RYSTAD ENERGY

THE EUROPEAN CCS MARKET

THE CCS OUTLOOK IN POLITICALLY UNCERTAIN WORLD

Norwegian Energy Partners

YVONNE LAM, HEAD OF CCUS RESEARCH

MAY 2022

Agenda

1) Carbon pricing and investment support in Europe

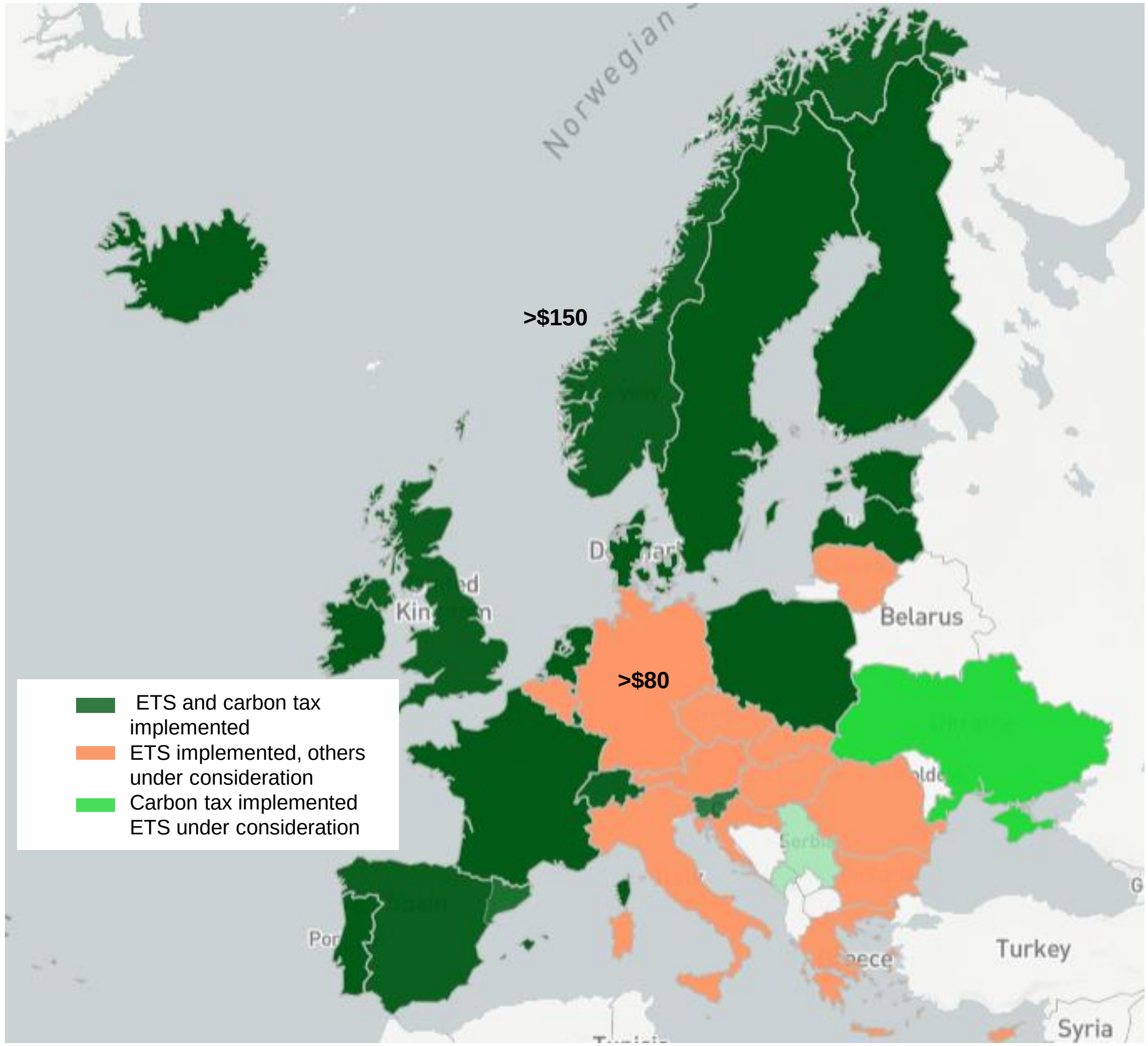
2) CCUS project landscape and trend

3) Impact of Russia’s invasion of Ukraine on CCUS market

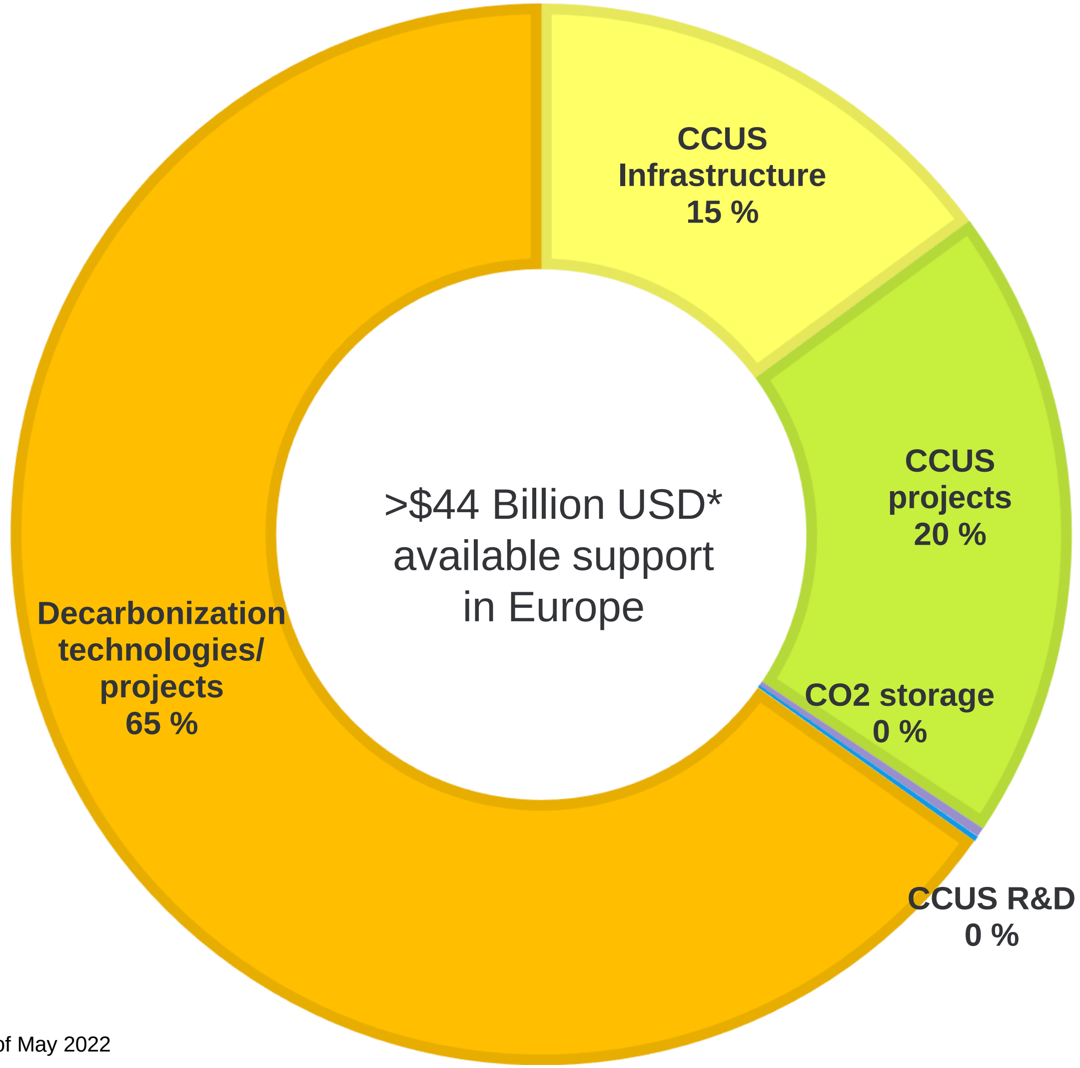
4) Short-medium-term demand and cost outlook

As penalty for emission increase, available support for CCUS follow through

Carbon Pricing landscape in Europe



Current planned and active fundings available for CCUS in Europe by type



*As of May 2022

Source: Rystad Energy CCUS dashbaord

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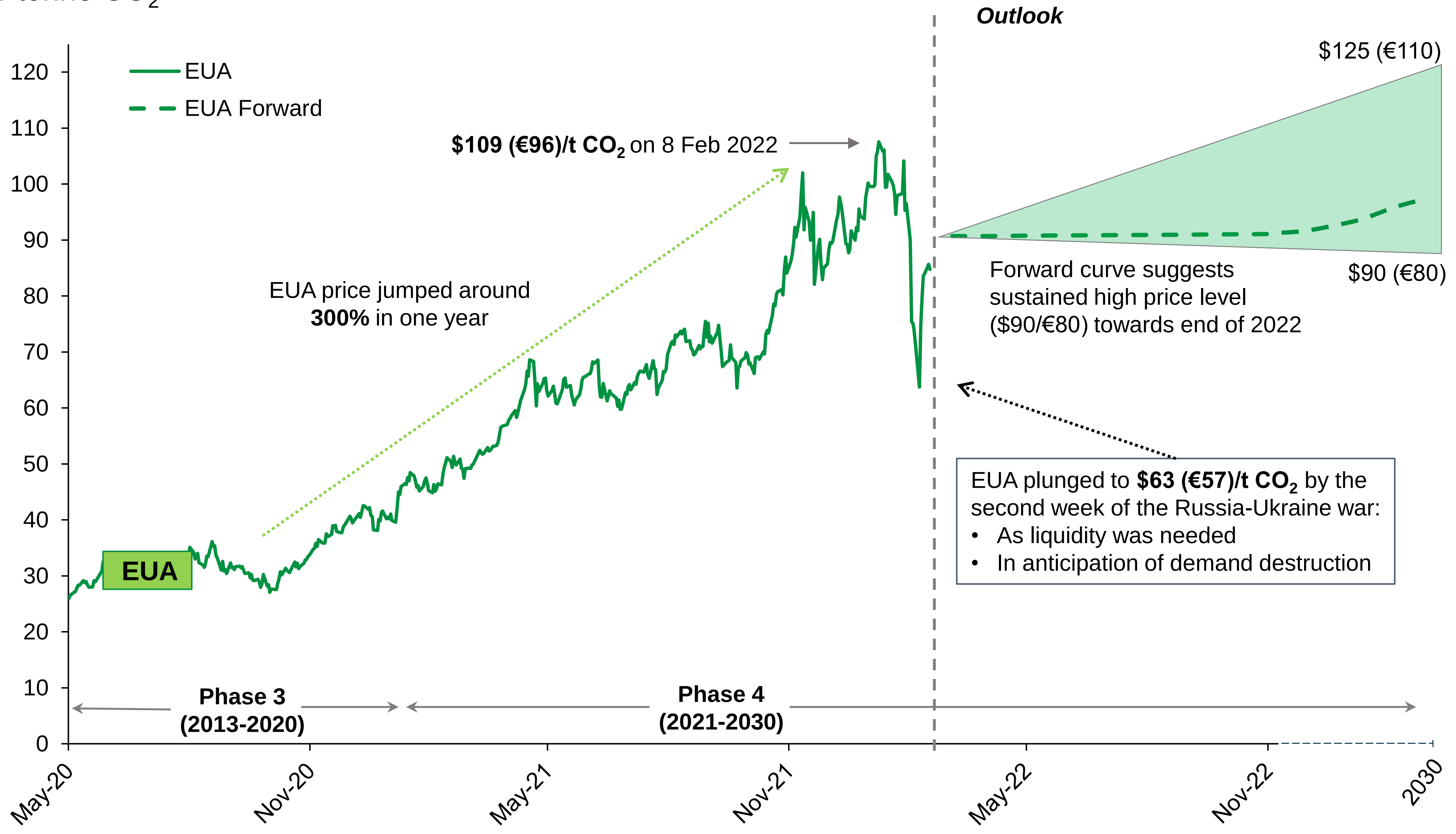
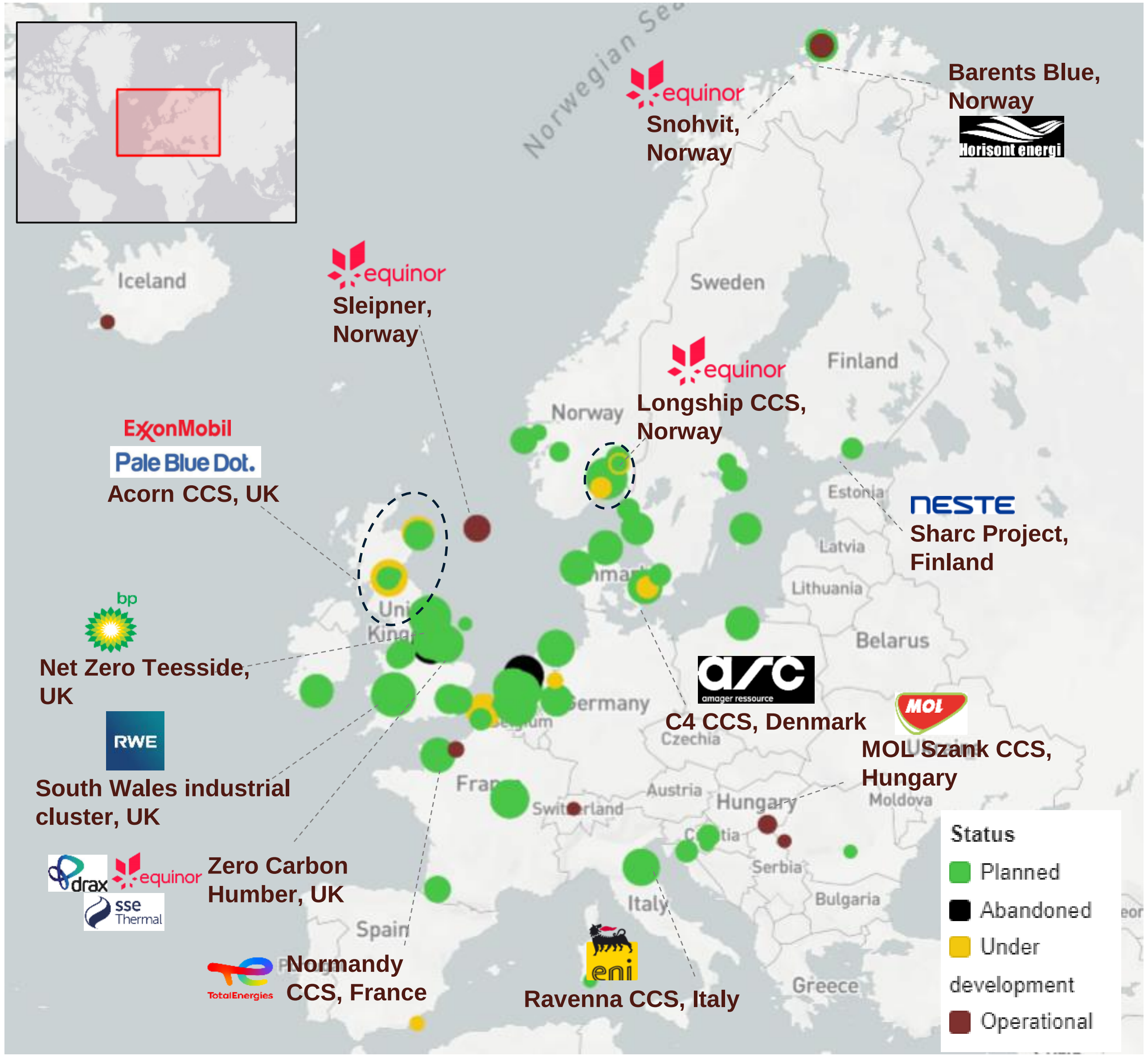
Moving into era of high ETS prices in Europe

USD per tonne CO_2



Source: Rystad Energy research and analysis, Bloomberg, European Commission

Boomed in commercial and pilot projects driven by policies

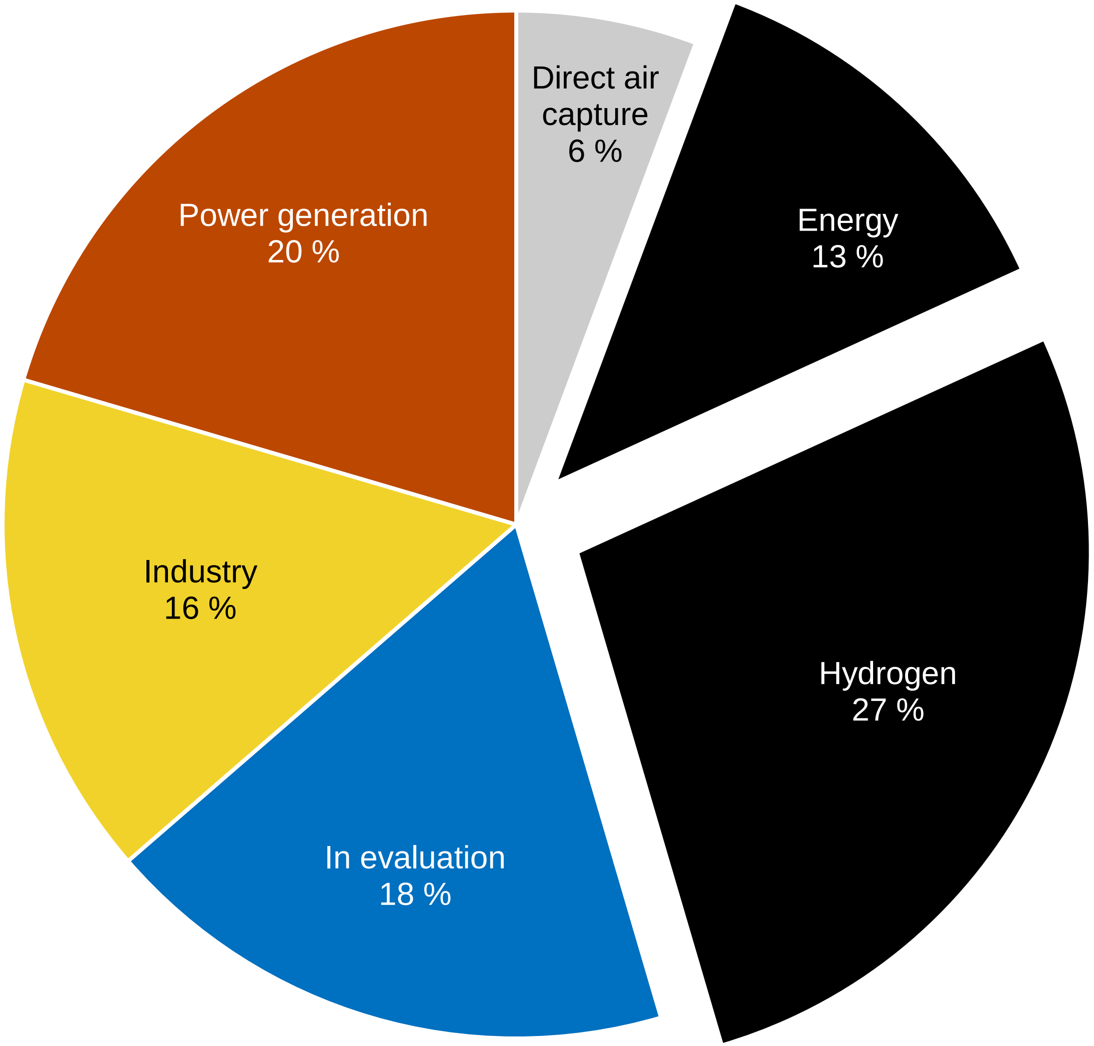


Source: Rystad Energy CCUSCube

- Europe has the highest new project count in 2021
- More than 40% of global project in pipeline are in Europe
- Clusters projects and hubs will continue to drive the European market
- Boom in pilot projects, especially in the UK with almost half of the project focused on DAC technology
- 19 projects expected to reach FID stage this year, but no project has reached that milestone so far
- Moving from project planning stage to project development stage

Announced CCUS projects* by carbon source in Europe

Share (%) of total number of projects

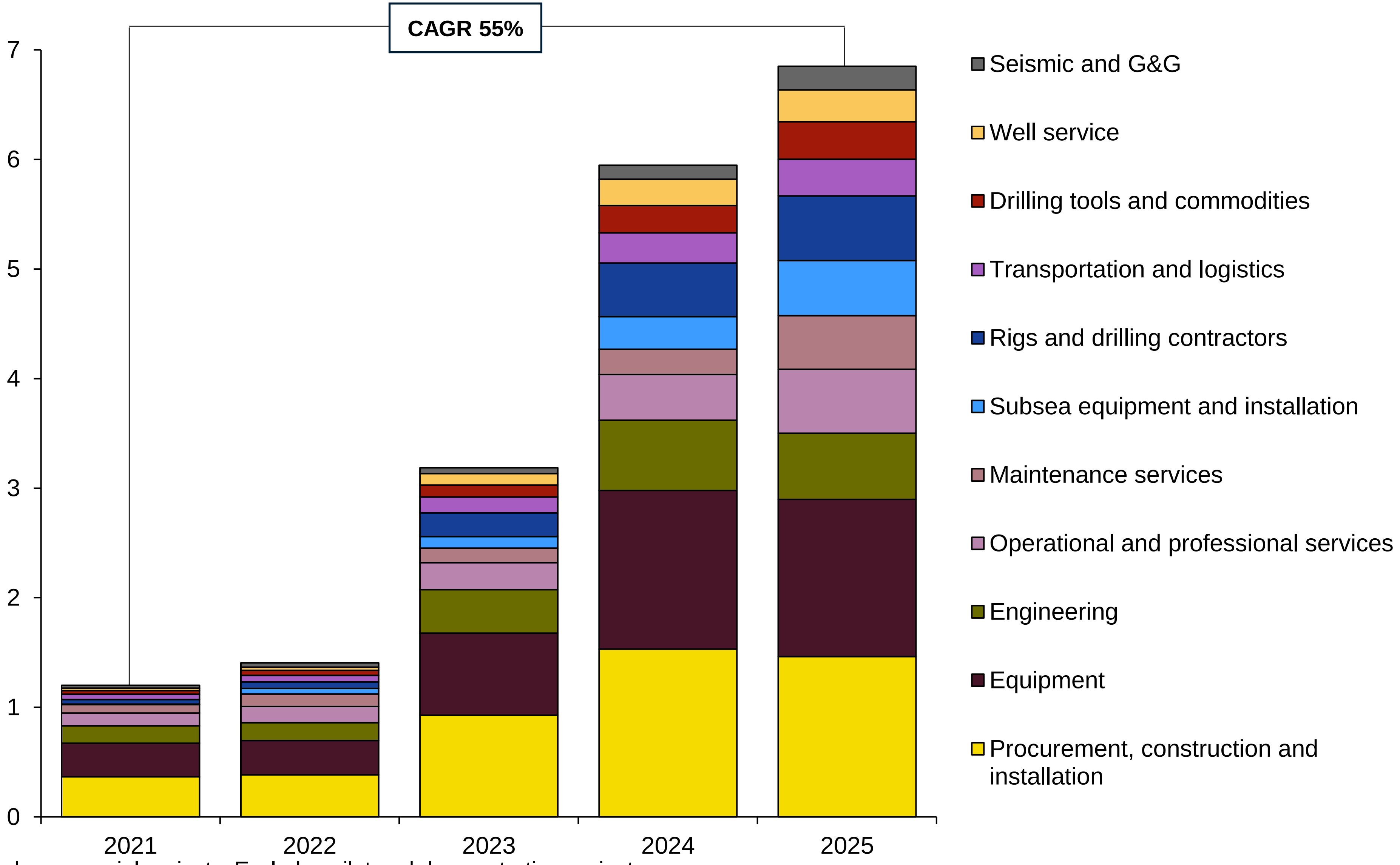


- High gas prices could lead to a shortage of natural gas supply for blue hydrogen, hence delay in project development
- Fluctuations in natural gas prices will not have a huge impact on the production cost
- High CCUS project announcements from hydrogen production in the region is not likely repeat itself
- Not likely to see any new CCUS projects linked to fossil fuel power plants moving forward

*Excluding abandoned projects
Source: Rystad Energy CCUS dashboard

Europe CCS purchases* by service segment

USD billion

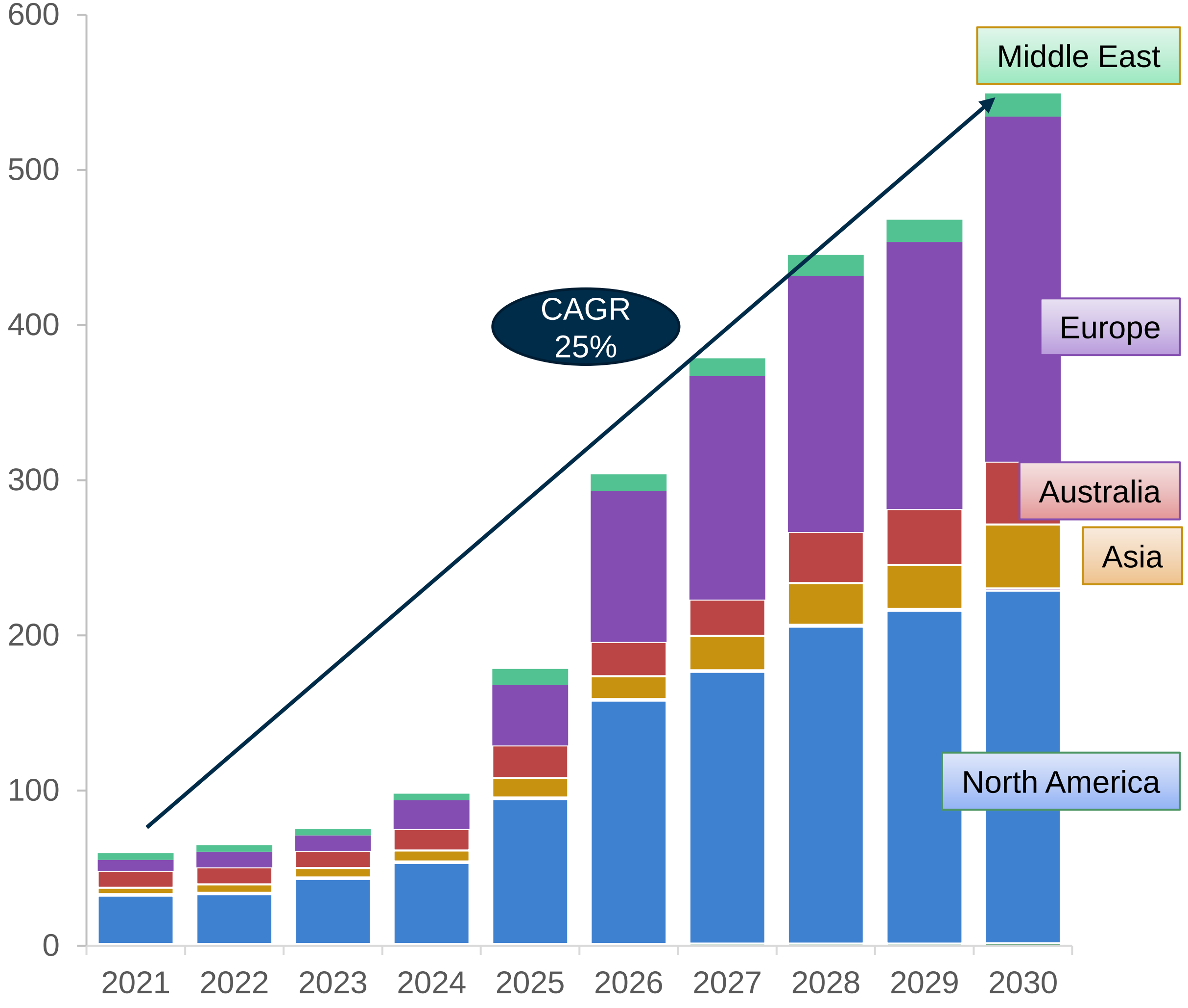


*Based on announced commercial projects. Excludes pilot and demonstration projects

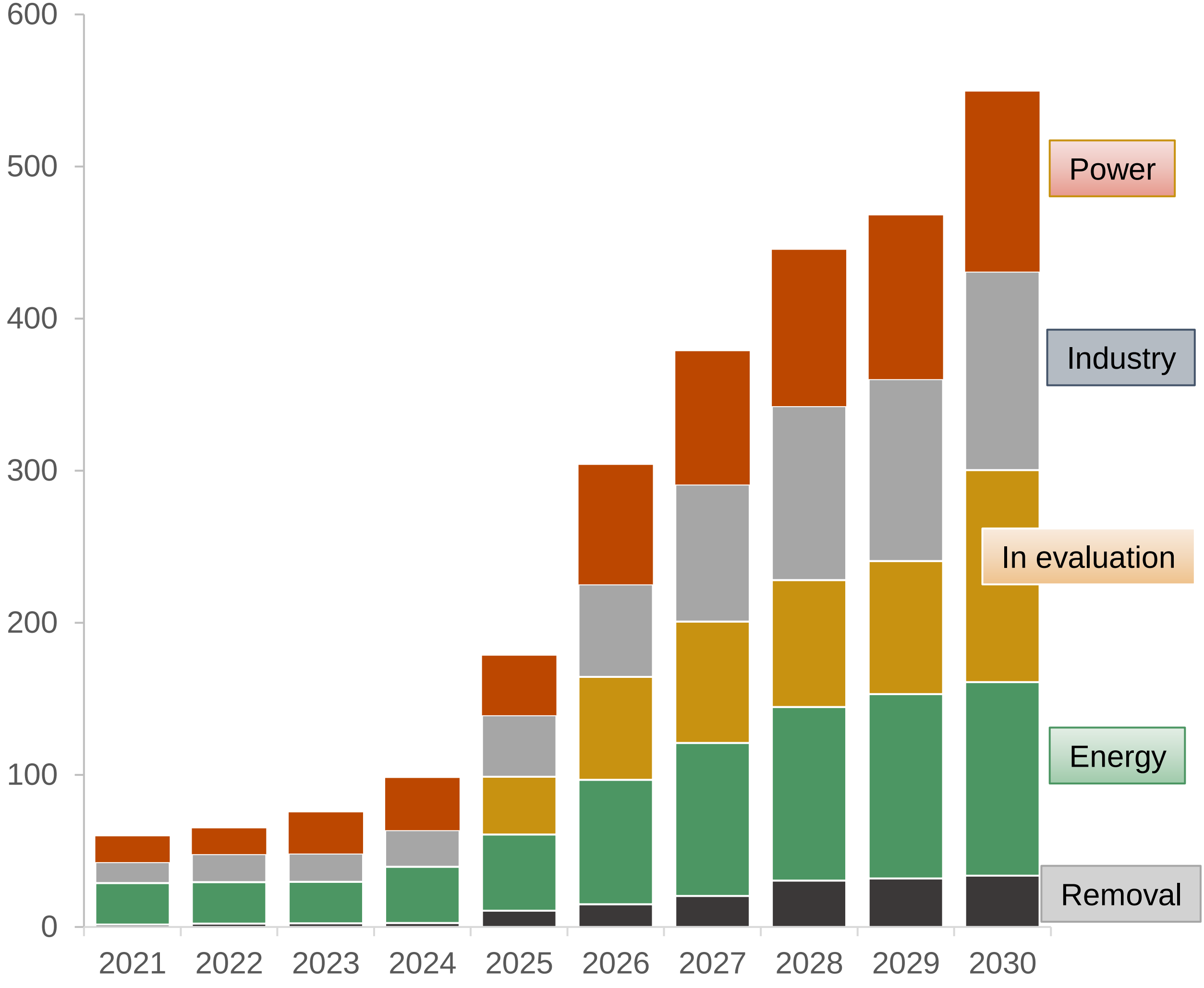
Source: Rystad Energy CCS Service Analysis dashboard

Positive outlook for CCUS project, but far from achieving final target

Global CO_2 capture capacity by region
Million tonnes (Mt) of CO_2

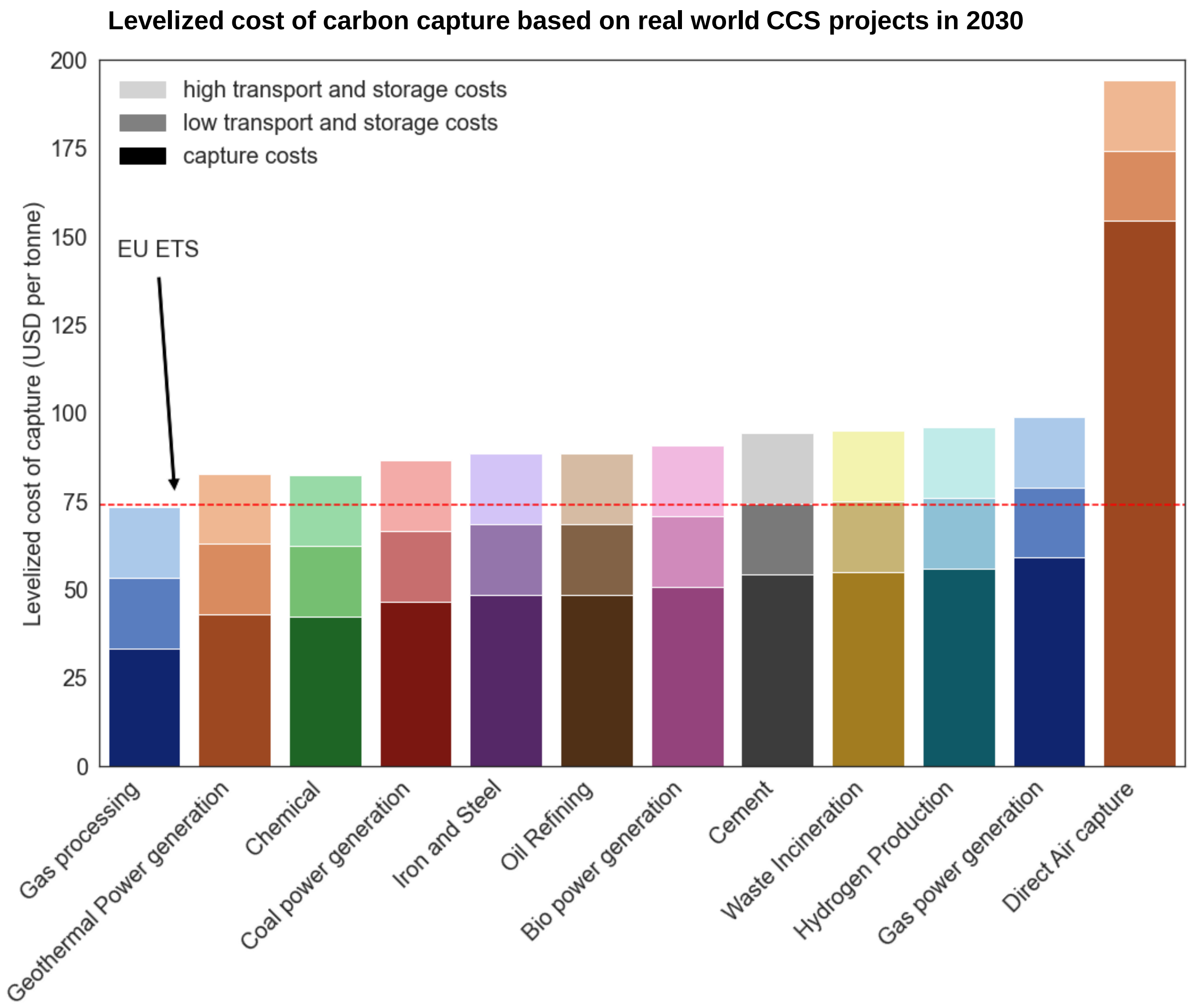


Global CO_2 capture capacity by CO_2 source
Million tonnes (Mt) of CO_2



Source: Rystad Energy CCUSCube

Cost parity for most CCS projects will fall between $75 to $100/tonne of CO2 by 2030



Source: Rystad Energy CCUS Dashboard

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Headquarters
Rystad Energy
Fjordalléen 16, 0250 Oslo, Norway

Americas +1 (281)-231-2600
EMEA +47 908 87 700
Asia Pacific +65 690 93 715

Email: support@rystadenergy.com

ccus.pl

AGH WiseEuropa Ministerstwo Rozwoju, Pracy i Technologii Narodowe Centrum Badań i Rozwoju

Paweł Gładysz, PhD
AGH University of Science and Technology
AGH UST Energy Center

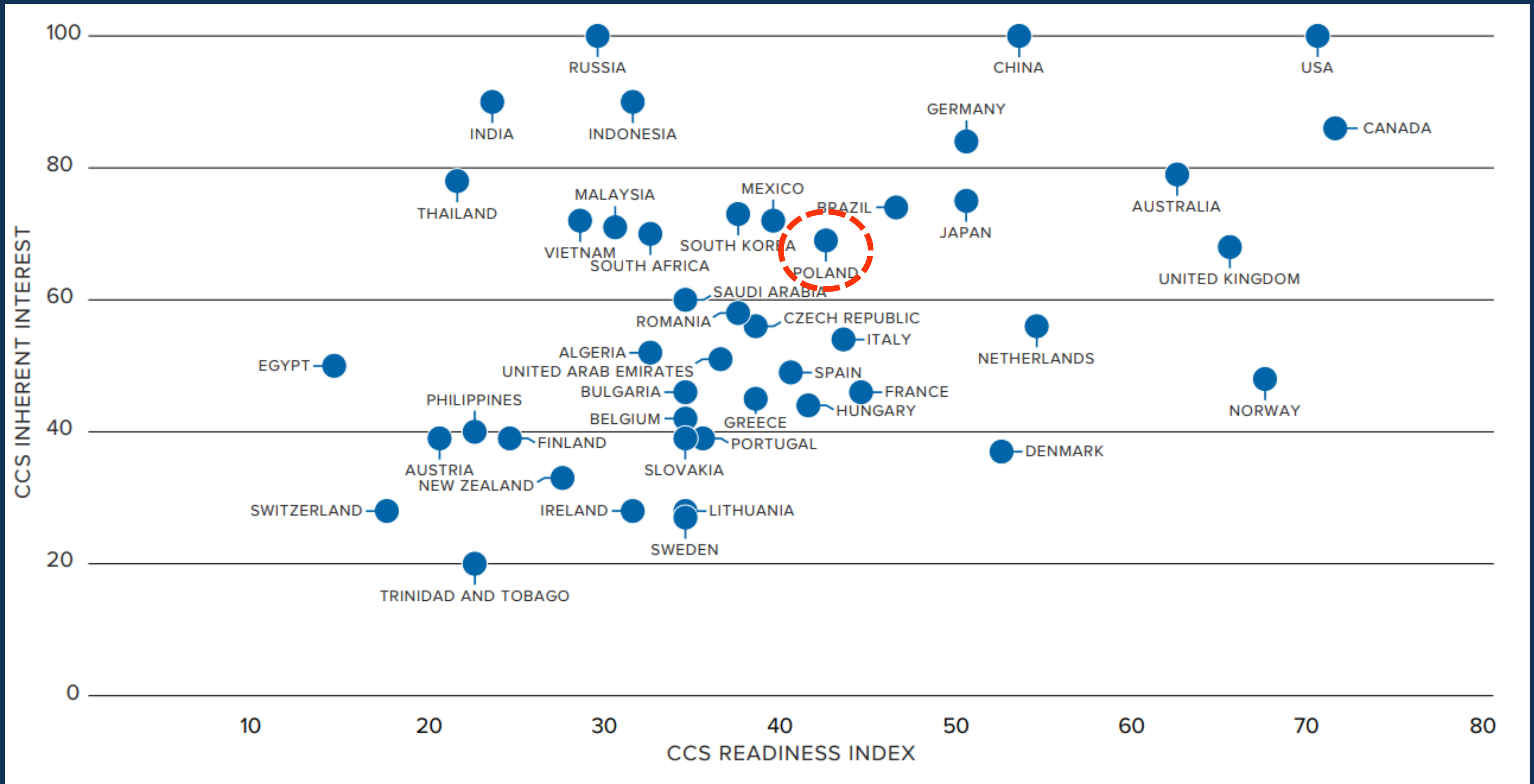
Preparation of Poland’s CCUS strategy and establishment of the first CCS Cluster in Poland

Are we ready for the CCS/CCU technologies in Poland?

CCS Readiness Index (CCS-RI):

- *policy developments*
- *legal and regulatory frameworks*
- *geological CO2 storage*

vs inherent CCS interest



For Poland (2018):

- **CCS inherent interest: 62 / 100 points**
- **CCS-RI: 42 / 100 points**, incl.:
  - geological CO_2 storage: 68 / 100 points
  - legal framework: 51 / 100 points
  - **policy development: 7 / 100 points**

Source and more:
https://www.globalccsinstitute.com/resources/publications-reports-research/the-carbon-capture-and-storage-readiness-index-2018-is-the-world-ready-for-carbon-capture-and-storage/

Strategy development for CO_2 capture, transport, utilization and storage in Poland, and pilot implementation of Polish CCUS Cluster

Acronym: **CCUS.pl**

Consortium:

- AGH University of Science and Technology (leader)
- Ministry of Economic Development and Technology (implementing entity)
- WiseEuropa Institute (independent think-tank)

Programme: **GOSPOSTRATEG III of the National Centre for Research and Development** (Poland)
Project start: 31st of March, 2021
Duration: 36 months

Project research team capacity:

- R&D project manager: **Prof. Wojciech Nowak**
- general project manager: **Dr. Paweł Gładysz**

AGH University of Science and Technology - over **40 experts** in 3 research teams:

- technological research teams (CO_2 capture, CO_2 utilization, CO_2 transport, CO_2 storage, power and industrial installations),
- comprehensive assessment research team (economic and environmental analysis, risk management),
- process modelling research team (models development, simulations and optimizations).

WiseEurope Institute – over 10 experts in macroeconomic and system models.

Ministry of Economic Development and Technology – experts in law and regulatory framework.

Main project goals:

1. preparation of the **strategy for the development of CCUS technology** in Poland,
2. preparation of appropriate **legal and regulatory framework stimulating this development** in an sustainable manner, taking into account economic, social and environmental aspects,
3. preparation of the first **Polish CCUS Cluster**.

Other goals:

4. development, validation and complementary demonstration of **research tools** for the selection and assessment of the impact of CCUS technologies at the level of individual installations, as well as energy and industrial clusters from the technological, economic, environmental and socio-economic point of view;
5. preparation of a number of **reports and studies** on the key aspects of the development of CCUS technologies in Poland;
6. preparation and implementation of a series of **activities disseminating** the effects of the project dedicated to various groups of stakeholders.

Phase A (first 18 months) – main outcomes

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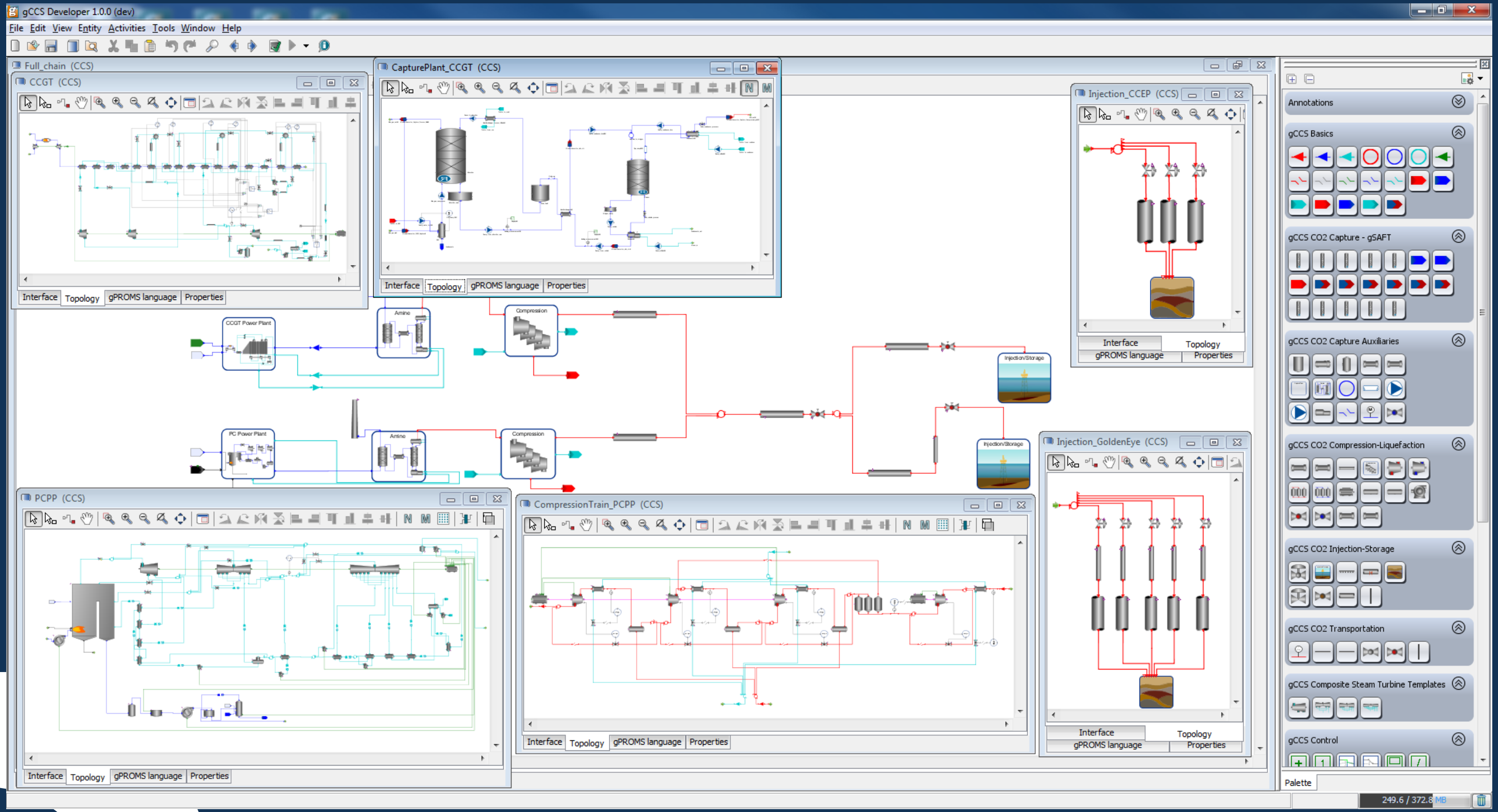
- **CCUS technological database**.
- Assessment methods for individual installations and CCUs clusters.
- Universal process model for simulation and optimization **studies of CCUS clusters**.

WiseEuropa

- **National-level fuel and energy model including CCUS technologies** (in energy sector and industry).
- **Macroeconomic model including CCUS technologies** in an integrated approach.

gPROMS software for the process modeling and optimization of CCUS installations and clusters.



Specialized research team (12 people) at AGH University devoted to the process simulations and optimization of CCUS installations and cluster using gPROMS software.

Team experience:

- participation in extensive training by software provider (Siemens PSE Enterprise),
- case studies development for Polish energy sector and industry,
- previous R&D&I projects.

Phase B (second 18 months, starts in October 2022) – main outcomes

AGH

- Preparation of **technological procedures and guidelines** for the implementation of CCUS technologies.
- Pilot of the **first Polish CCUS cluster**.
- Dissemination activities: thematic seminars, forum, online course.

WiseEuropa

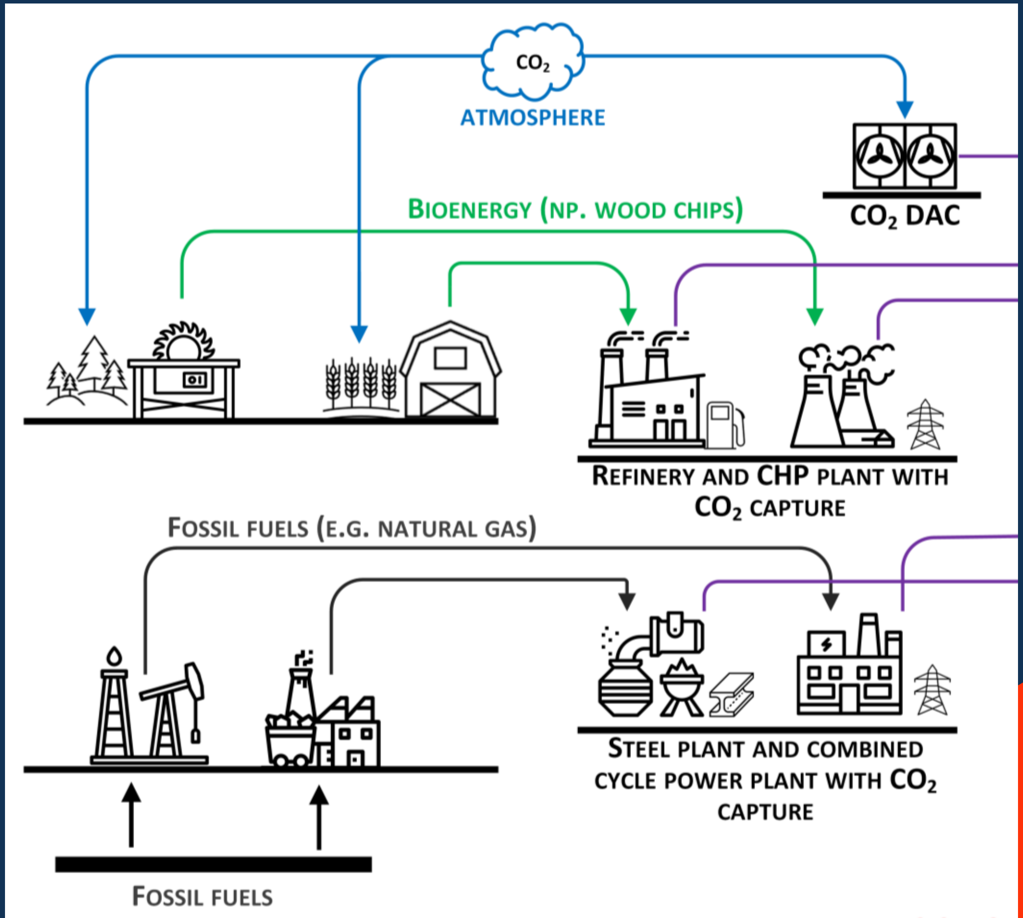
- **Quantitative and qualitative analyses in the area of CCUS technologies**.
- Reports supporting the implementation of the strategy.
- Information policy framework.
- Dissemination activities: thematic seminars.

Ministry

- **Strategy for the development of CCUS** technologies in Poland.
- **Draft legal and regulatory framework** in the area of technology development and energy-industrial clusters of CCUS technologies.
- Dissemination activities: thematic seminars.

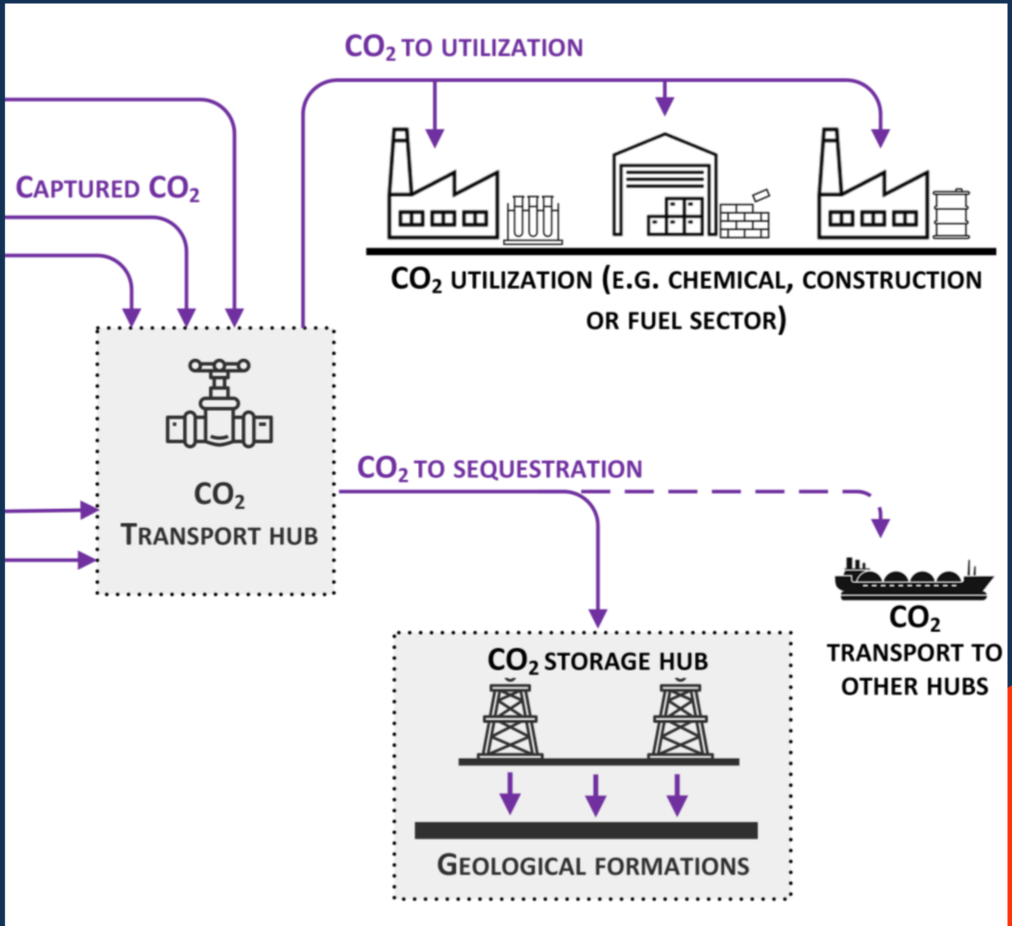
CCUS technologies analysed in the project:

- CO_2 capture from **power and CHP plants** (main focus on retrofit of existing plants);
- CO_2 capture from **industrial sources** (including integrated steel mills, cement plants, refineries and other point sources of emissions to the atmosphere);
- technologies for capturing CO_2 from sources using **bioenergy** (BECCUS - Bio-Energy CCUS);
- technologies for **direct removal of CO_2 from the atmosphere** (DAC - Direct Air Capture) and methods of their process integration

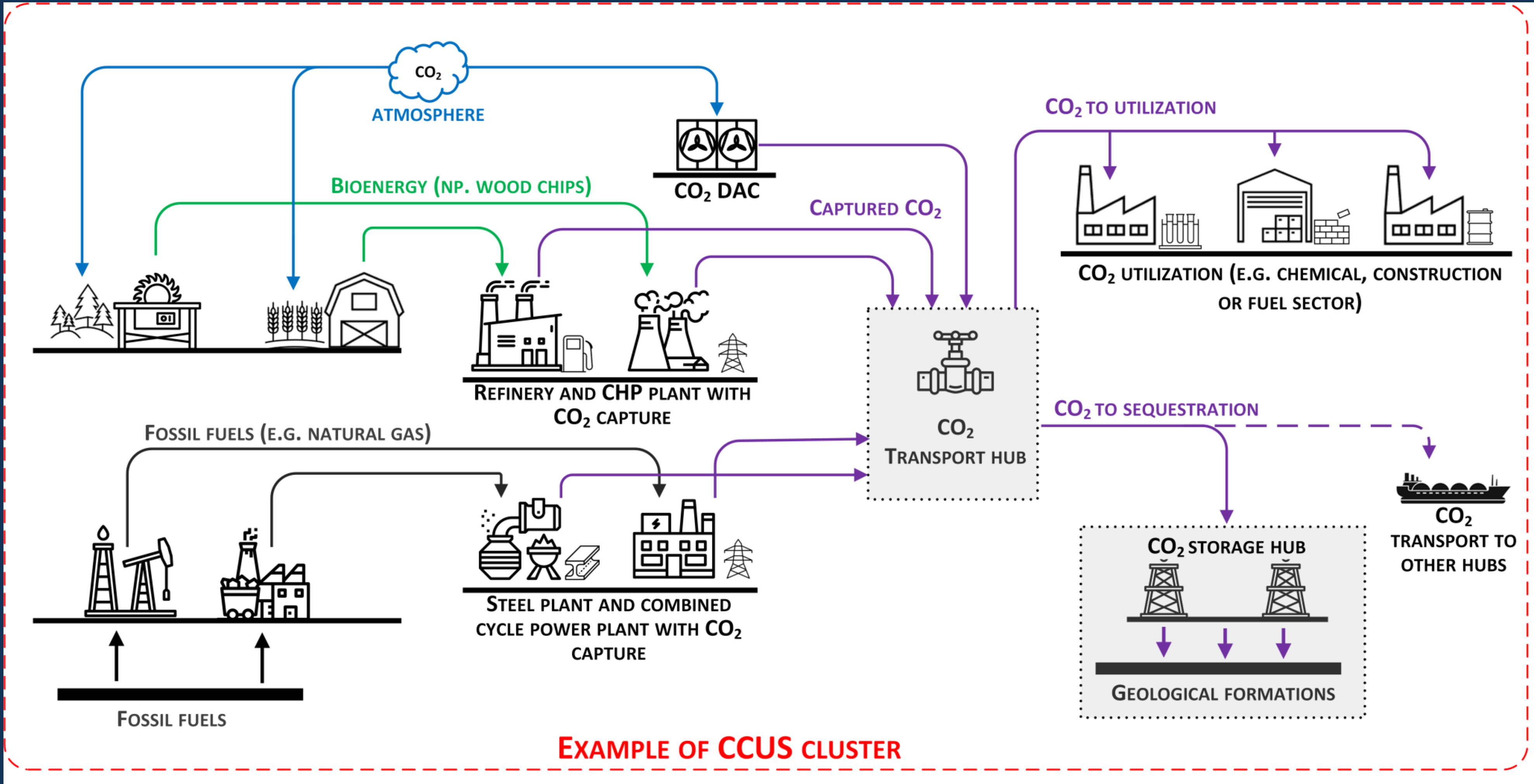


CCUS technologies analysed in the project:

- **CO_2 transport technologies** for various scales and distances (overground and submarine pipelines, tankers and cisterns), including transport hubs;
- technologies for the **industrial use of CO_2** in the economy (e.g. hydrogen economy, production of synthetic fuels, enhanced oil and gas recovery; enhanced coal bed methane, mineralisation);
- technologies and **locations for CO_2 storage in Poland**, including cross-border cooperation and CO_2 storage hubs.



CCUS clusters to be analysed – theoretical case studies and first Polish CCUS cluster case study



Future perspectives of CCUS.pl project

- **New technologies from CCUS chain added to database** – always open for contributions from technology providers.
- **New database for planned** (at different stages) **CCUS projects in Poland** – aggregation of what in happening in Poland to provide a „big picture" for administration and government.
- **Ideas for industrial CCUS clusters** – for the process modelling in gPROMS and assessment of different configurations.
- **CCUS.pl cluster** – organisation to aggregate and disseminate knowledge, as well as share experience, between involved stakeholders of CCUS projects.

Cluster agreement was sign in March 2022 between AGH University and WiseEurope Foundation (cluster founders). We are now starting to gather interested parties (stakeholders) to join.

During Phase B of the CCUS.pl project (starting from October 2022) we will foster the cluster development and use it as a main platform for project outcomes dissemination and consults for the CCUS strategy development.

Cluster actions are part of the **Gospostrateg programme goals**, and so the preparation of the pilot of the first Polish CCUS cluster, thus building social capital, which in the future may constitute a base for the further development of CCUS technology in Poland and act as a contact point for national and international partners in one of the most important part of CCUS.pl project.

Actions planned as part of the cluster activities:

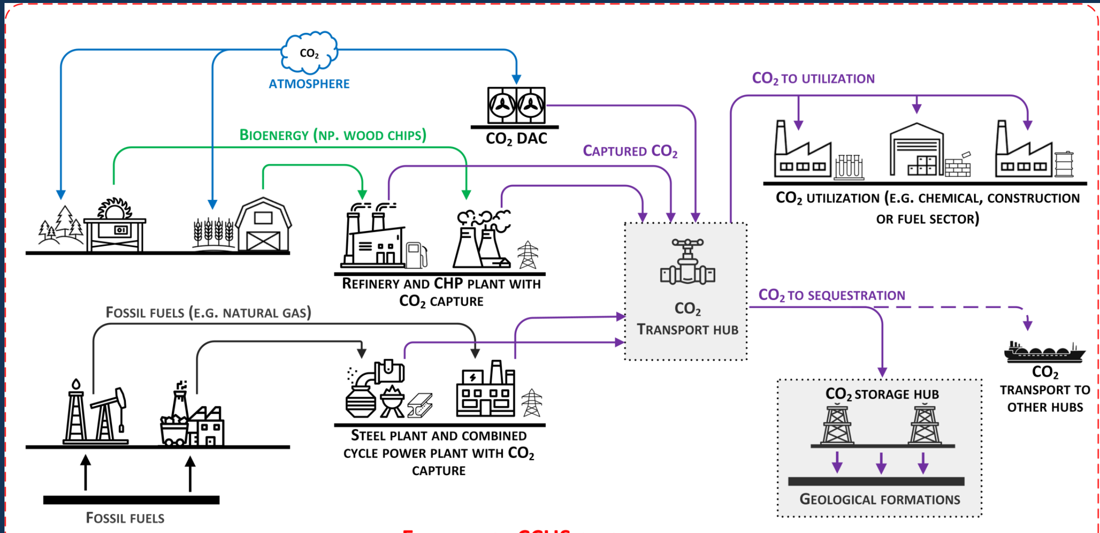
- stakeholders meetings and discussions (**open dialog**),
- individual **support for CCS/CCU projects** in Poland,
- consults on **project reports** in various areas of CCUS technologies development,
- consults on **CCUS strategy for Poland** developed within the project,
- consults on **CCUS legislation** developed within the project,
- dedicated **seminars** (minimum 7 events) and conferences (minimum 2 events – **first one in September 2022**),
- newsletter and **progress reports**,
- knowledge share (outreach) with **general public**,
- …

Actions planned as part of the cluster activities:

- database for **planned CCS/CCU project** in Poland,
- aggregation and **networking of stakeholders**,
- unified approach to **public consults for CCUS legislation** on Polish and EU level,
- **base for real-life cluster propositions to be analysed within the project** (Phase B of the project).

Prefeasibility study for Poland:

- **min. 5 capture installations (power and industry sector),**
- **min. 2 utilization options included,**
- **CO_2 transport hub,**
- **CO_2 storage site (in-land in Poland),**
- **optional CO_2 transnational transport and storage.**



EXAMPLE OF CCUS CLUSTER

Thank you for you attention.

pawel.gladysz@agh.edu.pl
rzecznik@ccus.pl

AkerSolutions

Connected Carbon
Enabling Permanent Storage At Large Scale

NORWEP Hydrogen & CCS Webinar – Europe

Craig Harvey | Chief Engineer | Carbon
Aker Solutions | Renewables


We solve global
energy challenges
for **future** generations
AkerSolutions

Broad participation across Aker Solutions for CCS projects

Engineering & Front End
Marte Mogstad

Renewables
Stephen Bull

Topside and Facilities
Sturla Magnus

Electrification, Maintenance and Modifications
Paal Eikeseth

Subsea
Maria Peralta

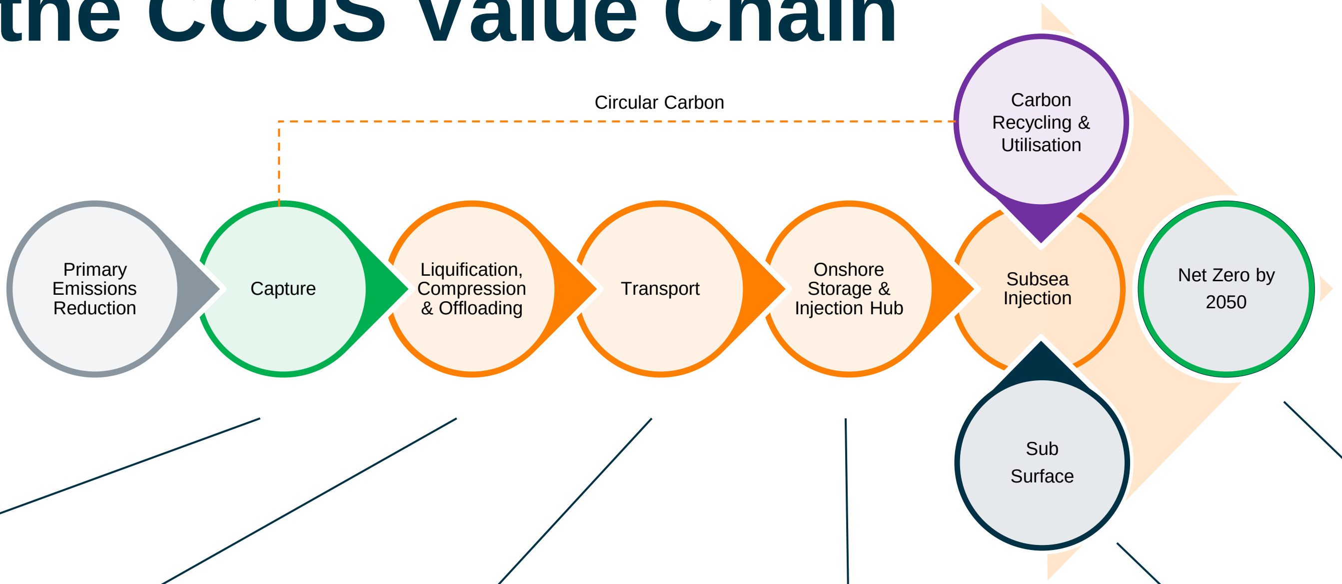
Global Presence

15,000+ EMPLOYEES

20+ COUNTRIES

50+ LOCATIONS

We connect the CCUS Value Chain



Integrate & Deliver EPC & BoP To Capture CO2 using selected Technology

Capture Technology

Prepare captured CO2 for transport

Transport CO2 from Capture hub to Storage hub

Prepare Large Volume CO2 for Permanent Storage

Inject & Store CO2 permanently offshore

Recycle CO2 to create sustainable value

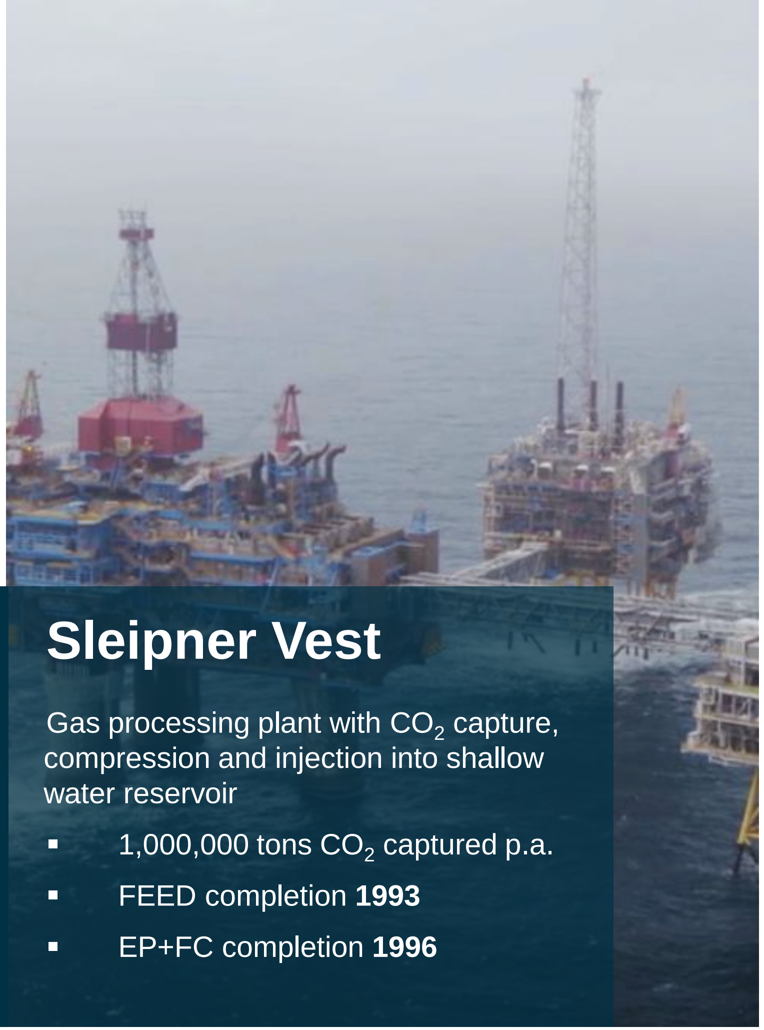
Utilisation Technology

Todays CCS Challenge

Connecting Carbon at **MegaScale** from **A to B** since **1996**

AkerSolutions

Connecting Carbon at industrial scale since 1996



Sleipner Vest

Gas processing plant with CO_2 capture, compression and injection into shallow water reservoir

- 1,000,000 tons CO_2 captured p.a.
- FEED completion **1993**
- EP+FC completion **1996**

TCM Mongstad

- EPC & Commissioning project for a CO_2 Technology Test Centre Mongstad for an Amine Plant
- 80,000 tons CO_2 captured p.a.

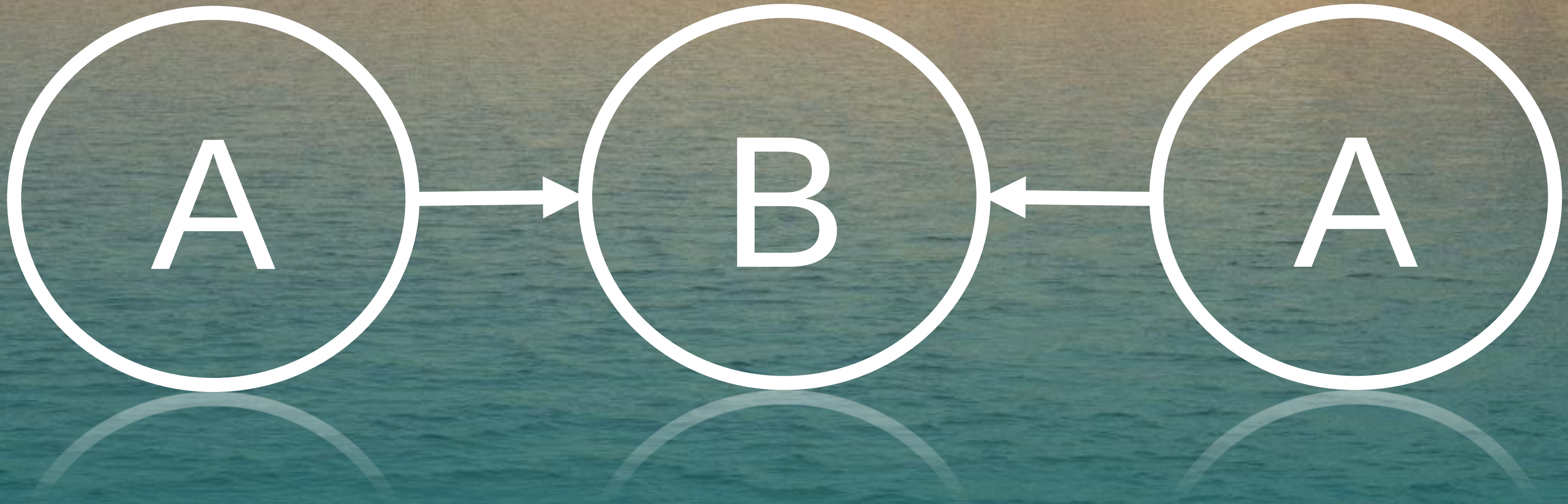
Snøhvit Pipeline

- Detail design and project management
- CO2 Pipeline
- Landfall
- Offshore Supervision

AkerSolutions

Tomorrows CCS Challenge

Connecting Carbon at **GigaScale** from **A*N to B** toward **2050**



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Longship & Northern Lights

Full-scale CCS | Demonstration project

CO_2 transport and storage in the North Sea

- Onshore terminal with buffer storage, pump and heater
- Landfall
- 12” 110 km pipeline
- One injection well

Onshore terminal in Øygarden, Hordaland

Fortum Oslo Varme AS
Waste-to-energy plant

Norcem AS, Brevik
Cement plant

- Capture of 400 kt/y Norcem
- Amine technology from ACC
- Includes CO_2 capture, liquefaction and buffer storage (4 days)

- Transport by ships
- 700 km distance
- Liquefied state (15 barg, -26°C)

AkerSolutions

Northern Lights Onshore Plant

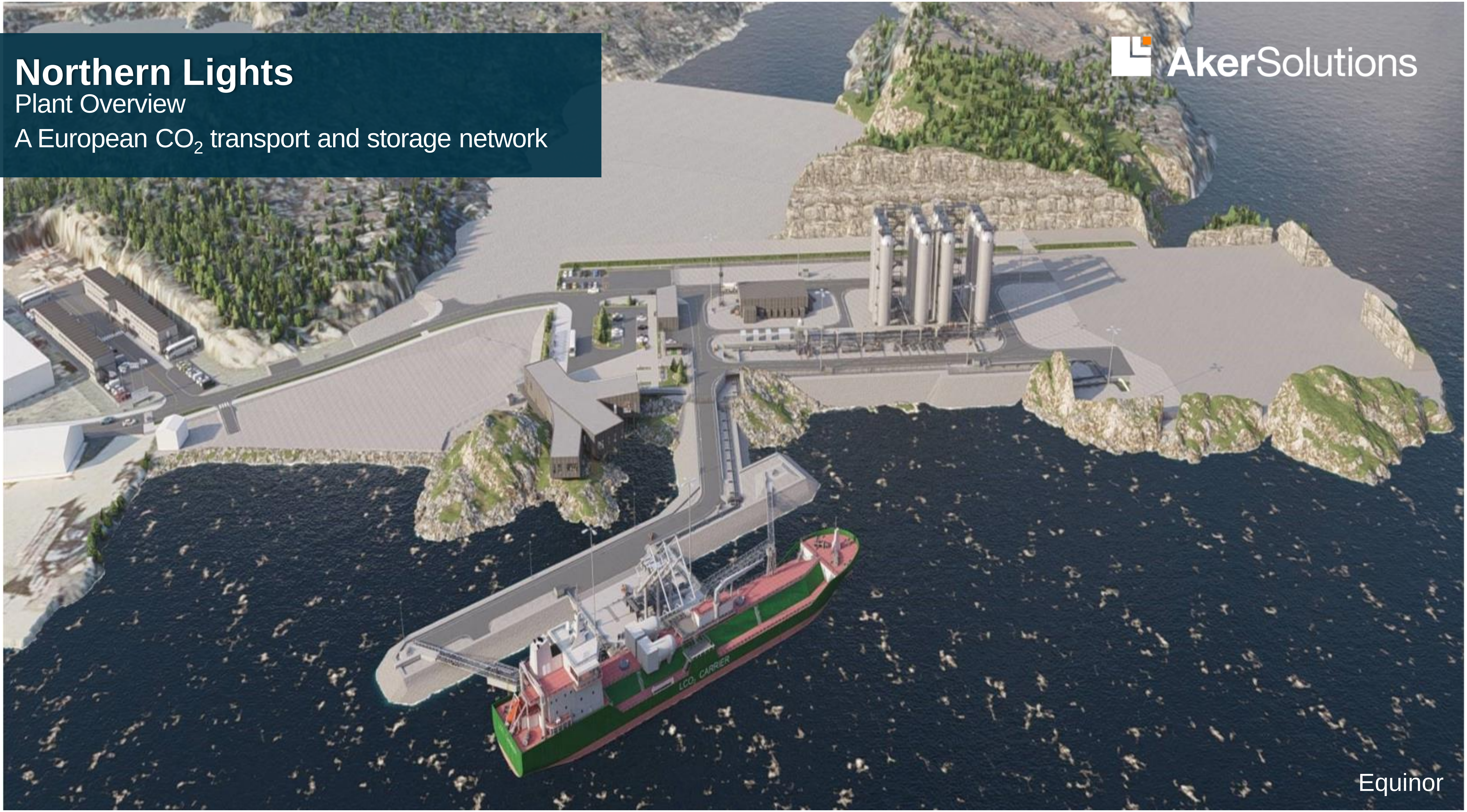
- EPC & Commissioning project
- Including the jetty for import of CO_2 from ships, storage tanks for intermediate storage of CO_2 and process systems for gas conditioning and subsea injection
- CO_2 subsea storage capacity:
  - Phase 1: 1,5M MtCO_2 p.a.
  - Phase 2: 5M MtCO_2 p.a
- Planned **operation in 2024**

Northern Lights

Plant Overview

A European CO_2 transport and storage network

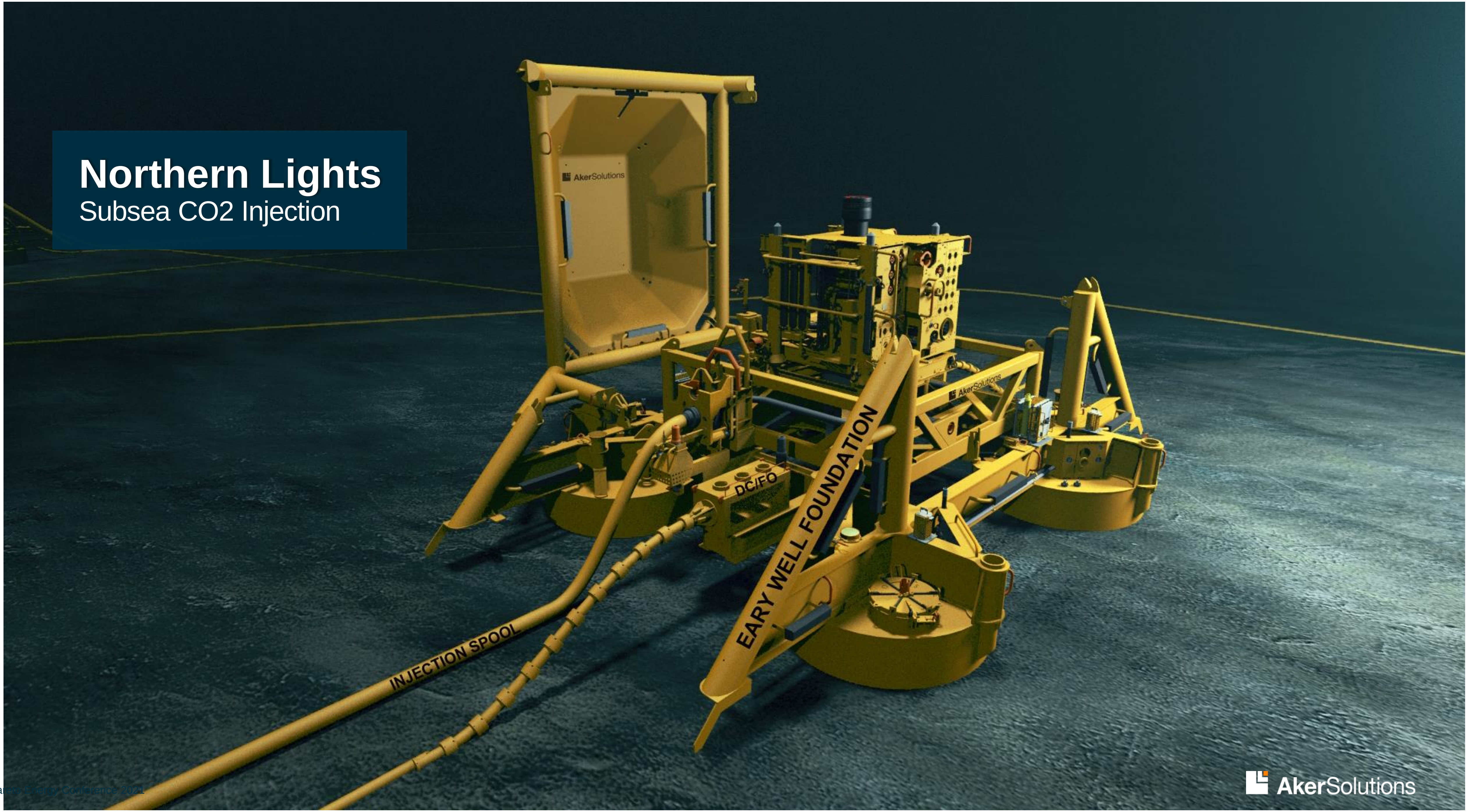
AkerSolutions



Equinor

Northern Lights

Subsea CO2 Injection



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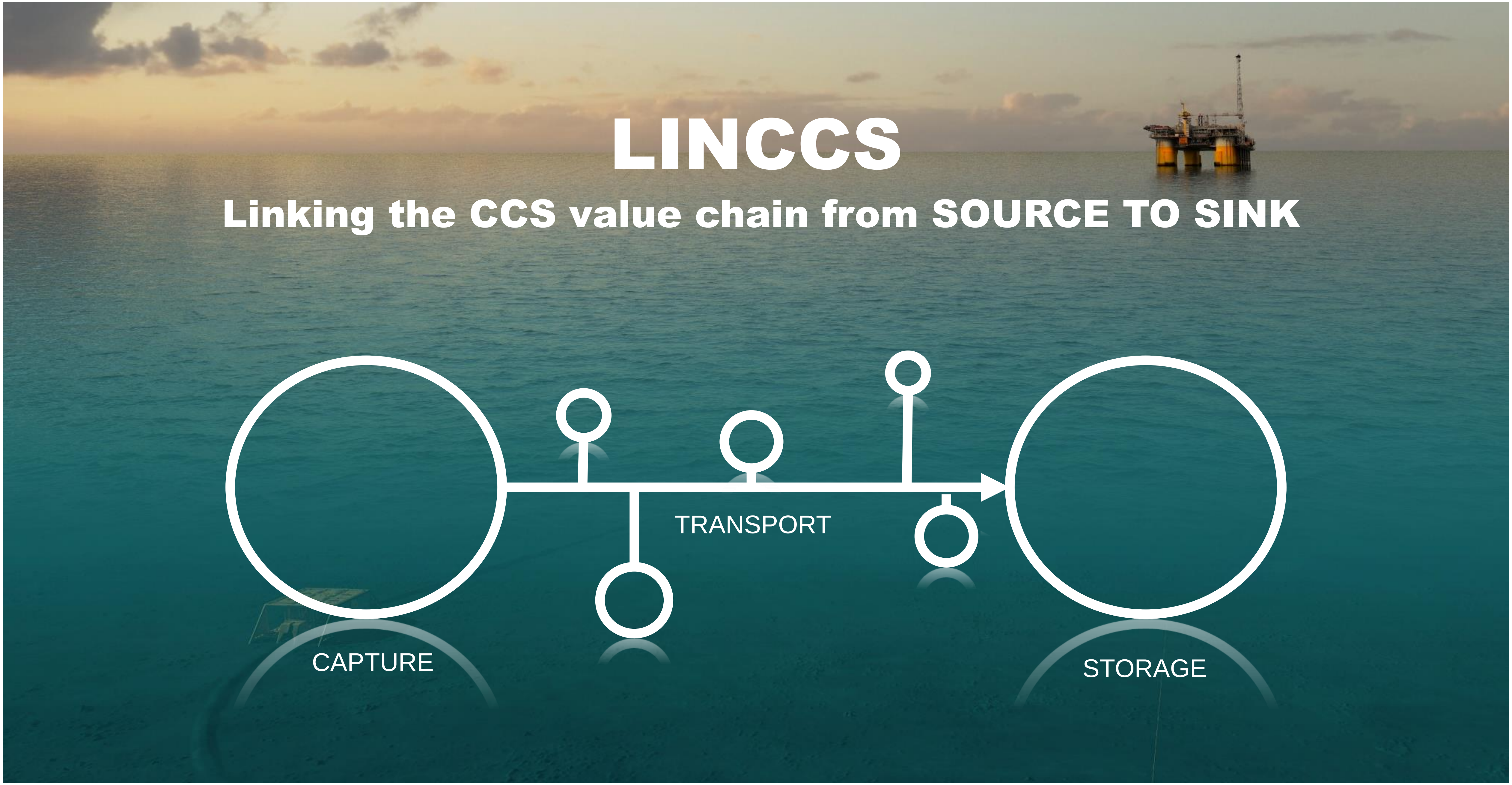
POWERING
NET ZERO

Net Zero Teesside FEED

AkerSolutions
AKER CARBON CAPTURE
DOOSAN
SIEMENS energy



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LINCCS

SOURCE

OFFSHORE

Enabling Unmanned Offshore Capture

MARITIME

Enabling Ship based Capture & Carbon Logistics

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Linking the CCS value chain from SOURCE TO SINK at SCALE

REUSE

Enabling Accelerated Reuse of Offshore Assets

STORAGE

Driving Down Cost of Storage

REMOVAL

Ecosystem for CDR System R&D

SINK

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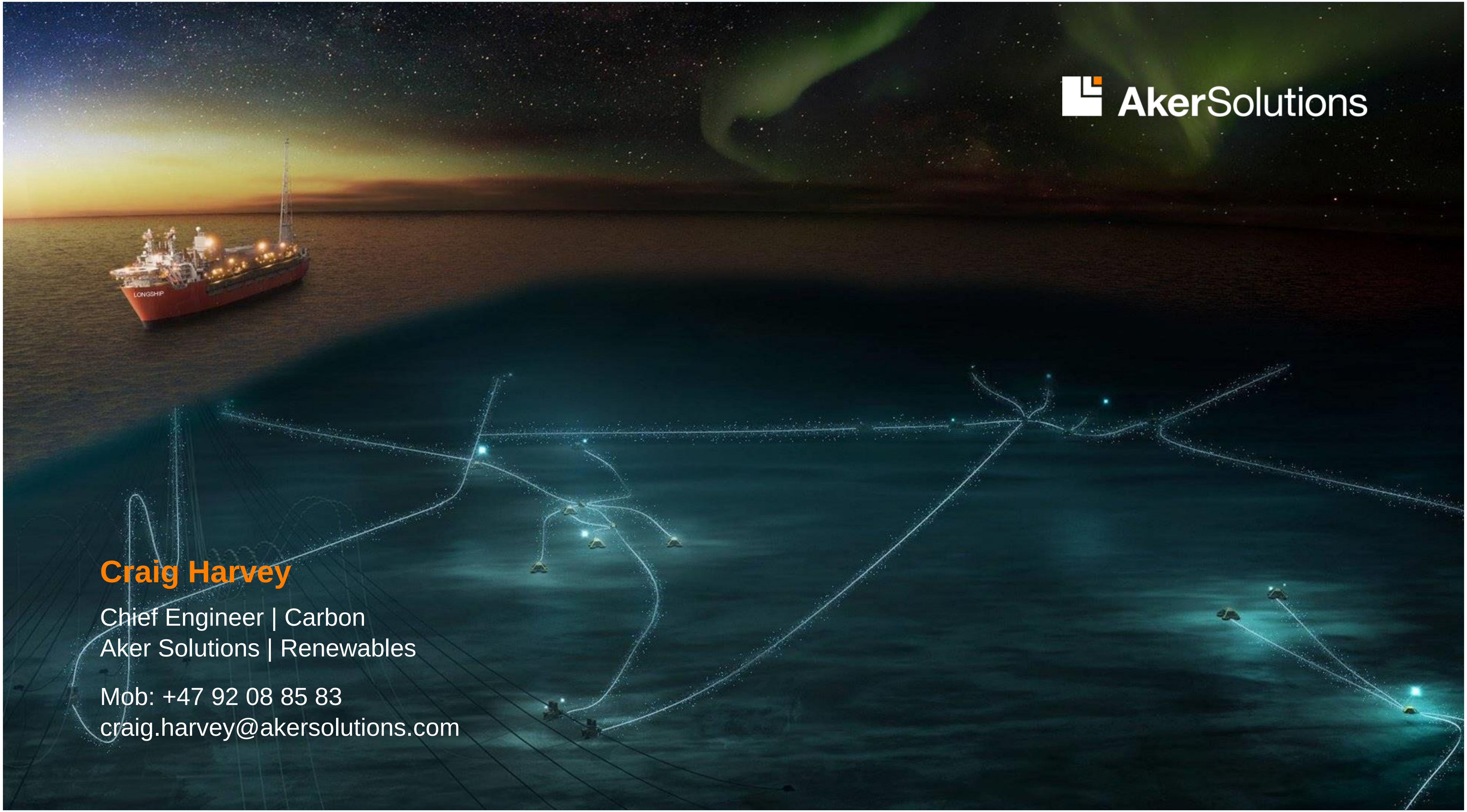

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Craig Harvey

Chief Engineer | Carbon
Aker Solutions | Renewables

Mob: +47 92 08 85 83
craig.harvey@akersolutions.com

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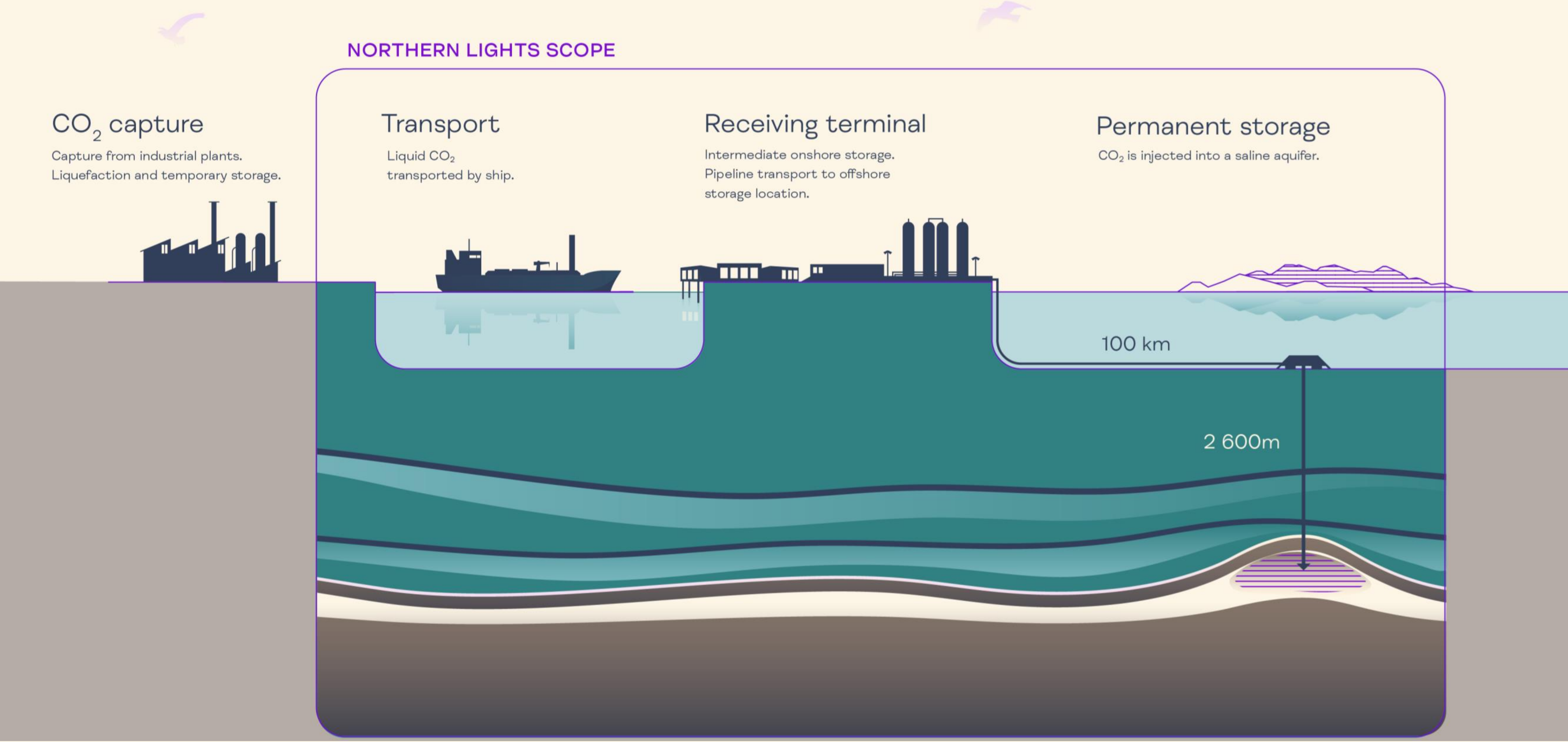
Northern Lights – becoming a reality

Birthe Nylund Sundt

CFO

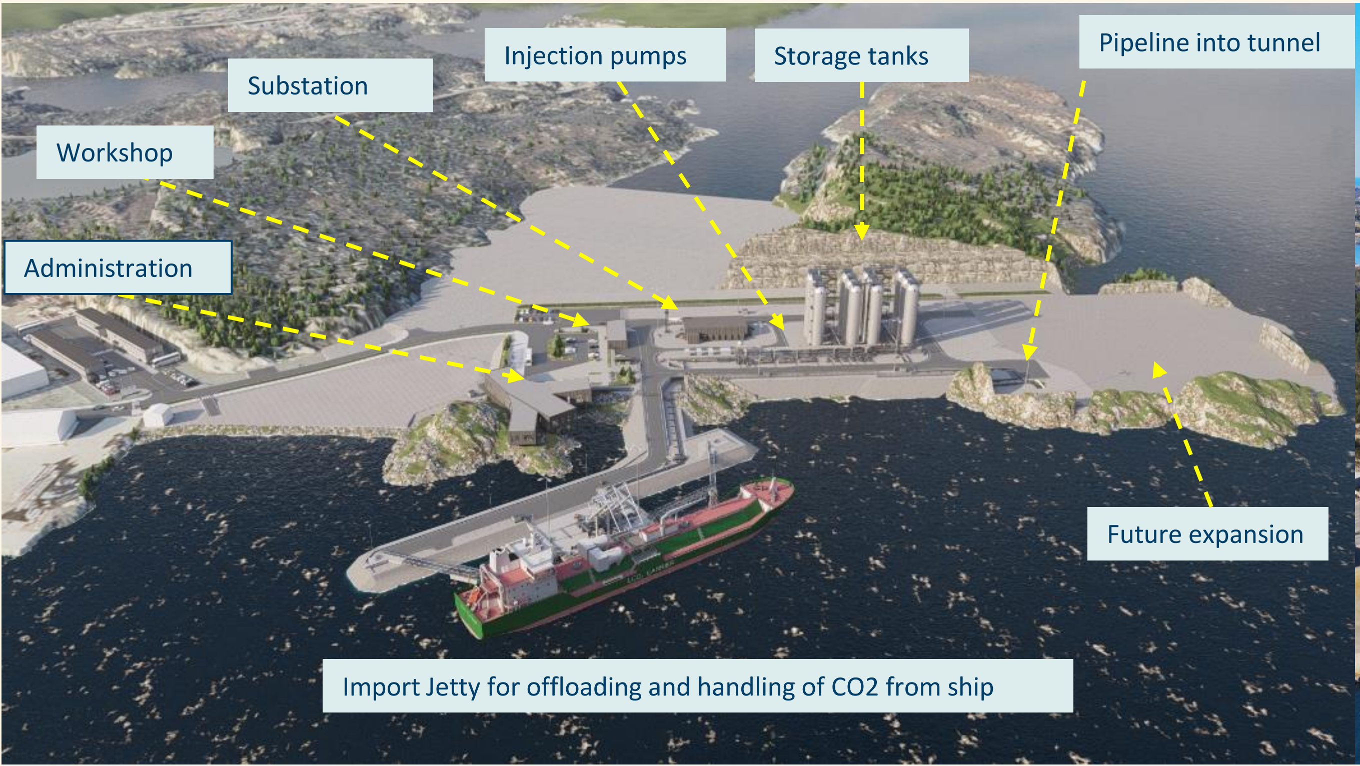
CO_2 transport & storage at scale



Receiving terminal Øygarden

Northern Lights

- → **Civil works completed**
- → **Import jetty construction well under way**
- → **Project office and visitor centre in in place**
- → **Detail engineering and procurement ongoing**
- → **Fabrication and installation of plant started**
- → **Additional area for expansion included**



Onshore facilities Øygarden

April 2022

Fabrication activities

Northern Lights

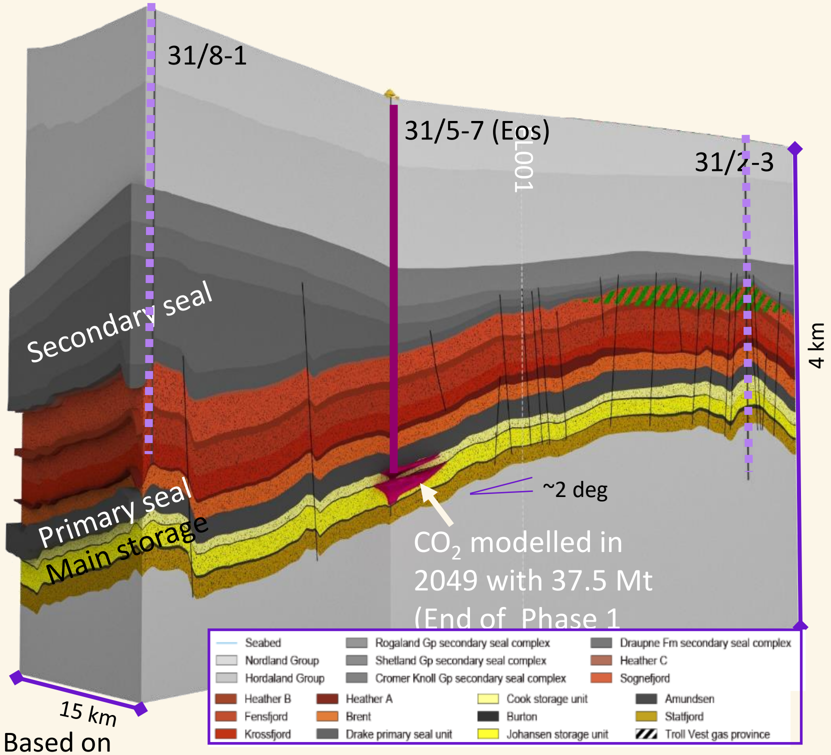
Fabrication of storage tanks by Idesa, Spain

Fabrication of subsea satellite by Aker Solutions, Egersund.

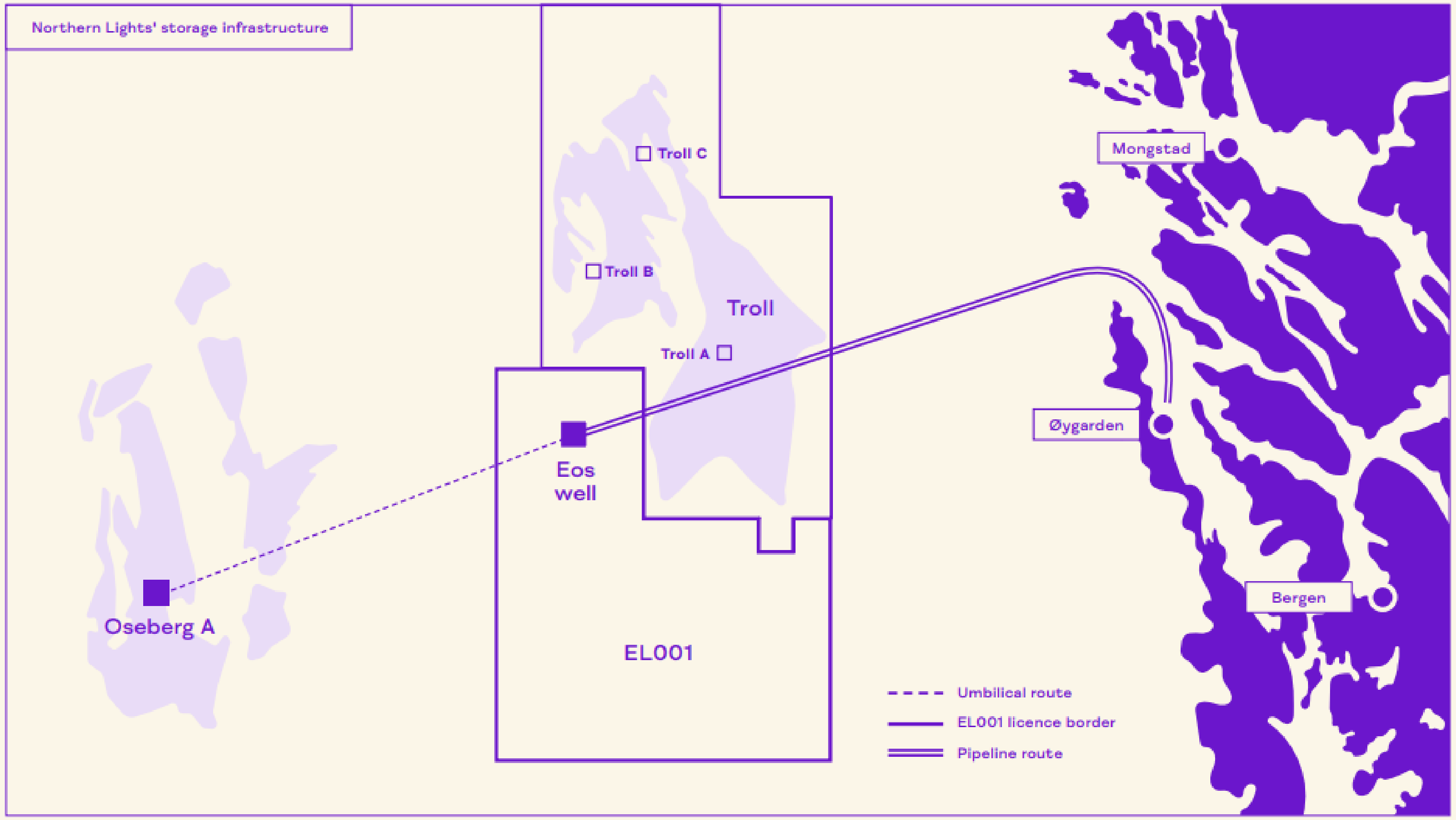
Fabrication of linepipe by Tenaris, Italy. Coating by Shawcor, Orkanger.

Detailed engineering ongoing (STASCO/Dalian, China).

Northern Lights storage



Based on seismic data from CGG



Building a market for CO_2 storage

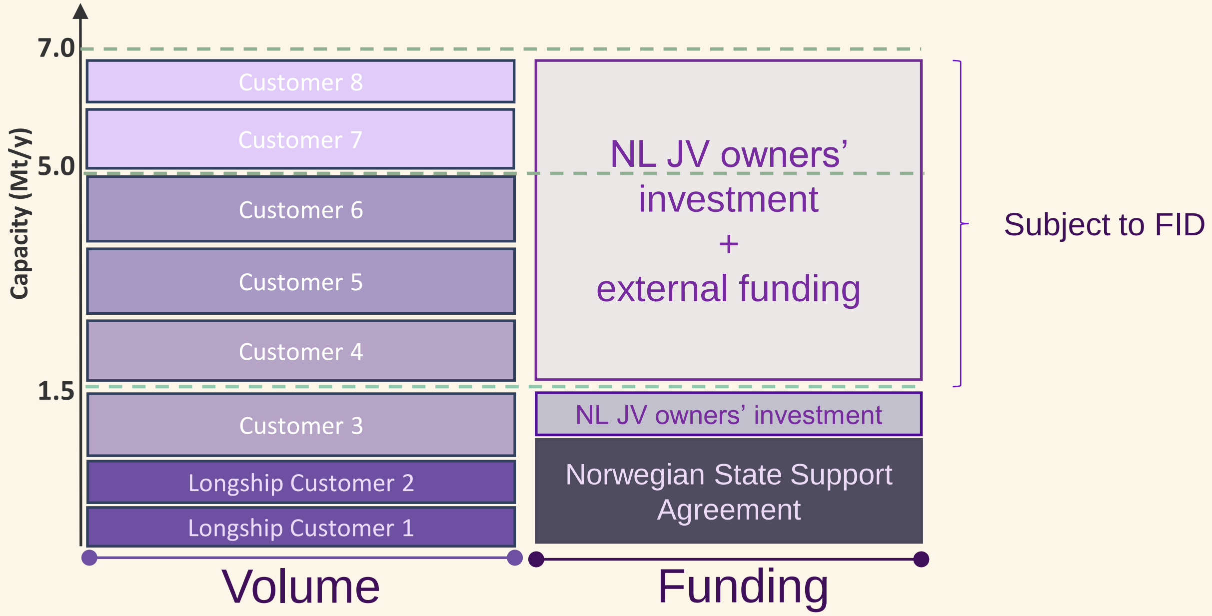
Significant demand for storage capacity

→ European Commission concern:
- not sufficient storage capacity being developed

→ Overcoming challenges:
- Everything we do is new
- First contracts of this type
- LCO_2 ships are new
- Little/no operational experience
- Risks management
- Costs
- De-risking subsurface is expensive
- Regulatory requirements – many firsts
- Northern Lights – Test Pilots

→ Northern Lights Phase 1
- capacity to transport, inject and store up to 1.5 Mtpa of CO_2

→ Northern Lights Phase 2
- capacity to transport, inject and store 5-7 Mtpa of CO_2



Key customer sectors

Northern Lights

Strong potential but different levels of experience and maturity in respect to CCS

- Cement
- Chemicals/ refineries
- Waste incineration
- Biofuels/bioenergy
- Direct air capture
- Steel

European CO_2 value chain

→ Northern Lights is developing the first open source CO_2-transport and storage network.

→ Offering flexible ship based transport and permanent storage.

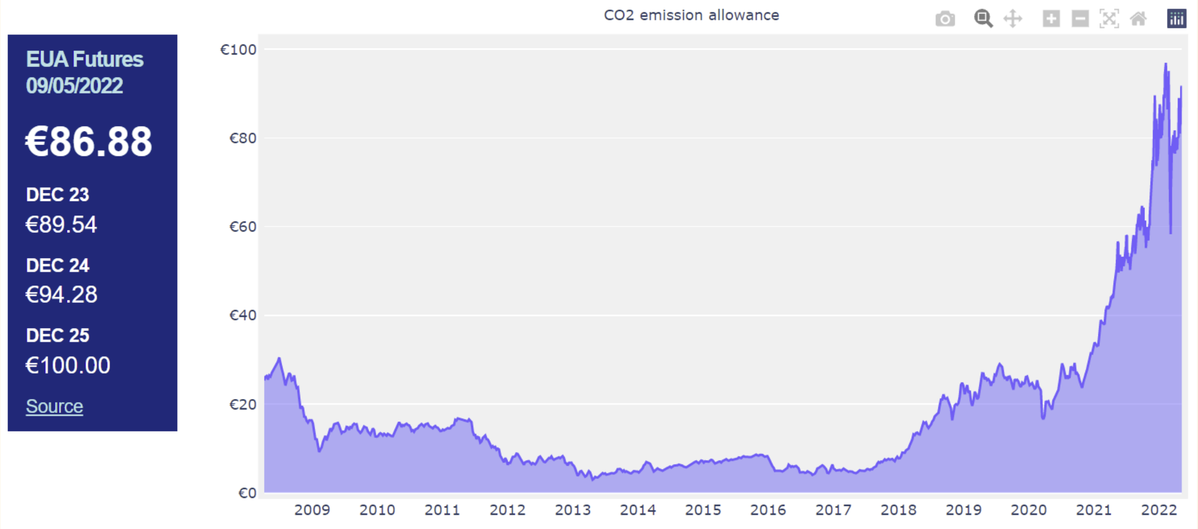
→ Discussions with potential customers ongoing.

→ Expecting to sign first commercial contract in 2022.

EU ETS important

- The high CO_2 price helps put CCS on the agenda but it is too early to say if it is triggering investment decisions.
- We are experiencing high interest from industrial companies in countries with CO_2 taxation schemes on top of ETS. Typically these countries also offer support mechanisms for realisation of industrial climate change mitigation initiatives.

EU ETS 9th May 2022



Source: https://sandbag.be/index.php/carbon-price-viewer/

Northern Lights

norlights.com

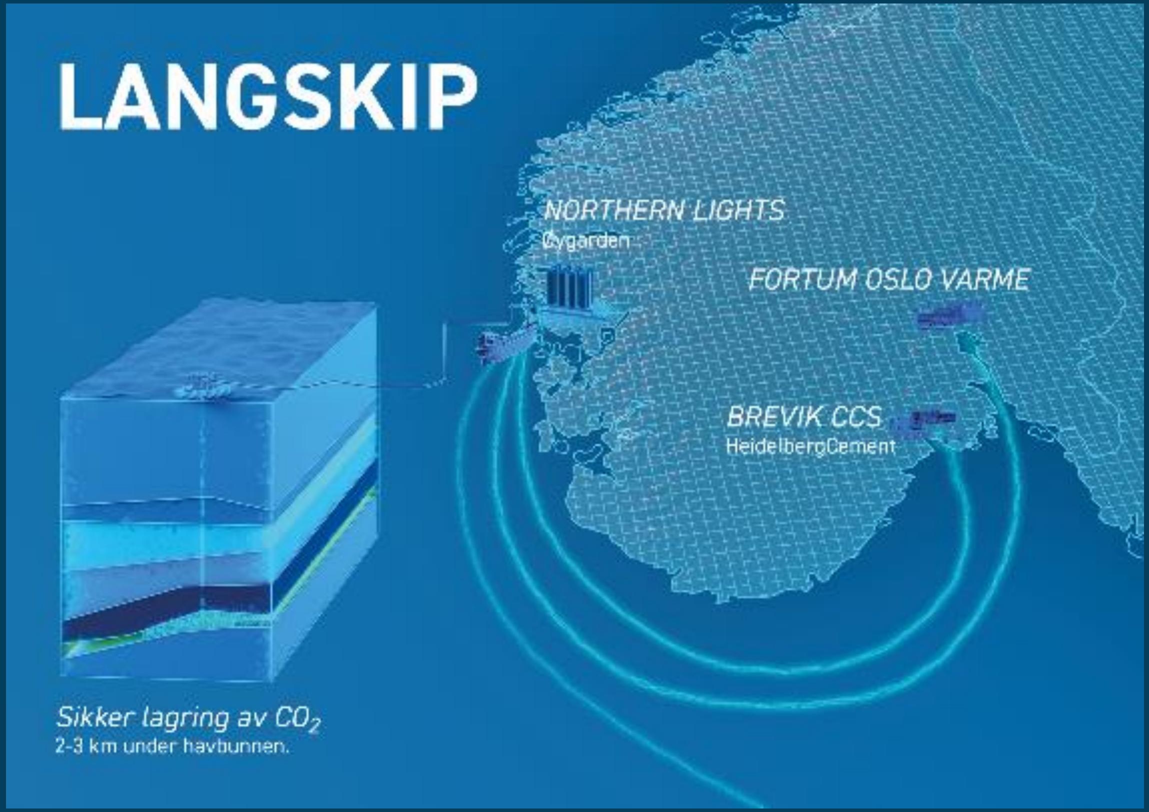
CCS in Norway

Audun Røsjorde,

Director CCS technology and knowledge hub

GASSNOVA

Longship Status



- Project under construction:
    - Gassnova «project integrator»
    - Progress according to plan, target start-up of CCS chain in 2024
    - Demolition and civil works ongoing at Norcem/Heidelberg cement plant
    - Cost overrun likely at capture plant
- 2nd Capture plant – Fortum Oslo Varme likely to fully join:
    - Retrofit of waste-to-energy plant
    - Securing financing through new owners
    - Potential start operations in 2026

TCM - Recent Test Campaigns

Proprietary Campaigns

2019 2021

2012-2018 → **2023**

FLUOR

MITSUBISHI HEAVY INDUSTRIES

MTR MEMBRANE TECHNOLOGY & RESEARCH

TDA

Site for emerging technologies

RTI INTERNATIONAL

Open Campaigns

→ **2023**

CESAR-1

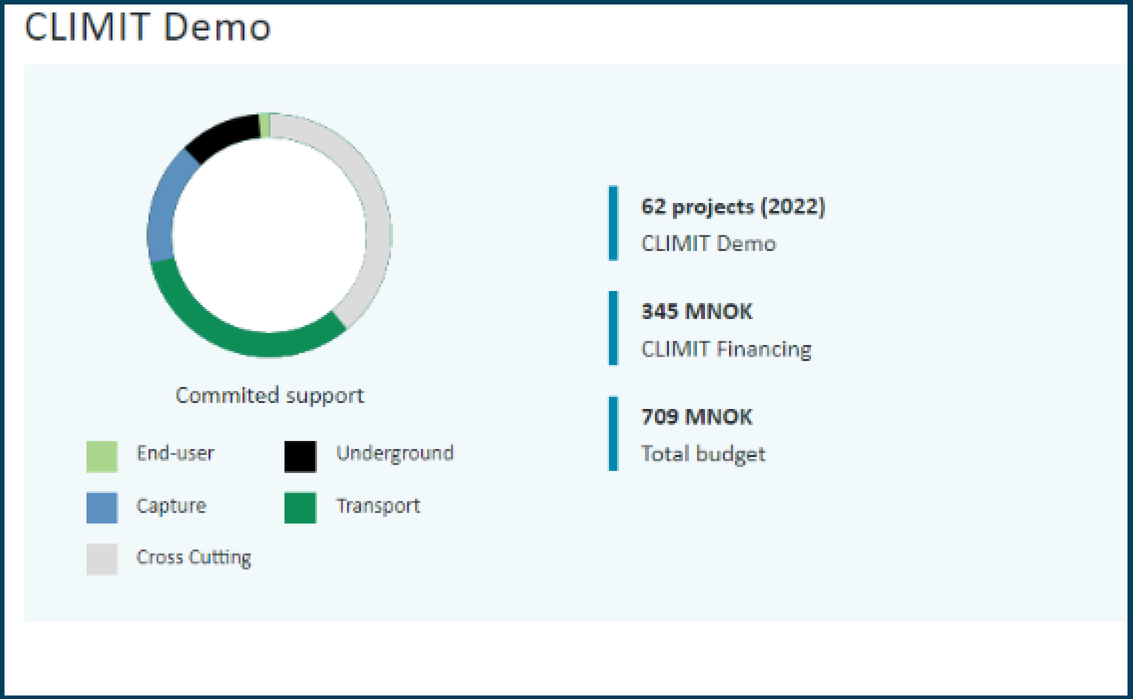
GASSNOVA equinor TotalEnergies

Support from CLIMIT

The Research Council of Norway

GASSNOVA

CLIMIT: The national programme for research, development and demonstration of technology for CCS



- Idea studies (up to 50% support - max. 200 kNOK)
- Technical-economic feasibility studies (maximum 50% support)
- Support for testing technology on a pilot scale (usually a maximum of 50% support)
- ACT4 call this summer

GASSNOVA

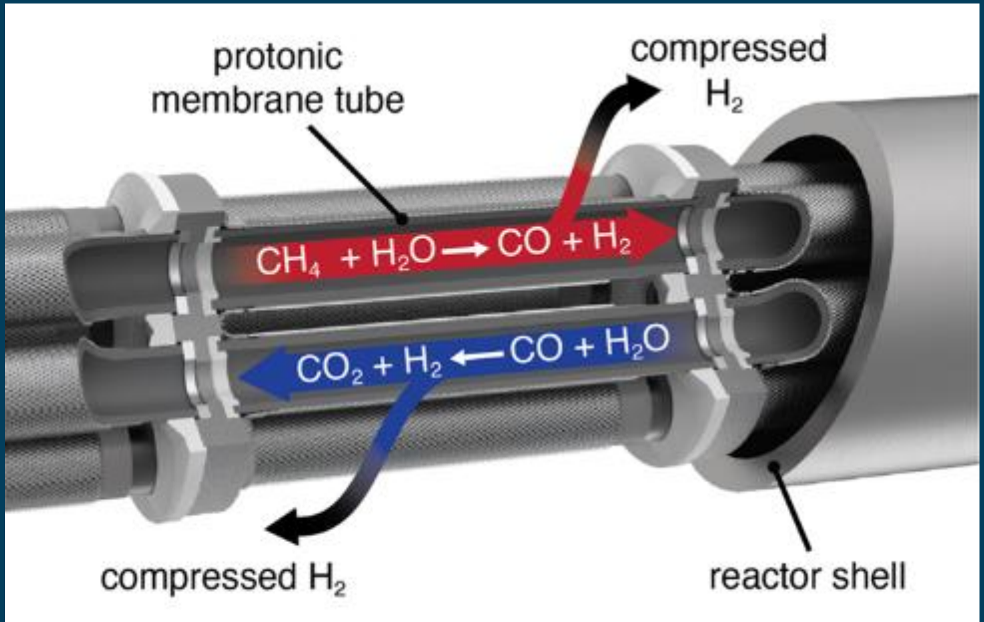
Electrochemical production of hydrogen from natural gas

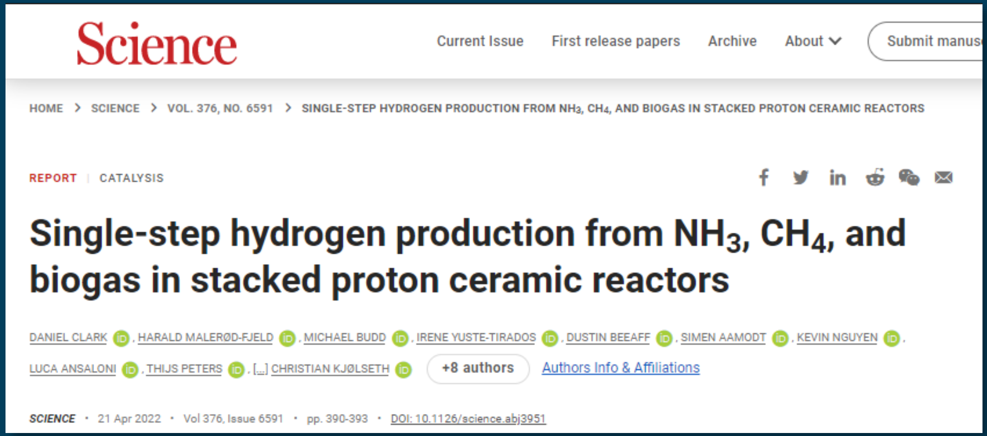
Partners	**CoorsTek Membrane Sciences** Equinor, ExxonMobile, Total, Shell, Saudi Aramco, ENGIE, Sintef
Project	2019 – 2022 (Phase I & II)
Budget [MNOK]	39 & 31.6
CLIMIT [MNOK]	17 (44 %) & 15 (47.5%)

- *Process intensification: reforming, water shift and H_2 compression in one step.*
- *Electricity as process energy – no natural gas for heating*
- *Heat integration balances energy demand*
- *Scalable technology*

Targeting:

- *90% efficiency*
- *99,99% H_2 purity*
- *Close to 100% carbon capture*




Science
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HOME > SCIENCE > VOL. 376, NO. 6591 > SINGLE-STEP HYDROGEN PRODUCTION FROM NH_3, CH_4, AND BIOGAS IN STACKED PROTON CERAMIC REACTORS

REPORT | CATALYSIS

Single-step hydrogen production from NH_3, CH_4, and biogas in stacked proton ceramic reactors

DANIEL CLARK, HARALD MALERØD-FJELD, MICHAEL BUDD, IRENE YUSTE-TIRADOS, DUSTIN BEEAFF, SIMEN AAMODT, KEVIN NGUYEN, LUCA ANSALONI, THIJS PETERS, [...] CHRISTIAN KJØLSETH +8 authors Authors Info & Affiliations

SCIENCE • 21 Apr 2022 • Vol 376, Issue 6591 • pp. 390-393 • DOI: 10.1126/science.abj3951

SCIENCE VOL. 376, NO. 6591

In addition to Longship…

- Hurdalsplattformen given focus to CCS on waste-to-energy
- Industrial clusters cooperate on studies and infrastructure
- Large-scale industrial CCS projects in early phase
- New cooperations for full value chain services
- More CO_2 storage under development

Hydrogen & CCS Webinar - Europe
11-12 May, 2022

Competitive, emission-free production of blue H2/Ammonia, efficient transportation and decarbonization

Torkild R. Reinertsen, PhD
Chairman & Market Lead Hydrogen
REINERTSEN New Energy AS
torkild.reinertsen@rein-energy.com

REINERTSEN
NEW ENERGY

.... Developing Clean Energy Solutions

REINERTSEN New Energy
Company Profile

Independent engineering / technology company

Developing clean energy technology and solutions for:

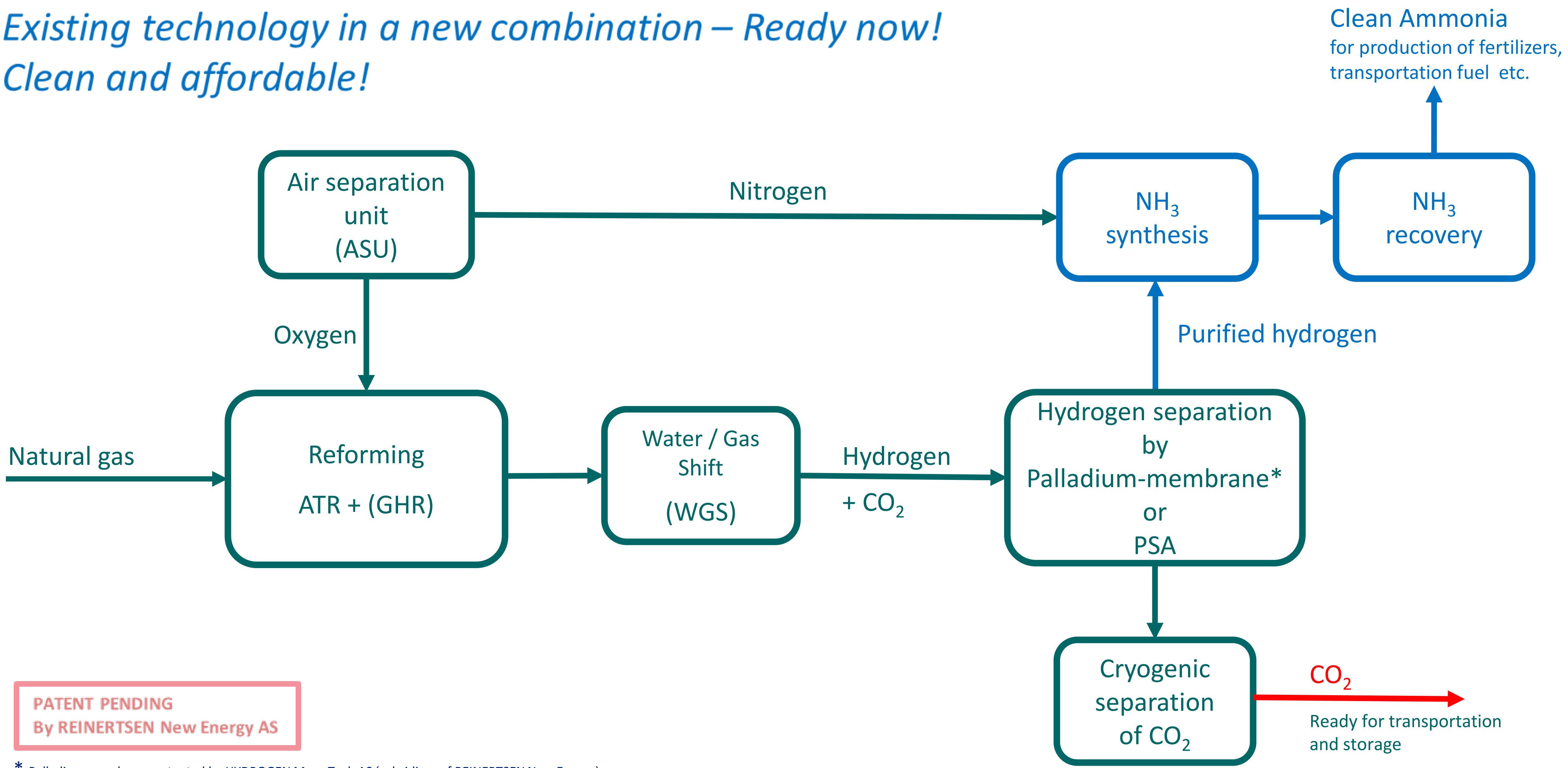
- ✓ Emission free production of hydrogen/ammonia from natural gas with CCS
- ✓ Pipelines for transportation Hydrogen, Natural gas and CO_2 , including:
  - ✓ Compression stations
  - ✓ H_2 blending / de-blending plants
- ✓ Hydrogen and ammonia for decarbonization in multiple sectors

REINERTSEN New Energy supplies engineering solutions to the hydrogen value chain. Serving as the independent engineer to global gas pioneers, we embark on a new and clean industrial adventure - for those that come after us and the world they will live in.

REAL-WORLD DECARBONIZATION | REINERTSEN NEW ENERGY

Emission-free production of hydrogen and ammonia - **HyPro-Zero™**

Existing technology in a new combination – Ready now!
Clean and affordable!

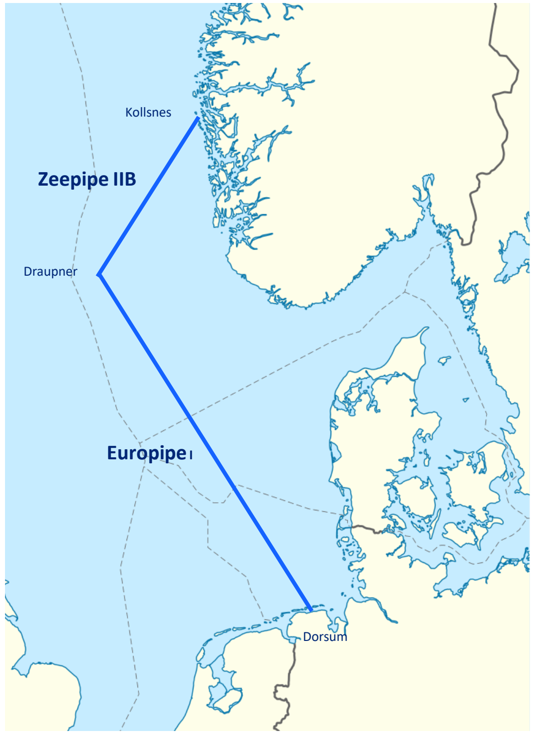


PATENT PENDING
By REINERTSEN New Energy AS

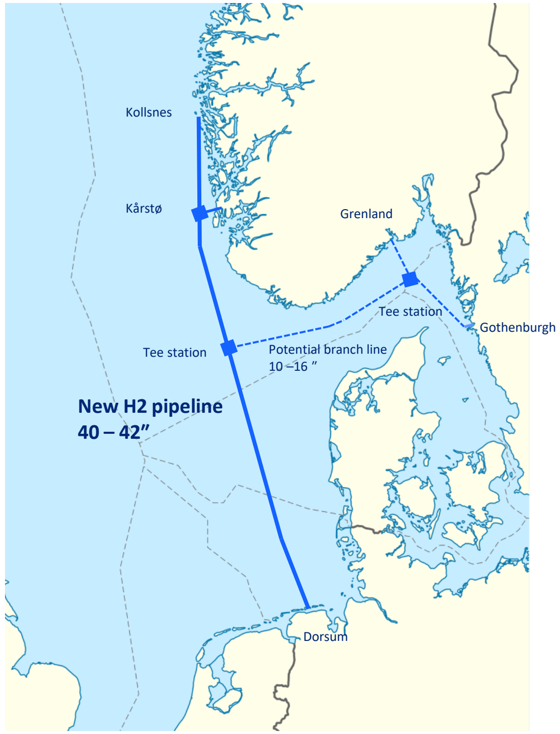
* Palladium membrane patented by HYDROGEN Mem-Tech AS (subsidiary of REINERTSEN New Energy)

Gas pipelines for efficient hydrogen transportation
Example: Norway to Netherlands/Germany

Existing gas pipeline converted to hydrogen service, 40”/924km



New hydrogen pipeline
42”/800km
(3.5 million ton H_2/year)



Cost of hydrogen transportation:
0.1- 0.2 Euro/kgH_2

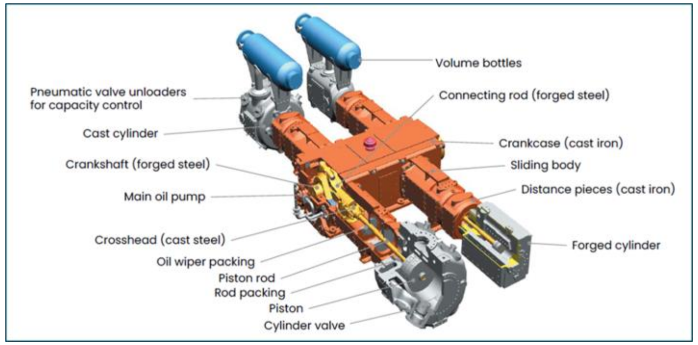
Blue and green hydrogen

- The most important vector in decarbonisation is electrification – renewable electricity should be used directly.
- Availability of valuable, renewable electricity will limit the volumes of green hydrogen.
- Natural gas will gradually be phased out. Therefore, natural gas will be an important source for large volumes of competitive, blue hydrogen.
- Until recently, blue hydrogen is very competitive (1.5 – 2.0 Euro/kgH2) – less than half the production cost of green hydrogen.
- When comparing blue and green hydrogen production cost, its important to consider the long term production cost and market price, for natural gas and renewable electricity. The market prices for renewable, natural gas and hydrogen are interconnected – more or less!
- Therefore, companies and nations that have access to natural gas and CO_2 storage facilities will be supplying a lot of hydrogen and ammonia to the market.

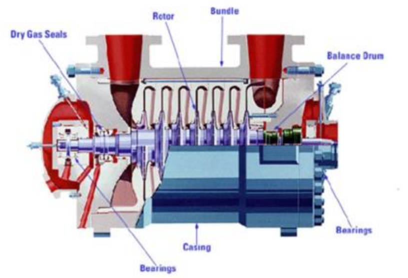
300 MW Compressor station for pipeline transportation of 3 million ton H2/year!

REINERTSEN New Energy awarded H_2 compressor study for GASSCO

Example: Large reciprocal compressor station for Hydrogen



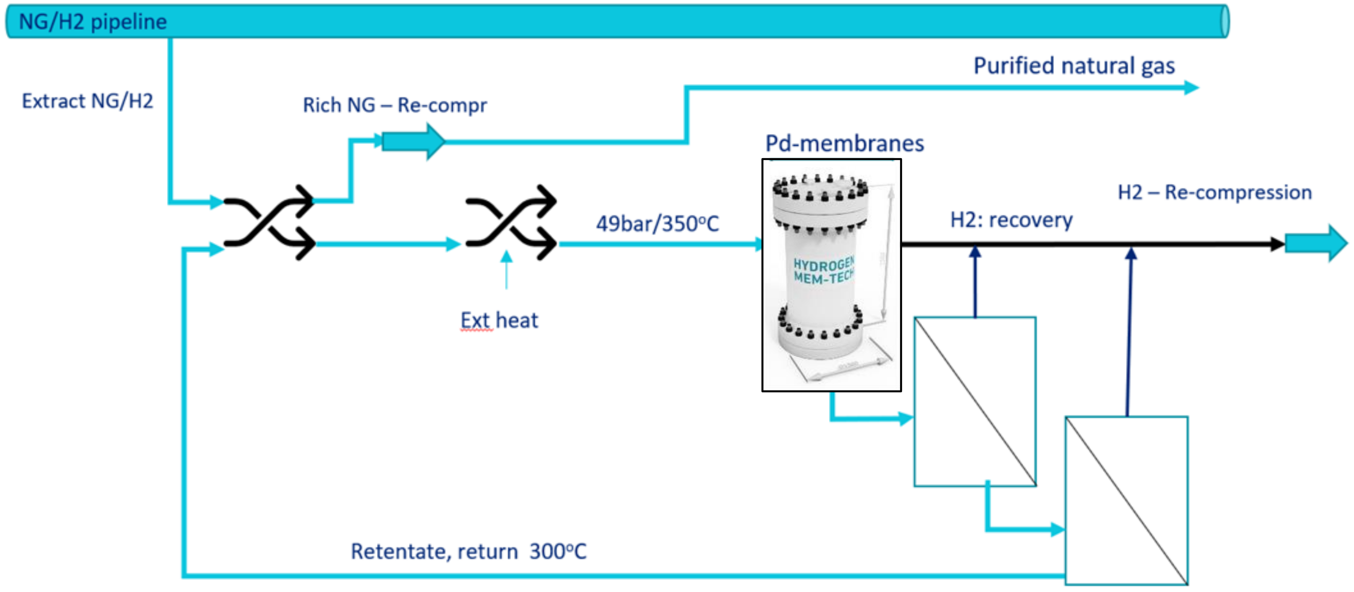
Centrifugal Compressor – Standard Barrel Type



- API 617 part 2 Compressor
- Traditional solid forged shaft
- Impellers shrink fit on the shaft
- Forged Steel Casing with inner casing

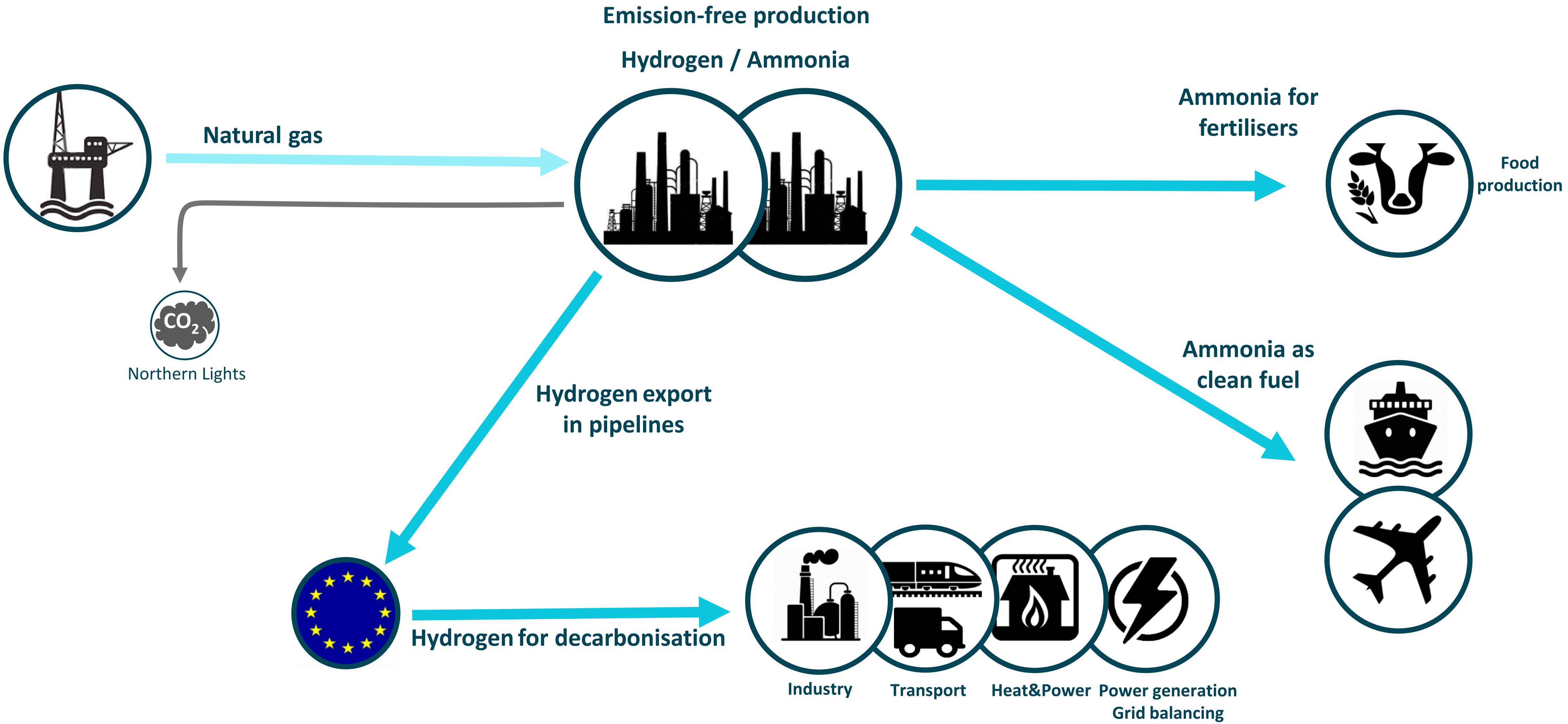
H_2 Blending and Extraction (Europipe 1)

Gas pipeline H_2 Extraction Station – concept study



REINERTSEN
NEW ENERGY

Blue hydrogen and ammonia – efficient transportation and decarbonisation



REINERTSEN
NEW ENERGY

Thank you for your attention!

Please contact:
Torkild R. Reinertsen, PhD
Chairman & Market Lead Hydrogen
REINERTSEN New Energy
+4792228646
torkild.reinertsen@rein-energy.com

www.rein-energy.com
www.hydrogen-mem-tech.com

Reinertsen New Energy has the technology to refine natural gas to hydrogen, without CO2 emissions. With more than 40 years of experience, we stand ready to start a new and clean industrial adventure here and now - for those that come after us and the world they will live in.

REINERTSEN
NEW ENERGY

Z·E·G

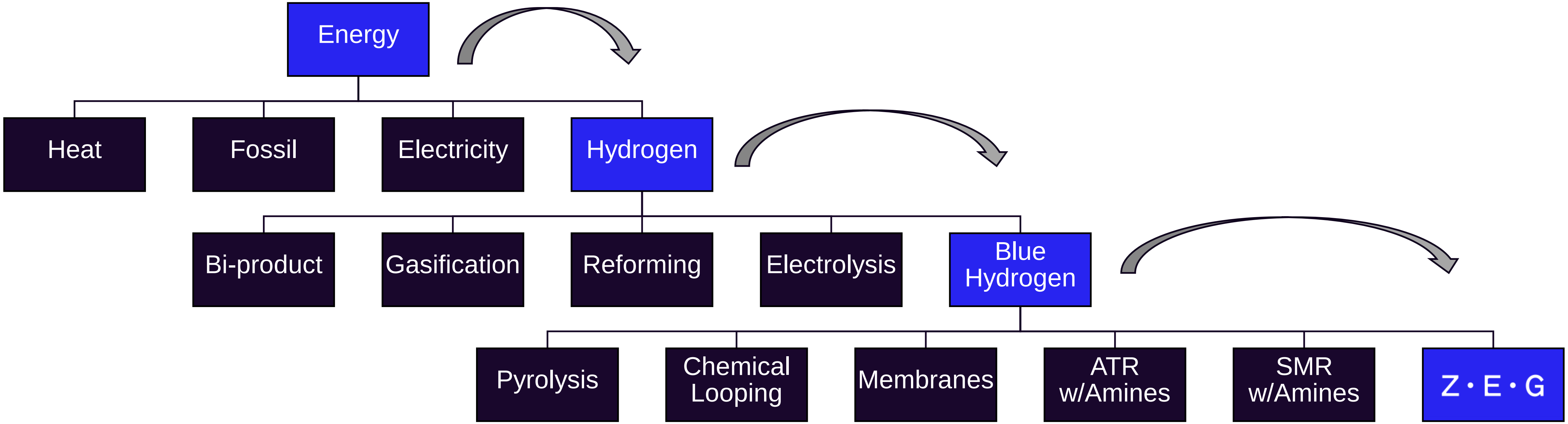
Clean Hydrogen from Norwegian natural gas in 2022

ZEG Power – CEO Arild Selvig

Norwep Hydrogen & CCS Webinar- Europe

Webinar 11-12.05.22

Blue hydrogen – Part of a complex energy transition landscape



(Illustrative examples, not exhaustive)

Z•E•G

ZEG offers a competitive solution to clean** hydrogen

High yield hydrogen production with integrated CO_2 capture

Input	Hydrogen production	Output
Water	**ZEG ICC™ Technology**	Hydrogen
Fuel • Natural gas • Biogas • Waste gas • Syngas	**Reformer**: H_2 generated from fuel, while CO_2 is captured in sorbent **Regenerator**: Sorbent regenerated, CO_2 extracted	CO_2

- **>90%** CO_2 capture
- **>70%** system efficiency
- **<USD1,5/kg*** levelized cost of hydrogen at industrial scale

* 2020 energy prices

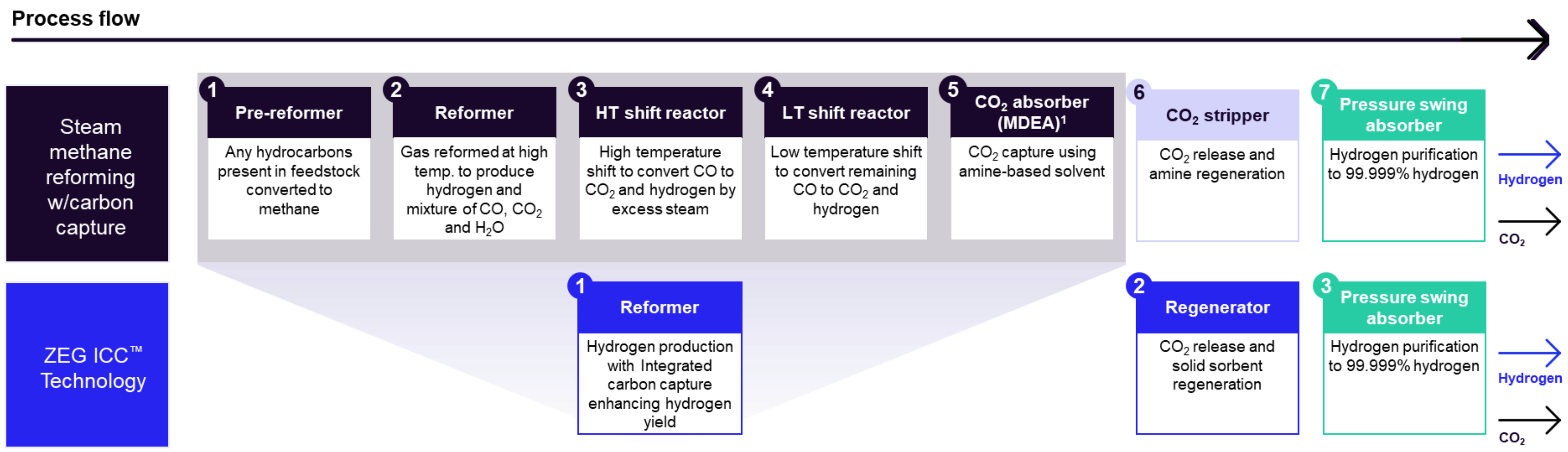
ZEG Owners: APVentures (Advance & Pioneer), SPARX, IFE, nysnø Climate Investments, STRATEL, Danske Invest, Nordea Asset Management, STARTUP LAB

Z·E·G

** Below 2022 EU taxonomy threshold of 3 Kg CO_2/Kg H_2

ZEG solution vs. conventional SMR w/CCS

Replace five SMR process steps with one



Competitiveness:
- High CO2 capture rate
- Increased hydrogen yield
- High thermal efficiency
- Low CAPEX, OPEX and footprint
- Non-toxid sorbent

Z·E·G

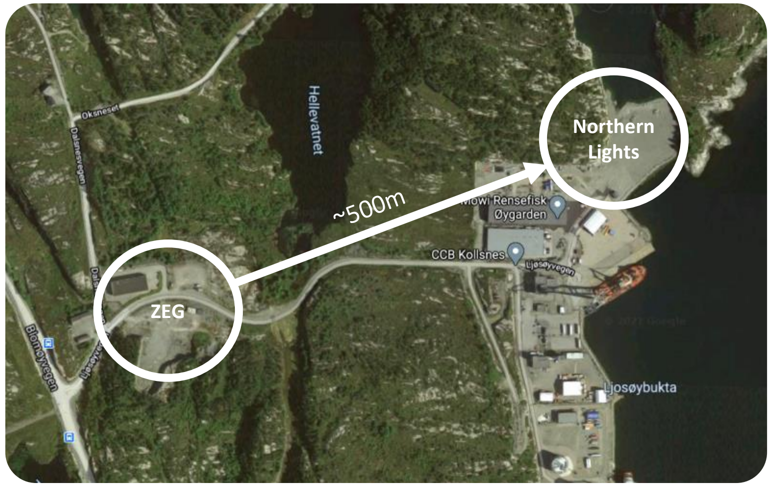
H1 Kollsnes – clean hydrogen production by end 2022 on the west-coast of Norway

Z • E • G

H1 Kollsnes project

H2 Production AS Customer of first ZEG H1	Q4 2022 Production ready
ZETON Signed EPC contract	NOK 77m Supported by Enova grant

Northern Lights CO_2-injection:



Manufactoring @ Zeton:

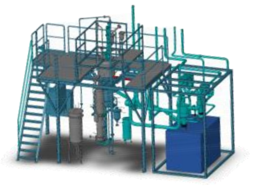
Z·E·G

Roadmap to improved competitiveness - Scale

→ 2020

ZEG Pilot Plant

22 kg H2/day



Partners:
Equinor • IFE • Innovation Norway • Climit • The Research Council of Norway

2021/22

ZEG small-scale technology platform

1-5 metric tonnes H2/day

Partners:
CCB Energy Holding • H2 Production • Enova • Norsk Energi • GEXCON • Zeton • Kanfa

2023/24

ZEG medium-scale technology platform

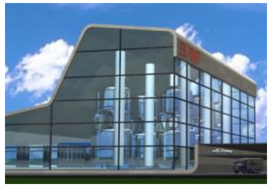
10-100 metric tonnes H2/day

Partners:
CCB Energy Holding • H2 Production
EPC partner TBD

2025 →

ZEG large-scale technology platform

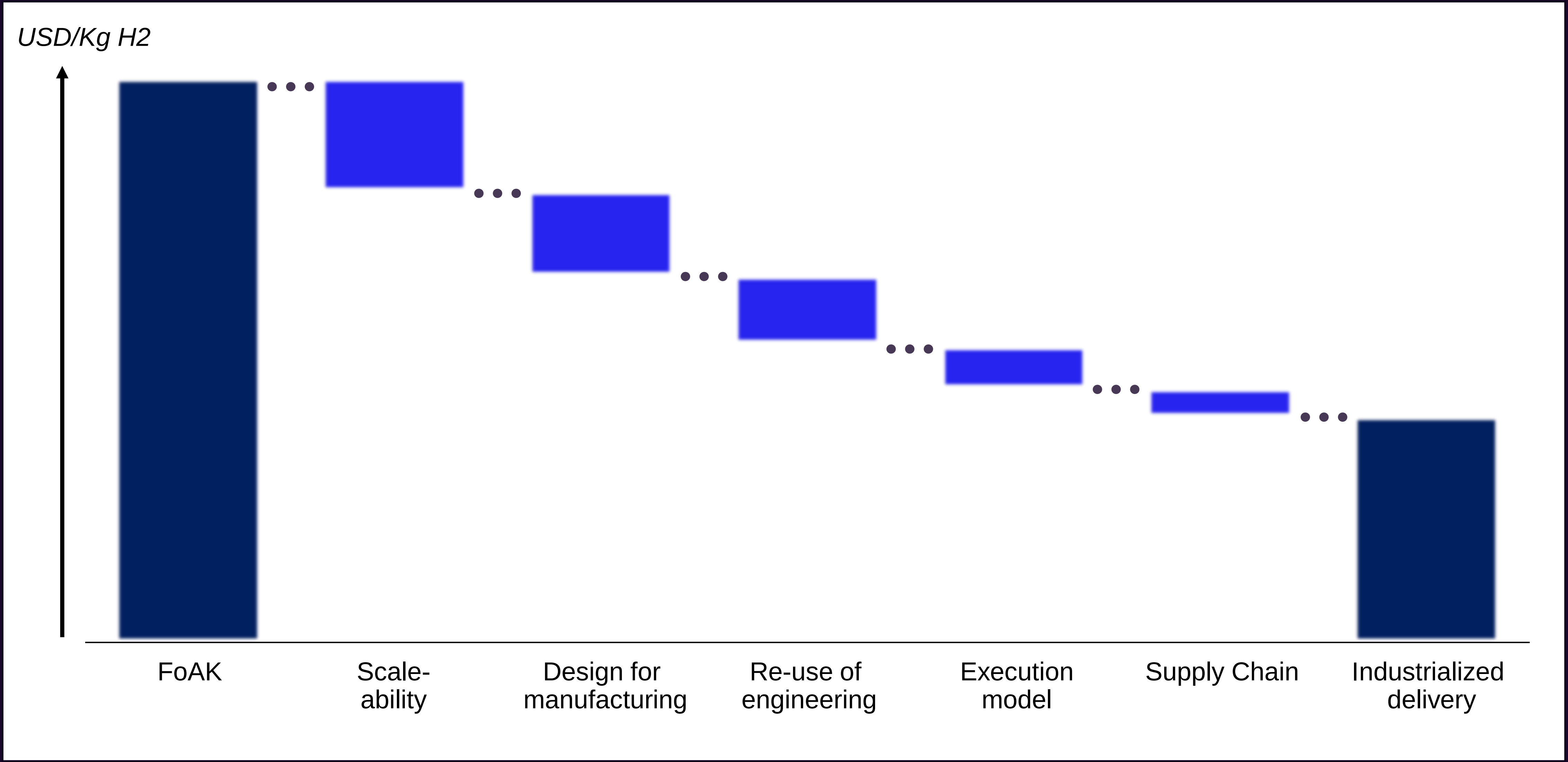
100-1000 metric tonnes H2/day



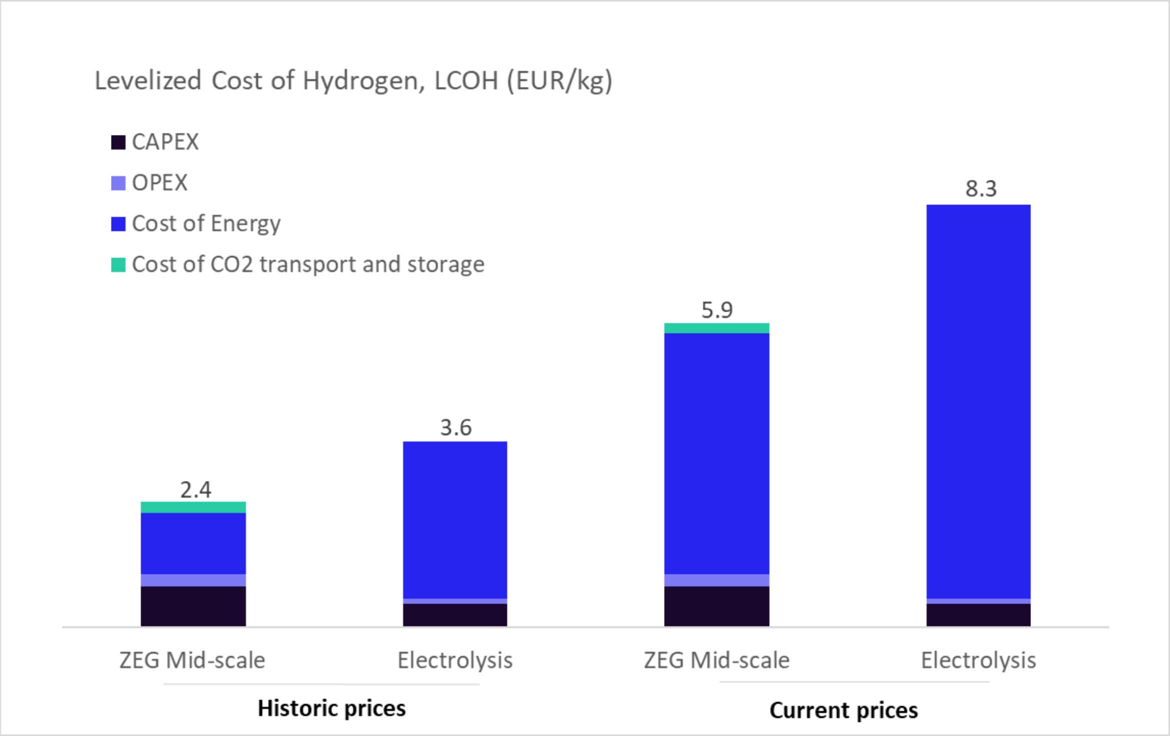
Partnership TBD

↑ Today

Roadmap to improved competitiveness - Industrialization



Clean hydrogen LCoH versus volatility in energy prices



Source: DNV GL: ZEG Power H_2 technology comparison study and company estimates. Cost of carbon transport and storage 25 EUR/ton

2020 energy prices: Natural gas 12 EUR/MWh, Electricity: 60 EUR/MWh

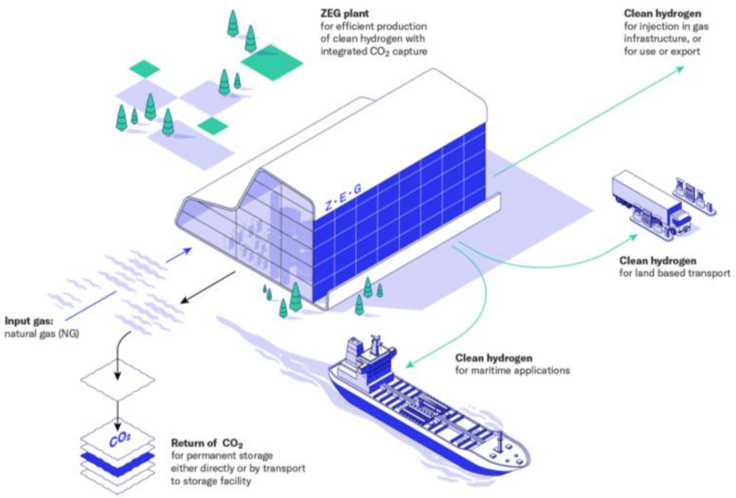
Late 2021 energy prices: Natural gas EUR 70/MWh, Electricity: 150 EUR/MWh

ZEG solutions can be used across industries

Examples:

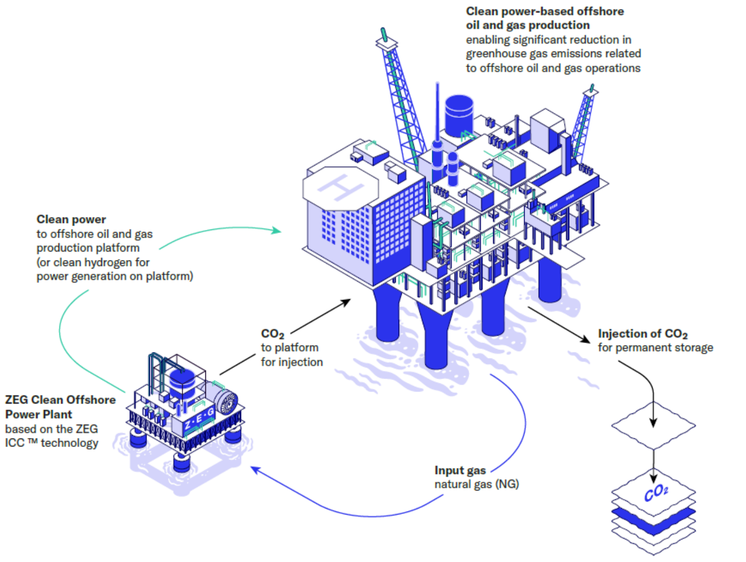
ZEG Clean Hydrogen Solution

Unlocking the value of natural gas



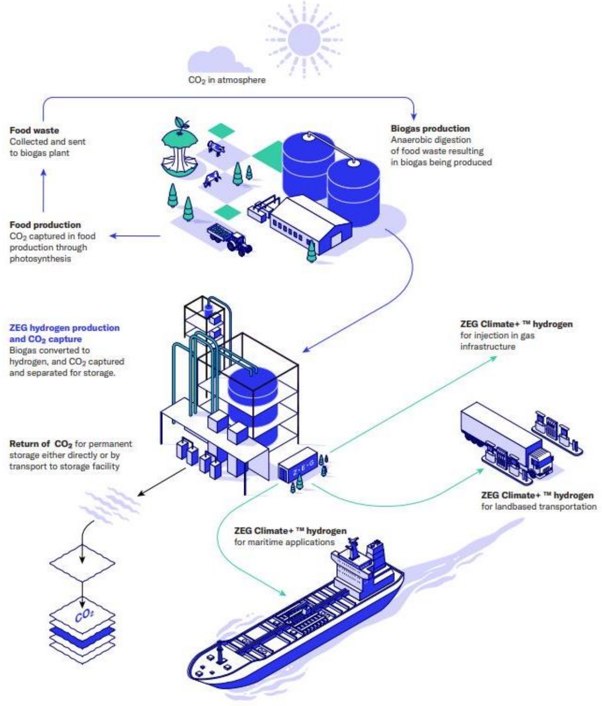
ZEG Clean Offshore Power Solution

Stable electricity supply to O&G installations



ZEG Climate+ Solution

Enabling net carbon removal

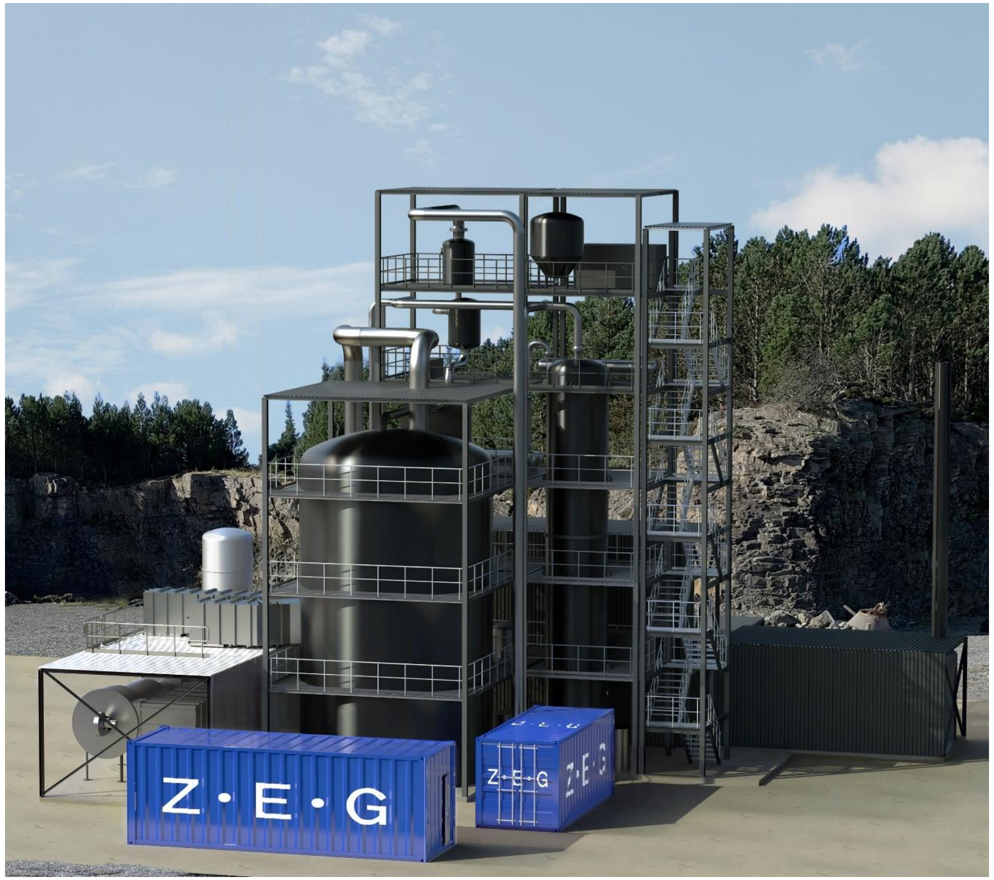


Carbon removal
775 $/ton CO2 for DAC – long-term
150 $/ton Bio-char – medium term

Z·E·G

Summary

- The future European energy mix will consist of multiple renewable energy sources and carriers
  - Sufficient “room” for both green and blue hydrogen in the mix
  - Complete hydrogen value chain perspective needed to drive hydrogen supply & demand
  - CO_2 emission taxes key to drive the transition
- ZEG industrialize world-leading solutions for clean hydrogen production based on hydrocarbon gas
  - Technology and solutions developed over 20 years to commercialization now at Kollsnes, Norway
  - EU taxonomy-compliant
  - FoAK production start-up end 2022
- The ZEG solution has potential across industries:
  - Clean hydrogen production – also at scale
  - Electrification of offshore production platforms
  - Carbon removal through ZEG Climate+



Z • E • G

WHEN TRUST MATTERS

New life for pipeline infrastructure in the energy transition

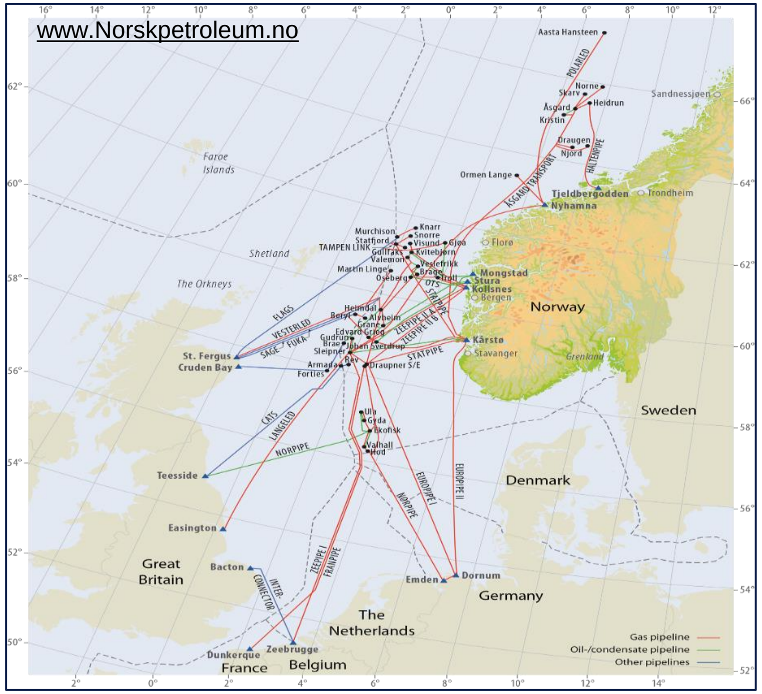
Norwegian Energy Partners Hydrogen and CCUS Webinar - Europe

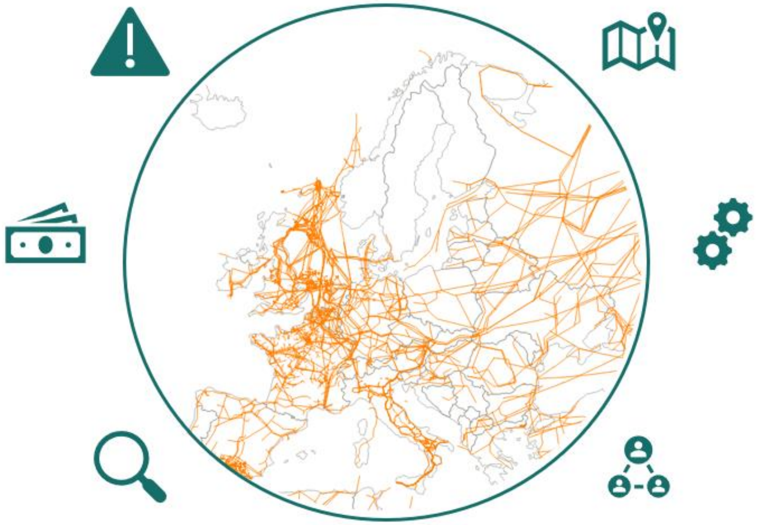
Bente Helen Leinum

12 May 2022

Introduction

- Pipelines will play a critical role in transporting CO_2 and H_2 in the years to come.
- There are extensive O&G pipeline networks in the North Sea and throughout Europe that may be reused to meet climate goals.
- Reuse of existing pipelines is indicated by various stakeholder to be 1-15% of the cost of a new construction. But are they suitable?
- Before we introduce O&G pipelines to H_2 or CO_2, we must better understand the challenges that these products brings along.

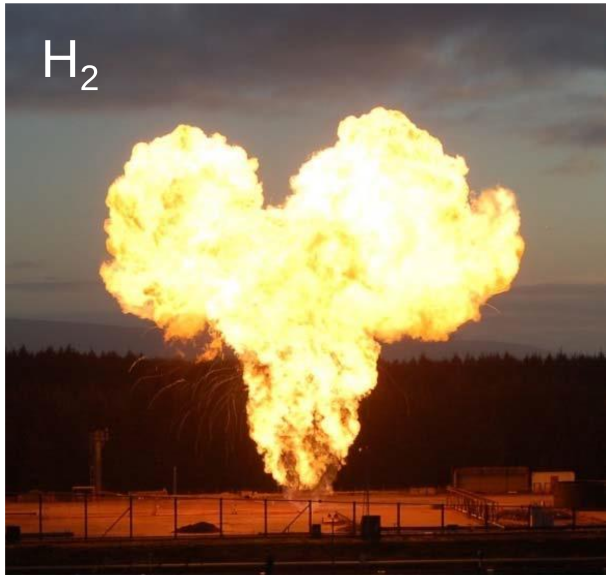




Re-stream project

The challenges

- For large scale CO_2 or H_2 infrastructures, reliability and integrity is key.
- The risk picture has changed
  - Safety risk
  - Financial risk
  - Societal risk
  - Energy security risk
- How to take original design and operational considerations into account in this new risk picture
- Need for innovation and R&D for effective integrity management.
- Need for standards and industry guidelines.



Conversion from O&G – Some key considerations

General	Dense Phase CO2	Hydrogen
• Composition • Materials compability Polymers • Available documentation • Regulations • Standards • Transport directions • Routing ….	• Minimum operating pressure • Safety - Consequence zones,.. • Capasity to withstand running fractures • Mechnical properties - fracture thoughess.. • Product weight - Frespan, … • Water Content • Corrosivity • Blowdown - Temperature, noise… • Dry ice formation …. **Gas Phase CO2** • Maximum operating pressure • Transport Capasity ….	• Brittle fracture properties in steel • Capasity to withstand running fracture • Weld flaws acceptance criteria • Steel fatigue criteria • Product weight - on-bottom stability… • Allowable operating pressure • Energy transport capasity • Safety - flammability, explosion pressure.. ….

How can we meet these challenges - The Value of Industry Standards & Guidelines

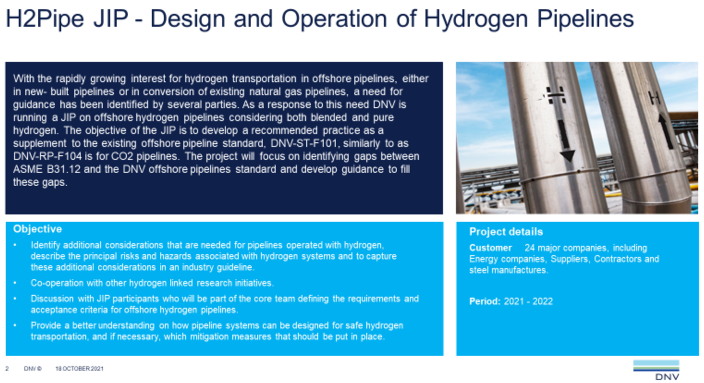
- Provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose.
- Provides guidance for the safe management of pipeline infrastructure - both for new design and re-use.
- Reflects industry experience and are often results of joint industry projects and R&D
- **Establish trust and confidence between stakeholders, authorities and the socity.**

Available standards and guidelines for CO_2 pipelines

DNV

DNV	**DNV-RP-J201** Qualification procedures for carbon dioxide capture technology	**DNV-RP-F104** Design and operation of carbon dioxide pipelines	**DNV-RP-J203** Geological storage of carbon dioxide
INTERNATIONAL STANDARD	**ISO 27919-1** Carbon dioxide capture – Performance evaluation methods for post-combustion CO_2 capture integrated with a power plant	**ISO 27913** Carbon dioxide capture, transportation and geological storage – Pipeline transportation system	**ISO 27914** Carbon dioxide capture, transportation and geological storage – Geological storage

Standards and guidelines for H_2 pipelines



H2Pipe JIP - Design and Operation of Hydrogen Pipelines

With the rapidly growing interest for hydrogen transportation in offshore pipelines, either in new- built pipelines or in conversion of existing natural gas pipelines, a need for guidance has been identified by several parties. As a response to this need DNV is running a JIP on offshore hydrogen pipelines considering both blended and pure hydrogen. The objective of the JIP is to develop a recommended practice as a supplement to the existing offshore pipeline standard, DNV-ST-F101, similarly to as DNV-RP-F104 is for CO2 pipelines. The project will focus on identifying gaps between ASME B31.12 and the DNV offshore pipelines standard and develop guidance to fill these gaps.

Objective

- Identify additional considerations that are needed for pipelines operated with hydrogen, describe the principal risks and hazards associated with hydrogen systems and to capture these additional considerations in an industry guideline.
- Co-operation with other hydrogen linked research initiatives.
- Discussion with JIP participants who will be part of the core team defining the requirements and acceptance criteria for offshore hydrogen pipelines.
- Provide a better understanding on how pipeline systems can be designed for safe hydrogen transportation, and if necessary, which mitigation measures that should be put in place.

Project details

Customer 24 major companies, including Energy companies, Suppliers, Contractors and steel manufactures.

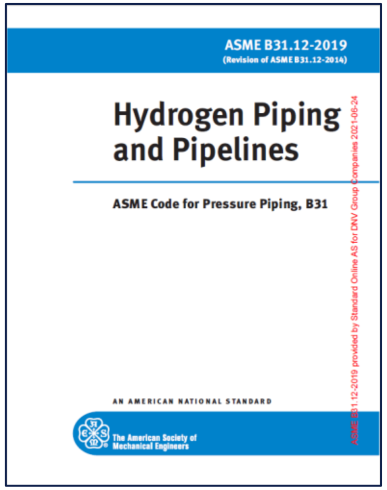
Period: 2021 - 2022

2 DNV © 18 OCTOBER 2021

DNV

DNV-RP-Fxxx

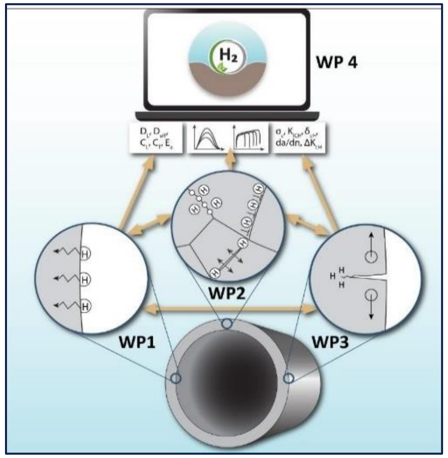
Design and operation of hydrogen pipelines



Example ongoing research project:
HyLINE - Safe Pipelines for Hydrogen Transport managed by SINTEF.

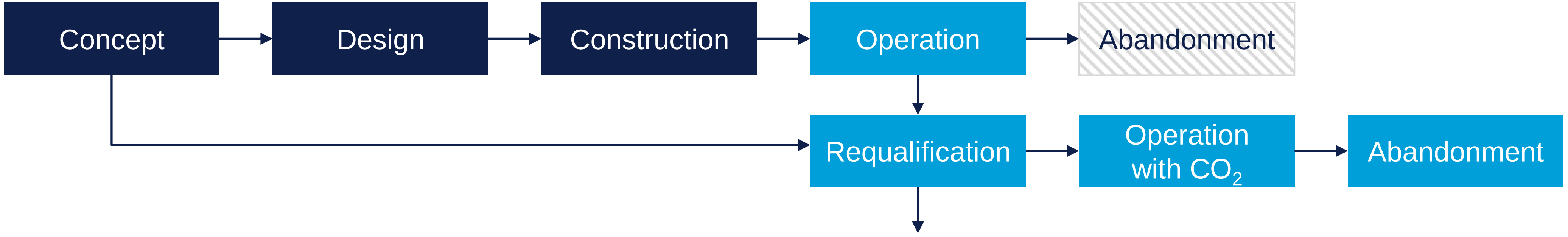
Industry partners: Equinor, Gassco, TechnipFMC, AirLiquide, NEL, TenarisDalmine, Total E&P

Research partners: SINTEF, NTNU and Kyushu University



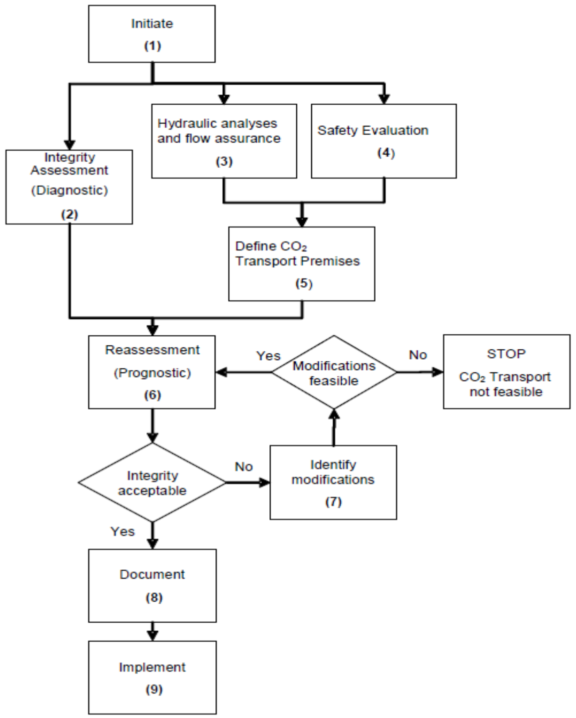
https://www.sintef.no/en/projects/2019/hyline-safe-pipelines-for-hydrogen-transport/

DNV Work Process: Re-qualification of pipelines for CO_2 or H_2 service



Basic principle:

- Re-qualification shall comply with the same requirements as for a pipeline designed especially for transportation of either CO_2 or H_2.
- Any deviations identified shall be thoroughly evaluated and concluded whether it is acceptable or not.



RECOMMENDED PRACTICE

DNV

DNVGL-RP-F104
Design and operation of carbon dioxide pipelines

DNV

H2Pipe JIP
Design and operation of hydrogen pipelines

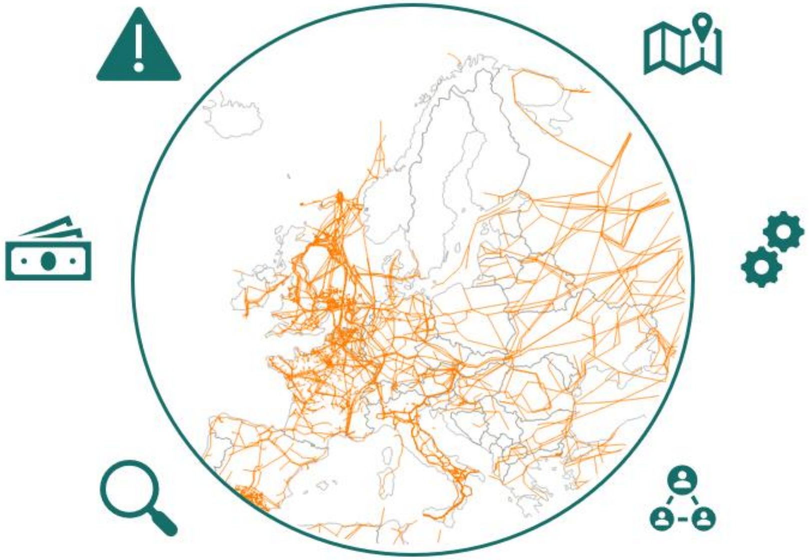
2021-2022

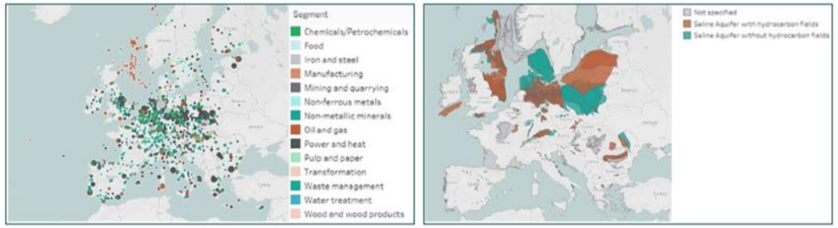
Re-stream – Study on the reuse of oil and gas infrastructure for hydrogen and CCS in Europe

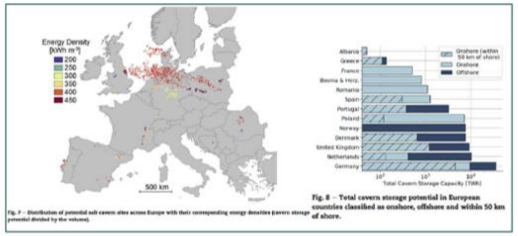
Re-Stream By Carbon Limits & DNV GL

- Assess the potential of existing European oil and gas infrastructure (in EU 27, UK and Norway) to transport H2 and/or CO2.
- Provide fact-based information to European policymakers and stakeholders in order to inform forthcoming debates on EU energy transition and climate policies.
- The study includes high level technical assessment of the infrastructure, identification of CO2 emitters and potential H2 users and producers that could benefit from the reuse of the infrastructure; and economic assessments of reuse compared to new build on specific cases.

NOTE: An initial technical screening was undertaken considering the data provided by the pipeline operators. This analysis does not replace a full pipeline re-qualification process that would require way more inputs for each pipeline







Contractors:

CARBON LIMITS

DNV·GL

Stakeholders:

IOGP International Association of Oil & Gas Producers	entsog	Concawe	gie
Offshore pipelines oil /gas	Onshore pipelines gas	Onshore pipelines oil/product	Underground Gas Storage / LNG plants
~32,000 km - 335 pipelines- 73 operators - 30 IOGP members	~225,000 km 44 TSO members, 3 Associated Partners and 9 Observers	~34,000 km - 409 pipeline sections - 46 operators	

https://www.carbonlimits.no/project/re-stream-reuse-of-oil-and-gas-infrastructure-to-transport-hydrogen-and-co2-in-europe/

DNV

H2Pipe JIP - Design and Operation of Hydrogen Pipelines

Objective

With the rapidly growing interest for hydrogen transportation in offshore pipelines, either in new- built pipelines or in conversion of existing natural gas pipelines, a need for guidance has been identified by several parties. There is today no offshore pipeline code covering hydrogen transport. As a response to this, DNV is running a JIP on offshore hydrogen pipelines considering both blended and pure hydrogen. The objective of the JIP is to develop a recommended practice as a supplement to the existing offshore pipeline standard, DNV-ST-F101.

Benefits

- Provide a better understanding on how a pipeline system can be designed for safe hydrogen gas transportation, and if necessary, which mitigation measures that should be put in place.
- Enhance the general understanding on how hydrogen gas affects the material properties (both as 100% H2 and a blend with natural gas) and further the real design limitations.
- Ensure less conservative design and material requirements.
- Ensure better utilization of the pipeline system when transporting hydrogen.

Project details

Customer 28 major companies, including Energy companies, Suppliers, Contractors and steel manufactures.

Period: 2021 - 2022

H2Pipe JIP Members

H2Pipe members

- ArcelorMittal
- TATA STEEL
- TotalEnergies
- ANSTEEL 鞍钢集团
- CORINTH PIPEWORKS
- DNV
- Allseas
- bp
- Intecsea Worley Group
- wintershall dea
- TechnipFMC
- equinor
- gasunie
- vallourec
- Ørsted
- ENERGINET
- Tenaris
- HYUNDAI STEEL
- WELSPUN
- GASSCO
- subsea 7
- Shell
- SAIPEM
- JFE
- wood.
- NEPTUNE ENERGY
- SINTEF
- Trans Adriatic Pipeline
- JINDAL SAW LTD. TOTAL PIPE SOLUTIONS
- NIPPON STEEL

CO_2 Safe & Sour JIP

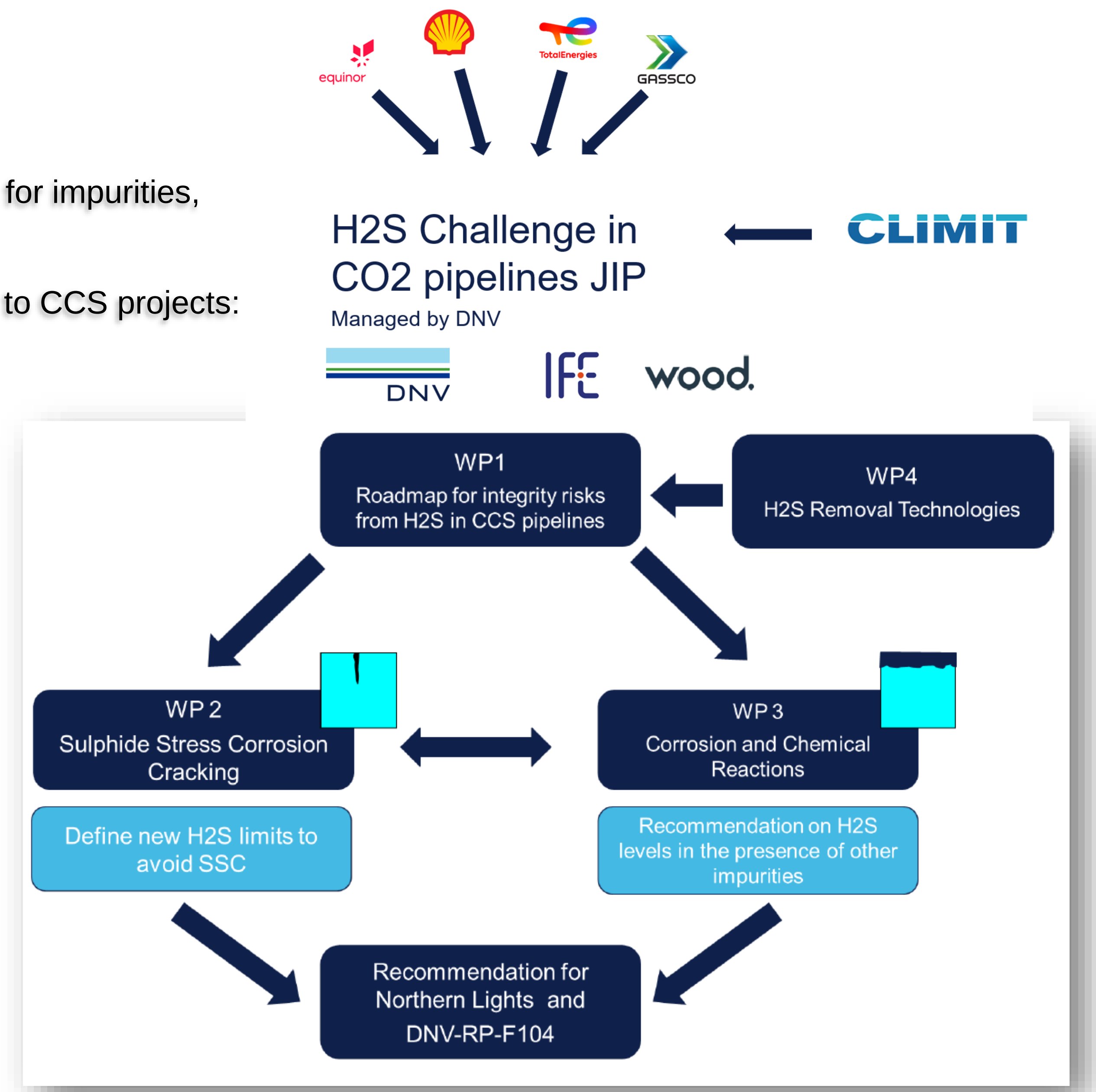
The Northern Lights pipeline is being developed with tight tolerances for impurities, including H2S.

Increased tolerance levels for impurities can give considerable value to CCS projects:
- Makes CCS more accessible for different sources/customers
- Limiting customers need for gas processing

Goal
- Increase tolerance levels for impurities resulting in sour service conditions.
- Enable cost effective development of Northern Lights and other CCS Hub projects.

Objective
- Understand the implication of H2S on the integrity of CO2 pipelines and quantify limits for safe operation.

End-state
- Knowledge basis for update of DNV-RP-F104 on allowable H_2S limits in operation.



DNV

CO2SafeArrest – Fracture propagation testing

Two full scale fracture arrest tests for validation of the numerical models at DNV's Spadeadam full scale test site during 2017/2018.

Full-scale fracture propagation testing to understand ductile fracture propagation/arrest behaviour of pipelines.

Improving safety and efficiency of CO_2 pipelines by developing and validating predictive models for CO_2 pipeline design.

SOLUTION

DNV's validation of fracture arrest models and design requirements will:

- Eliminate project-specific full scale fracture arrest tests
- Remove excessive conservatism (sufficient wall thickness and material properties identified)
- Reduce costs for new CO_2 pipeline projects
- Input to definition of safety class and selection of pipeline safety factors.

PROJECT DETAILS

Customer
Gassnova + Energy Pipelines CRC

Location
UK + Norway

Date
2017-2020

Full scale testing of Submerged CO_2 pipelines

DNV supports **Wintershall DEA** and the **OTH Regensburg University of Applied Sciences** to explore how existing natural gas pipelines in the southern North Sea can be used for future CO_2 transport.

A key activity is performing large-scale CO_2 pipeline testing of running fracture in air and in submerged (water) condition at DNV's Testing and Research Facility at Spadeadam in the UK

SOLUTION

Quantify the effect of the water surrounding the pipeline on the crack arrest behavior for a specific pipeline, and thus better define the model parameters used for different backfill types.

https://www.dnv.com/news/dnv-supports-world-first-large-scale-testing-of-submerged-co2-pipelines

PROJECT DETAILS

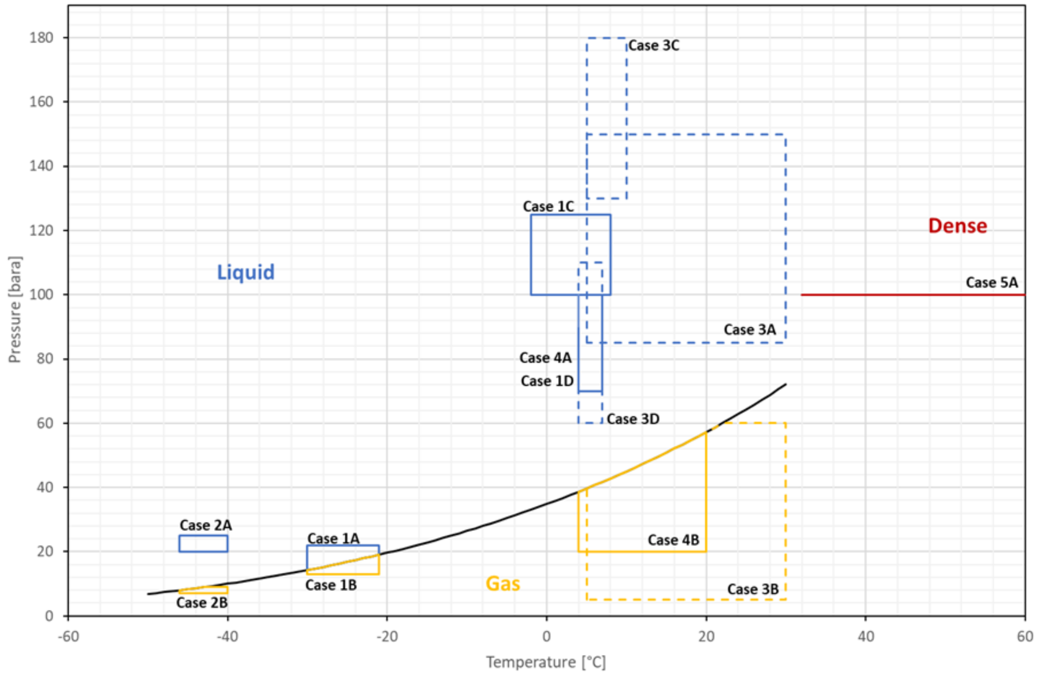
Customer
Wintershall Dea (Germany)

Location
Germany + UK + Norway

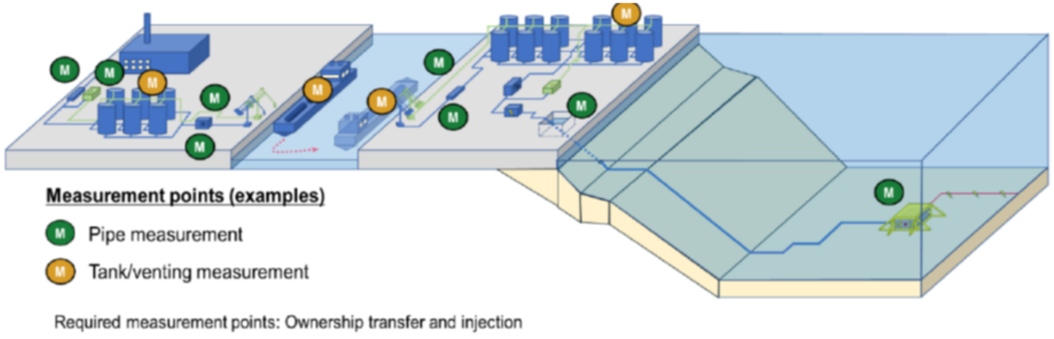
CO_2 flow metering JIP

Wide range and scale of flow regimes:

- Ship (off)loading liquid and vapor (case 1A/B, 2A/B)
- Pipeline and wellhead injection (case 1C/D, 3C/D)
- Offshore pipelines liquid and vapor (case 4A/B)
- Onshore pipelines vapor and supercritical (case 3A/B, 5A)



- Metrological requirements for CO_2 metering in gas, liquid and dense phase set by EU ETS commission regulation 2018/2066:
  - Maximum permissible uncertainty: 2.5% on mass
  - Traceability through international standards and ISO17025 accredited labs
- Limited (or lack) of facilities available for CO_2 flow testing & calibration

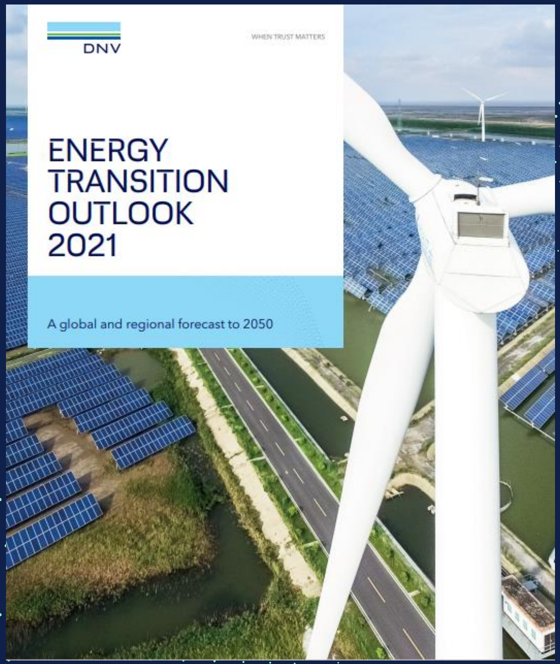


J.M. Kocbach *et al.*, NSFMW (2020)

Thank you for your kind attention

See also DNV Energy Transition Outlook 2021

https://eto.dnv.com/2021

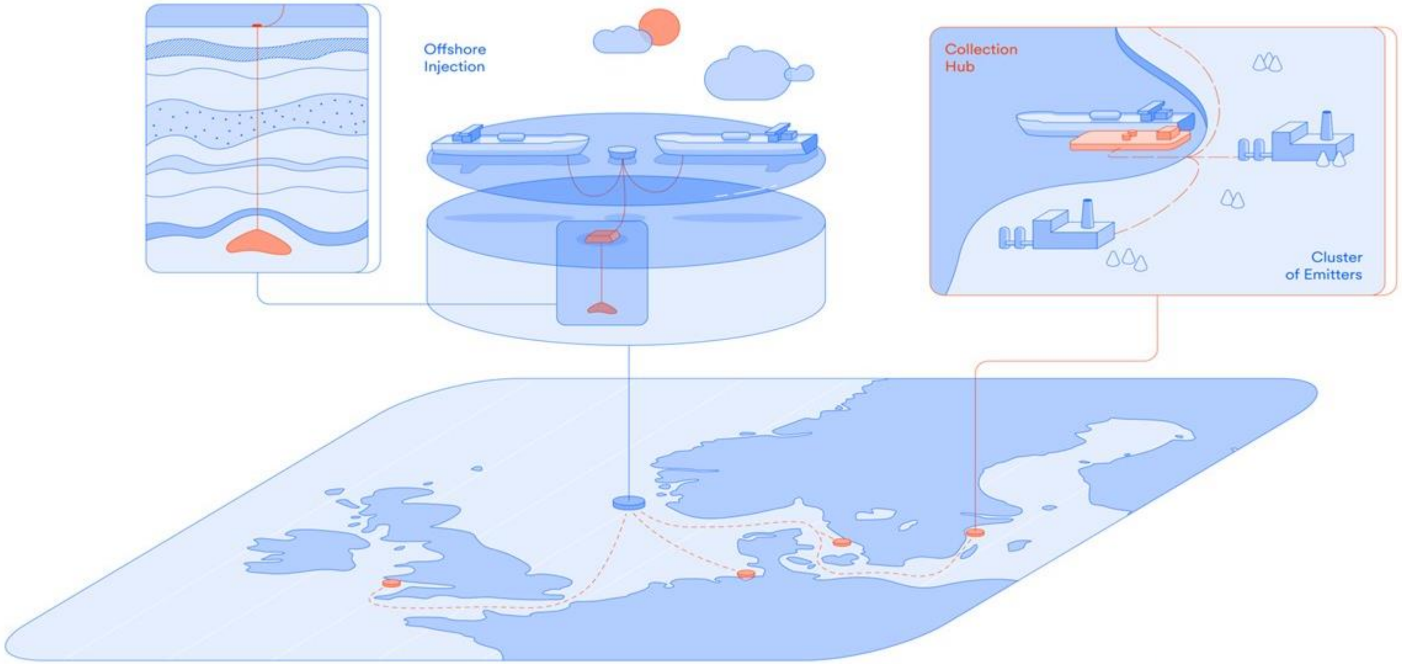


Bente Helen Leinum
+47 41907649 bente.leinum@dnv.com

www.dnv.com

Altera and Höegh LNG scaling up CCS

The Stella Maris Project



Tore Lunde
tore.lunde@hoeghlng.com
+47019557
Höegh LNG

12 May 2022

altera HÖEGH LNG

Höegh LNG and Altera at a glance

Altera

29 Shuttle Tankers	9 FPSO & 5 FSO	10 Towing Vessels

- Industry leader and pioneer in harsh weather FPSOs
- Industry leader and market segment developer of Dynamically Positioned Shuttle Tankers
- 30+ years of experience

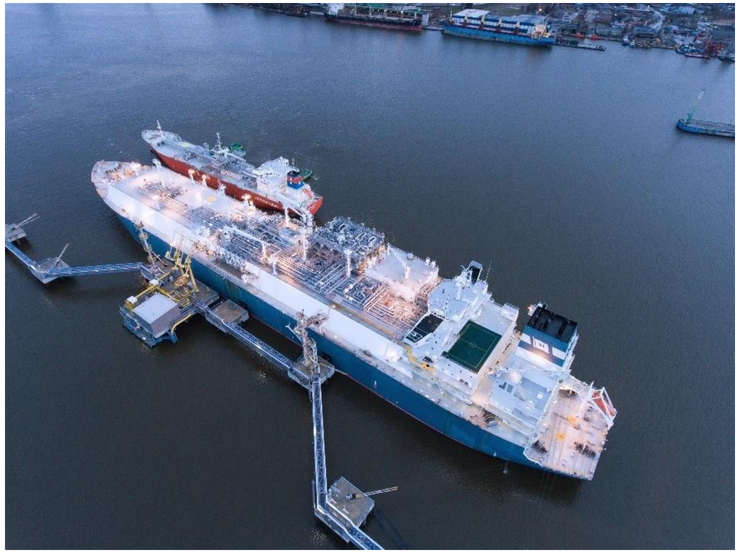
Höegh LNG

10 FSRU & 2 LNGC

- Industry leader in the FSRU market
- 45+ years of gas handling experience
- Developed floating LNG import terminals worldwide
- Part owner & ship management of small LNG carrier fleet

Our collective competence and experience in these three industry segments makes us unique and puts us in a stellar position to lead our industry to a sustainable CCS future.

Offshore CO2 transport, injection and storage – FPSO, shuttle and FSRU business “in reverse”



Collection, Processing and Export

Transport and DP offloading

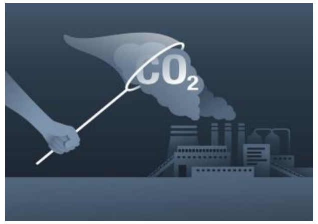
Offshore Injection and storage

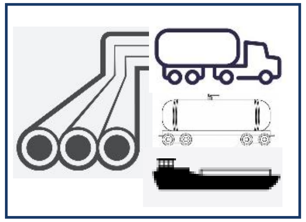
O&G related competence used to realize CCS

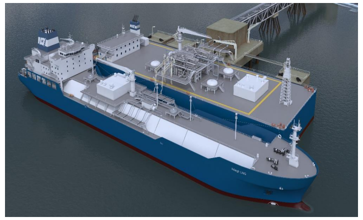
The Stella Maris CCS Project

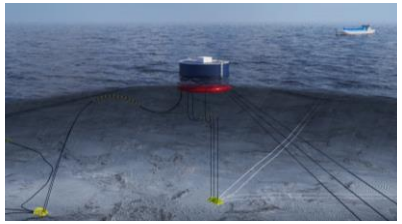
To get CCS costs down, large scale flexible solutions are required!

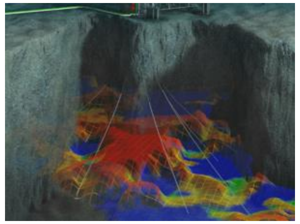
← **Infrastructure planned can handle ≥ 10 mtpa of CO2** →











Capturing Technology	Transport CO2 from Emitter to CCSO	Collection & export	Transportation	Injection of CO2	Offshore Storage Reservoir
Emitter specific but Stella Maris CCS can offer this in cooperation with capture technology company	*In cooperation with emitter (pipeline, truck, rail, barge, etc)*	CO2 Collection, Storage and Offloading (CCSO) 2 units (50-80 cbm)	CO2-shuttle carriers 4 units (50k cbm low pressure)	Floating Injection Unit 1 unmanned unit connected to 2 STL systems	

- Zero emission capable
- Scalable Worldwide – design one – build many
- Solution to be deployed for large scale emitters and clusters in 2026
- One stop-shop from collection to storage
- Cooperate close with industry and policy makers nationally and internationally

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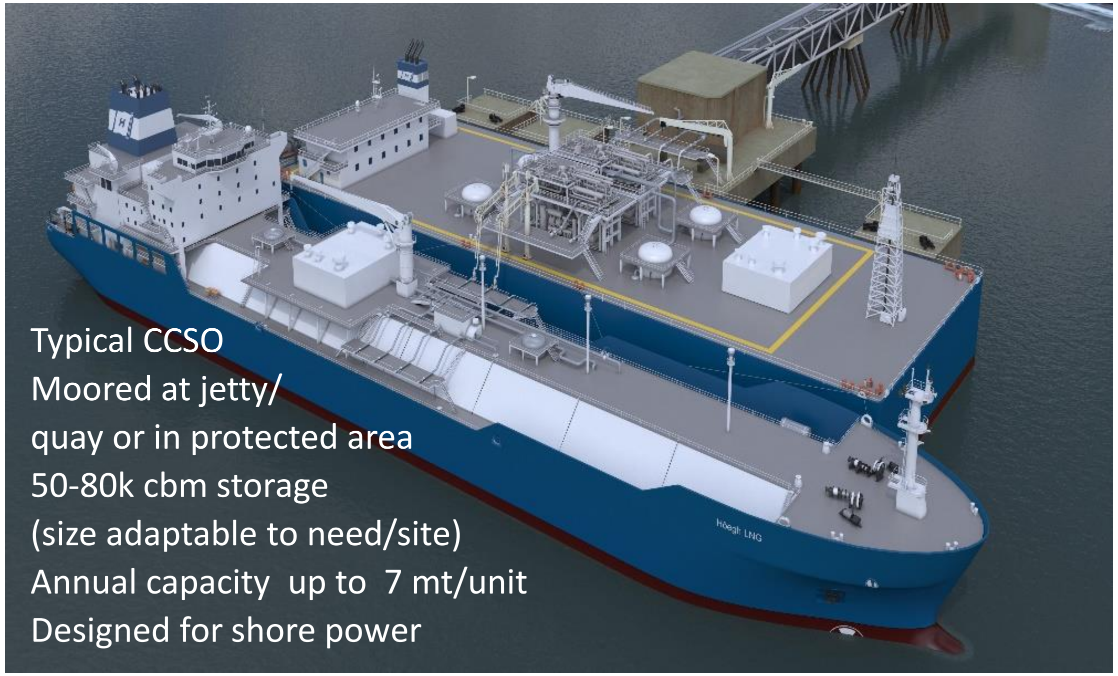
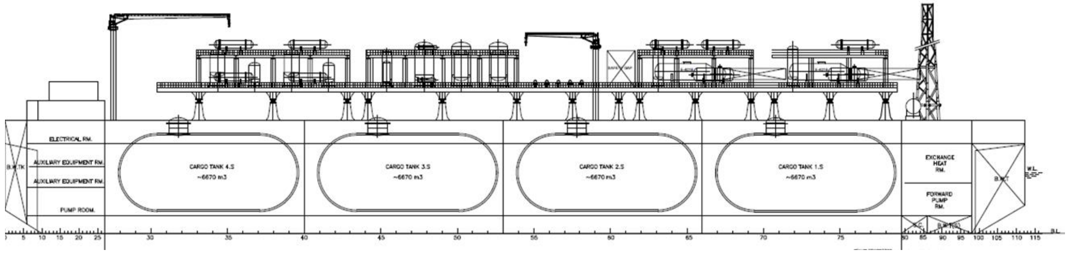
Carbon Collection, Storage and Offloading Unit (CCSO)



Typical CCSO
Moored at jetty/
quay or in protected area
50-80k cbm storage
(size adaptable to need/site)
Annual capacity up to 7 mt/unit
Designed for shore power



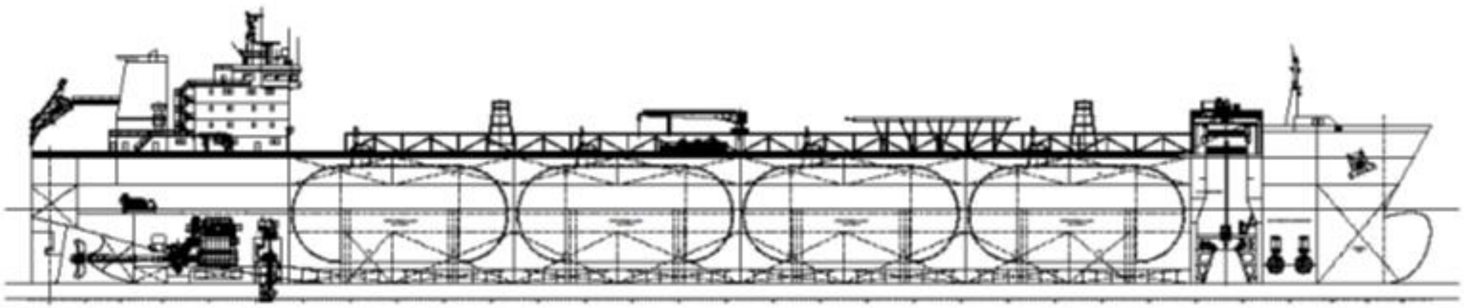
Designed to receive and process:

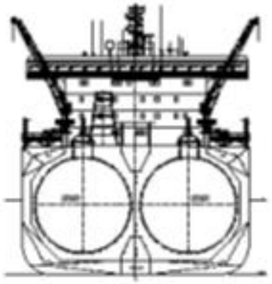
- High- & low-pressure gas from pipelines
- Medium & low-pressure liquid from trucks, rail, ships, barge
- Various qualities with different levels of impurity

Principal Dimensions (80k cbm design):

Length o.a.	220m
Breath (M)	58m
Depth (M)	24,5m
Design Draft	13m

CO2 Shuttle Carriers





Principal dimensions:

Length o.a:	238m
Breadth (M):	38m
Depth (M):	22m
Design draft:	13m
Cargo cap:	50k cbm

- New, state of the art CO2 shuttle carrier design
- 50,000 cbm - low pressure tanks
- CO2 stored and transported as liquid at 6,5 barg & -47°C
- Zero emission capable
- Electric Power distribution
- Battery hybrid installation
- LNG/Bio gas/NH3 as fuel

Optional:

- Size to meet needs
- Direct injection capability

Key Innovations

- Low pressure CO2 tanks
- Dynamically positioned CO2 carrier
- Equipment for offshore un-loading of CO2
- Power Source for injection unit

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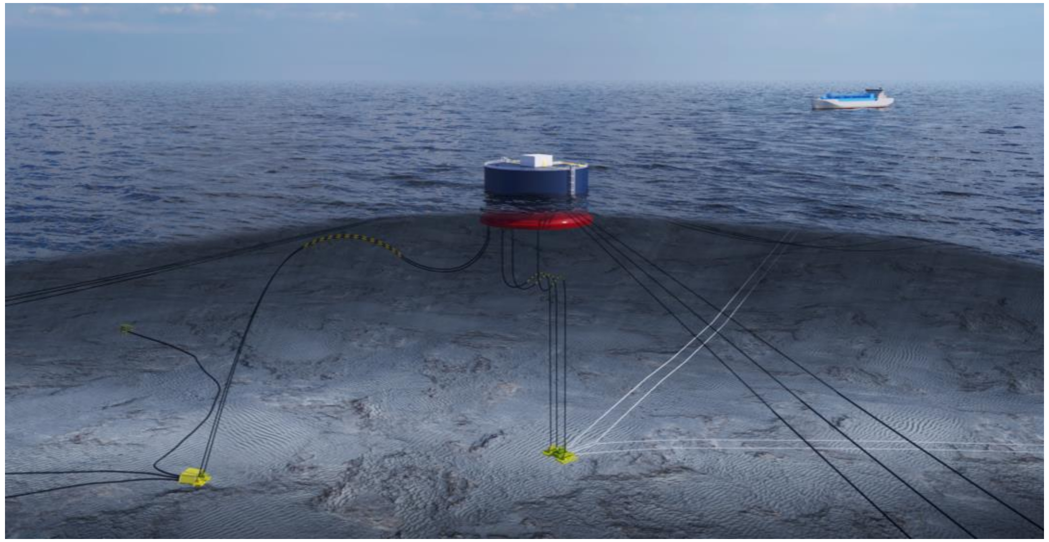
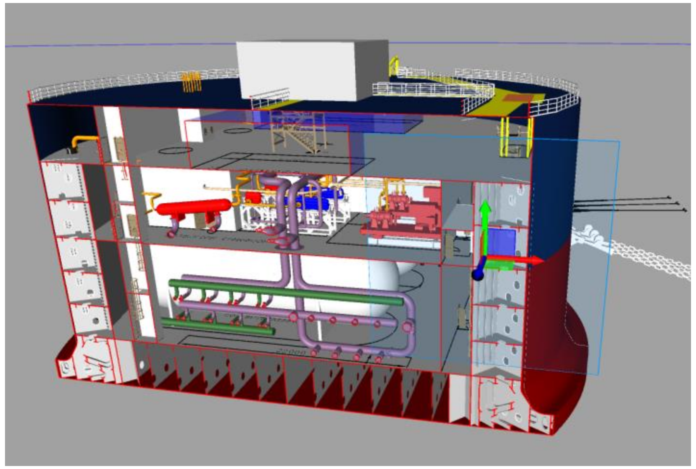
Floating Injection Unit (FIU)



Principal dimensions:

Hull Diameter	50m
Bilge Box diameter:	62m
Main Deck diameter	50m
Hull Depth:	22m
Design draft:	13m
Draft loaded	14m



- Allows continuous injection
- Heating and injection modules below deck
- Power from Shuttle carrier (+ battery back-up)
- Unmanned and operations from shore, communication via shuttle carrier
- CO_2 heated and injected into reservoir in dense phase (>5°C & 65 -160 barg)

Alternatives:

- Injection facilities on an existing offshore installation or on new fixed offshore structure
- Direct injection from shuttle carrier

Key Innovations

- Power from CO_2 Shuttle Carrier
- Normally Unmanned
- Equipment for offshore loading of CO_2
- Zero emission capable

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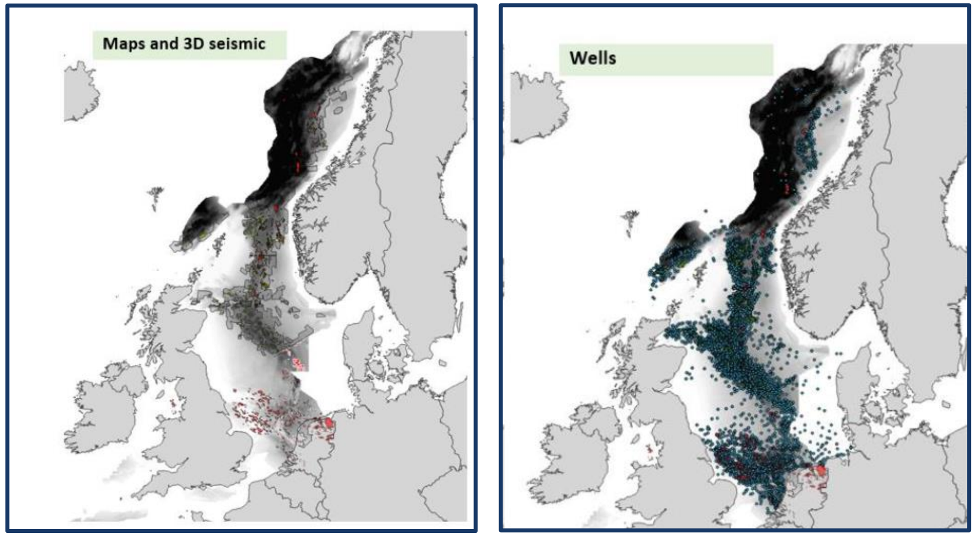
Potential CO_2 injection and storage reservoirs

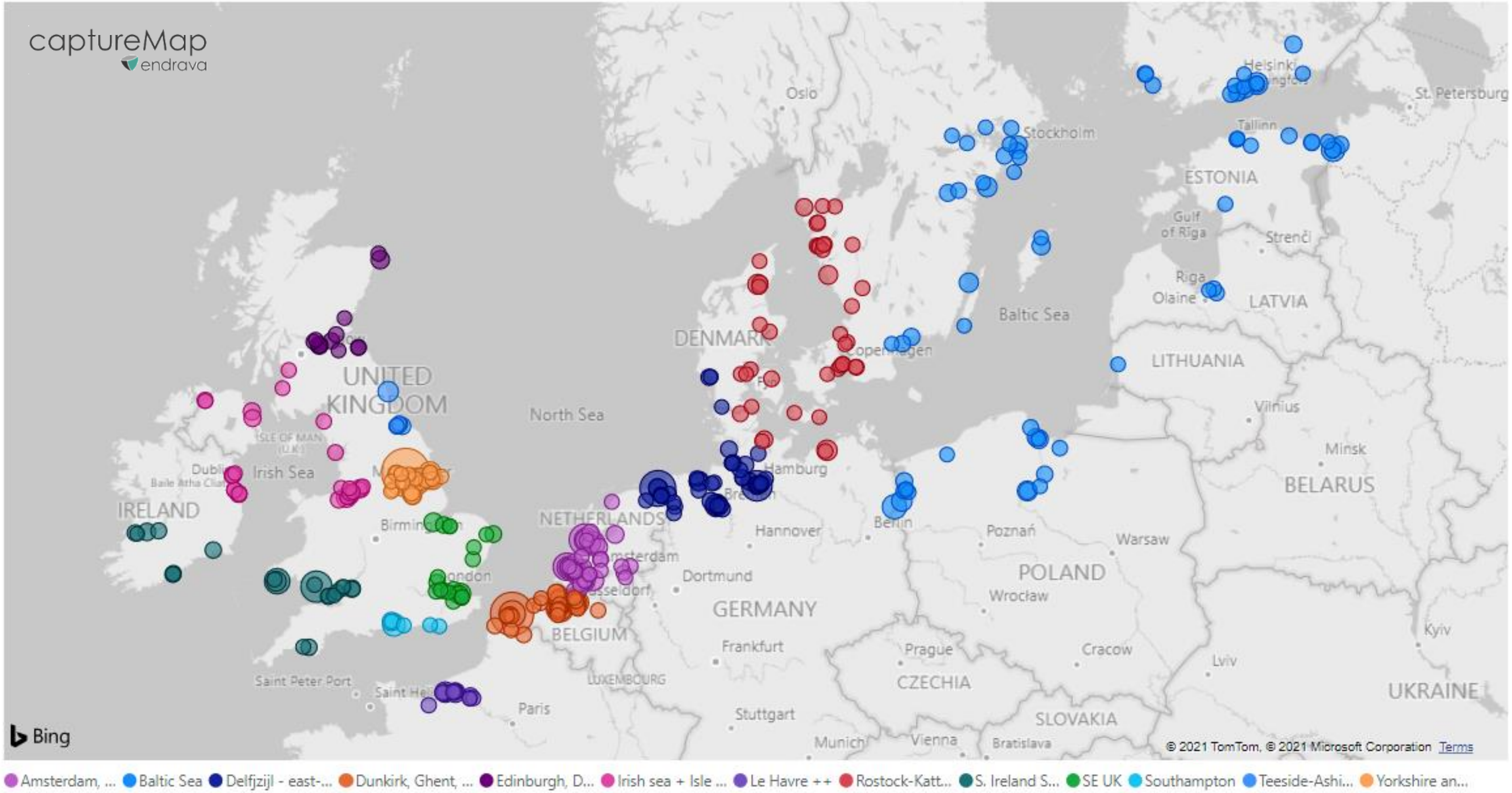


Data coverage (wells, 3D seismics and maps)

- Screening of potential reservoirs on the Norwegian Continental shelf (NCS) to identify;
  - ✓ Geologically stable areas with strong confining seals, adequate size, permeability, porosity and depth so that the pressure and the temperature in the reservoir are high enough to permanently maintain the injected CO2 at supercritical condition
  - ✓ Saline reservoirs without HC
- A work program carried out in 2021/22 to identify suitable reservoirs and develop geological models
- **To get a license on NCS, it is important that interested companies form part of a value chain based business case**
- Entered into cooperation with recognized E&P company to be part of Stella Maris CCS and to be subsurface operator

Building business cases

- 13 hub areas
- Variances in magnitude and type of industry
- Focus on largest contributions in each cluster first, and company emitters



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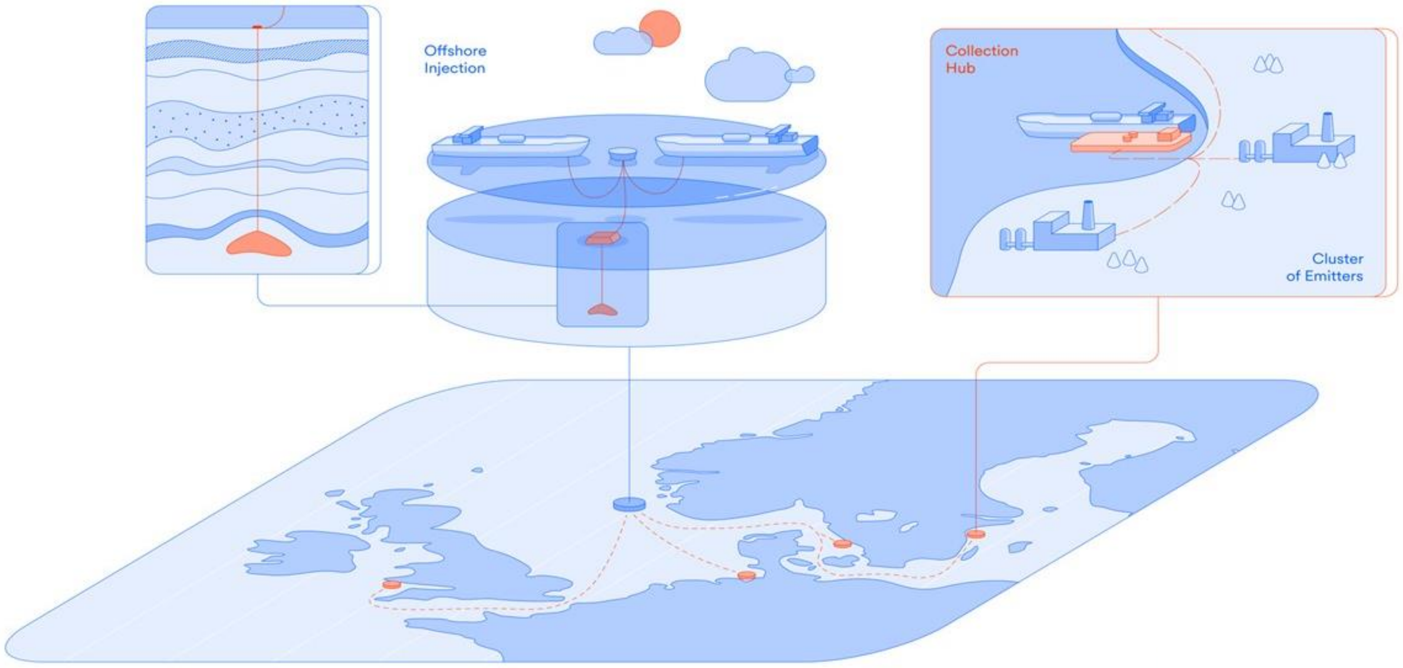
Stella Maris CCS

Large Scale, Flexible, Scalable Maritime CO_2 Logistics Solution

During the next 12 months we will;

- finalize technical concept and secure subsurface storage license
- finalize joint development agreements and establish joint project team to deliver Stella Maris CCS
- continue marketing our solution to individual companies, industry clusters and national authorities
- become a one-shop-stop provider of a competitive and cost-efficient CO_2 solution from collection to storage



The Stella Maris Project

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The
Stella Maris CCS
Project
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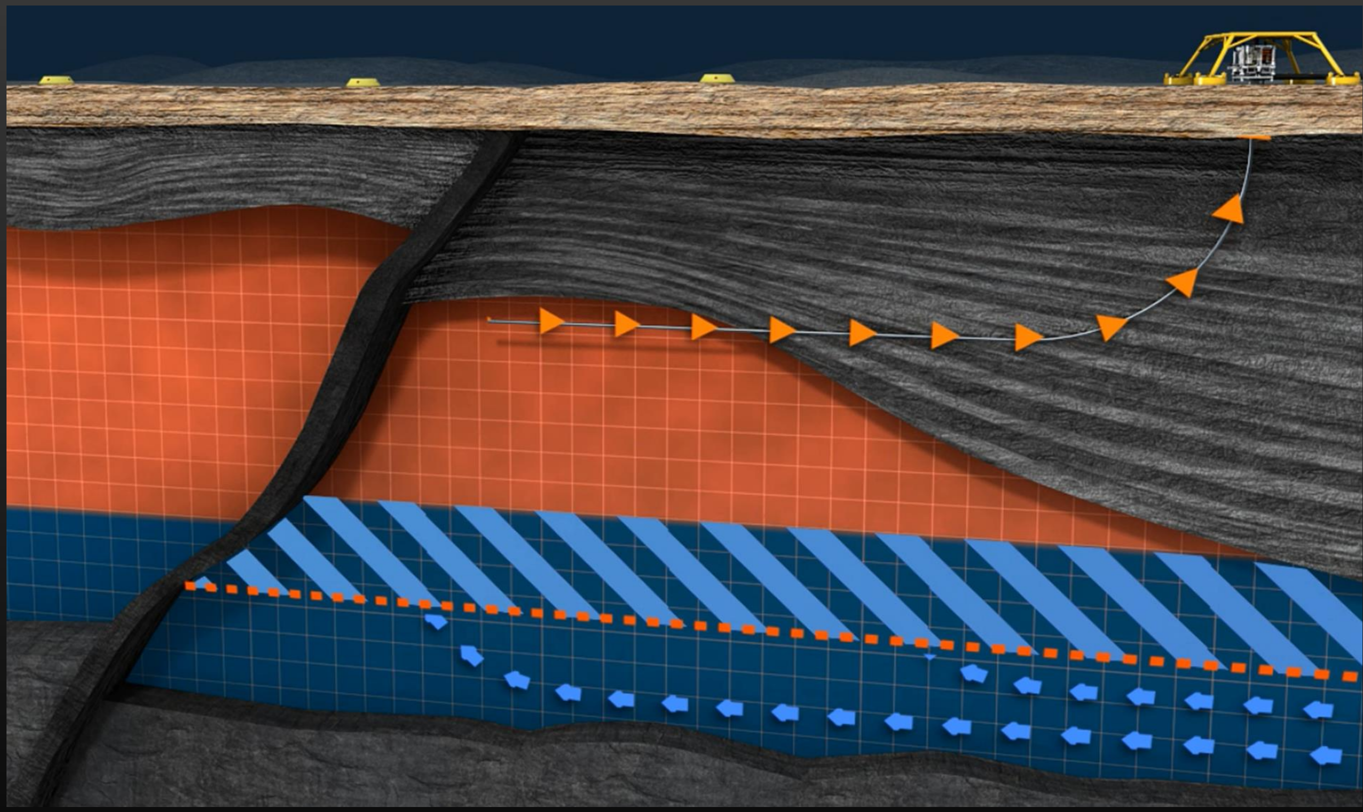
HÖEGH LNG

A cost-effective holistic approach to monitoring of CO_2 storage

gWatch Technology in a nutshell

$$F = G\frac{Mm}{r^2}$$



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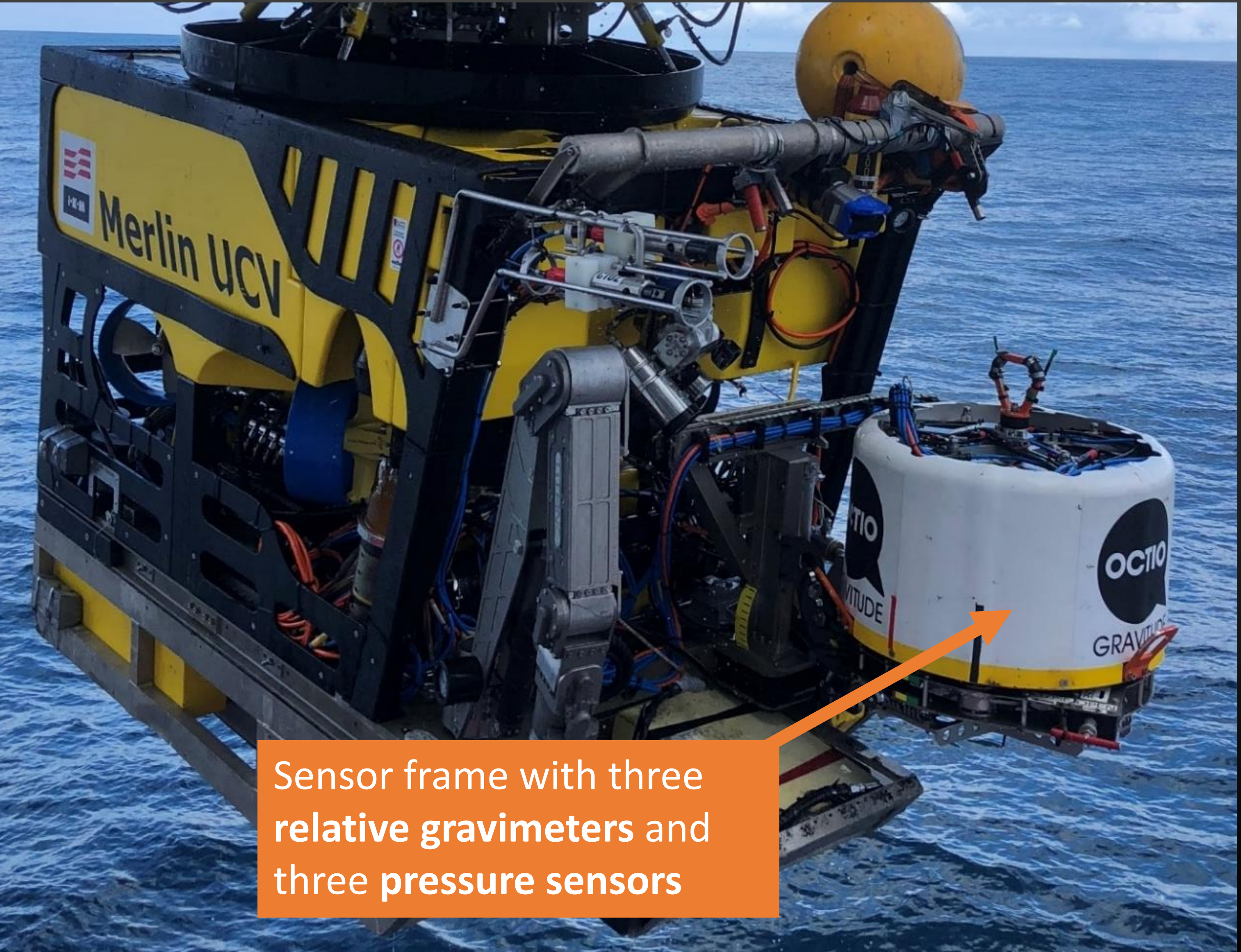
gWatch Technology in a nutshell



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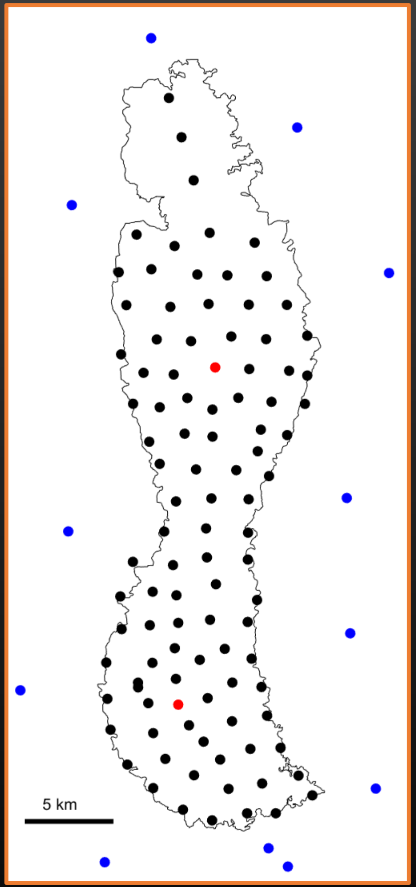
gWatch Technology in a nutshell



gWatch

Two independent measurements

Gravity : Sensitive to mass changes

- Monitor fluid movements
- Maps hydrocarbon depletion
- Distinguishes drive mechanism

Seafloor deformation: Sensitive to reservoir compaction and expansion

- Pressure drop
- Pore compressibility

Ruiz, H., et al., 2016, Monitoring offshore reservoirs using 4D gravity and subsidence with improved tide corrections, SEG Annual Meeting, October 2016, Dallas, SEG-2016-13576781

OCTIO GRAVITUDE

Value proposition for hydrocarbon production

Efficient reservoir management

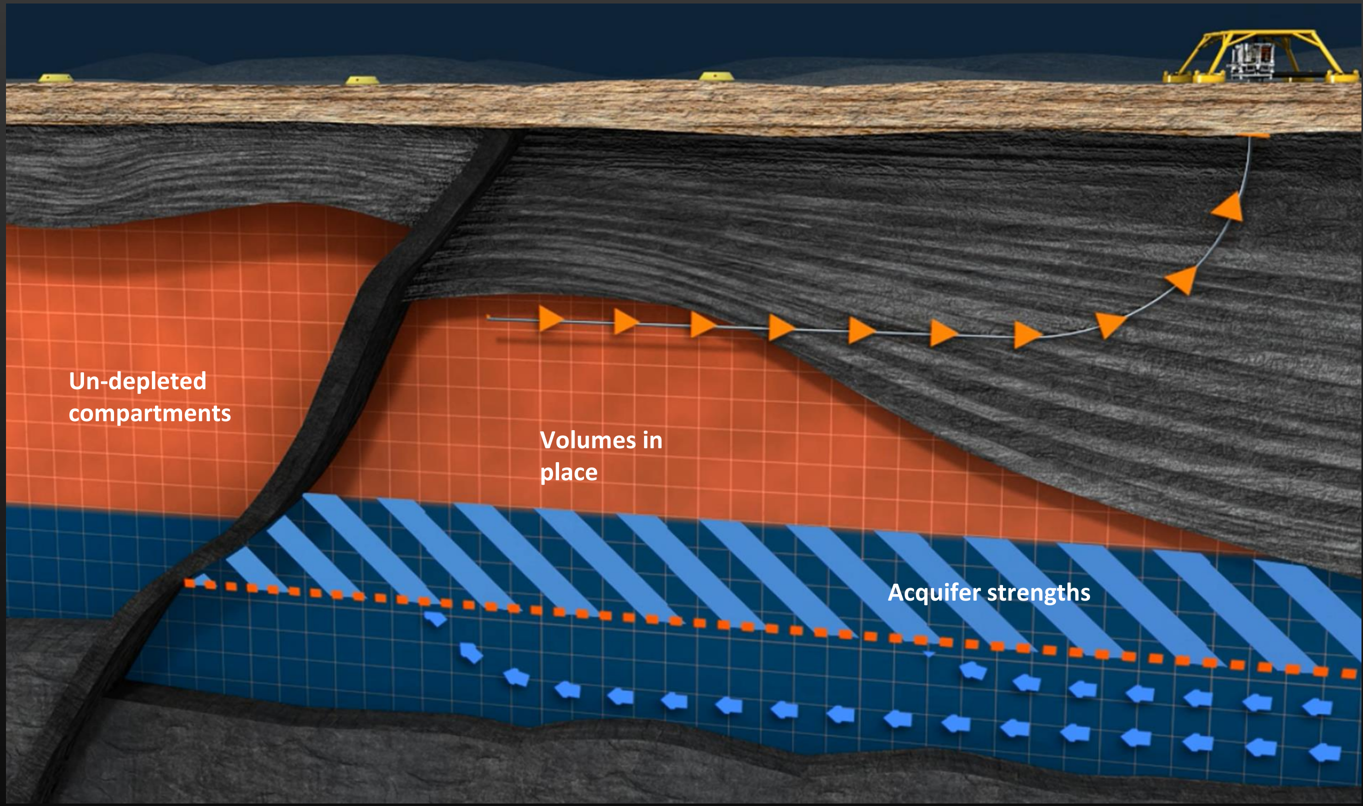
- Understanding of reserve depletion
- Target untapped reserves

Field development strategy

- Incremental hydrocarbon recovery
- Efficient top-side infrastructure

Cost effective

- 1/10 conventional 4D seismic
- Simplified operations and logistics



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Value proposition for CO_2 storage

Efficient reservoir management

- Constrain uncertainties in the volumetric expansion of the injection plume
- Reduce uncertainties in in-situ CO_2 density
- Pressure communication in the reservoir
- Detect vertical leakage of the CO_2 plume

Field development strategy

- Optimize injection rates
- Confirm long term containment and storage capacity

Cost-effective

- 1/10 conventional 4D seismic
- Simplified operations and logistics

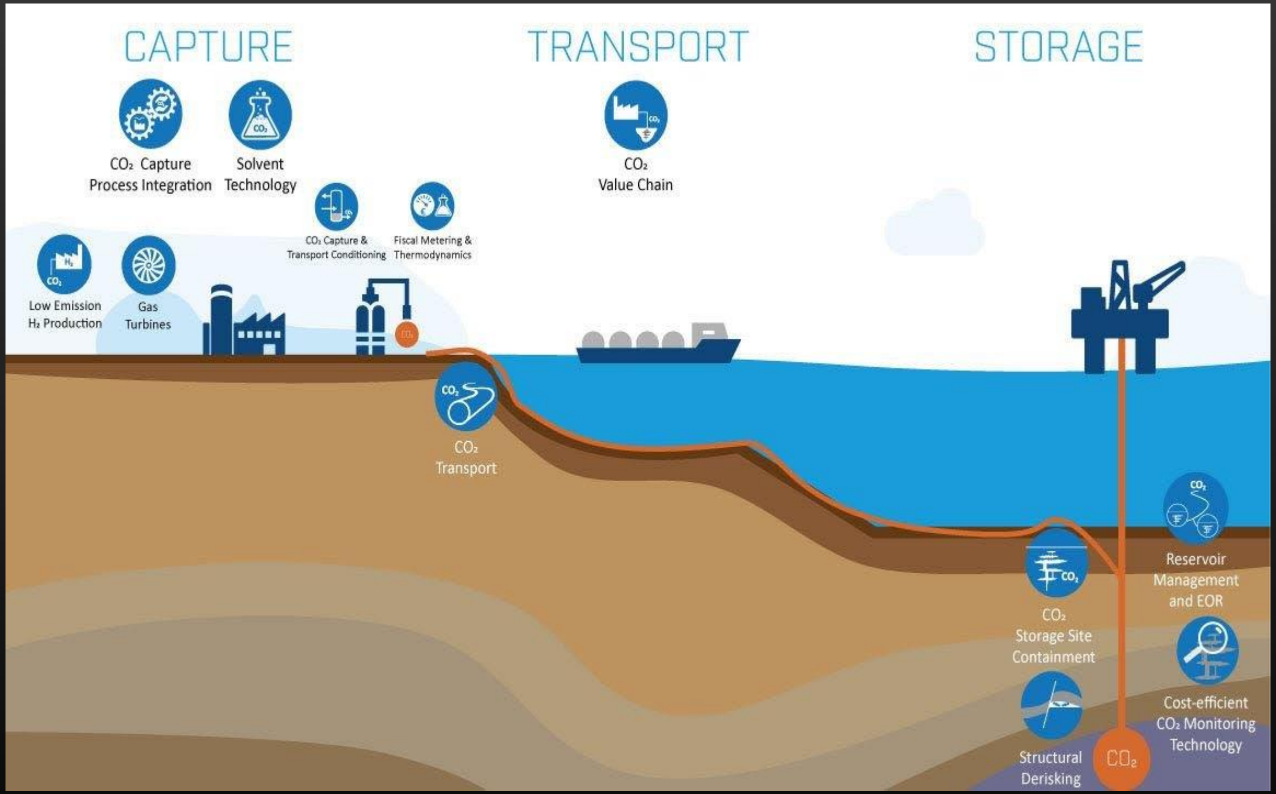

Illustration from Norwegian CCS Research centre

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*: No-4D seismic at all

Technology track record

Field	Since	No. surveys	Burial depth (m)	Concrete platforms	Main applications (Main contribution from: gravity, subsidence)
Troll	1998	8	1400	113	Compressibility Aquifer support, prediction of water break-through
Sleipner	2002	4	800/2350	50	Properties of injected CO_2
Mikkel*	2006	4	2500	21	Aquifer strength, volume of gas in place
Midgard	2006	5	2500	60	Identified undrained compartment: successful infill well Aquifer strength, prediction of water breakthrough
Snøhvit / Albatross	2007	3	2500	86	GIIP, prediction of water break-through
Ormen Lange	2007	7	2000	120	Aquifer influx, compartmentalization Reservoir compaction, pressure depletion
Statfjord (oil)	2012	2	2750	53	Subsidence, aquifer properties, reservoir compressibility Improved geomechanical for better 4D seismic
Aasta Hansteen*	2018	2	2300	31	Aquifer influx, optimize production
3 oil fields in the GoM	2018	1	2500	-	Node DepthWatch
Oil field in the GoM	2018	2	800 - 2000	11 frames	DepthWatch at a water depth of 2800 m Client been trying alternative technologies
Oil field in the GoM	2021	1	1700 - 2900	-	Node DepthWatch

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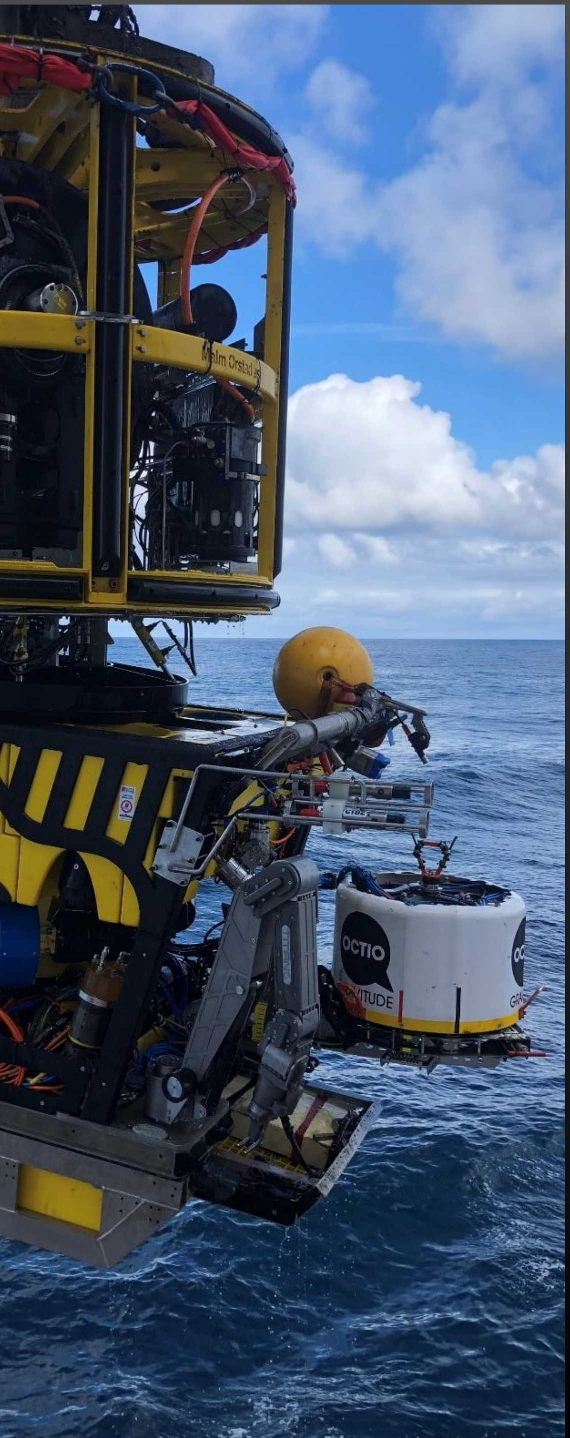


Conclusions and outlook

Field-wide mapping for efficient reservoir management of:

- Constrain uncertainties in the volumetric expansion of the injection plume
- Reduce uncertainties in in-situ CO_2 density
- Pressure communication in the reservoir
- Detect vertical leakage of the CO_2 plume

Field development strategy

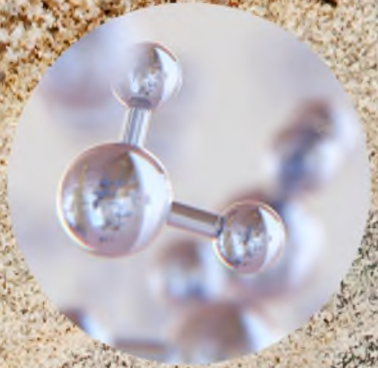
- Optimize injection rates
- Confirm long term containment and storage capacity

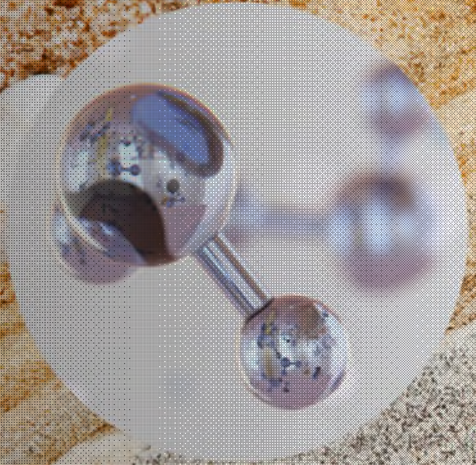
OCTIO GRAVITUDE


Thank you
OCTIO
GRAVITUDE

NOV's Unique Products and Capabilities within Carbon Capture, Conditioning and Transport Value Chain

NORWEP H2 & CCS Webinar - Europe





12th May 2022

Company Structure

Wellstream Processing

NOV Rig Technologies

NOV Wellbore Technologies

NOV

NOV Completion & Production Solutions

→ Process and Flow Technologies

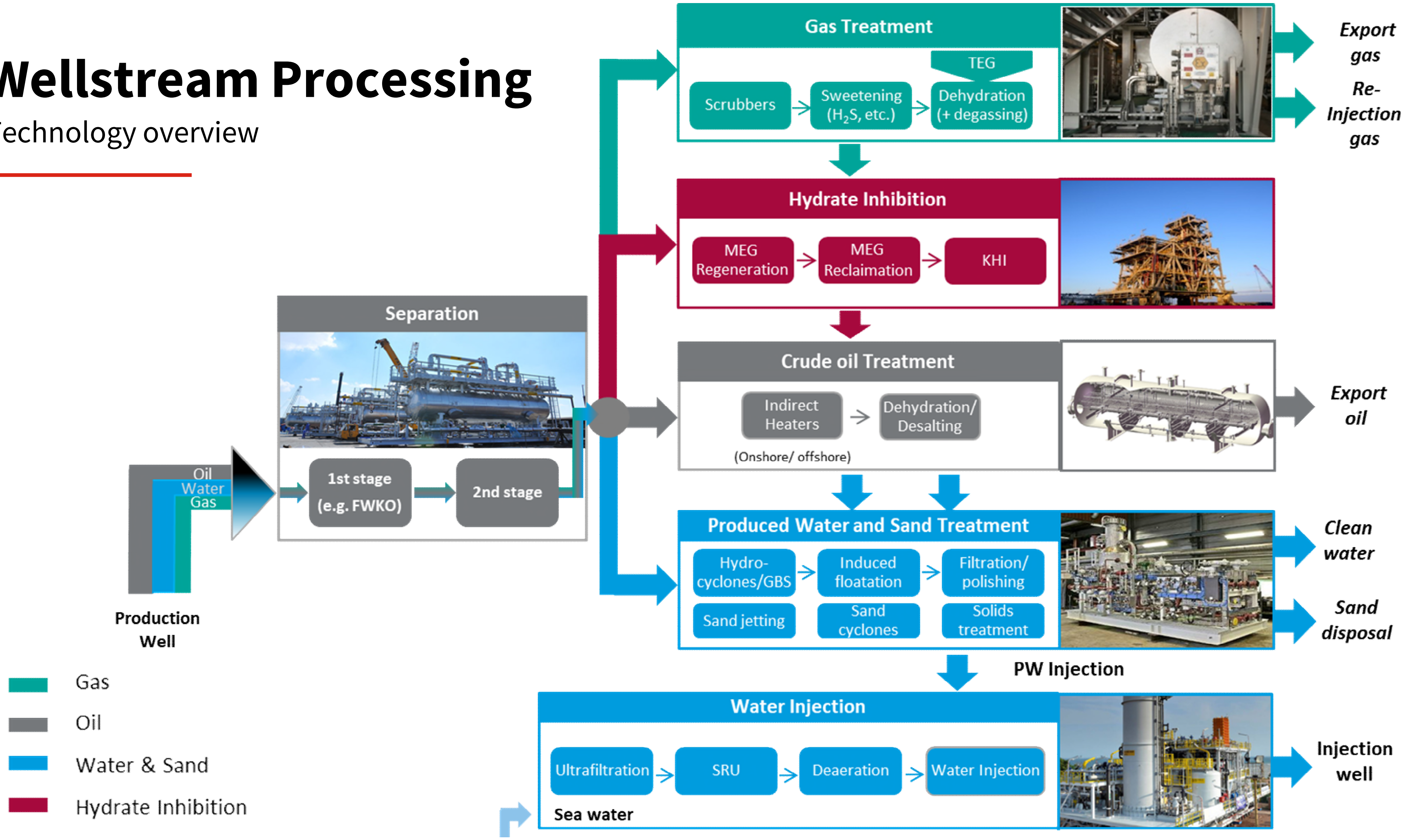
→ Wellstream Processing

Technologies

Wellstream Processing

Wellstream Processing

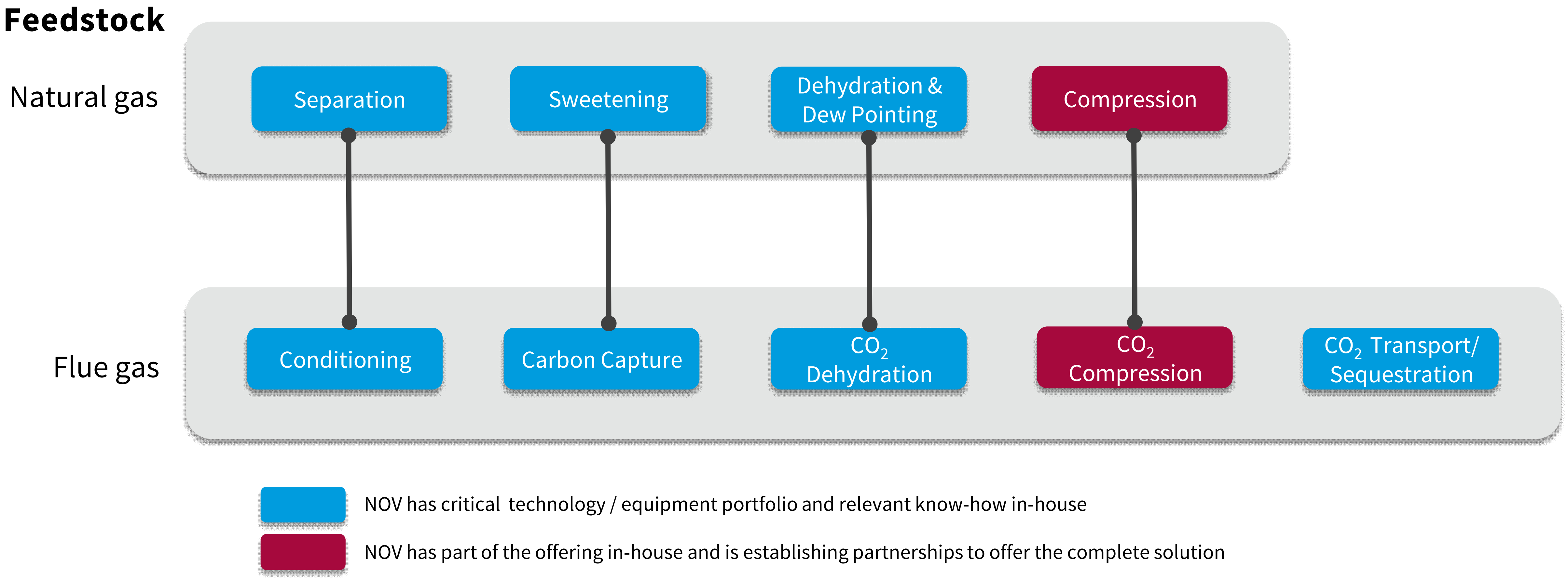
Technology overview



Carbon Capture, Conditioning & Transport Technologies Portfolio

NOV Carbon Capture Utilization and Storage (CCUS) Offering

Transferability of our natural gas processing technical and execution know-how to CCUS

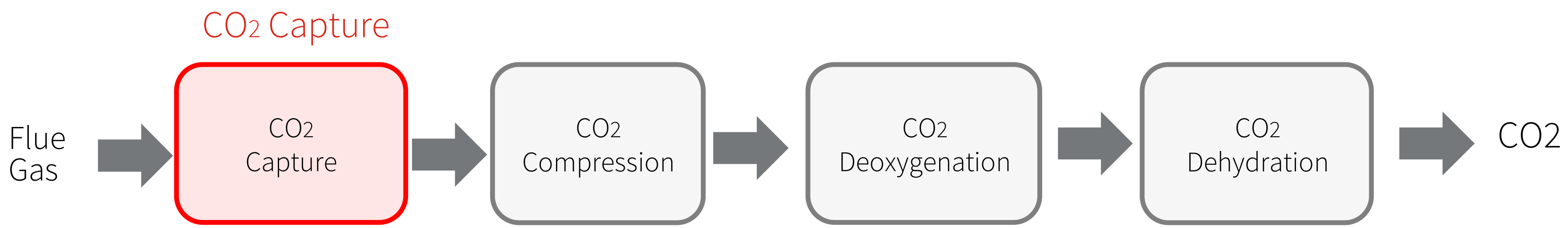


Carbon Capture & Conditioning

Carbon Capture

Experienced gas processing systems provider

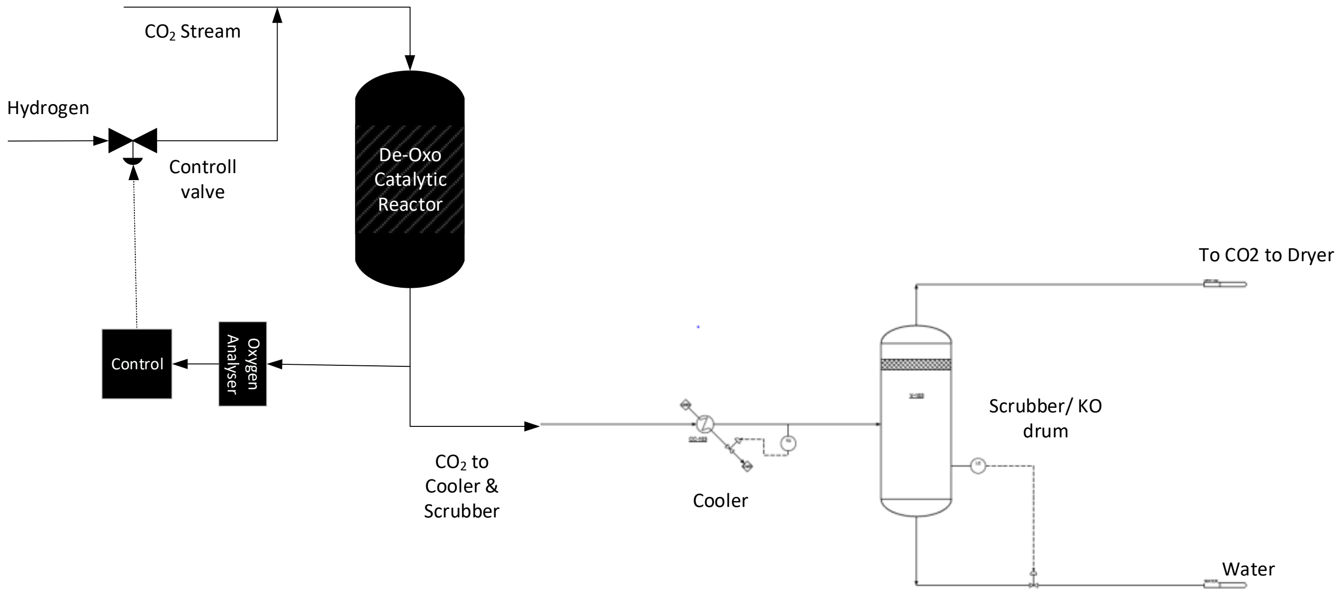
- Extensive technology portfolio for post-combustion carbon capture from various emission sources.
- Strategic collaboration with critical technology suppliers for:
  - Chemical solvents
  - Novel technologies
- Cost-efficient designs and effective execution models from process systems deliveries to the upstream oil and gas industry.

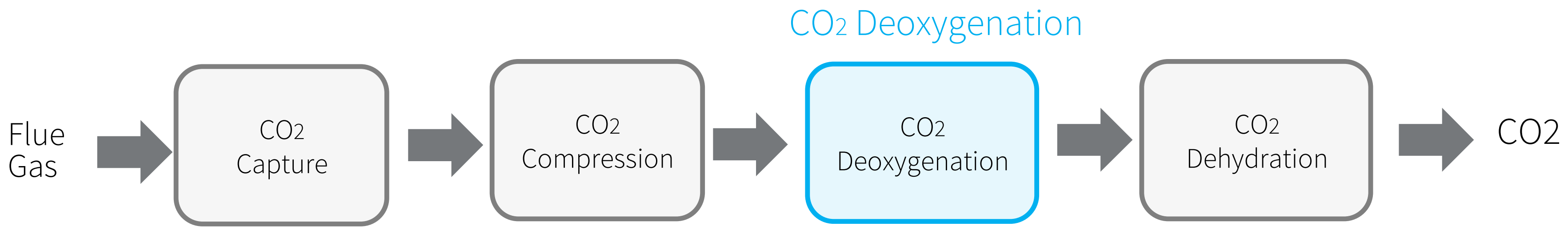


CO_2 Deoxygenation

Removes O_2 from CO_2

- O_2 reacted with H_2 over platinum/Palladium catalyst
- Water is produced as a product
- Placed upstream of the dryer unit





CO_2 Dehydration

Extensive technology portfolio

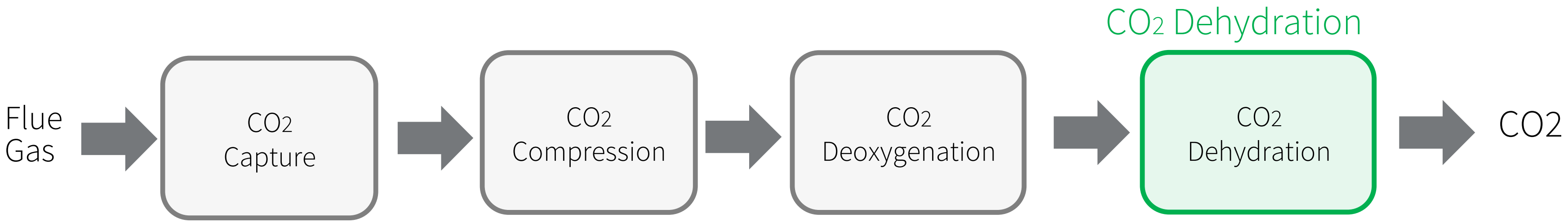
- Flexible & robust dehydration portfolio
  - TEG, molecular sieves, and silica gel
  - Industry-leading references for TEG dehydration systems

- 100 + projects executed – standardized design and cost-efficient execution model

- Optimized designs resulting in systems with lower CAPEX and OPEX costs.

Molecular sieves

TEG units



Flue gas & CO_2 Transport

Flue Gas Composite Ducting

40+

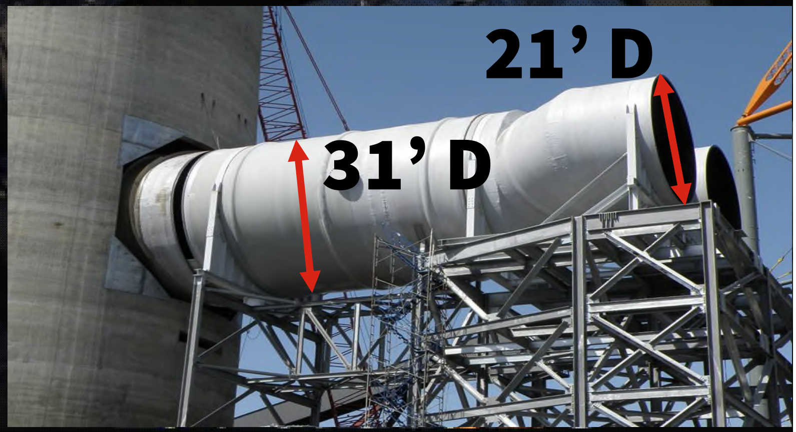
Year since our first power plant installation

177

Maximum operating temperature for our ductwork, in degrees C

40

Our largest diameter duct (in feet) ever wound in the field



Composite Solutions

Onshore CO_2 transportation

Advantages for CO_2 transport

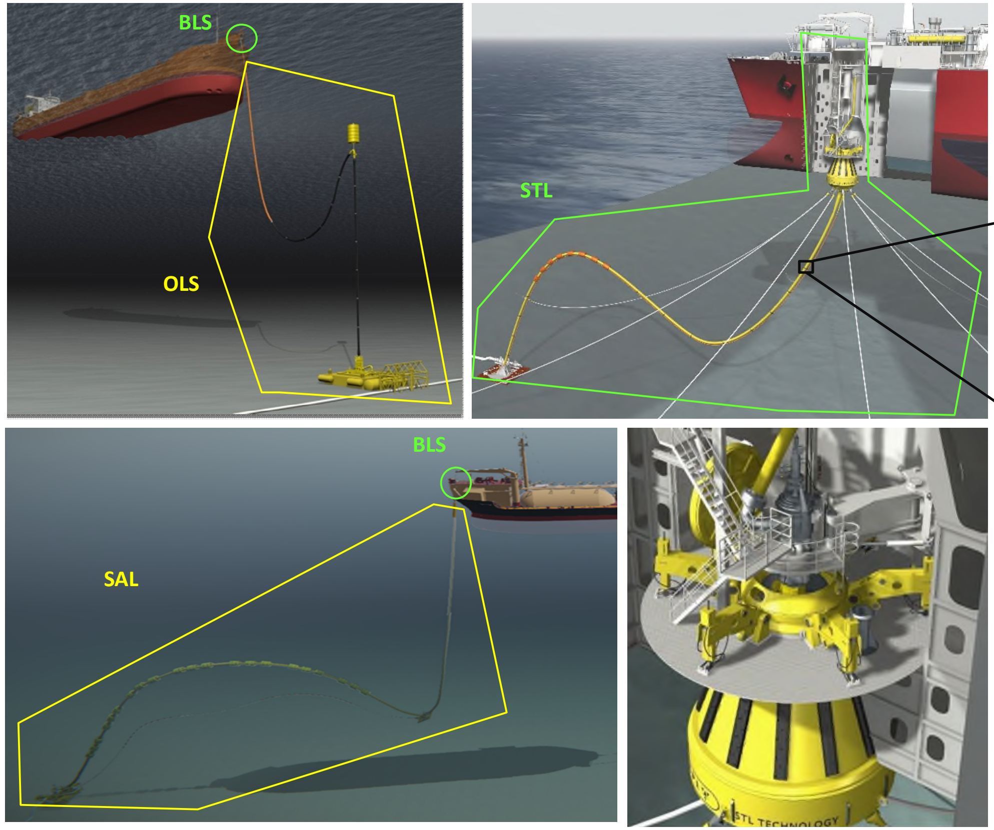
- Excellent corrosion resistance—handles up to 100% concentrations of CO_2
- Require less energy to produce than carbon steel
- Superior smoothness compared to steel results in meaningful lower energy requirements
- GRE pipe has 50 years of proven use in CO_2 applications

Why can you trust us?

- Installation of millions of feet of composite pipe for CO_2 handling across the United States
- Largest global provider of GRE pipe in the world

NOV Offerings for CO_2 Offshore Offloading Systems

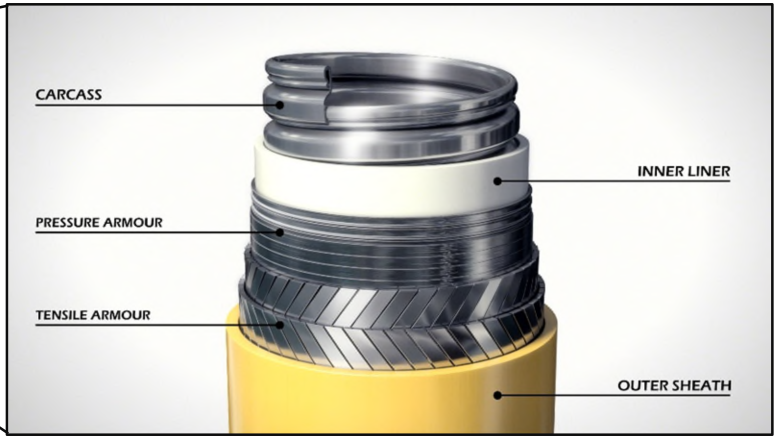
CO_2 Offshore Offloading Systems



Submerged Turret Loading (STL)
Offshore Loading System (OLS)

Single Anchor Loading (SAL)
Blow Loading System (BLS)

CO_2 Static and dynamic High Pressure flexible pipes



- 2.5” to 16” Inner Diameter
- Pressure rating up to 10.000 psi
- Water depth up to 2500m
- Hydrogen compatible
- Dynamic risers and, jumpers
- Static flowlines and jumpers

Norwep – Hydrogen & CCS Webinar - Europe

Archer

Unique downhole technologies and workflow assures integrity in permanent CO_2 storage

Agenda:

- Introduction
- Archer Well Integrity Workflow
- Stronghold® Defender & Barricade
- CFLEX – Multistage Cementing tool
- Summary

11.05.2022

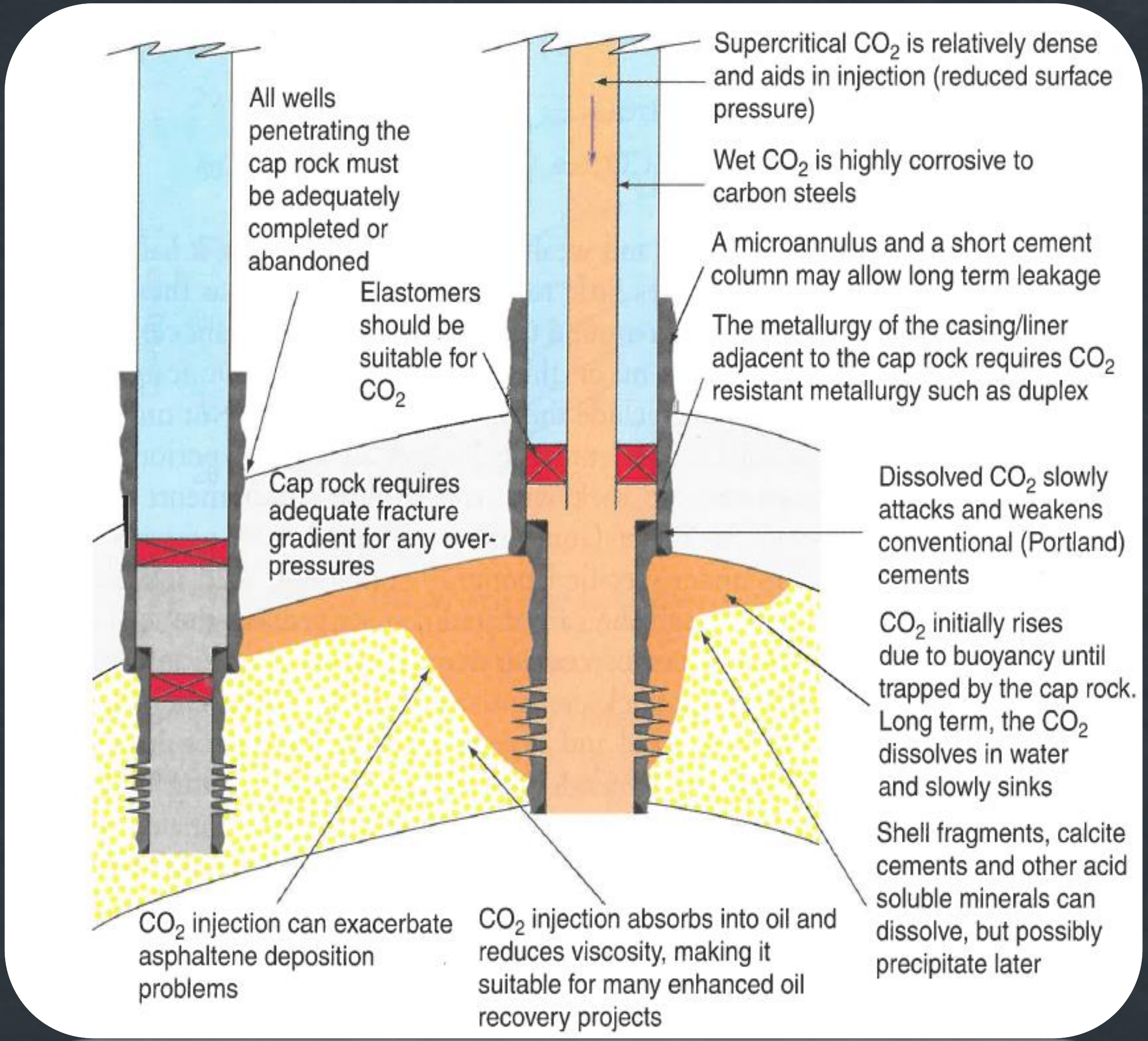
Archer

CCUS (Carbon Capture Utilisation & Storage)

Introduction

1. Repurposing depleted offshore fields (platform wells) or development of new offshore saline reservoirs (subsea wells).

2. Hostile environment - very cold temperatures due to JT effects combined with acidic environment (wet CO2) attacking steel & Portland cement.



ARCHER WELL INTEGRITY WORKFLOW

WELL DESIGN, MONITORING, REPAIRING AND ABANDOMENT

1. Designing wells for CO2 injection

- Different challenges for injectors & monitoring wells (V0 “gas tight”)
- Assessment of abandoned wells & existing wells (Slot Recovery, X-it®)
- Cement placement (CFLEX® & MCAP®)
- Harnessing creeping formations (Stronghold® Defender and Barricade)

2. Well monitoring: Testing & logging

- Assessment of annular barriers – cement bonding, defects & creeping formations (Radial Bond Log, SPACE® Ultrasonics)
- Detecting CO2 leaks (VIVID®)
- Corrosion logging (MIT Caliper, SPACE® Vernier)

3. Repairing annular isolation

- Cement squeeze
- PWC system (Stronghold® Barricade)
- Resins

4. Regulations & standards

- ISO 27914: Geological storage of CO2
- OEUK Well Decommissioning guidelines for reuse of reservoir for CCUS – Q3 2022

STRONDHOLD®
DEFENDER and BARRICADE

Permanent Caprock Integrity

STRONGHOLD® SYSTEM

Introduction

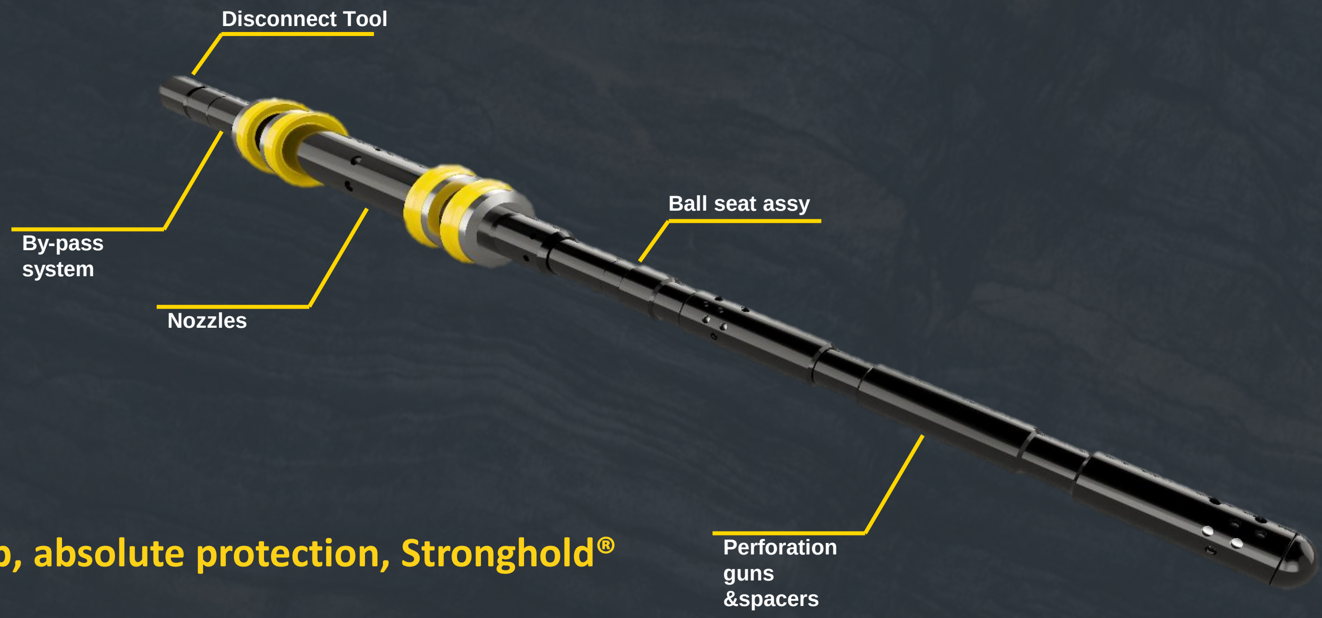
A permanent "rock-to-rock" barrier achieved in a single trip:

STRONGHOLD® DEFENDER

- Perforate the casing
- Test the Integrity of the Annulus
- Cement across the perforated area

STRONGHOLD® BARRICADE

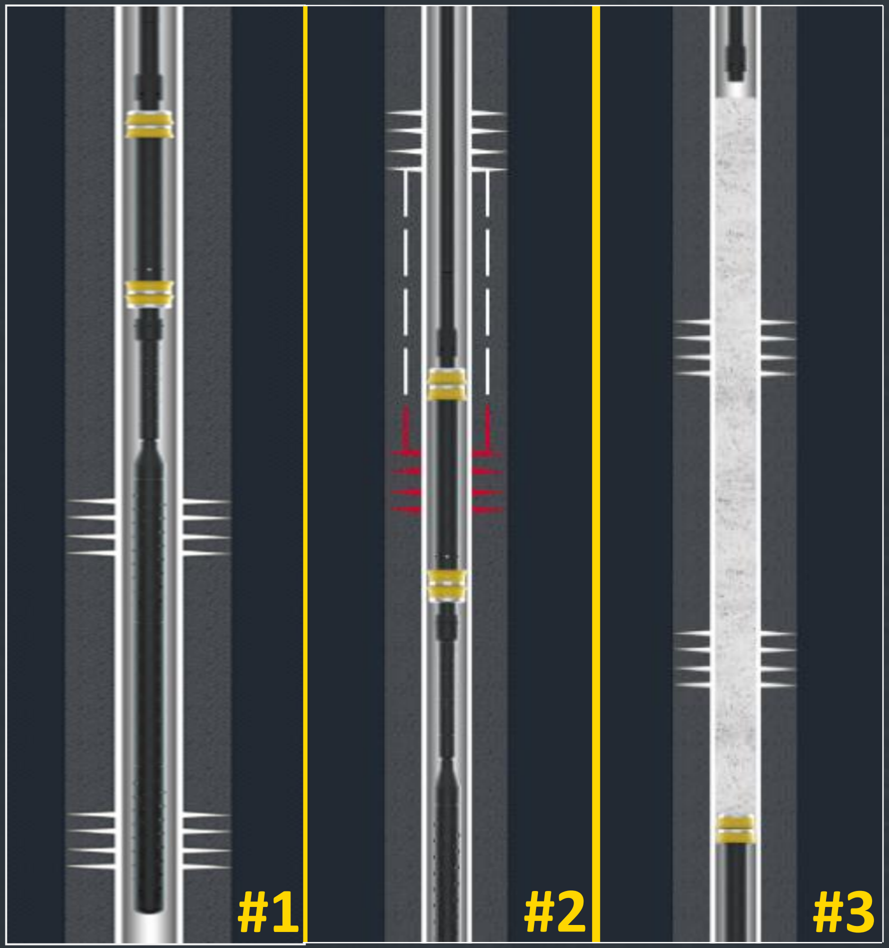
- Perforate the casing
- Wash cement, barite or shales in the annulus
- Cement across the perforated area



Result: one trip, absolute protection, Stronghold®

STRONGHOLD® DEFENDER SYSTEM

Operational Sequence



Step #1

- RIH with the Defender® System to the desired depth
- Perforate the top and bottom of the planned interval

Step #2

- Position the Cups across the deep perforations and pressure test for communication

Step #3

If positive test:

- Disconnect the Defender® system below perforations as base for the cement
- Pump cement across the perforated and tested area (for reservoir abandonment)

If negative test:

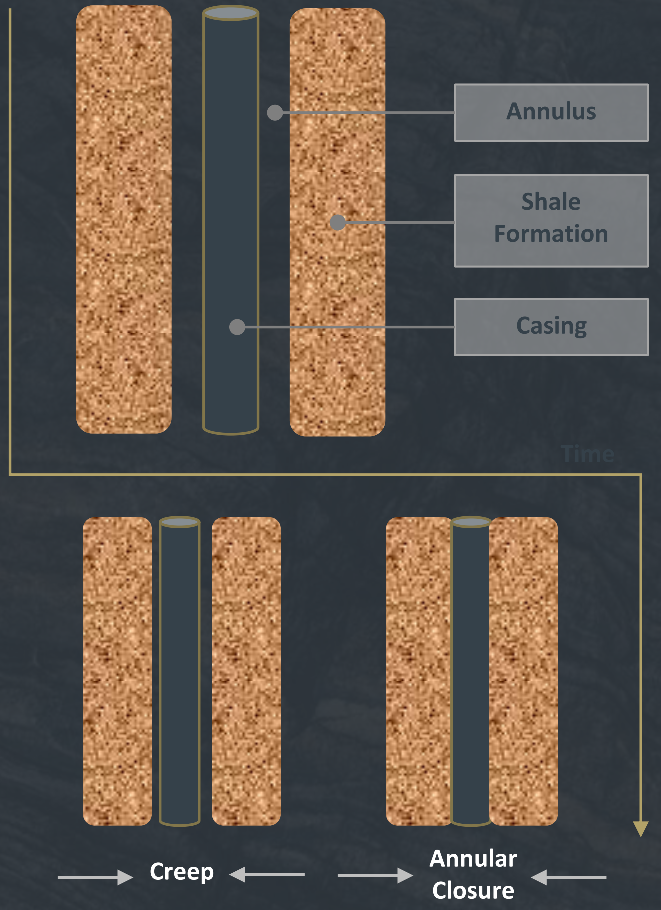
- Perform Barricade® (Perf, Wash and Cement) operation to establish new rock-to-rock barrier in the annulus and drill out cement inside casing.

STRONGHOLD® DEFENDER® SYSTEM

Natural Shale Barriers reducing the need for Cement

- The creeping shale needs to be qualified and tested as per local industry regulation to act as a barrier. Archer is providing the Stronghold® Defender® as an efficient one-trip formation integrity test system to qualify this.

- One example for using this method is the SPE-200755-MS *"Innovative One Trip System Helps Qualifying Creeping Shale as Permanent Barrier for Plug and Abandonment of Wells on the Gyda Field in the North sea"*

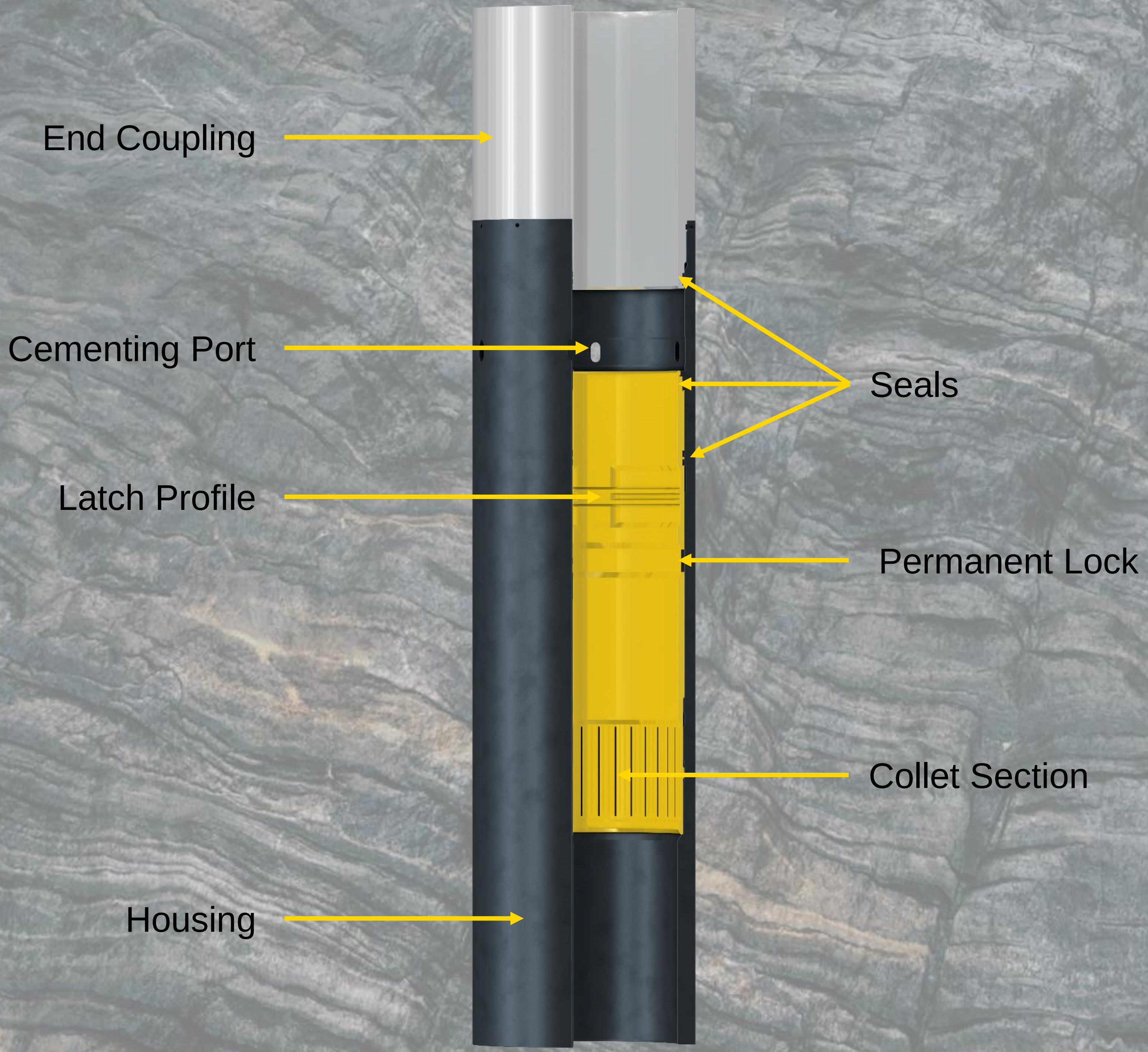


CFLEX®

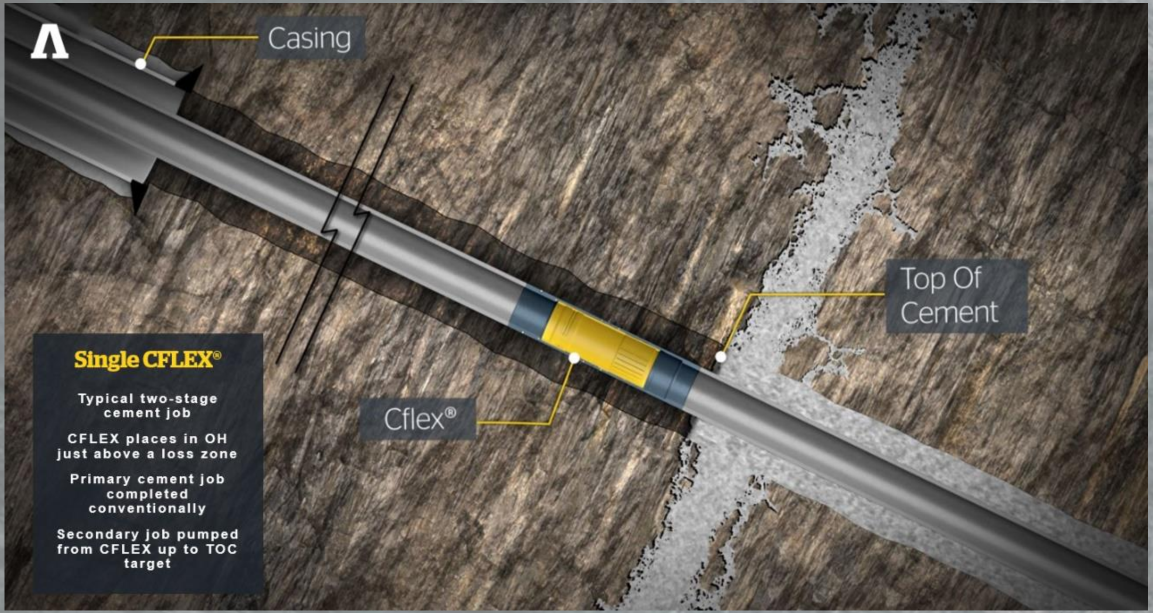
Multi-Stage Cementing system

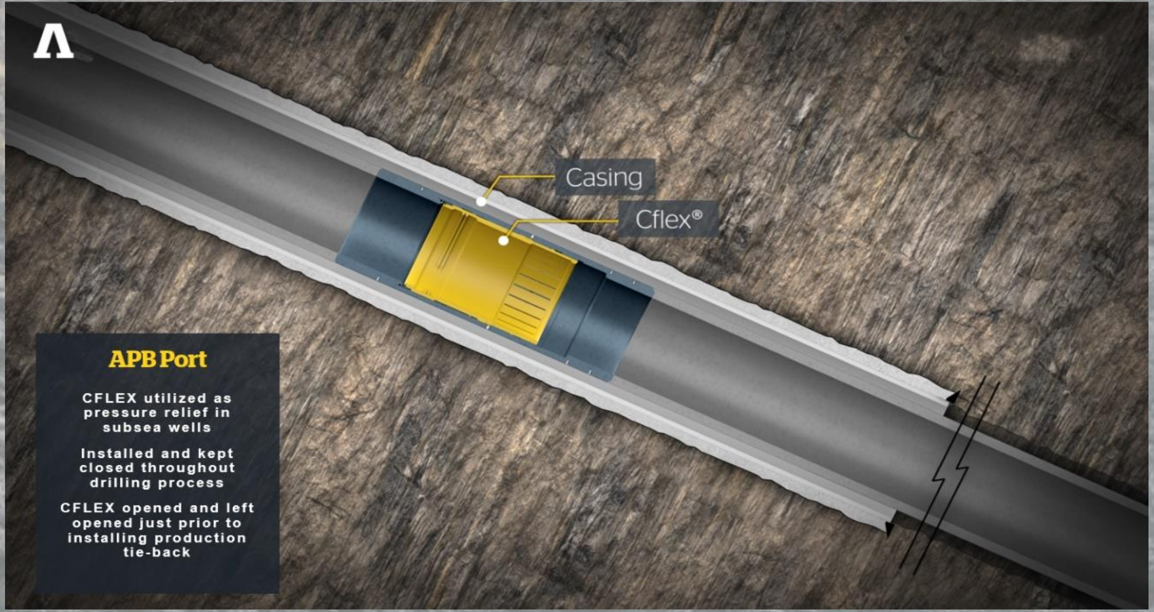
Principal Schematic
CFLEX®

- CFLEX accept most premium threads
- Large TFA through cementing ports
- Multiple seal options
- 80 / 20 latch profile with emergency release
- Two stage hydraulic permanent lock
- Collet section controls opening / closing forces



Applications





SUMMARY

Unique downhole technologies assures well integrity in CO_2 wells

Creeping shales need qualification as barriers in the caprock

Certified “gas tight” under ISO 14310 V0 are a must in CO_2 wells

One Archer. One Team.

For more information,

Check our website: www.archerwell.com

Or contact: Mark.Urquhart@archerwell.com

Fernando.Bermudez@archerwell.com

AKER CARBON CAPTURE

On-site Demonstration of CO_2 Capture from the Hydrogen Processing Unit

Results and Feasibility Study

12/05/2022

Rayane Hoballah

The Mobile Test Unit Solvent Campaigns at the Preemraff Lysekil Refinery

The Mobile Test Unit (MTU)

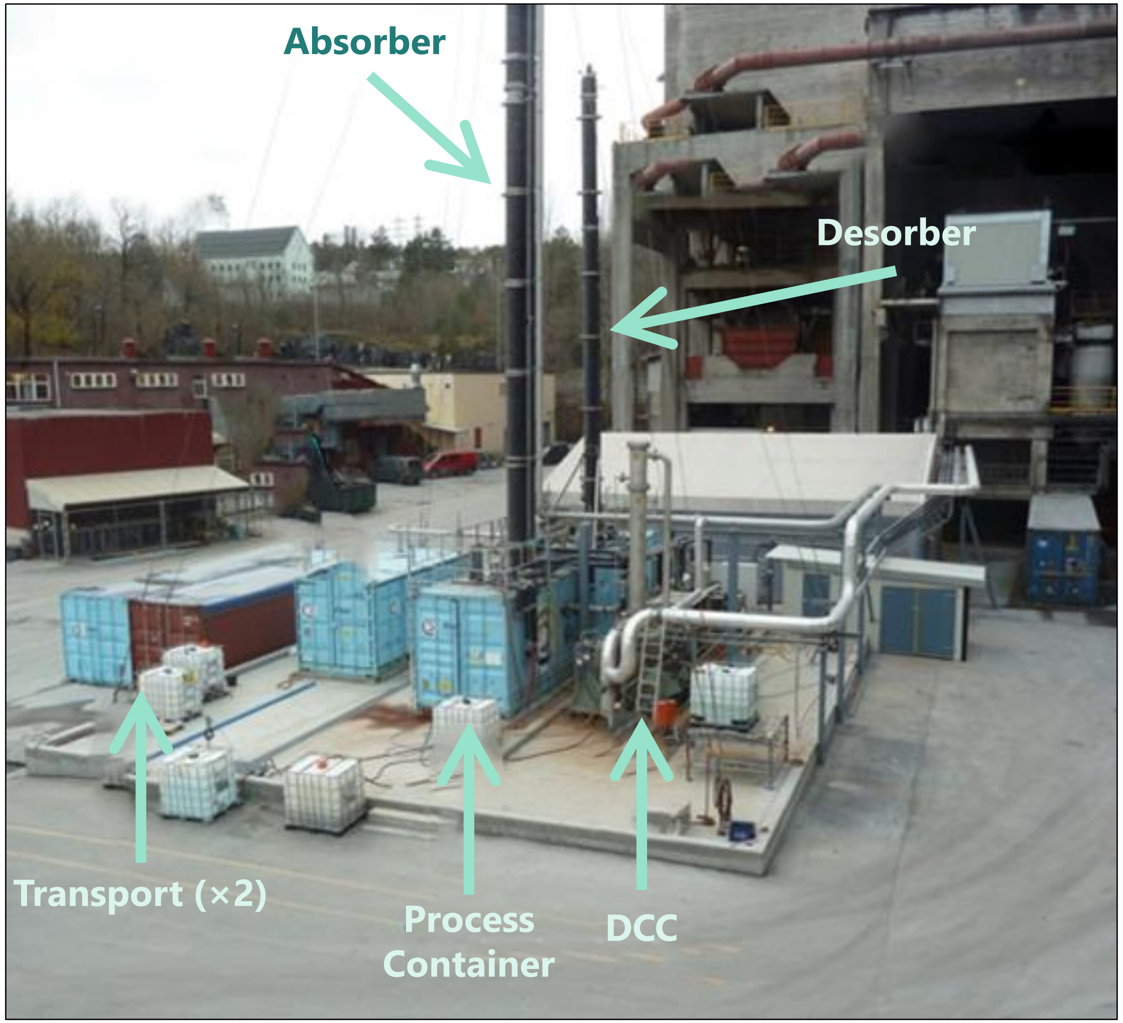
50000
hours in operation

Key Data

- Up to 1200 Sm^3/h flue gas
- CO_2 inlet concentration: 3 – 25 %
- CO_2 production: 100 – 200 kg/h
- Capture rate: ~ 85 – 95 %

- Designed and constructed by Aker Solutions / Aker Carbon Capture
- First put in operation in 2008
- Has the ACC™ technology
- Includes all functions as found in our large-scale systems
- Built for operation at a wide range of flue gases and locations
- Consists of 6 units that can be easily transported for testing our CO_2 capture technology on actual sources of flue gas
- Main purposes of the MTU:
  - Qualify flue gas for ACC™ and develop full scale projects
  - Development and testing of new technology and solvents

The Mobile Test Unit (MTU)



3 process units

- Main process container: 40 ft. container
- Direct Contact Cooler (DCC): 40 ft. skid
- Amine reclaimer unit (ARU): 20 ft. container

4 auxiliary containers

- 20 ft. container for tools, PPE, etc.
- 40 ft. container for column sections
- 40 ft. container for fans, crates etc.
- 8 ft. transport container for chemicals

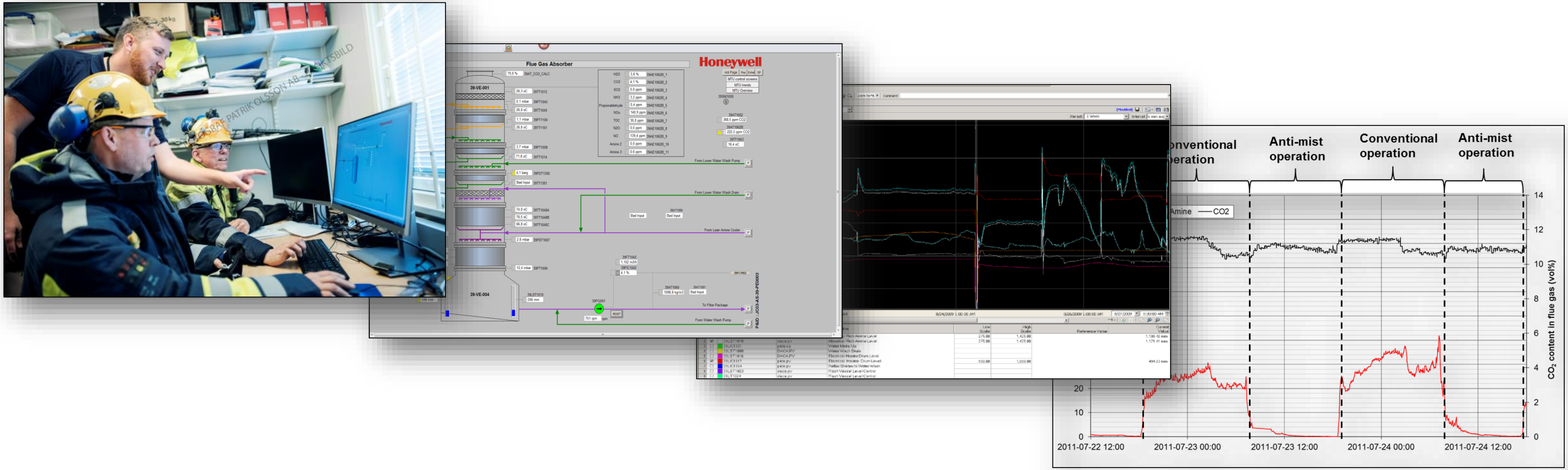
1 control room barrack with servers

Absorber: D = 0.4 m, H = 18 m absorption + two water wash sections + 1 acid wash section

Desorber: D = 0.32 m, H = 8 m stripping section + 1 water wash section

The Mobile Test Unit (MTU)

- Easily accessible via internet server from anywhere in the world
- Contains real-time details and data from the MTU CO_2 capture process
- Enables advanced trending and analysis of data for process development and optimisation



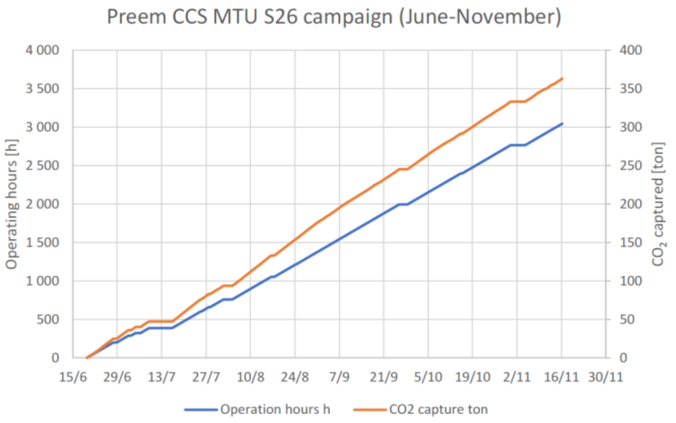

capture

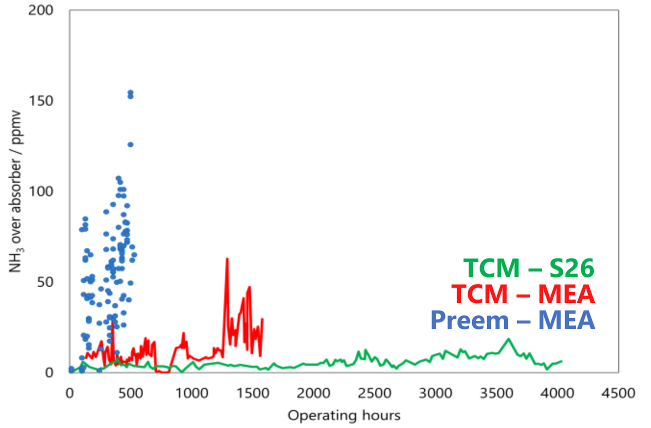
Inside an MTU campaign

Typical MTU campaign structure

- Thousands of hours of operation on real flue gas
  - Continuous emission monitoring
  - Regular inventory analysis
  - Dedicated emission campaign
  - Process optimisation
- Technology risk reduction

MEA

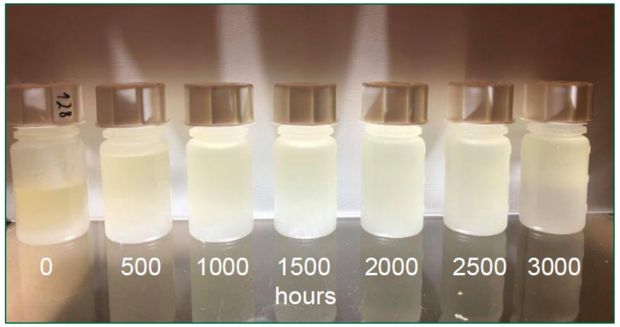


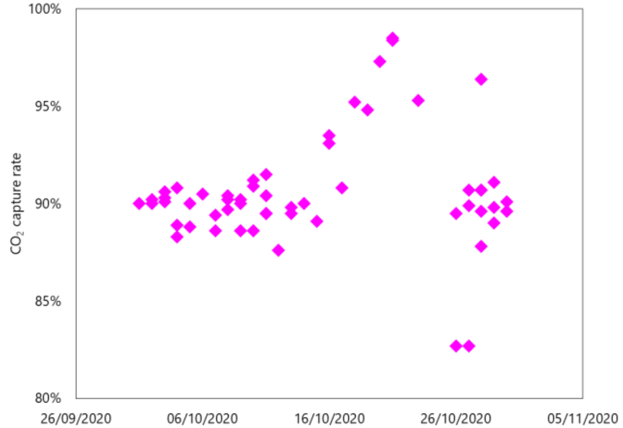


ACC™ S26 campaign at Preem Lysekil's Refinery

- Spot-checks at different capture rates
- Better energy performance than MEA
- Good solvent stability
- Low corrosivity
- Low emissions
- Low degradation

ACC™ S26





Aker Carbon Capture's Feasibility Study at the Preemraff Lysekil Refinery

Preem CCS Full scale CO_2 capture feasibility study

- Objectives
  - Develop a design for a carbon capture, liquefaction and intermediary storage facility at the Preemraff Lysekil facility:
    - With 90% CO_2 capture rate from the Hydrogen Production Unit (HPU) flue gas
    - Equivalent to capture 600 000 tpy CO_2 (8 500 operating hours per year)
  - Feasibility study ~ cost estimate ±40% accuracy

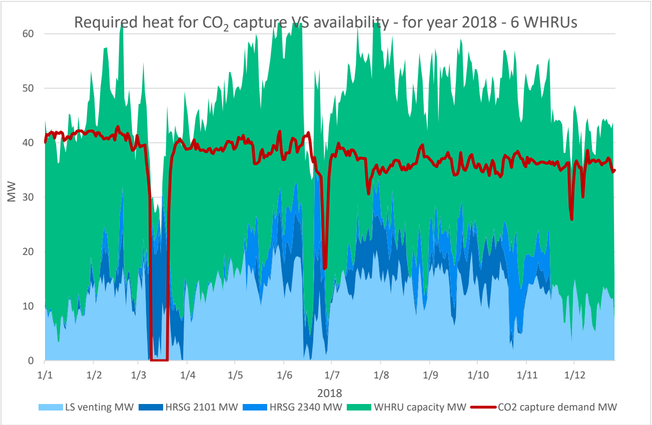
	Flue gas characteristics
Flow rate (Nm^3/h)	184 000 – 212 000
CO_2 (mol%)	18.6 – 21.5

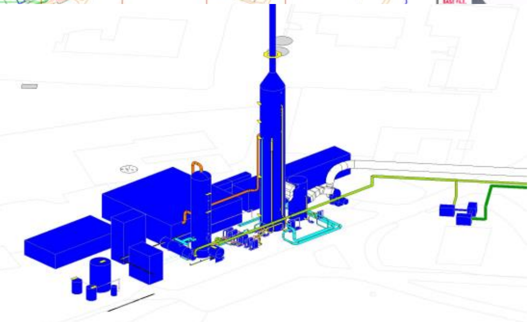
- Scope
  - **CO_2 capture**
    - including all main equipment
    - preconditioning and capture of CO_2 from the flue gas
    - solvent handling and regeneration
  - **CO_2 conditioning**
    - compression, liquefaction, drying and inerts removal
    - intermediate storage
    - ship loading system at the Preemraff harbour
  - **Main utilities** assessments/availability/solutions
    - heat demand/availability
    - cooling demand/solutions

External Heat Recovery for the Capture Unit

- Heat duty from ACC’s process is **2.0 GJ per ton CO_2 captured**
- This demand is covered excess and residual waste heat sources: covers ACC’s heat duty
- The capture plant can operate fully on waste heat:
  - No additional steam demand from the Preemraff Lysekil refinery
  - **Cost effective solution!**

- Project schedule:
  - 8 months' FEED
  - 40 months' EPC phase inclusive of 3 months for commissioning





Evaluation of Aker Carbon Capture at Preemraff Lysekil

Mobile Test Unit

Low risk from a technology perspective

- Aker Carbon Capture's ACC ™ performances were demonstrated during 3 800 hours of onsite operation

Low risk from an environmental perspective

- Aker Carbon Capture's ACC™ solvent S26 showed low to negligible emissions and very low degradation rates throughout the 3 800 hours of operation

Feasibility Study

Applicable layout

- The feasibility study confirms that, a full scale CO_2 capture plant for 90% CO_2 capture from Preemraff Lysekil HPU flue gas can fit well within the current site

Cost effective solution

- The feasibility study illustrated how heat integration with the Preemraff Lysekil plant could provide substantial OPEX gains making this project cost attractive

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Copyright

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