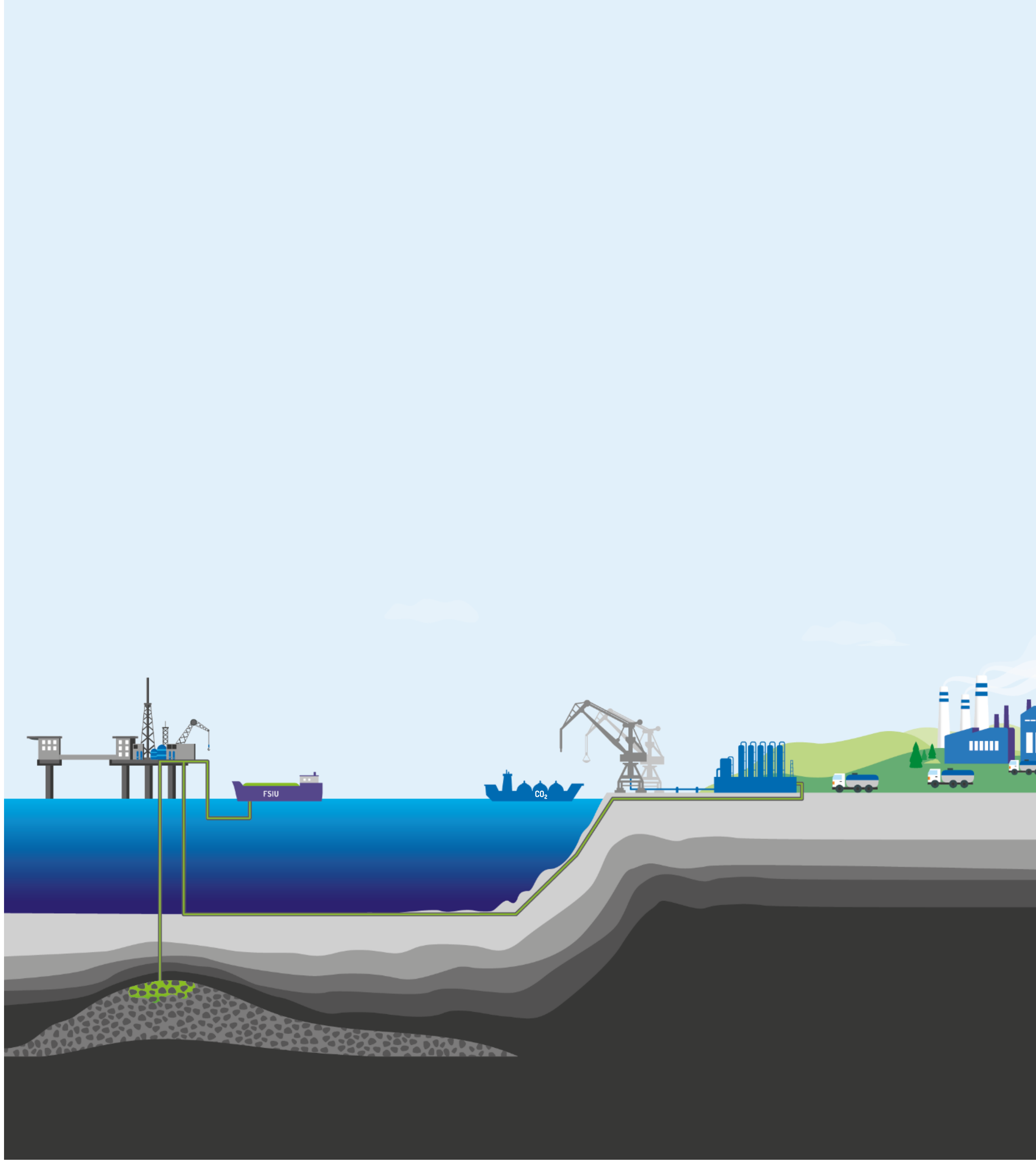
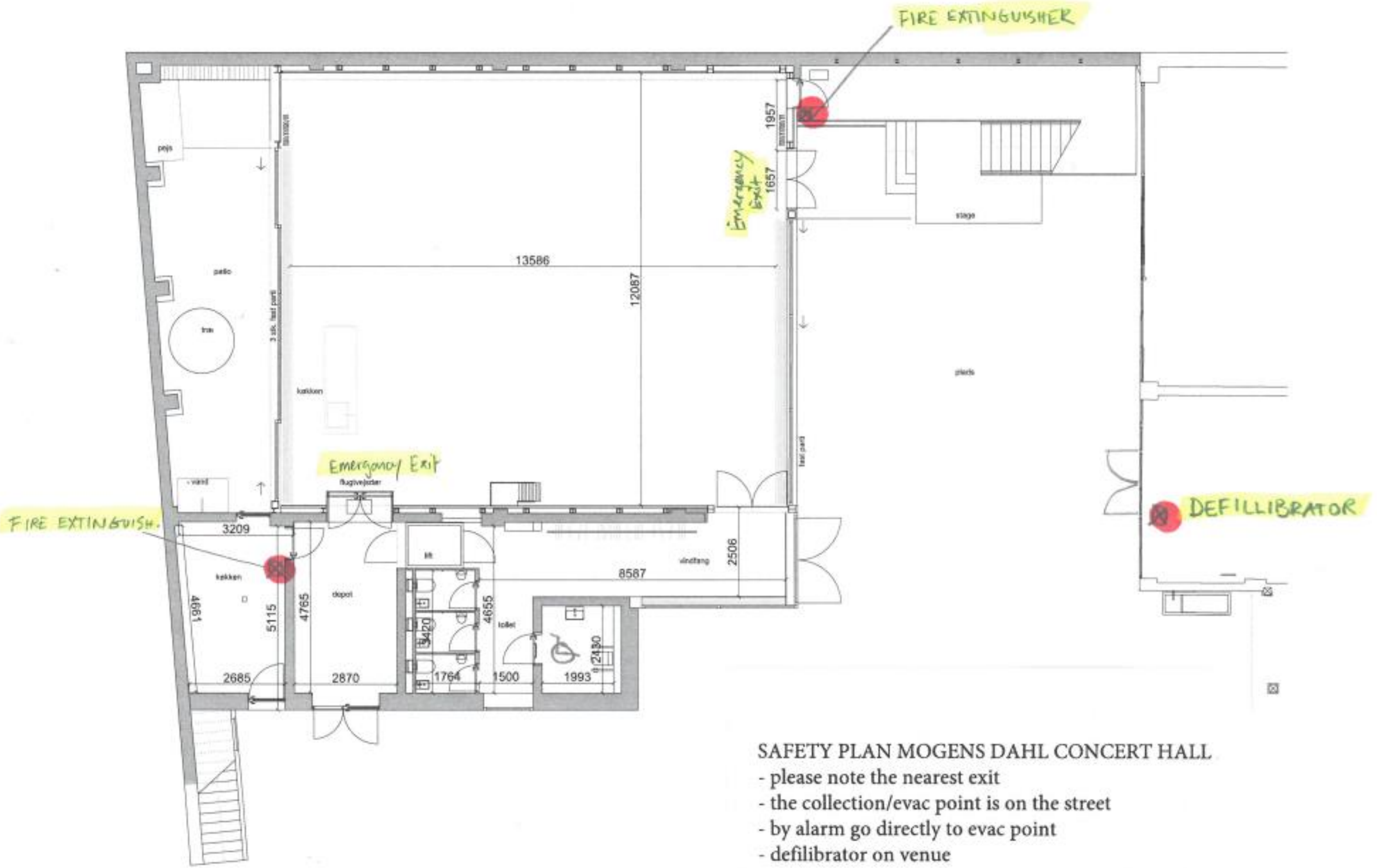
Welcome by the moderator and Safety Moment

Ida Ebbensgaard

Moderator of the conference

bifrost





SAFETY PLAN MOGENS DAHL CONCERT HALL
- please note the nearest exit
- the collection/evac point is on the street
- by alarm go directly to evac point
- defilibrator on venue

Opening speech

Morten Bødskov

Minister for Industry, Business and Financial Affairs

bifrost

Keynote speech

Martin Rune Pedersen

Country Chair, TotalEnergies Denmark

bifrost

Partly funded by

EUDP

Project Bifrost

Pioneering CO_2 storage for a NetZero future

bifrost

David Nevicato
Danish CCS offshore Cluster Project Manager, TotalEnergies Denmark

Malene Rod Vest
Program Director, Danish Offshore Technology Centre, DTU

Jacob Ladenburg
Professor, Department of Technology, Management and Economics, DTU

Jesper Kok Frost
Senior Project Manager, Ørsted

Agenda

bifrost

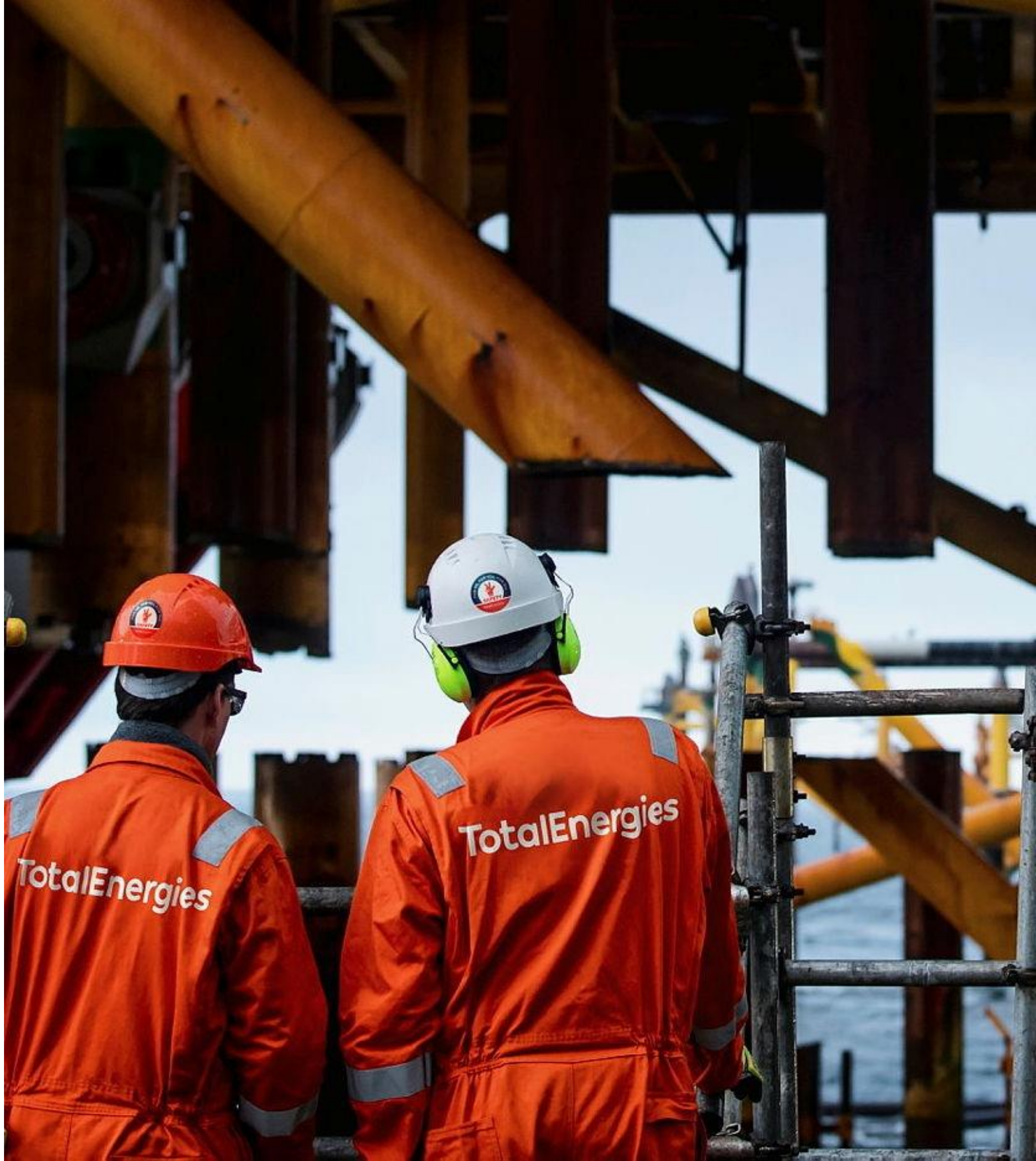
Workstreams: Introduction

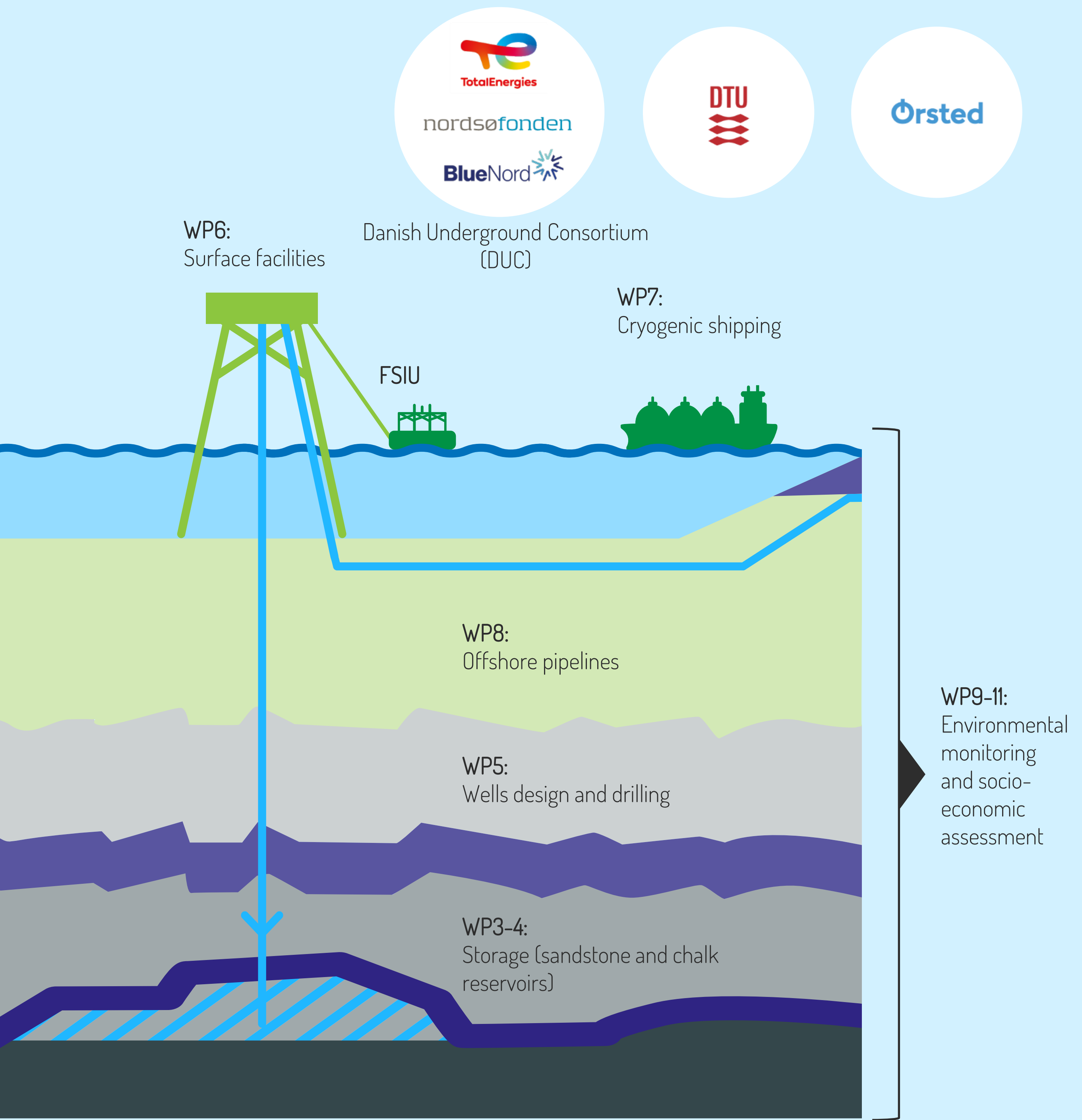
David Nevicato

CCS Bifrost Asset Manager,

TotalEnergies Denmark

bifrost





The project is divided in 11 workstreams

- 1-2. Management and communication (DUC)
- 3-4. Storage and an investigation of sandstone vs. chalk reservoirs (DTU + DUC)
- 5. Design of wells and drilling (DUC)
- 6. Using the existing surface facilities (DUC)
- 7. Cryogenic shipping for transport of captured CO_2 (DUC)
- 8. Offshore pipelines for transport of captured CO_2 (Ørsted)
- 9-11. Environmental monitoring and socioeconomic assessment (DTU + DUC)

bifrost

Transportation: Ship

David Nevicato
CCS Bifrost Asset Manager,
TotalEnergies Denmark

bifrost

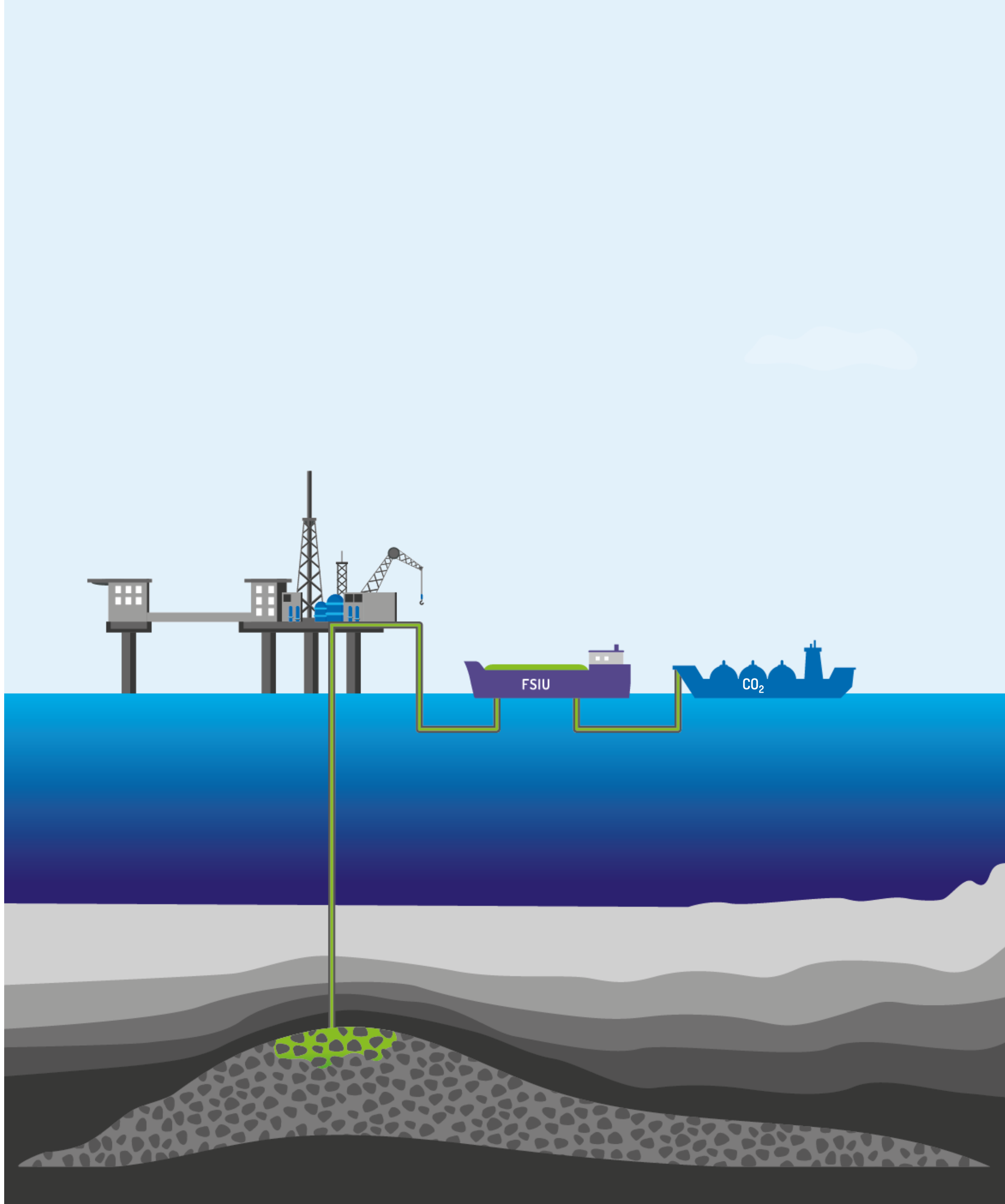
Offshore loading solutions

A continuous injection of CO_2 via one platform well into the Harald West reservoir. This chain comprises of a fleet of medium pressure cryogenic shuttle tankers for offshore offloading, a Floating Storage and Injection unit (FSIU) for CO_2 buffer storage and conditioning for injection, and integration modifications on the Harald West facilities.

CO_2 carriers: Northern Lights design

- Interoperability with other CCS projects
- 12,000 m^3
- Cryogenic and liquid CO_2 at -25°C and 18 barg

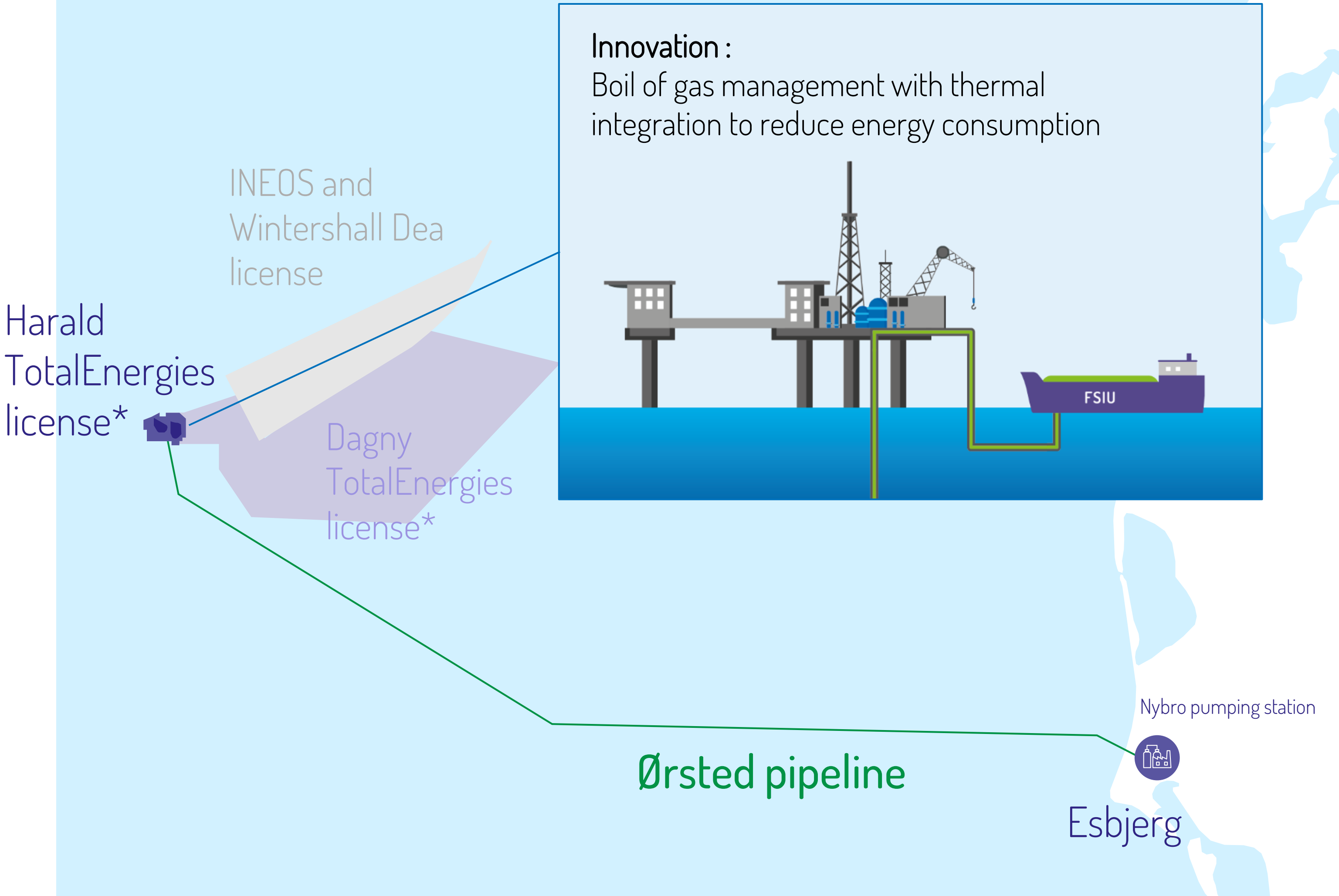
bifrost



Offshore loading solutions

- The floating storage and injection unit is a permanently moored unpropelled:
  - 30,000 m^3 capacity unit fitted with type-C storage tank and operating under 13 to 18 barg., -22°C to -30°C)
  - Designed to received liquid CO_2 from liquid CO_2 carriers, store the product, re-heat and pressurize it for final transfer to the injection location

bifrost

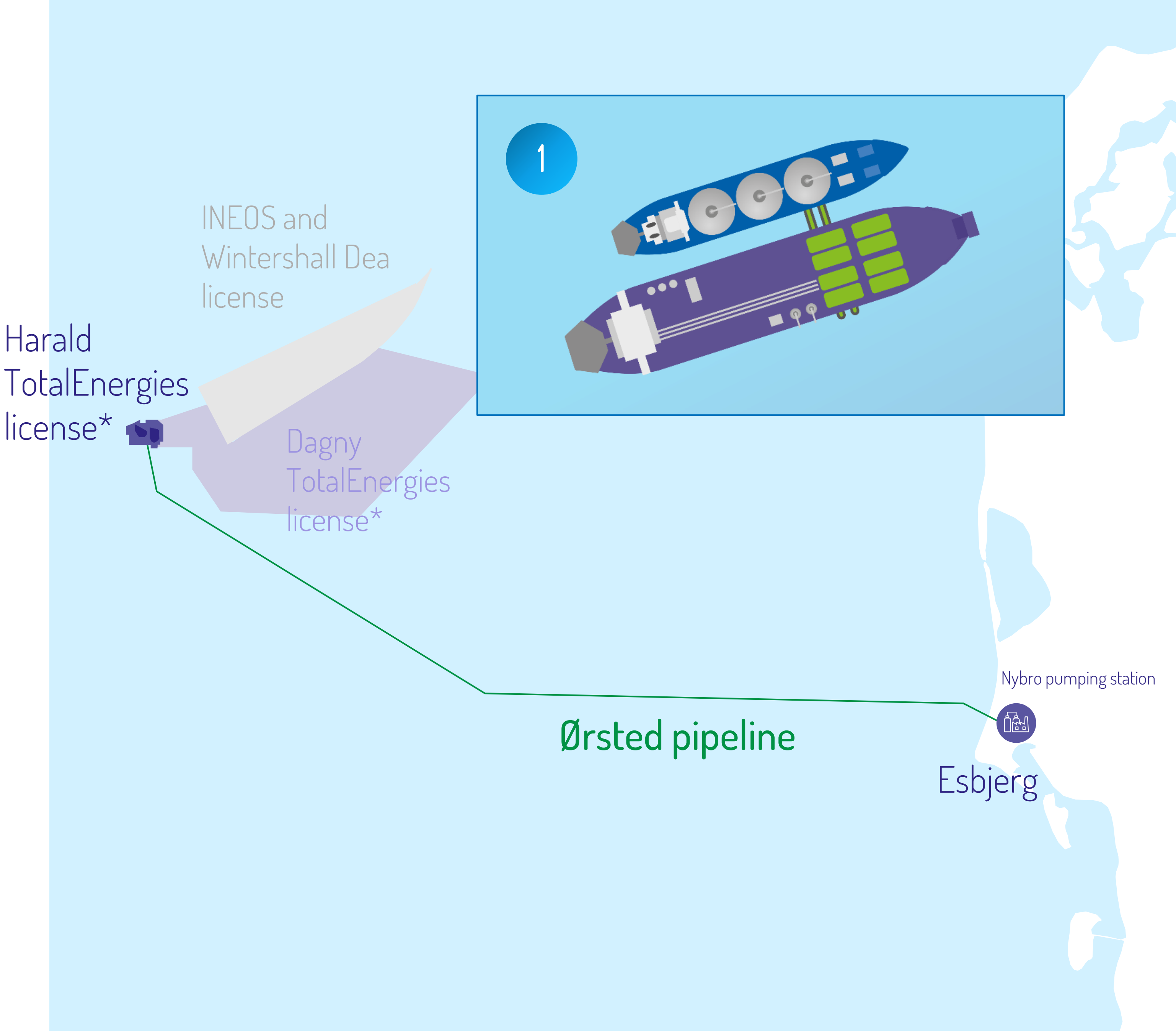


(*) Nordsøfonden will represent the Danish state with a share of 20% in the three exploration and storage of CO_2 licenses in the Danish subsoil in the North Sea.

Offshore loading solutions

Two different concepts were investigated

1. Side by side via flexible lines accommodated on saddles between both ship and FSIU manifold

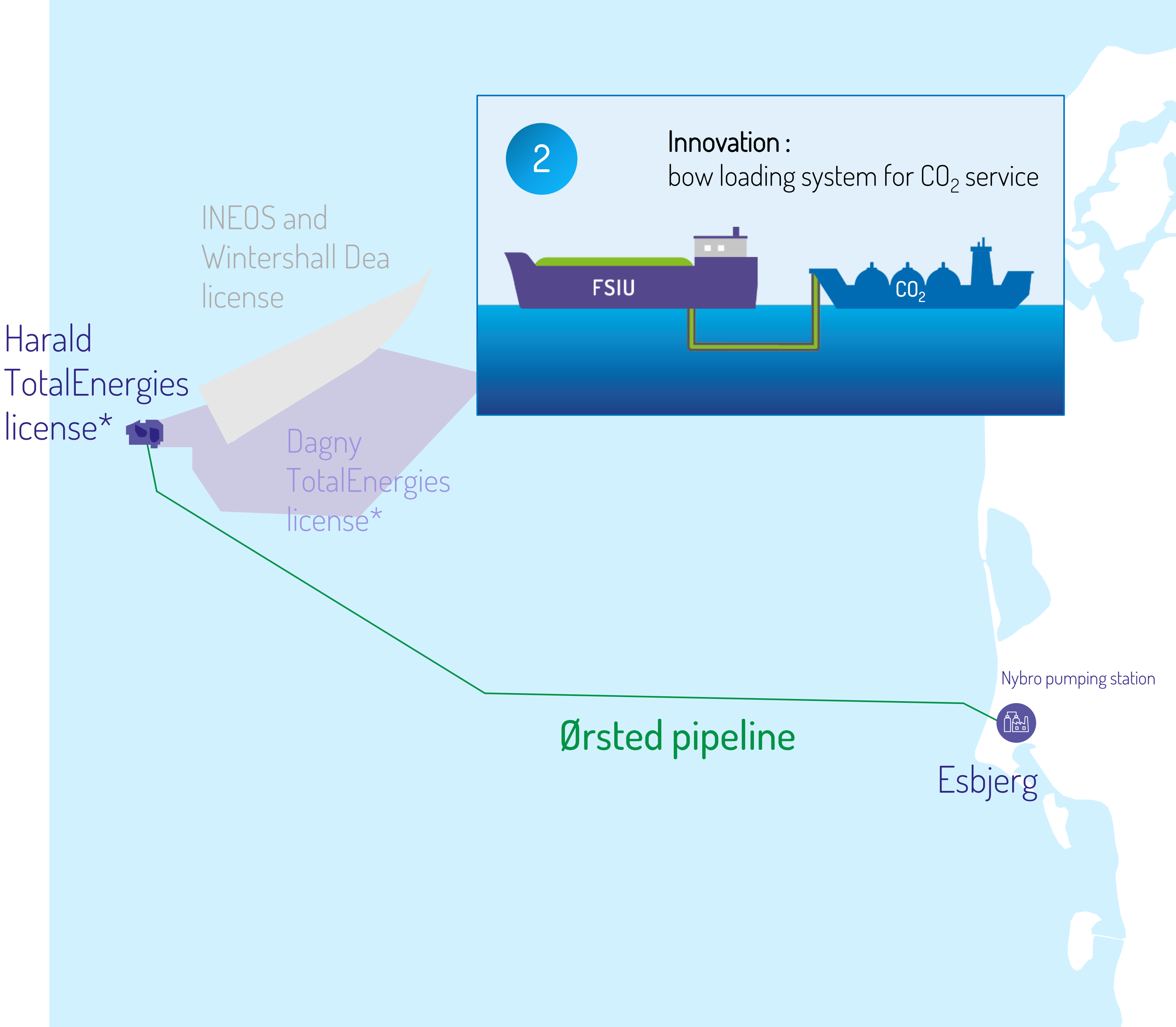


(*) Nordsøfonden will represent the Danish state with a share of 20% in the three exploration and storage of CO_2 licenses in the Danish subsoil in the North Sea.

Offshore loading solutions

Two different concepts were investigated

2 In tandem by Liquid-CO_2 carrier fitted with Dynamic Positioning System and a bow transfer manifold.



(*) Nordsøfonden will represent the Danish state with a share of 20% in the three exploration and storage of CO_2 licenses in the Danish subsoil in the North Sea.

bifrost

Transportation: Pipeline and onshore terminal

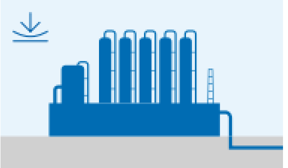
Jesper Kok Frost

Senior Project Manager, Ørsted

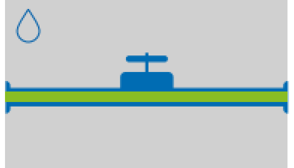
bifrost

Repurposing pipelines

Interface:
Shipping to port

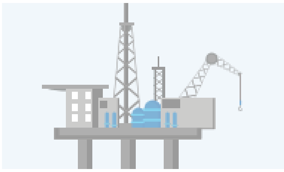


New Onshore terminal

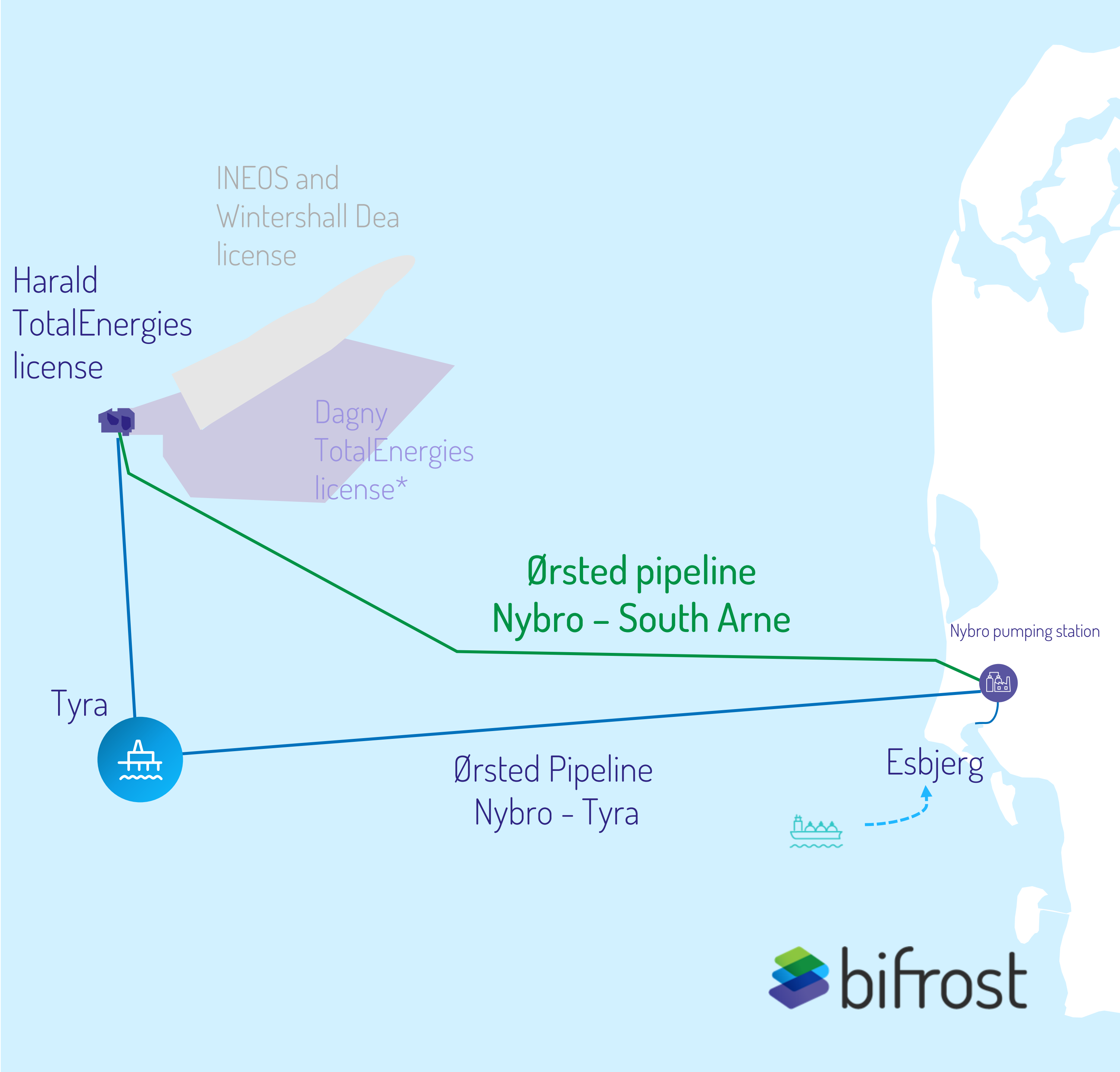


New Onshore Pipeline

Existing Ørsted offshore pipelines repurposed for CO_2 transport



Interface: Arrival at Harald platform



Conclusions so far

New onshore temporary storage

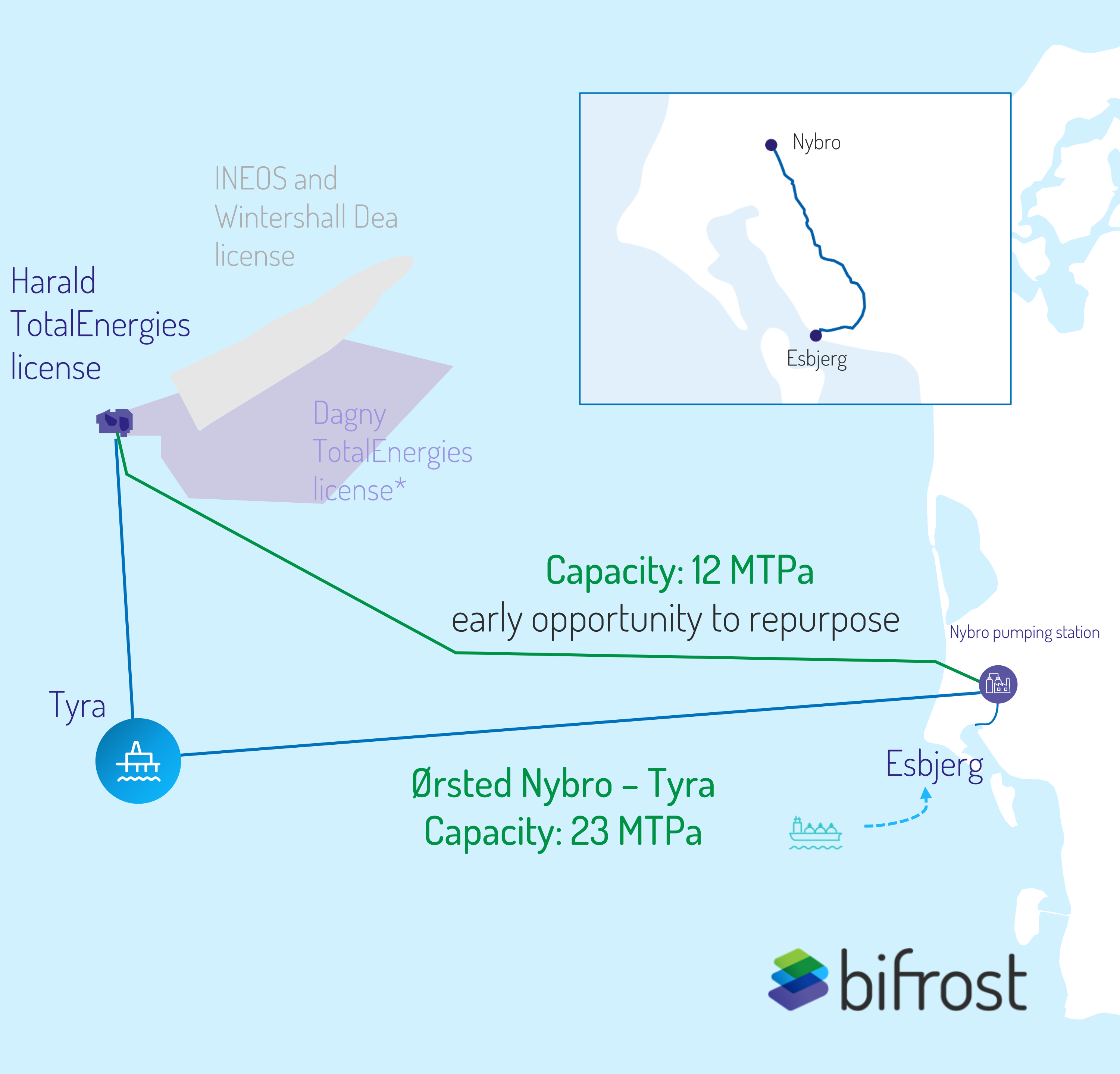
- ✓ Interface to shipping – Key factor to sizing the terminal capacity
- ✓ Selecting the location for temporary CO_2 storage is important for the safety of the surroundings

New onshore pipeline

- ✓ Pressure increase to keep CO_2 dense phase during both transport and enable longer standstill to avoid venting of CO_2

Existing Offshore Pipelines:

- ✓ All existing Offshore pipelines are fit for service
- ✓ **High Capacity in all pipelines**
- ✓ **An early opportunity repurpose "Harald to Nybro" pipeline**
- ✓ Dry CO_2 purity >99.5 mol% is initially required
- ✓ **Verified by 3. Party**

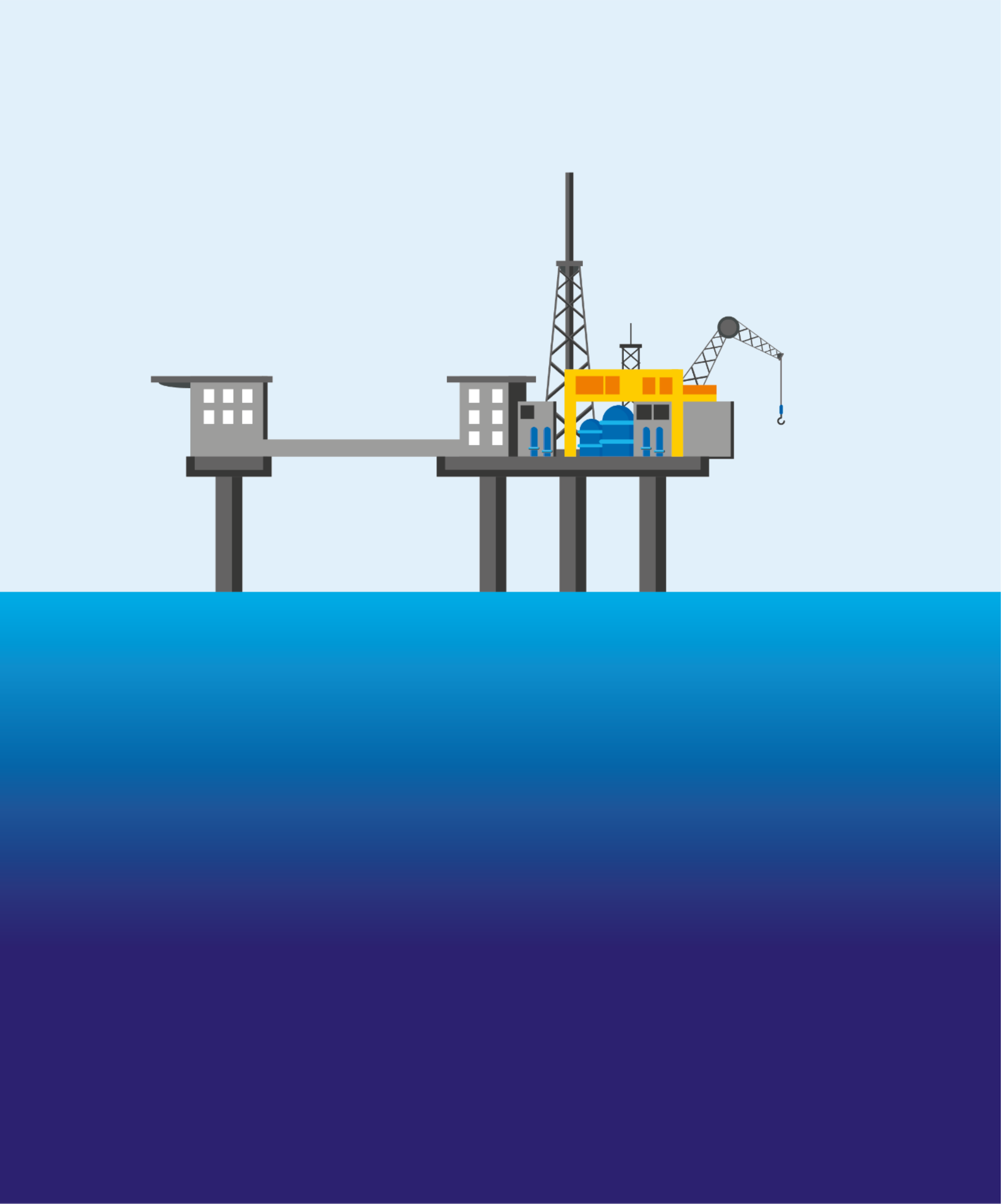


Offshore facilities: Wells and platform facilities

David Nevicato

CCS Bifrost Asset Manager,
TotalEnergies Denmark

bifrost



Reuse Harald platforms: Lifecycle extension

The Harald platforms were installed in 1996 and started production in 1997, with an initial design life of 25 years

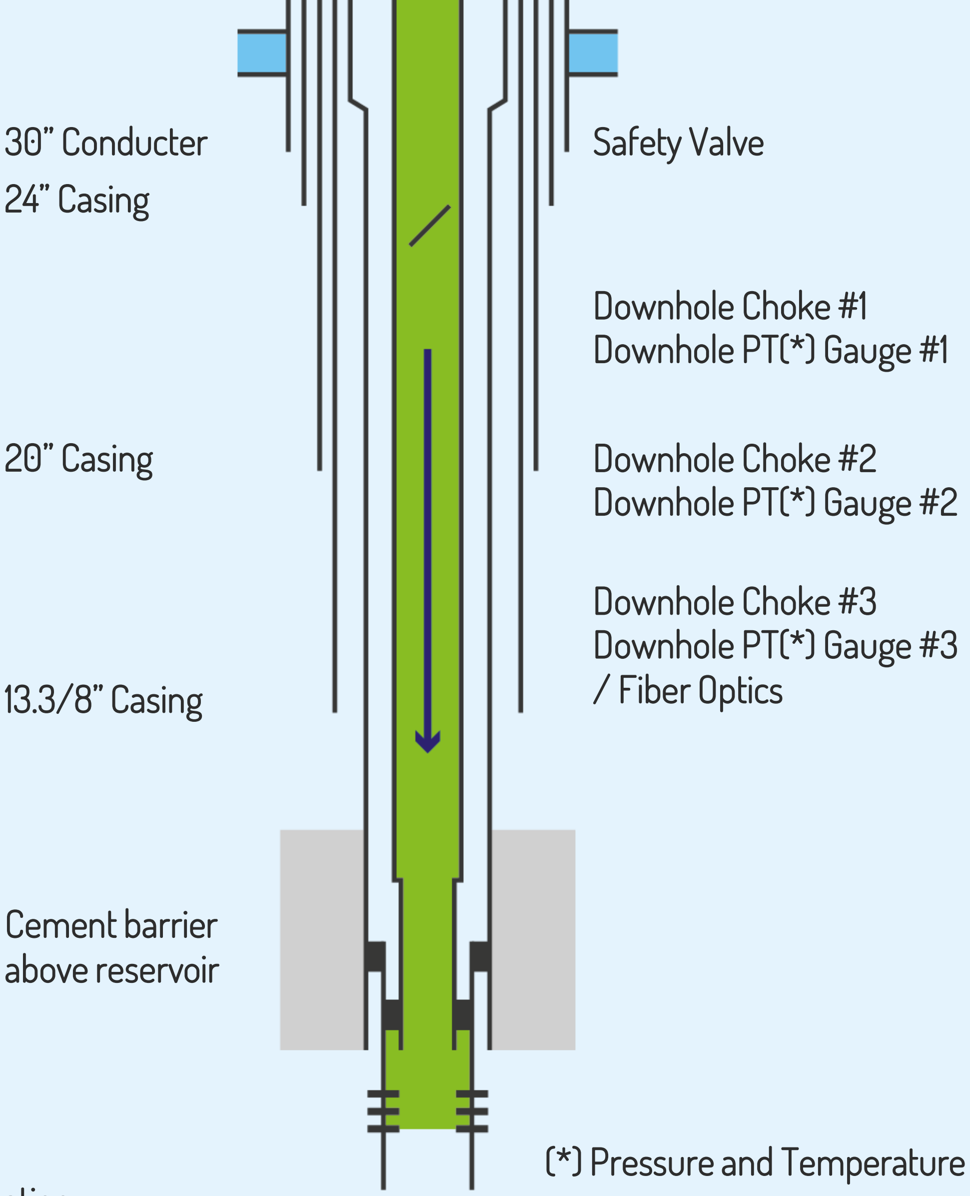
- Integration of an additional riser and J-tube connecting to the FSIU
- Integration of a CCS module to reduce offshore work and allow for additional power generation and CO_2 boosting pumps
- Structure : some reinforcement is required to sustain the extreme wave and wind load cases

bifrost

Reuse former gas production well

Five existing wells – two gas production wells and three abandoned exploration wells have been reviewed :

- All abandoned wells are equipped with sufficient barriers to permit permanent CO_2 storage,
- One of the gas production wells was found suitable for conversion to a CO_2 injection well,
  - a new inner liner was designed in order to isolate any worn or corroded sections and to ensure a robust well design.
  - Continuous and dense stream of CO_2 at the wellhead for high injection rate and integrity
  - Other gas production well will be abandoned



Innovation :
a friction-based design, using downhole flow restrictions /choke

bifrost

CCS in the Harald fields has limited impact on health, safety, environment

- Permit and Consent Register upon experience from existing oil and gas projects in the Danish sector of the North Sea :
  - specification of the responsible authorities,
  - description of relevant regulations, challenges, and the expected timeline for each permit/consent.
- Assessment of the environmental existing data and current knowledge of the surrounding environment from the TotalEnergies Esbjerg office monitoring program as well as the protected areas
  - Negligible impact on the seabed conditions and the benthic fauna communities around Harald. All contaminant concentrations are below the Effects Range Low (ERL)

bifrost

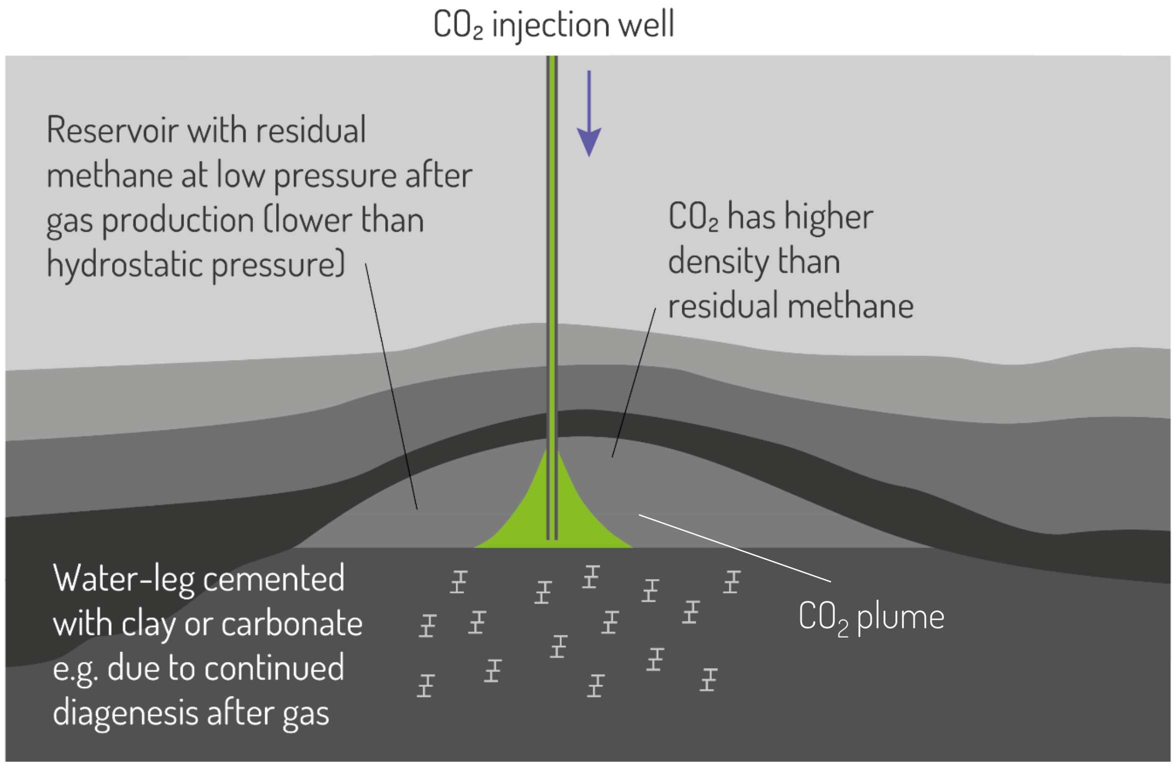
Storage: Sandstone and chalk reservoirs

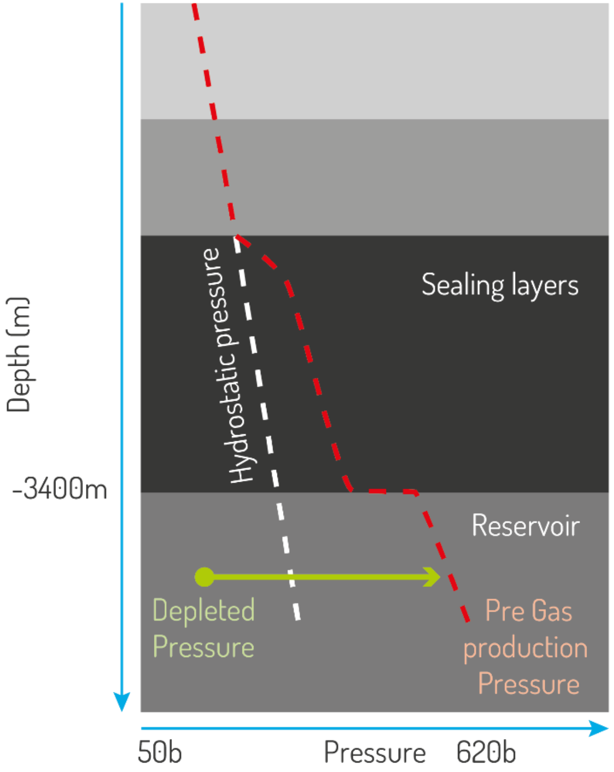
Malene Rod Vest
Program Director, Danish Offshore Technology Centre, DTU

David Nevicato
CCS Bifrost Asset Manager, TotalEnergies Denmark

bifrost

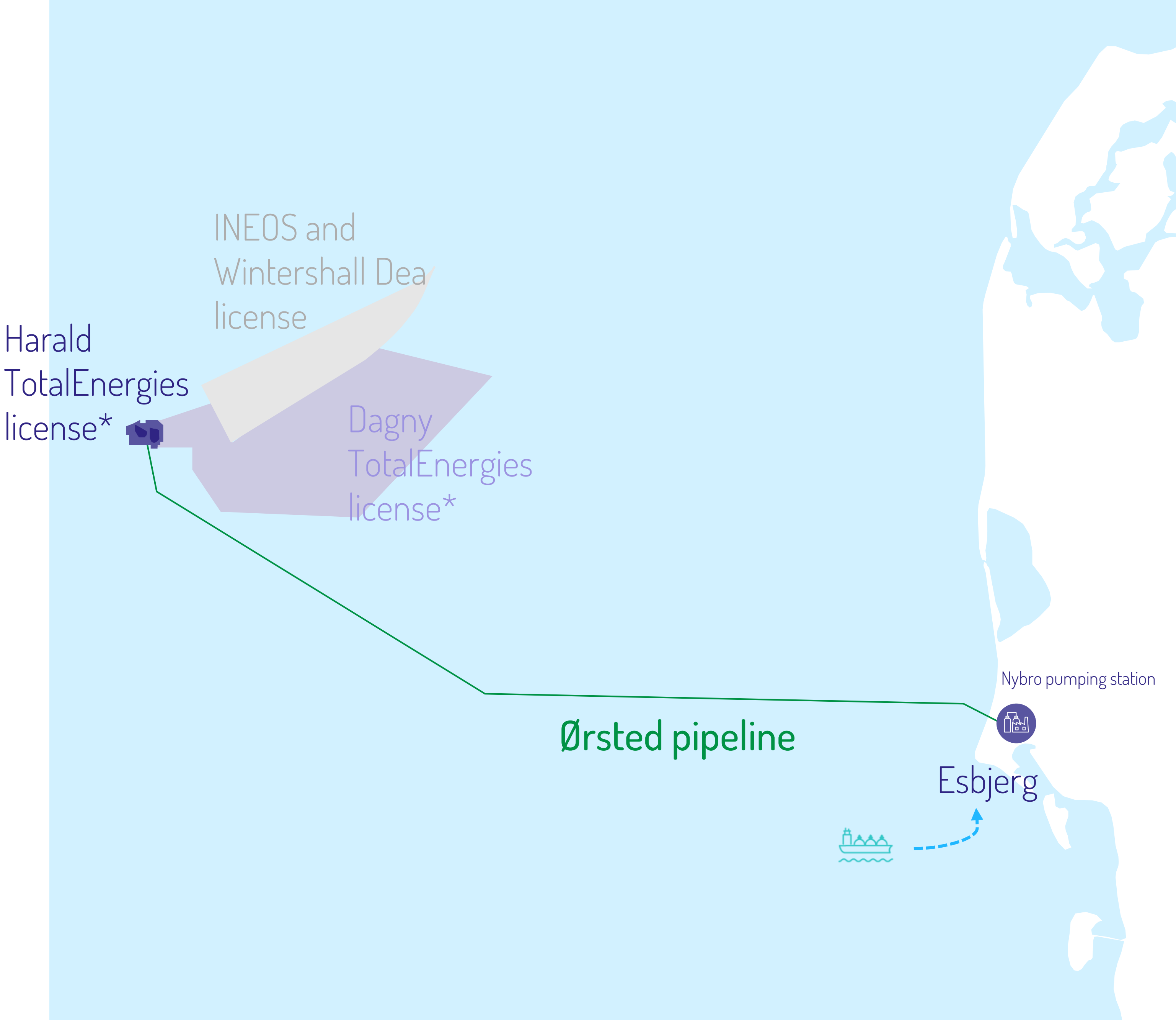
CO_2 geological storage in depleted gas fields: how does it work?





The Harald fields: A particularly suitable destination for developing CCS-solutions

- Harald West and East are two gas reservoirs, discovered in the 80's and have been in production since 1997
- The Harald fields consist of both sandstone and chalk. The Harald West, where the first injection will take place, is a sandstone reservoir



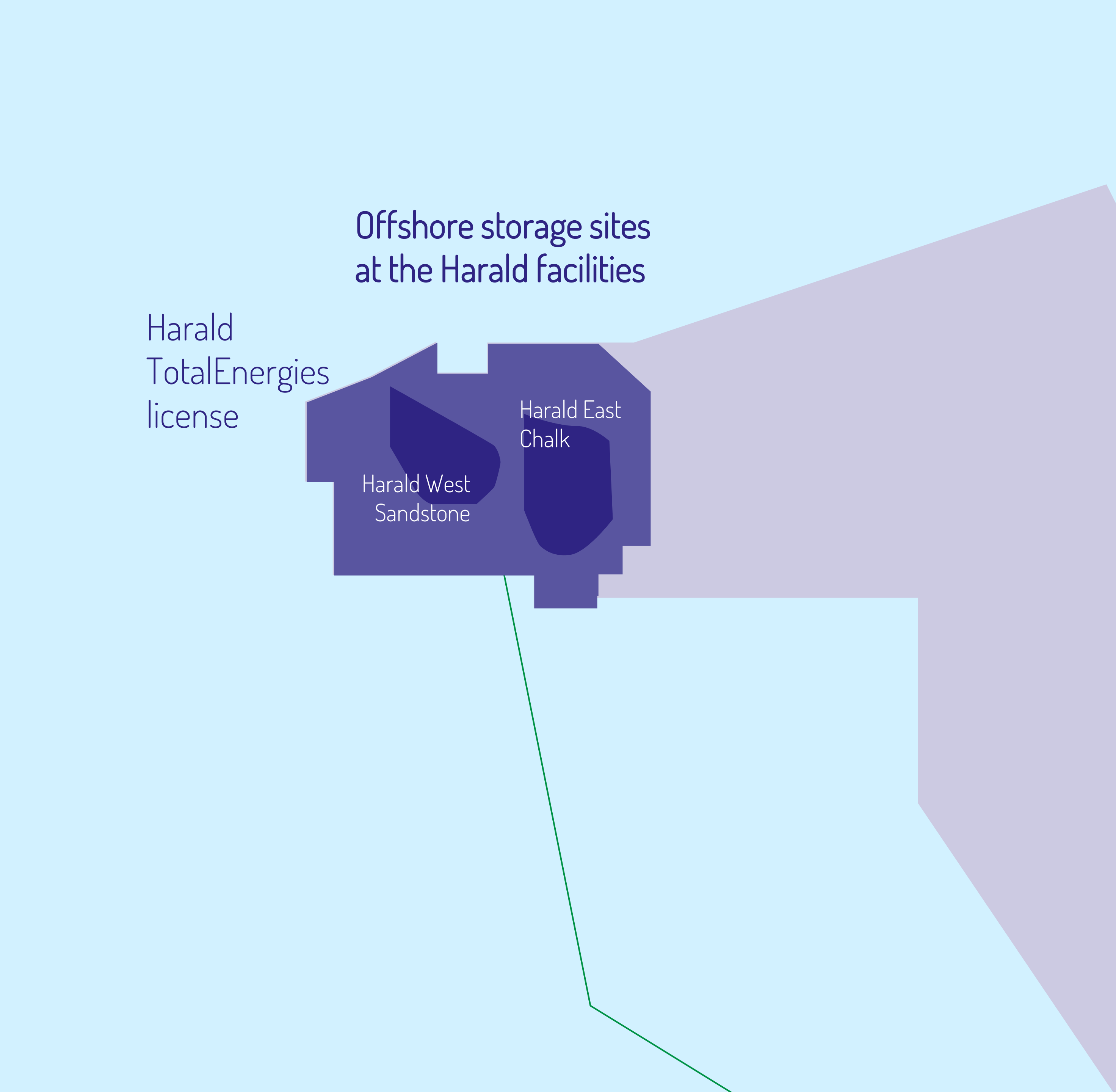
(*) Nordsøfonden will represent the Danish state with a share of 20% in the three exploration and storage of CO_2 licenses in the Danish subsoil in the North Sea.

bifrost

The Harald fields: A particularly suitable destination for developing CCS-solutions

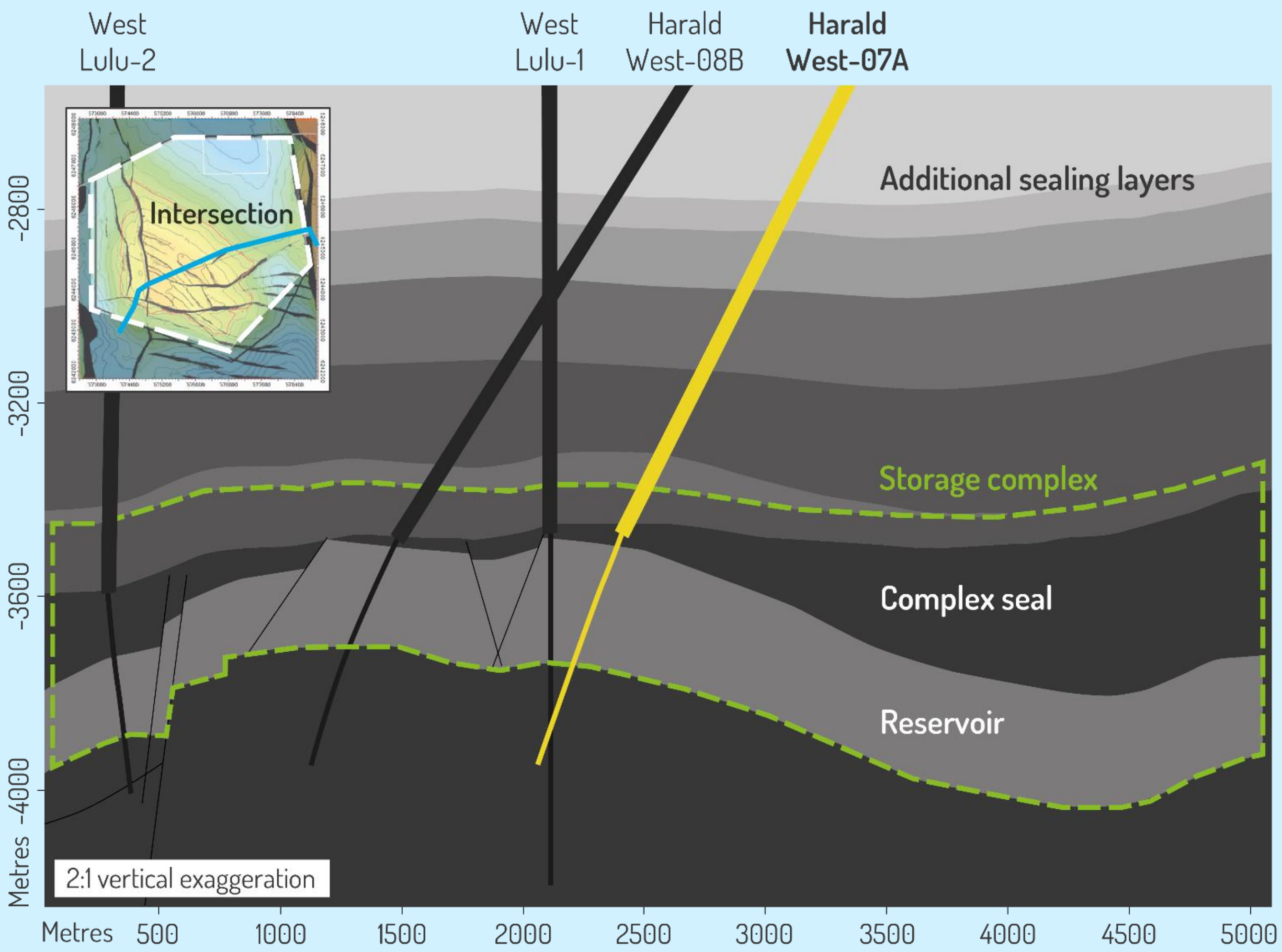
- Harald West and East are two gas reservoirs, discovered in the 80's and have been in production since 1997
- The Harald field consist of both sandstone and chalk. The Harald West, where the first injection will take place, is a sandstone reservoir

bifrost



Sandstone Harald West

- Harald West is situated at a depth of approximately 3,700 meters
- CO_2 injection with just one reused well with a rates of 2–3 million tons CO_2 per year
- CO_2 plume will remain within the storage unit at safe distance from spill points
- Pressure will stay below the pre-production reservoir pressure
- No degradation of the seal by geochemical reaction of gas, water, CO_2, and potential impurities and seal rock minerals
- Seal is just one of many seals that exists between the storage complex and the seabed



bifrost

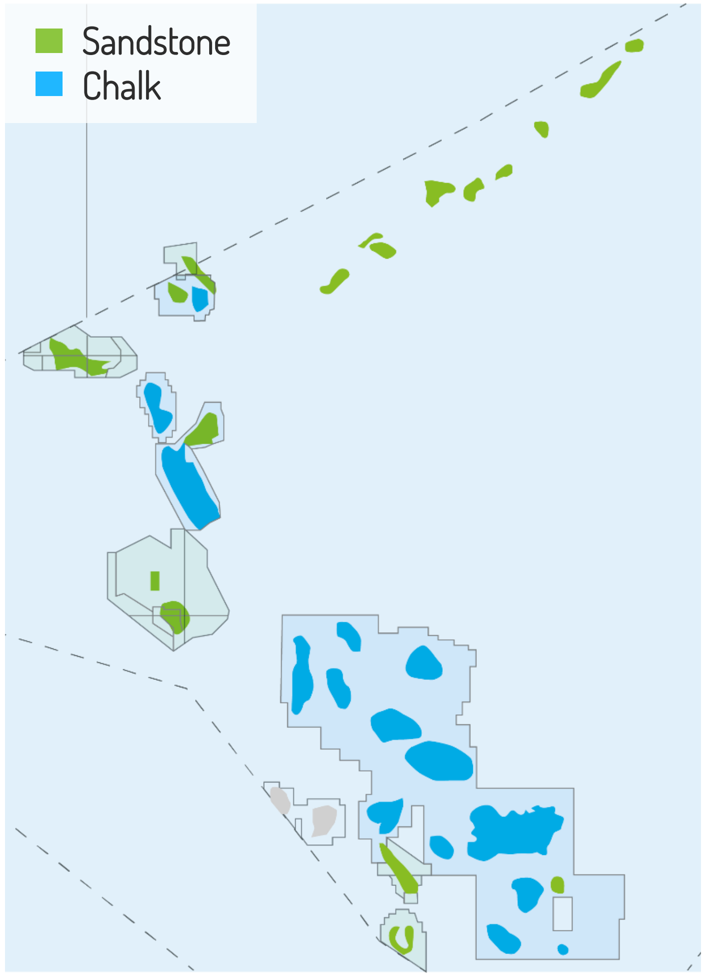
Chalk Harald East

Sandstone

- Hard and often compact rock
- Primarily composed of sand grains (quarts, feldspar,…)
- Good flow properties (high permeability of 1000 mD)
- Known from construction material and from some of nature's greatest phenomenons

Chalk

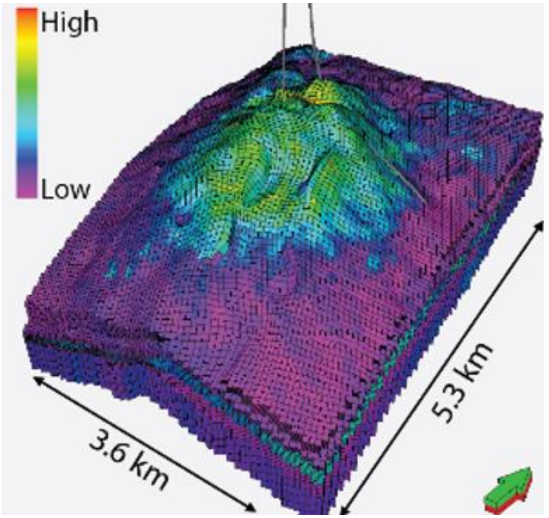
- Soft porous rock
- Primarily composed of calciumcarbonate from exoskeletons of marine organisms
- Fine-grained and tight (low permeability of 1-2 mD)
- Known from classrooms and from e.g. Møns and Stevns Klint

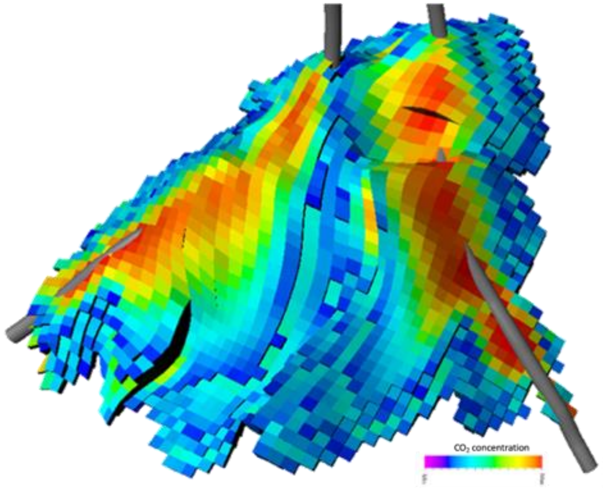


bifrost

The potential of storing in the chalk in the Danish subsoil

- EUDP Bifrost study results support that CO_2 can be stored safely in Harald East chalk
- Our analysis shows that reservoir integrity remains intact
- The result is important because it means that there is an opportunity to scale up CO_2 storage in depleted gas and oil reservoirs in Denmark
- Additional studies are needed before a commercial stage is reached





Monitoring, containment and protection aspects of CO_2 storage

Malene Rod Vest
Program Director, Danish
Offshore Technology Centre, DTU

David Nevicato
CCS Bifrost Asset Manager,
TotalEnergies Denmark

bifrost

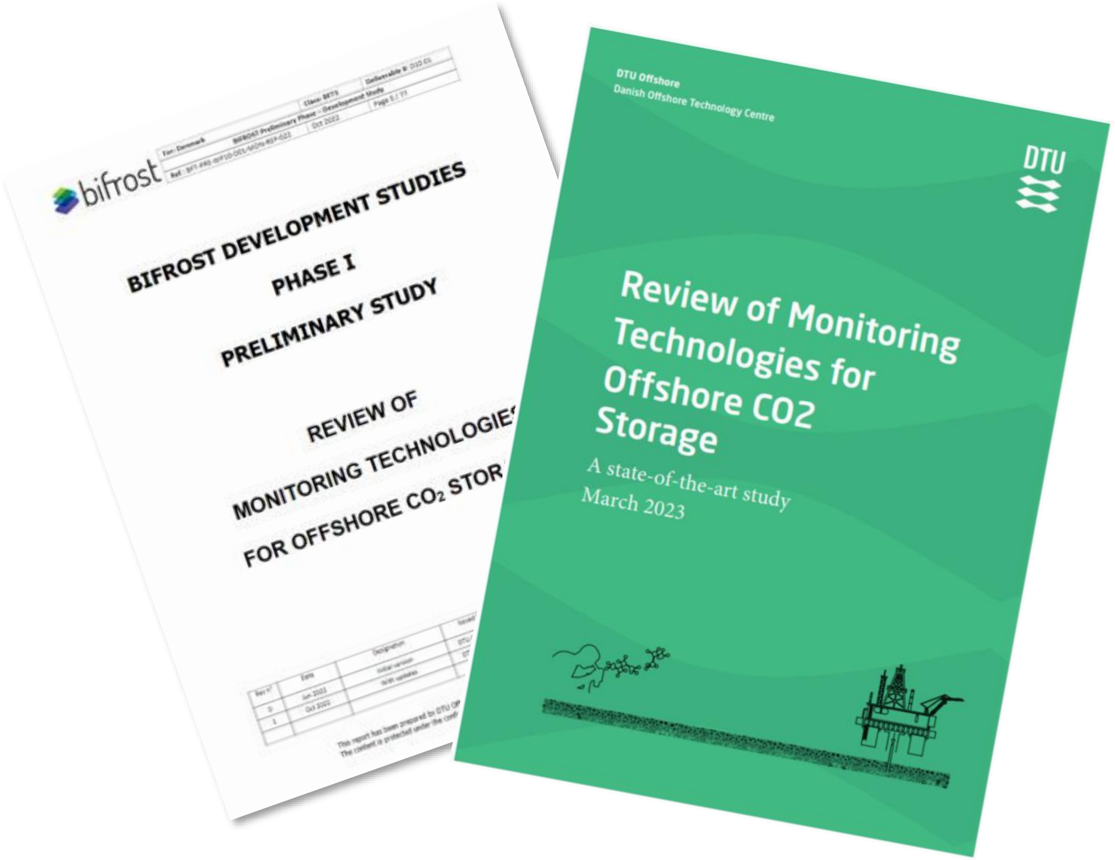
Ensuring the CO_2 is stored permanently by seismic surveys, sensors and seabed inspections

- 4D seismic: Imaging the subsurface using repeated seismic surveys to detect changes in the 3D volume
- Micro-seismic and sensors: Passive seismic detection at the seabed and in a monitor well just above the CO_2 injection point to detect evolution of pressure and temperature
- Seabed inspections near the Harald platform and former wells

bifrost

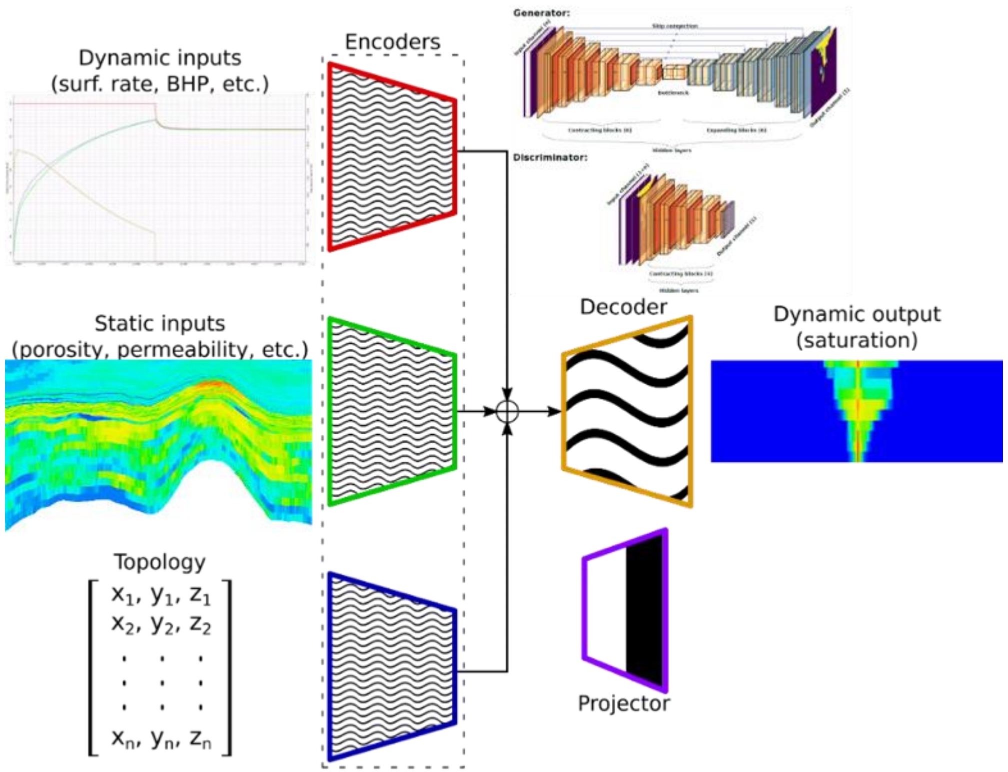
Focus on safety and the environment

- It is central to the success of any CCS project to identify the most suitable and cost-effective MMV technologies.
- For the upscaling of CCS as a climate mitigation technology there is a need for reliable and cost-effective monitoring technologies
- DTU is developing two new, innovative technologies based on a review of existing technologies and gaps.



bifrost

Focus on safety and the environment

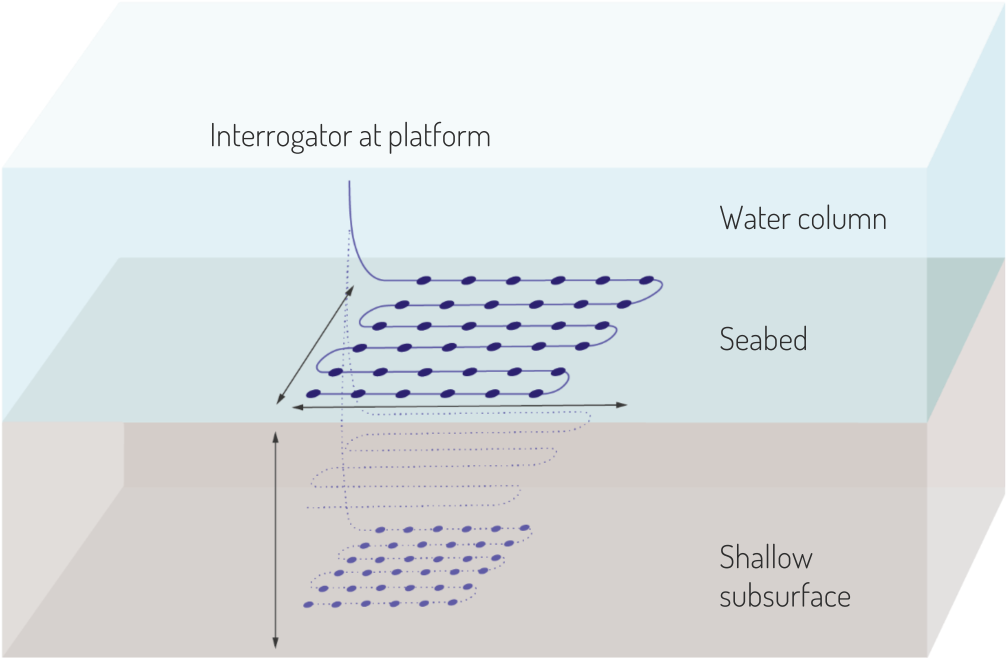


Technology 1: Digital twin

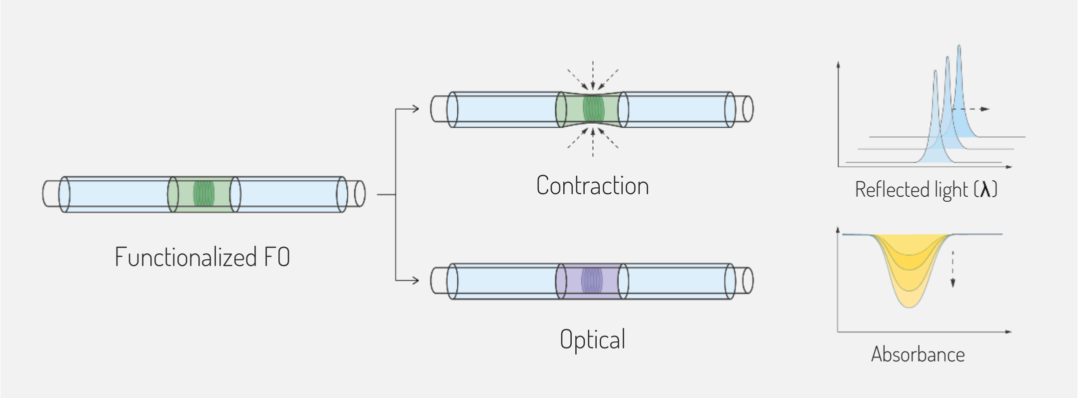
- Machine Learning application for monitoring and prediction of the CO_2 plume
- Advantages: processing large data sets, automated verification of containment, fast response compared to conventional subsurface models
- Development of this solution continues in Project Cerberus funded by the Danish innovation fund IFD

Focus on safety and the environment

Technology 2: Fibre optical CO_2 measurer



- Development of cost-effective sensors for detecting changes in the near seabed environment
- Advantages: low cost, continuous and areally distributed measurements incl. baseline, reduced impact on marine environment



bifrost

Public Acceptance: Analysis

Jacob Ladenburg

Professor, Department of Technology, Management and Economics, DTU

bifrost

We measure acceptance and preferences through surveys

National survey data collected in 2022 and 2023 via E-Boks (digital mailbox where individuals receive letters/emails from the public authorities, insurance companies, bank etc).

- Response rate of 22.3-22.5%
- Questions about CCS acceptance
- Questions about CCS willingness to pay

Three RTC information experiments included in the acceptance and willingness to pay questions in both survey rounds (2022 and 2023)

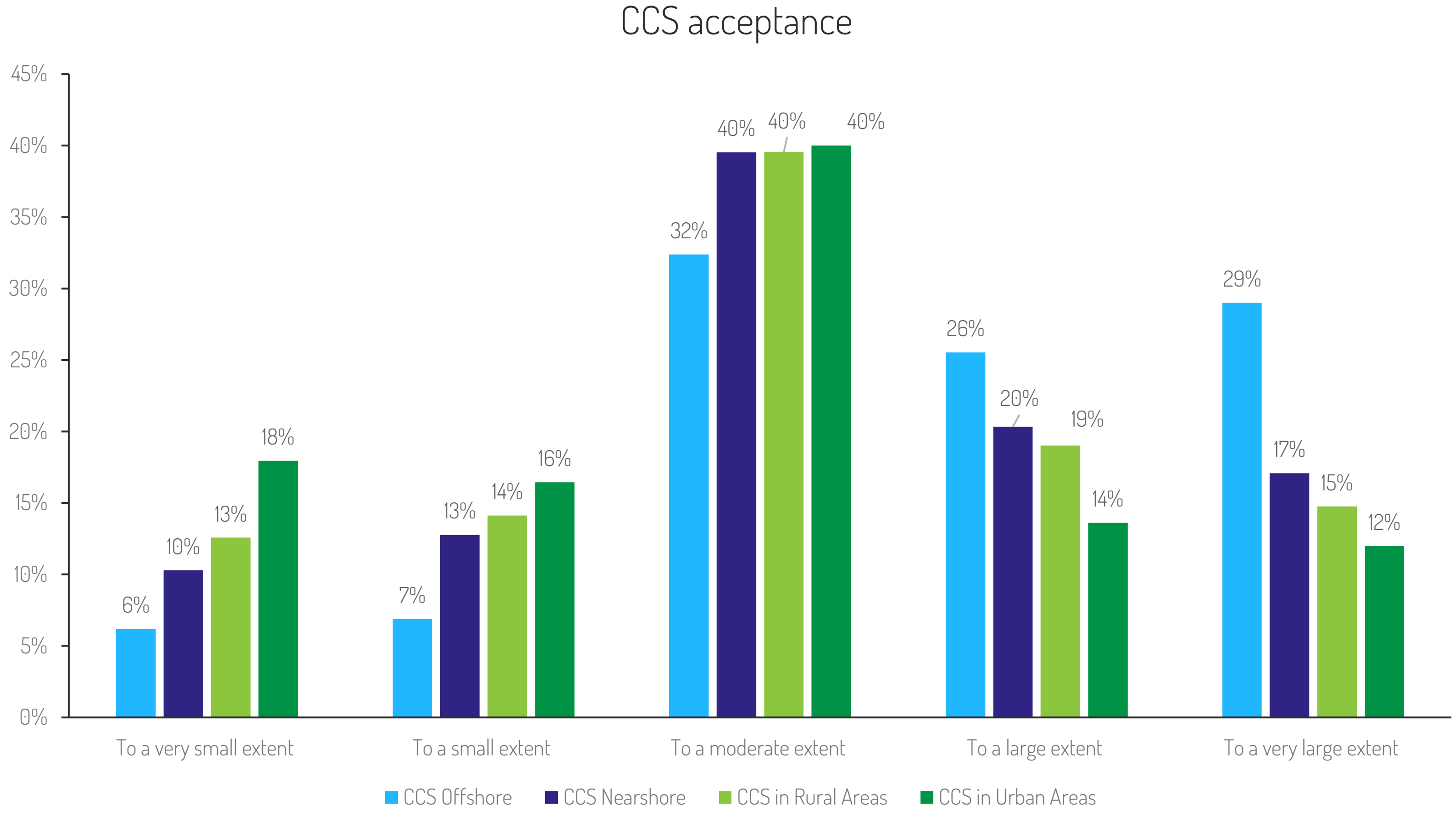
Public Survey
2022

Public Survey
2023

bifrost

A majority of Danes support CO_2 storage offshore

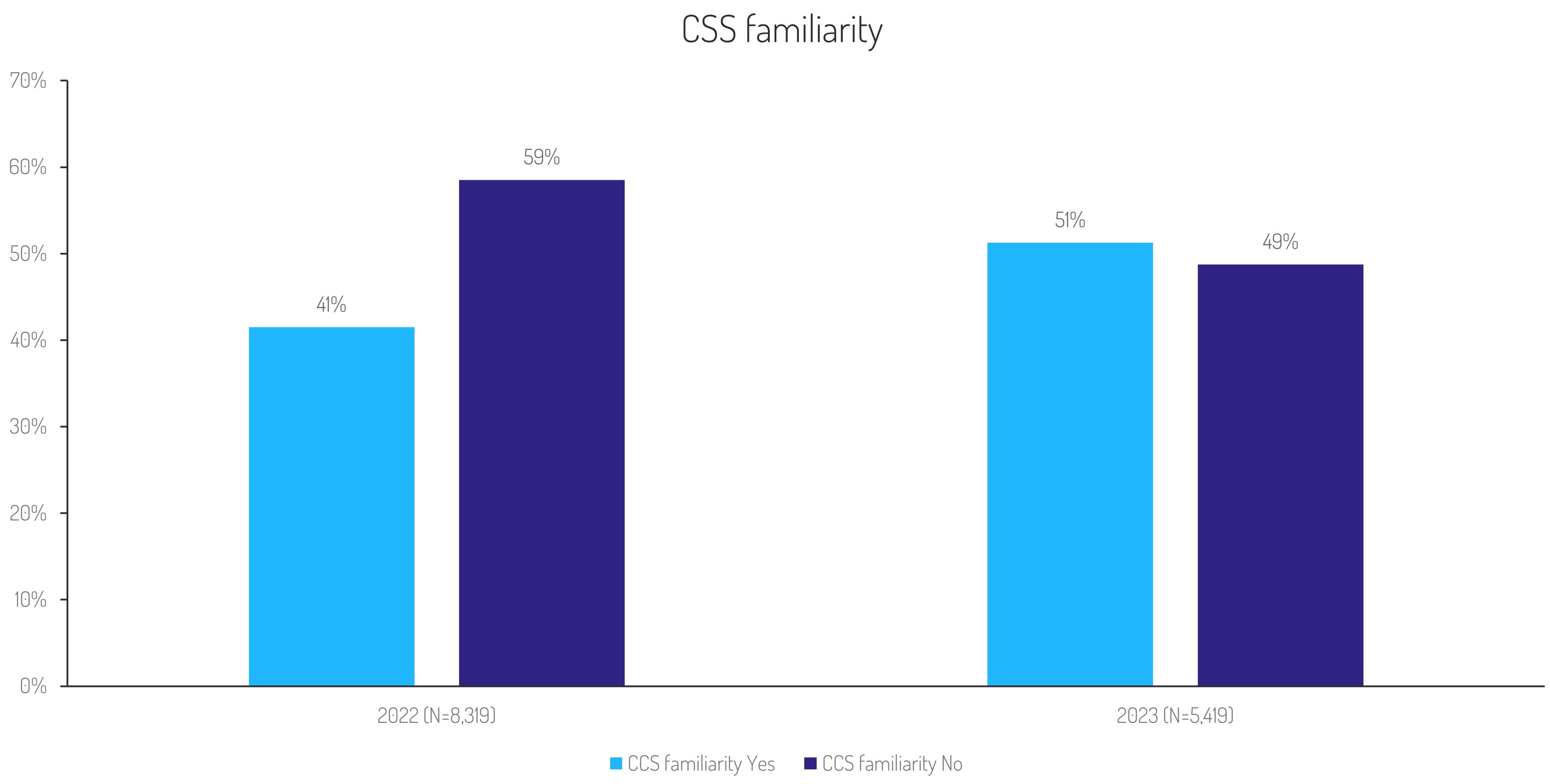
To what extent do you think Denmark should use the following technologies to reduce CO_2 emissions?



$N_{2022\ survey}$= 1,588-1,590 respondents

bifrost

CCS is a new technology, and more knowledge is needed



Increasing the knowledge through information scenarios

Baseline information

CO_2 capture and storage (CCS) is a technology where CO_2 is captured at power plants or industries. The CO_2 is transported via pipes/by ship to the storage site, and pumped deep into the subsoil, where nature itself ensures that the CO_2 stays there. In Denmark, we are already testing the possibilities of capturing CO_2 and storing it in two large old oil/gas fields in the North Sea.

Baseline information + International CCS experience Information

CO_2 capture and storage (CCS) is a technology where CO_2 is captured at power plants or industries. The CO_2 is transported via pipes/by ship to the storage site, and pumped deep into the subsoil, where nature itself ensures that the CO_2 stays there. In Denmark, we are already testing the possibilities of capturing CO_2 and storing it in two large old oil/gas fields in the North Sea.

The technology has been used abroad for almost 40 years

Baseline information + International CCS and Danish natural gas storage experience Information

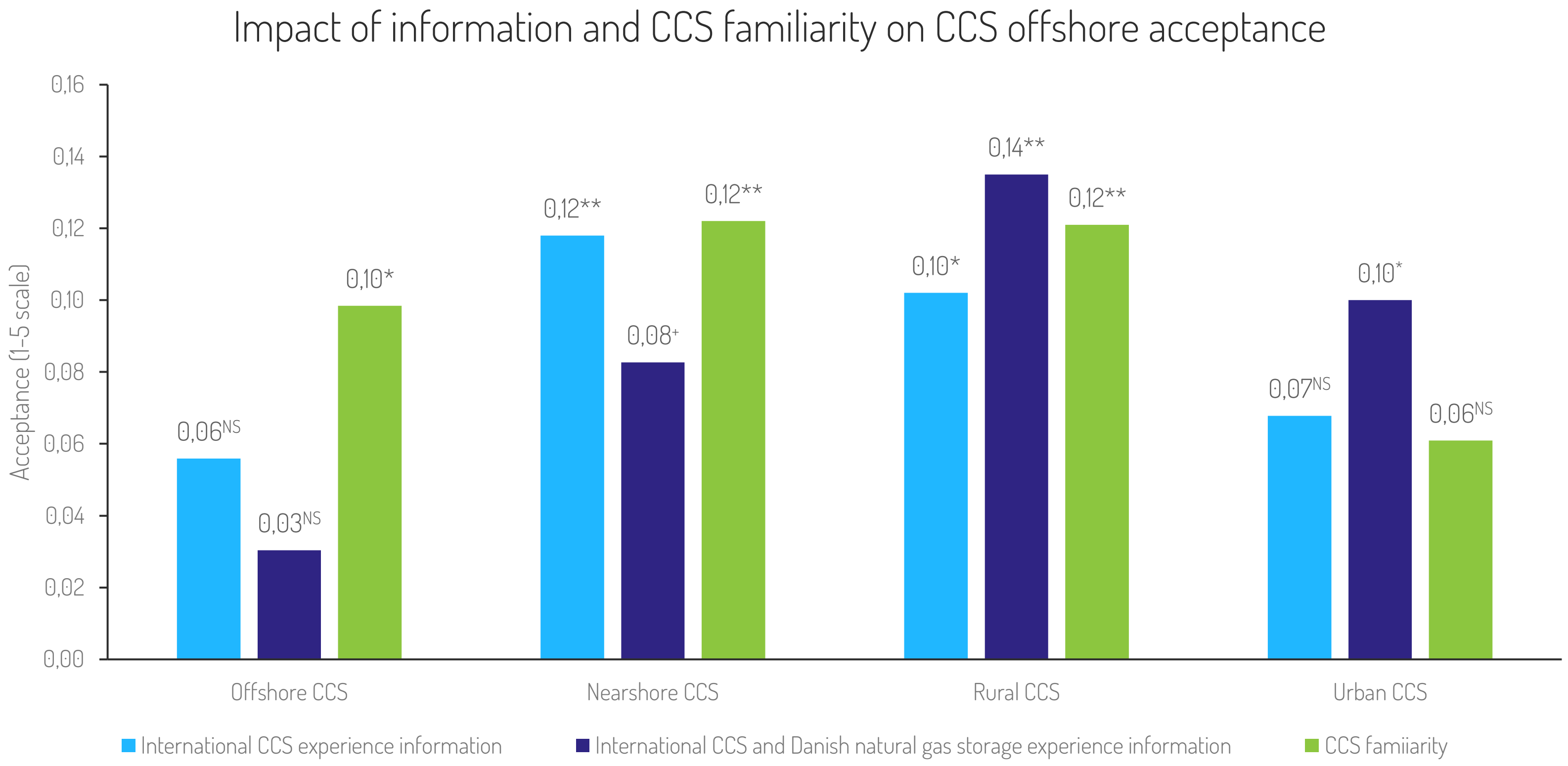
CO_2 capture and storage (CCS) is a technology where CO_2 is captured at power plants or industries. The CO_2 is transported via pipes/by ship to the storage site, and pumped deep into the subsoil, where nature itself ensures that the CO_2 stays there. In Denmark, we are already testing the possibilities of capturing CO_2 and storing it in two large old oil/gas fields in the North Sea.

The technology has been used abroad for almost 40 years

Gas storage is not a new technology in Denmark. Since the mid-80s and 90s, millions of cubic meters of natural gas have been stored and extracted annually underground in Jutland (Lille Torup) and Zealand (Stenlille).

bifrost

The acceptance is influenced by level of knowledge and information

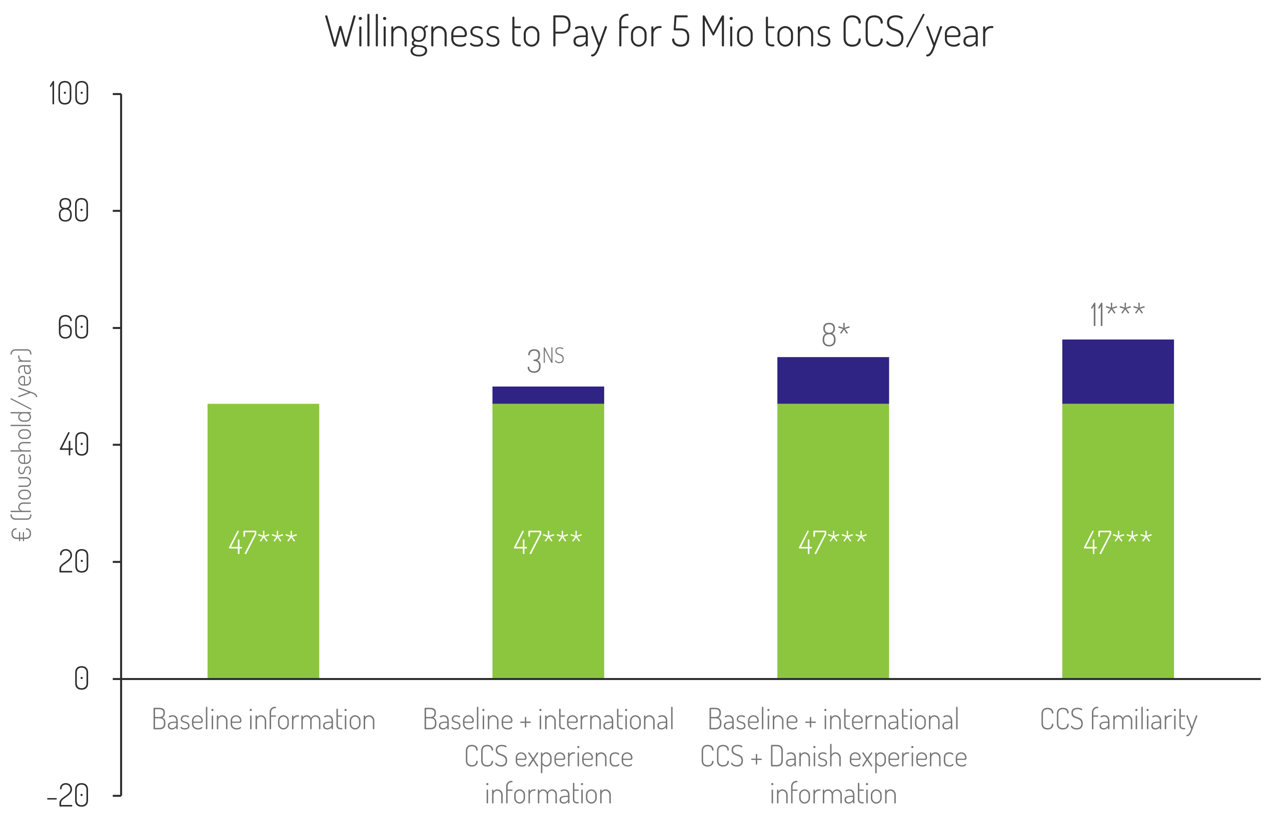


$N_{2022\ survey}$= 3,877-3,879 respondents, response rate 22.3%

Danish households are willing to pay for CCS

We asked the respondents, how much they were willing to pay for using CCS to capture and store 5 Mio tons CO_2 and 10 Mio tons CO_2, respectively

Information about CCS was randomised among the respondents



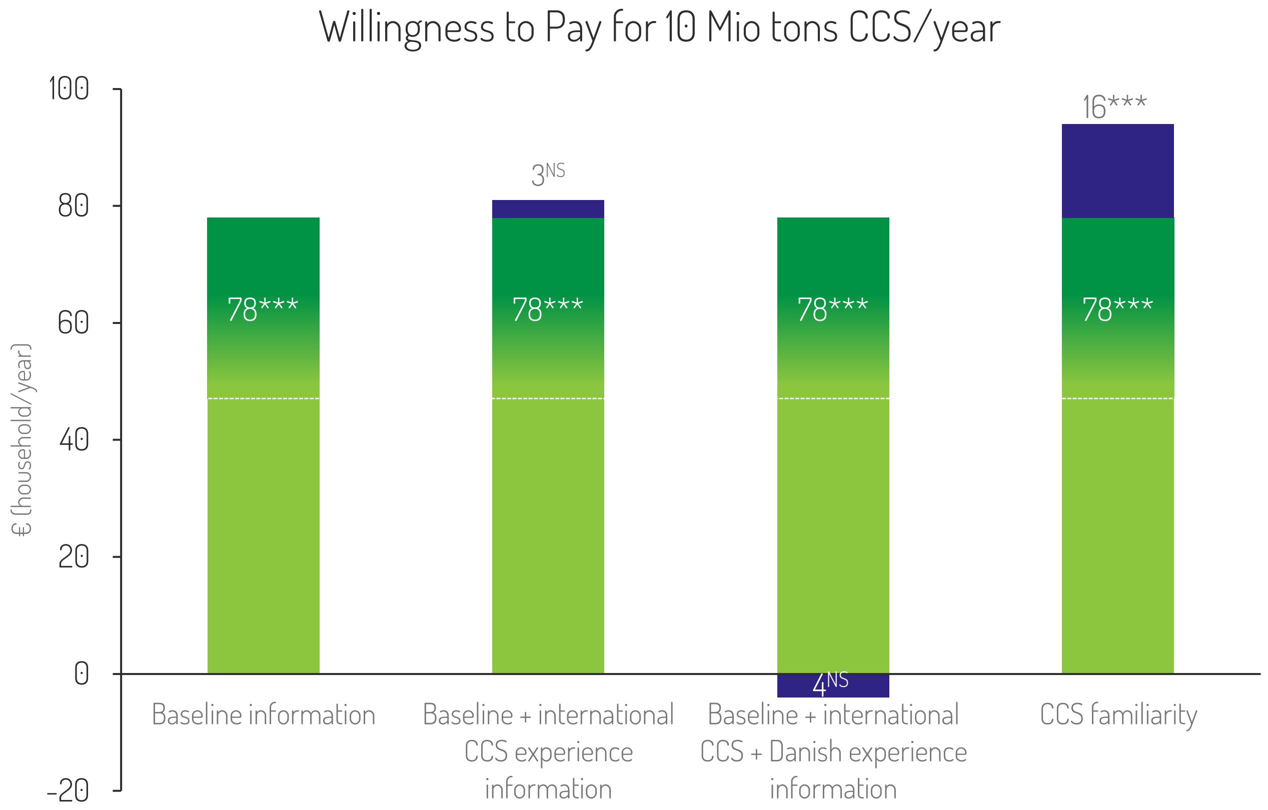
NS Not significant, * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$

bifrost

Danish households are willing to pay for CCS

We asked the respondents, how much they were willing to pay for using CCS to capture and store 5 Mio tons CO_2 and 10 Mio tons CO_2, respectively

Information about CCS was randomised among the respondents

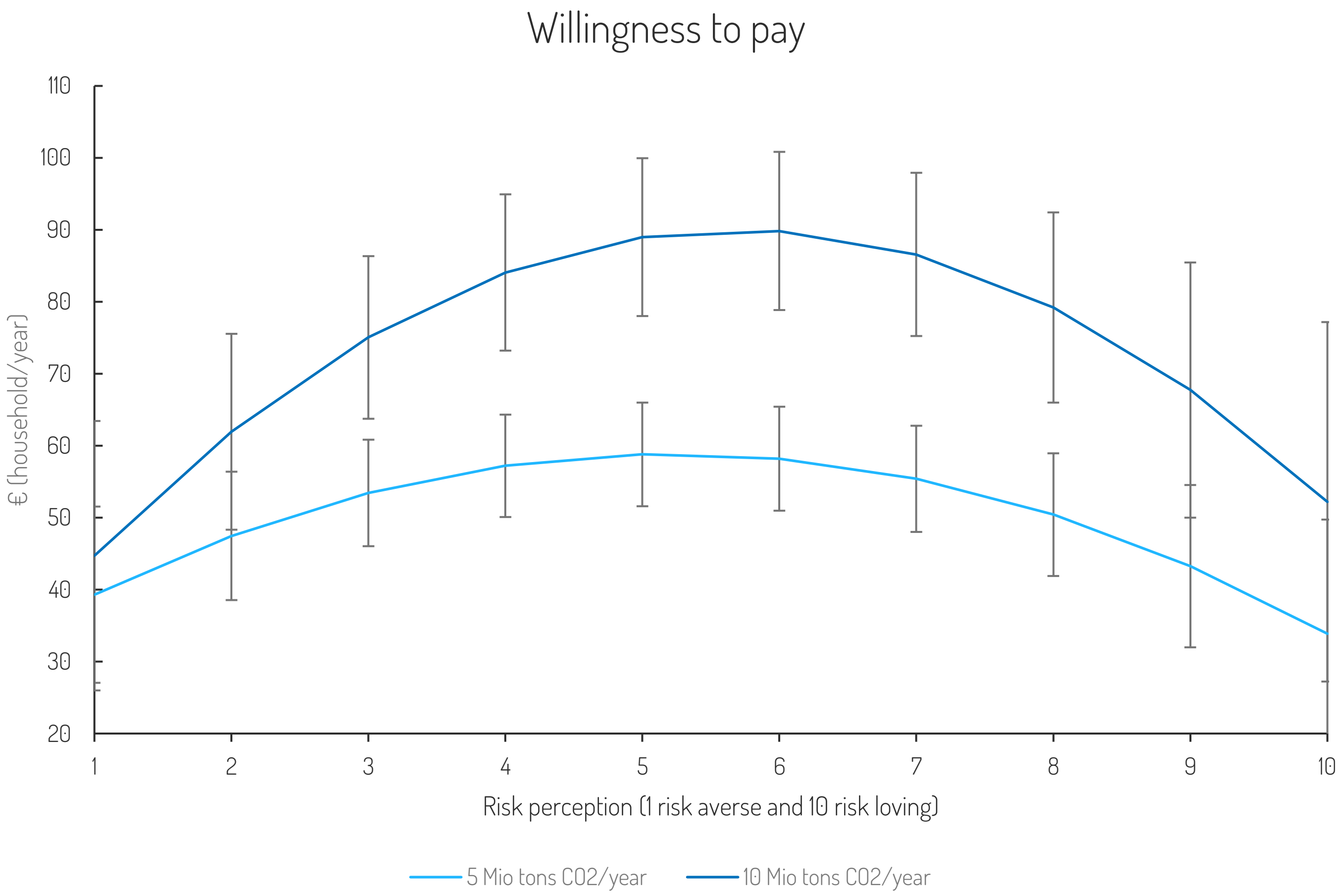


NS Not significant, * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$

bifrost

Risk perception and willingness to pay

Risk measured on a 1-10-point scale
1 =Not at all willing to take risks
10 = Very willing to take risks

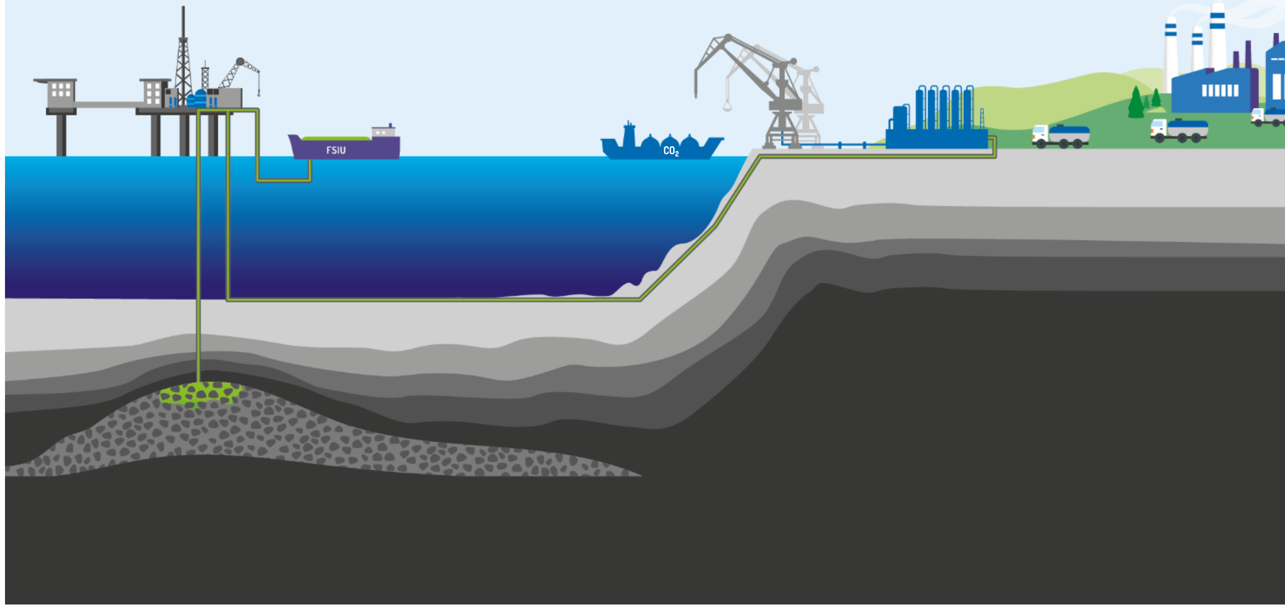


What's next?

David Nevicato

CCS Bifrost Asset Manager,
TotalEnergies Denmark

bifrost



Any questions?

bifrost

Panel discussion

Martin Rune Pedersen
Country Chair,
TotalEnergies Denmark

Kim Kristensen
CEO, Evida

Rune Rasmussen
CEO, Associated Danish
Ports

Randi Skytte
Head of Infrastructure,
Ørsted

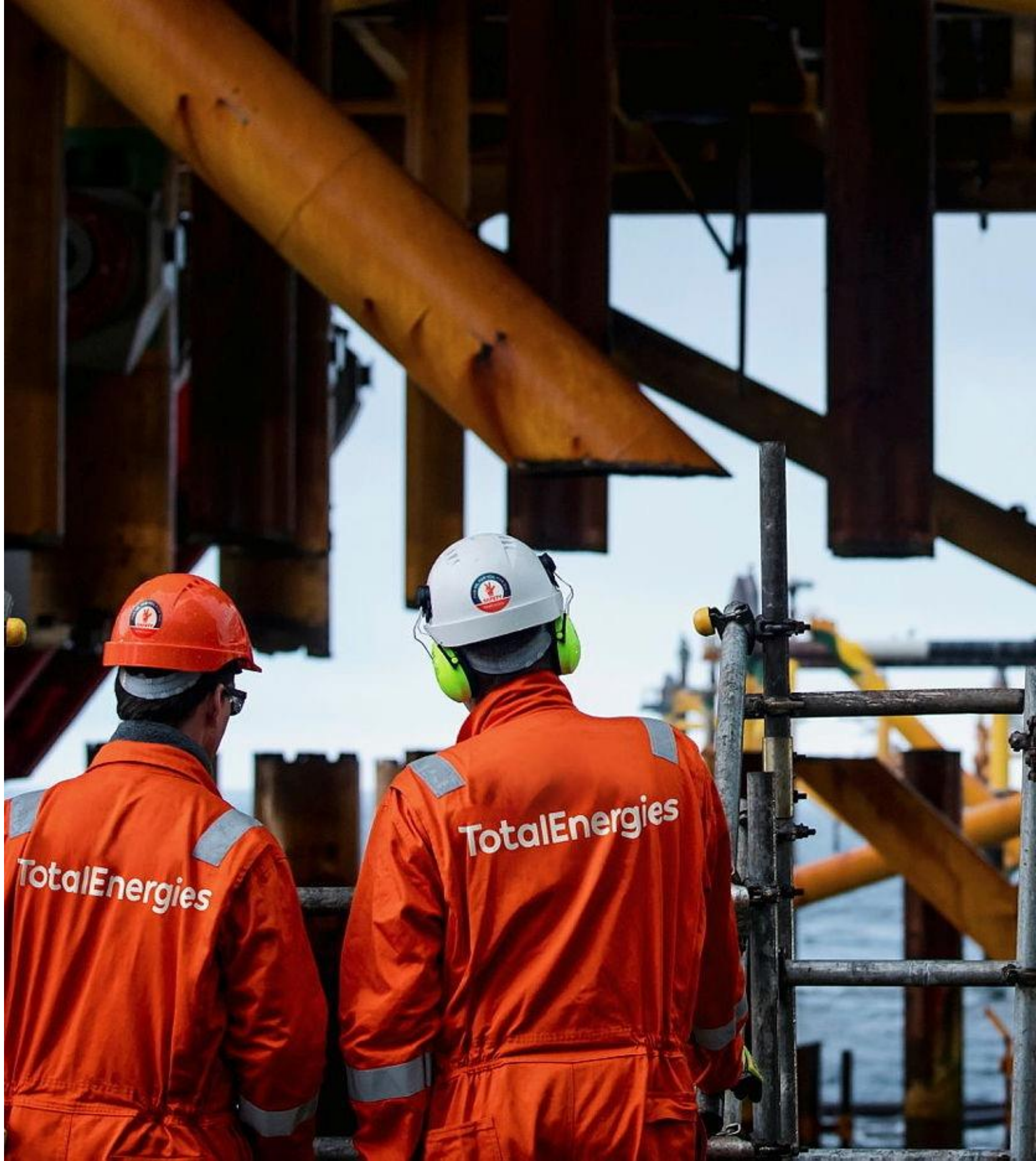
bifrost

Final word and goodbye

Martin Rune Pedersen

Country Chair, TotalEnergies Denmark

bifrost



End of conference

bifrost