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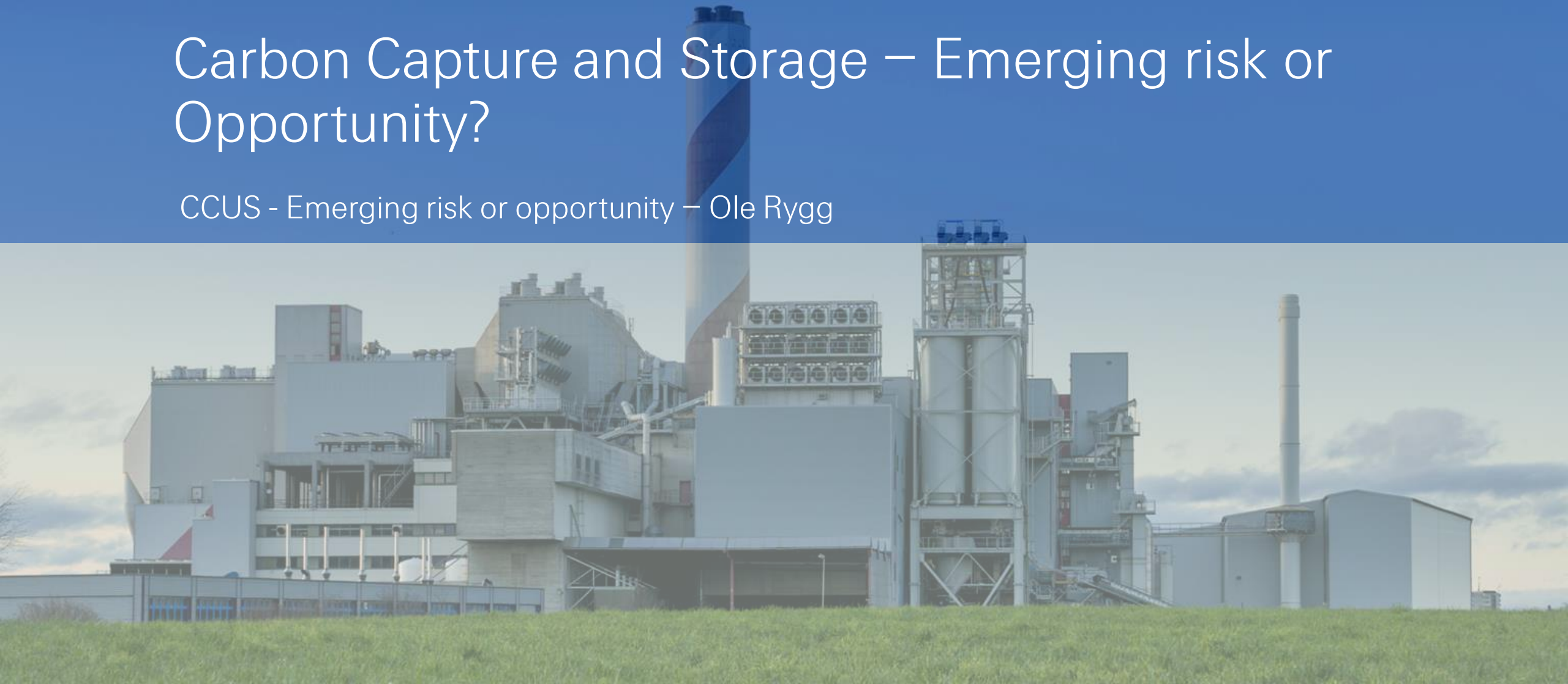
Carbon Capture and Storage – Emerging risk or Opportunity?

CCUS - Emerging risk or opportunity – Ole Rygg

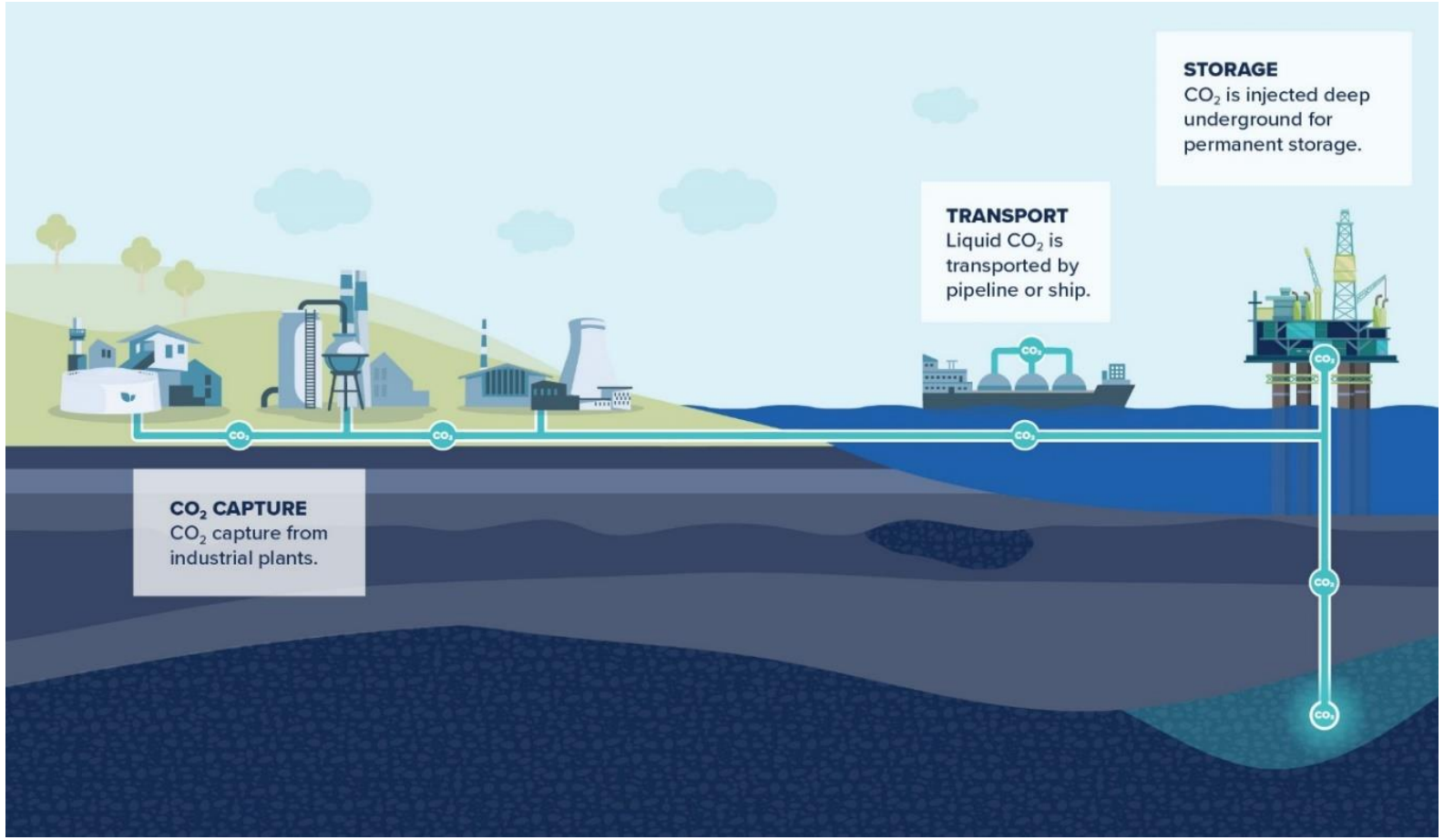


CCUS - Emerging risk or opportunity

Dr. Ole B. Rygg, March 2023

Presentation Overview

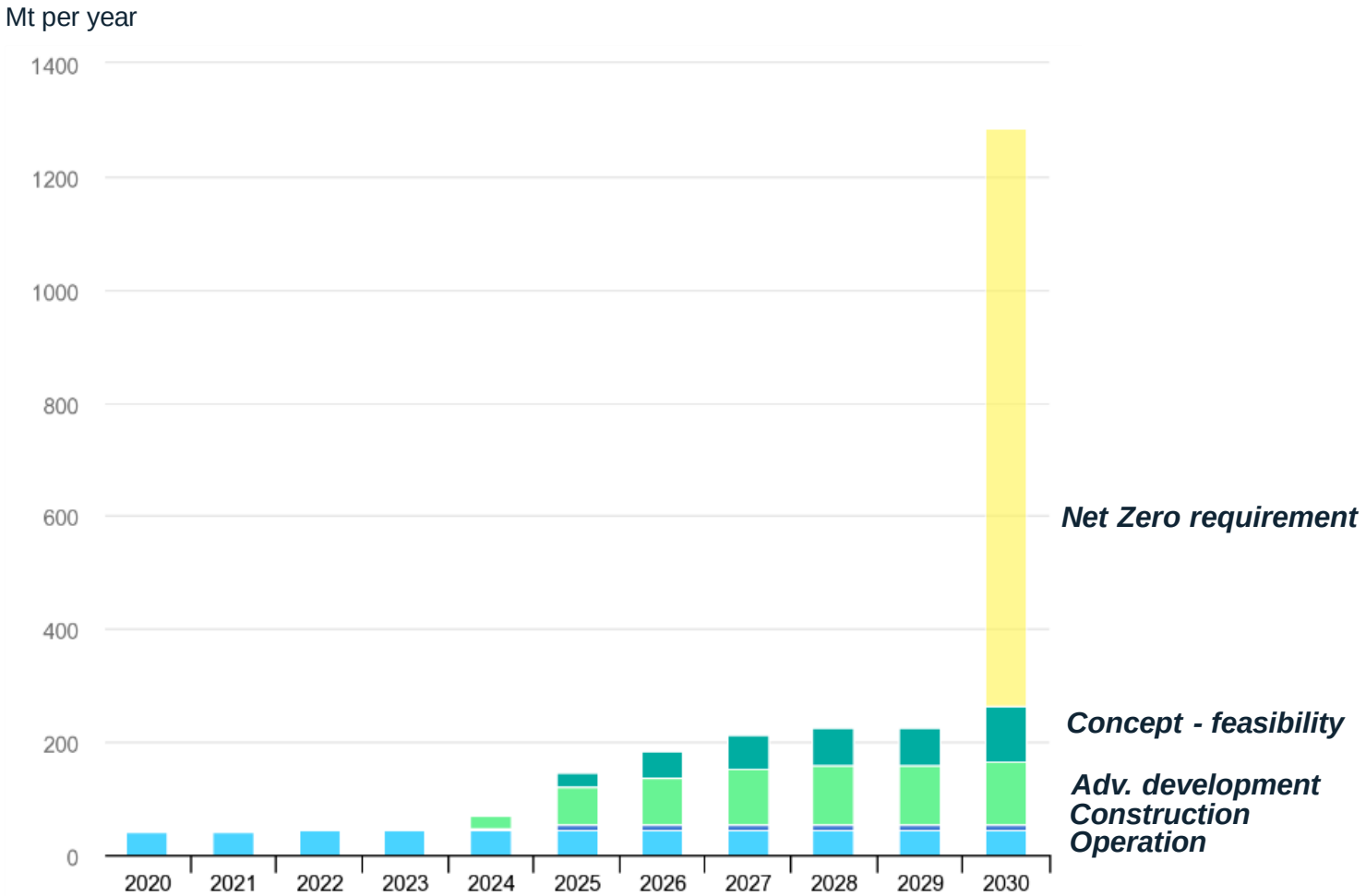
CCUS Overview



- CCUS – Carbon Capture Utilization and Storage
- BECCS – Bioenergy with Carbon Capture and Storage
- DAC – Direct Air Capture
- The need for CCS is huge and “utilization” will only be a minor part
- CCS important for cement, steel, process and power industry.

Where we are – where we need to go

Capacity of large-scale CO2 capture projects, current and planned vs. the Net Zero Scenario, 2020-2030

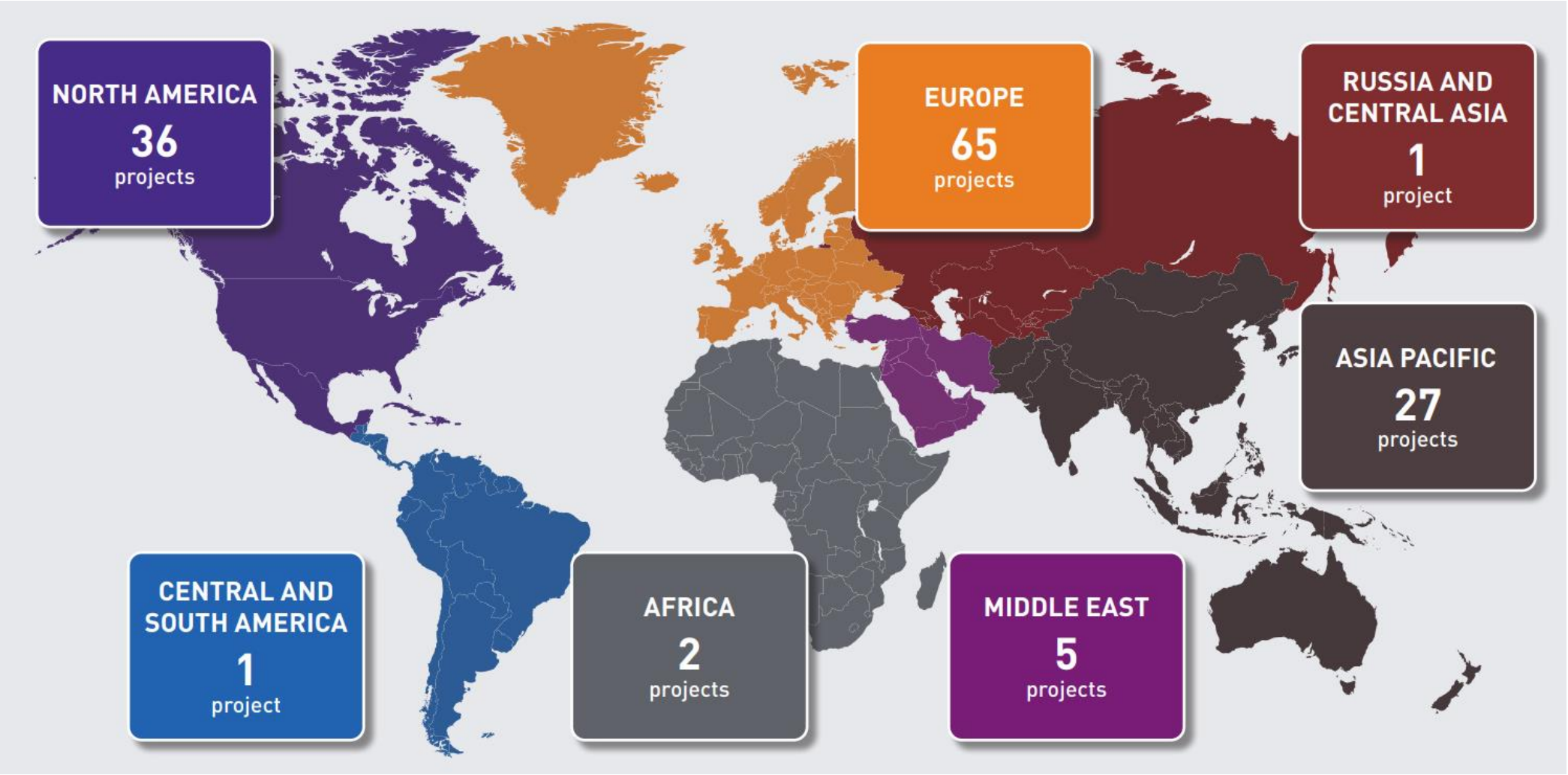


(Source: IEA)

Facts

- Current Capturing of CO2:
  45 Mt CO2 per year
- 35 commercial facilities applying CCUS to industrial processes
  - fuel transformation
  - power generation
- CCUS development has been behind expectations
- Momentum has grown substantially in recent years, with around 300 projects in various stages of development across the CCUS value chain.
- Project developers have announced ambitions for over 200 new capture facilities to be operating by 2030, capturing over 220 Mt CO2 per year.
- Only10 commercial capture projects under development have taken FID as of June 2022.

Global CCUS Projects (January 2022)



(Source: IOGP)

CCUS projects in Europe (Updated January 2023)

Overview of existing and planned CCUS facilities

AUSTRIA
1. Vienna Green CO_2*

BELGIUM
1. Leilac 1
2. Antwerp@C*
3. Carbon Connect Delta
4. Steelanol
5. C4U
6. North-CCU-Hub
7. Power-to-Methanol Antwerp BV
8. Kairos@C€
9. H2BE*

BULGARIA
1. ANRAV€

CROATIA
1. Petrokemija Kutina
2. Bio-Refinery Project
3. CCGeo€
4. **CO_2 EOR Project Croatia**

DENMARK
1. Greensand*
2. C4: Carbon Capture Cluster Copenhagen
3. Bifrost*

FINLAND
1. SHARC€

FRANCE
1. DMX Demonstration in Dunkirk*
2. Pycasso*
3. K6€
4. CalCC€
5. **Cryocap**
6. D'Artagnan

GERMANY
1. H2morrow*
2. Leilac 2
3. BlueHyNow*
4. OXYFUEL100 (subproject of Westkuste100)
5. H2GE Rostock*

GREECE
1. Prinos CCS
2. RECODE

ICELAND
1. **Orca**
2. **Silverstone€**
3. Coda Terminal€

ITALY
1. CCS Ravenna Hub*
2. Cleankerk

THE NETHERLANDS
1. Porthos*
2. Aramis*
3. H2M*
4. H-Vision*
5. Twence*
6. **AVR-Duiven**
7. AZUR*
8. L10 CCS

NORWAY
1. **Sleipner CO_2 Storage***
2. Longship (including Northern Lights)*
3. Barents Blue*
4. Norsk e-fuel
5. Borg CO_2*
6. **Snøhvit CO_2 Storage***
7. Smeaheia*

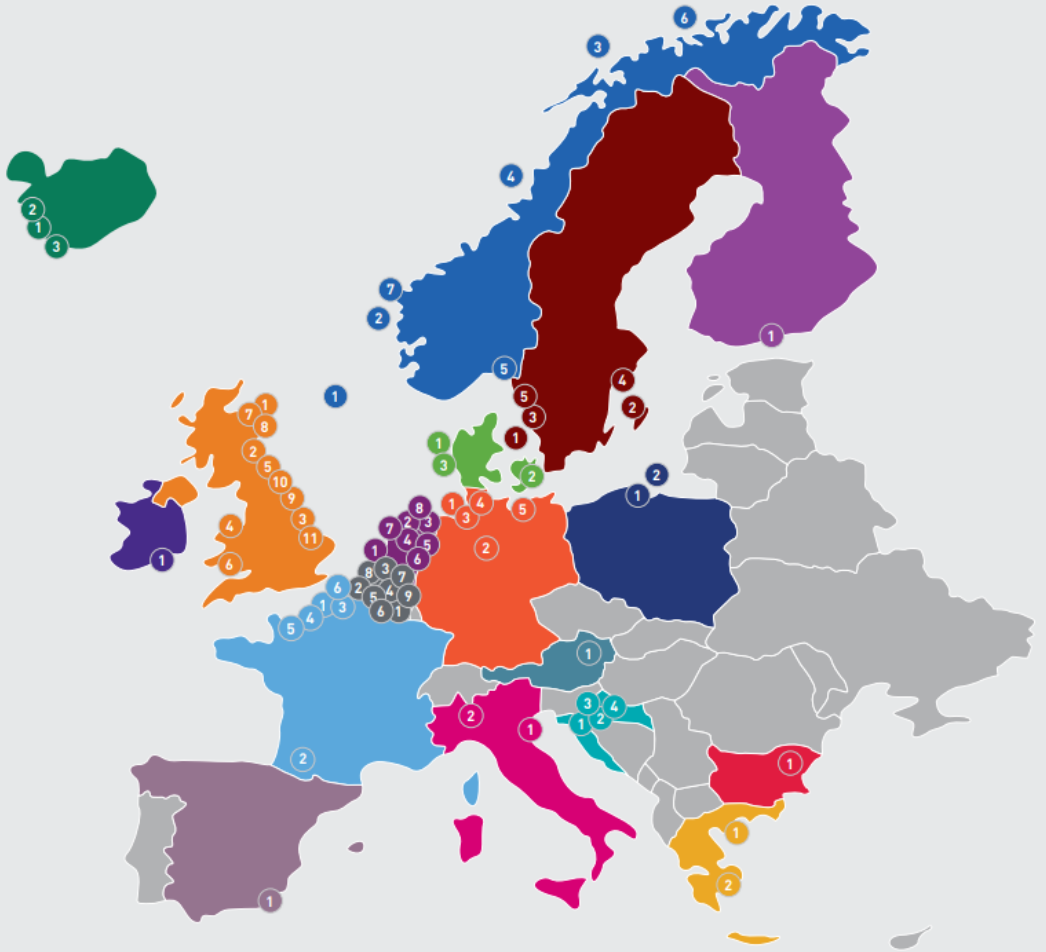
POLAND
1. Poland - EU CCS Interconnector
2. Go4ECOPlanet€

REPUBLIC OF IRELAND
1. Ervia Cork CCS

SPAIN
1. ECCO2

SWEDEN
1. Preem CCS*
2. Slite CCS
3. CinfraCap
4. BECCS@STHLM€
5. Project AIR€

UK
1. Acorn*
2. Caledonia Clean Energy
3. Zero Carbon Humber*
4. HyNet*
5. Net Zero Teesside*
6. South Wales Industrial Cluster
7. Peterhead CCS Power Station*
8. Acorn CO_2 SAPLING*
9. Northern Endurance Partnership*
10. H2Teeside*
11. H2H Saltend*



* Project where IOGP Members are involved
€ EU Innovation Fund (11 selected, **4 awarded**)
Projects listed in **bold** are in operation

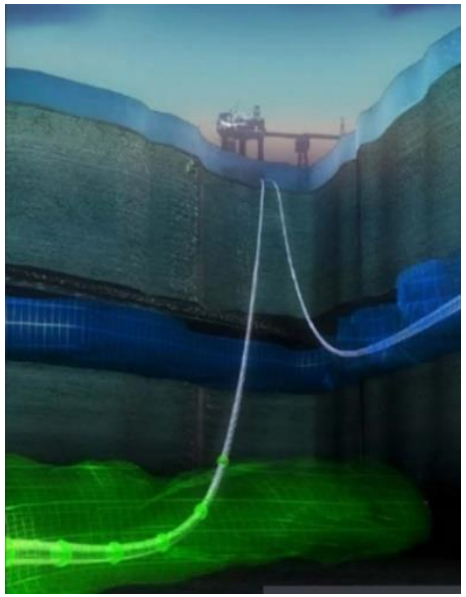
Total number of projects: **72**
Around 80 $MtCO_2$/yr stored by 2030

(Source: IOGP)

Sleipner CO2 injection – Offshore CCS in operation since 1996

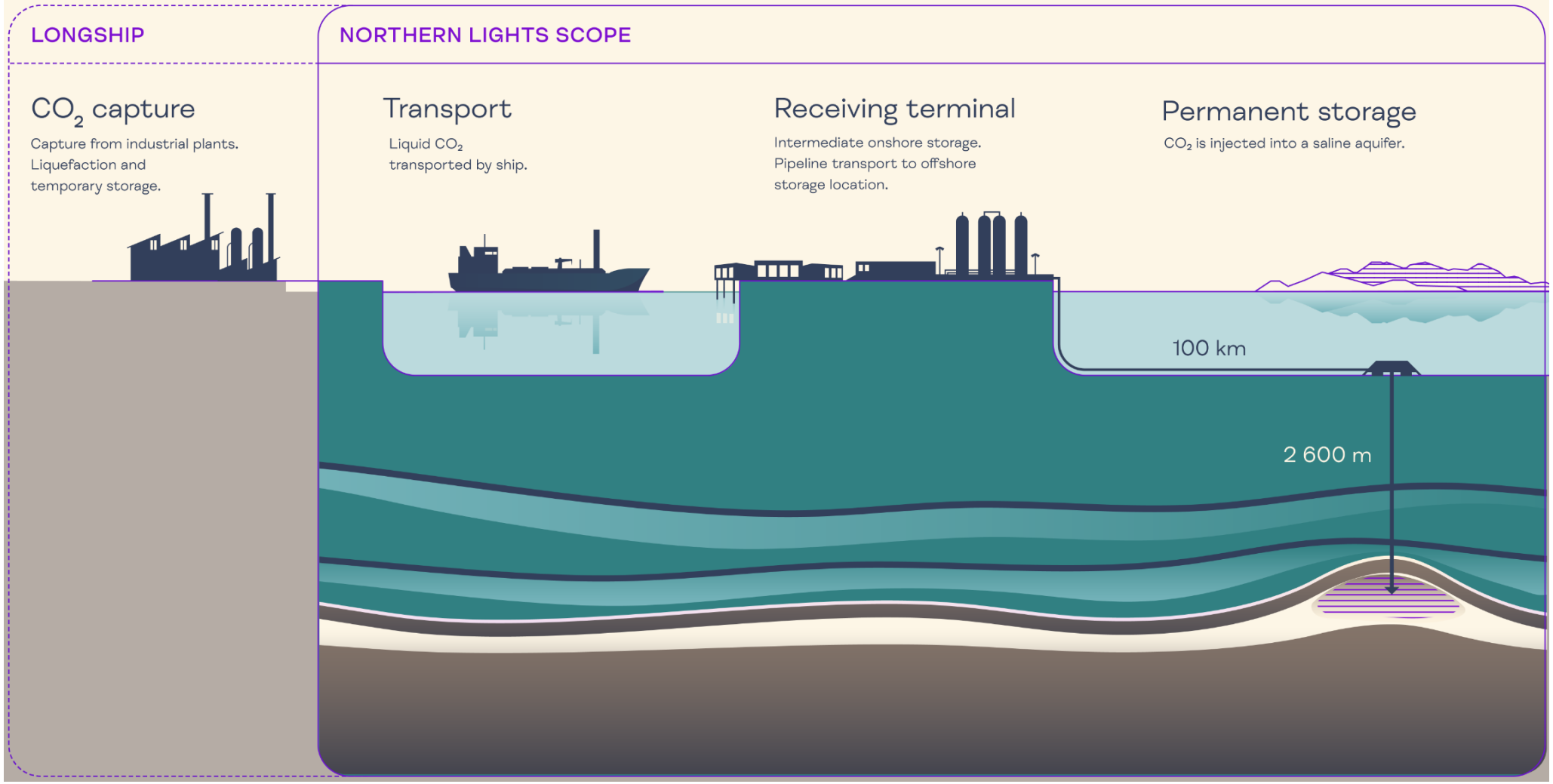
- Sleipner CCS project has been operational since 1996 and it is known as the world's first offshore CCS implementation.
- The produced natural gas at Sleipner area contains around 9% of CO2 and therefore the production is driven to a processing and CO2 removal platform (Sleipner T) where 2.800t of CO2 are separated and injected daily in the Utsira saline formation, 800m below the seabed.
- The project is the result of a tax on CO2 emissions which was introduced in Norway in 1991.
- 1 Mt CO2 injected per year

The Sleipner field in the North Sea. (Photo: Harald Pettersen / Equinor ASA)



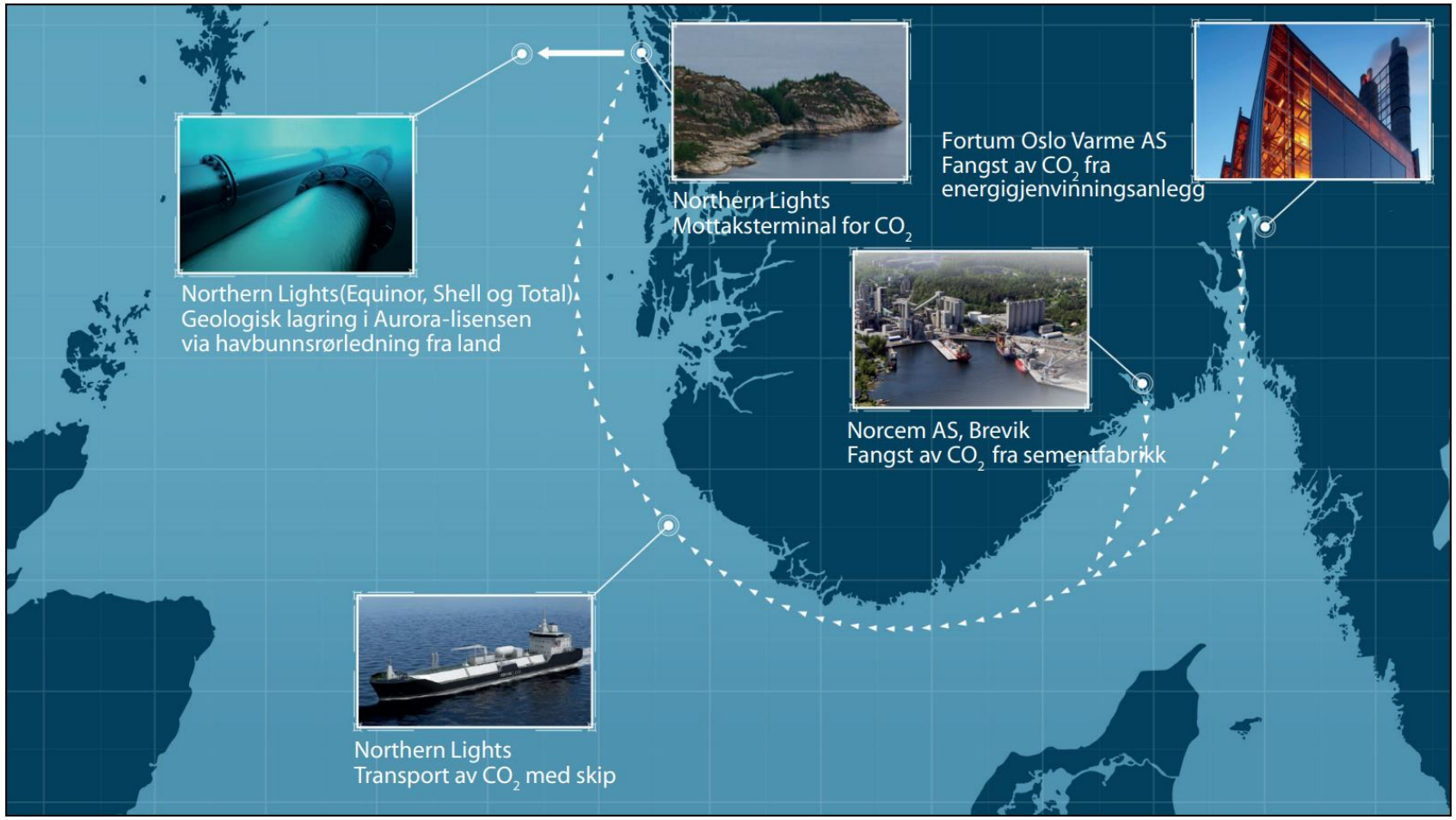
Project
Longship

Longship – Northern Light Project



(Source: Northern Light project)

Longship – Northern Light Project



(Source: Northern Light project)

Facts

- Northern Lights is responsible for developing and operating CO2 transport and storage facilities, open to third parties, as part of Longship.
- Phase one of the project will be completed in **mid-2024** with a capacity of up to 1.5 Mt of CO2 per year.
- Longship includes capturing CO2 from industrial sources in the Oslo-fjord region (cement and waste-to-energy) and shipping liquid CO2 from these industrial capture sites to an onshore terminal on the Norwegian west coast. From there, the liquefied CO2 will be transported by pipeline to an offshore storage location subsea in the North Sea, for permanent storage.
- Capture of CO2 at the Norcem (Heidelberg Group) cement factory in Brevik.
- Capture of CO2 at the waste-to-energy plant Hafslund Oslo Celsio in Oslo.
- Agreement with Yara Sluiskil fertilizer plant in the Netherlands. First cross border CO2 storage.
- A combined transport and storage solution, managed by Northern Lights JV DA.

Brevik CCS – World's first CO2-capture facility at a cement plant

Brevik CCS

(Source: Brevik CCS project)

Facts

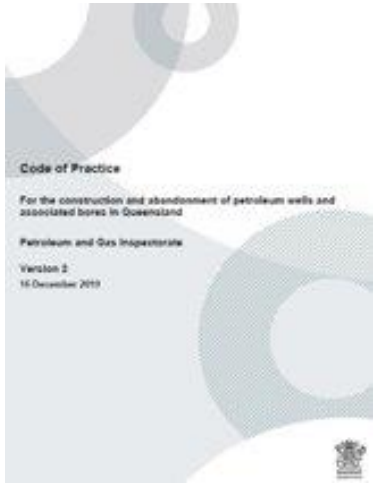
- Technology: Amine – Post combustion capture
- Capture, liquefaction, pipe transfer, storage on quay
- Annual CO2 captured: 400,000 t per year
- 50% of plant emission captured
- Part of the Northern Lights/Longship project

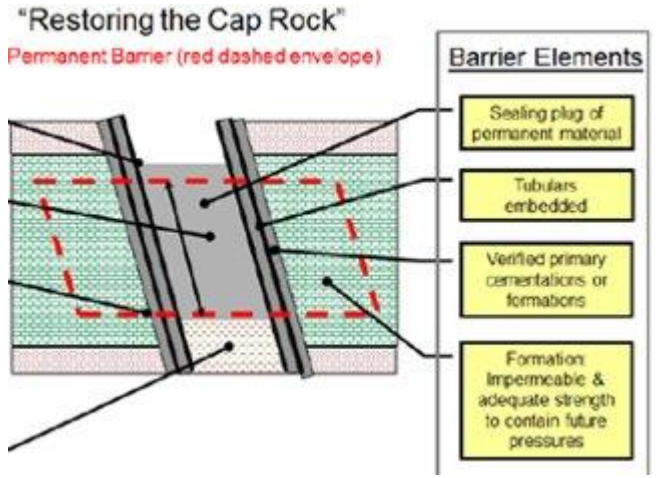
Knowledge Transfer

From O&G Technology and Experience to CCS applications

Knowledge transfer from O&G - Technology and Processes

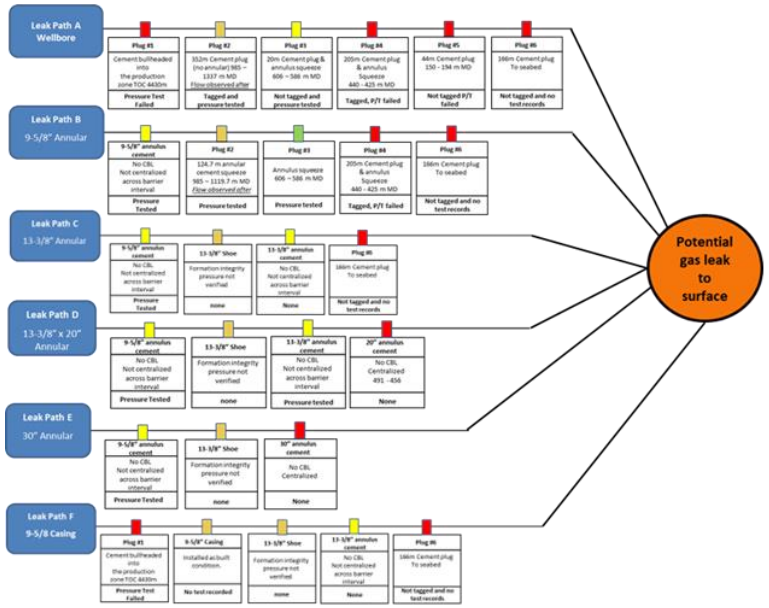
- Well integrity process used for extraction and/or injection of fluids
- Compliance with Well Integrity standards and best practices
  - NORSOK D-010 Well Integrity Standard
  - OGUK - Well Decom. GL (2018) (guidelines);
  - NOROG Guidelines for Well Integrity (GL 117).
  - IOGP
- Development of project assurance process, tailored to CCS specific activities
- Development of risk and opportunity matrix
- Apply comprehensive hydrocarbon industry well construction guidelines
- Compliance with regulations, CCS vs O&G regulations

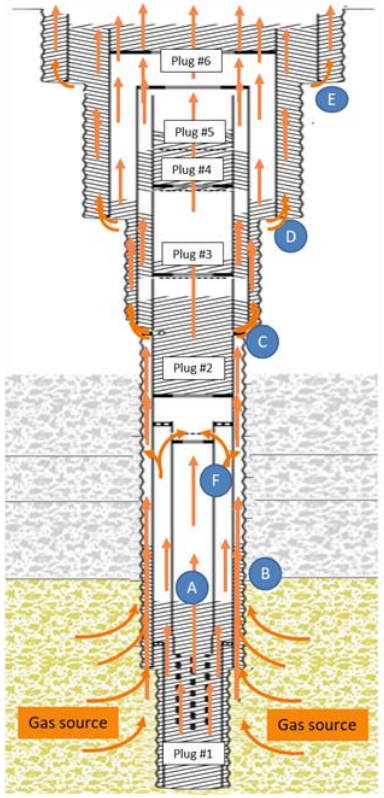




How to evaluate old wells for a CCS application?

- Assess well integrity and reservoir performance and CCS compatibility
- Evaluate infrastructure risks and opportunities
- Define injection requirements and delivery constraints
- Develop a work program to support well conversion requirements.





From and oil or gas producer to a CO2 injector

Transportation

CCS - Transportation

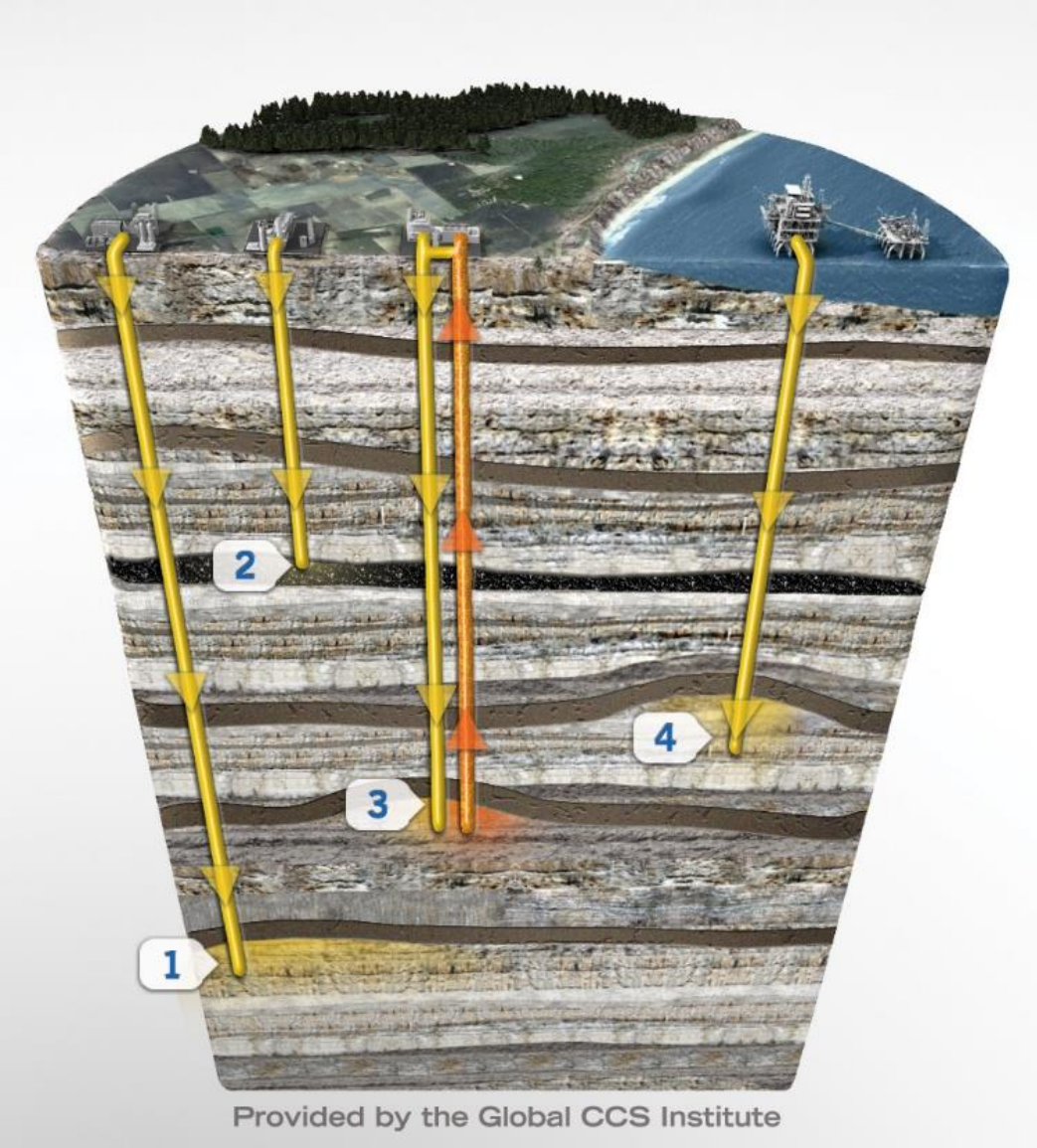
Tankers or pipelines

Risks

- Operational risks
  - Temperature
  - Pressure constraints
  - Corrosion
- Fluid characterization and technical risk related to cold temperatures and potential for ice and hydrate formation
- Offshore operations in challenging environment
- Shut-in resulting in pressure fluctuations and multi-phase flow challenges

Storage

Storage of CO2



Storage Options - Risks

- Storage options:
  1. Saline formations
  2. Injection into un-minable coal seams or ECBM (Enhanced Coal Bed Methane)
  3. EOR (Enhanced Oil Recovery)
  4. Depleted Oil and Gas Reservoirs
- Challenges and Risks
  - Trapping: stratigraphic, structural, residual, solubility, and mineral
  - Re-pressurization of the reservoir leading to Hydrocarbon release
  - Leakage in cap rock- monitoring – Leak detection
  - Limitation of fracture pressure of the formation
  - Well Integrity in depleted reservoirs
  - Well Control – “blowout” from a CO2 reservoir
  - Corrosion
  - Contamination of drinking water
  - Public perception

Project

CStore1 - Australia
Multi-user Carbon Capture and Storage Hub

Project – CStore1

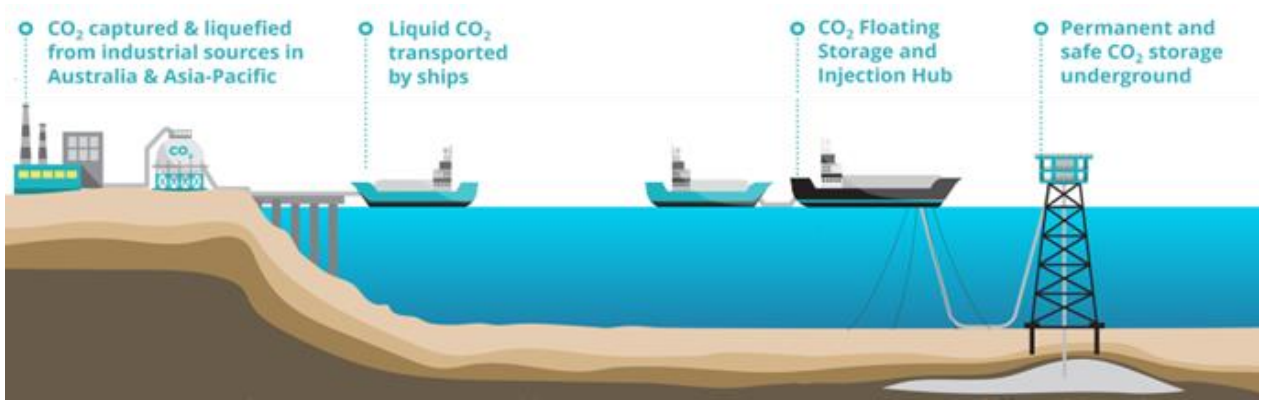
CStore1 project will be the development and operation of Australia and Asia Pacific's first floating multi-user Carbon Capture and Storage (CCS) hub

- Capturing and liquefying CO_2 from multiple industrial sources in Australia and potentially the Asia-Pacific Region.
- Shipping liquid CO_2 from industrial sources to CStore1's Floating Storage and Injection (FSI) Hub located in offshore Northern / Western Australia.
- Offloading and temporarily storing liquid CO_2 at the FSI Hub prior to injection.
- Injecting and storing CO_2 in a permanent subsurface geological formation near the FSI Hub
- Planned CO_2 injection capacity of between 1.5 and 7.5 million tons per annum.

The CStore1 Project supports industry and community goals towards decarbonization and transitioning to a future green economy.

- Be Australia and Asia Pacific's first floating multi-user CCS hub.
- Deliver a CCS project that aligns with the Australian Commonwealth Government's Low Emissions Technology Statement.

ABL/Add Energy is a project partner and will solely engineer, procure, drill, complete and operate the CO_2 injection wells for CStore1. Other partners: Transborders Energy, CSIRO, JX Nippon Oil & Gas Exploration, Kyushu Electric Power Inc., Mitsui OSK Lines, Osaka Gas, Technip Energies, Toho Gas



(Source: DeepCStore)

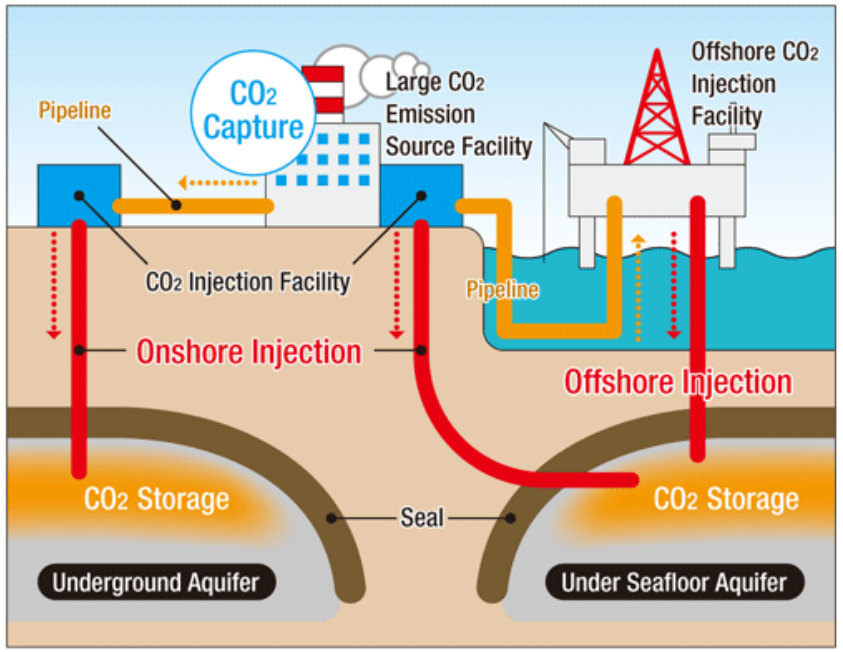
Project

Moomba - Australia
Converting the producing asset into a CO_2 downhole injection facility

South Australia - Moomba CCS project

Depleted gas reservoir

- Converting the producing asset into a CO_2 downhole injection facility.
- Storage capacity: 1.7 Mt CO2 per year



Well integrity Risks

- Verify well integrity suitability for CO_2 injection
- Legacy wells in the fields to meet regulatory requirements, in line with accepted industry practices
- Well barrier acceptance
- Compliance rating of well barriers
- What actions need to be taken to assure safe and successful injection and storage of CO_2
- Overall risk profile of the project

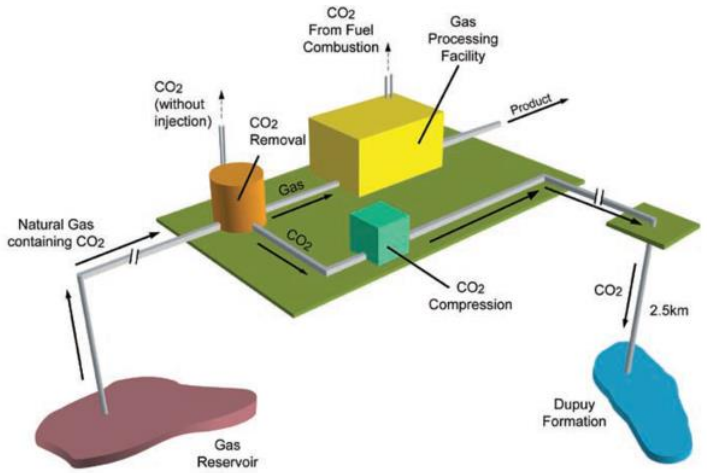
Projects

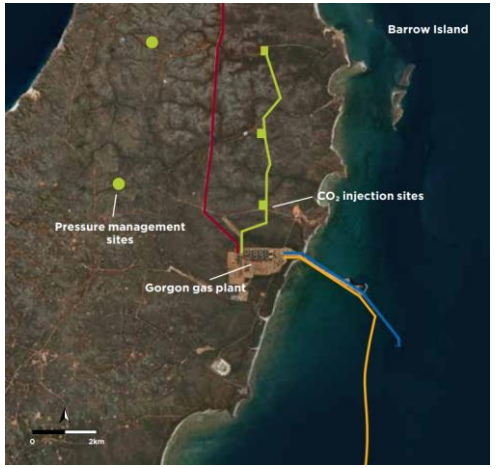
Chevron Gorgon – Barrow Island CO2 Storage

Well Control

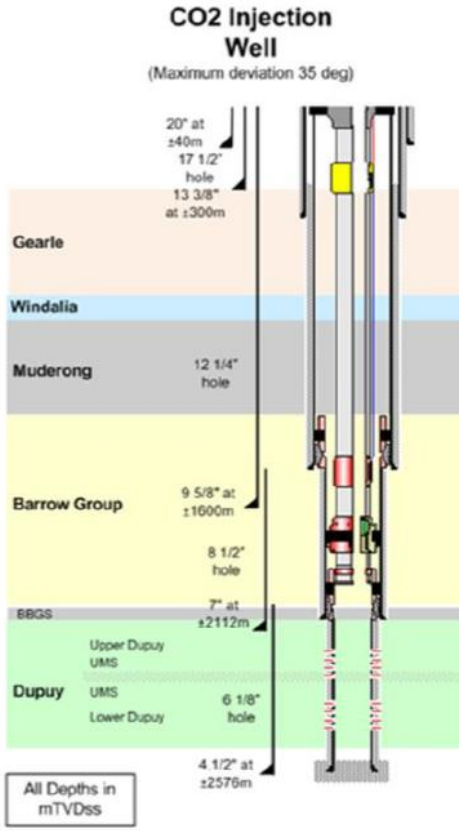
Well Control Evaluation for CO2 Injection wells

Chevron Barrow Island/Gorgon





(Source: Chevron)



Opportunities and risks

- Re-use of existing wells and infrastructure
- Well Integrity often not addressed properly
- Quality of the well elements not sustainable for the life span of the injection/storage
- Well Control of the injection wells or the new wells?
- How to avoid a “Macondo” of CCS

Concluding Remarks

- Current Capturing of CO2
  - 45 Mt CO2 per year, 35 commercial facilities
- CCUS development has been behind expectations – we need to step up
- New technologies for CCUS are being developed – but it takes time.
- We have been using CCS for decades, but mostly for EOR
- Longship is an example of a new type of project including capturing from Cement Factory and Waste Plant and cross border transportation of CO2
- Knowledge transfer from O&G is a key
- Focus areas are transportation and storage – both comes with risk factors that needs to be assessed
- Storage leak paths, equipment and facility degradation, well integrity and well control are risk that needs careful evaluations.

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Thank you for your attention!

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