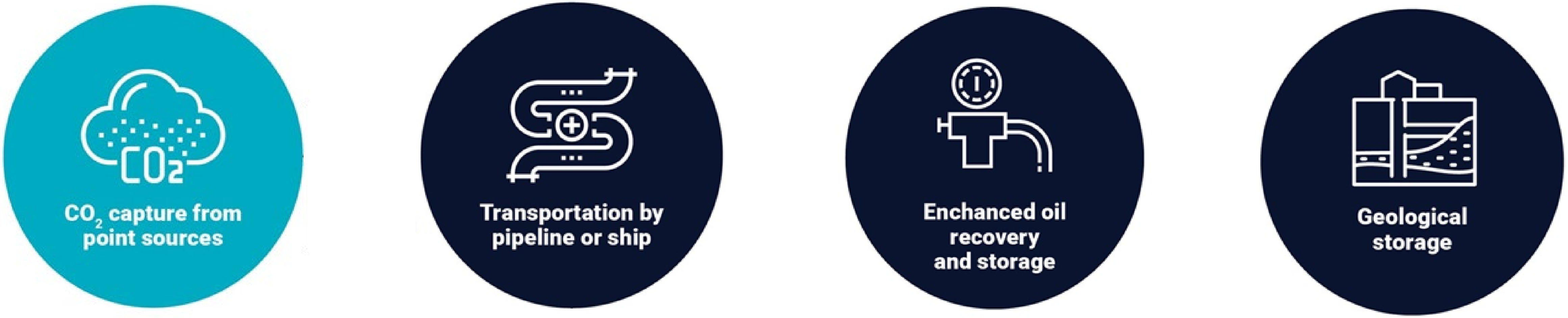
- CO_2 injection started in September 1996.
- Well perforation should have corresponded to a water injectivity of 100 m^3/day/bar.
- **Almost immediate signs of low injectivity due to sand influx.**
- Sand screens of 300 microns were installed in December of the same year resulting in an improved injection rate.
- During this period, it was necessary to vent CO_2 into the air.

Solution: (1) Re-perforation of the injection interval, (2) installation of sand screen and gravel packs, and (3) increased filtration capacity.



Sleipner CO_2 injection well 15/9-A16 (Hansen et al., 2005)

Opportunities: CCUS Value Chain



Formation Dry-out and Salt Precipitation

Gas fields:
Produced gas may contain significant quantities of CO_2 and / or sand leading to flow assurance issues

Pipeline:
Solid impurities transported with SC-CO_2 transport systems can cause flow assurance issues

CO_2 injection:
Mechanism of CO_2 residual trapping by fines migration and mineral reactions can cause pore plugging

Saline aquifers:
Challenges related to water production and re-injection wells in terms of sand production / influx

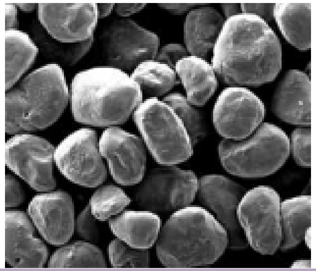
Sand Management Technologies

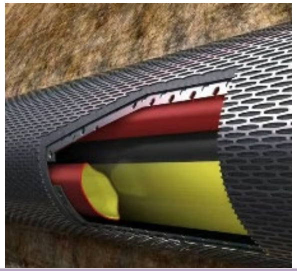
Downhole sand management techniques:

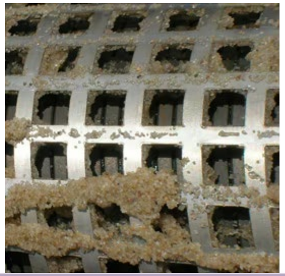
- **Baker Hughes:** GeoFORM conformable sand management system
- **SLB:** SandSet sand consolidation technology
- **Weatherford:** ZetaFlow® Sand-Conglomeration Services
- **Halliburton:** PetroGuard® Mesh-DS Screen
- **3M:** Ceramic Sand Screen
- **Tendeka:** FloShroud Range

Surface filtration technologies :

- **Mechanical (strainer) metal filters:** larger sized impurities and waste materials
- **Cloth filters:** combinable with mechanical filters to catch micron-sized pollutants
- **Gravel filters or sand filters:** classified and washed bed of gravels in a steel tank catches all the impurities
- **Hydrochemical filtration systems**

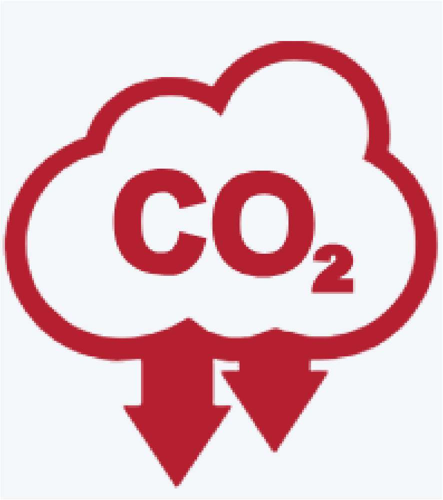






Key Takeaways

- Concerted effort is required to achieve the **Energy Transition**.
- Ability to achieve and maintain an adequate level of CO_2 injectivity is critical to guarantee the successful implementation of CCS projects.
- Leverage technical 'know-how' and expertise of the sand management community.

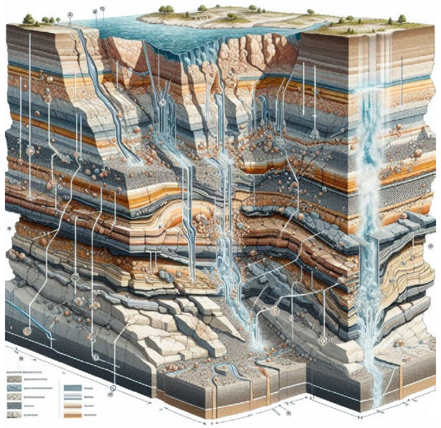


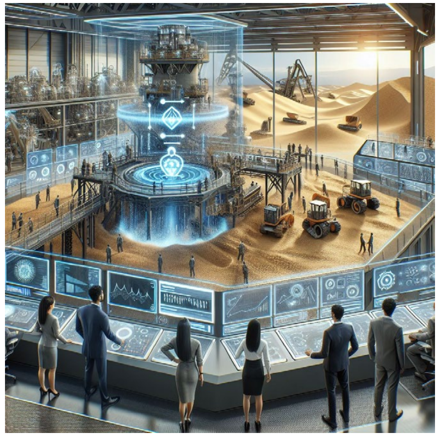
Offer: "UK has a global leading geological advantage – having one of the greatest CO_2 storage potentials …. accounting for approximately 25% of Europe's CO_2 storage potential and which can safely store 78 billion tonnes of CO_2" – UK Government

Future Direction

Research and development areas:

1. Rock failure prediction for CO_2 sequestration projects.
2. Underground hydrogen storage (UHS) and rock-fluid interaction.
3. Digital twin and AI technology integration in sand management and control systems.





Thank you for listening!