



SINTEF

# CCS R & D in SINTEF

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Hydrogen & CCS Symposium 15-16 Feb 2022





# SINTEF in brief

- A non-profit contract R & D organization
- Dedicated to applied sciences (CCS being a good example)
- Around 2000 staff in total
- Mainly based in Norway, but serving customers all over the world



SINTEF

## Role in CCS R & D

- Works together with all types of entities in progressing technology development
- Can sometimes initiate technology development, but often works in collaboration with industrial entities
- Spans the spectrum from low TRL technology development to studies of CCUS value chains and integration in industry
- Some work is published while other work is the property of customers
- Has good connections with funding agencies (national and EU)



SINTEF

# Topics and disciplines covered:

- Post-Combustion CO<sub>2</sub> Capture
  - Absorption/Solvent technology
  - Adsorption
  - Membranes
- Oxycombustion
- Chemical Looping Combustion
- Hydrogen technology
- CO<sub>2</sub> transport
- CO<sub>2</sub> Storage
- Full value chain analysis (capture-transport-storage)
- Techno-Economic Analysis





SINTEF

## Research & Development

### SOLVit: Key European CCS R&D programme

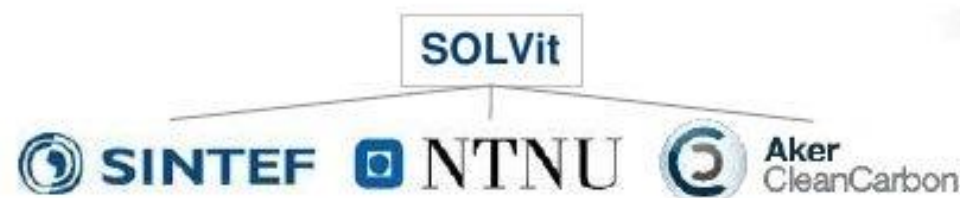
#### SOLVit objective:

Solvent development and selection – key to CCS cost reduction

#### 8 year programme from 2008

317 MNOK (~ \$60 million), of which phase II MNOK 90

- Research contributors: SINTEF, Norwegian University of Science and Technology (NTNU), ACC
- Supported by: Gassnova, Climit (Norwegian state)
- Industrial partners: E.ON and EnBW
- The project is managed by ACC



The preferred partner

| 4  
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# The SOLVit project provided the basis for ACCs commercial capture technology

# ACCCESS is positioned to deliver three major innovations:



## **Innovation 1**

Piloting of environmentally benign enzymatic solvent combined with an RPB absorber



## **Innovation 2**

Piloting of recarbonation of demolition concrete fines



## **Innovation 3**

Development of a radically new cement kiln integrated with amine capture





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A wide-angle photograph of an industrial facility, likely a power plant or refinery, captured during the "golden hour" of sunset. The sun is a bright, glowing orb on the horizon, casting a warm, orange light across the scene. Two prominent smokestacks in the foreground are emitting thick plumes of white smoke that drift towards the right. The background shows a vast industrial complex with numerous buildings and structures, all bathed in the soft, hazy light of the setting sun.

Improving our understanding of  
amine-based CO<sub>2</sub> capture



SINTEF

Technology for a  
better society

# Northern Lights JV DA

Kim Bye Bruun, Communications and Government Relations Director

# CO<sub>2</sub> transport & storage at scale



## NORTHERN LIGHTS SCOPE

### CO<sub>2</sub> capture

Capture from industrial plants.  
Liquefaction and temporary storage.



### Transport

Liquid CO<sub>2</sub>  
transported by ship.



### Receiving terminal

Intermediate onshore storage.  
Pipeline transport to offshore  
storage location.



### Permanent storage

CO<sub>2</sub> is injected into a saline aquifer.

100 km

2 600m



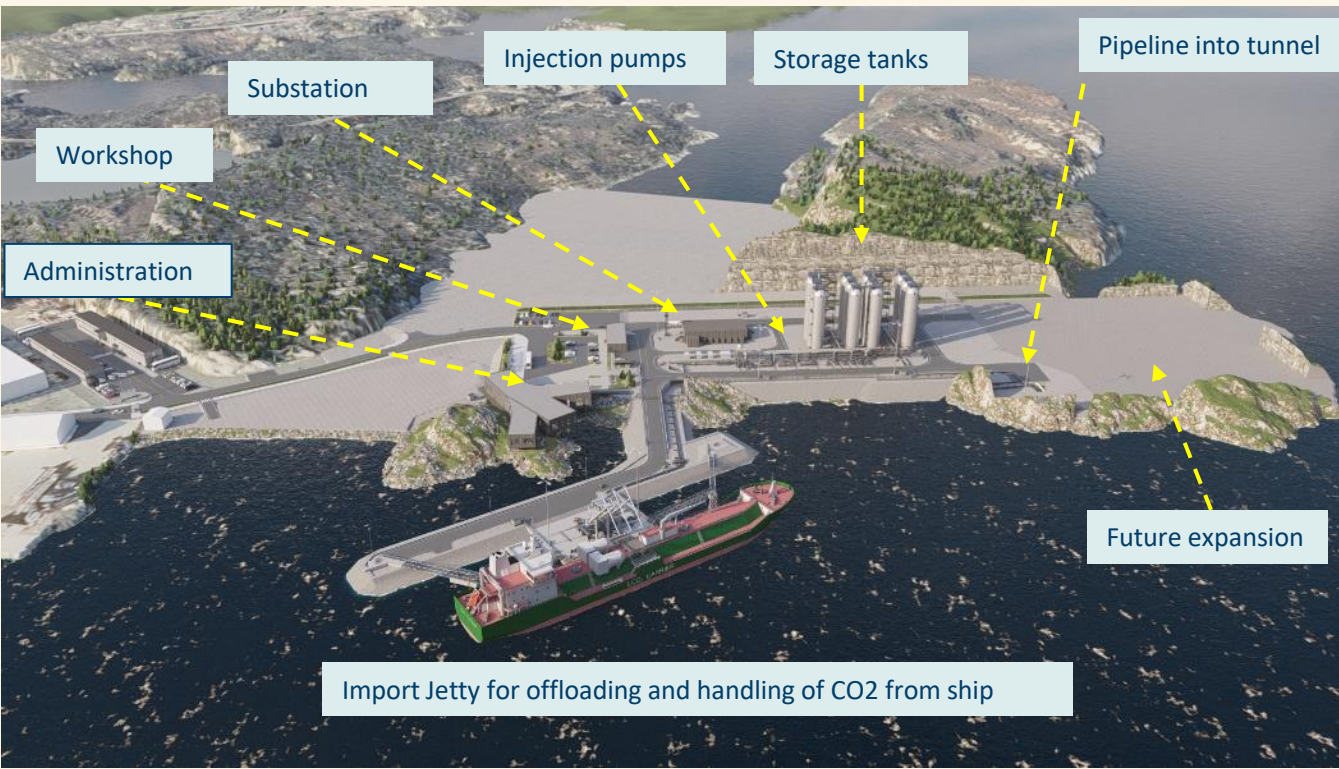


# Receiving terminal Øygarden



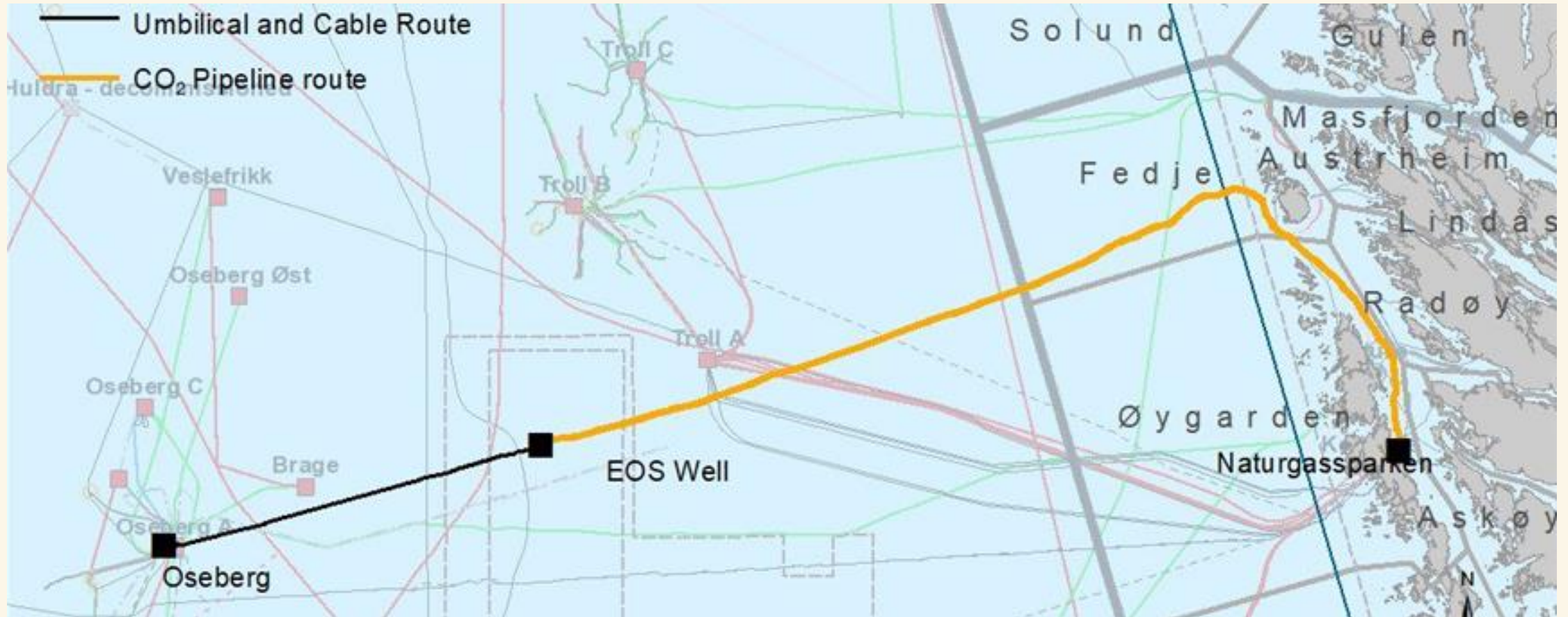
- Civil works well under way
- Import jetty construction started
- Project office and visitor centre in in place

- Detail engineering and procurement ongoing
- Fabrication and installation of plant starts spring 2022
- Additional area for expansion included



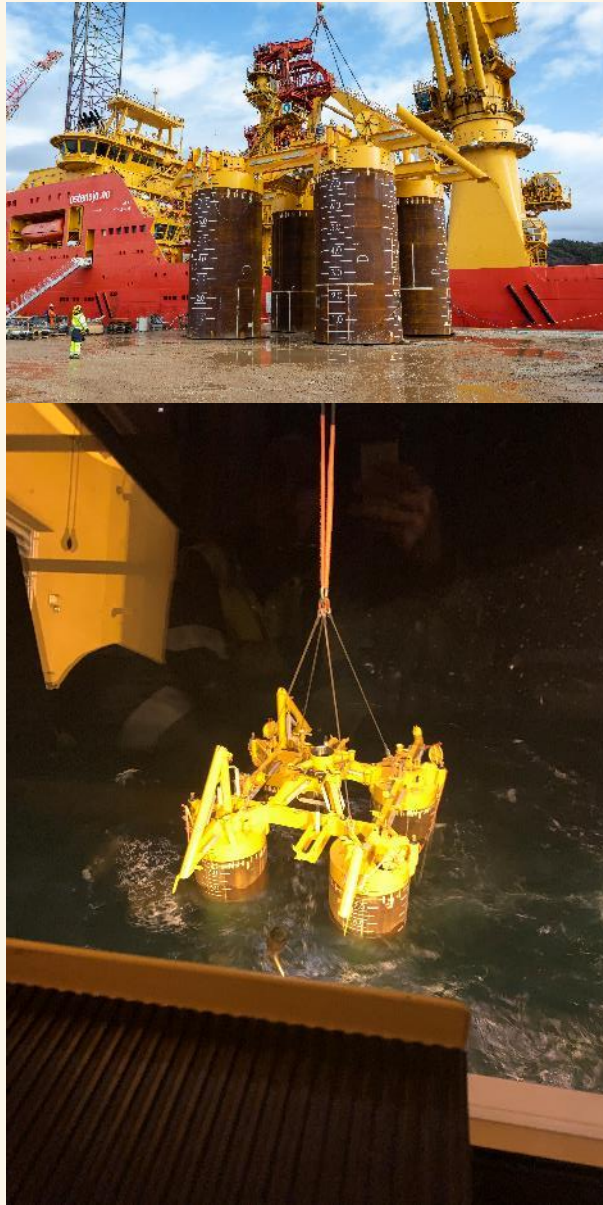


# Pipeline and subsea facilities



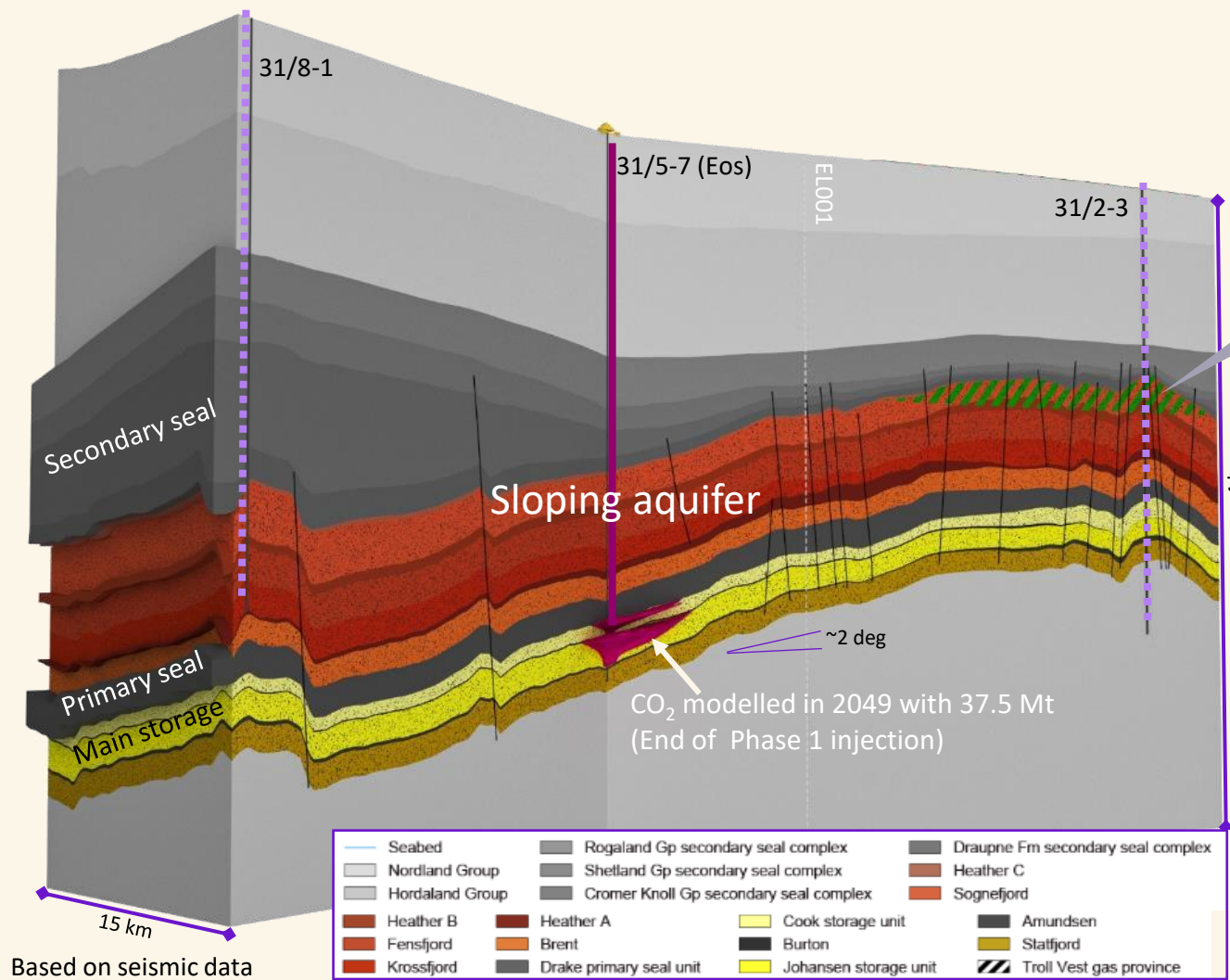


# Pipeline and subsea facilities



- Template installed in 2019, well 31/5-7 drilled in 2020
- Fabrication of umbilical complete
- Fabrication of power and fibre optic control cable ongoing
- Engineering and procurement of topsides modifications at Oseberg ongoing
- Engineering of pipelay ongoing
- Fabrication of pipeline ongoing
- Engineering for pipeline tunnel ongoing
- Sidetrack will be drilled in 2022
- Second well will be drilled in 2022

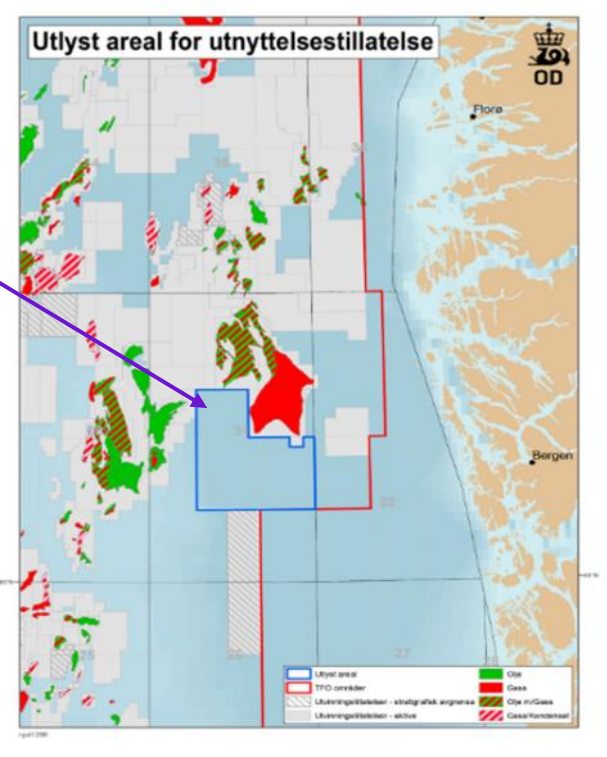
# Northern Lights storage concept



Based on seismic data from CGG

Troll oil and gas field

EL001



All data (83 GB) from well made public

# Shipping will be needed

→ Small number of storage sites

→ Large number of emitters

- Cluster developments
- Individual locations

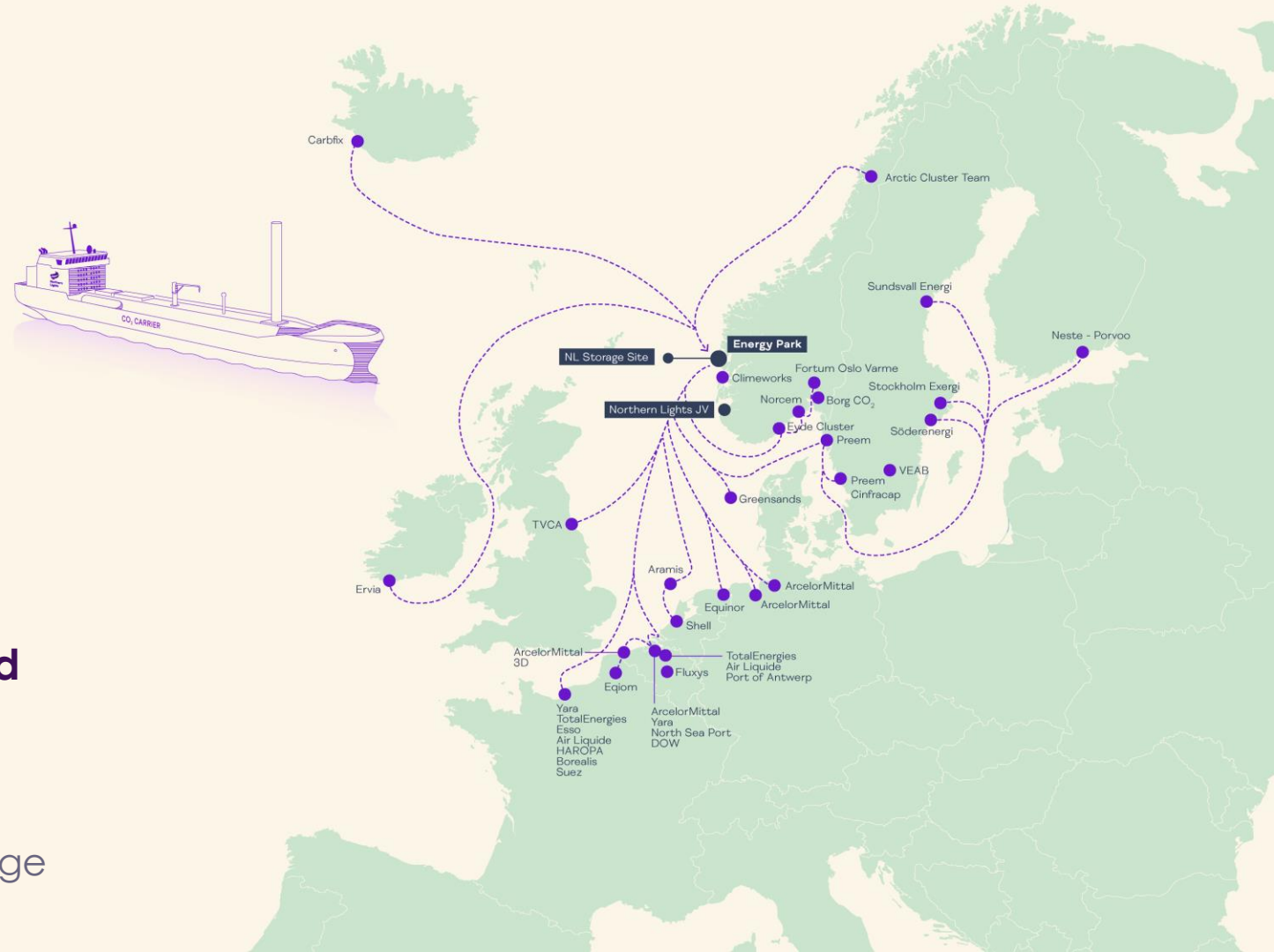
→ Several locations

- Coastal
- Along rivers and canals
- Landlocked

→ No pipeline infrastructure available

The European Commission has nominated Northern Lights as a Project of Common Interest (PCI)

- Connecting European carbon capture initiatives with permanent carbon storage infrastructure (see map)





# Northern Lights shipping solution



- Ship building contracts awarded October 2021 (two vessels)
- Cargo size: 7,500 m<sup>3</sup> (8000 tonnes CO<sub>2</sub>)
- Length: 130m
- Ready for delivery by mid 2024
- Designed to transport liquid CO<sub>2</sub>
- Purpose-built pressurised cargo tanks
- Primary fuel: LNG
- Wind assisted propulsion system and air lubrication installed
  - Will reduce carbon intensity by around 34% compared to conventional systems
- To be registered in Norway (NOR)
- Additional 9 vessels needed
  - Subject to Phase 2 FID



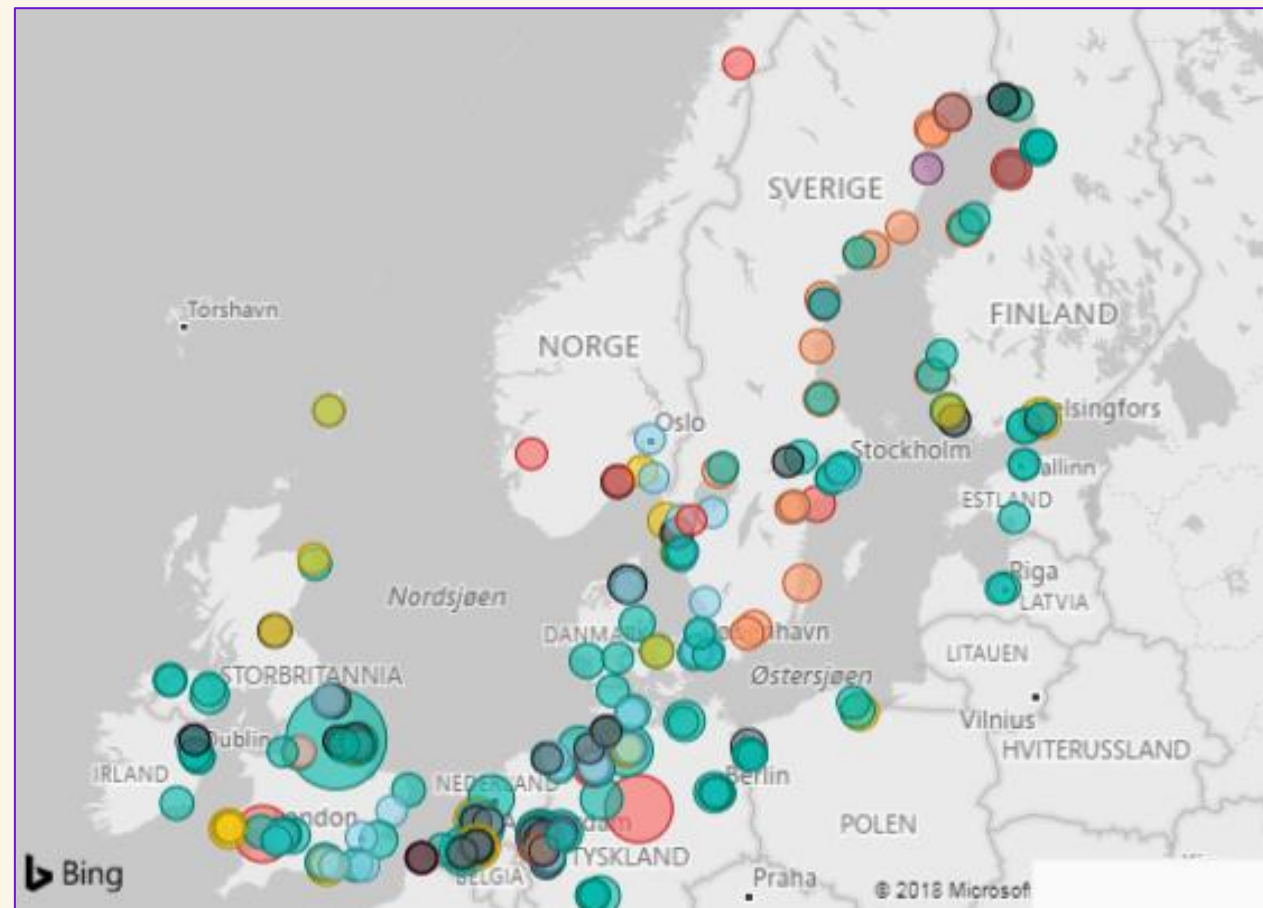
# Market context

## → Large potential with long-life sectors:

- Waste incineration
- Cement
- Steel and other metal
- Refinery
- Fertilisers and ammonia
- Biomass and biofuel
- DAC

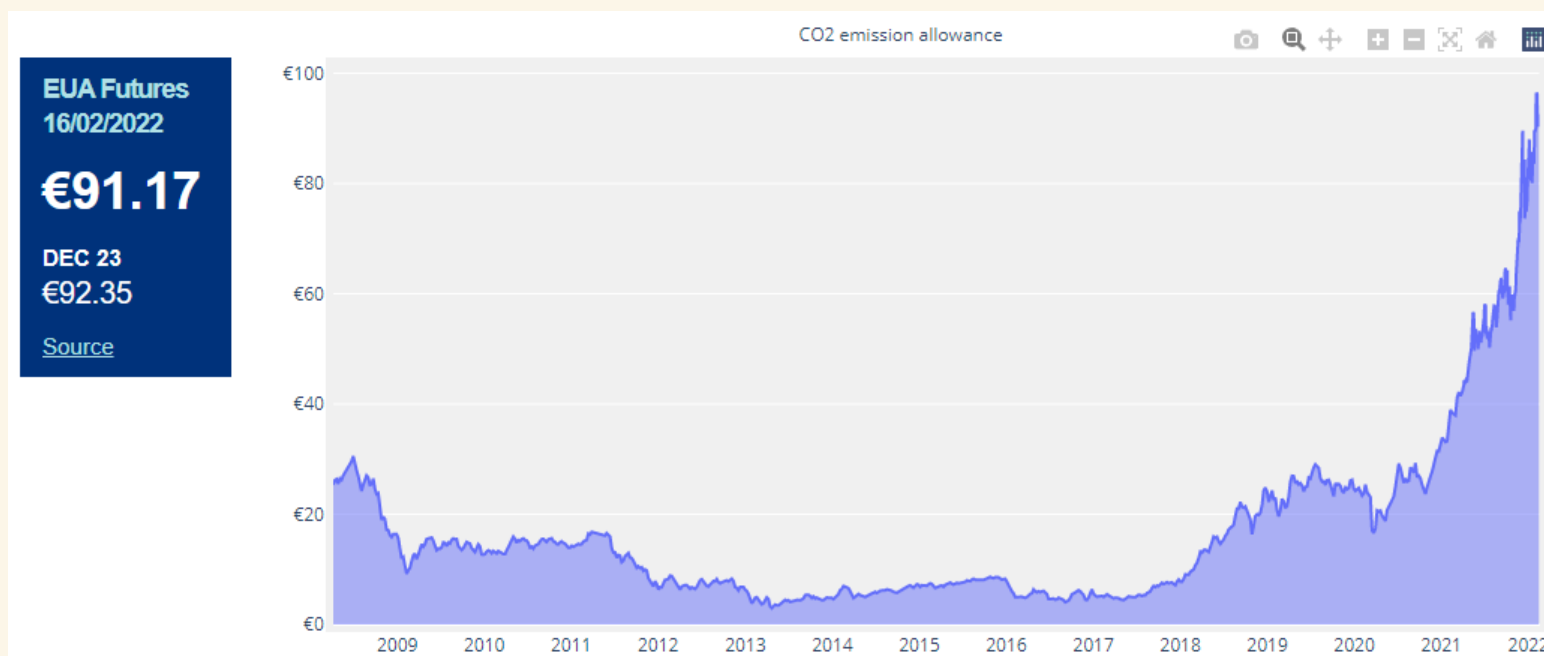
## → Northern Lights is relevant and within reach for about 350 large scale emitters in Europe

## → Support mechanisms important in the first phase. Thereafter general policy incentives (CO2-price).



# European CO<sub>2</sub> value chain

- Northern Lights is developing the first open source CO<sub>2</sub>-transport and storage network.
- Offering flexible ship based transport and permanent storage.
- Discussions with potential customers ongoing.
- ETS-price important
- Expecting to sign first commercial contract in 2022.



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



**Northern  
Lights**

[norlights.com](https://norlights.com)



An aerial photograph of a complex industrial facility, likely a CO2 capture plant. The image shows a dense network of metal structures, pipes, and walkways. Two workers in high-visibility yellow-green suits and hard hats are standing on a circular platform in the center-right of the frame. The background is filled with more industrial equipment, including large storage tanks and intricate piping systems. The overall scene is industrial and technical.

# Derisking industrial deployment of CO2 capture technologies

Freddy Garcia

Technology Manager



*- catching our future*





Mongstad ●

Bergen ●







## We are a carbon capture competence centre

The world's largest technology test centre with the aim to facilitate industrial scale deployment of carbon capture

Our strenghts:

- Last step before full-scale deployment.
- Simulating real-world conditions.
- Flexible facilities with thousands of measuring points.
- Unique knowledge from ten years of operations.

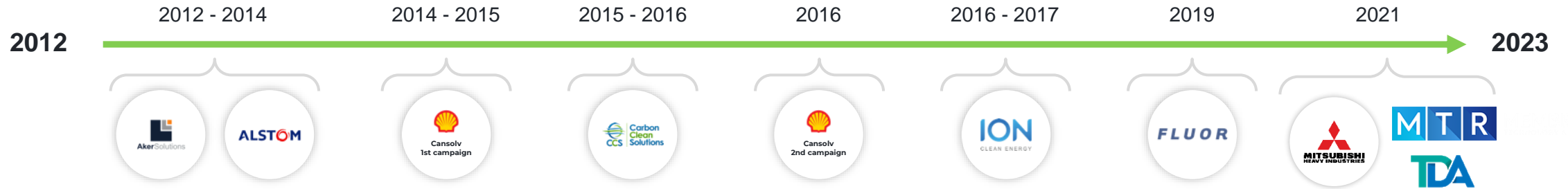
Our activities:

- Technology testing
- Advisory services

# Conducted Test Campaigns

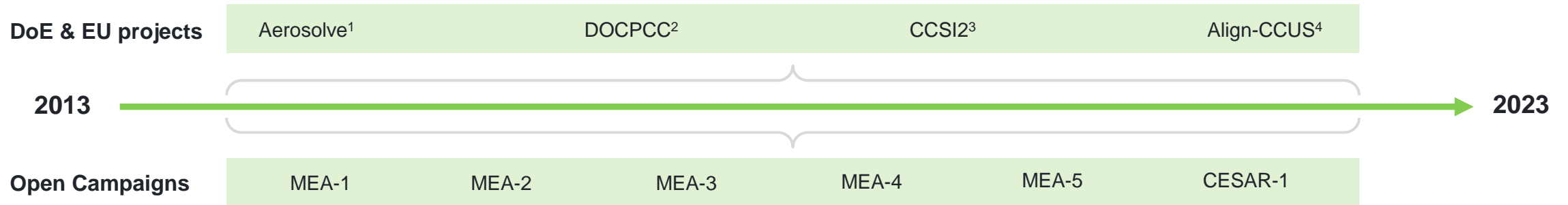
## Proprietary Campaigns > 20,000 h

Technology Vendors perform tests with their own proprietary technology



## Open and Public Campaigns > 20,000 h

A large amount of open scientific test campaigns with non-proprietary technology in cooperation with universities, research institutes, U.S. Department of Energy and the European Union



# Testing activities

Strong pipeline of activities, with a clear strategy towards 2025



Non aqueous solvent



Flue gas purification and sorbent technology



Non-amine based solvent, Rotating Packed Bed



Metal Organic Framework







TECHNOLOGY  
CENTRE  
MONGSTAD



Hydrogen & CCS Symposium – Canada  
15-16 February

Blue Hydrogen and Ammonia – Emission-free production, efficient transportation and decarbonization

Torkild R. Reinertsen, PhD  
Chairman & Market Lead Hydrogen  
REINERTSEN New Energy AS  
[torkild.reinertsen@rein-energy.com](mailto: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
  - ✓ Green hydrogen production
  - ✓ Hydrogen compression
  - ✓ Hydrogen and CO<sub>2</sub> transportation in pipelines, incl. H<sub>2</sub> blending / de-blending
  - ✓ Hydrogen and ammonia for decarbonization in multiple sectors

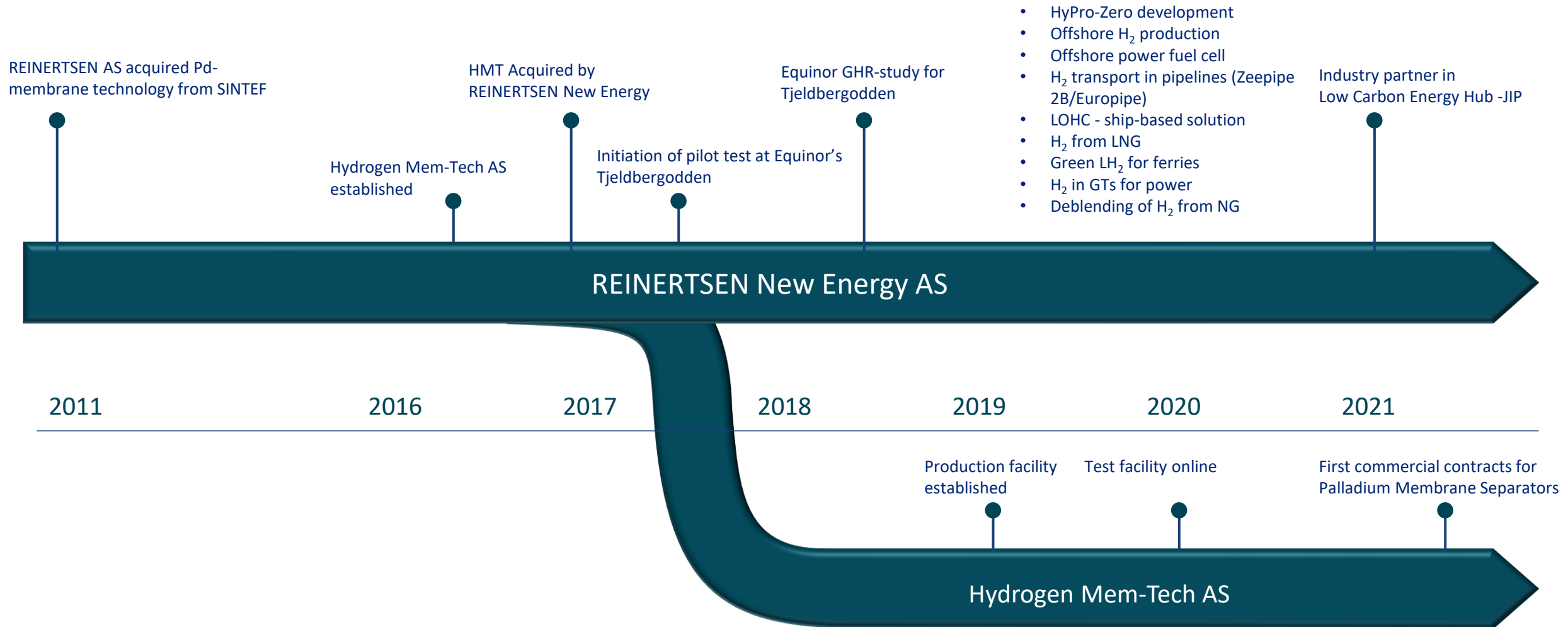


Reinertsen New Energy has the technology to refine natural gas to hydrogen, without CO<sub>2</sub> emissions. With more than 40 years of experience, we stand ready to start a new and clean industrial adventure here and now - for those that come after us and the world they will live in.

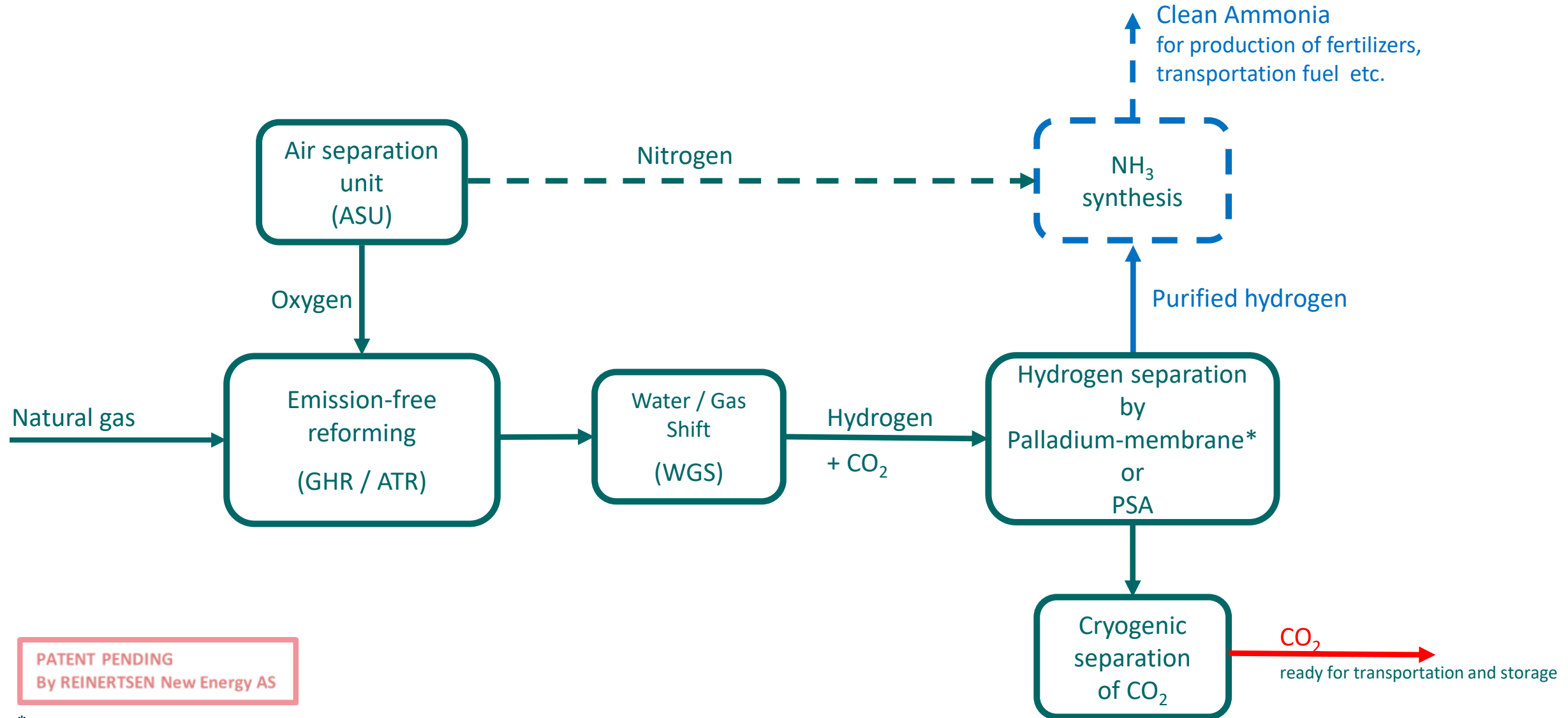
**REINERTSEN**  
NEW ENERGY



# Hydrogen development history



# Emission-free production of hydrogen and ammonia with “HyPro-Zero”

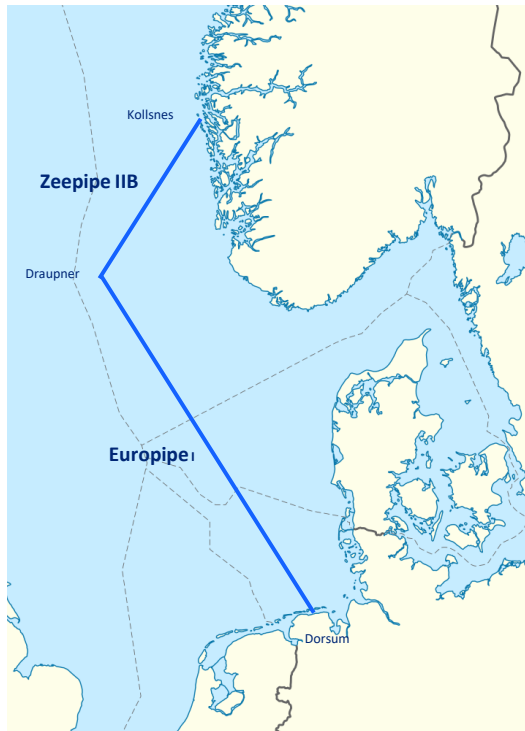


\* Palladium membrane patented by HYDROGEN Mem-Tech AS (subsidiary of REINERTSEN New Energy)

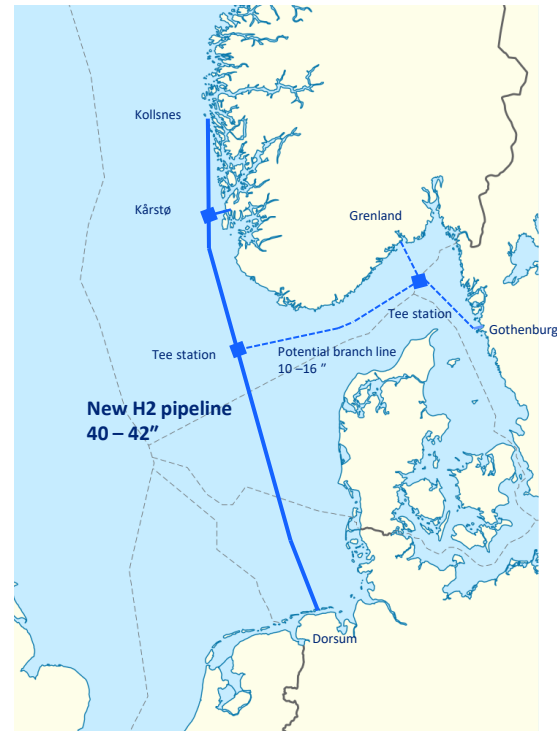
# Gas pipelines for efficient hydrogen transportation

## Example: Norway to Netherlands/Germany

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



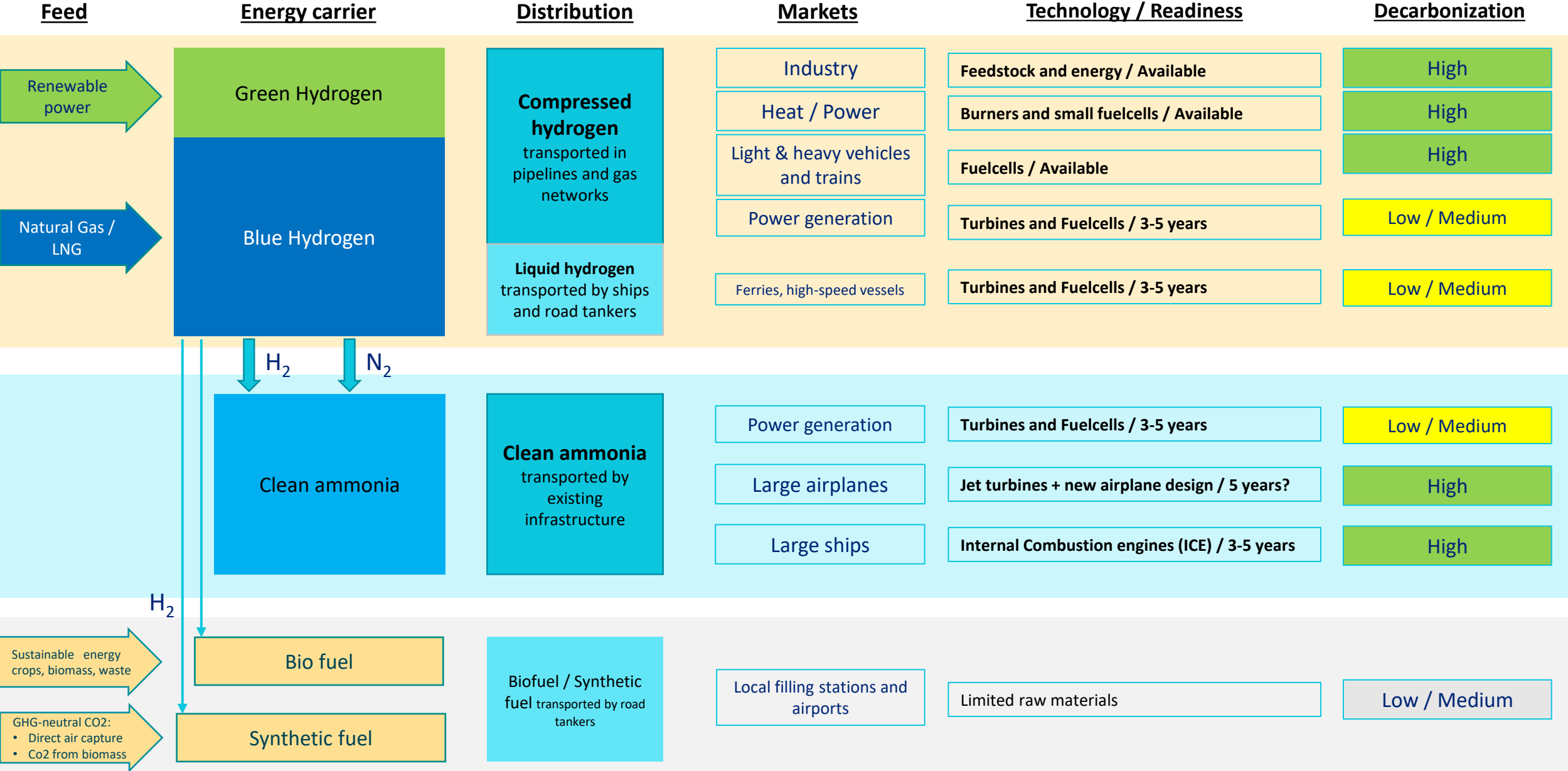
New hydrogen pipeline  
42"/800km  
(3.5 million ton H<sub>2</sub>/year)



**Cost of hydrogen transportation:**  
**~ 0.10 €/kgH<sub>2</sub>\***

\*Net cost, excl. financing etc.

# Decarbonization by hydrogen



# Potential for Cooperation with Canada

- REINERTSEN New Energy – Technology and Solutions
  - ✓ Blue hydrogen and ammonia production with ultra high CO<sub>2</sub> capture and low power consumption.
  - ✓ Transportation of hydrogen to markets in pipelines
    - Re-purposing existing gas pipelines, with H<sub>2</sub> blending/de-blending
    - Design of new pipelines for H<sub>2</sub> transportation
    - H<sub>2</sub> compressor stations
    - Deblending-/ H<sub>2</sub> Extraction stations
  - ✓ Transportation of clean ammonia to markets
  - ✓ Use of hydrogen and ammonia for decarbonisation in multiple sectors
- Cooperation with relevant Canadian Engineering Companies and R&D institutions
- Mutual cooperation in Canada, Norway and other countries.

Thank you for your attention!

Please contact:

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Chairman & Market Lead Hydrogen

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[www.rein-energy.com](http://www.rein-energy.com)

[www.hydrogen-mem-tech.com](http://www.hydrogen-mem-tech.com)



FROM THOSE WHO  
DEVELOPED THE SOLUTION

TO THOSE WHO WHO  
WILL DEPEND ON IT

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

# Providing solutions for clean hydrogen from gas

ZEG Power

Hydrogen & CCS Symposium – Canada

16 February 2022

Zero Emission Gas




Z · E · G

ZEG delivers solutions for clean hydrogen production  
using the novel ZEG ICC™ Technology



# Z · E · G is a pure-play clean hydrogen company

Vision: To empower the world with clean energy

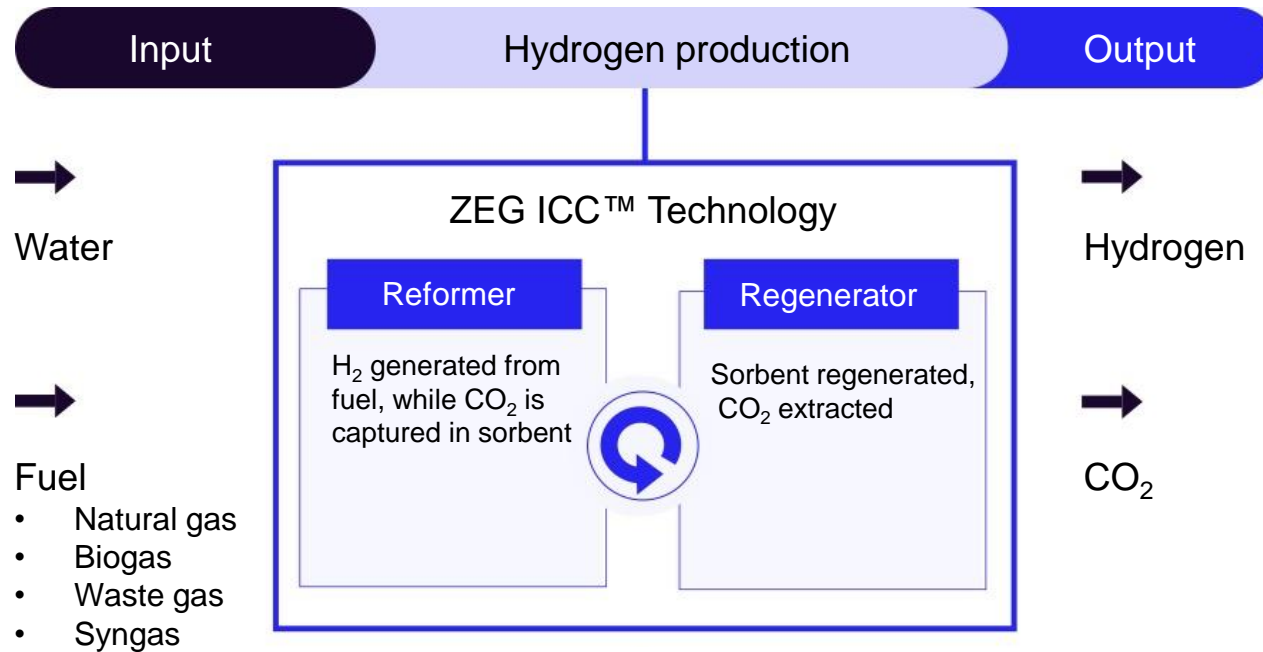
	90-99% CO <sub>2</sub> capture <sup>1</sup>		<\$1,5/kg levelized cost of hydrogen <sup>2</sup>		NOK 210m R&D since 2001
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- ZEG provides systems to produce clean hydrogen from hydrocarbon gas with proprietary integrated carbon capture technology
- ZEG's target is to provide hydrogen with the lowest cost and carbon intensity to the market, enabled by the ZEG ICC™ Technology
- The **ZEG ICC™ Technology**
  - IP protected across eight approved patent families
  - high thermal efficiency
  - verified at pilot plant scale
  - first commercial sale secured
  - roadmap to industrial scale established
  - enables EU taxonomy compliant clean hydrogen



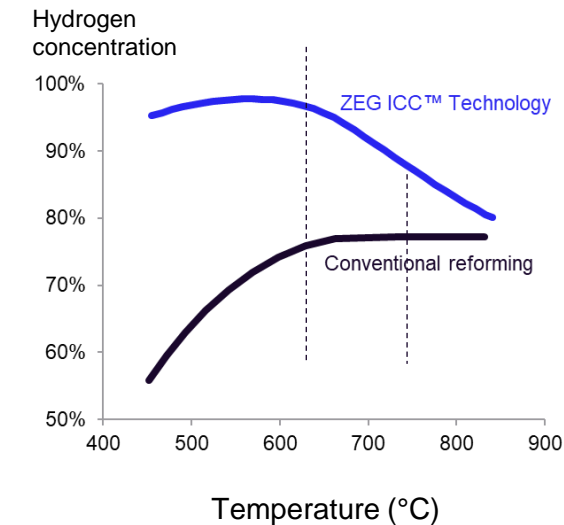
# ZEG offers a very competitive route to clean hydrogen

High yield hydrogen - integrated CO<sub>2</sub> capture



## Uniqueness of the ZEG ICC™ Technology

- Captures the CO<sub>2</sub> inside the reformer where the CO<sub>2</sub> concentration is the highest, enables high CO<sub>2</sub> capture rate
- Increases the yield of hydrogen
- Enables high thermal efficiency
- Eliminates the need for Water Gas Shift needed in traditional reforming, creating a step change reduction in footprint, driving size, CAPEX and OPEX down

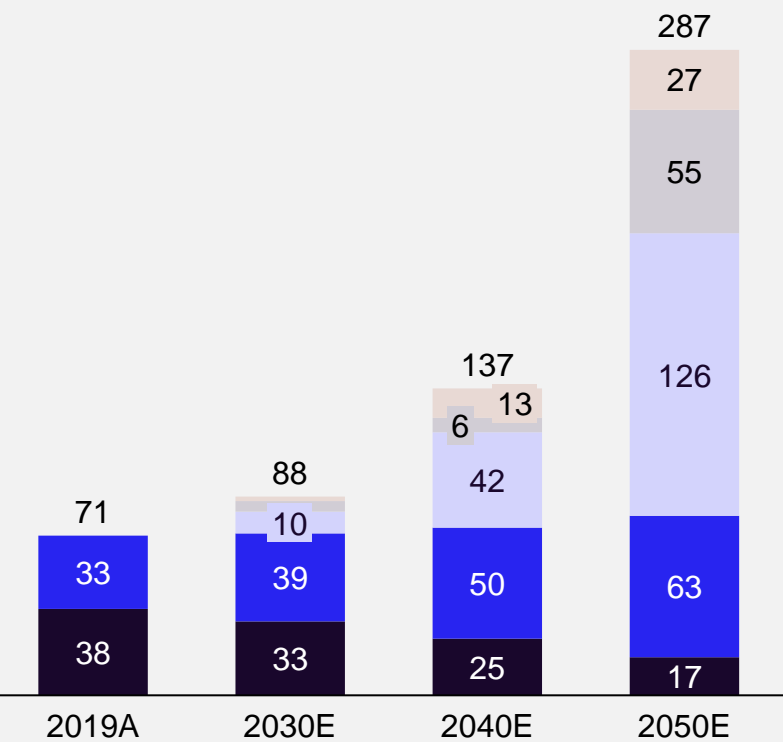





# Significant growth in hydrogen demand expected

Hydrogen identified as critical to decarbonise the economy

## Global hydrogen demand by application

Hydrogen (million tonnes)

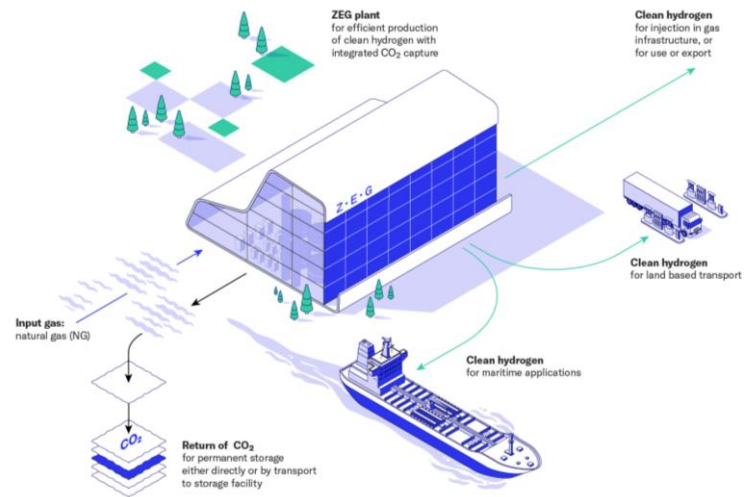


Legend	CAGR '19-'50	CAGR '30-'50	Key comments
Building heat and power	NA	14%	 Hydrogen will play an important role in a range of industrial applications where fossil fuels are used today
Industry heat and power	NA	13%	
Transportation <sup>1</sup>	NA	14%	 Transportation is expected to be a key demand driver, particularly in heavy duty transport at road, rail and sea
Industry	2%	2%	 Hydrogen is the most affordable solution to decarbonise hard to abate industries such as steel production
Refining	-3%	-3%	

# ZEG promotes two solutions to the market

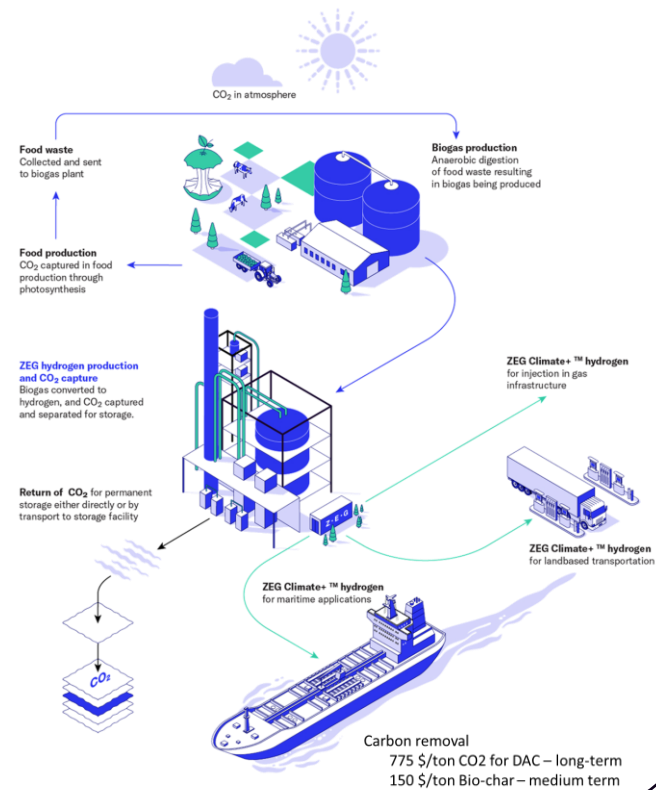
## ZEG Clean Hydrogen Solution

Sustainably unlocking the value of natural gas



## ZEG Climate+ Solution

Enabling carbon removal



# On a clear path towards larger-scale plant realisation

ZEG upscaling and development pipeline

1

**ZEG H1 – H5 product platform**



2

**ZEG H10 – H50 product platform**



Capacity

1-5 metric tonne hydrogen per day

10-50 metric tonnes hydrogen per day



Turnkey delivery

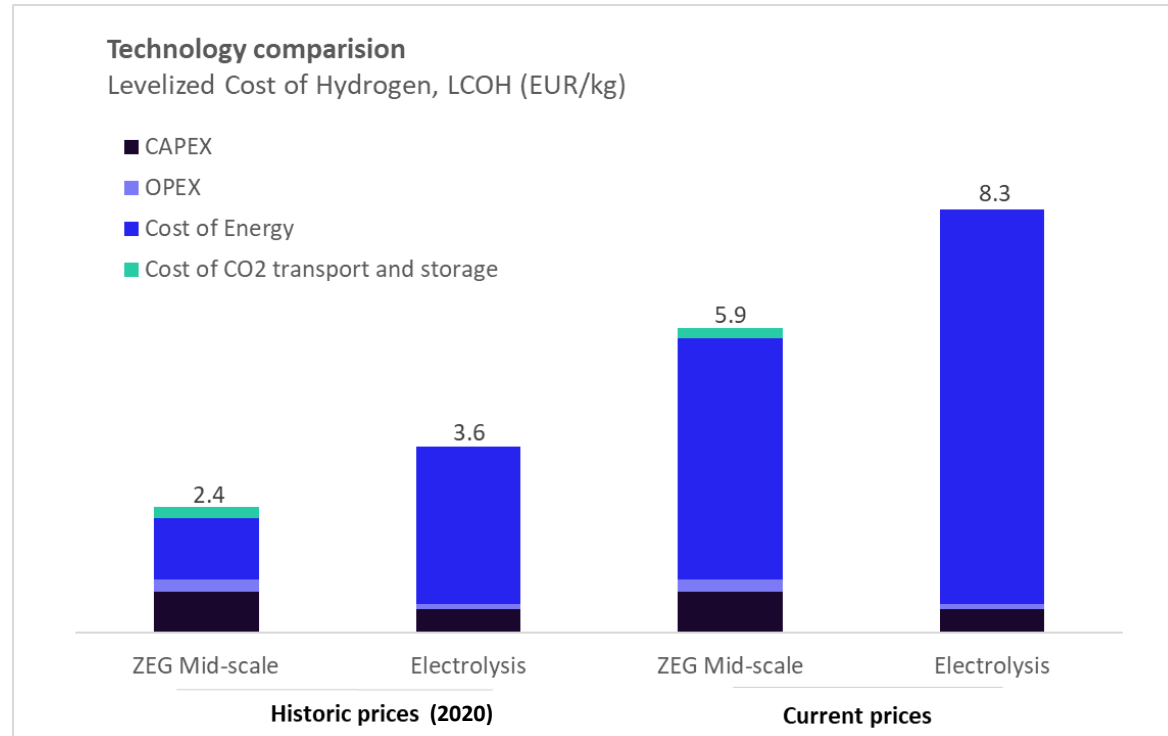
Q4 2022 and onwards  
(Project in execution)

Q4 2024 and onwards  
(LOI entered for first-of-a-kind H15 plant,  
NRC grant received 2021 with partners)



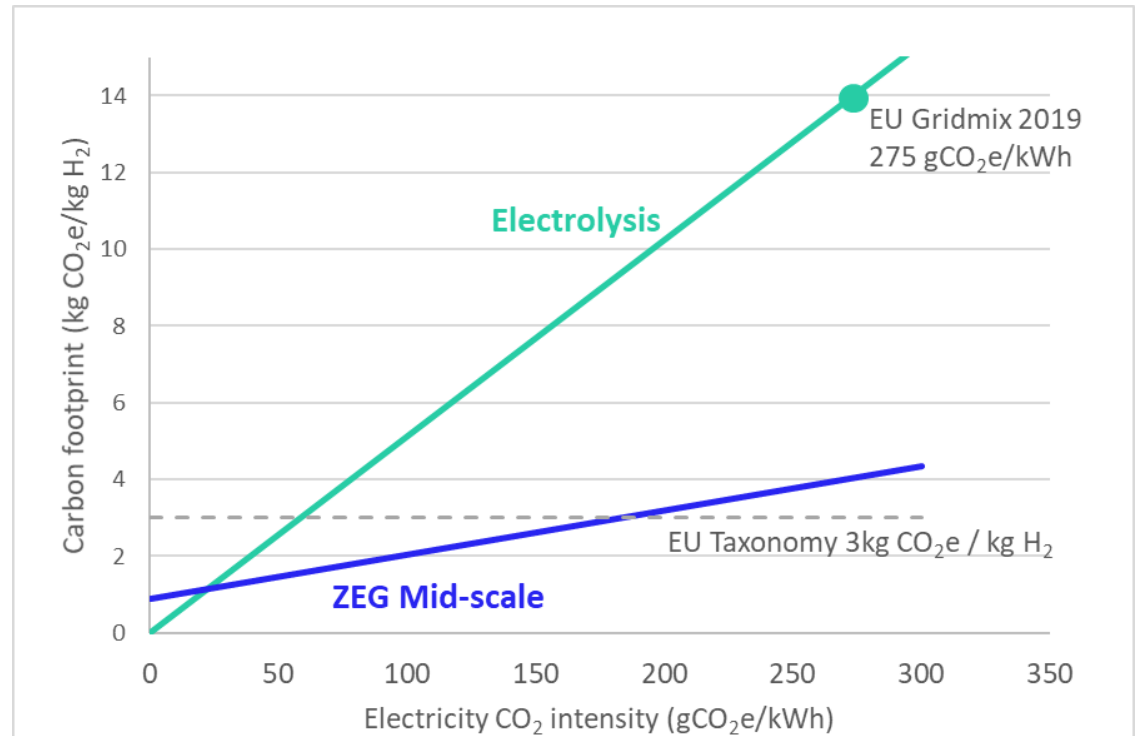
# ZEG provides cost-efficient and clean hydrogen

Hydrogen at competitive price...



Source: Company estimates. Historic Energy prices (2020): Natural gas 12 EUR/MWh, Electricity: 60 EUR/MWh. Current Energy prices: Natural gas EUR 70/MWh, Electricity: 150 EUR/MWh. Cost of carbon transport and storage 25 EUR/ton.

...and with low carbon footprint



Source: DNV GL: GHG Emissions from hydrogen production using ZEG Power Technology (Dec 2021) and company estimates.

# First EU taxonomy-compliant blue hydrogen plant

- First customer – H2 Production AS, a subsidiary of CCB Energy Holding AS - a Norwegian clean industry hub developer
- The ZEG H1 plant has ~1 ton/day hydrogen production capacity
- NOK 77m of Enova grant funding awarded to the project
- Construction underway with EPC partner Zeton
- The ZEG H1 plant will be production ready in Q4 2022 and commissioned in early 2023
- Letter of intent signed for further expansion on same site with a ZEG H15 plant with ~15 ton/day hydrogen production capacity

## Får 77 Enova-millioner til karbonfangst

ZEG Power og CBB får tildelt støtte fra Enova til utslippsfri hydrogenproduksjon og karbonfangst.

## ZEG Power and CCB enters into strategic cooperation to establish cost efficient, clean hydrogen production from gas at Kollsnes

September 19, 2019 / in Aktuelt @en. News / by zegpower

[Bergen 19 September 2019] In accordance with a mutual desire to promote cost efficient, clean and sustainable energy, ZEG Power and CCB today announced the signing of a Letter of Intent (LoI).



**H2 Production AS**

Customer of first ZEG H1



**Q4 2022**

Production ready



**ZETON**

Signed EPC contract



**NOK 77m**

Supported by Enova grant

# First commercial ZEG plant located at a sweet spot for blue hydrogen

Proximity to Northern Lights CO<sub>2</sub> storage, natural gas terminal and local hydrogen market

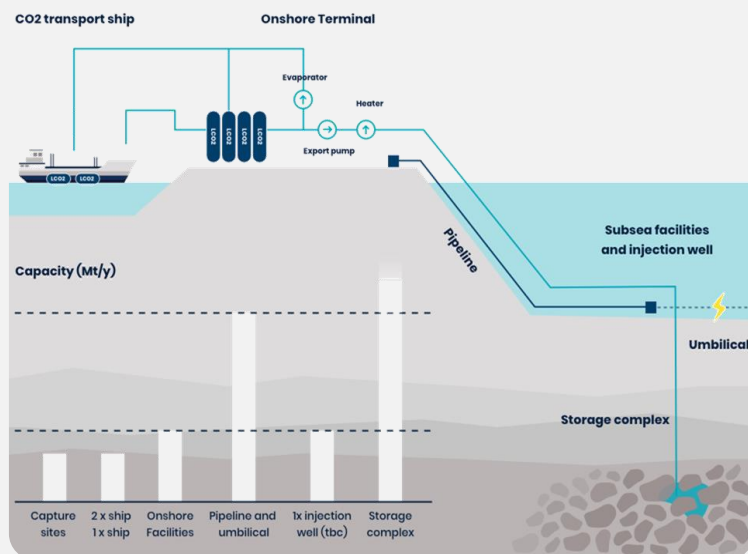
## Northern lights project



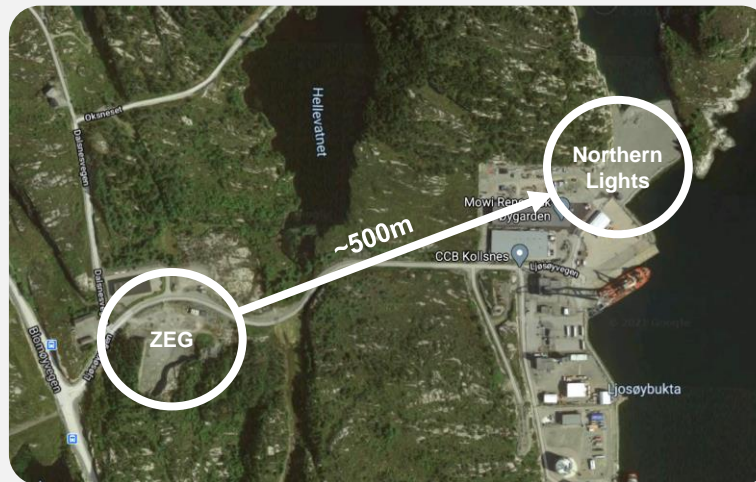
## Proximity to CO<sub>2</sub> offtake



## Emerging local hydrogen market



CCB Energy Park, Kollsnes is also the location for a large-scale CO<sub>2</sub> storage ("Northern lights") to be operational from 2024, a highly strategic national, full-scale CCS led by Equinor, Shell and Total and the Norwegian Government



The CO<sub>2</sub> will be captured and stored through the Northern Lights' CO<sub>2</sub> storage terminal, located only ~500m away from the ZEG hydrogen production site



The combination of a strong local market for hydrogen and the opportunity to store CO<sub>2</sub> on site means CCB Energy Park is the unique location for clean hydrogen production

# Sustainability is the core of ZEG Power

The UN Sustainable Development Goals are the blueprint to achieve a better and more sustainable future for all

- ZEG unlocks the energy of natural gas
  - Goal 7: affordable and clean energy
- ZEG is based on patented technology for clean hydrogen production with integrated CO<sub>2</sub> capture
  - Goal 9: industry, innovation and infrastructure
- ZEG uses natural sorbent to capture CO<sub>2</sub> with no toxic emissions to air or water
  - Goal 12: responsible consumption and production
- ZEG works to achieve carbon removal, using biogas as feedstock combined with CCS
  - Goal 13: climate action





Z • E • G

Now let's make  
a change



# Brevik CCS

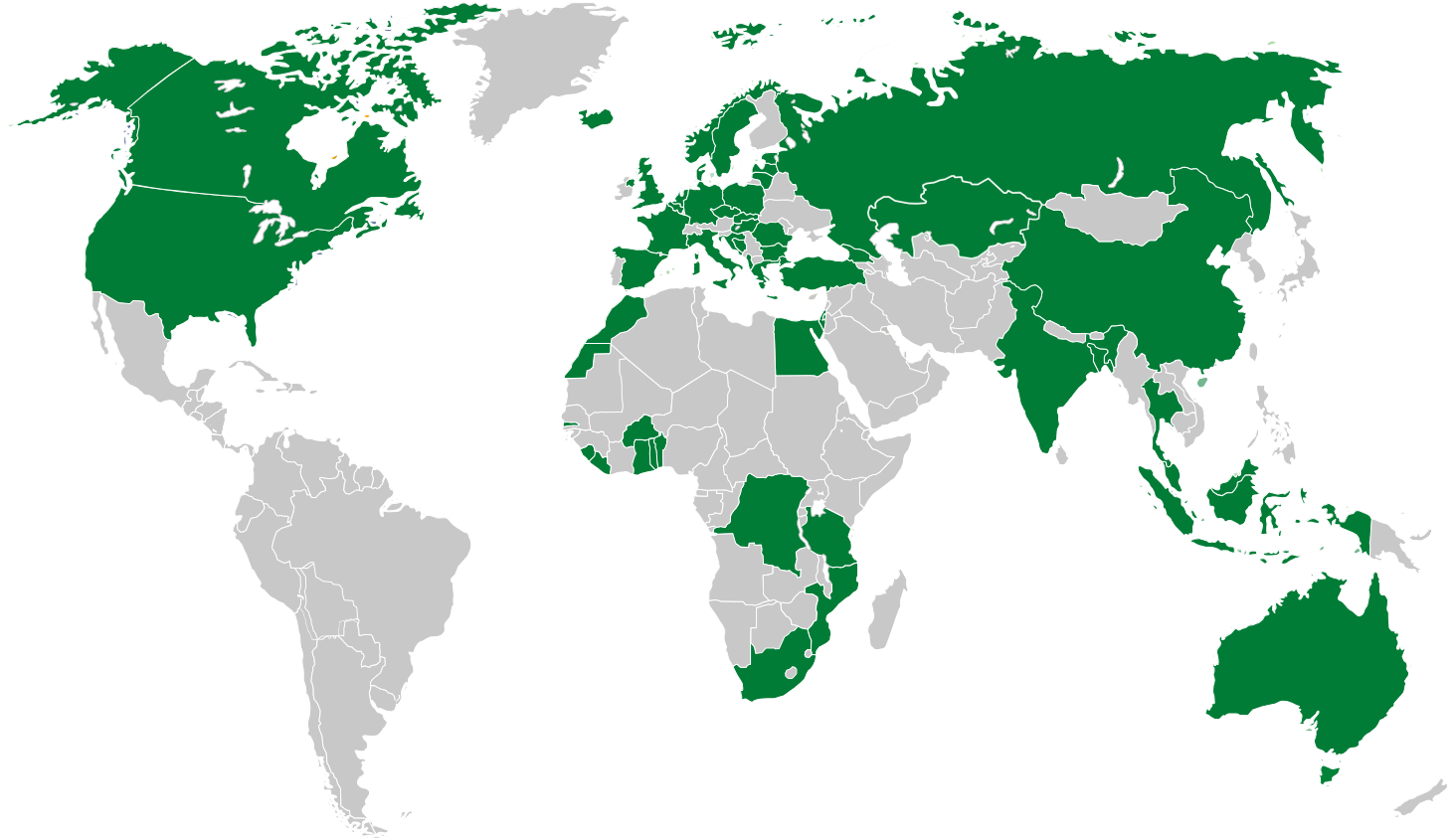
Realizing full-scale CO<sub>2</sub> capture at a cement plant

Per Brevik, Sustainability director HC NE  
16 February 2022

# HC is the largest vertically integrated building materials producer in the world

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- 53,000 employees
- Leading market positions in aggregates, cement, and ready-mixed concrete
- 3,000 production sites in more than 50 countries
- Cement capacity 184 mt (incl. joint ventures)
- Aggregates resources and reserves 19.2 bnt

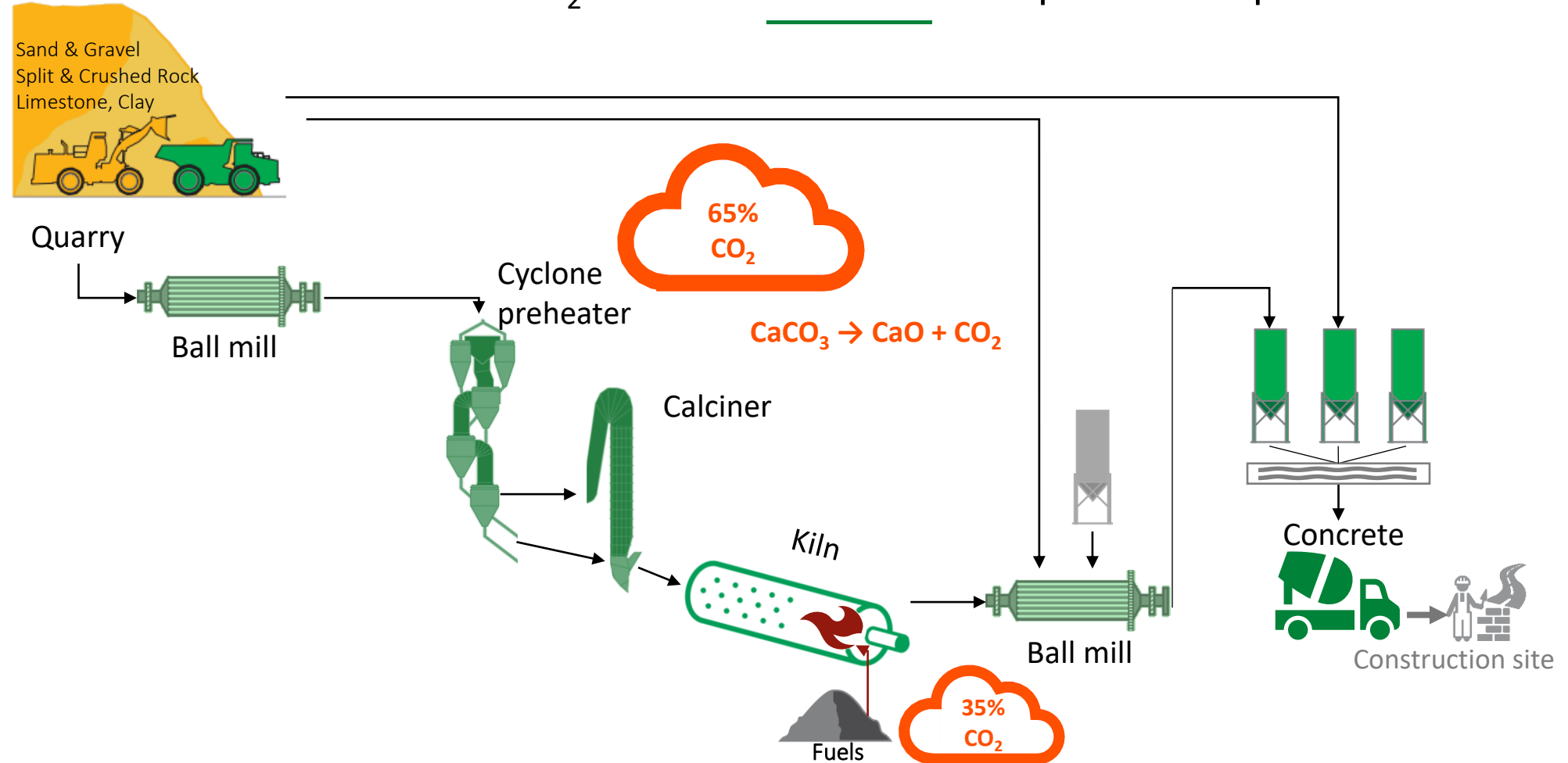




# Concrete is essential for building a sustainable society



# 65% of the CO<sub>2</sub> emissions from cement production process



## CO<sub>2</sub> capture Brevik

Demonstration plant:

400.000 tons per year

- ✓ 55 tons CO<sub>2</sub> per hour
- ✓ 50% capture rate

Simultaneously building a new factory whilst maintaining full operational capacity in the current plant

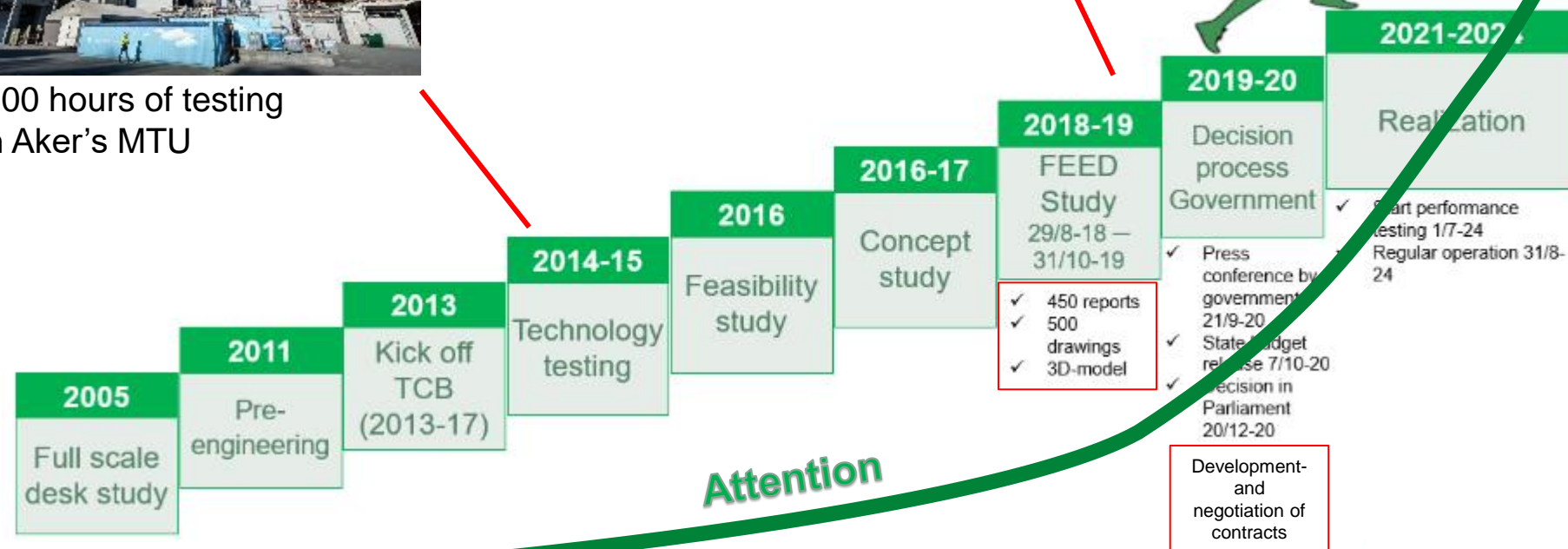




>7500 hours of testing with Aker's MTU



3000 hours of testing with pilot boiler



# We have started the journey towards 2024

Started  
2021



Demolition phase



Building phase



Testing phase



2024

Estimated view July 2024





# Brevik CCS will be the first in a row of carbon capture plant!

## **Brevik, Norge**

*Bygging har startet*

*Skal fange 400 000 tonn CO<sub>2</sub>/årlig*



## **Slite, Gotland, Sverige**

*Feasibility study started*

*Kan potensielt fange 1 500 000 tonn CO<sub>2</sub>/årlig*



## **Lixhe, Belgia.**

*Fanger potensielt 1 200 000 tonn CO<sub>2</sub>/år*



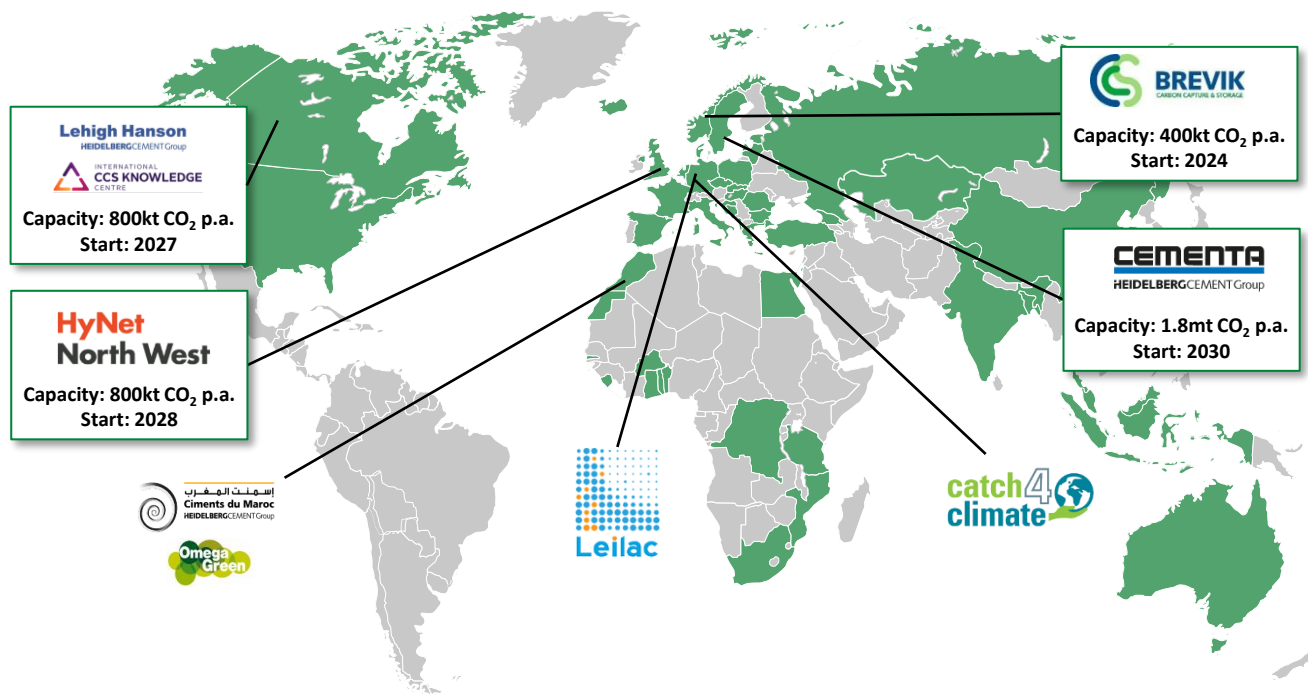
## **Hannover, Tyskland**

*Pre-feasibility studie*

*Kan potensielt fange 640 000 tonn CO<sub>2</sub>/år*



We target up to 10mt\* of CO<sub>2</sub> reduction with our current CCU/S projects until 2030



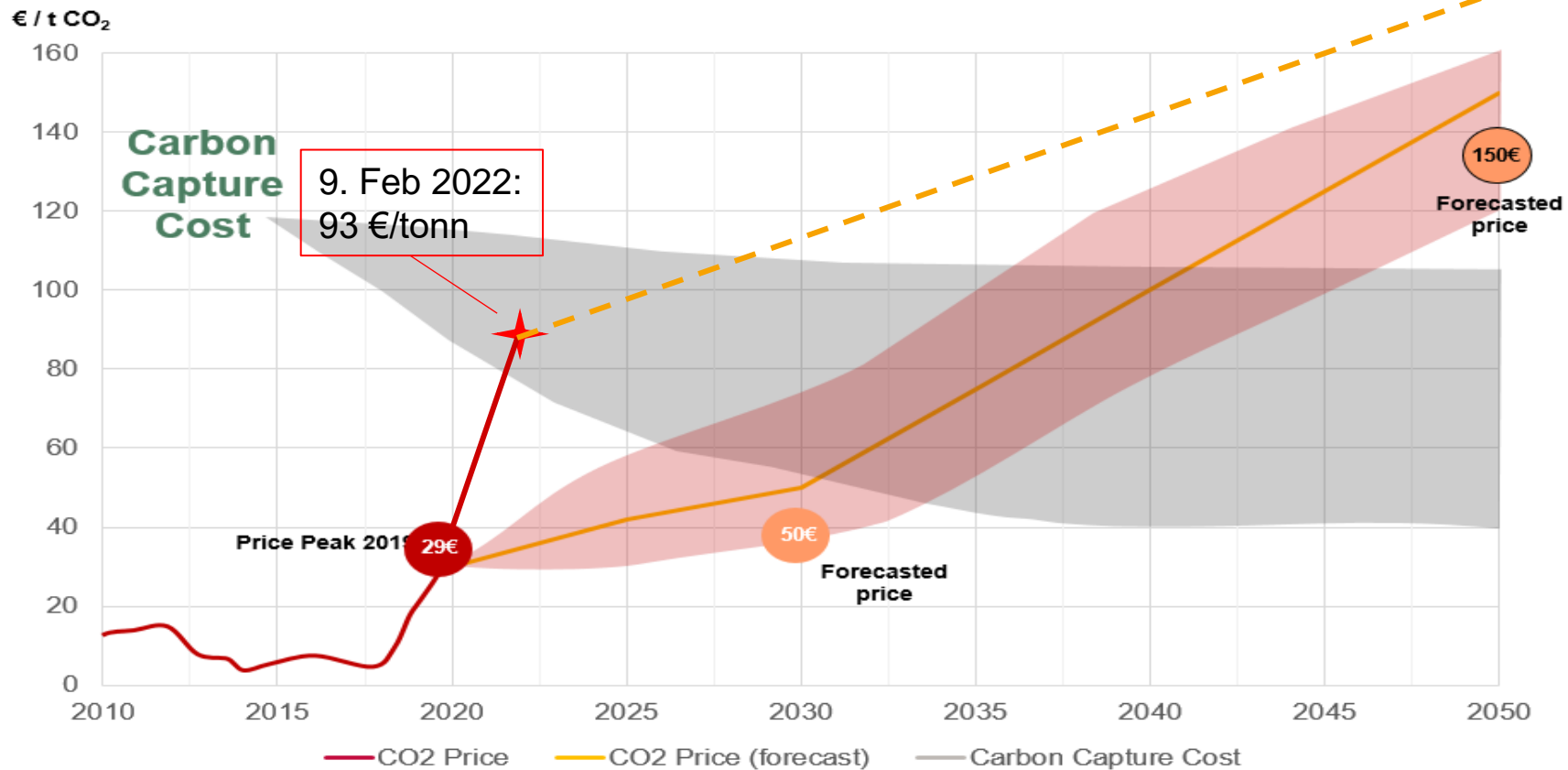
- Targeting ~4mt\*\* CO<sub>2</sub> reduction p.a. from 2030 with our announced CCU/S projects
- Further CCS projects with significant CO<sub>2</sub> reduction potential in Eastern Europe in the pipeline
- We are the frontrunner in the industrial scale-up of CCU/S technologies in the sector

\* Include accumulated contribution from CCU/S projects Brevik, Edmonton, Slite, and HyNet from 2024 to 2030

\*\* Include yearly contribution from CCU/S projects Brevik, Edmonton, Slite, and HyNet as of 2030



## Cost of capturing vs cost of emitting ?





**NORCEM**  
HEIDELBERGCEMENT Group

Thank you for your attention

Questions?



AKER CARBON  
CAPTURE

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# Technology for medium and large scale carbon capture

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February 16, 2022

Jon Christopher Knudsen, Chief Commercial Officer





## Our mission

Enabling carbon removals from industries  
and energy solutions



# Our values

**Working together**

**Bold innovation**

**Doing the right thing**

# Aker Carbon Capture in brief

**Pure play** carbon capture company delivering ready-to-use capture plants

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**Best-in-class HSE** friendly solvent and other patented plant technologies for better all-round plant performance

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**Validated and certified** market-leading proprietary technology with more than 50,000 operating hours

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# Ongoing – EPC projects in carbon capture



Twence  
W2E Hengelo - CCU

Signed contract 100,000 TPA - with options  
CO<sub>2</sub> distributed by trucks to local greenhouses  
CO<sub>2</sub> will boost greenhouse production = CCU  
Ongoing project, planned operation in 2023



Norcem HeidelbergCement  
Brevik CCS

400,000 TPA CO<sub>2</sub> capture and liquefaction plant  
Equivalent to emissions from 205,000 fossil cars  
CO<sub>2</sub> transport by ship to permanent storage  
Ongoing EPC project, planned operation in 2024



# 10 in 25

## Ambitious goals for the future

Secure contracts to  
capture **10** million  
tonnes per annum CO<sub>2</sub>  
by **2025**



Waste-to-  
energy



Cement



Gas-to-  
power

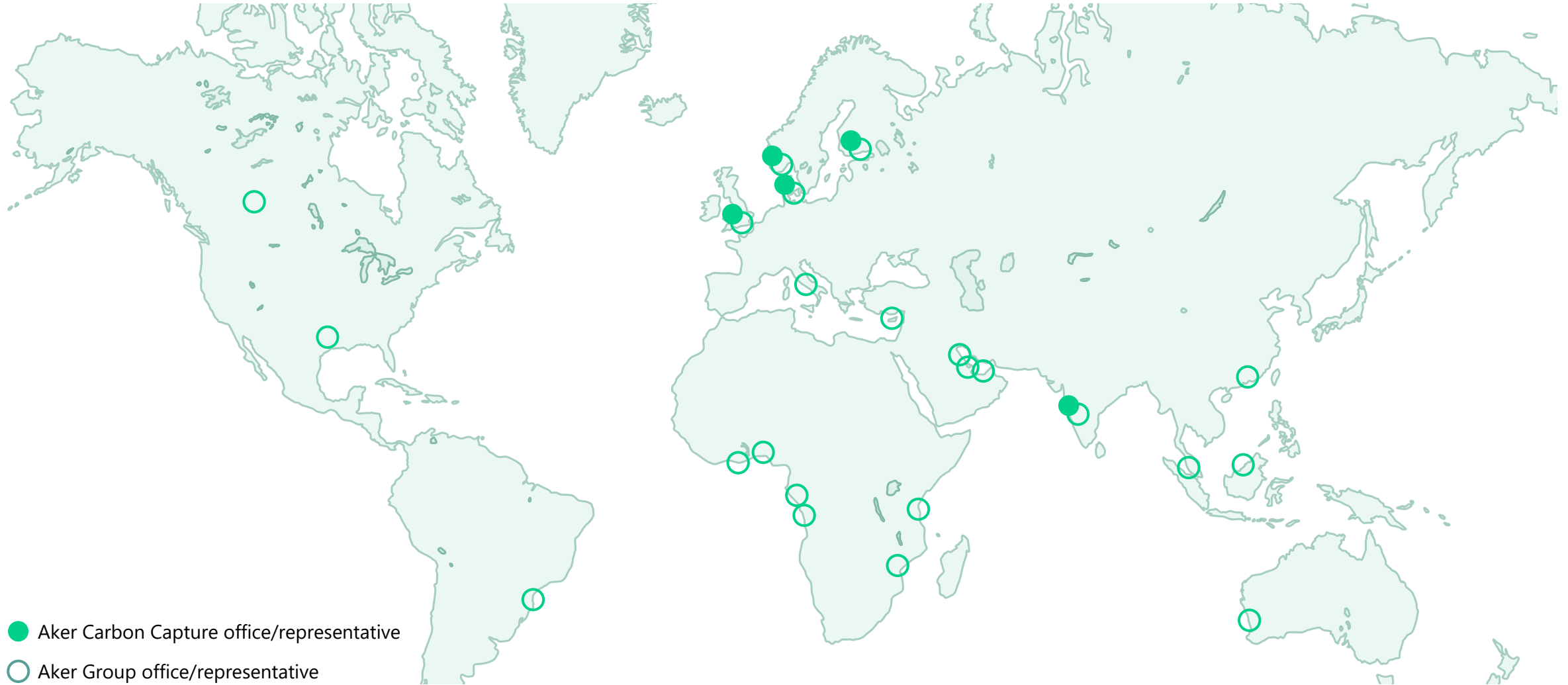


Hydrogen

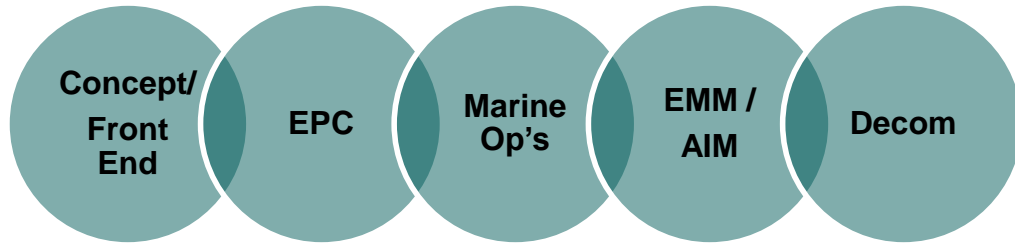




# Based in Norway, global reach through the Aker Group



# Over 30 years in Canada...



## ExxonMobil Hibernia

- GBS
- Topsides



## ExxonMobil Sable

- Topsides
- Jackets
- Subsea



## Cenovus (Husky) Energy SeaRose FPSO

- EPCI Topside
- EMM Frame Agr.
- Life Extension



## ExxonMobil Hebron

- GBS
- Marine
- EMM FA



## ExxonMobil Sable Decommission Studies



## Ovintiv / SBM Deep Panuke

- Decom
- PFC Transport



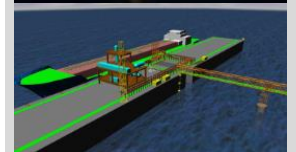
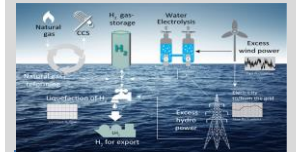
## Cenovus (Husky) Energy West White Rose Development

- Marine Ops T&I
- HUC



## Studies

- H2+CCS
- Floaters
- LNG



## Equinor Bay du Nord

- Concept / Pre-FEED



1990-1997

1998-2001

2002-

2010-

2016-2020

2017-ongoing

2018-2022

# Aker and Canada

- Continuous presence in Canada with Aker Solutions for over 30 years beginning with development of the Hibernia project offshore Newfoundland
- Based in St. John's with over 180 skilled resources
- Effective integration with the international Aker network
- Solutions provider to energy industry in both eastern and western Canada
  - Engineering, Procurement, Construction
  - Concept & Feasibility Studies
  - Low Carbon Solutions
  - Marine Operations
  - Hook-Up, Commissioning & Decommissioning
  - Asset Integrity
- Active energy transition studies including *Feasibility of Blue Hydrogen Production in Canada's Offshore Oil and Gas Industry*

## Strategic Integration Provider for Energy Transition Developments

# Experience through 20+ years





# Our three product offers

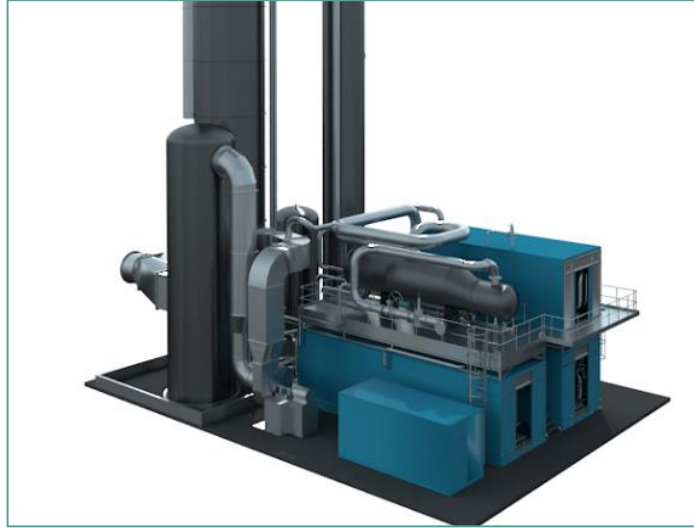


## Big Catch

Launched: 1996

Capacity: > 400,000 tonnes/year

- Made to order
- ~30-36 months delivery time<sup>1</sup>
- Larger footprint
- Using bulk materials – cost efficient
- Retrofit potential



## Just Catch™

Launched: 2018

Capacity: 40,000 & 100,000 tonnes/year

- Modularized and cost efficient
- ~15 months delivery time<sup>1</sup>
- Easy transport and installation
- Compact design – 25m x 18m
- 100% automated



## Offshore Just Catch™

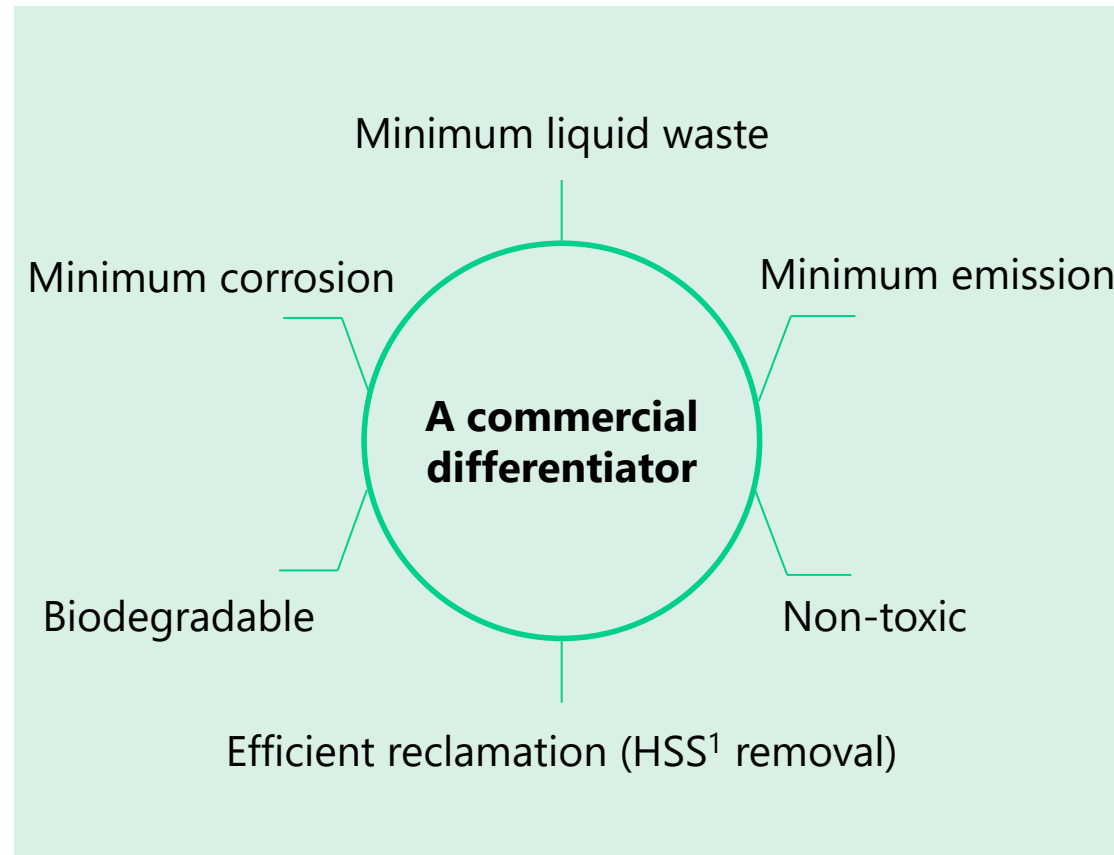
Launched: 2019

Capacity: 120 – 360,000 tonnes/year

- Modularized and cost efficient
- ~20 – 24 months delivery time<sup>1</sup>
- Self-contained system
- Compact design
- Retrofit potential

# Unique HSE profile – a key differentiator

- High CO<sub>2</sub> capture rate (~90%) and Energy efficient reclamation



Regular amine solvent: High solvent degradation (discoloring) in operation on coal flue gas



ACC S26 solvent - no discoloration



# Carbon capture phase in the value chain

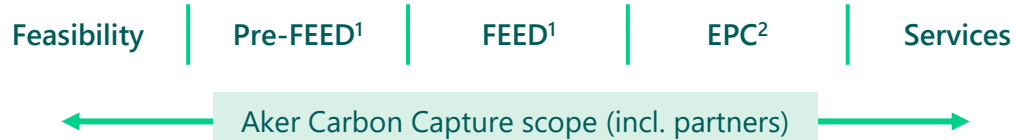
## Carbon capture

## Transportation

## Storage or utilisation

### Key Focus

Supporting customers throughout plant lifecycle



Early engagement improves integration, capture and conditioning in selected carbon capture solution

### Supporting Specialist Competence

- Significant knowledge of the entire carbon capture, utilisation and storage value chain
- Strong competence within utilisation areas (e.g. greenhouse, methanol and fuels) and storage solutions, including EOR<sup>3</sup>



CO<sub>2</sub> capture



Liquefaction  
(CO<sub>2</sub> compression)



Intermediate  
storage  
(at site)



Land- and sea-  
based  
transportation



Other intermediate  
storage(s)

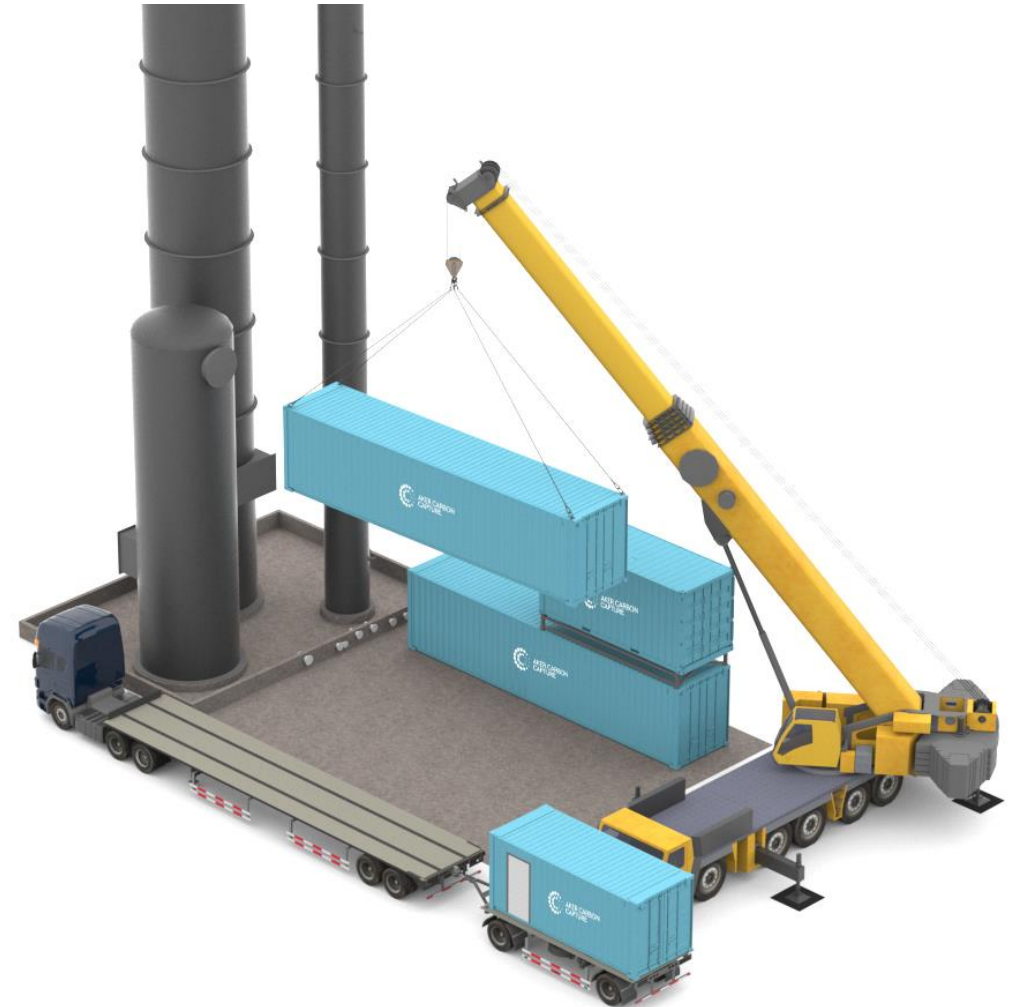


Utilization/  
permanent storage



# A new modular carbon capture plant

- Capture capacity up to about 100,000 tons CO<sub>2</sub> per year
- Just Catch is delivered as a complete package
- The plant is fully automated (remote control)
- A complete plant normally contains three elements:
  - 4 standard containers (2x20ft & 2x40ft)
  - 3 columns, reboiler and fan
  - "Green" and robust solvent
- Delivery time from order about 15 months
- Basic principles:
  - Standard P&ID's
  - Standard layout configuration (3D-model)
  - Standard equipped containers
  - Standard concrete foundation



# One technology – several offerings

## Key offerings



### Big Catch™

Capacity: > 400,000 tonnes/year

- Made to order
- ~30-36 months delivery time<sup>1</sup>
- Larger footprint
- Using bulk materials – cost efficient
- Retrofit potential



### Just Catch™

Capacity: 40,000 and 100,000 tonnes/year

- Modularized and cost efficient
- ~15 months delivery time
- Easy transport and installation
- Compact design – 25m x 20m
- 100% automated

## Delivery models

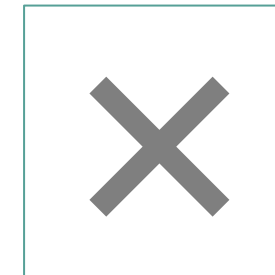
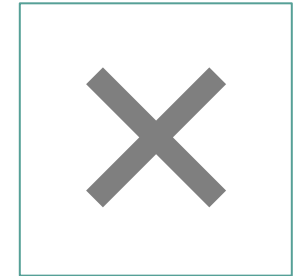
### EPC



### License and key equipment



### Carbon Capture as a Service



# Carbon Capture as a Service: Carbon capture made easy™

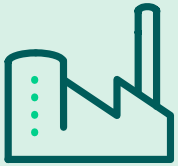
From a complex management of the full CCS value chain...



Interface, contracts and risk across the full CCS life-cycle



Financing



Carbon Capture



Liquefaction



Temporary storage



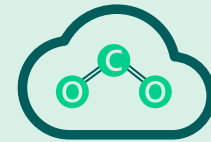
Transportation



Permanent storage



...to carbon capture made easy



**CARBON CAPTURE AS A SERVICE**  
Carbon capture made easy™





Thank you!



**Jon Christopher Knudsen**  
Chief Commercial Officer

Aker Carbon Capture Norway AS

Phone: +47 67 55 81 10 Mobile: +47 930 33 599

E-mail: [jon.c.knudsen@akercarboncapture.com](mailto:jon.c.knudsen@akercarboncapture.com)

[www.akercarboncapture.com](http://www.akercarboncapture.com)

# Fortum Oslo Varme's CCS project

From waste-to-energy to negative emissions



Jannicke Gerner Bjerås  
Director CCS

Fortum Oslo Varme



## Energy sources:



EXCESS  
WASTE HEAT



ELECTRICITY



HEATPUMP/  
SEWER



DATACENTER



WOOD PELLET



BIOFUEL

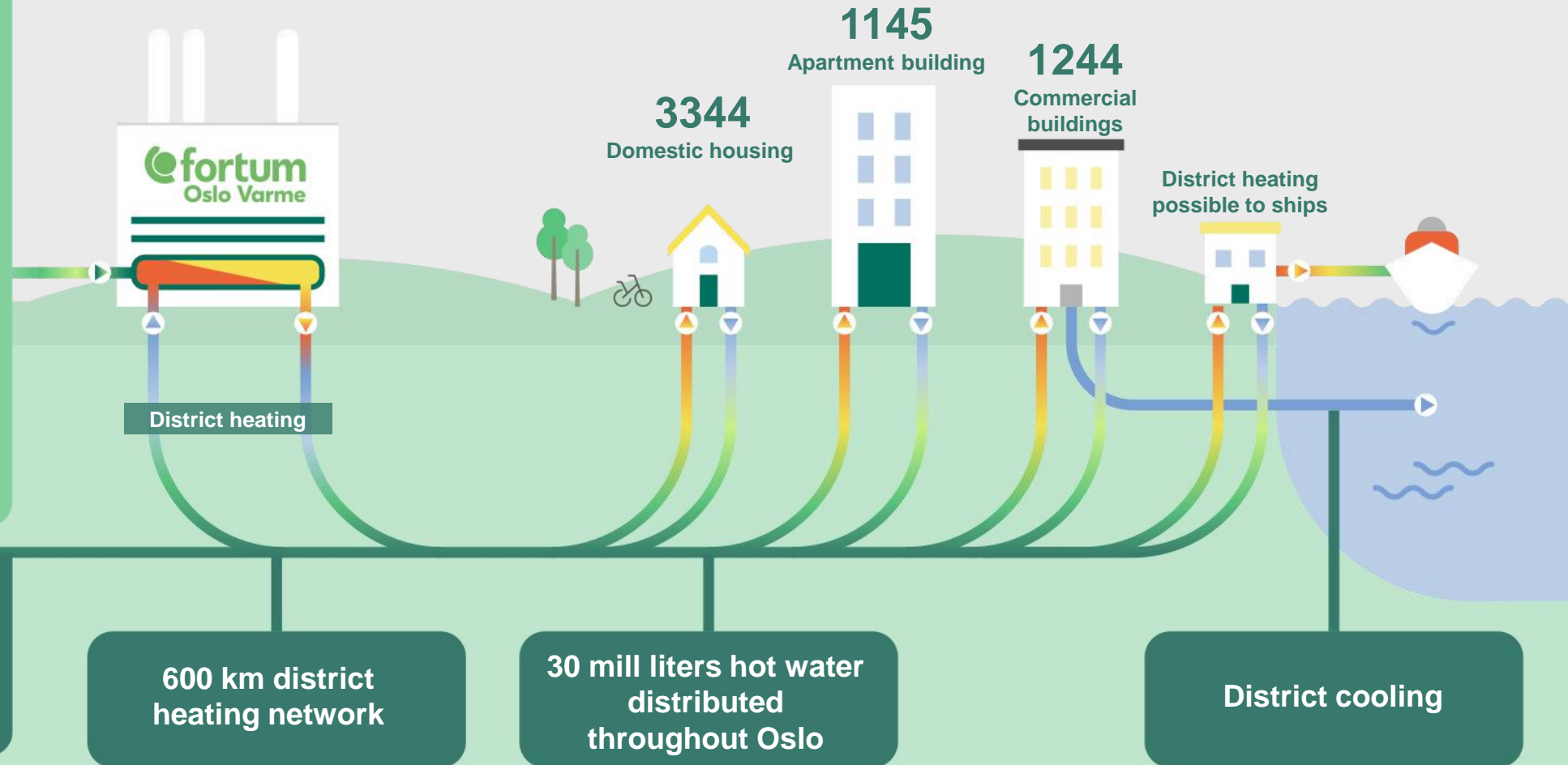


FOSSIL OIL



LNG

# Fortum Oslo Varme AS



ENERGY RECOVERY  
FROM 400.000 TONNES  
WASTE/ YEAR

600 km district  
heating network

30 mill liters hot water  
distributed  
throughout Oslo

District cooling

Production approx  
**152 GWh**  
electricity (est. 200)

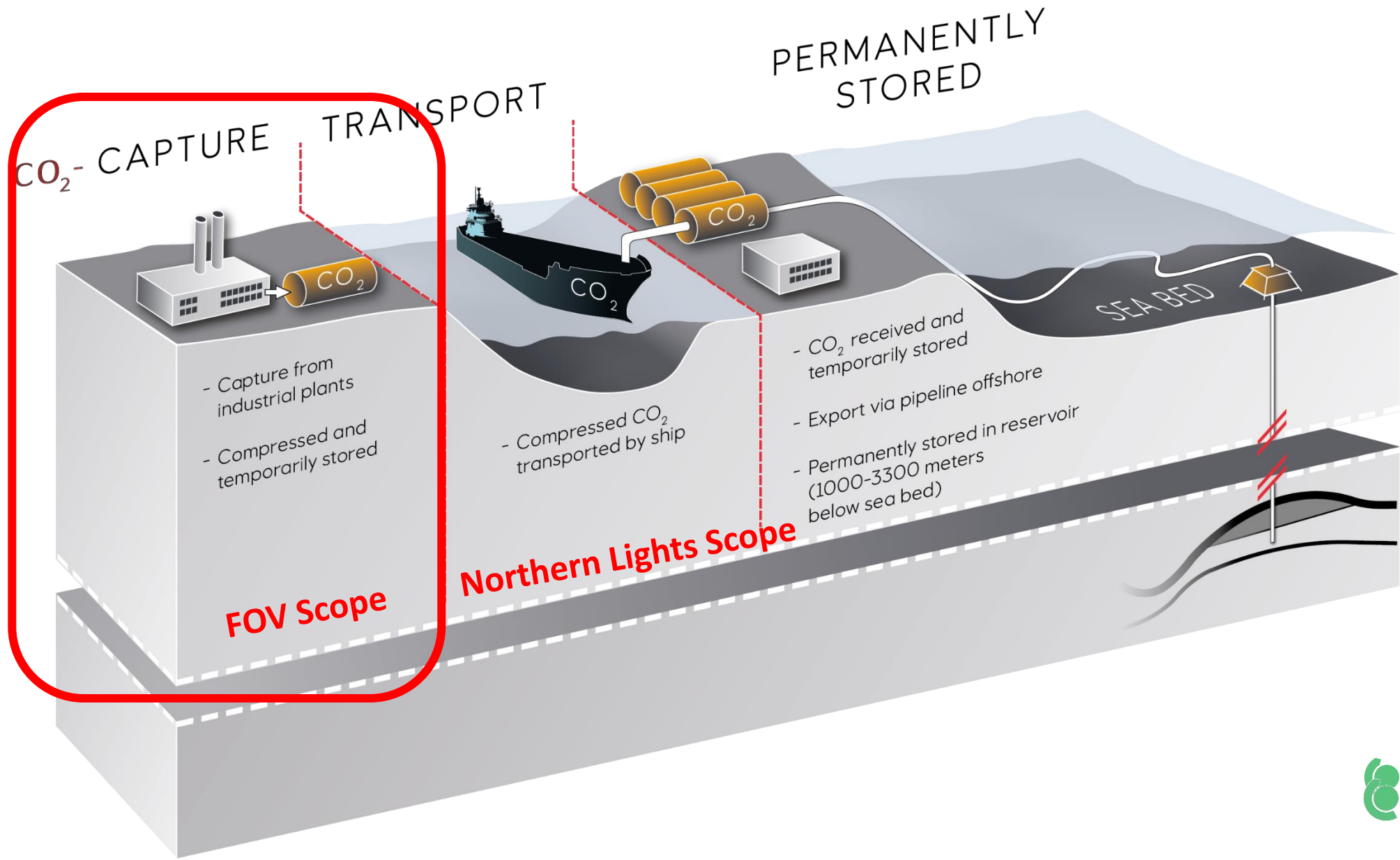




# World's first full-scale CCS project on Waste-to-Energy

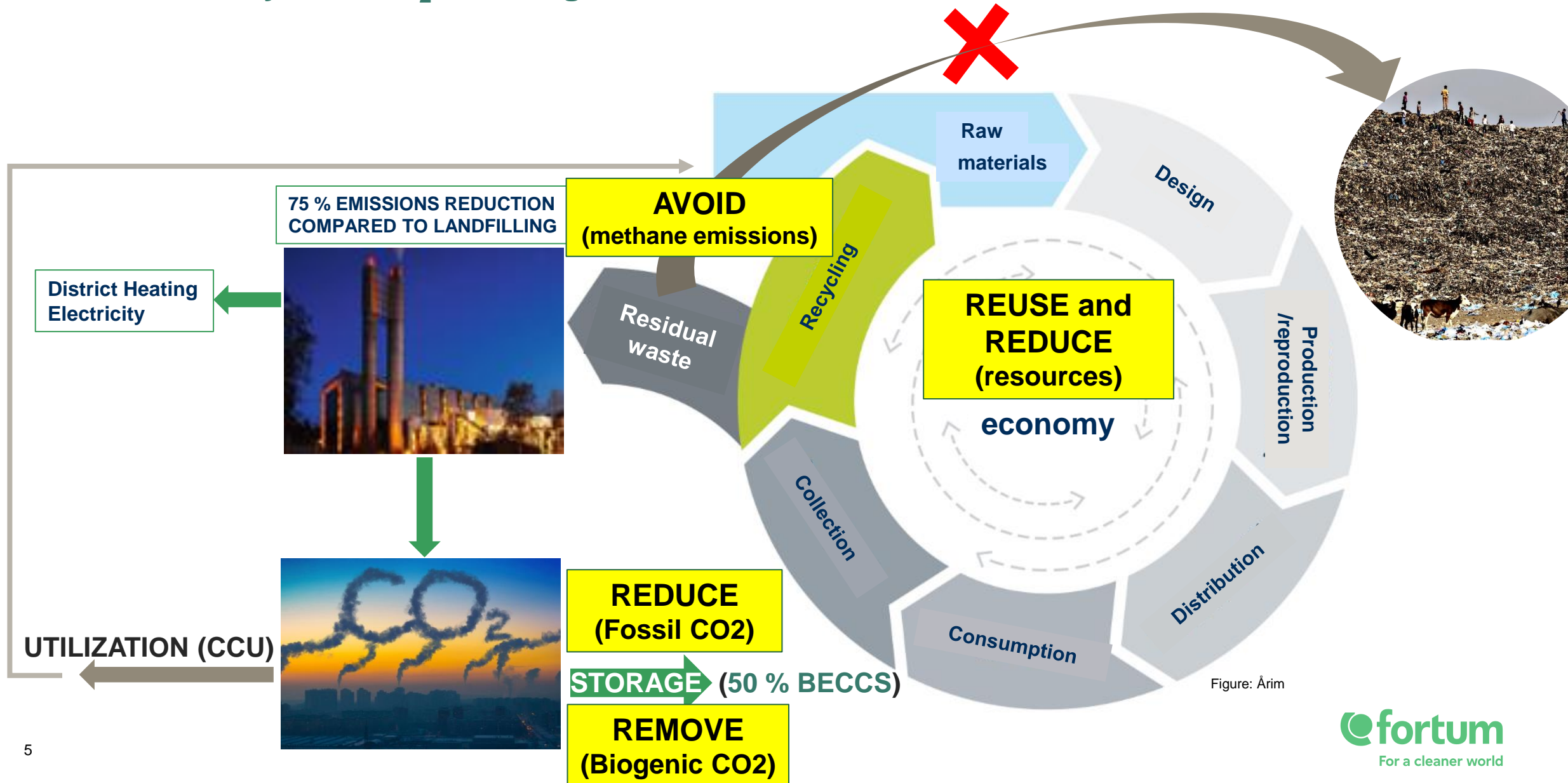
- Part of **Longship** CCS project; permanent geological storage below seabed
- **400 000** tons CO<sub>2</sub>/year, **90%** CO<sub>2</sub> capture
- CCS on Waste-to-Energy provides **50 % CDR**
- Studies completed **2015-2019**
- Demonstrates truck transport of CO<sub>2</sub> to port
- Successful pilot testing on **real flue gas**, new test period with **Shell amine** ongoing





# Avoid, reduce, reuse, recycle - and remove!

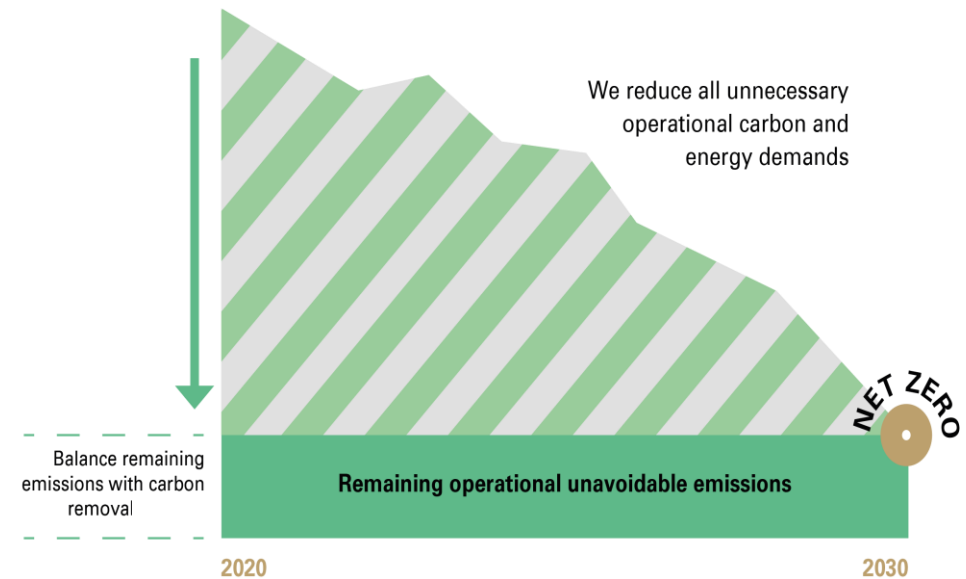
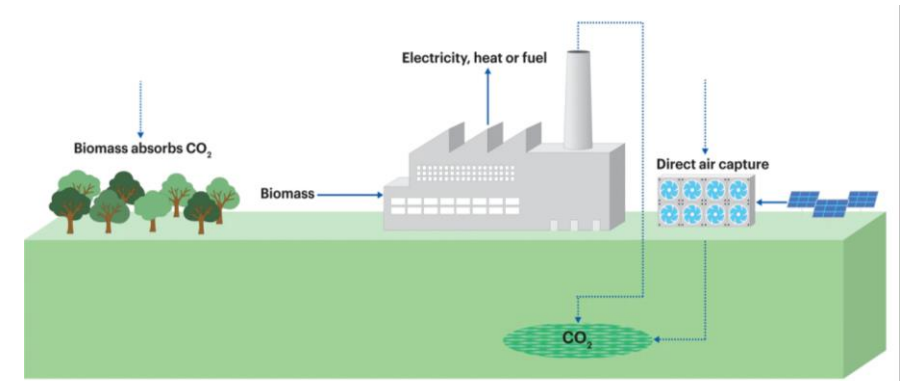
Circular economy with CO<sub>2</sub> handling on end-solution for waste





# The potential of Carbon removal

- **BECCS**; capture and permanent storage of CO<sub>2</sub> from processes where biomass is burned to generate energy
- No regulatory mechanism in place to encourage the deployment of technology-based removals (BECCS, DACS)
- Countries, cities and companies committing to **net zero** by 2050
- Private initiatives and voluntary marketplaces for CO<sub>2</sub> removals
- EU legislation/framework for certifying carbon removal methods (CORC) in 2022. Anticipated to address
  - Permanence
  - Sustainability
  - Single counting of removal



# Thank you

[Jannicke.Bjerkas@fortum.com](mailto:Jannicke.Bjerkas@fortum.com)

# ROCKSOLID™ THERMITE-BASED BARRIER

CHRISTIAN ROSNES



# DISCLAIMER AND LEGAL NOTE

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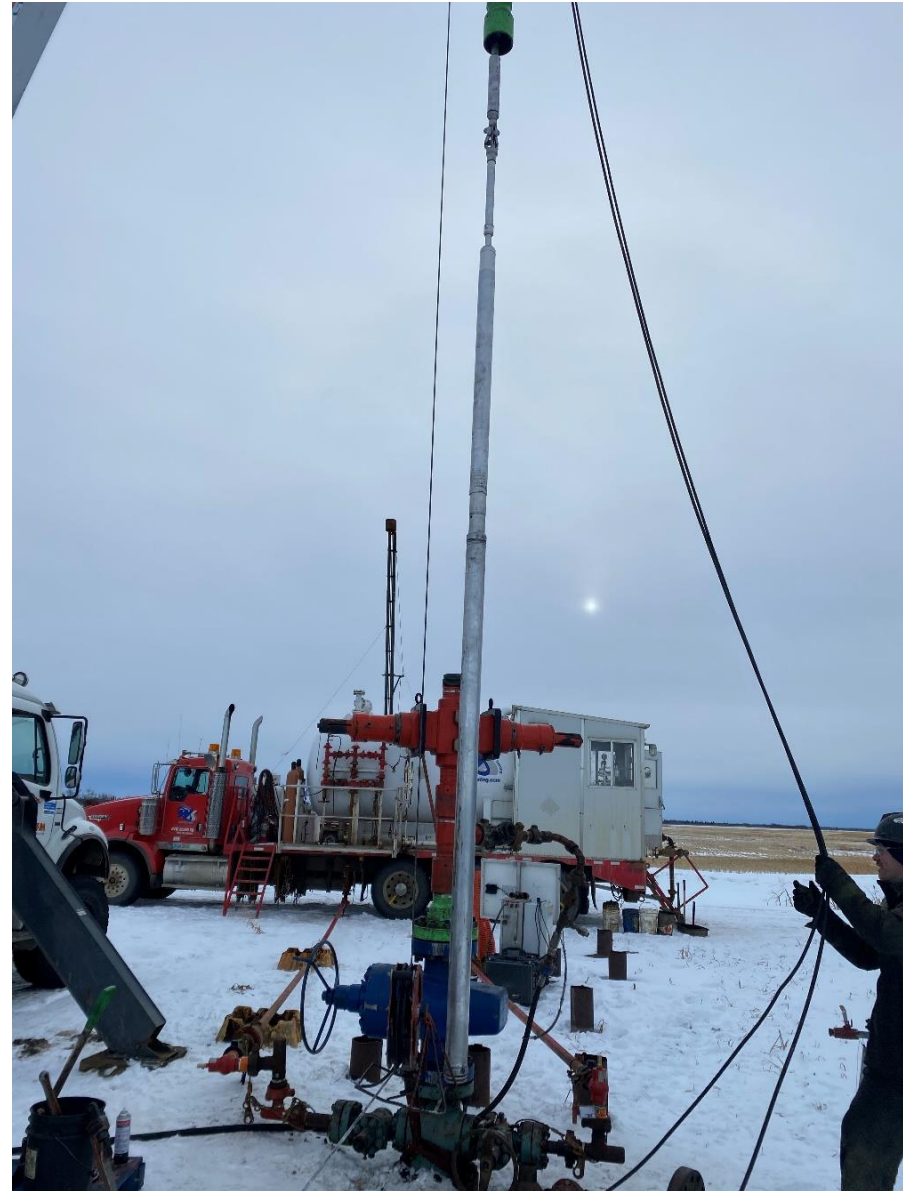
*This Presentation contains summary information about Interwell AS ("Interwell"), its affiliates, and their activities as at the date of this Presentation. The information in this Presentation is of general background, is provided "as is" and does not purport to be complete. The information is provided for information purposes only and Interwell disclaims any liability or responsibility arising therefrom.*

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# AGENDA

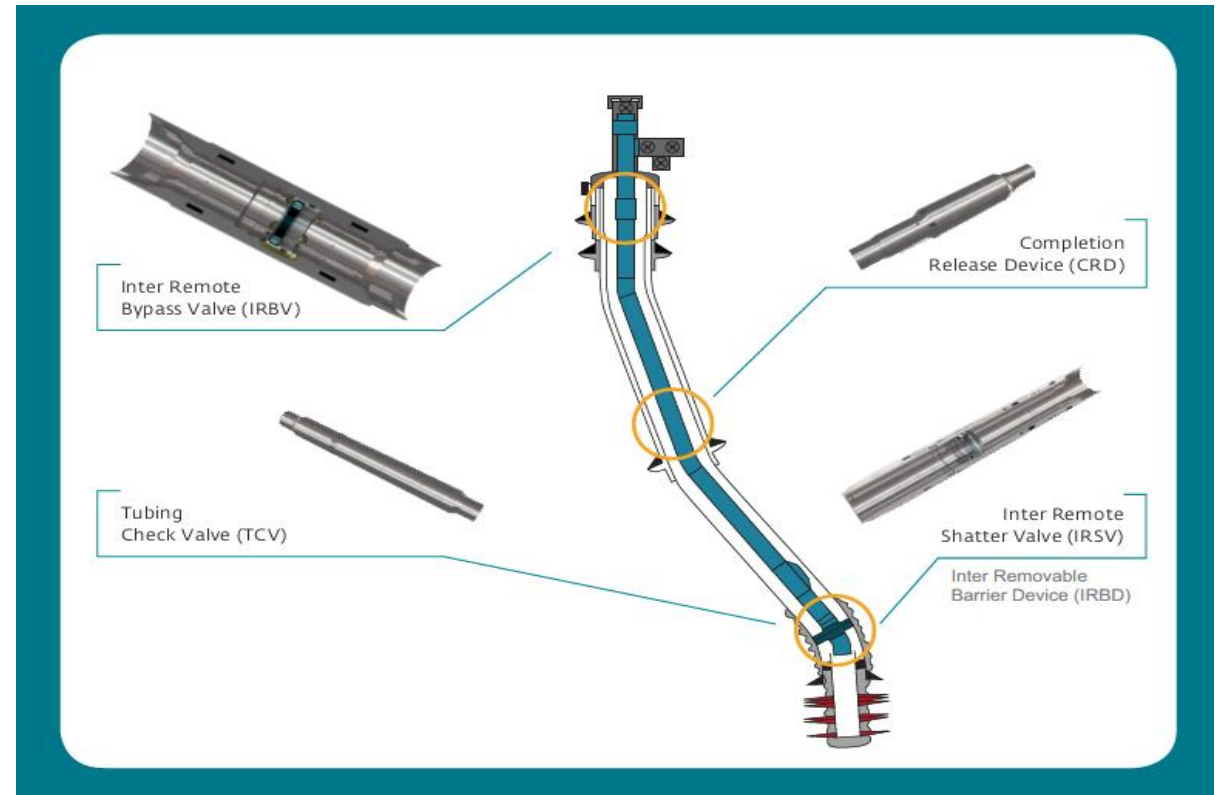
1. Interwell portfolio
2. RockSolid™ Barrier
3. Technical Qualification Process
4. Deployment History
5. Results
6. Q&A



# Interwell Completions

## Benefits

- Intervention-less completion deployment utilizing glass barrier technology
- Over 150 global installations
- Self-filling capabilities
- Full bore access after opening





# Core Barrier Solutions



## Medium Expansion (ME)

- Up to 5,000 psi differential pressure
- Up to temperatures of 150°C
- Sizes: 2-3/8" to 13-3/8"



## High Pressure High Temperature (HPHT)

- Up to 12,500 psi differential pressure
- Up to temperatures of 220°C
- Sizes: 2-7/8" to 7 5/8"



## High Expansion (HEX)

- Up to 4,000 psi differential pressure
- Up to temperatures of 110°C
- Sizes: 2-7/8" to 14"



## Temperature High Expansion (THEX)

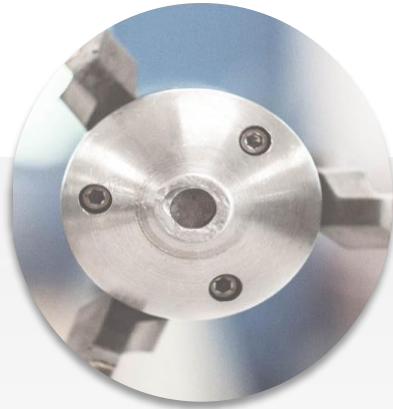
- Up to 5,000 psi differential pressure
- Up to temperatures of 160°C
- Sizes: 4 1/2" to 7"

# New Technology



## Multi Set Wireline Plug (MSWP)

Set and unset multiple times in the same run



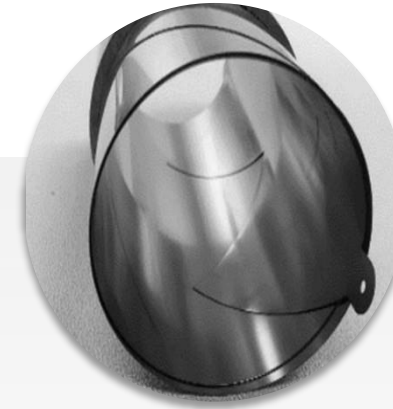
## Plug, Punch and Cut

Allows 3 operations to be carried out in 1 run



## Surface Intervention System (SIS)

Reduce wellsite footprint and POB



## Springblade Patch

Reinstate well integrity and maximise the ID

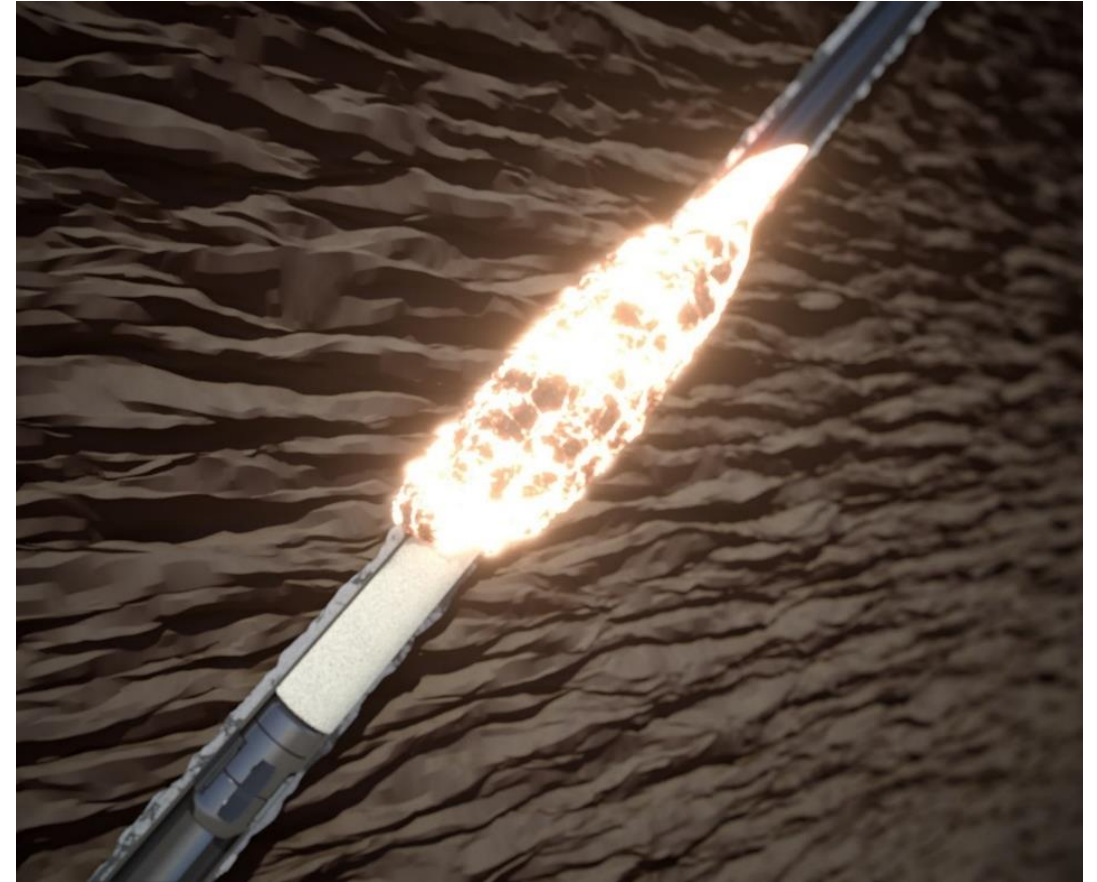


## Electrical Precision Drilling Tool (e-PDT)

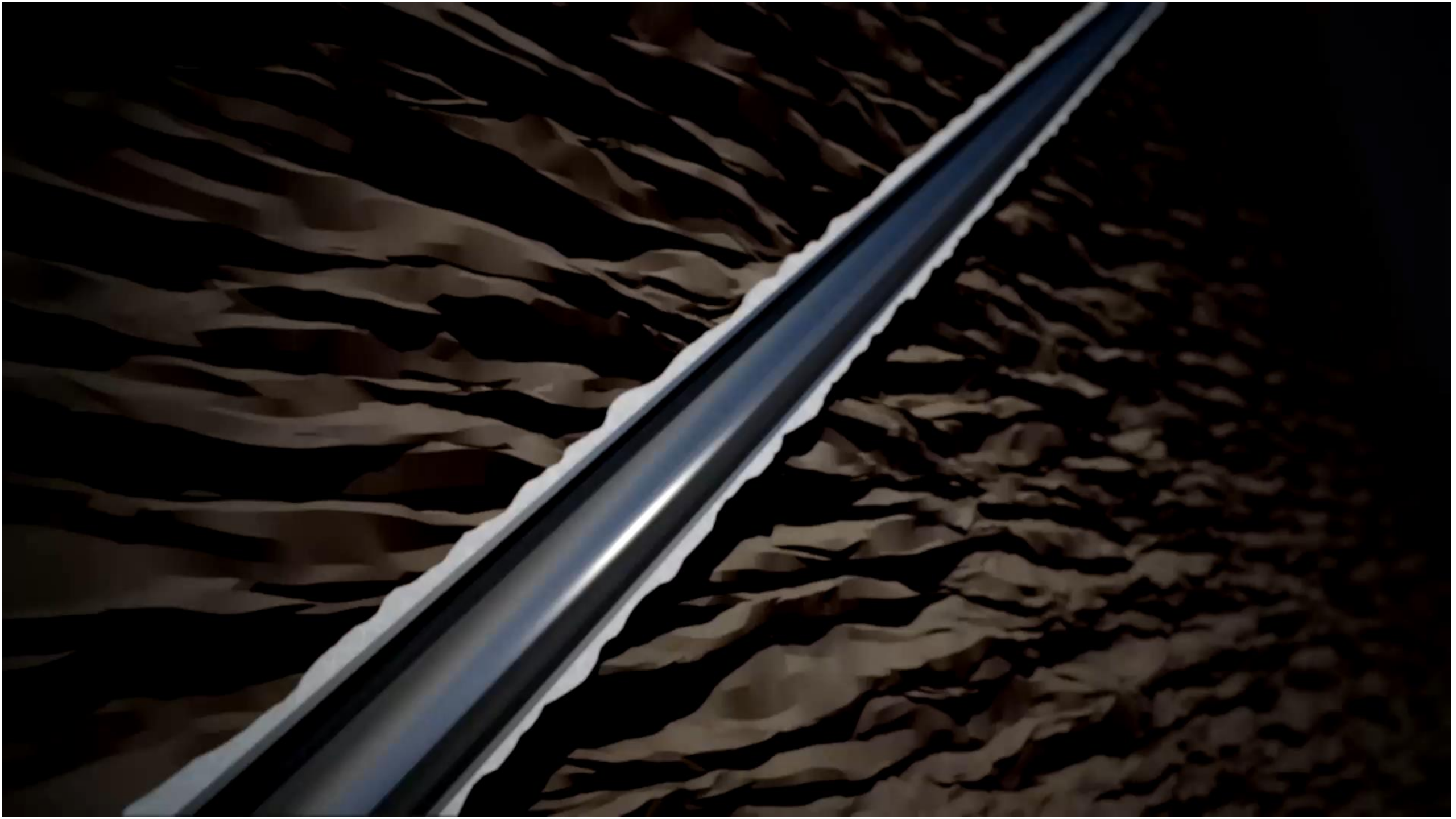
Drill multiple holes and set plugs and packers in one run

# ROCKSOLID™ BARRIER

- Permanent and irreversible
- The wellbore elements are no longer limiting factors
- Creates an uninfluenced barrier system with a rock-to-rock seal
- It is a process that reinstates caprock integrity and creates a gas-tight seal
- It is a completely new and patented process
- THERMIT® itself creates the barrier







# Rock Solid TQ Process

Technology Qualification process initiated in 2014

- Feasibility Study 2012-2014
- Statement of Feasibility 2014
- Technology Qualification Testing 2014-2016
- Endorsement of Qualification Plan 2016

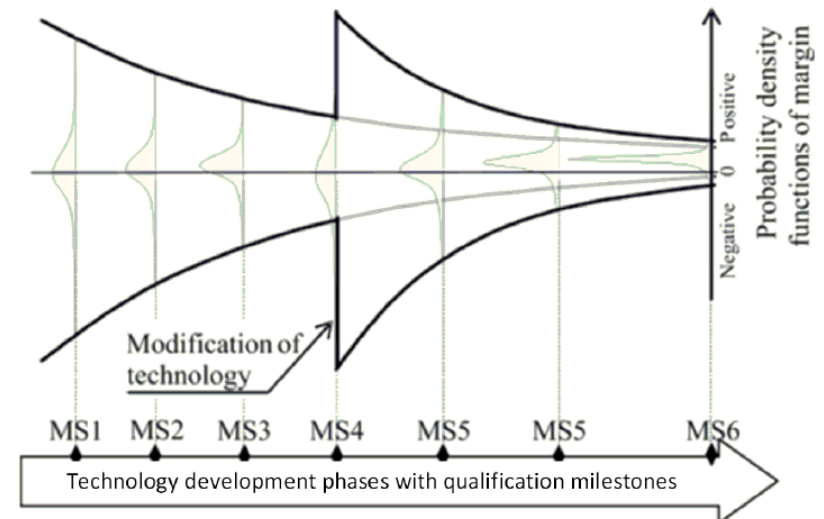
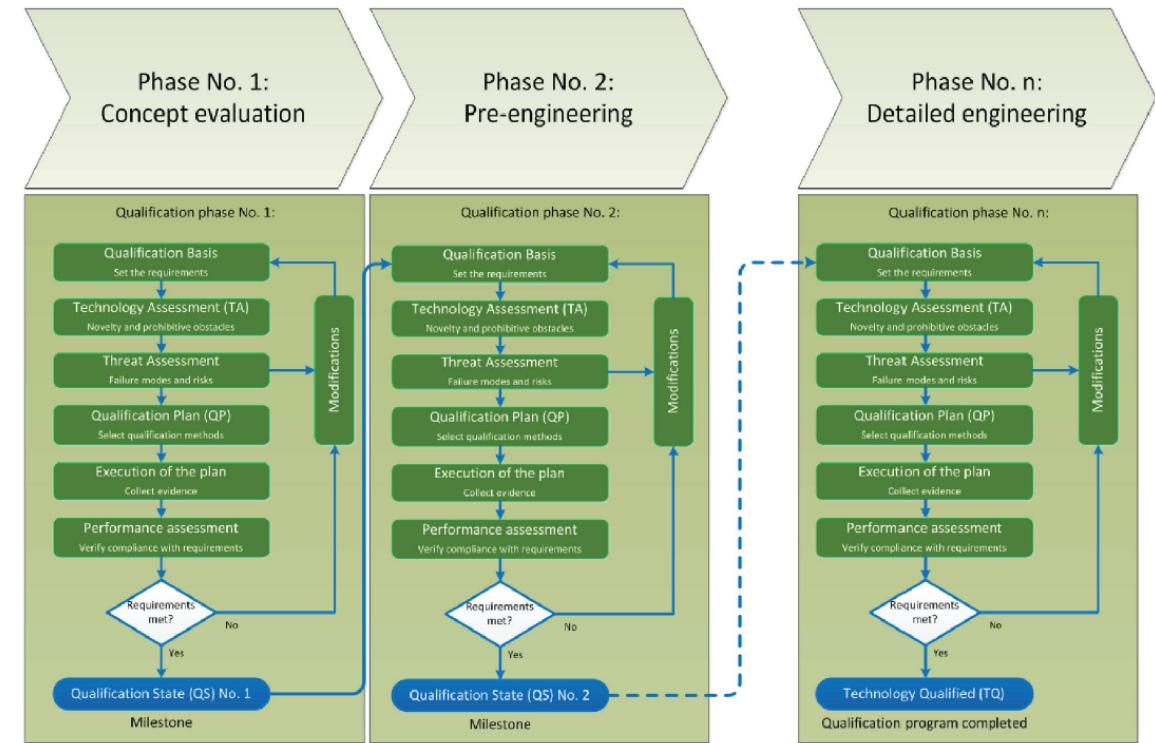
Pilot program and field trials 2016-2019

- Technology Review 2019
- Viable concept, not robust enough

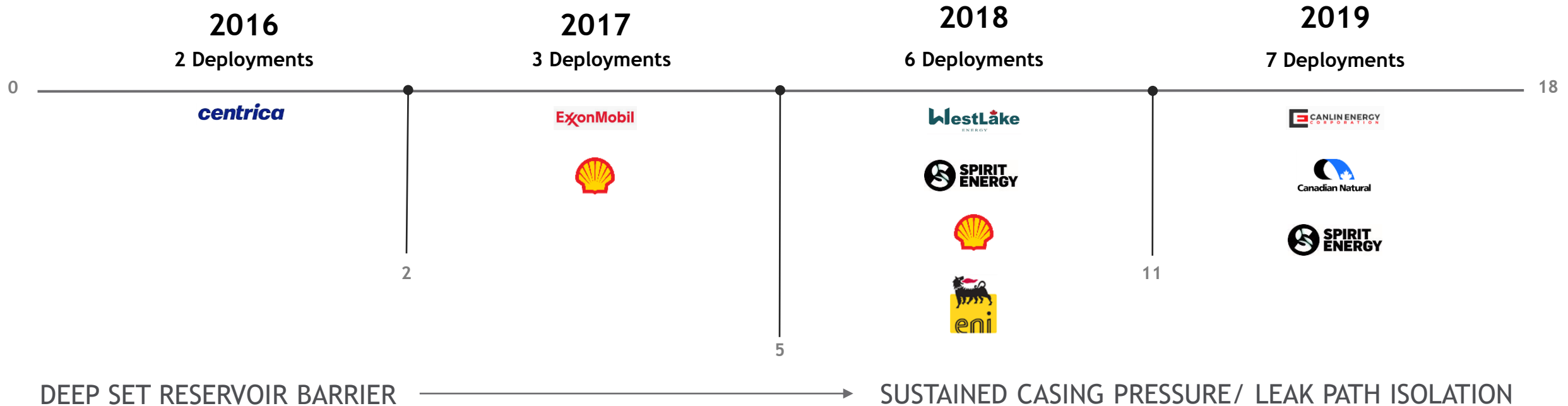
Re-design of concept and technology (2nd Generation)

Revised Technology Qualification plan 2020








- Technology Qualification Testing



# DEPLOYMENT- PROTOTYPE



# DEPLOYMENT - COMMERCIAL

NOV 2020	DEC 2020	MAR 2021	MAR 2021	MAR 2021	NOV 2021	NOV 2021
						
Girouxville, AB 1706m	Groundbirch, BC 672m	Kakut, AB 1507m	Groundbirch, BC 773m	Enchant, AB 642m	Gilby, AB 1833m	Wroses, AB 1247m
<ul style="list-style-type: none"> <li>• 1 attempt</li> <li>• Deemed successful by operator</li> </ul>	<ul style="list-style-type: none"> <li>• 1 attempt</li> <li>• Traditional method had failed</li> <li>• Deemed successful by operator</li> <li>• Passed bubble test</li> </ul>	<ul style="list-style-type: none"> <li>• 1 attempt</li> <li>• Deemed successful by operator</li> </ul>	<ul style="list-style-type: none"> <li>• 1 attempt</li> <li>• Deemed successful by operator</li> </ul>	<ul style="list-style-type: none"> <li>• 1 attempt</li> <li>• Deemed successful by operator</li> </ul>	<ul style="list-style-type: none"> <li>• 1 attempt</li> <li>• Deemed successful by operator</li> </ul>	<ul style="list-style-type: none"> <li>• 1 attempt</li> <li>• Deemed successful by operator</li> </ul>
GAS TIGHT BARRIER APPROVED BY REGULATOR	GAS TIGHT BARRIER APPROVED BY REGULATOR	GAS TIGHT BARRIER APPROVED BY REGULATOR	GAS TIGHT BARRIER APPROVED BY REGULATOR	GAS TIGHT BARRIER APPROVED BY REGULATOR	GAS TIGHT BARRIER APPROVED BY REGULATOR	GAS TIGHT BARRIER APPROVED BY REGULATOR



# Serving Every Well

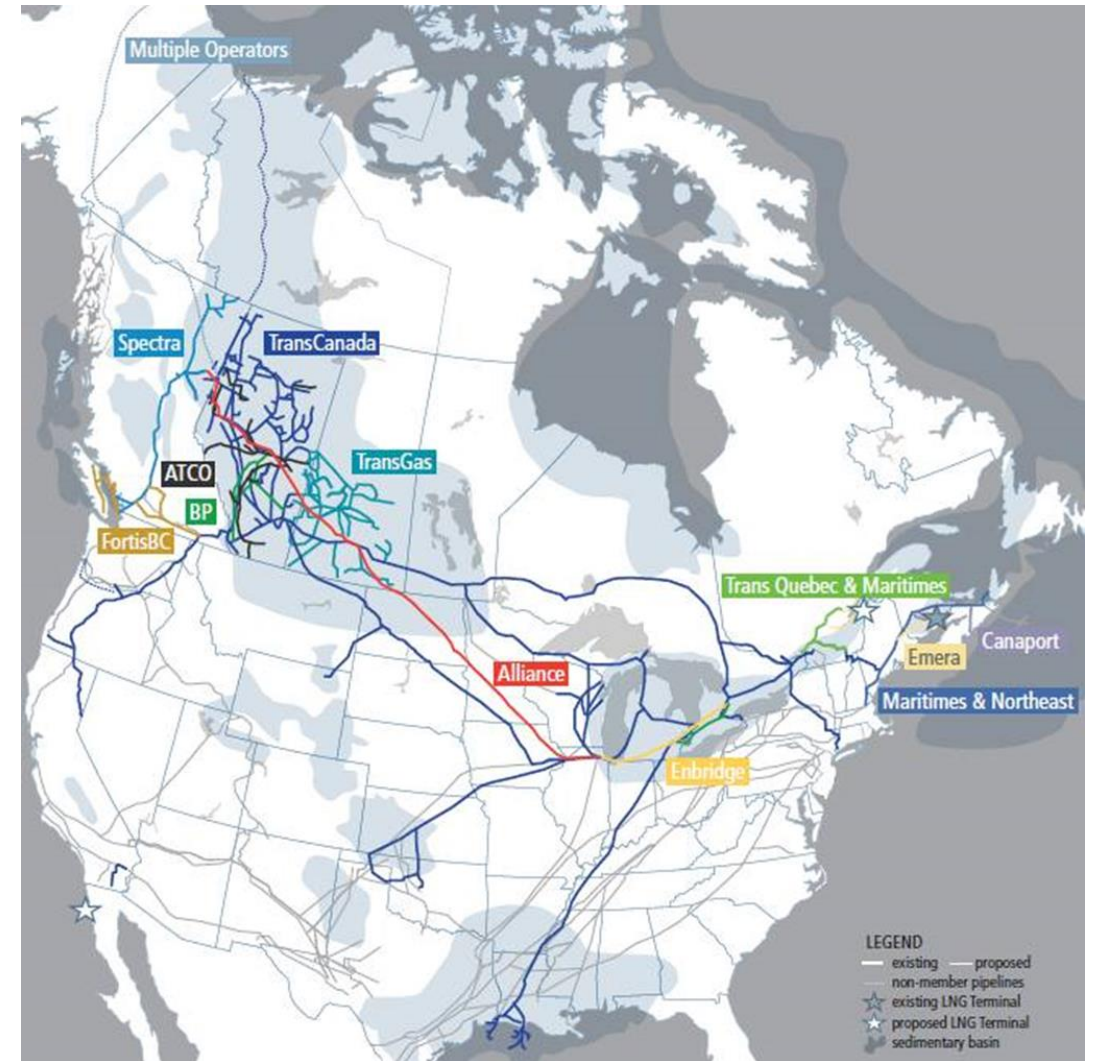
# New life for pipelines in the energy transition

Hydrogen & CCS Symposium  
16 February 2022

Jake Abes

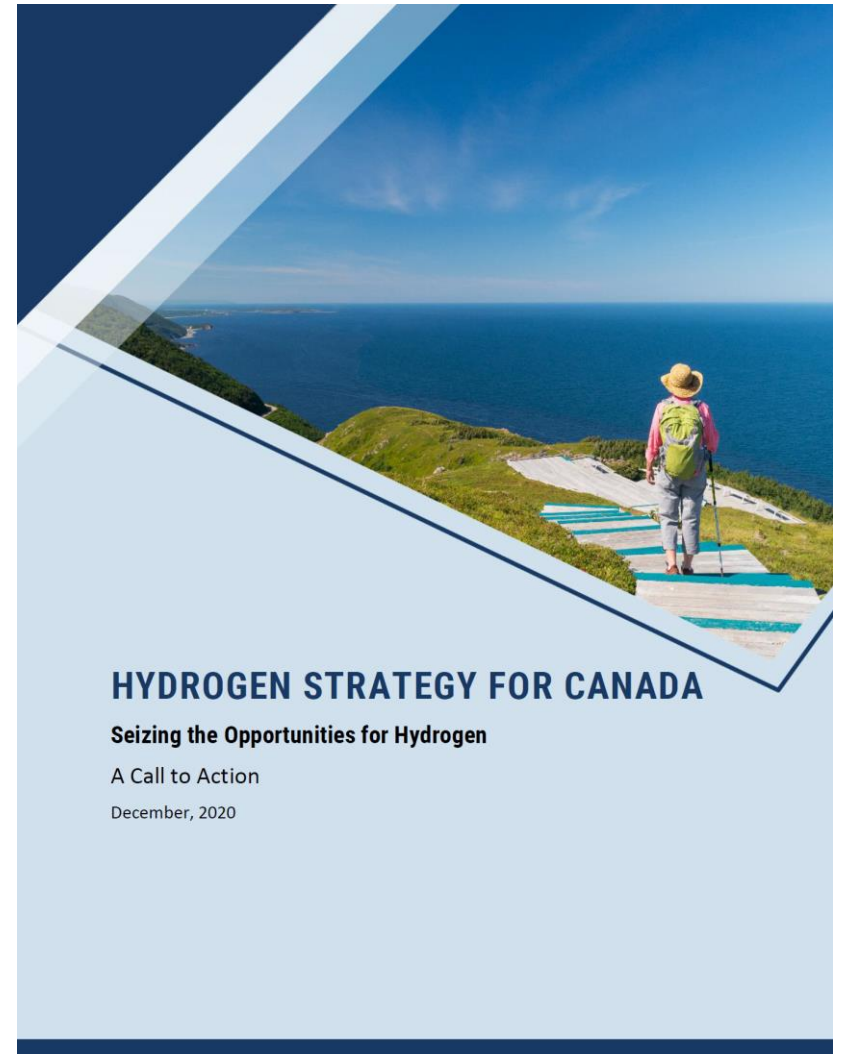
# Pipeline systems in Canada

- ~850,000 km of oil and gas pipelines across Canada
  - 280,000 km upstream gathering systems primarily in the Western provinces
  - 450,000 km gas distribution systems across the country
  - 120,000 km are large diameter, high pressure oil and gas transmission systems that transport products across provinces and to the U.S.
- CO2 pipelines
  - Quest
  - ACTL



# Energy transition

- Canada has committed to net-zero emissions by 2050, with hydrogen delivering up to 30% of Canada's end-use energy by then.
- Carbon pollution pricing
- Both hydrogen and carbon capture utilization and storage (CCUS) are expected to play strategic roles in the energy transition.
- CO2 Storage capacity – saline formations in Alberta and Saskatchewan
- Repurposing existing pipeline infrastructure for CO2 transport





# Requalification process for pipeline system change to CO2 transport

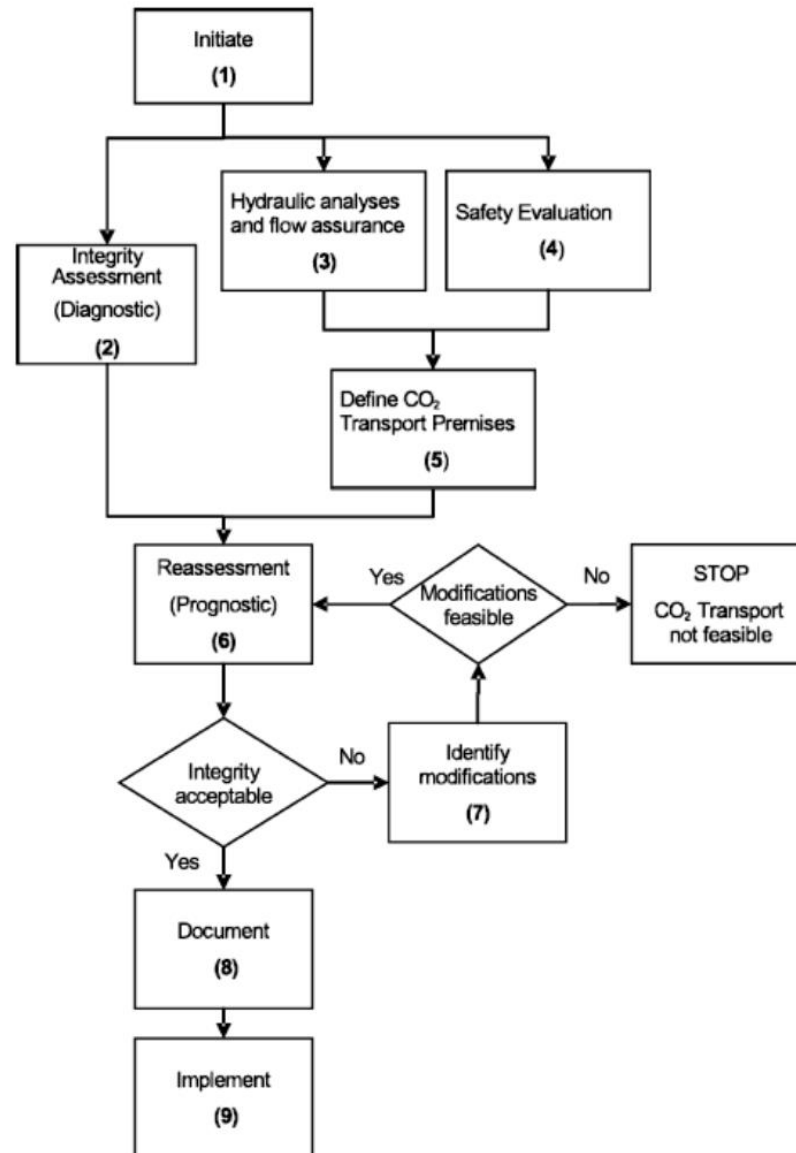
DNV GL

## RECOMMENDED PRACTICE

DNVGL-RP-F104

Edition September 2019

### Design and operation of carbon dioxide pipelines



## Structured reviews

- Integrity assessment
  - Current and future condition
  - Fracture control
- Hydraulic analysis
  - Pipeline capacity
  - Phase behaviour
  - CO2 quality
- Safety evaluation
  - Dispersion
  - Topography effects
- Define transport basis

# Technical considerations for requalification of pipelines for CO<sub>2</sub> transport

- Flow assurance – gas phase/dense phase; effect of impurities; hydrate formation; equations of state; transient operation; topography; effect of existing defects on pipeline capacity
- Materials – fracture control; fatigue; elastomers
- Safety – release rate; dispersion; heavier than air; topography effects; etc.
- Operations – upset conditions; leak detection; odorization; public awareness; purging; venting; repairs
- Integrity – defect tolerance; internal corrosion (water control); corrosion growth rates; inspection capability
- Equipment – compression requirements; valves; meters; pressure control/pressure relief; gas detectors
- Human factors – training; social acceptance; emergency response

# Technical considerations for requalification of pipelines for Hydrogen and Hydrogen blends

- Hydraulic analysis – capacity; blend uniformity; flow velocity
- Materials – hydrogen embrittlement; fatigue crack growth rate; welding
- Safety – leakage; gas migration; dispersion; flammability; ignition; fire; flame speed; explosion; pressure waves; etc.
- Operations – leak detection; odorization; public awareness; purging; venting; repairs
- Integrity – defect tolerance; corrosion protection;
- Stations & Equipment – compression requirements; valves; meters; pressure control; gas detectors; flow-induced turbulence/pulsation; acoustic induced vibration
- End-use equipment
- Scalability
- Human factors – training, social acceptance, emergency response

# Thank you.

Jake.abes@dnv.com

Pipeline Services Canada

[www.dnv.com](http://www.dnv.com)



# Altera and Höegh LNG scaling up CCS

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**Christian Fjell**

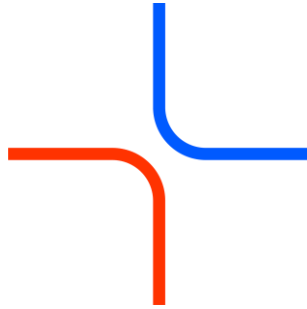
Director, Sustainability – Altera Infrastructure

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**Tore Lunde**

Senior Advisor, Business Development – Höegh LNG

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**The  
Stella Maris CCS  
Project**

# Höegh LNG and Altera at a glance

Partners

## Altera

24

Shuttle  
Tankers

9

FPSO

&

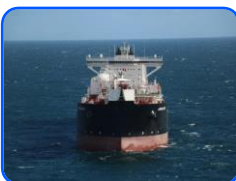
3

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

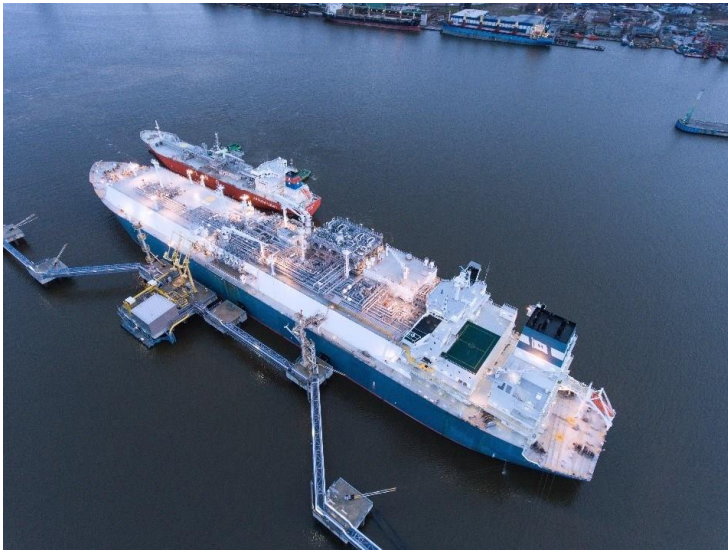
LNGC



- 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 realise CCS



# Stella Maris CCS

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

**10 Mt CO<sub>2</sub> / year**

**Infrastructure will include:**

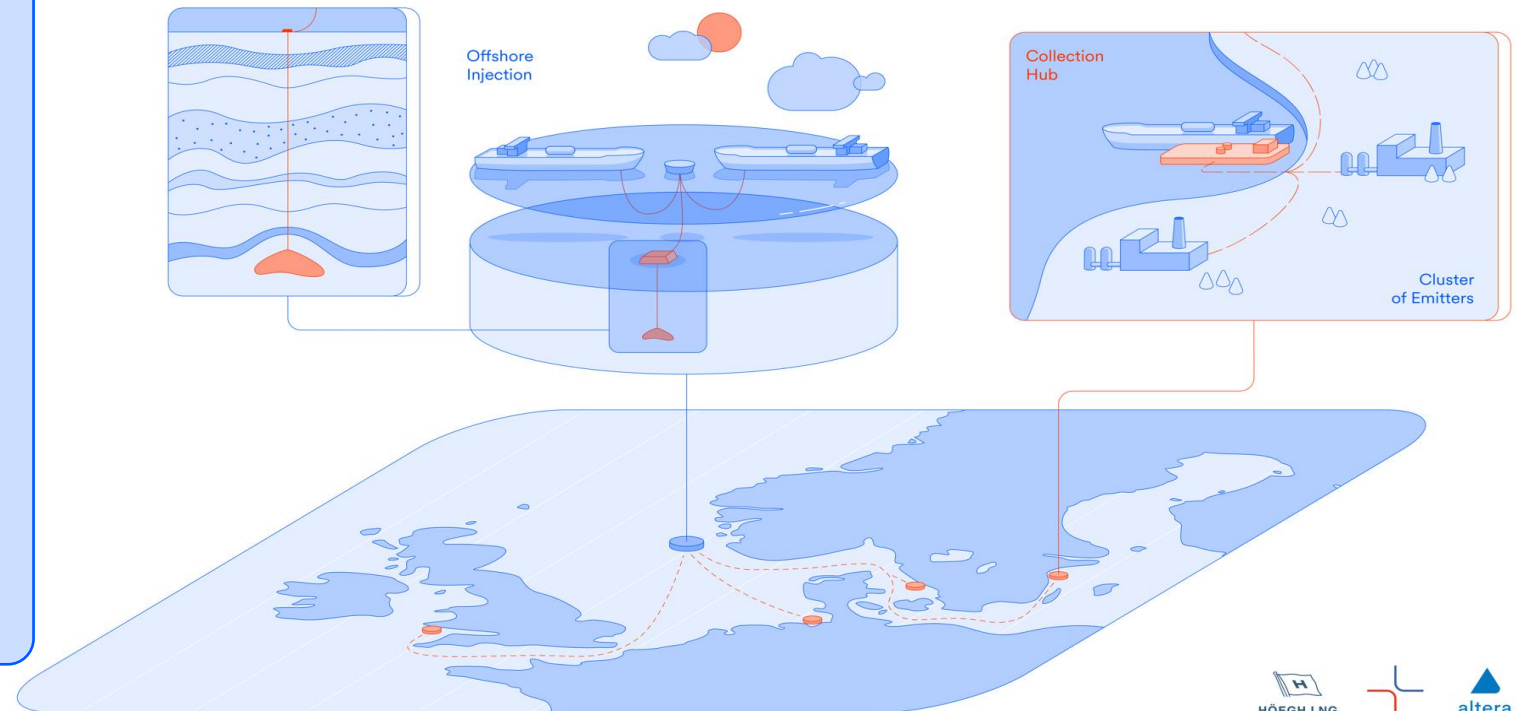
- Carbon Collection Storage Offloading units (2-3) to be located at key location(s) as export hubs

Capable of receiving various grades of CO<sub>2</sub> from multiple emitters

- A fleet of large CO<sub>2</sub> shuttle carriers (3-4)

50 000m<sup>3</sup> – low pressure tanks

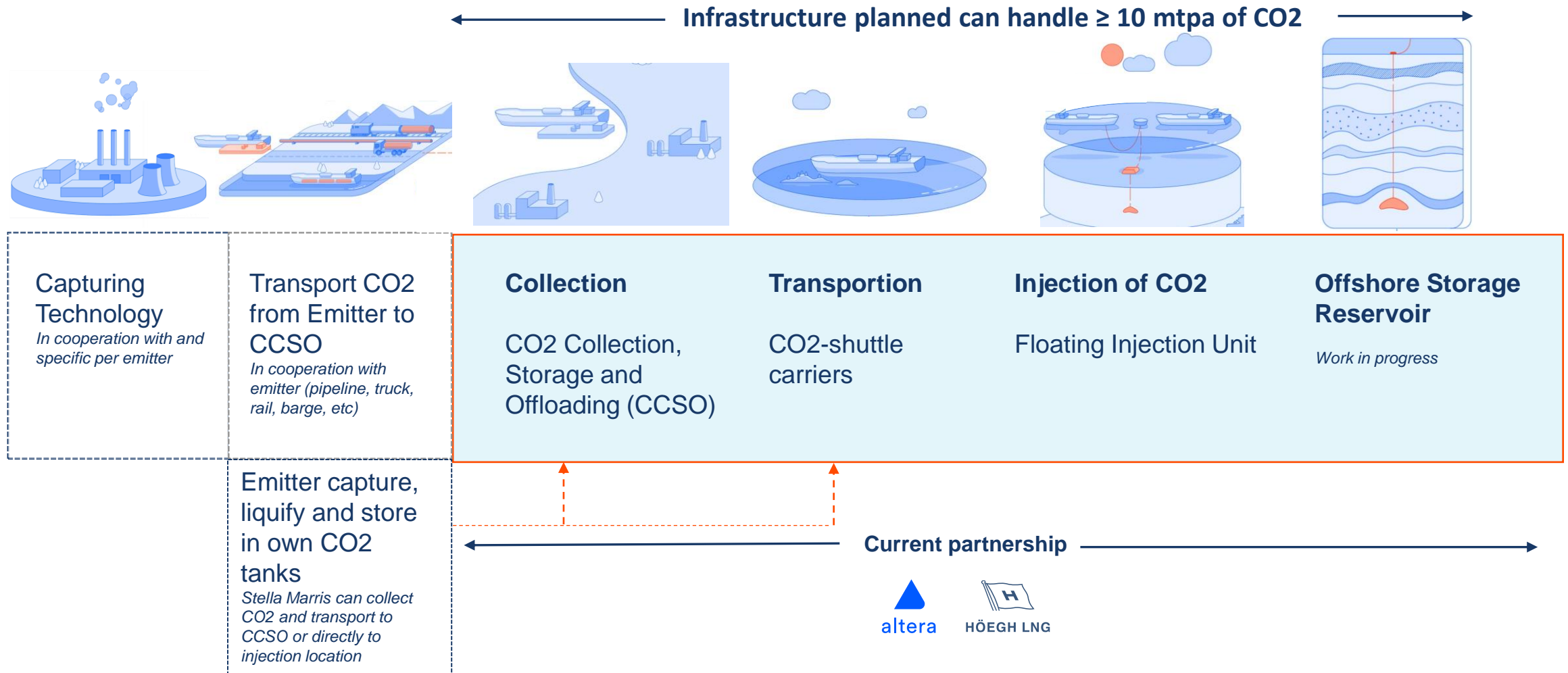
- Offloading and continuous injection of CO<sub>2</sub> offshore
- Zero emission capable
- Scalable Worldwide – design one – build many
- Solution deployed for large scale emitters, clusters and/or nation states in 2026
- One stop-shop from collection to storage
- Cooperate close with industry and policy makers nationally and internationally



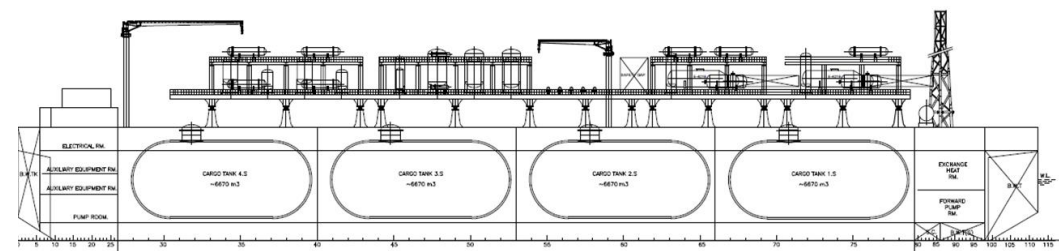
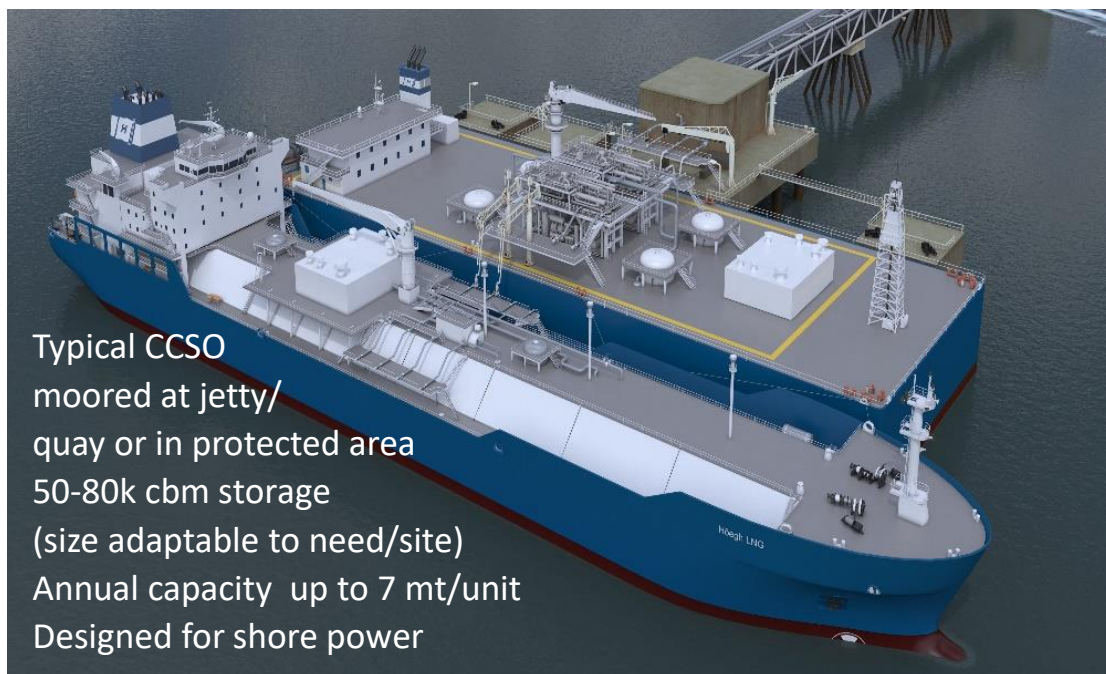
# The Stella Maris CCS Project

Infrastructure

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



# Carbon Collection, Storage and Offloading Unit (CCSO)



*Designed to receive and process:*



High- & low-pressure gas from pipelines



Medium & low-pressure liquid from road, rail, ships or barges

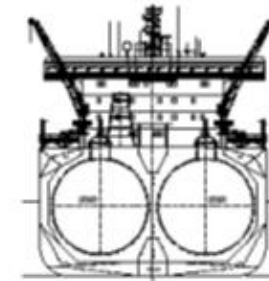
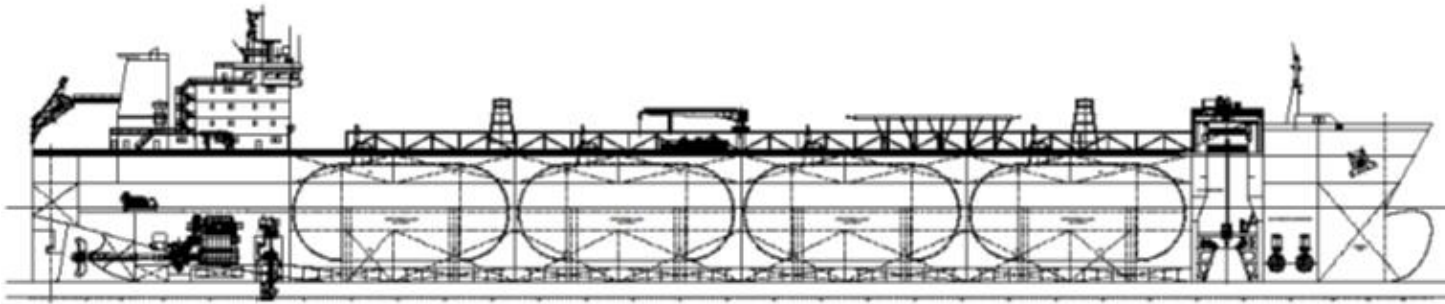


Various qualities with different levels of impurity

*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

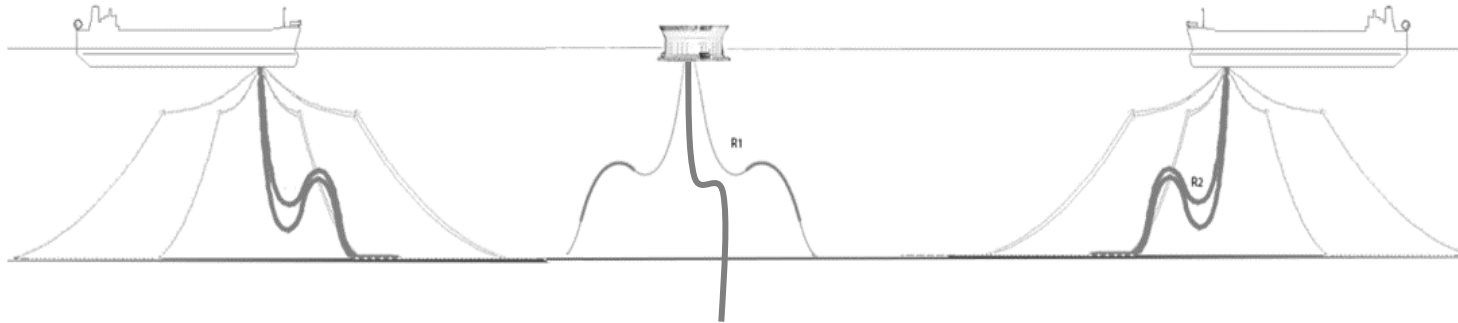
- New, state of the art CO2 shuttle carrier design
  - 50,000 cbm - low pressure tanks
  - CO2 stored and transported as liquid at 6,5 barg & -47°C
  - Zero emission capable
  - Electric Power distribution
  - Battery hybrid installation
  - LNG/Bio gas/NH3 as fuel
- Optional:
- Size to meet needs
 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

## **Key Innovations:**

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



# Floating Injection Unit (FIU)



- 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<sub>2</sub> heated and injected into reservoir in dense phase (>5°C & 65 -160 barg)

## ***Principal dimensions:***

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

## **Alternatives:**

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

## Offshore Injection and storage



## Key Innovations

- Power from CO<sub>2</sub> Shuttle Carrier
- Normally Unmanned
- Equipment for offshore loading of CO<sub>2</sub>
- Zero emission capable

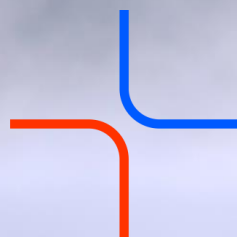
# Stella Maris CCS

## Large-scale, Flexible, Scalable Maritime CO2 Logistics Solution

During the next year we will:

- Finalize technical concept for the Stella Maris logistical solution
- Establish cooperation & partnerships to deliver Stella Maris
- Market our solution to individual companies, industry clusters and national authorities
- Become a one-shop-stop provider of a competitive and cost-efficient CO2 solution from collection to storage.

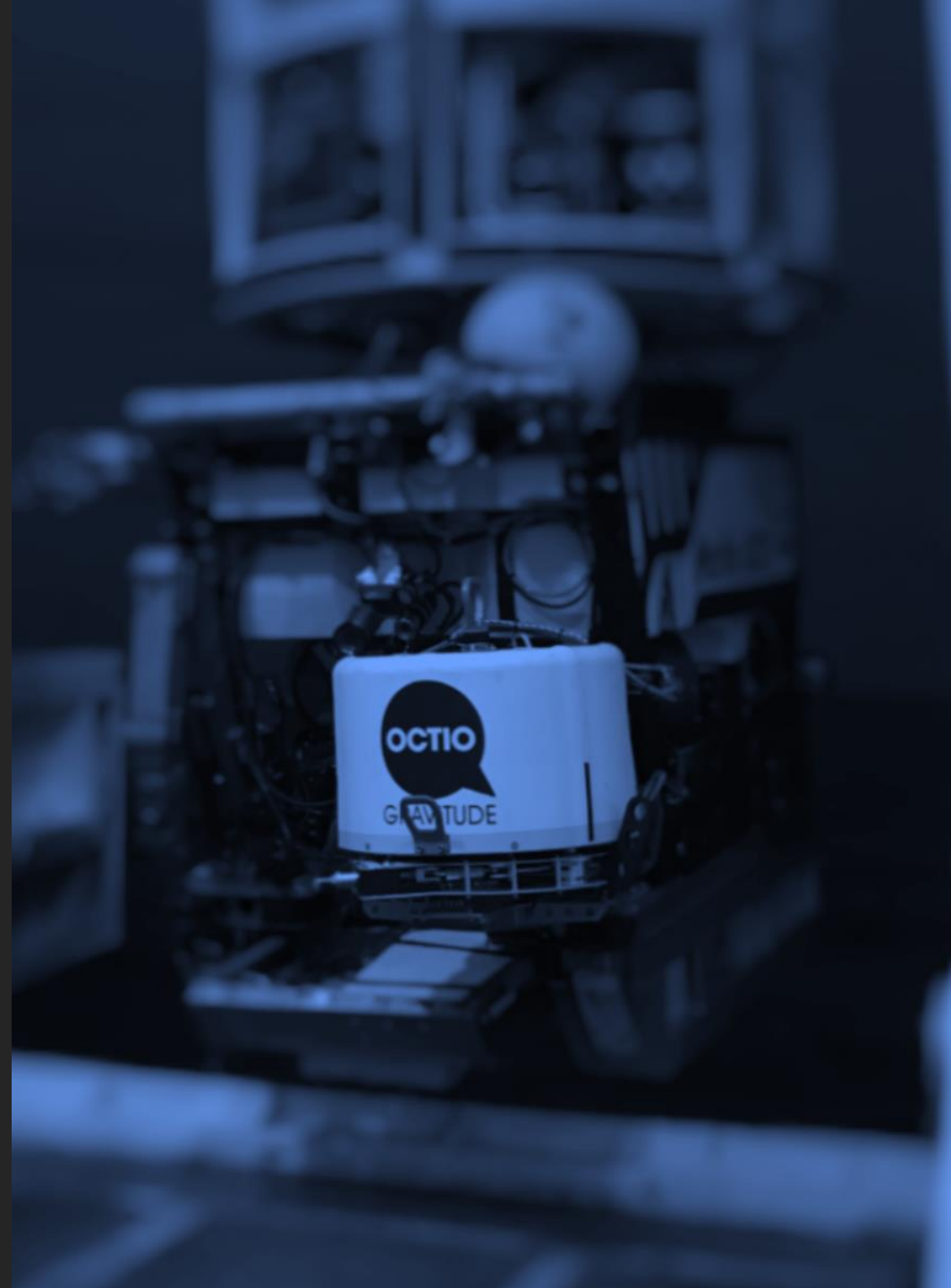




# The Stella Maris CCS Project

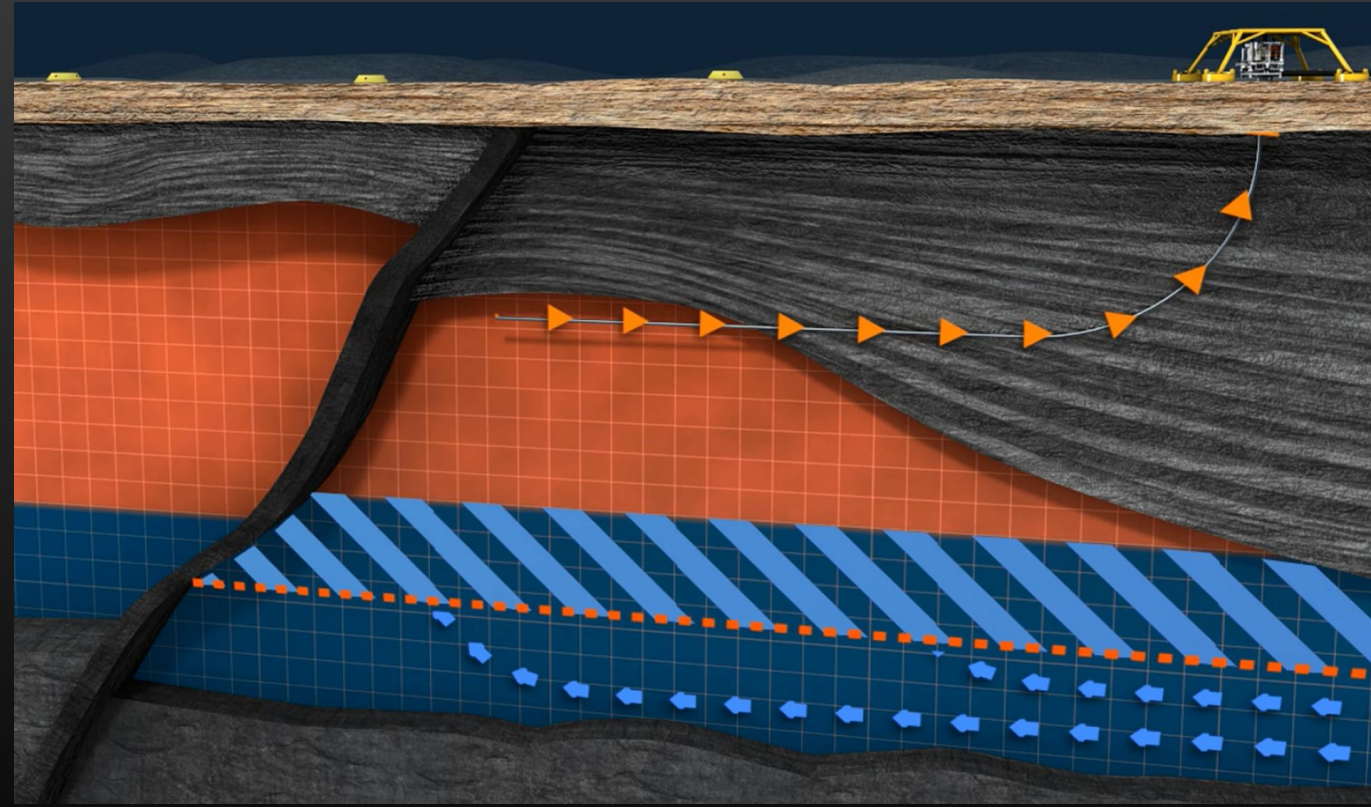
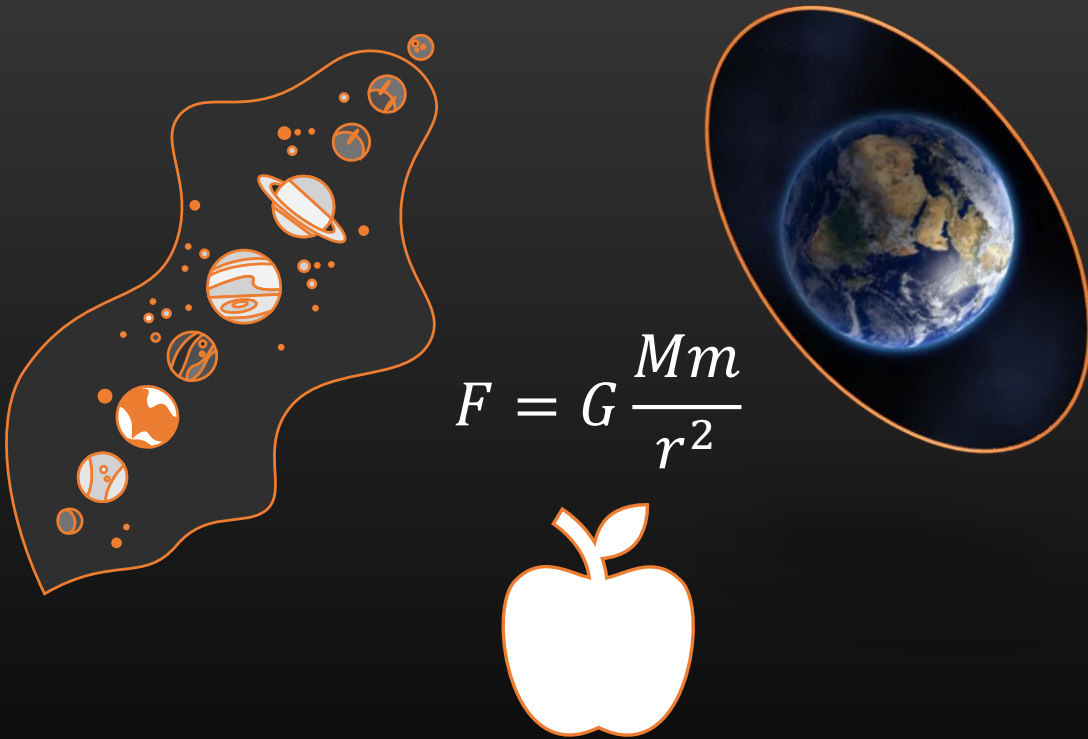


**A cost-effective holistic  
approach to monitoring of  
CO2 storage**

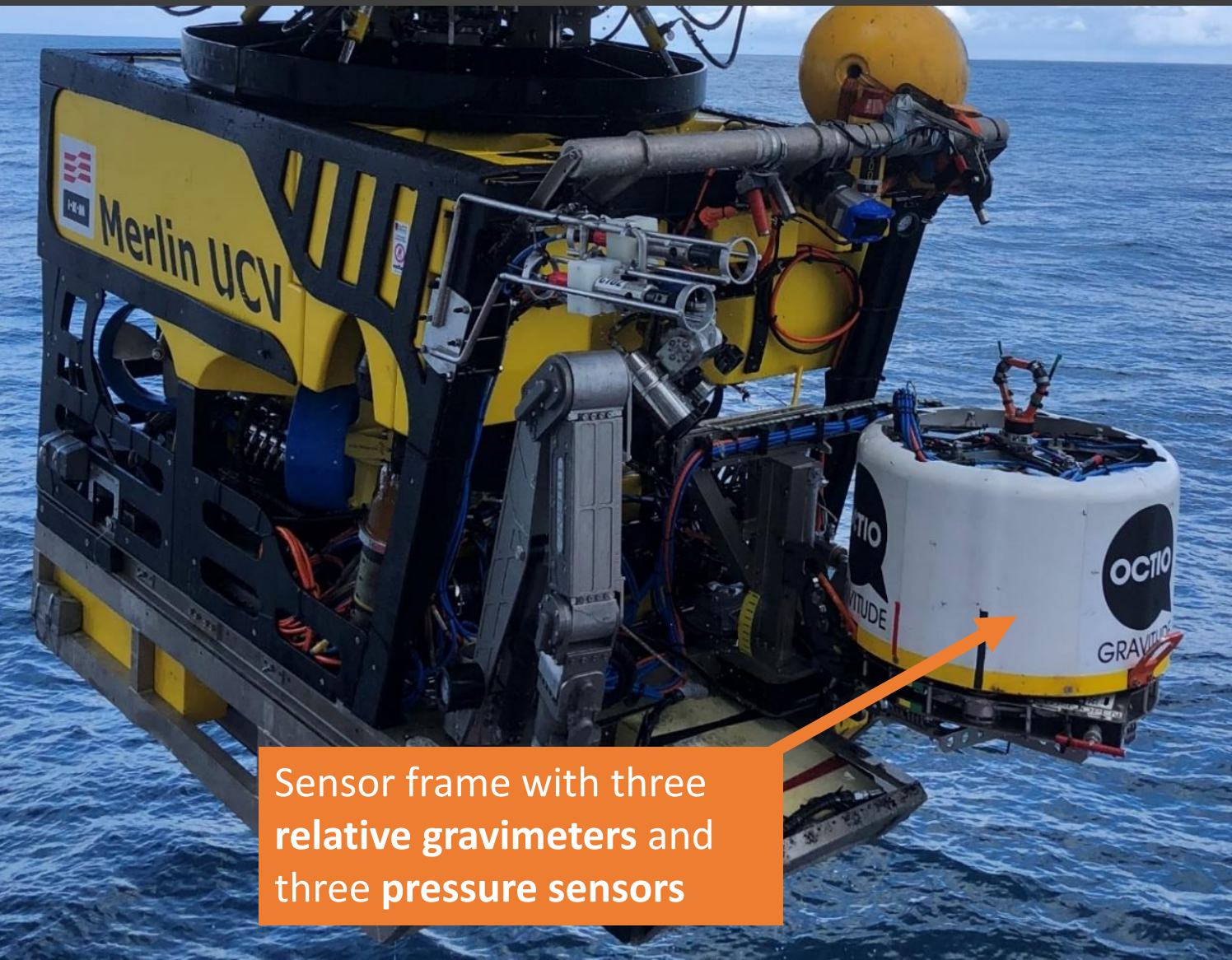




# gWatch Technology in a nutshell



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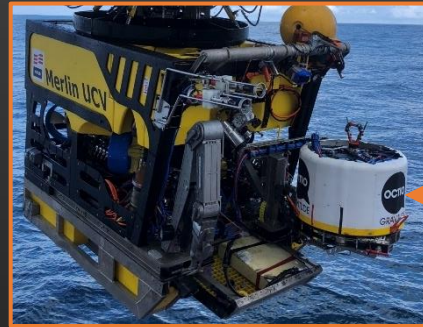
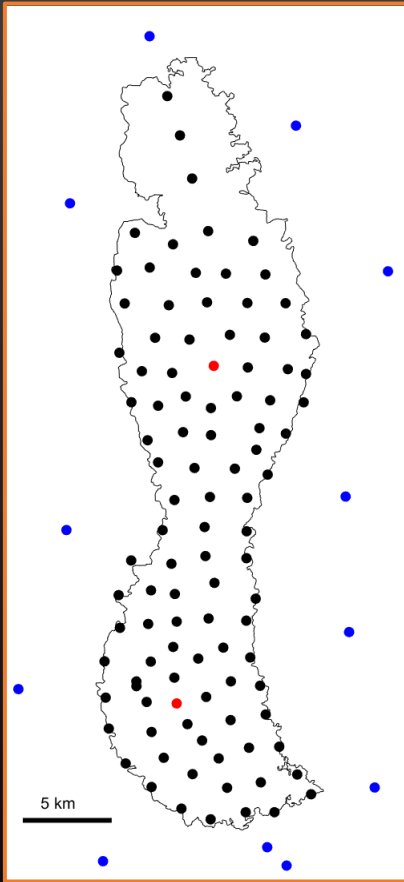


Sensor frame with three  
relative gravimeters and  
three pressure sensors





# gWatch Technology in a nutshell



## gWatch

Two independent measurements

Gravity: Sensitive to mass changes

- Maps the CO<sub>2</sub> injection plume
- Monitor CO<sub>2</sub> density
- Detect vertical leakage

Seafloor deformation: Sensitive to reservoir deformation

- Pressure distribution
- Pore compressibility

# Value proposition for hydrocarbon production

## Efficient reservoir management

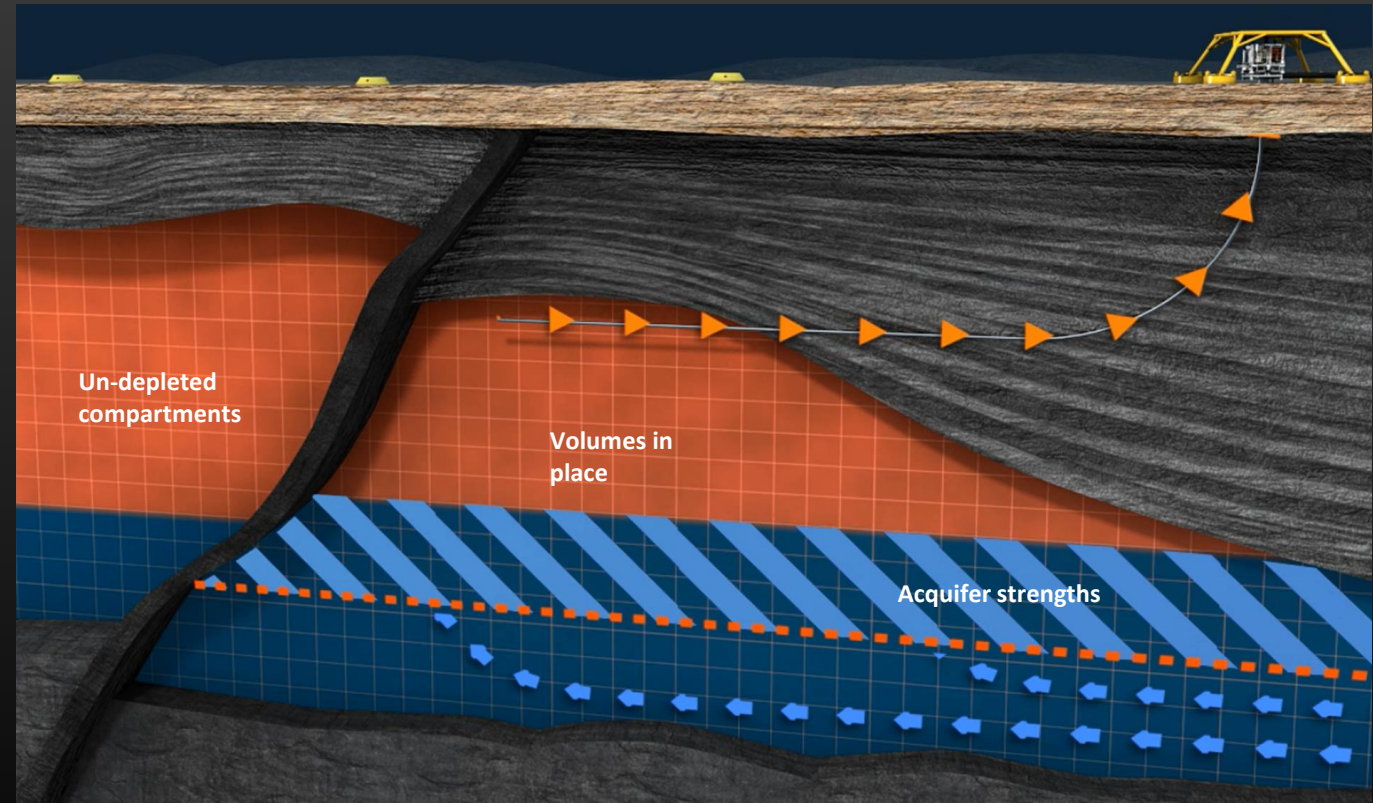
- Understanding of reserve depletion
- Target untapped reserves

## Field development strategy

- Incremental hydrocarbon recovery
- Efficient top-side infrastructure

## Cost effective

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





# Value proposition for CO<sub>2</sub> storage

## Efficient reservoir management

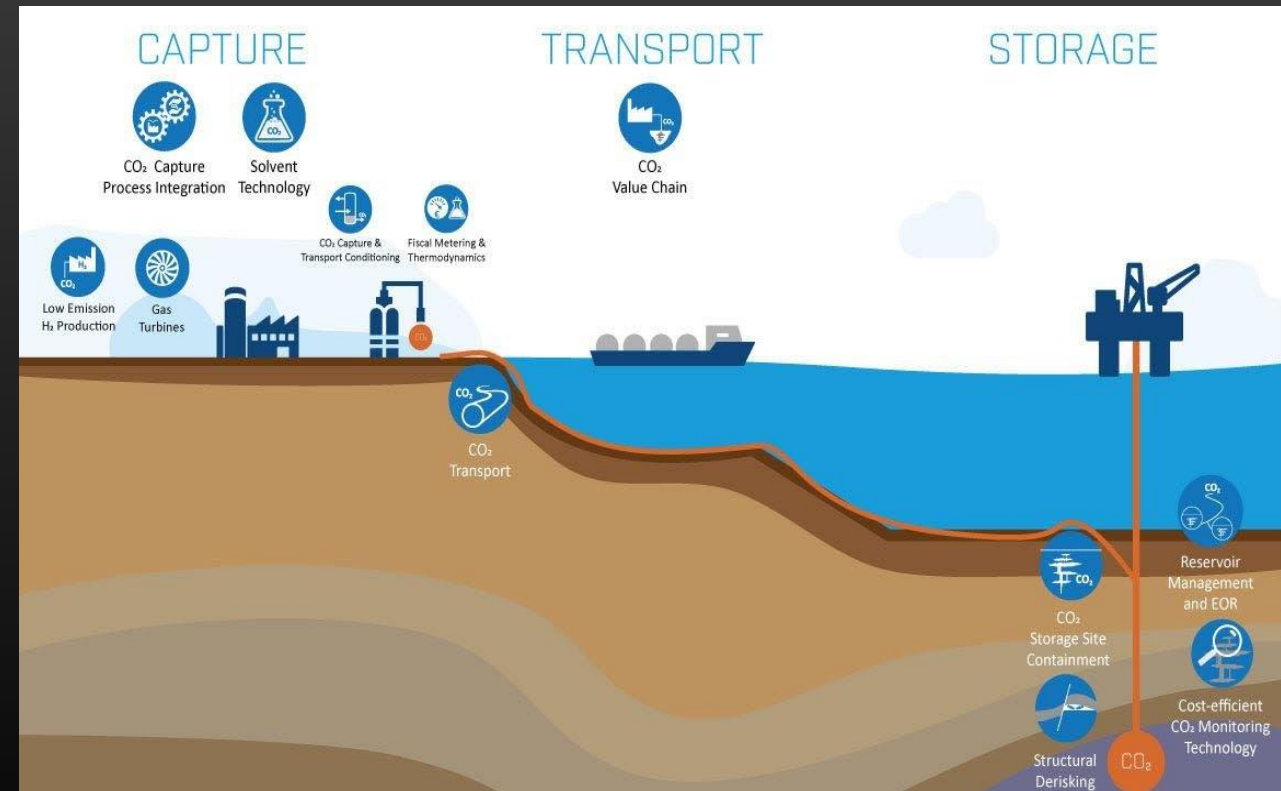
- Constrain uncertainties in the volumetric expansion of the injection plume
- Reduce uncertainties in in-situ CO<sub>2</sub> density
- Pressure communication in the reservoir
- Detect vertical leakage of the CO<sub>2</sub> plume

## 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*

# Gravity and subsidence: 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 <sub>2</sub>
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

# Thank you

