GreenShift

Securing the European Green transition through Research, Business and Government Collaboratation

CCUS Summit Düsseldorf

21st of September, 2023

SINTEF

Innovation Norway

NRW.ENERGY 4CLIMATE

Norwegian Embassy *The Hague*

Norwegian Embassy *Brussels*

Norwegian Embassy *Copenhagen*

Norwegian Embassy *Berlin*

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Alexander Engh

Deputy director general and head of the CCS section at the Ministry of Petroleum and Energy, Norway

Prior to joining the Ministry in 2019 he spent 17 years in the energy industry, serving as commercial director of Infragas, management consulting and various commercial and financial roles at ExxonMobil.

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Alexander Engh, Ministry of Petroleum and Energy

Main Messages:

We need to develop an integrated market for CCS in Europe; the golden aim is a spot market that allows stakeholders to make investment decisions independently. But to start we need to lift value chains bilaterally.

Simplicity is key. Look at the IRA – everyone understands it. Europe is different – but we should still aim for a framework that is easy to understand.

Trust – is gained over years and lost in seconds. We need to do this in a safe manner.

We need to reduce costs. R&D, scale, collaboration, competition, regulation. And the right type of capital and competence in the right parts of the value chain at the right time.

There is momentum in the market – we need to act on it.

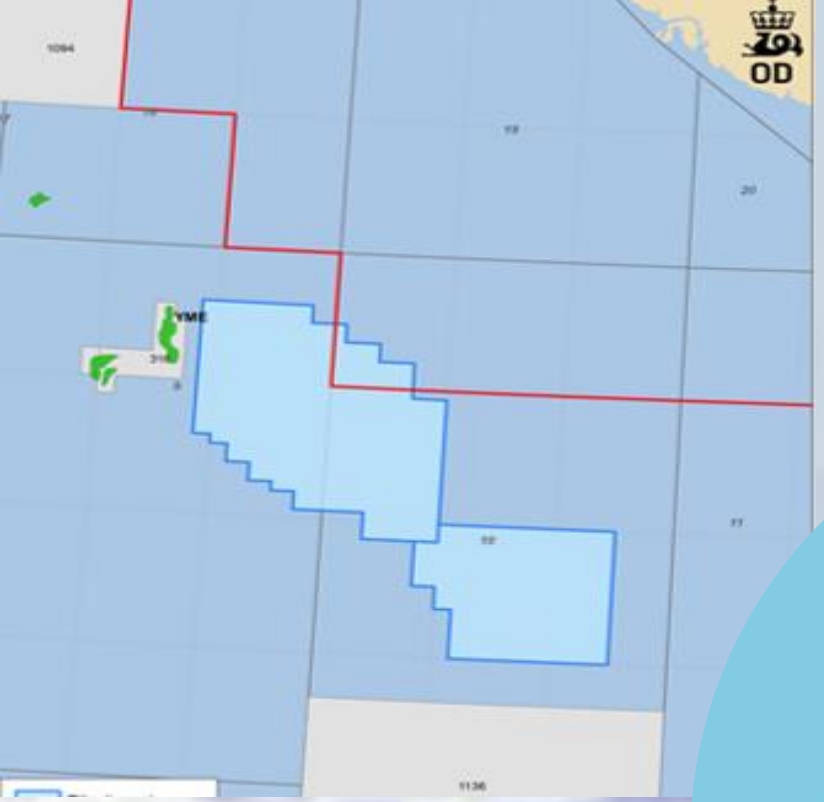
Olje- og energidepartementet

Green shift

Alex Engh

Düsseldorf Sep 21, 2023

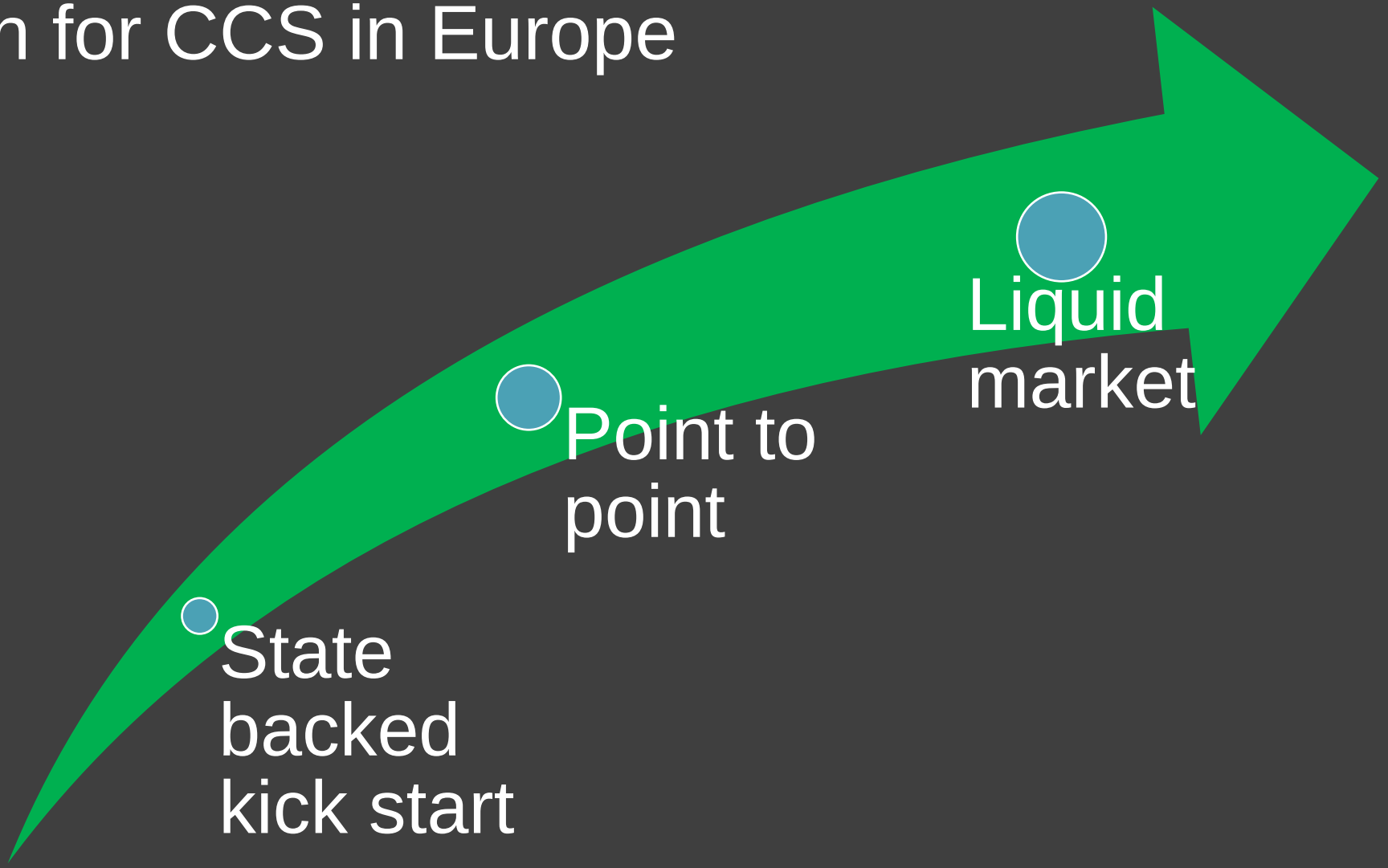
Status CCS


OD

NOR-GE Pipeline
CO_2
CO_2
Wilhelmshaven
Hamburg
CO_2 Pipeline System

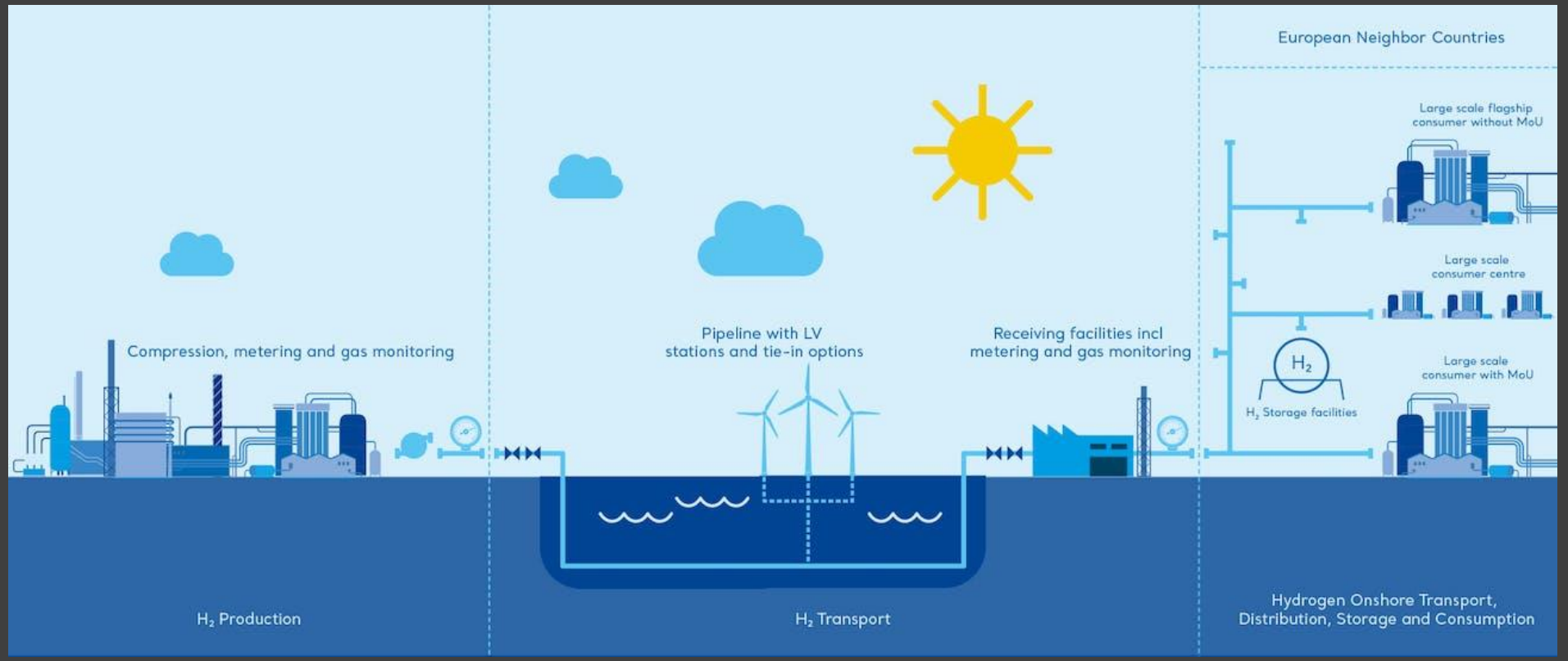
Storage site
BREVIK CCS
CO_2 capture
YARA SLUISKIL
CO_2 capture

Vision for CCS in Europe



Hydrogen: International cooperation

A feasibility study on hydrogen export from Norway to Germany



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Michael Schlaug

Managing director and plant manager at Yara Sluiskil

He has dedicated over 25 years to the Norwegian multinational, previously holding positions in Germany, Norway, Belgium and Belle Plaine (Canada). With a Dipl.Ing. degree in Process Engineering from the Technical University of Aachen, he brings strong business orientation. Yara Sluiskil boasts the largest ammonia and nitrate fertilizer capacities in Europe. Michael's duties encompass ensuring safe plant operations and overseeing all aspects of the company, including organizational development, finance, and strategy.

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Michael Schlaug, Yara Sluiskil

Main message:

Responsibly feed the world and protect the planet - Yara Sluiskil's Climate Roadmap 2030

The role of blue hydrogen/ammonia as accelerator/enabler for green hydrogen/ammonia

Yara Sluiskil as frontrunner and system player in the energy transition

The urgent need for collaboration (clustering, cross-boarder, industry-policy makers-NGO's) to ensure sizable and fast decarbonisation steps

Knowledge grows

GreenShift - Accelerating sizable de-carbonisation steps

Michael Schlaug

Managing Director & Plant Manager

Yara Sluiskil B.V.

Yara Sluiskil B.V.

Yara Sluiskil - Key indicators 2022

2

Billion EUR Turnover

2

BCM/yr Natural Gas Consumption

80%

as feedstock

4.5

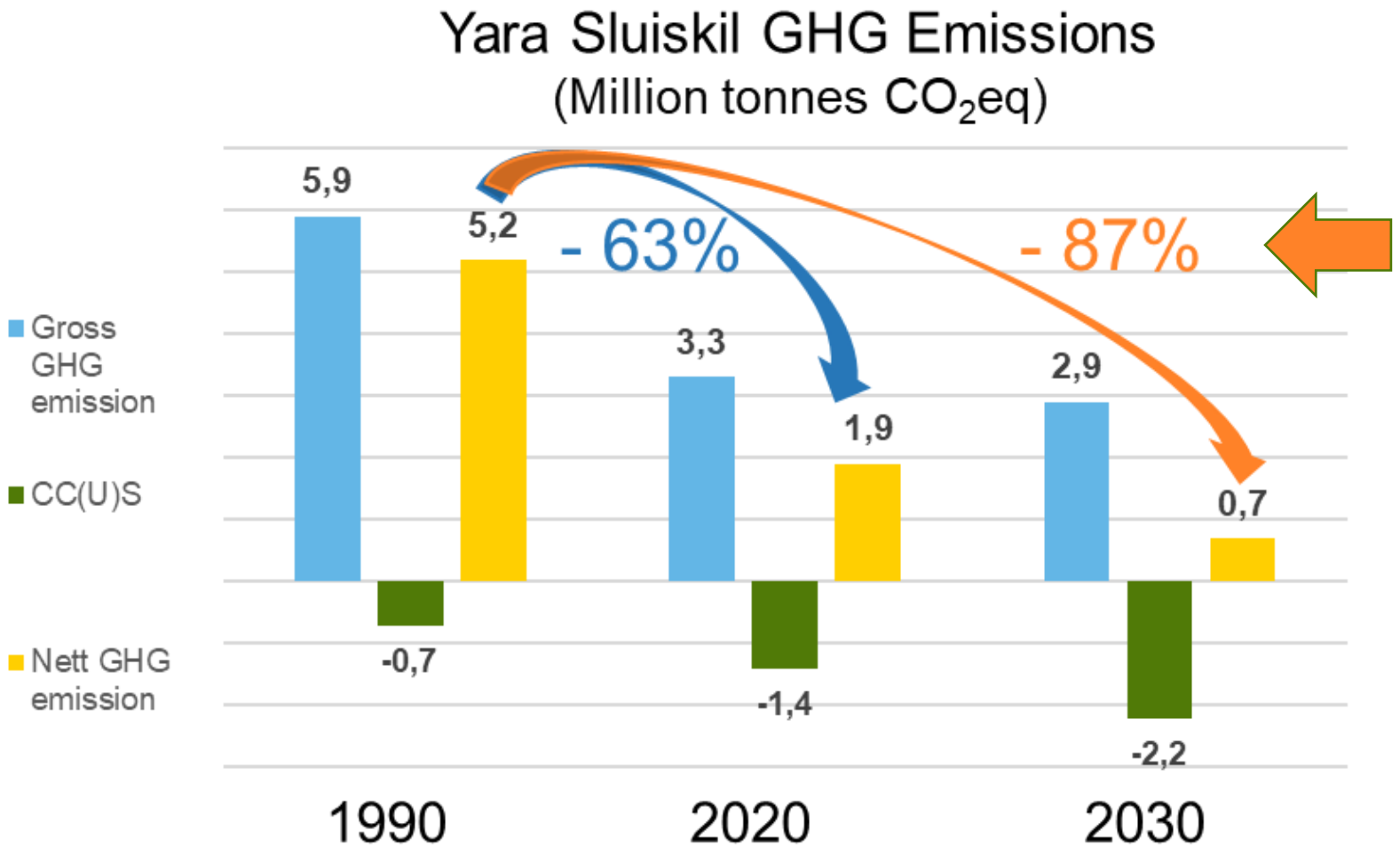
Mio ton/yr Products

Ammonia
Nitrates
Urea/AdBlue
Ind Chemicals

-65%

CO_2 reduction
(since 1990)

Yara Sluiskil – Our De-carbonisation Roadmap



Key Activities

- Upgrade ex. units (-0,5 Mt/yr)
- CCS (-0.8Mt/yr)
- Connection to H2-backbone
- Blue/Green ammonia import

The role of blue hydrogen/ammonia as accelerator/enabler for green hydrogen/ammonia


Yara Glomfjord, 1980th

Some hurdles for de-carbonisation projects

- Sound business case
- Hydrogen availability / CO2 storage capacity
- Balanced risk management
- Infrastructure
- Political clarity/ Level Playing field
- Societal consensus

The urgent need for collaboration to ensure sizable and fast decarbonisation steps

Collaboration is key in various dimensions

- Industry clustering
- Cross-border integration
- Aligning Politics/Industry/NGO's

Knowledge grows

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Prof. Roland Span

Head of the Chair of Thermodynamics at Ruhr-University Bochum

Mechanical engineering graduate from Ruhr-University Bochum, achieved his Ph.D. in 1992, revolutionizing carbon dioxide thermodynamics with a new reference equation. He worked on gas-turbine topics at ALSTOM Power Technologies in Switzerland and then took on chairs in Thermodynamics and Energy Technologies at the University of Paderborn and Ruhr-University Bochum. His scientific papers focuses on thermodynamic properties and modeling for energy technology simulations. His research has earned numerous awards, including the NTNU & SINTEF CCS Award in 2019 and an ERC Advanced Grant in 2022. He actively contributes to various scientific committees, including energy technology advisory boards. Prof. Span also coordinates CO2 transport activities for the JP CCS of the European Energy Research Alliance and serves in leadership roles in various academic and research institutions.

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Prof. Roland Span, Rhur-University Bochum

Main message:

Research will enable more efficient CCUS solutions - but do the established structures allow us to be fast enough?

Building the CCUS Industry by Applied Research

Research will enable more efficient CCUS solutions - but do the established structures allow us to be fast enough?

Three Minutes – Three Slides – Three Messages

Prof. Dr.-Ing. Roland Span

GreenShift CCUS Summit

Düsseldorf, September 21st, 2023

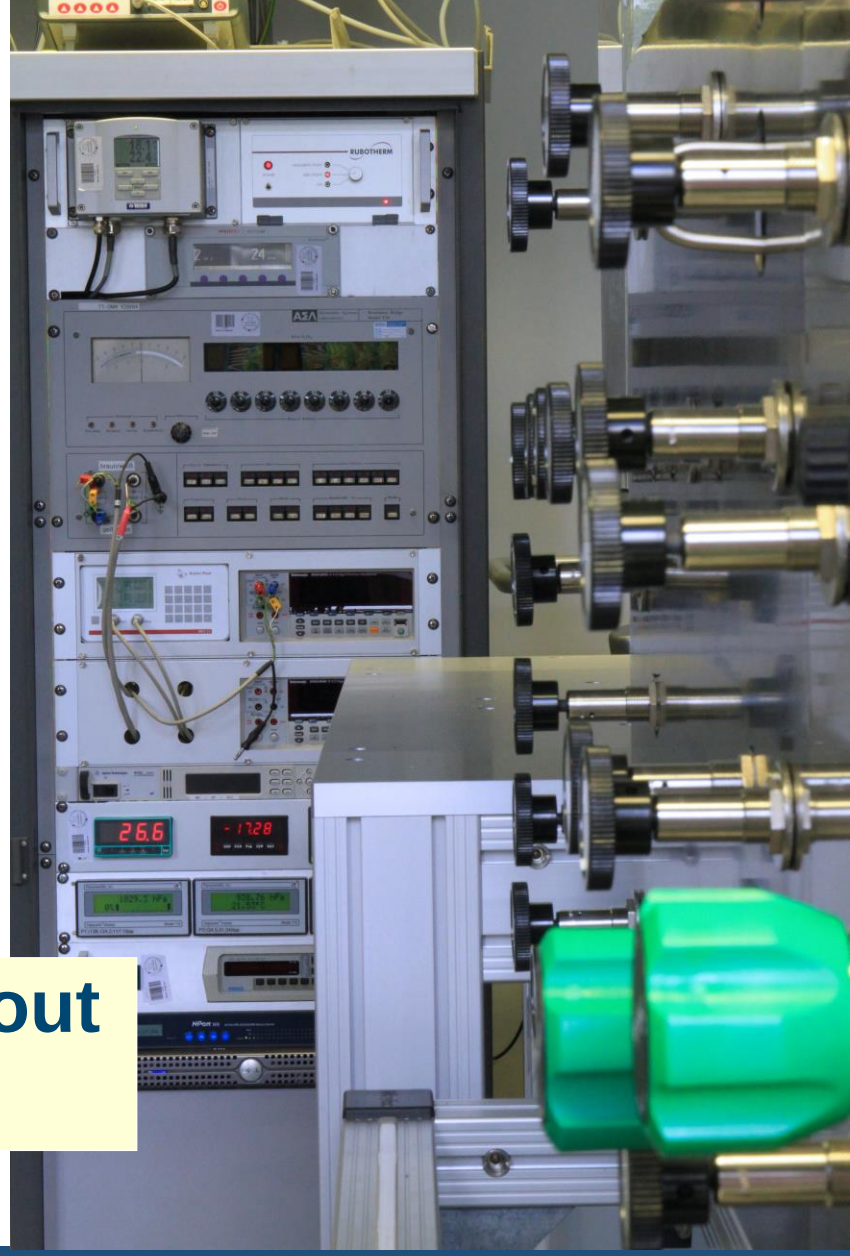
Fundamental research can…

… aim at the development of new technologies

- long way to application
- low Technical Readiness Level, TRL scale applies

… aim at optimizing existing technologies (targeted fundamental research)

- way to (global) application can be very short
- the TRL scale does not apply!

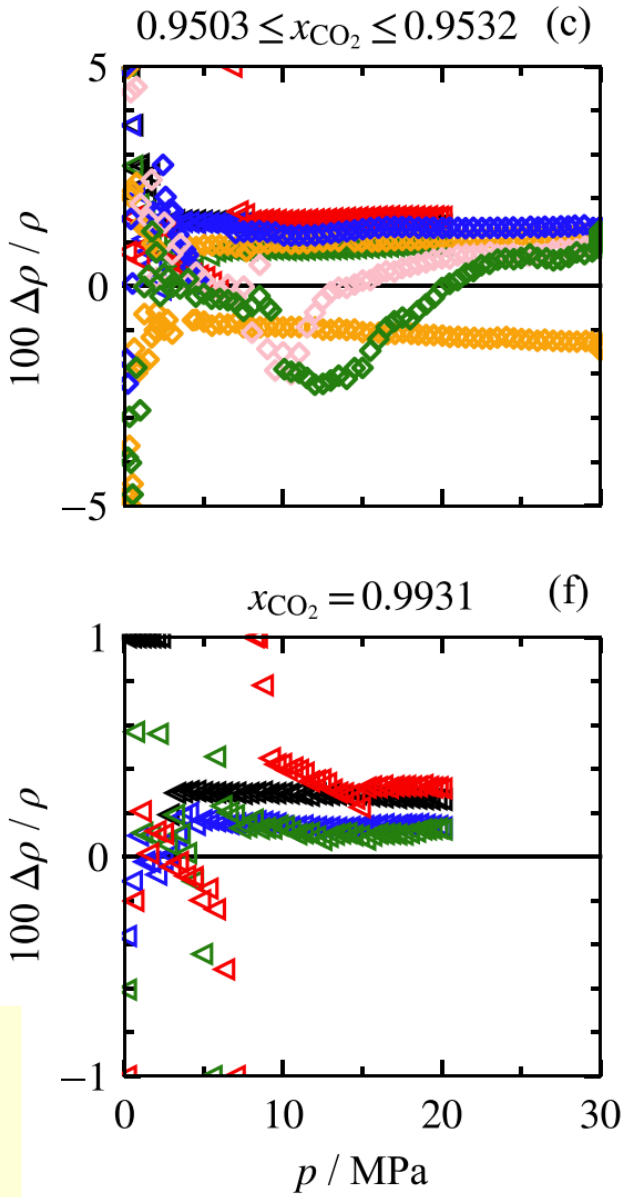


Forget about the TRL scale, when talking about targeted fundamental research!

Targeted fundamental research can…

… make CCUS chains more efficient

- for transport currently discussion on more strict SO_X limits (30 ppm ⇒ 10 ppm)
- SO_X stands for SO_2 and SO_3
- SO_2 has little effect on formation of a corrosive phase
- SO_3 has a very strong effect
- detailed knowledge missing on the effect of SO_2 / SO_3 and on the (development of the) distribution of SO_2 / SO_3



Some research needs are obvious, some will become obvious; we know who can tackle them!

Structures to identify research needs are established

- both EC and national governments have established advisory groups
- input of advisory groups is reflected in development plans and in calls for research & innovation work
- experts evaluate research proposals (of consortia)
- effective for the development of new technologies, not for addressing specific research questions relevant for the optimization of high TRL technologies

More direct structures are required to speed up targeted fundamental research for CCUS!

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Dr. Gunhild A. Reigstad

Senior Research Scientist at SINTEF

Gunhild A. Reigstad has 19 years experience within the gas technology research field. Since 2017 she has focused on the European energy transition needed to fulfill the Paris climate agreement, and the role of hydrogen and CCS in the transition. She has been a part of the Hydrogen4EU study team, demonstrating the impact of technology knowledge in holistic transition studies for energy systems.

Gunhild A. Reigstad holds a P.hD. from the Norwegian University of Science and Technology (NTNU) in Trondheim, within the field of CFD analysis of parallel flows in heat exchangers.

ACCSESS

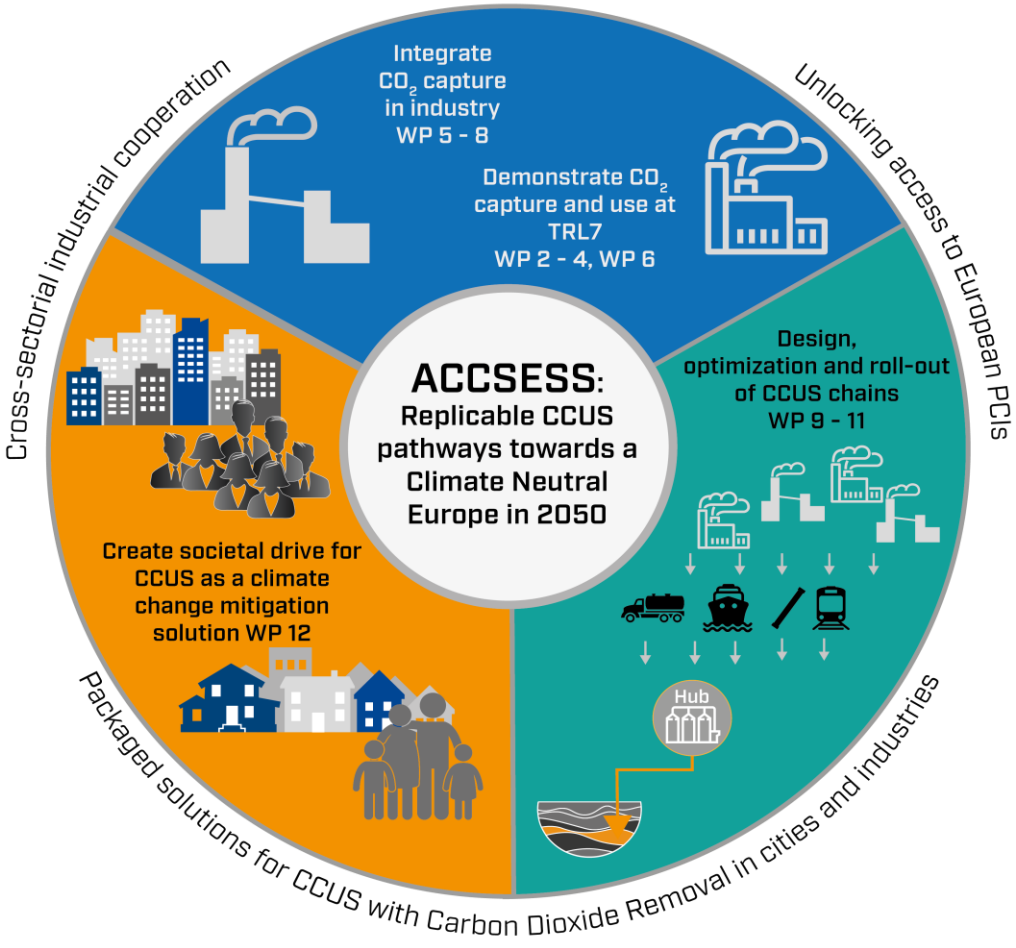
Providing access to cost-efficient, replicable, safe, and flexible CCUS

Horizon2020 Innovation Action

Duration: May 2021- April 2025

Coordinator: SINTEF Energy

Budget: 18.4 MEUR, EU funding 15.0 MEUR



ACCSESS

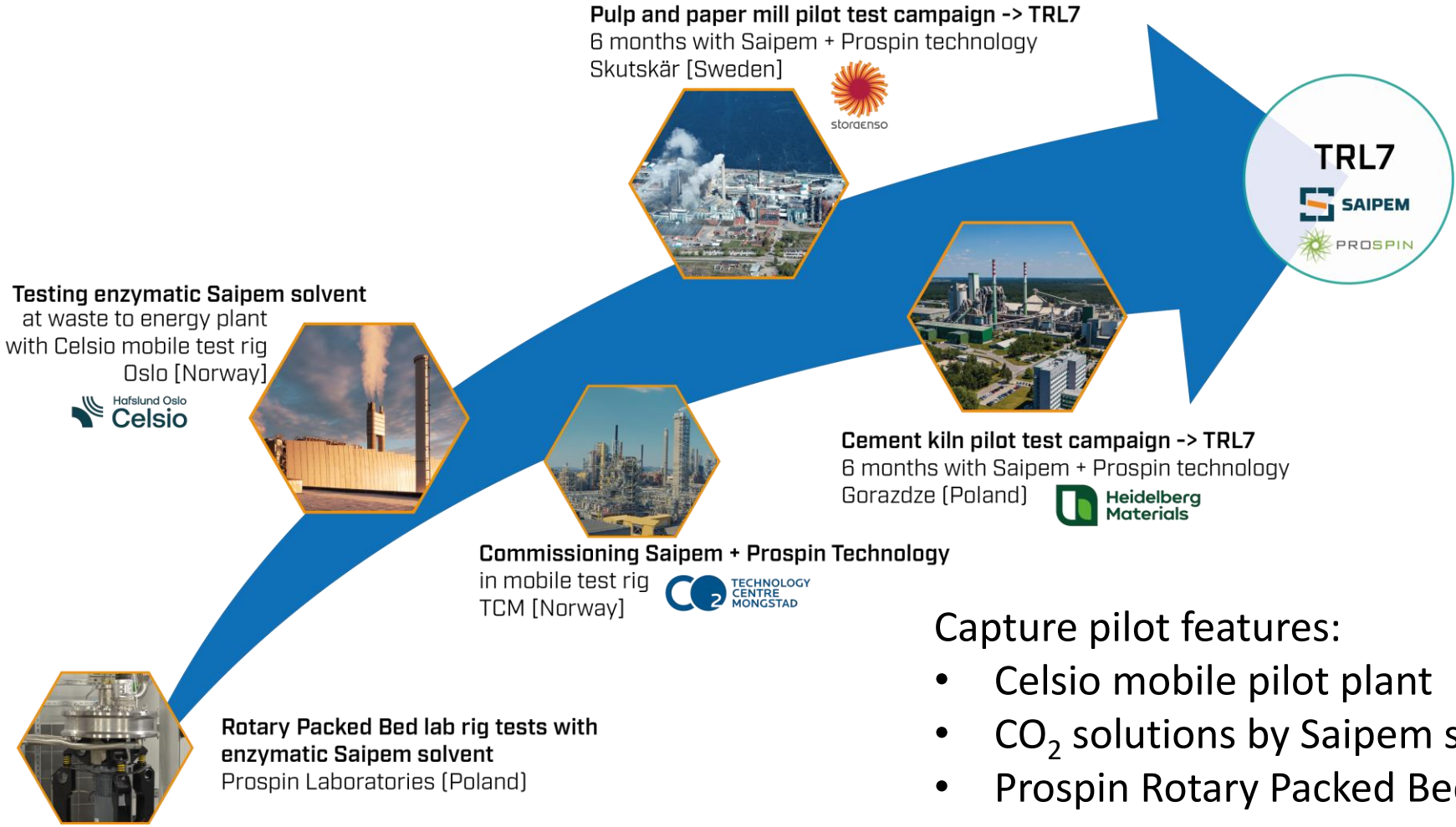
Pulp & paper

Waste to energy

Cement

Biorefineries

CO_2 capture piloting

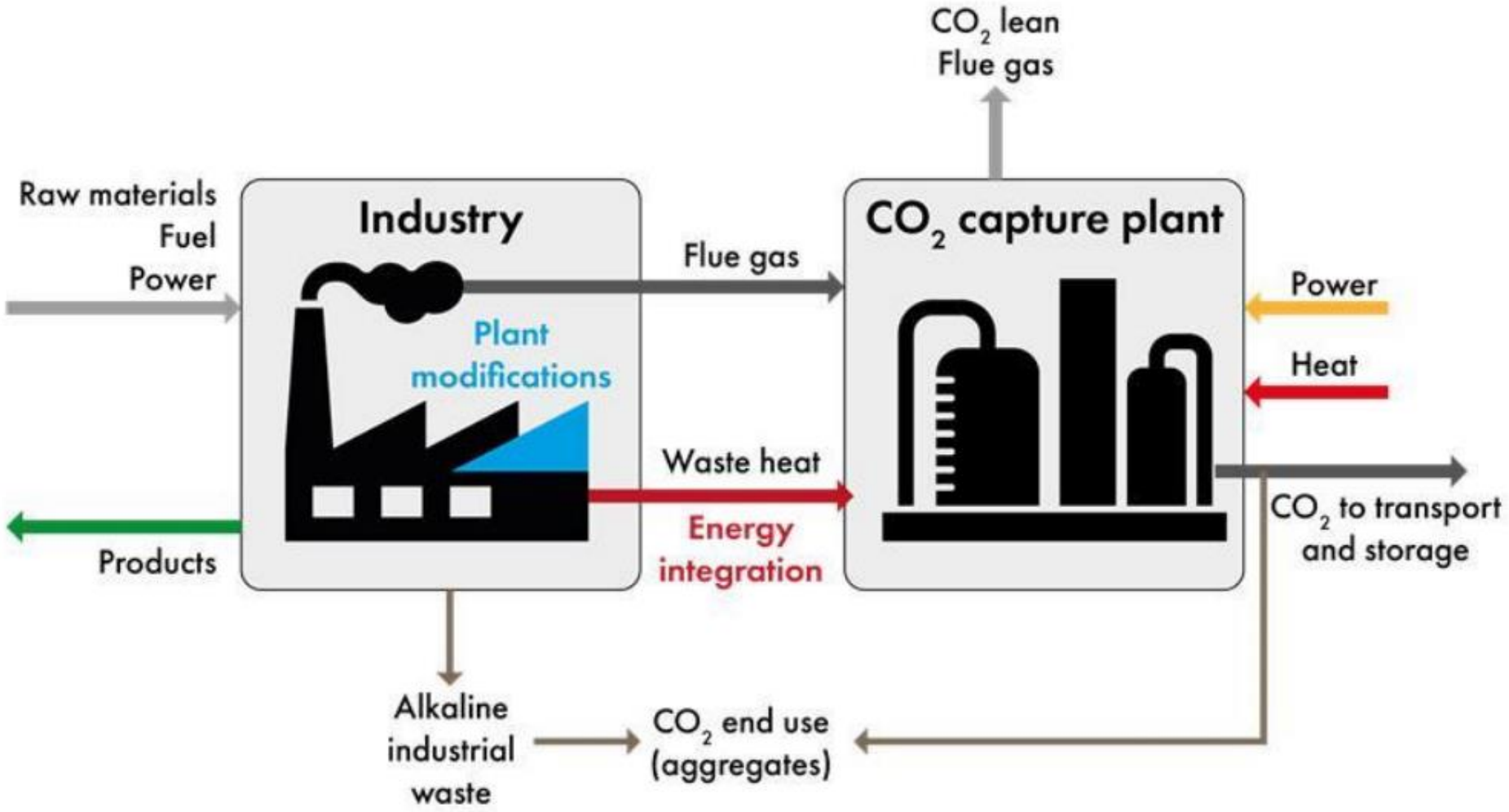


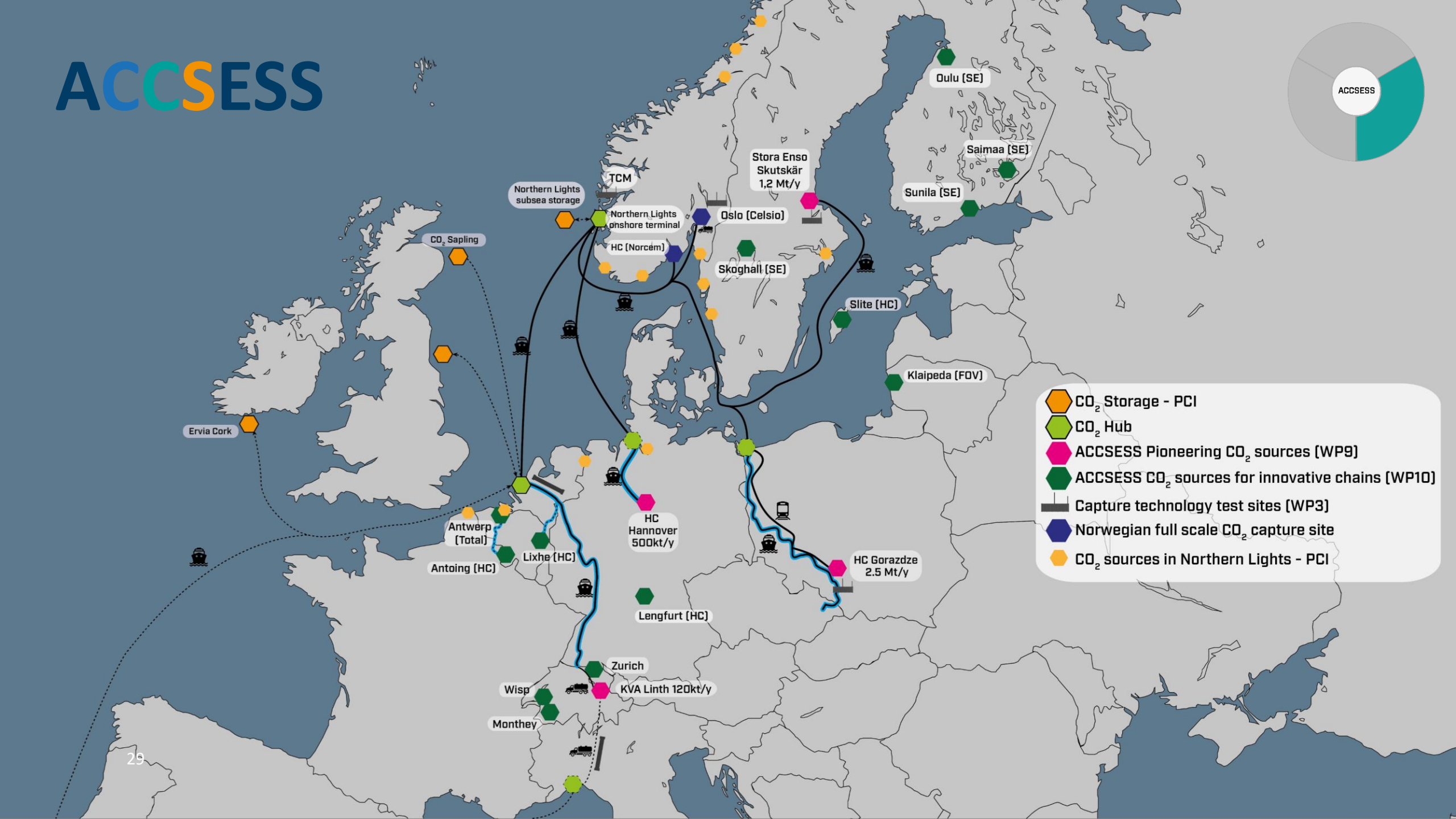
Capture pilot features:

- Celsio mobile pilot plant
- CO_2 solutions by Saipem solvent
- Prospin Rotary Packed Bed absorber

Definition of TRL7: system prototype demonstration in operational environment

CO_2 capture integration




ACCSESS
Oulu (SE)
Saimaa (SE)
Stora Enso Skutskär 1,2 Mt/y
Sunila (SE)
TCM
Northern Lights subsea storage
Northern Lights onshore terminal
Oslo (Celsio)
HC (Norcem)
CO2 Sapling
Skoghall (SE)
Slite (HC)
Klaipeda (FOV)
Ervia Cork
HC Hannover 500kt/y
Antwerp (Total)
Lixhe (HC)
Antoing (HC)
HC Gorazdze 2.5 Mt/y
Lengfurt (HC)
Zurich
Wisp
KVA Linth 120kt/y
Monthey
CO2 Storage - PCI
CO2 Hub
ACCSESS Pioneering CO2 sources (WP9)
ACCSESS CO2 sources for innovative chains (WP10)
Capture technology test sites (WP3)
Norwegian full scale CO2 capture site
CO2 sources in Northern Lights - PCI

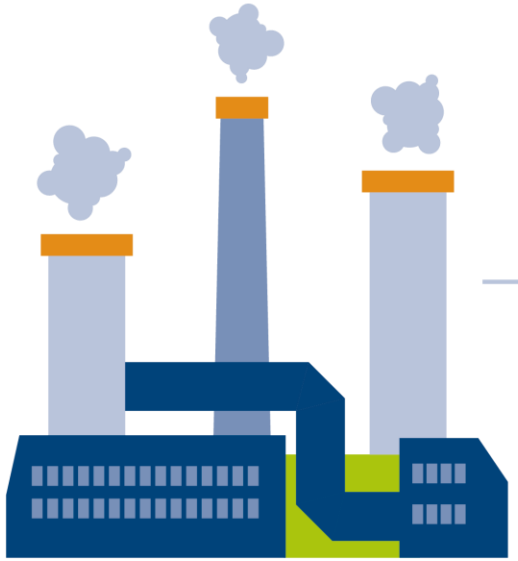
CCUS end-products cost

Cement industry

Cost increase cement
+ 70 %

Cost increase building
Less than
+ 0.5 %

Rootzén, J. & Johnsson. F.
Climate Policy 17:6 (2017) p. 781-800



CCUS mitigation costs at point emissions currently significantly higher than EU-ETS

Value chain analysis of end-products and services

EU Sustainable cities
Demand for climate neutral or climate positive end-products and services

"Marginal increase in cost and price of end-products, while significantly reducing their carbon footprint, or even providing CDR"

Consortium

Linked third parties

Acknowledgement

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Martijn Smit

Director Business Development at Northern Lights

Martijn Smit is an energy professional with 23 years of experience across the value chain. He worked for Accenture and Gasterra in the Netherlands before joining Norsk Hydro (now Equinor) in downstream gas marketing in Brussels. In his 16 years in Equinor he has subsequently worked on gas sales strategy, business development for exploration in Sub sahara Africa and he was country manager for Equinor in the Netherlands, South Africa and Surinam before joining Northern Lights in Dec 2020 as business development director. Martijn holds a master degree in geology and business (Utrecht University / Nijenrode University) is married and has three children.

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Martijn Smit, Northern Lights

Main messages:

NLJV part of longship will be ready for operations September 2024. We are putting words into action

NLJV has established a commercial framework with agreements with Ørsted and Yara

Demand is large, over 5 time oversubscription in volume terms, NLJV additional capacity requires an investment and an investable business case which will be taken in line with the customer commitments

Northern Lights
CO_2 transport and storage at scale

Northern Lights

Martijn Smit
Director Business Development

Putting words into action

Building on 25 yrs of experience

Onshore facilities

- Construction progressing according to plan, **more than 80% complete**
- **Ready for operation in 2024**

Ship construction progress

Northern Lights

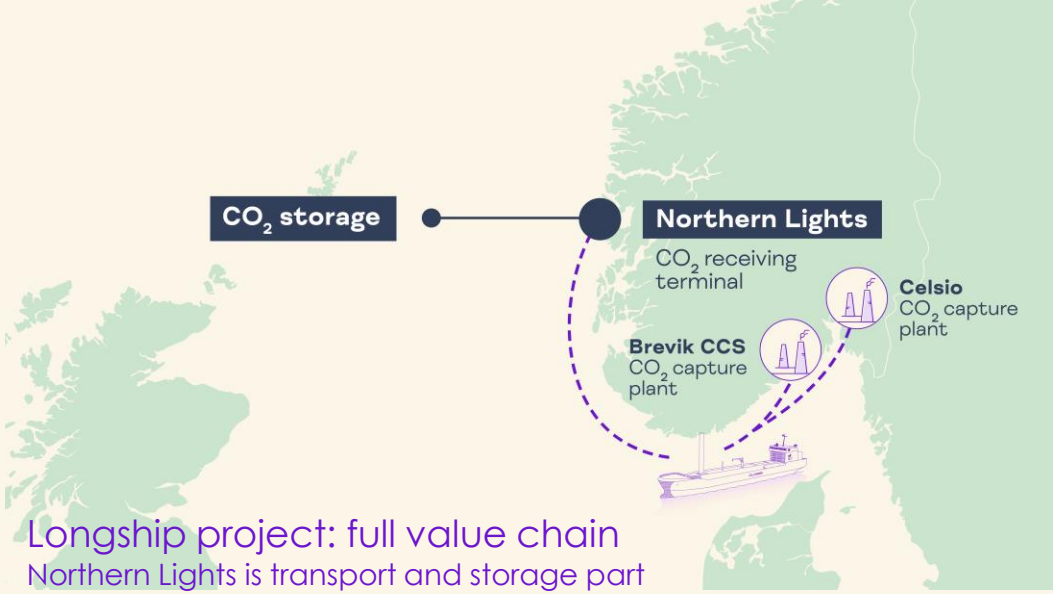
Dalian Shipbuilding Industry Company, China

Northern Lights' ambition

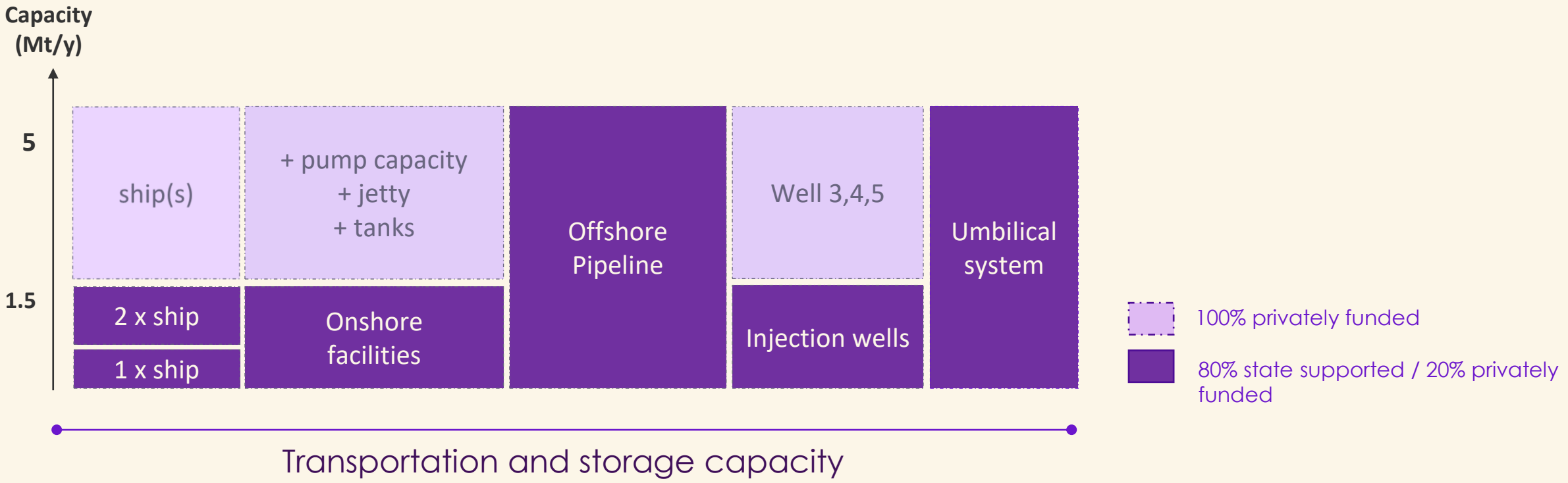
- NLJV BD provides **decarbonisation solution for Europe**
  - Northern Lights is an independent service provider (not oil and gas)
  - Ship based solution provides access to emitters across EU
  - Open-source infrastructure - fair and equitable access
- **Norcem, Heidelberg Materials (cement) and Oslo Hafslund Celsio (Waste-to-Power)** are cornerstone industries with 'hard-to-abite' emisssions
- Demonstrate CCS at industrial scale is **safe and reliable**
- Open a **new profitable industry** in Norway and EU **develop legal commercial framework**
- **Accelerate the energy transition**; potential to facilitate blue hydrogen, BioCCS and Biofuels
- Support new **technology development** e.g. DAC

Public Private partnership

- Phase 1 on track, ready for operations second half of 2024
- Phase 2: Current start-up ambition based on market



Longship project: full value chain
Northern Lights is transport and storage part



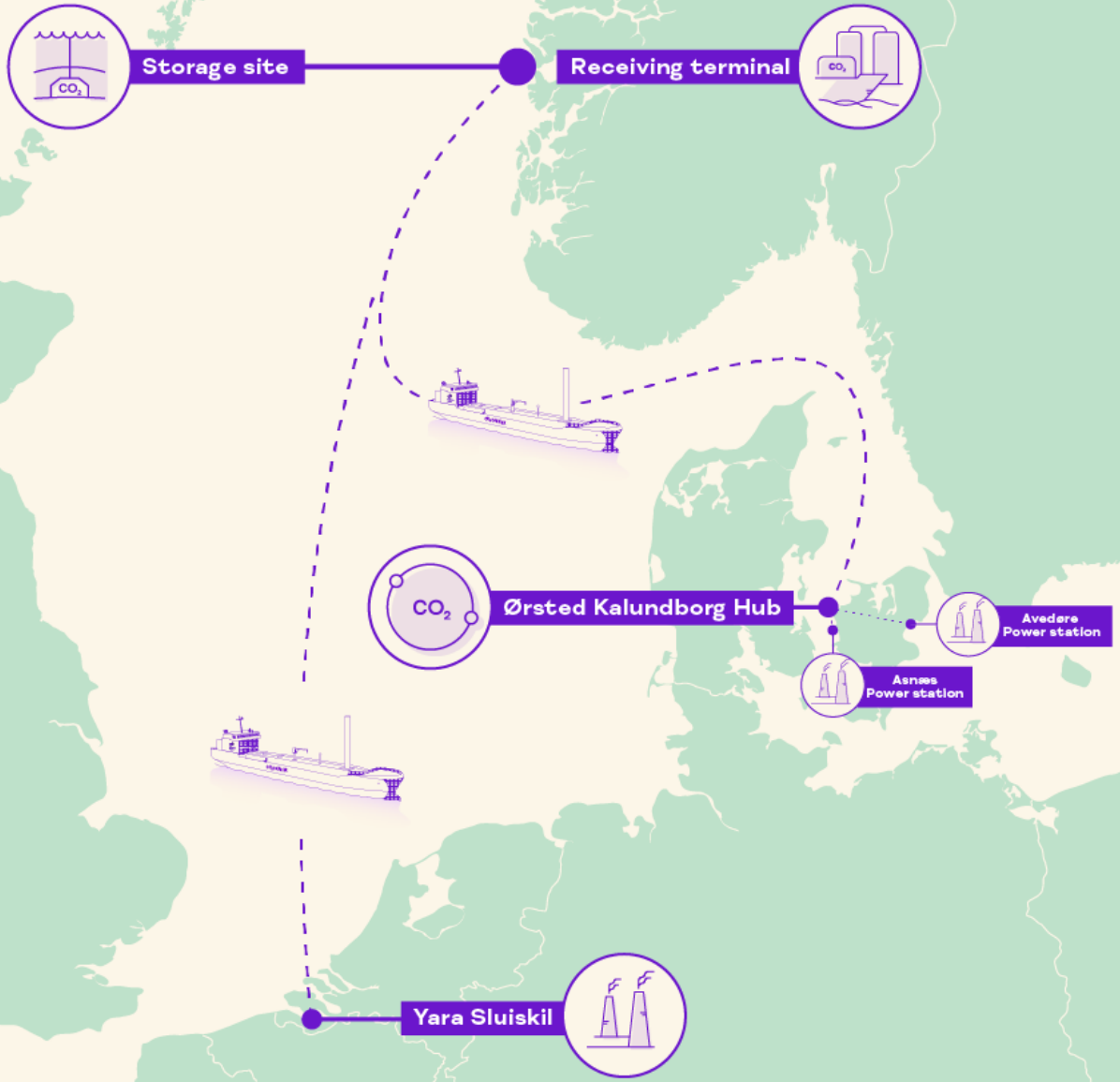
Commercial contracts

Yara

- Ammonia and fertilizer plant in the Netherlands
- Main terms of agreement signed in August 2022
- 800.000 tonnes CO2 annually

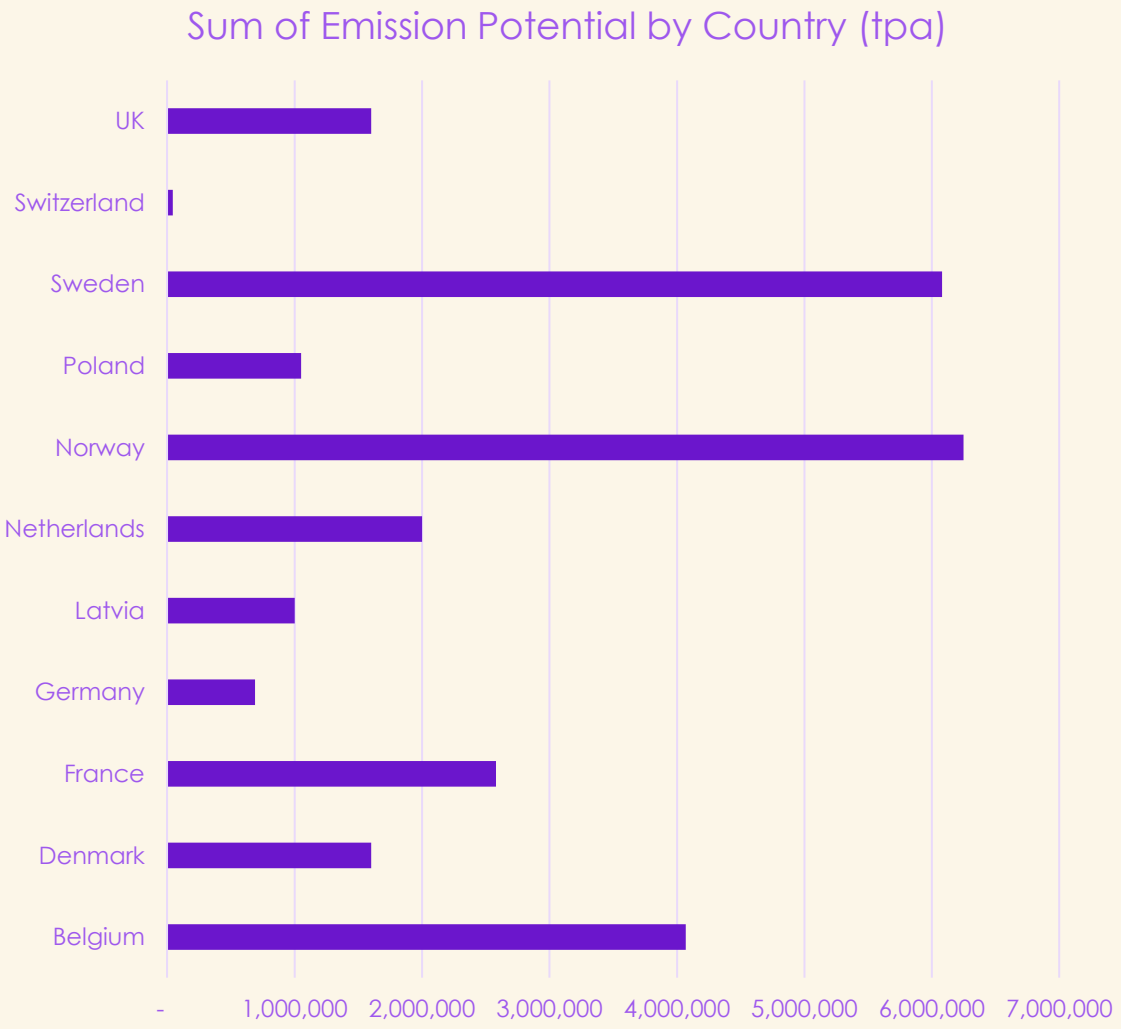
Ørsted

- Bioenergy plants in Denmark
- Transport and Services Agreement signed in May 2023
- 430.000 tonnes CO2 annually



Active customers by geography

Norway and Sweden represent over 50%, Poland and Germany relatively small volumes compared to emissions



Industry	Emission (tpa)
Belgium	4,070,000
Denmark	1,600,000
France	2,580,000
Germany	690,000
Latvia	1,000,000
Netherlands	2,000,000
Norway	6,248,000
Poland	1,050,000
Sweden	6,080,000
Switzerland	45,000
UK	1,600,000
Sum	**26,963,000**

*excludes North Sea Port

CCS commercialisation challenges

Northern Lights

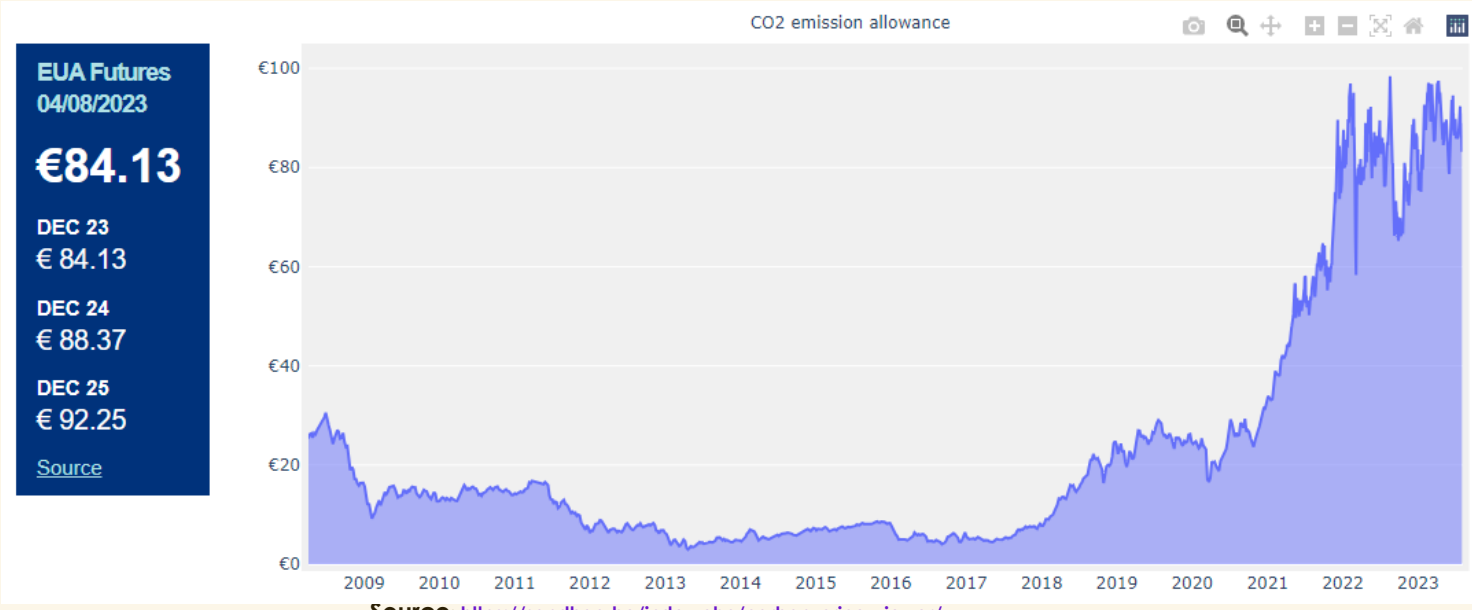
Timing/Market maturity (chicken and egg):

- **Uncertainty** on product markets outside EU, evolving geopolitics and global competitive position for emitters
- **First mover fear:** Advantage to be first, taking duration of the agreement into account and emitting cheaper than CCS
- **Inter-dependencies** across the value chain (commercial contract signature is linked to many other contracts)
- **Price/Cost:** Inflationary environment and under-estimation of CCS costs by emitters

- Time/timing
- Courage
- Trust
- Price

CCS enablers:

- High EU ETS price helps putting CCS on the agenda (Too early to say if it is triggering investment decisions).
- CO_2 taxation schemes on top of EU ETS.
- Green premium products
- Negative emissions
- Subsidies



Source: https://sandbag.be/index.php/carbon-price-viewer/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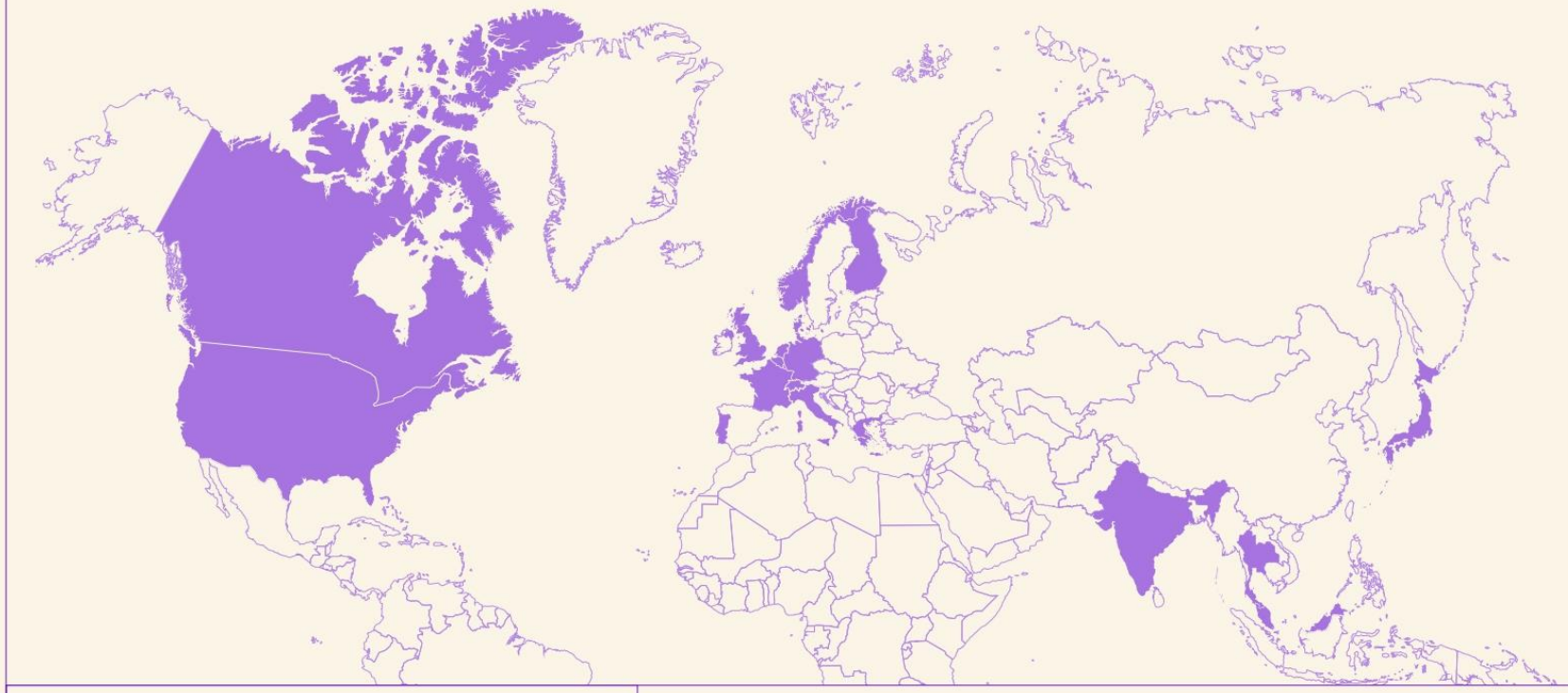
As a first mover, it is part of our mandate to share our experience and knowledge transparently with the world

Visitors in 2022

Northern Lights

Northern Lights



Visitors from all over the world

- Belgium
- Canada
- Denmark
- Finland
- France
- Germany
- Greece
- India
- Italy
- Japan
- Malaysia
- Netherlands
- Norway
- Portugal
- Switzerland
- Thailand
- UK
- USA

Total number of visitors: 2255

- Academia: 18%
- Industry players: 49%
- Policy makers: 13%
- Interest groups: 17%
- Media: 3%

Northern Lights

norlights.com

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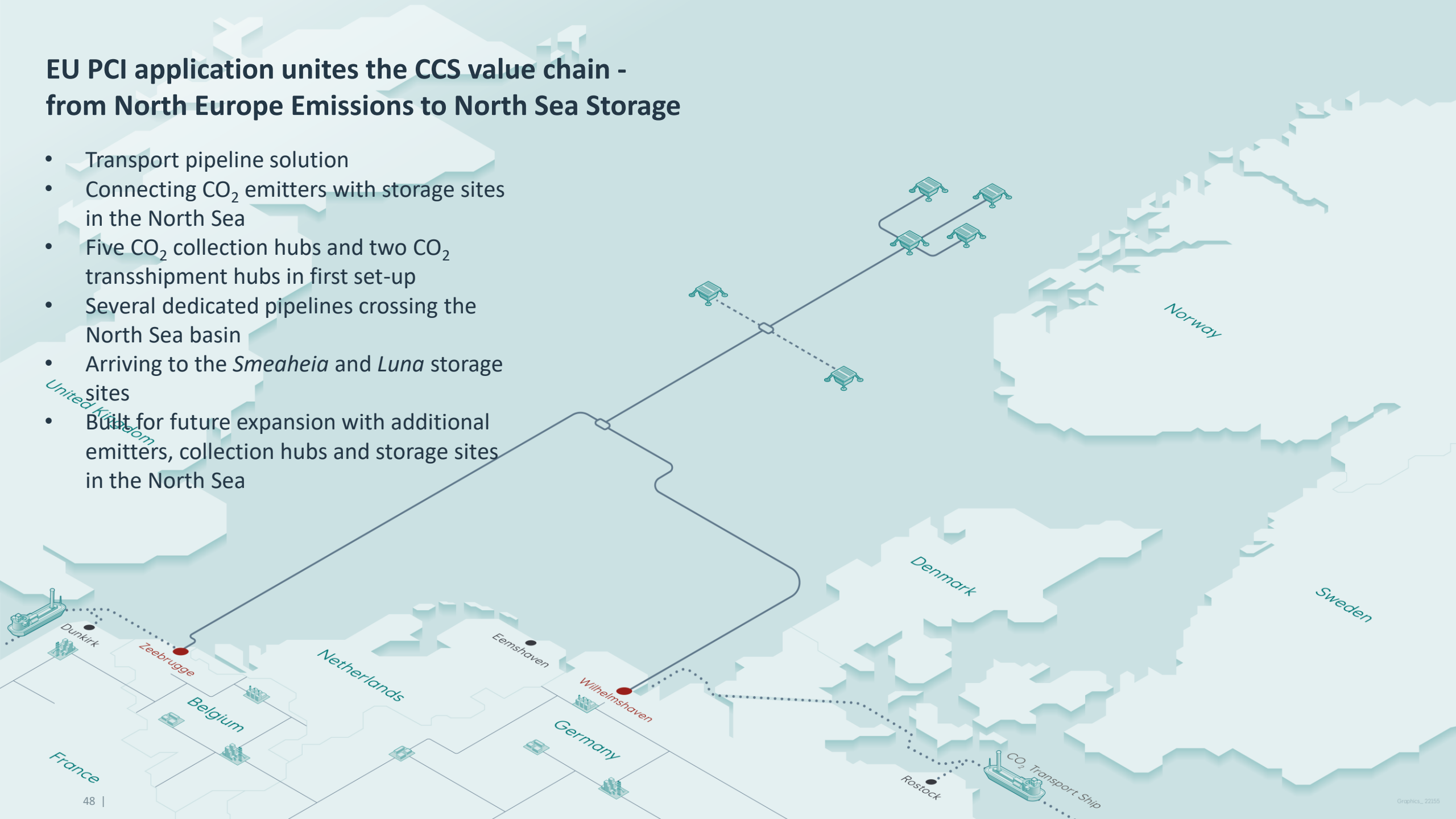
Dr. Per Sandberg

Senior advisor in Equinor Low Carbon Solutions at Equinor

He has his specialization in CCS and hydrogen projects, with a focus on European policy. He previously led business development for the Northern Lights project, a CO2 transport and storage initiative involving Equinor, Shell, and Total. Sandberg also served as the secretariat lead for the Norwegian government's expert commission on Green Competitiveness and held the position of Chief of Innovation at Statoil. He has a background in chemical engineering and a PhD in ethical issues related to biotechnology from the Norwegian University of Science and Technology (NTNU).

EU PCI application unites the CCS value chain - from North Europe Emissions to North Sea Storage

- Transport pipeline solution
- Connecting CO_2 emitters with storage sites in the North Sea
- Five CO_2 collection hubs and two CO_2 transshipment hubs in first set-up
- Several dedicated pipelines crossing the North Sea basin
- Arriving to the *Smeaheia* and *Luna* storage sites
- Built for future expansion with additional emitters, collection hubs and storage sites in the North Sea



Candidate PCI ‘EU2NSEA