

AXCEL FUTURE

CCUS

CARBON CAPTURE, USAGE AND STORAGE

ALLIANCE

DANSK INDUSTRI – DANSKE REDERIER – DANSK FJERNVARME – DANSK METAL
DANSK OFFSHORE – AXCEL FUTURE – GREEN POWER DENMARK

WELCOME TO CCUS ALLIANCE WORKSHOP

September 28th 2023

AGENDA

Welcome and moderator: Finn Lauritzen, Axcelfuture

UK: Kate Pilling, Department for Energy Security & Net Zero

Netherlands: Joep Sweyen, Aramis

Norway: Aslak Viumdal, Gassnova; Truls Jemtland, Hafslund Oslo
Celsio and Per Brevik, Heidelberg Materials Northern Europe

Denmark: Lars Bruun Sørensen, Ørsted and Kathrine Thomsen, Ministry
of Climate

Discussion



Department for
Energy Security
& Net Zero



Addressing Challenges in CCS – The UK Experience

Kate Pilling

28th September 2023

kate.pilling@energysecurity.gov.uk



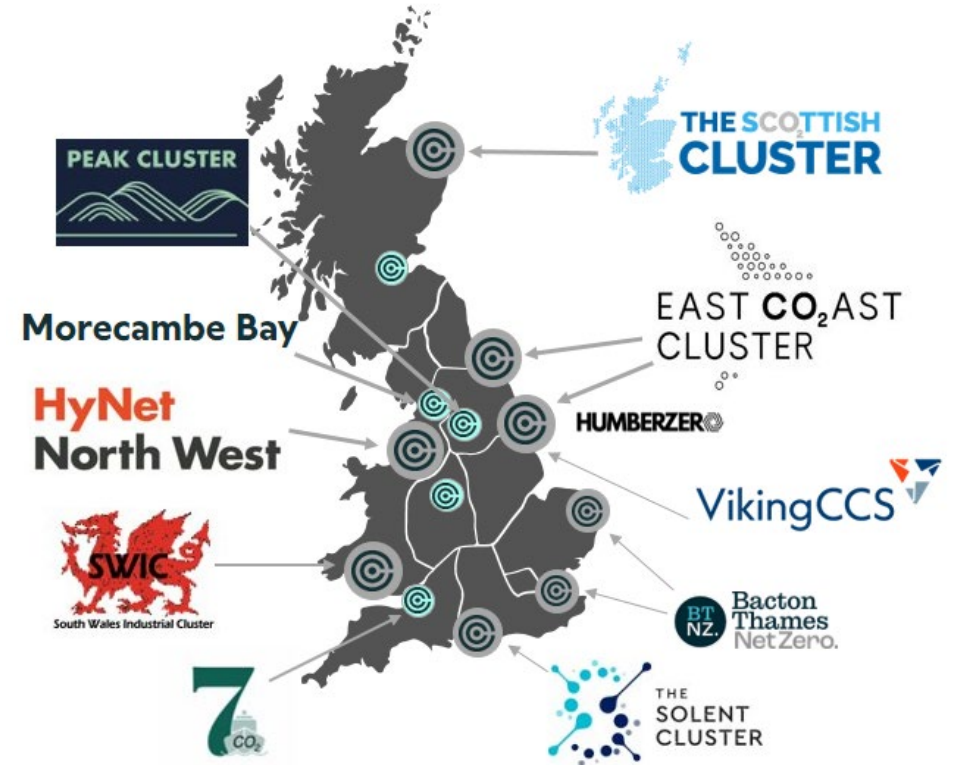
UK Potential for CCUS

Our **2050 Net Zero Strategy** emphasised the importance of decarbonising industry using CCUS technologies. This has the added benefit of long-term UK energy security.

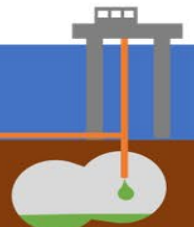
The UK has theoretical potential to store more than **78 billion tonnes of carbon dioxide (CO₂)** in its continental shelf, which is one of the largest potential storage capacities in Europe.

An ambition to capture **20-30Mt** of carbon dioxide a year by 2030 was included as part of the [Net Zero Strategy](#).

The UK approach focuses on establishing CCUS 'Clusters', which take advantage of the fact that many emissions-intensive facilities are located in tight geographical clusters and would be able to connect to a large-scale CO₂ storage site using shared infrastructure.

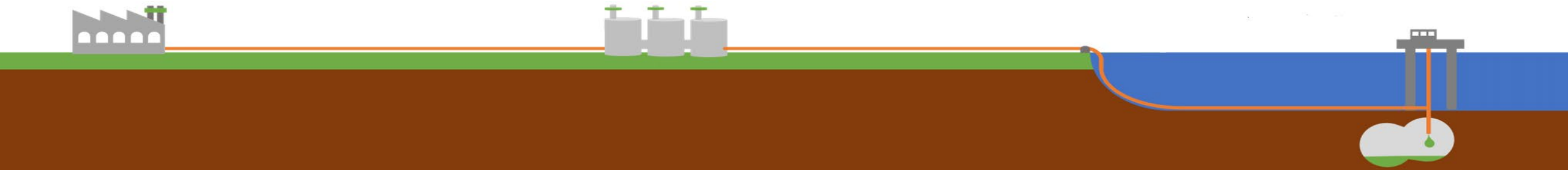


Map of UK clusters.
Source: CCSA May 2023.



*At least two CO₂ capture projects with access to a transport and storage network

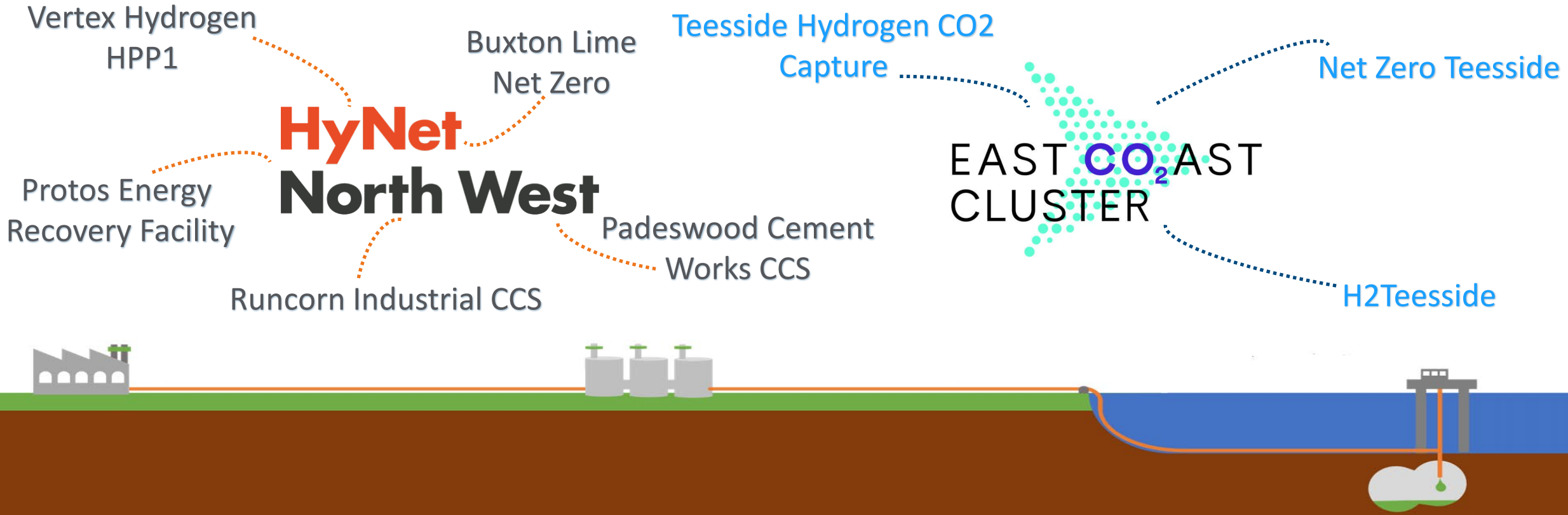
Where We Are Today



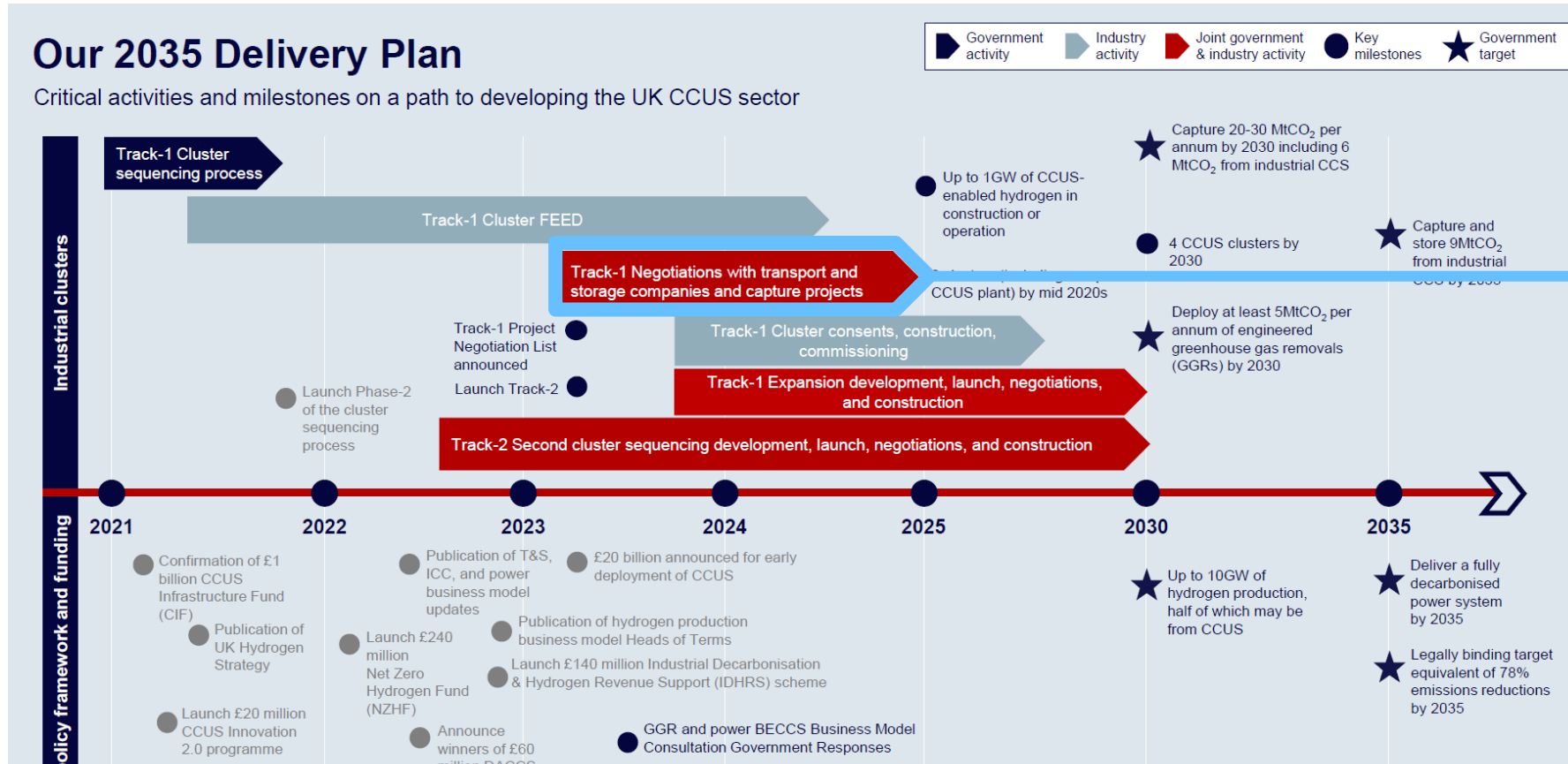
Track 1 Clusters

The first phase of the cluster sequencing process resulted in Hynet and The East Coast Cluster confirmed as the Track 1 clusters. Phase 2 of the cluster sequencing process then determined which projects, out of a shortlist of 20, would enter negotiations for CCS support.

In March this year, the UK government published the Track 1 Project Negotiation List, which includes **8 projects** to progress to negotiations to form the Track 1 clusters.



Progressing Track 1 to Investment Decision



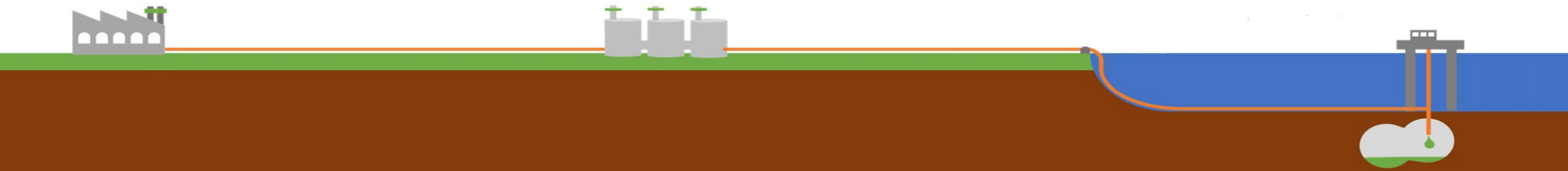
We are currently in negotiation with the Track 1 transport and storage companies and capture projects.

This involves understanding and assuring project costs, as the projects mature and have greater cost certainty, as well as negotiating commercial aspects of the CCUS contracts. Negotiable areas include agreed project returns and efficient allocation of risk.

The CCUS programme is working towards achieving final investment decisions in 2024.

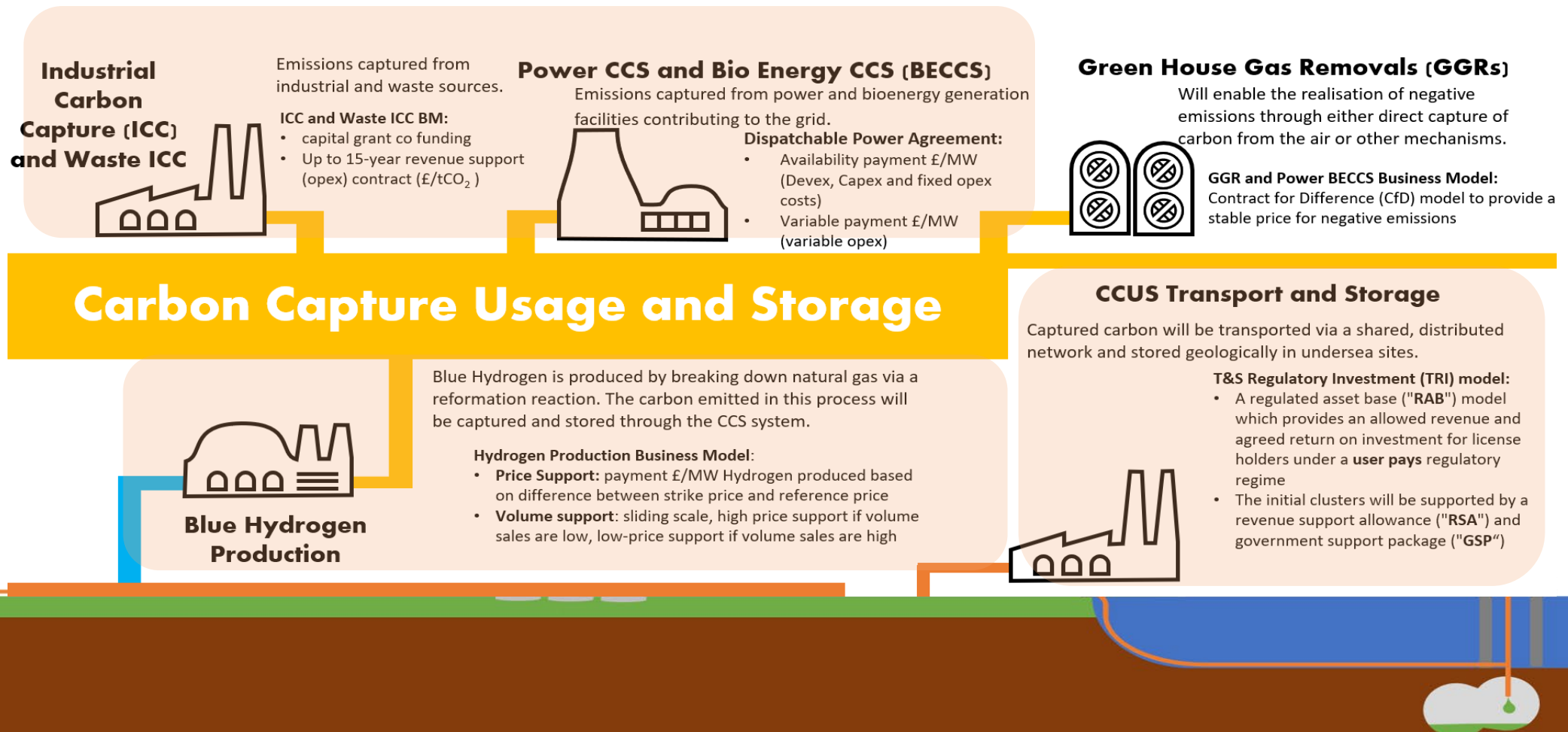


Tackling the Commercial Challenges of CCUS

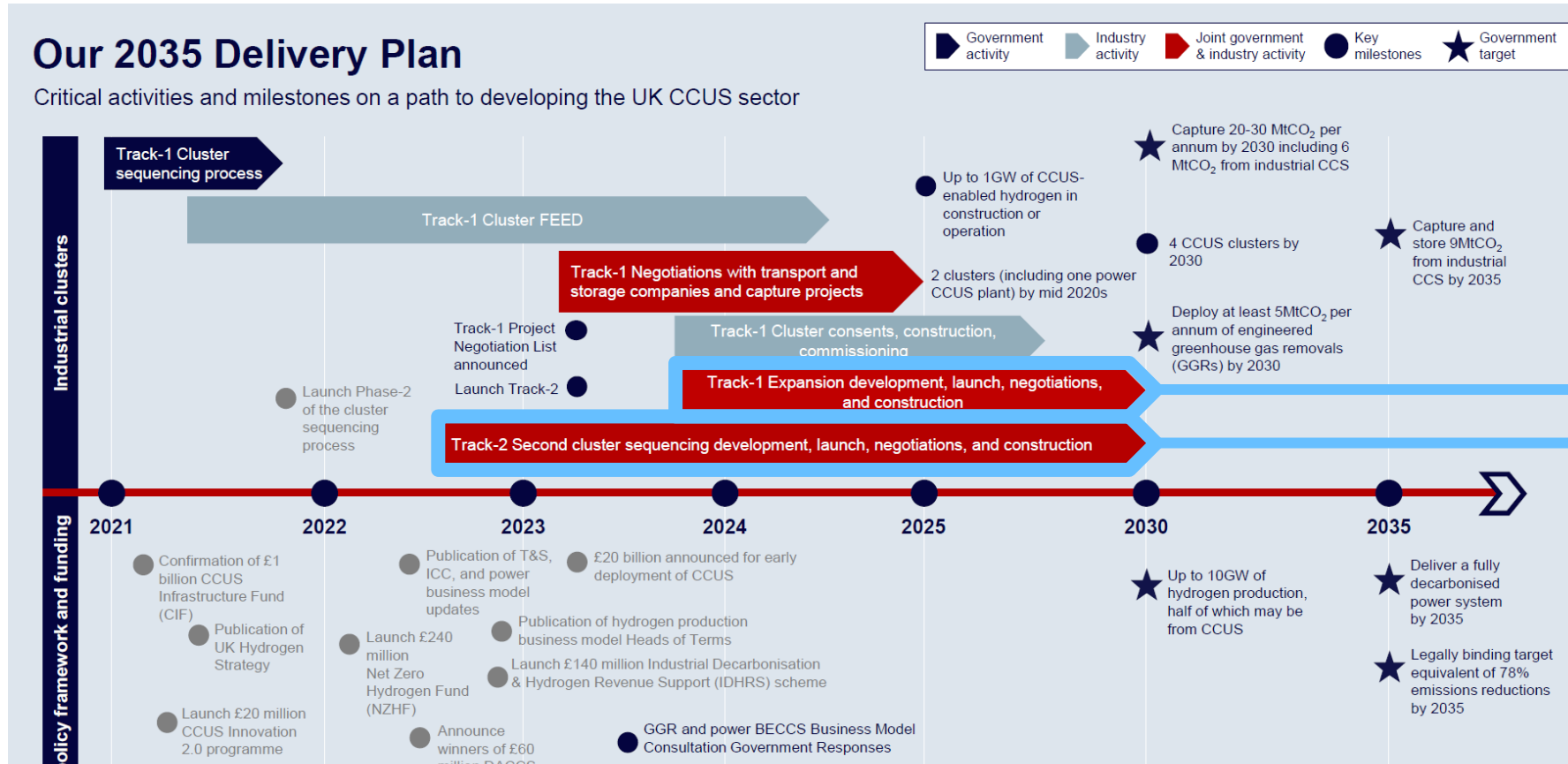


The UK CCUS Business Models

Our business models incorporate lessons learned from previous CCUS competitions in the UK and the successful offshore wind contracts for difference. Learnings from Track 1 will then be taken forward into Track 1 expansion and Track 2.



Track 1 and Beyond



While negotiating with Track 1 transport and storage companies and capture projects, the CCUS programme is also working on expanding the Track 1 clusters. The Track 1 expansion work will identify projects that could be potential alternatives to any of the initial Track-1 projects, if any are unable to agree contracts within the criteria and timelines required.

We are also working on establishing Track 2, which aims to establish an additional 2 CCUS clusters. In March this year, Acorn and Viking were identified as best-placed to deliver our CCUS objectives.



Danish CCS-alliance webinar
28 September 2023



CCS Developments in the Netherlands

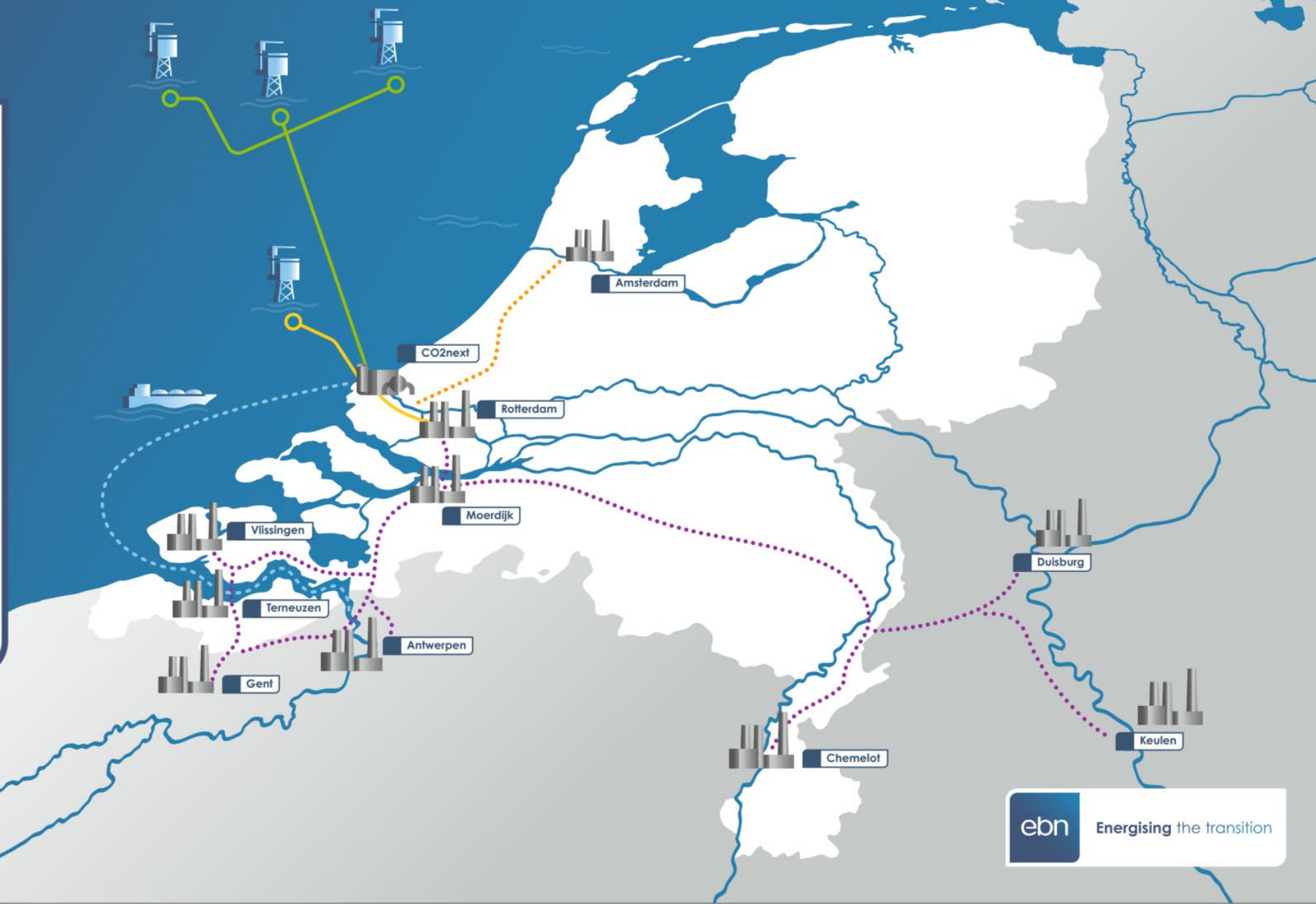
Joep Sweyen

EBN CCS and Aramis Project Public Affairs Lead

Joep.sweyen@ebn.nl



Ontwikkeling CCS-infrastructuur



CO₂ reduction through storage under the North Sea



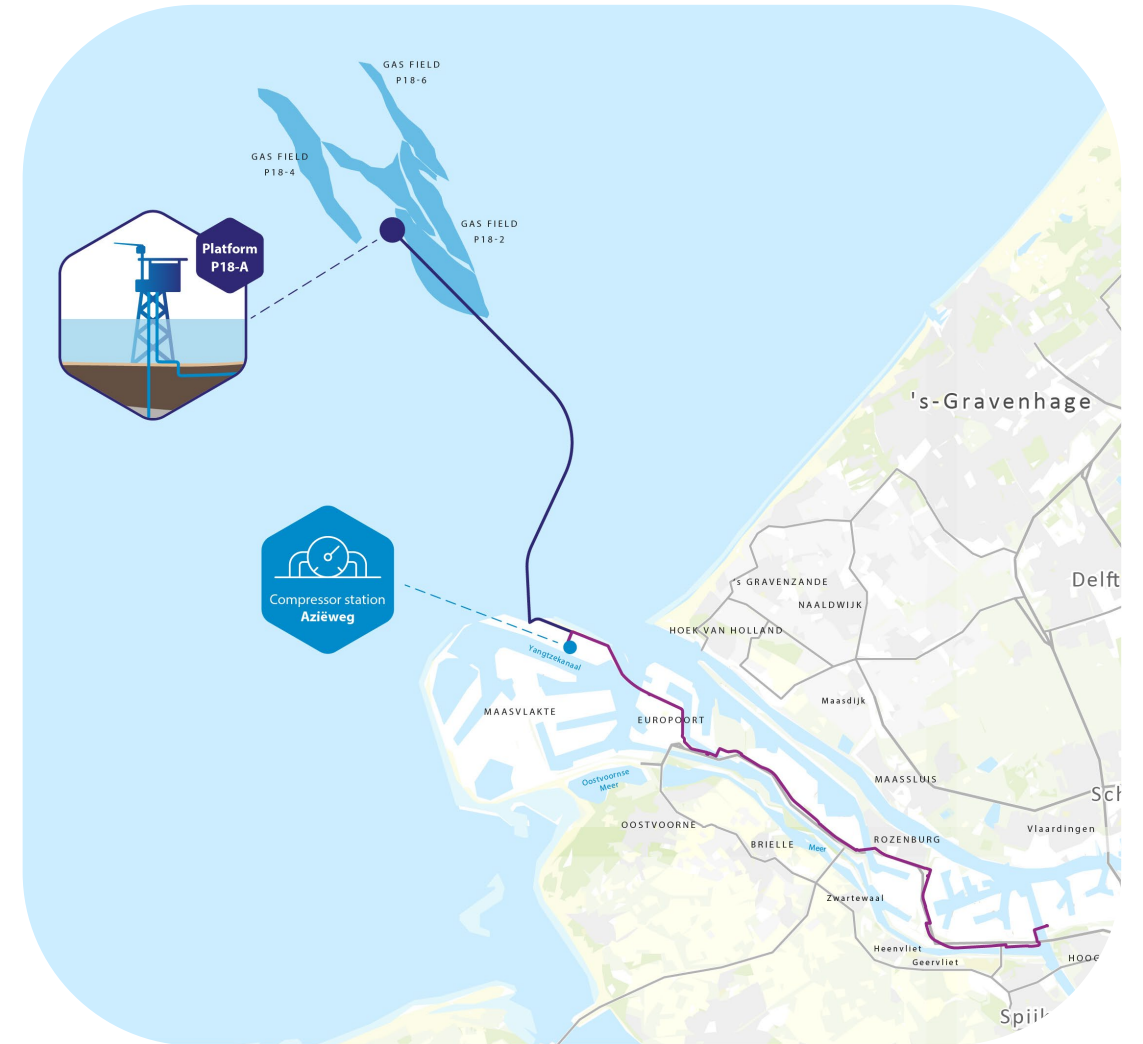
Co-financed by the
Connecting Europe Facility
of the European Union



Porthos
CO₂ TRANSPORT & STORAGE

Project overview

- Infrastructure for CO₂ transport and storage
- CO₂ capture by customers
- Dutch state-owned parties: EBN, Gasunie, Port of Rotterdam Authority
- Customers: Air Liquide, Air Products, ExxonMobil, Shell
- Capacity P18 fields: ~ 37 Mton
- Storage: ~ 2.5 Mton per year



Porthos is ready for FID



Positive ruling Council of State

- November 2021: ngo MOB appeals against nature permits Porthos (nitrogen issue)
- November 2022: construction exemption lapses in ruling Council of State
- August 2023: positive ruling Council of State on ecological assessment Porthos

➤ Final Investment Decision (FID)



Dutch court rules huge carbon capture project can go ahead

rTLnieuws

Geen significante gevolgen natuur

Omstreden CO2-opslagproject Porthos mag doorgaan

De Telegraaf
Raad van State geeft groen licht voor CO2-opslagproject Porthos

de Volkskrant

Raad van State:
klimaatproject Porthos mag doorgaan



CO2-opslag Rotterdamse haven mag doorgaan, klimaatdoelen niet in gevaar

NOS
Raad van State keurt project voor opslag CO2 in Noordzee goed



Status and planning



Current

- Preparing for FID
- Preparing for construction phase
- European tenders for construction compressor station



End of 2023

- Final Investment Decision (FID)



2024

- Start of construction works

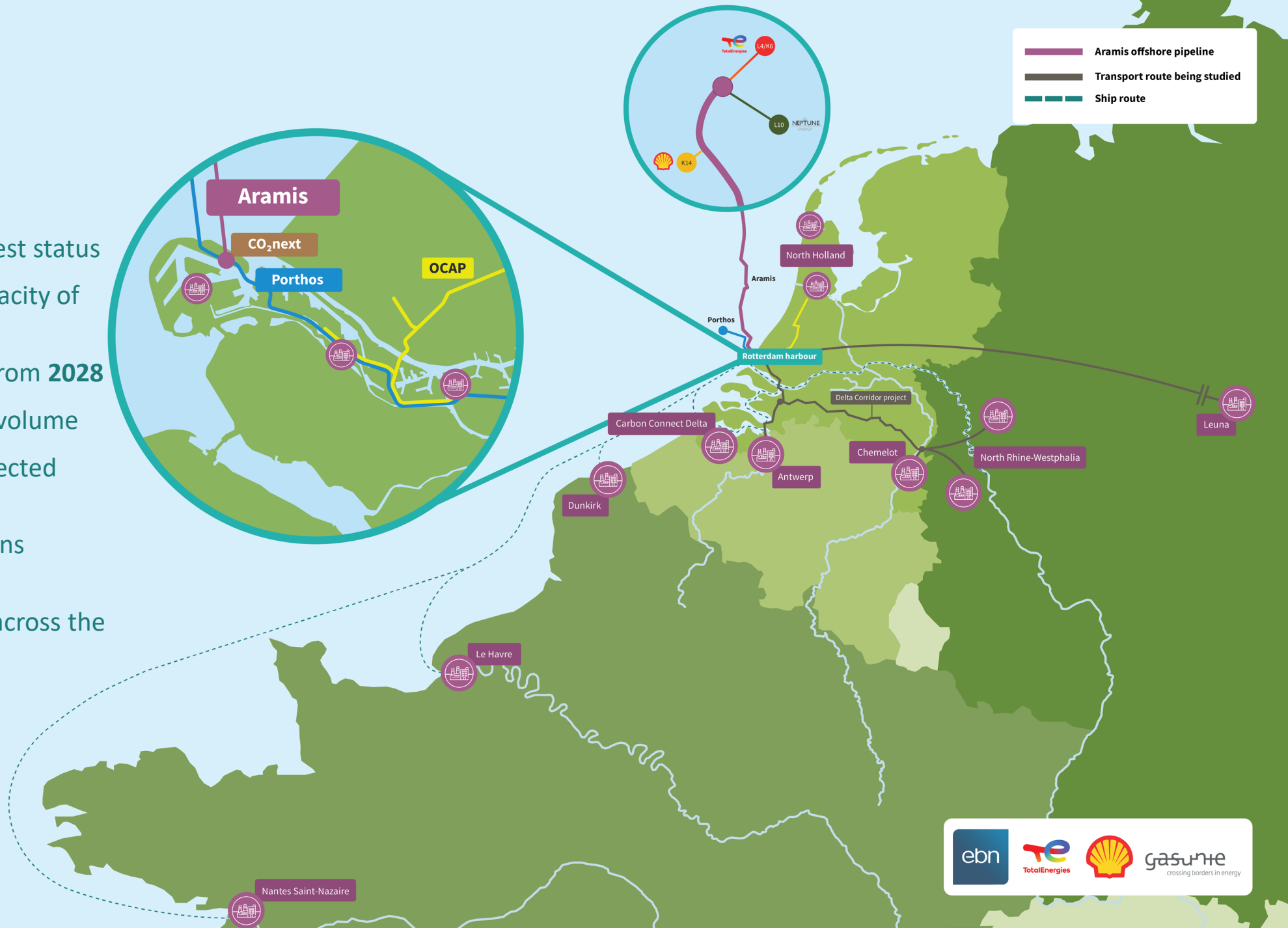


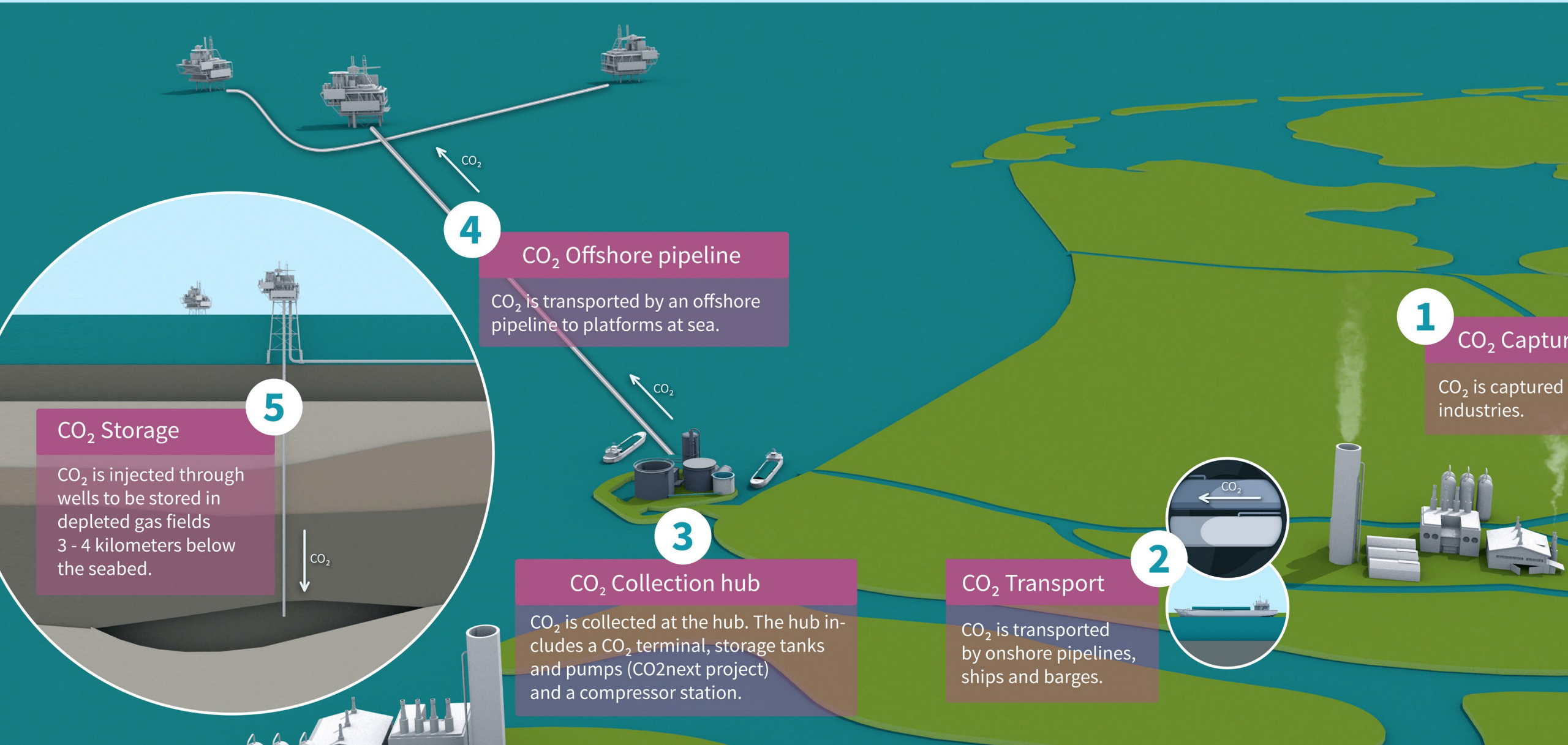
2026

- System operational



- Public-private partnership
- EU Project of Common Interest status
- Aramis offshore pipeline capacity of **22 Mtpa**
- Expected to be operational from **2028**
- Minimum **7,5 Mtpa** starting volume
- Overall storage capacity expected **>400 Mt**
- Aramis will enable connections to several European clusters
- Strong cooperation needed across the CCS value chain

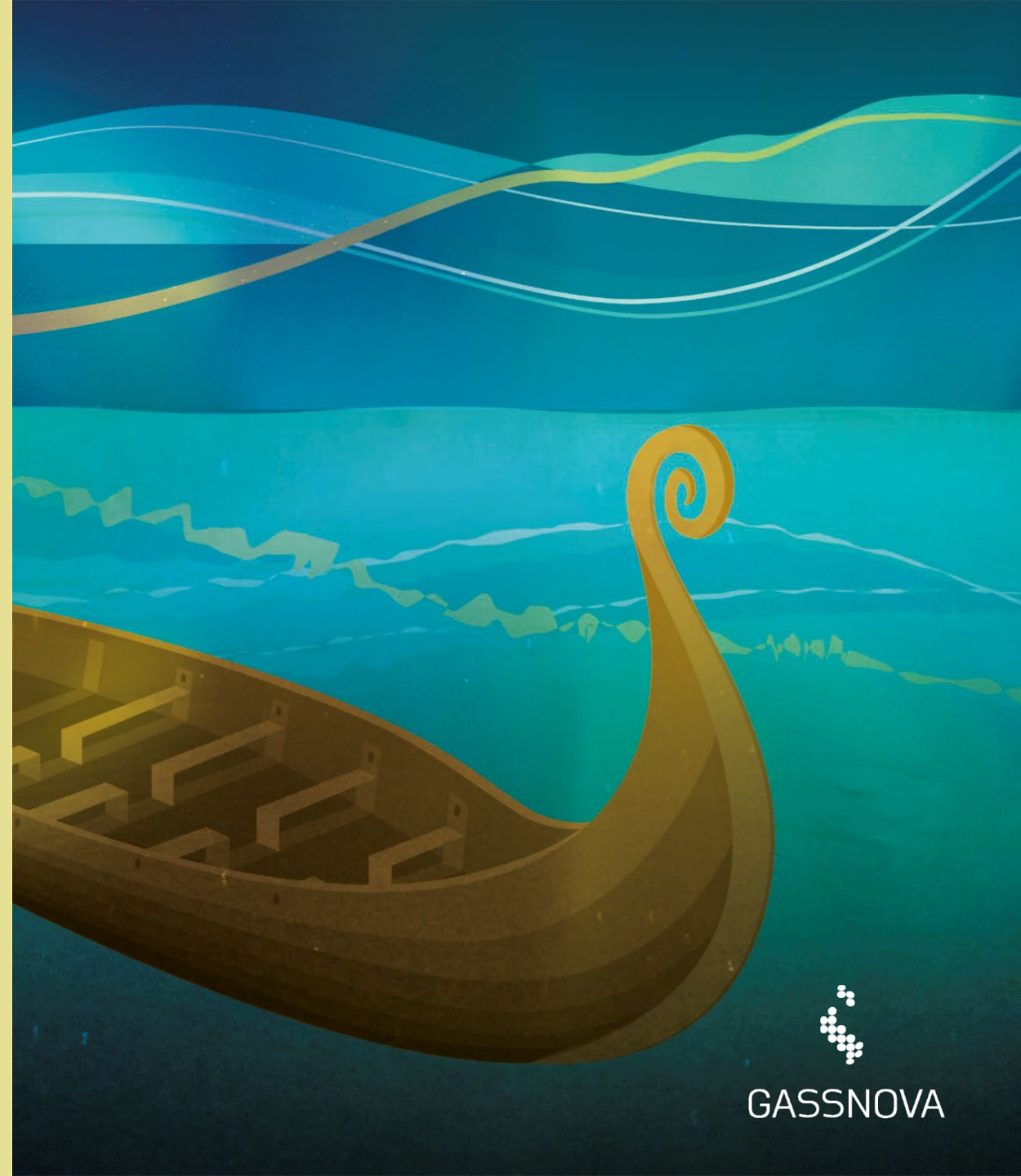




Experience from Longship

Workshop on CCS, Copenhagen/webinar
28th of September 2023

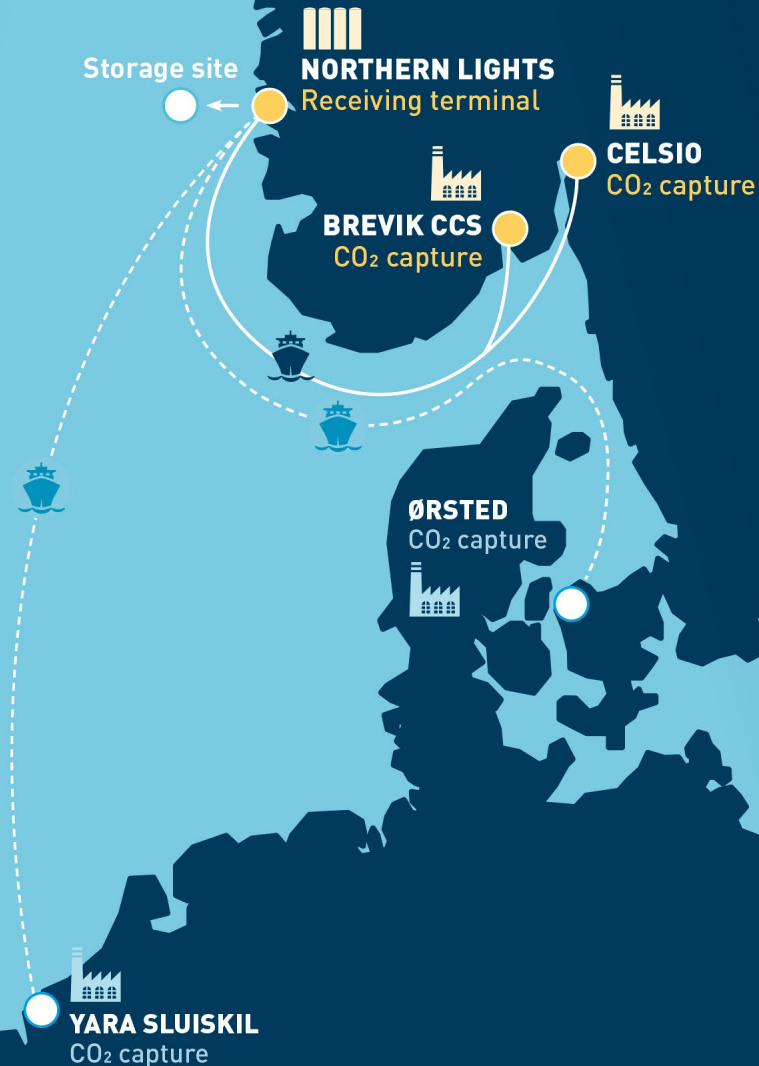
Aslak Viumdal, Gassnova SF



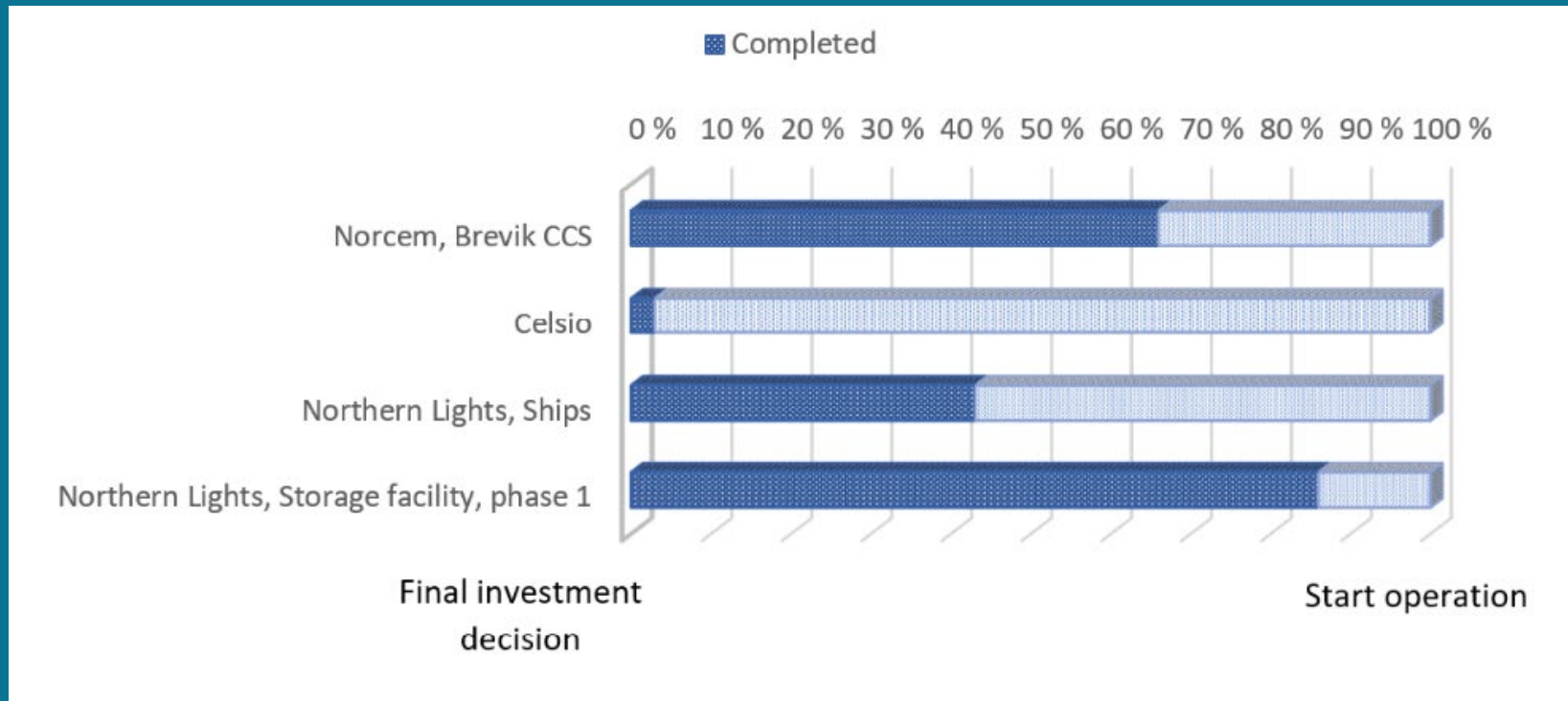
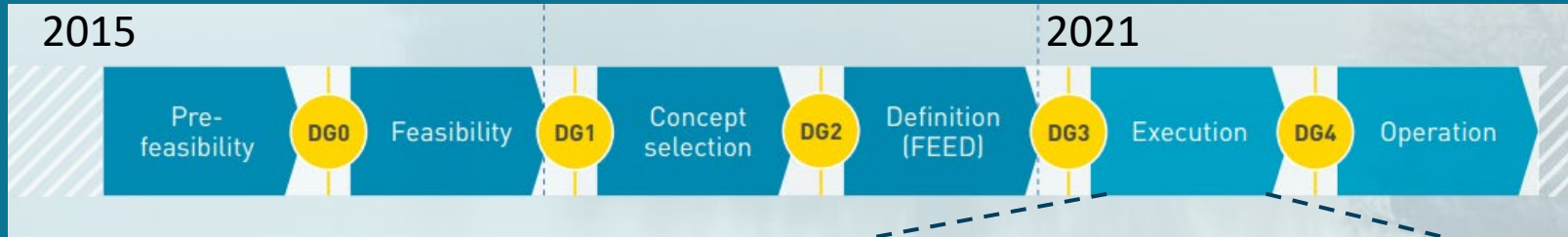
GASSNOVA

Longship is a first-of-a-kind CCS project. Construction started in 2021

- Demonstration of a full-scale CCS chain, based on hard-to-abate industries
- Application of EU - and Norwegian regulations on industrial scale CCS projects
- Including both biogenic– and fossil-based CO₂
- Establishing flexible transport (ship based) and an open-source infrastructure
- Aimed at catalyzing CCS market development in Europe, including cross-border CCS chains



Overall - current status of Longship (summer 2023)



Status cost development – Longship projects

	Cost development since FID. CAPEX and 10 years of OPEX. P50. Adjusted for inflation. July 2023
Northern Lights	- 7,2 %
Heidelberg Materials, Brevik CCS	+ 19,6 %
Oslo Hafslund Celsio	Cost increase – exceeded funding. Currently in a «cost reducing phase». Constructions on pause. New cost estimates expected next summer

Some examples of issues causing cost increase:

- Availability and price of raw materials, currencies fluctuations
- The complexity of the capture projects
 - Underestimated project management
 - Brown field, limited space and complex integration at a plant in full operation
- Being a part of a public subsidy scheme
 - Larger pause between FEED and start of constructions



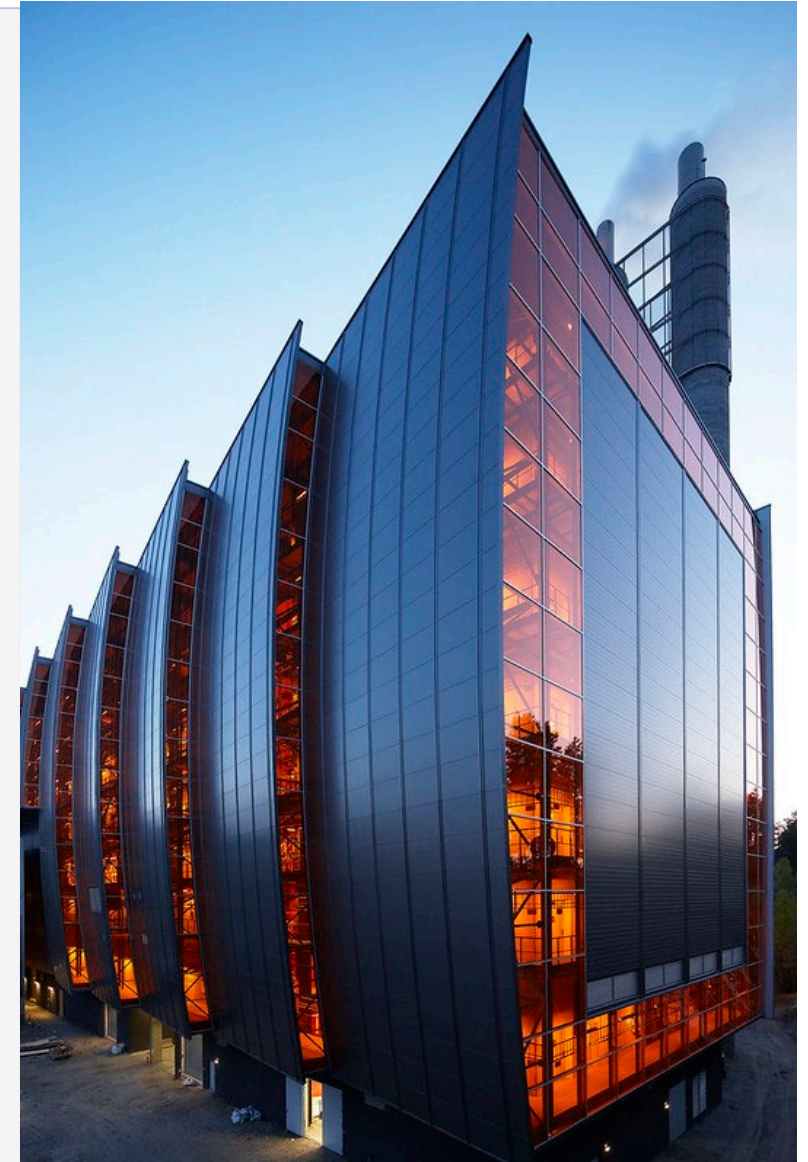
Hafslund Oslo
Celsio

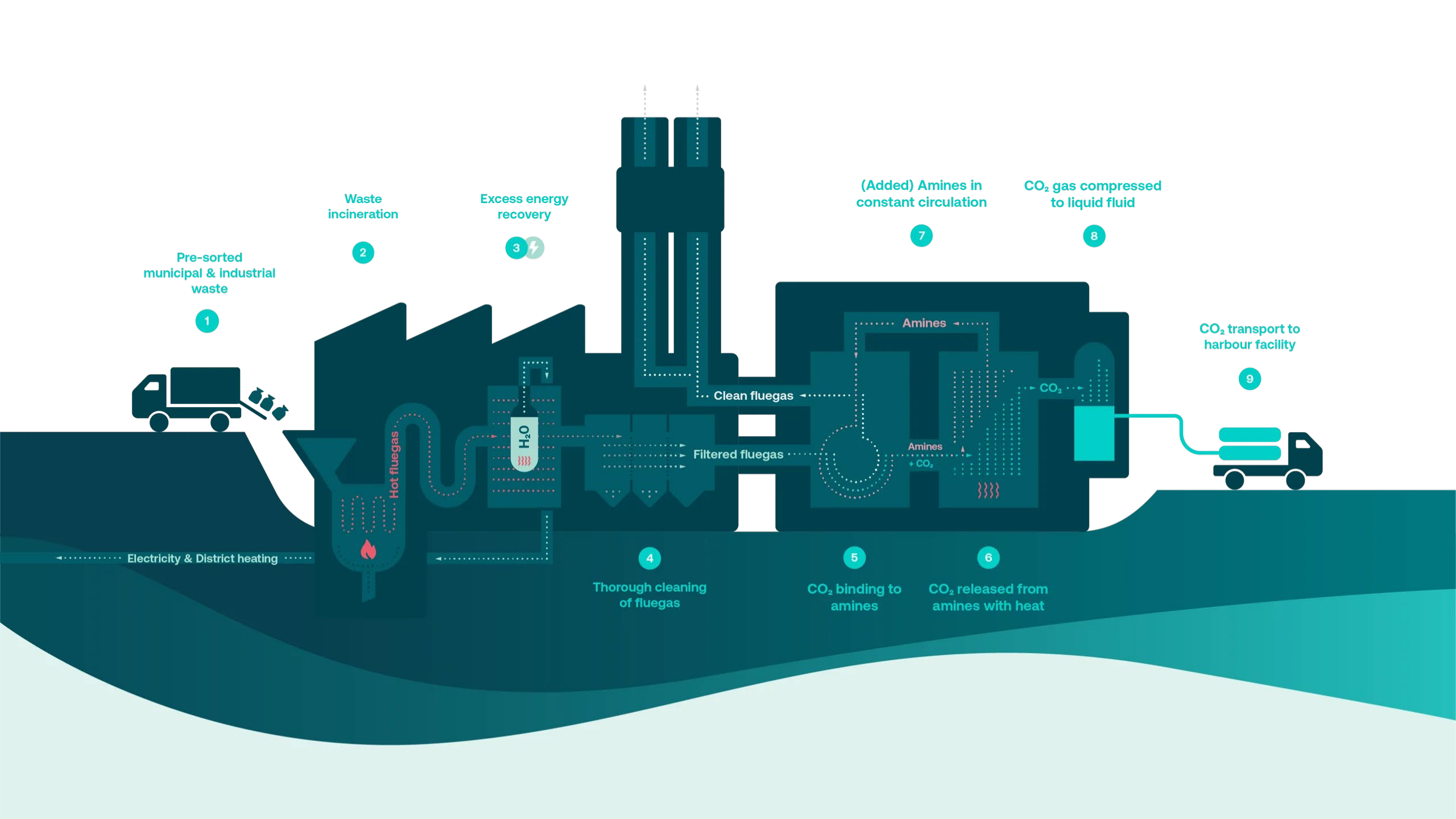
Norway's circular energy company

Truls Jemtland
Communication manager

Full-scale CCS on Waste-to-Energy

- Part of **Longship CCS** project; permanent geological storage below seabed
- Full scale CCS, **90% CO2** capture
- CCS on Waste-to-Energy provides **50 % CDR**
- Studies completed **2015-2019**
- Demonstrates emission free transport of CO2 to port
- Successful testing on **real flue gas 2018**, new test period with **Shell amine** concluded 2021
- Technology supplier with experience
- Replicable to **500 WtE** plants in Europe





CCS project financing FID 2022

- **Total Project cost 910 Mill EUR** (1 Euro =157,90 Yen)
 - **CAPEX 550 Mill EUR**
 - **OPEX 350 Mill EUR** for 10 years operation
- **State support 300 Mill EUR**
 - +10 years transport and storage service
 - +10 year support period for operations;
Payment per ton CO2 delivered at port (= ETS price)
- **City of Oslo direct investment in preference shares of 210 Mill EUR**
- **Remaining funding 390 Mill EUR** by Celsio



Parliament of Norway
Acc: Stortinget.no



Oslo City Hall



Celsio plant

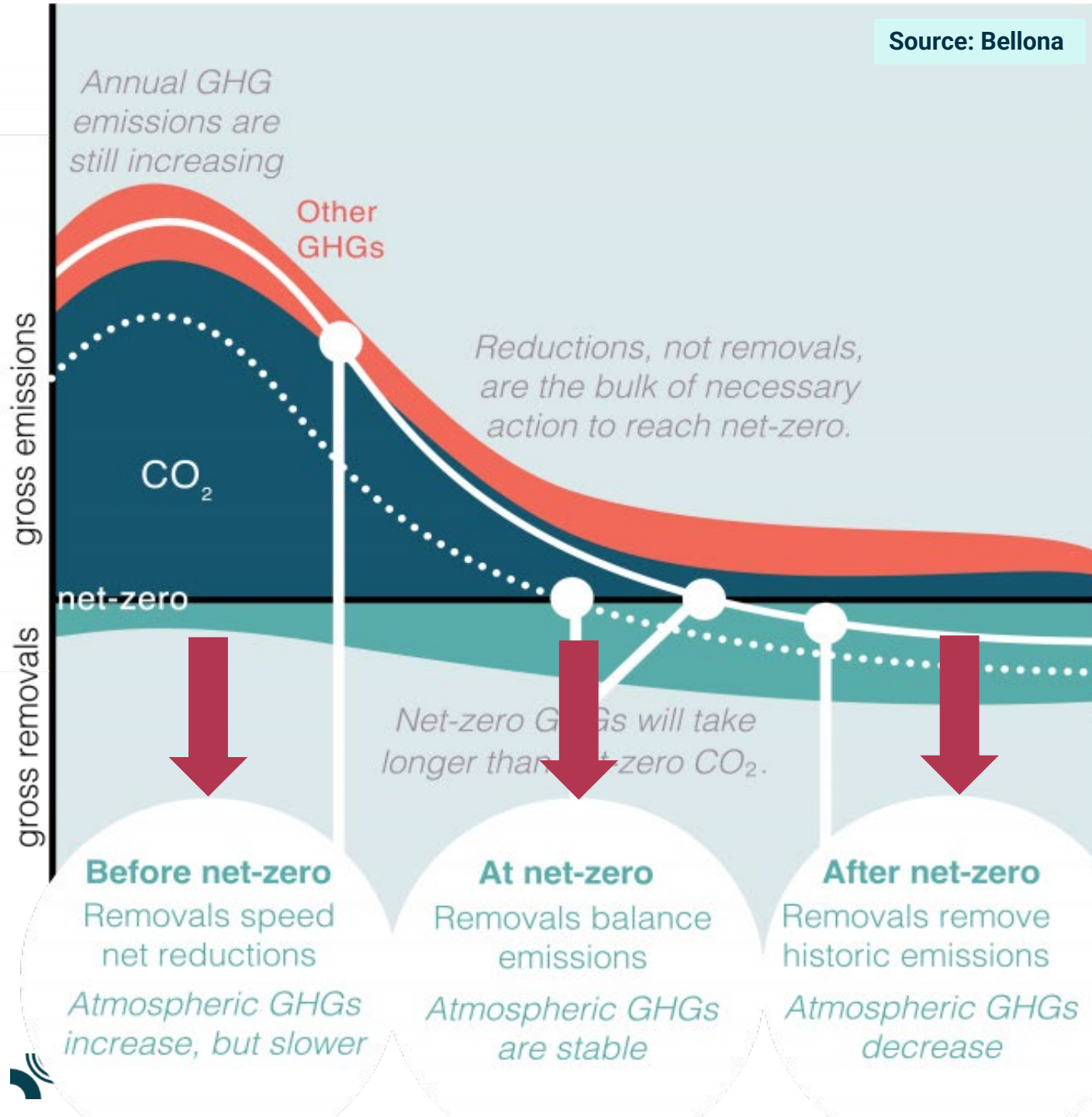
Cost increases causes cost-reducing phase

- 1) Inflation, power prices, market situation, currency
- 2) Organization – necessary with more resources
- 3) Area demand and infrastructure
 - a) Logistics and rig areas
 - b) Temporary solutions for parking, admin etc.
 - c) New entrance to incineration plant



- 4) Final location at Port of Oslo changed
- 5) Local power demand and timeline for new transformer station





Future enablers

Avoided costs (fossil part of emissions)

- Norwegian CO₂ tax
- Future ETS price

Cannot be cheaper to move waste down the waste pyramid!

1. Carbon removal (CDR) certificates (BECCS)
2. Net Zero Plastic certificates
3. Higher gate fee for carbon free waste services
4. Improved standing for district heating

Brevik CCS

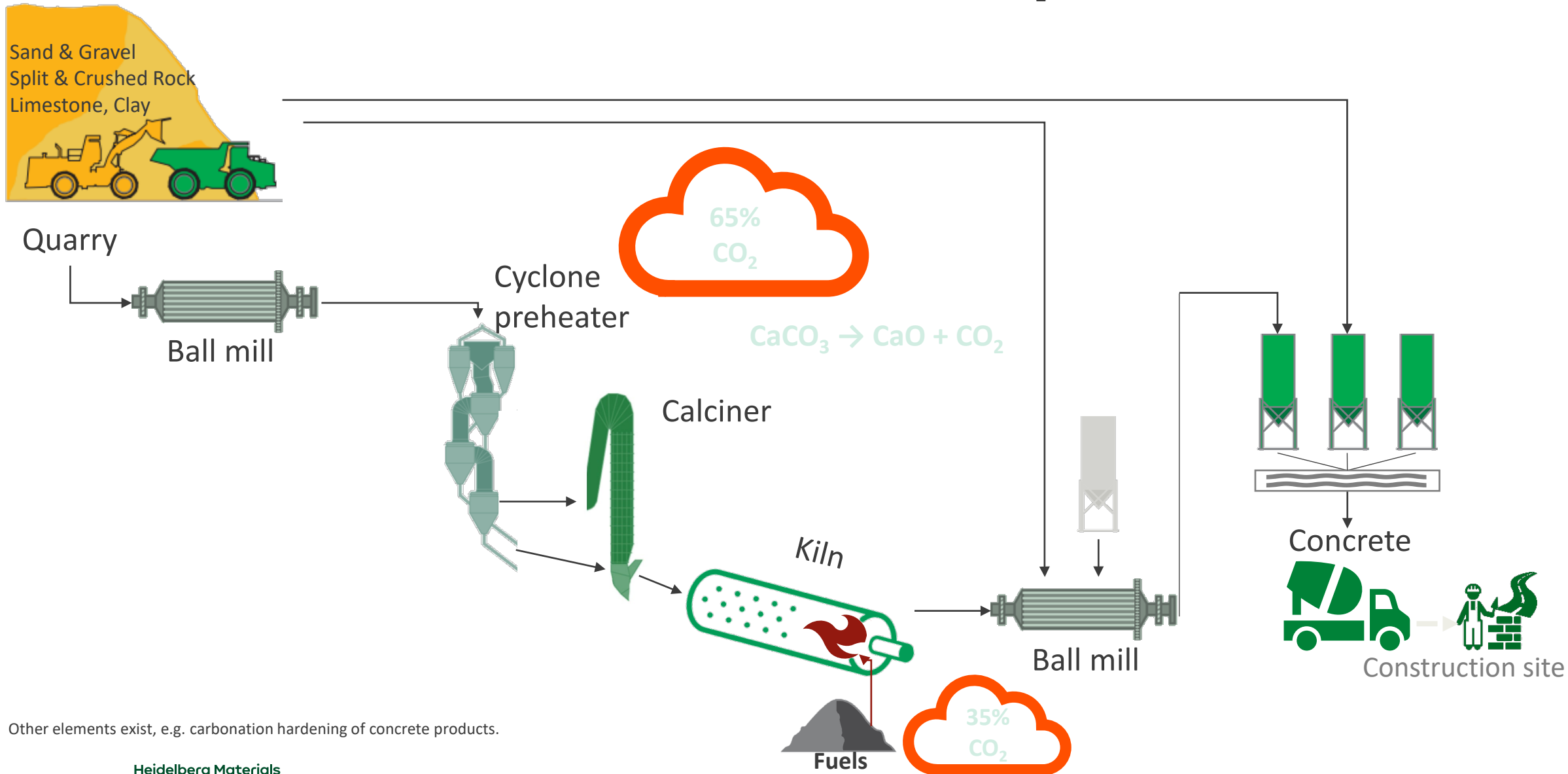
Experiences from the Longship-project

Per Brevik, HM NE

28.09.2023



Cement production is a “hard-to-abate” industry; 6 – 8% of total CO₂ emissions

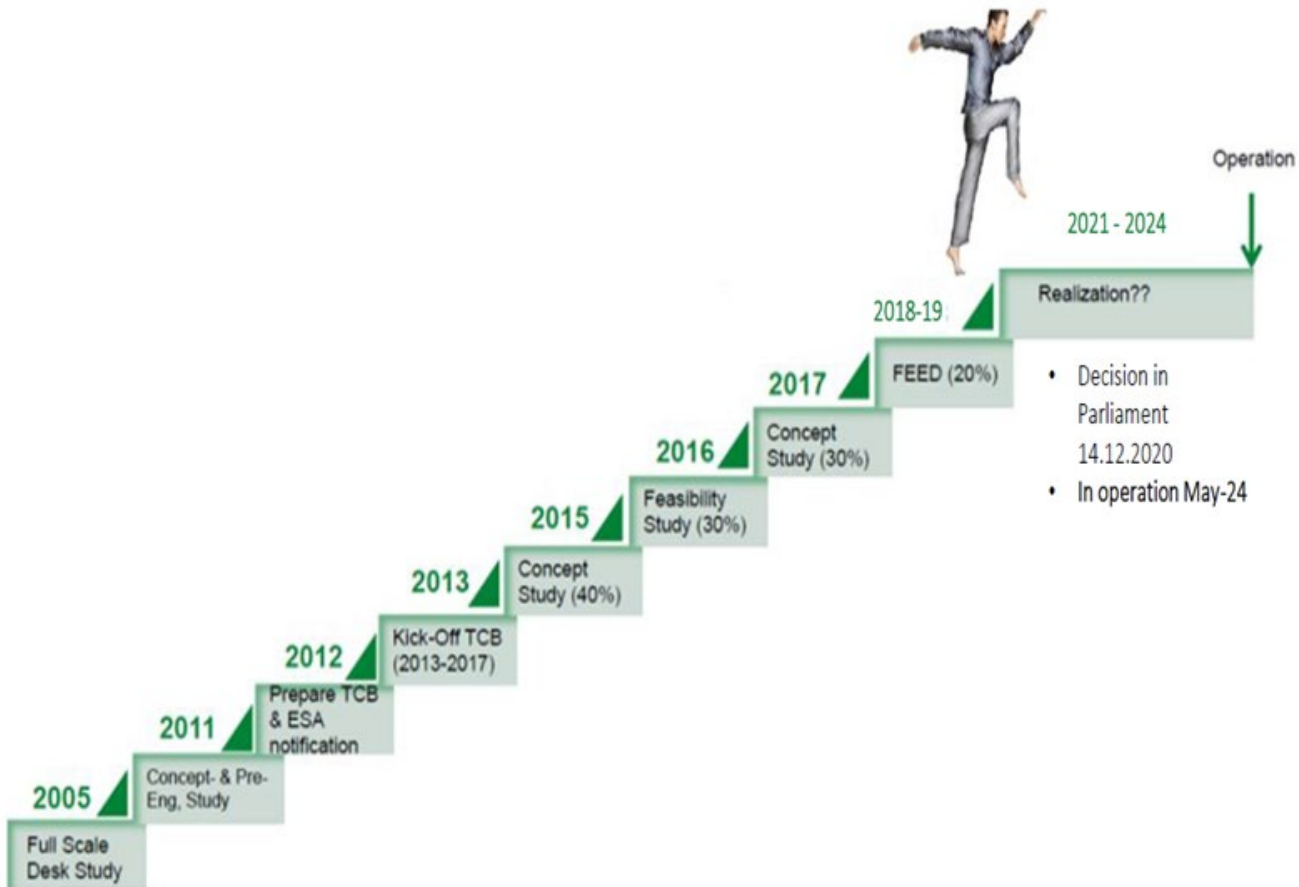


Other elements exist, e.g. carbonation hardening of concrete products.

1) In addition: kiln efficiency, green hydrogen fuel, electrification of kilns.



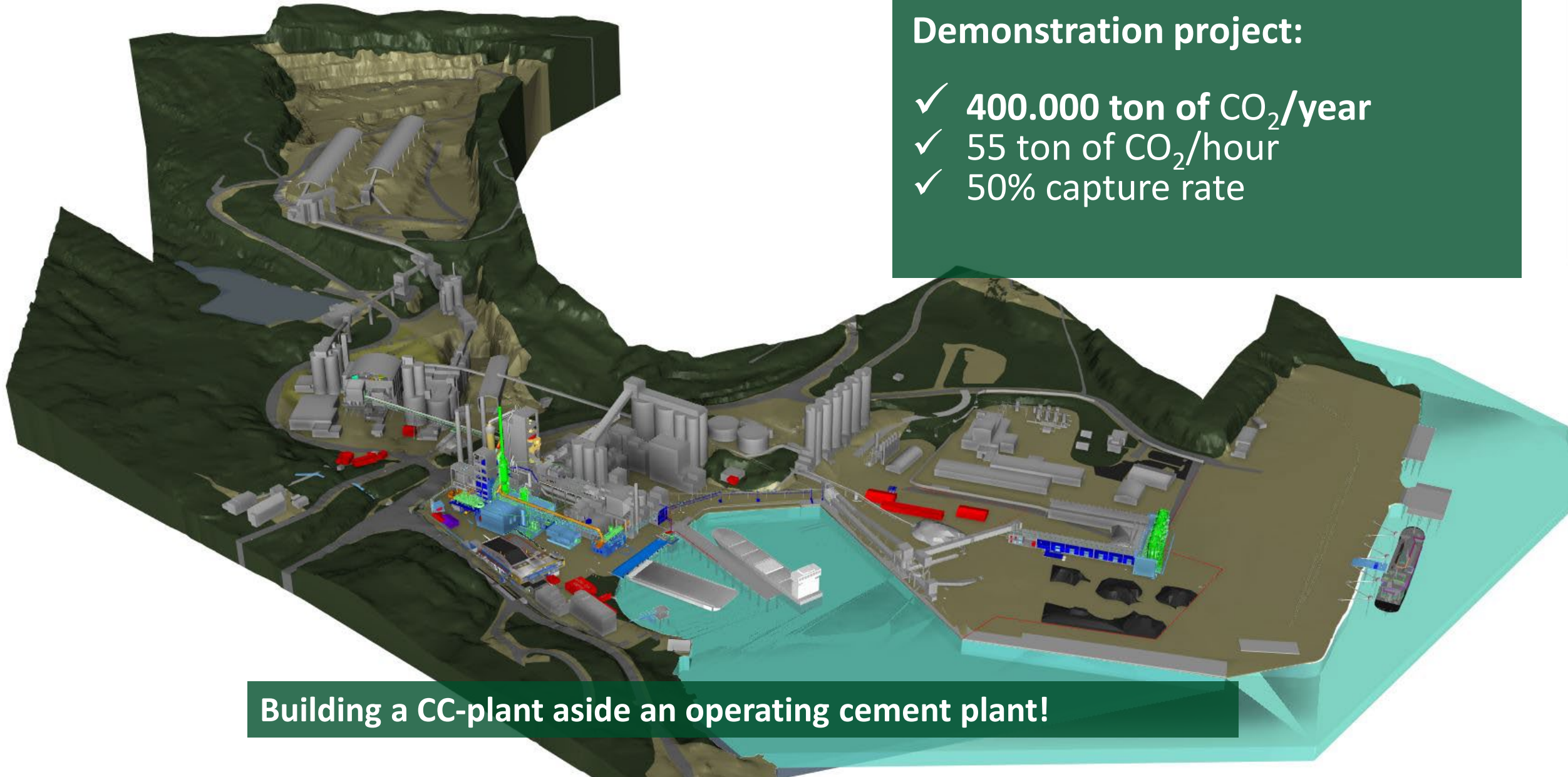
Our «step-by-step» strategy



- First internal desk studies in co-operation with Regional Technical college. R&D-project.
- Received 2010 economic support (100 k€) from ECRA to develop an application for Gassnova funding
- The test-project 2013 – 17 key for developing carbon capture at Norcem Brevik. The project is still the basis for our work. First results presented at the CCS-seminar in Langesund in May 2015.
- From 2015 part of Norwegian Carbon capture Development project (Feasibility, Concept and FEED studies)
- Longship launched 21 September 2020



Brevik CCS



Demonstration project:

- ✓ 400.000 ton of CO₂/year
- ✓ 55 ton of CO₂/hour
- ✓ 50% capture rate

Building a CC-plant aside an operating cement plant!

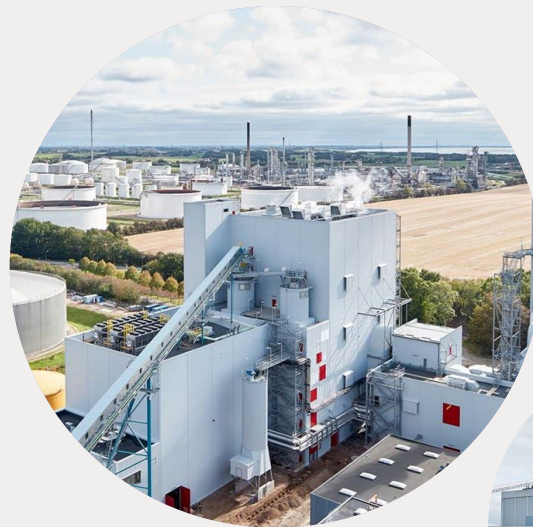
Brevik CCS – experiences

- Project maturity
 - Development of a «first-of-a-kind» project.
 - Testing of technology on your own flue gas
 - Design changes and project development are extremely costly after start-up
- Delays and cost over-runs (Pandemic, Ukraine war, sanctions and the effects for supply chains).
- A competent and efficient project team is crucial; cultural differences between plant operation and the project (many consultants).
- Government support and funding (launching of the Norwegian Carbon capture development project); incl. solution for treatment of biogenic CO₂ has been absolutely necessary.
- **Our experiences from realization and operation can hopefully be valuable for both the cement industry and other process industries!**



Ørsted Kalundborg Hub

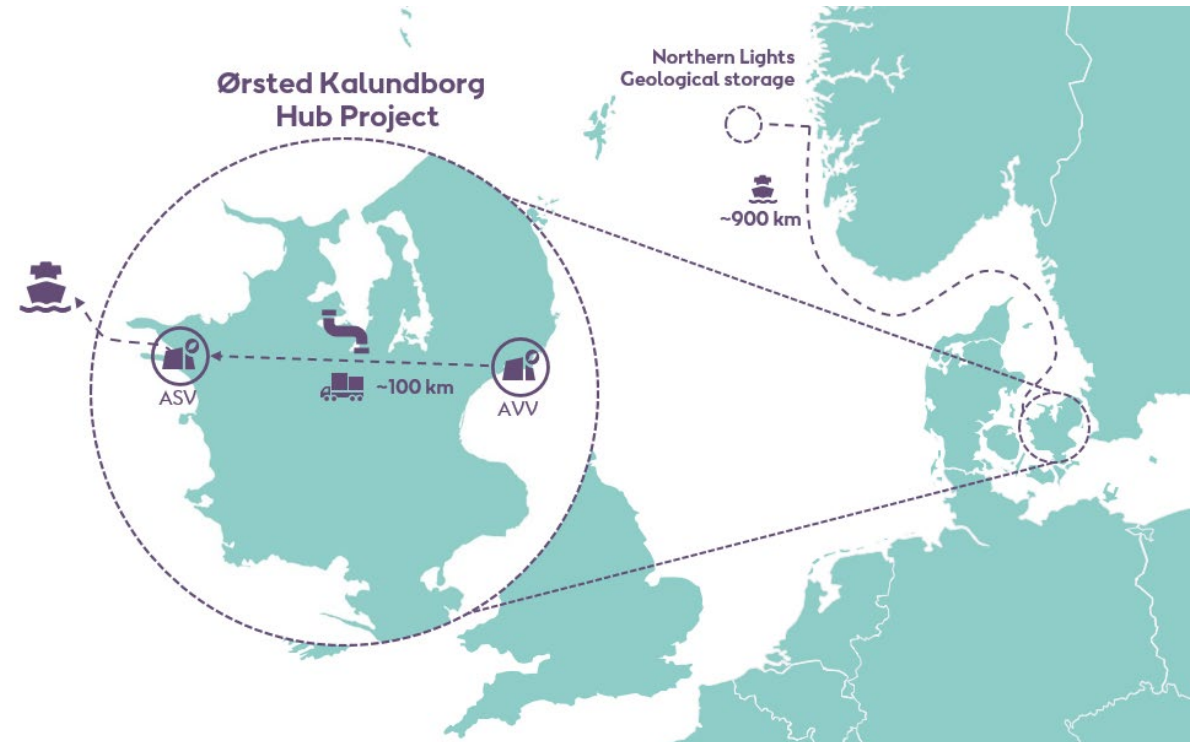
Lars Bruun Sørensen
Head of Ccx



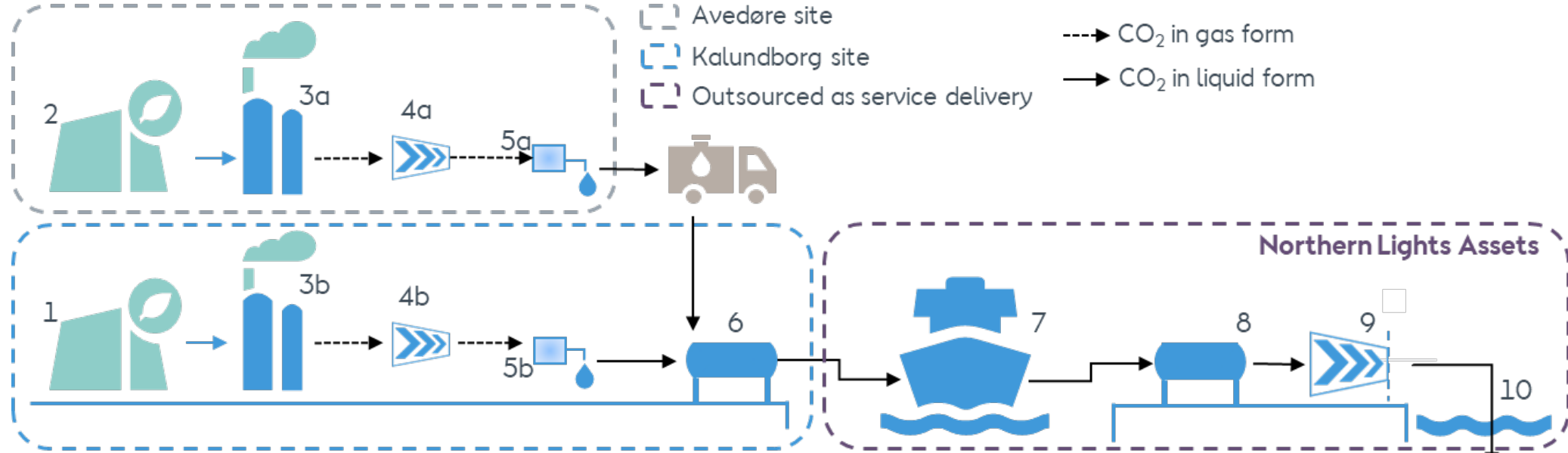
Project Concept

Carbon capture on two sites and transport to permanent offshore storage

- From 2026, more than 430.000 tons of biogenic CO₂ is captured each year on two sites on the island of Zealand in Denmark:
 - Site 1: Avedøreværket in Copenhagen, AVV
 - Site 2: Asnæsværket in Kalundborg, ASV
- CO₂ from the AVV site is transported initially via truck and later via pipe to the ASV site where the combined CO₂ streams awaits transport to permanent storage
- From the ASV site all of the CO₂ is transported by ship to the Northern Lights geological storage terminal in Norway
- The Northern Lights terminal receives CO₂ from multiple sources in North-western Europe and injects it into a dedicated saline aquifer under the North Sea



Ørsted's key partners in the Ørsted Kalundborg Hub project

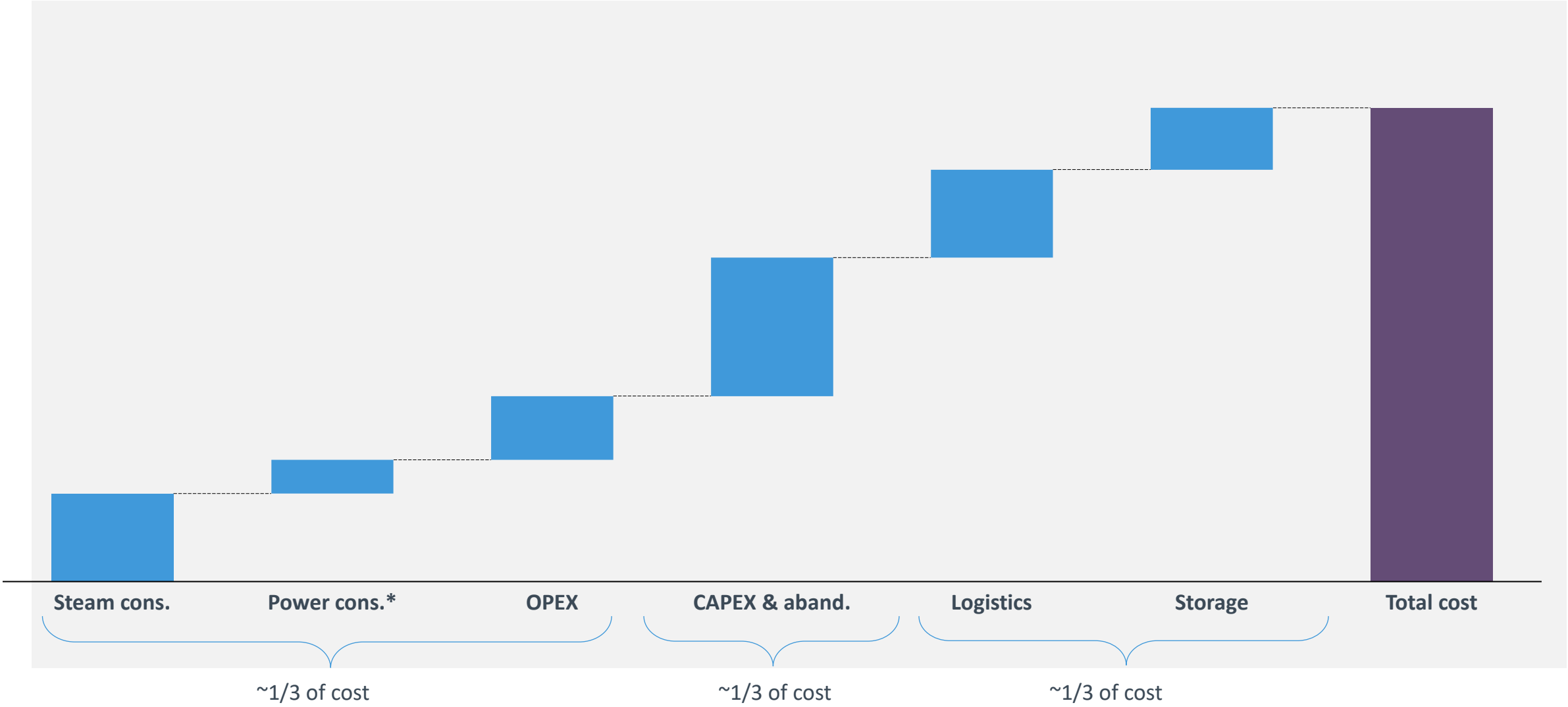


Description

<p>The solution is based on a concept with the two point sources:</p> <ul style="list-style-type: none"> (1) Asnæsværket unit 6 (ASV6) (2) Avedøreværket, unit 55 Straw Boiler 	<p>CO₂ is captured from five carbon capture modules (3) before it is liquefied by compression and cooling (4). The liquid CO₂ streams are joined in the shared intermediate storage and shipping terminal, awaiting transport (5)</p>	<p>Transportation of captured CO₂ from AVV to ASV via truck (6)</p> <p>At ASV terminal the CO₂ is loaded to intermediate storage tanks (7)</p>	<p>Transport is performed by ship (8), at a rate consistent to the operation of the two CC units. Liquid CO₂ is delivered to onshore intermediate storage terminal (9) ahead of transfer and injection into offshore permanent geological reservoir (10) 2,600 m</p>	<p>Carbon removal certificates (11) from BECCS at ASV and AVV can be sold through bilateral offtake agreements and commodity trading platforms</p>
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General BECCS cost structure



Cost structure based upon CC with liquifaction and non-pipe transport to geological storage.

*Power consumption primarily related to liquifaction.

Industry challenges highlight the need for scaling efficient value chains

The market is in need of solutions that are cost efficient, flexible and easily scalable, because:

1

CCS is a low cost game driven by cost efficiency to scale up investment

2

The CCS industry is growing, though the exact capture timelines are difficult to predict

3

Available storage uncertainties in regards to capacity and timeline

4

Scaling of transport solutions needs to be aligned with above and at low cost





DENMARK AS A LARGE SCALE STORAGE ENABLER IN EUROPE, PLANS AND STATUS

- KATRINE THOMSEN, DANISH MINISTRY OF CLIMATE, ENERGY AND UTILITIES

CCS ACHIEVEMENTS –NEXT STEPS

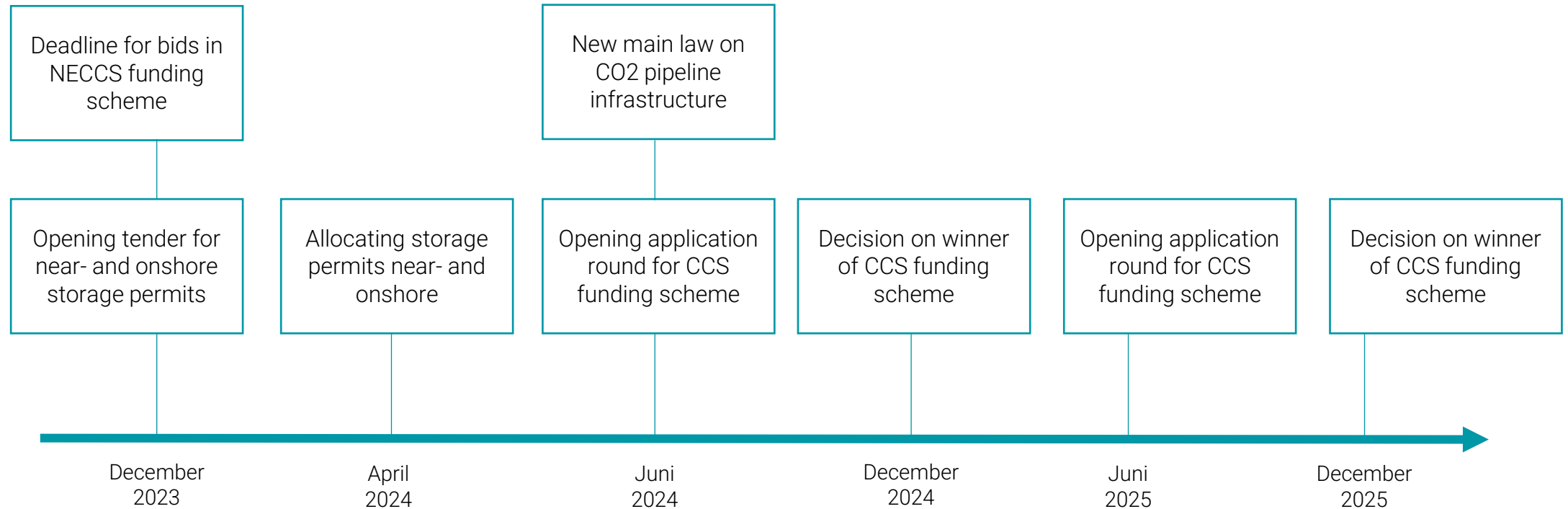
New political agreement September 20th 2023

- Combining our funding schemes into one CCS scheme
 - Making it easier for industry to understand and apply, combined fund of DKK 27 billion (EUR 3,6 billion)
 - Two tender rounds in June 2024 and June 2025
 - Capturing and storing 2,3 mio. ton CO₂ from 2029
- 20% state ownership of storage licenses both on- and offshore
 - Removing doubts and uncertainties in the market
- Denmark's first main law on CO₂ pipeline infrastructure
 - Enabling both public and private ownership
 - Removing doubts on expropriation rights
 - Enabling the "Danish Utility Regulator" to regulate

Other next steps

- Opening first Danish tender on near- and onshore storage permits
 - Enabling more storage sites
 - Good for both Danish and other European emitters
- Launching funding scheme for negative emissions (NECCS fund)
 - Ensuring negative emission of 0,5 mio. ton CO₂ yearly from 2025
 - Deadline for bids 1. December 2023
- More bilateral agreements on transport of CO₂ with the purpose of geological storage under the sea bed
 - In Europe, the legal framework is clear through relevant directives (e.g. CCS and ETS)
 - Internationally, the state level responsibility handover in case of cross-border transport is clear
 - Removing doubts in the market and enabling a scale-based common single market for CCS in Europe

ESTIMATED TIMELINE



POTENTIAL FOR CO₂ STORAGE

