

# Onboard Carbon Capture

## Experience from Clipper Eris

IMO Technical Seminar  
11. September 2025





# The marine industry's three pathways for decarbonisation

## **Burn less fuel**

More efficient operations and solutions

## **Clean up emissions**

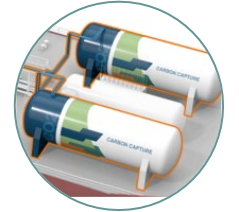
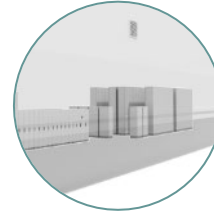
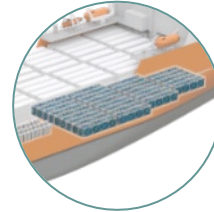
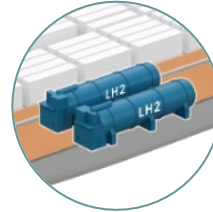
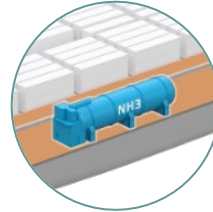
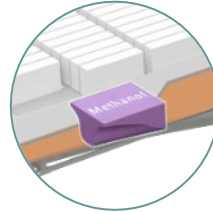
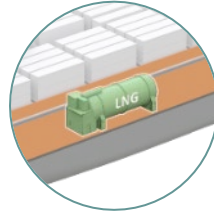
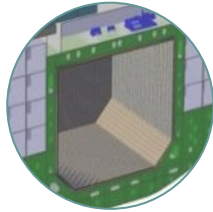
Carbon capture, exhaust treatment

## **Use alternative energy sources**

Sustainable fuels, hybridisation and electrification

A 100% reduction in greenhouse gas emissions will require the adoption of sustainable fuels

# COST OF EMISSIONS WILL INCREASE THE FUEL- AND EMISSION- RELATED PRICE, AND IMPROVE THE BUSINESS CASE FOR CARBON CAPTURE



Fuel type	Low Sulphur Fuel Oil @ 20°C	Liquefied Natural Gas @ -162°C	Methanol @ 20°C	Ammonia @ -33°C	Liquid Hydrogen @ -253°C	Compressed Hydrogen @ 350bar	Marine Battery Rack	Carbon Capture @ -26°C
Fuel price factor (per GJ) <sup>1)</sup>	1x	1.1x - 4.6x <sup>2)</sup>	2.6x - 5.5x <sup>3)</sup>	2.4x - 4.3x <sup>4)</sup>	3.6x - 4.6x <sup>4)</sup>	2.1x - 3.1x <sup>4)</sup>	2.0x - 5.3x <sup>8)</sup>	1.3x - 1.5x <sup>9)</sup>
Gross tank size factor <sup>6)</sup>	1x	1.7x - 2.4x <sup>7)</sup>	1.7x	3.9x	7.3x	19.5x	~40x (~20x potential)	2x - 3x

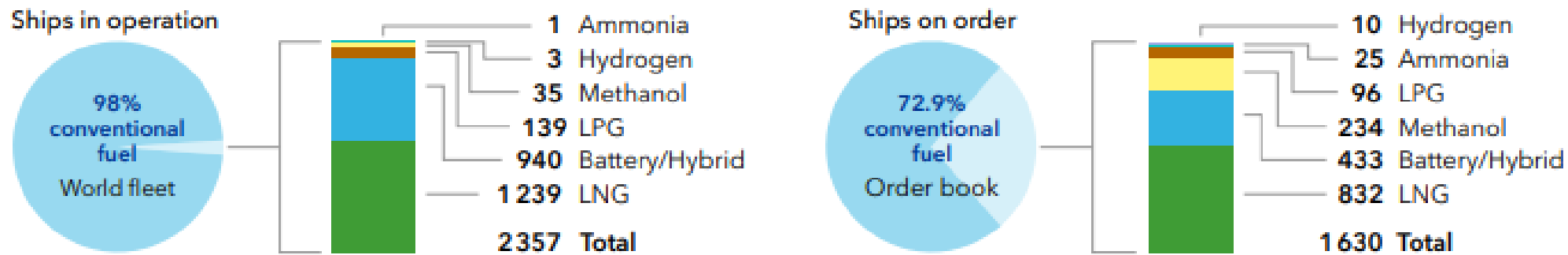
1) Fuel production cost estimate for 2025; source: Maersk Mc-Kinney Møller Center for Zero Carbon Shipping - NavigaTE 2023; 2) Price range spans between fossil & electro- methane; 3) Price range spans between bio- & electro- methanol; 4) Price range spans between blue- & electro- ammonia/hydrogen; 5) Assuming 100% consumption subject to EU Fit-for-55, EU allowances at EUR 159/ton (source: Transport & Environment NGO); 6) Gross tank estimations based on Wärtsilä data; 7) 1.7x membrane tanks, 2.4x type C tanks; 8) Shore energy price EUR 0.1-0.27/kWh; 9) HFO consumption, 10% additional energy demand, carbon capture rate at 70% and cost of sequestration EUR 40-60/tonCO2, excluding CapEx

# SHIPPING INDUSTRY IS A HARD TO ABATE SECTOR

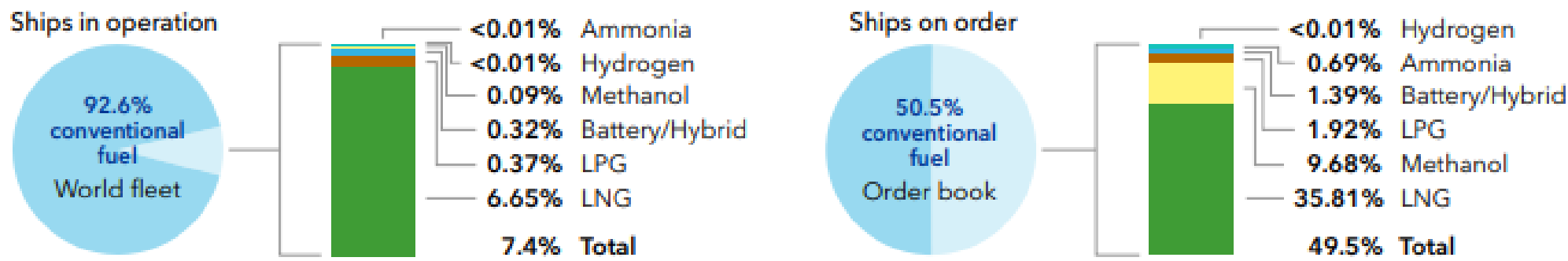
Existing fleet and OB is almost exclusively operating on fossil fuels, and it is not expected to be easy to convert existing fleet to alternative fuels when they become widely available

Alternative fuel uptake in the world fleet in number of ships (upper) and gross tonnage (lower), as of June 2024

## NUMBER OF SHIPS



## GROSS TONNAGE



Sources: IHSMarkit (ihsmarkit.com) and DNV's Alternative Fuels Insights for the shipping industry - AFI platform (afi.dnv.com)

# CARBON CAPTURE

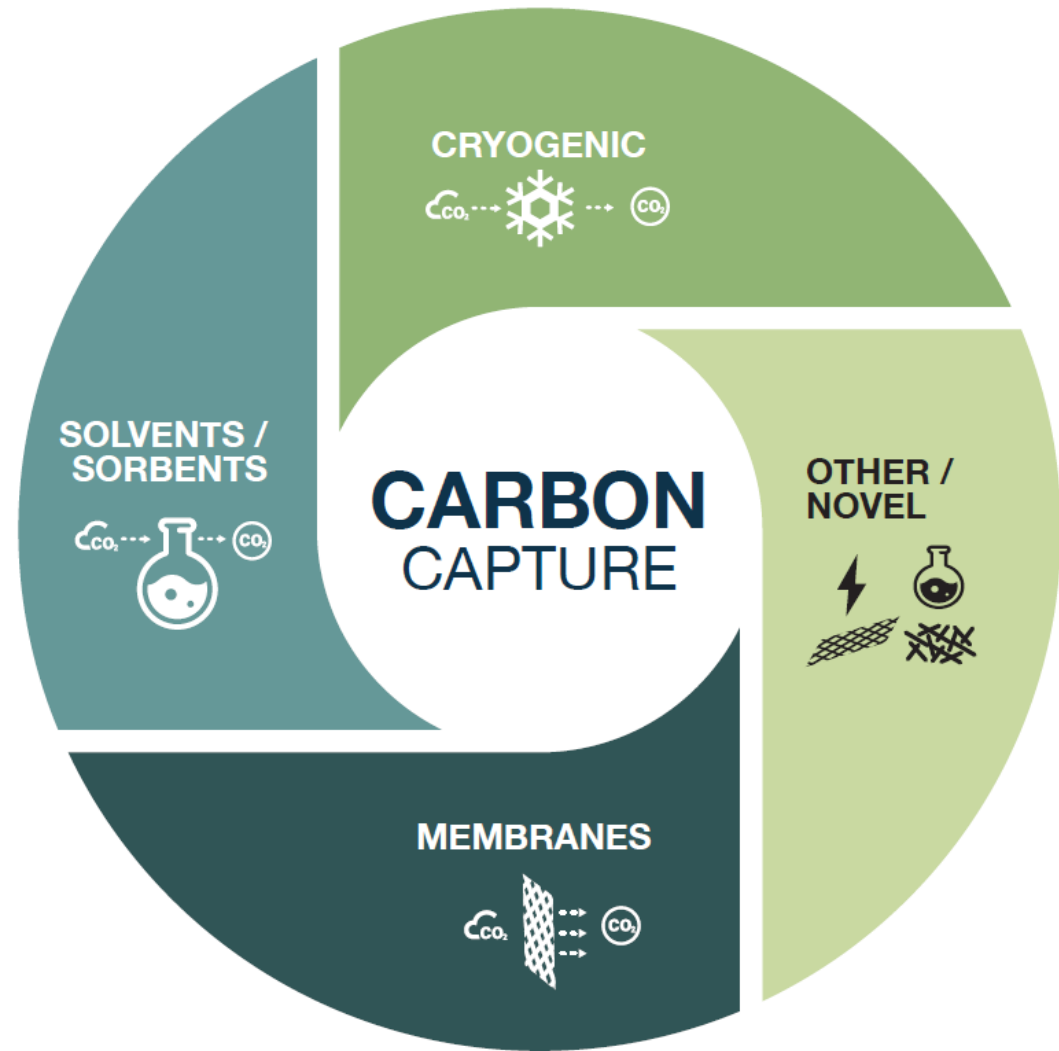
## The basic methods

There are three basic methods for post-combustion carbon capture, considered for ships:

- Absorption with a solvent or sorbent
- Membrane separation
- Cryogenic separation

Solvent-based absorption is the most technically mature solution

CO<sub>2</sub> is absorbed from the flue gas into a liquid carrier, and pressure and/or temperature is used to release the CO<sub>2</sub> from the solvent







## WÄRTSILÄ CCS INVESTMENT

Wärtsilä has launched a multi-million investment program for developing CCS technology for the maritime industry.

We have designed and installed a 1 MW pilot plant in our test facility in Moss, Norway in order to test our CCS technology in a range of scenarios and conditions.

We have been able to confirm the design assumptions and have been operating the system successfully since January 2022 achieving consistent CO<sub>2</sub> capture rates of 70%.



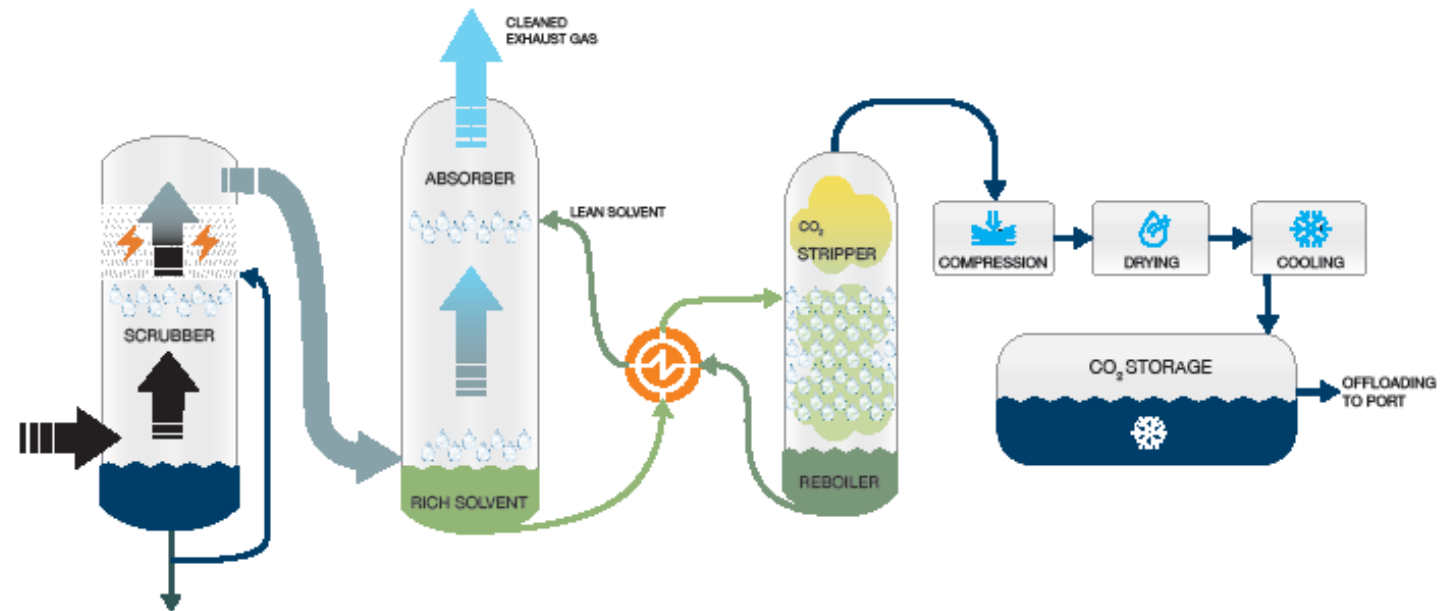
# How to Capture CO<sub>2</sub>?

## Solvent-based absorption – simplified explanation

1. \*Exhaust gas is treated to remove SO<sub>x</sub> and cool it down
2. \*Through the WESP\*\* the particulate matter is removed
3. Exhaust gas is then led to bottom of absorber
4. Lean solvent enters at the top of absorber
5. CO<sub>2</sub> is captured by the solvent when gas and solvent are mixed
6. Cleaned exhaust gas exits
7. Rich solvent is pumped via heat exchanger to the stripper
8. CO<sub>2</sub> is stripped from the rich solvent in the reboiler, becoming lean, and then recirculated to the absorber.
9. Water vapor content is condensed out of the gas stream
10. The CO<sub>2</sub> gas is then compressed, dried, and cooled
11. Finally the liquid CO<sub>2</sub> is stored in a tank, typically at 16 bar / -26°C

\* In case of LNG, only cooling is needed

\*\* Wet Electrostatic Precipitator



## WORLD'S FIRST COMPREHENSIVE, FULL-SCALE SOLUTION ONBOARD SOLVANG ASA'S CLIPPER ERIS, WHERE THE TECHNOLOGY CAPTURES EMISSIONS FROM ALL EXHAUST GAS SOURCES



- Earlier this year, Wärtsilä installed its CCS technology onboard the 21,000 m<sup>3</sup> ethylene carrier for full scale testing and optimisation.
- The solutions, which has been in operation since the Clipper Eris set sail from Singapore in February 2025, will support Solvang ASA's commitment to reducing carbon emissions and promoting sustainable maritime operations.
- Capture rates exceeding 70%

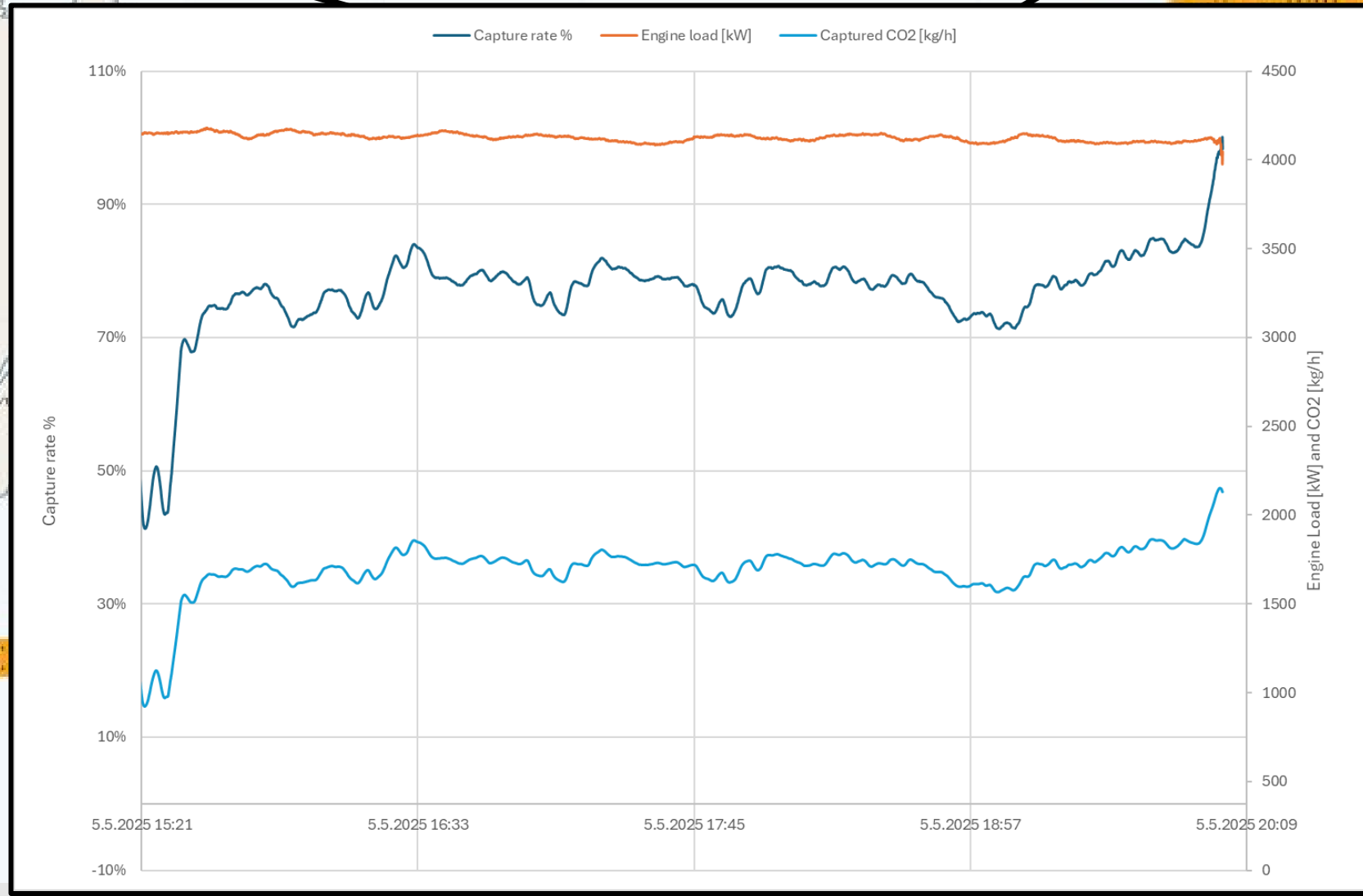




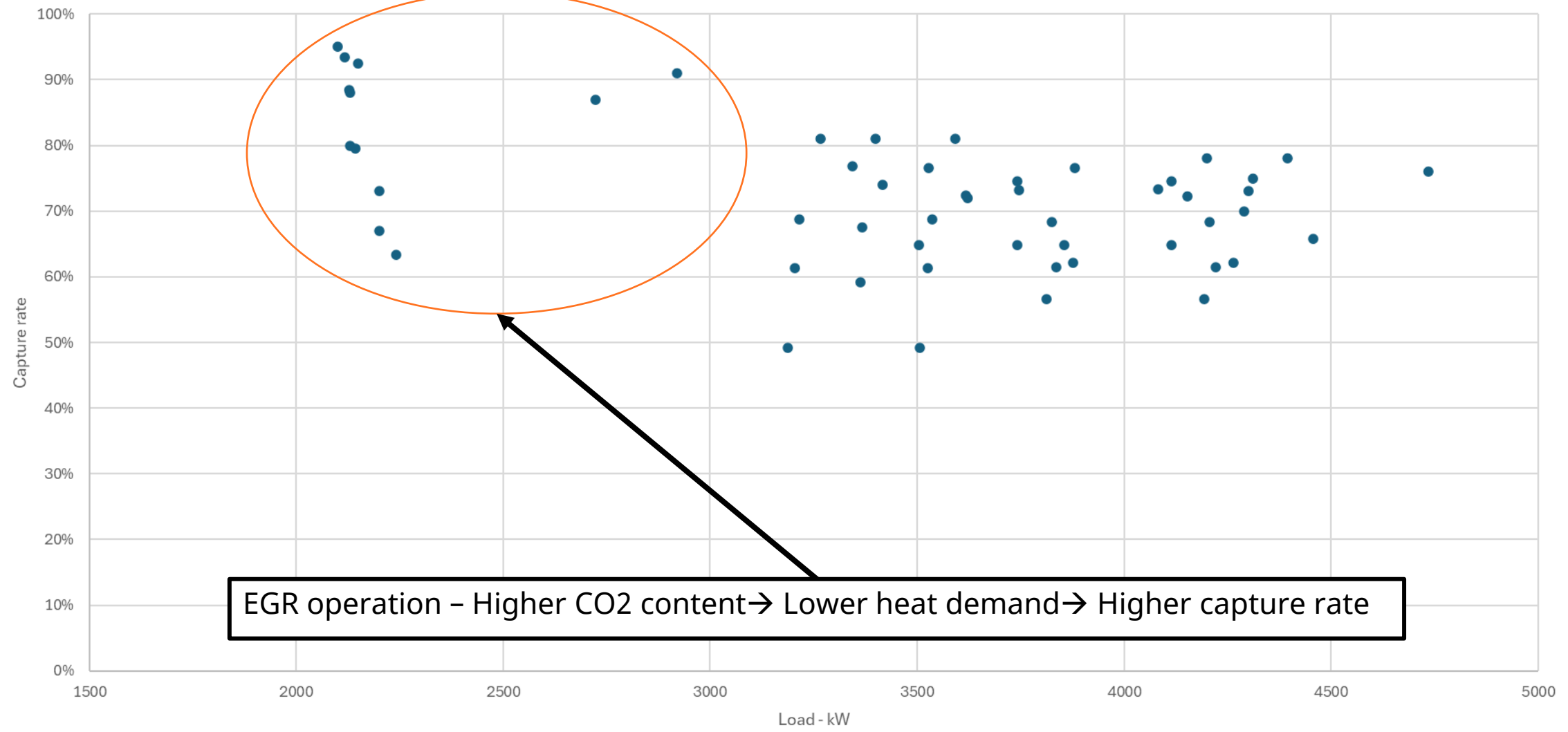
WÄRTSILÄ

1<sup>st</sup> to 8<sup>th</sup> of May – Performance testing of CCS System

78% capture rate achieved 2<sup>nd</sup> of May – 1900 kg/h LCO<sub>2</sub>



Capture rate



EGR operation - Higher CO2 content → Lower heat demand → Higher capture rate



# CCS

- Size/Weight
- Energy consumption
  - Heat demand
  - Parasitic loads
- Solvent
  - Performance/efficacy
  - Lifetime
  - Treatment/Regeneration
  - Availability
  - HSE
- Capex
- Opex
- Purity





The background image shows two polar bears on a small, melting ice floe in a dark blue sea. The bears are looking at each other. In the background, there are more ice floes and a distant shoreline. On the left side of the image, there is a list of pollutants: SOx, NOx, PM, and CARBON DIOXIDES. At the bottom, there is a title: THE GREEN FUTURE OF CONVENTIONAL FUELS.

~~SO<sub>x</sub>~~

~~NO<sub>x</sub>~~

~~PM~~

~~CARBON DIOXIDES~~

THE GREEN FUTURE OF CONVENTIONAL FUELS





**WÄRTSILÄ**



Clipper Eris The world's first ship with full-scale carbon capture

Fleet director Tor Øyvind Ask



# 27 vessels (7)



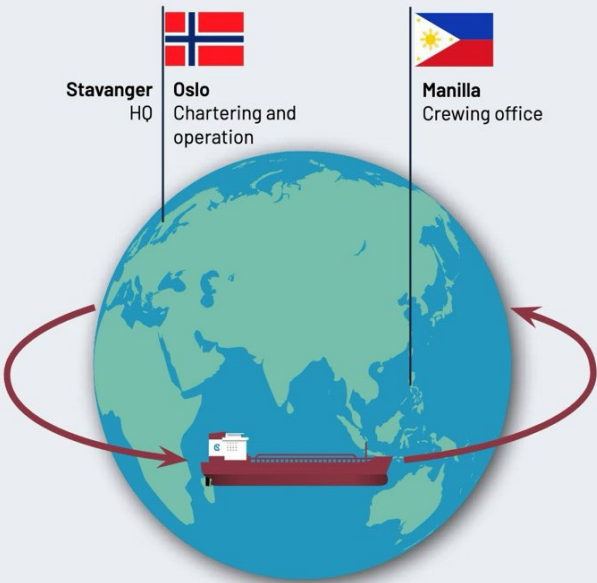
6 Semi-refrigerated Ethylene Carriers



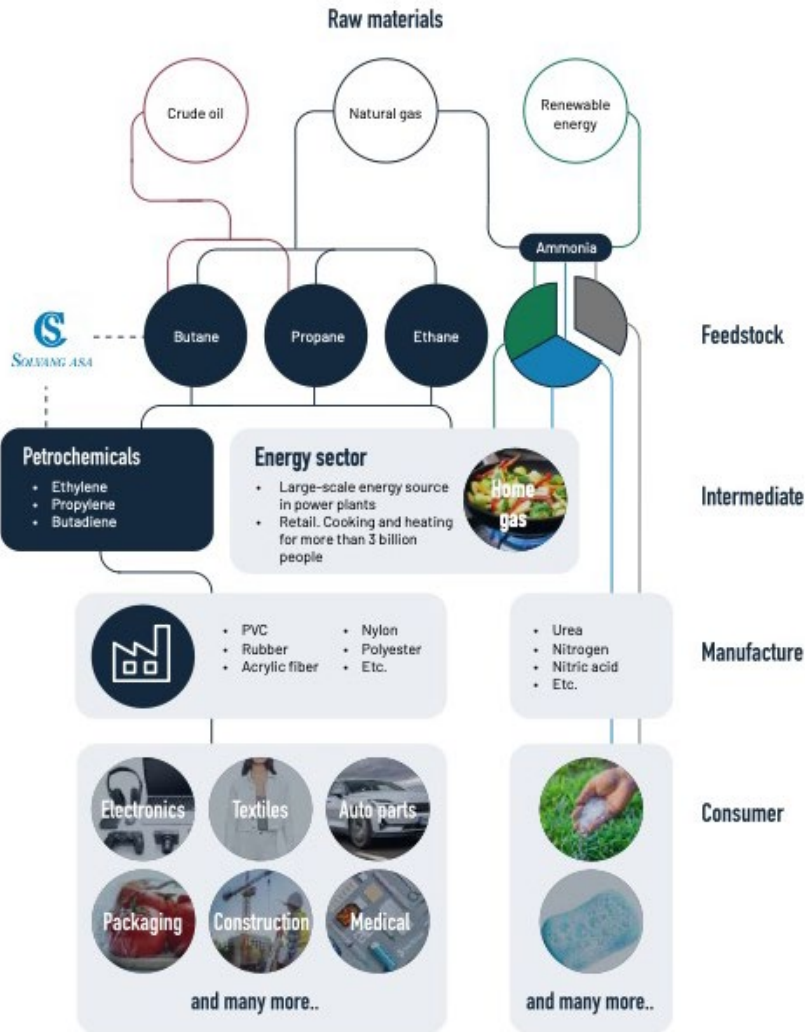
8 Large Gas Carriers



6 + (7) Very Large Gas Carriers



## Our Cargo







## SOLVANG MISSION STATEMENT

Solvang aims to be an industry leading provider of LPG and petrochemical tonnage to our clients in the safest, cleanest and most cost-effective manner.

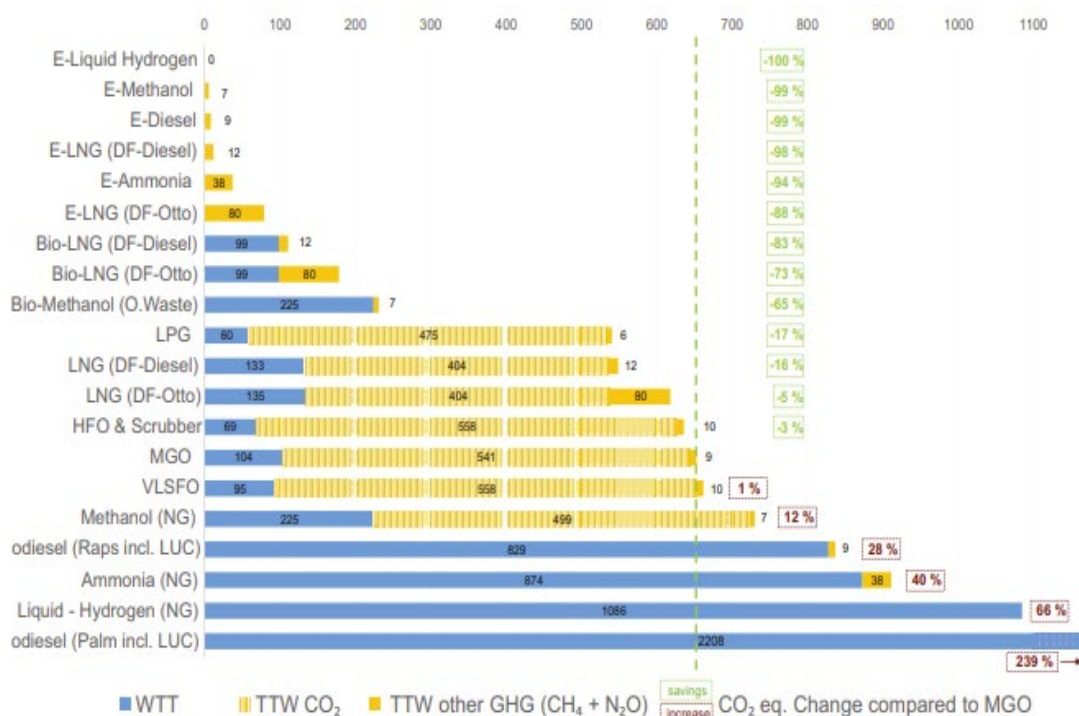


# Highlights of Solvang's ECO timeline and Emission control with exhaust gas cleaning (EGC)

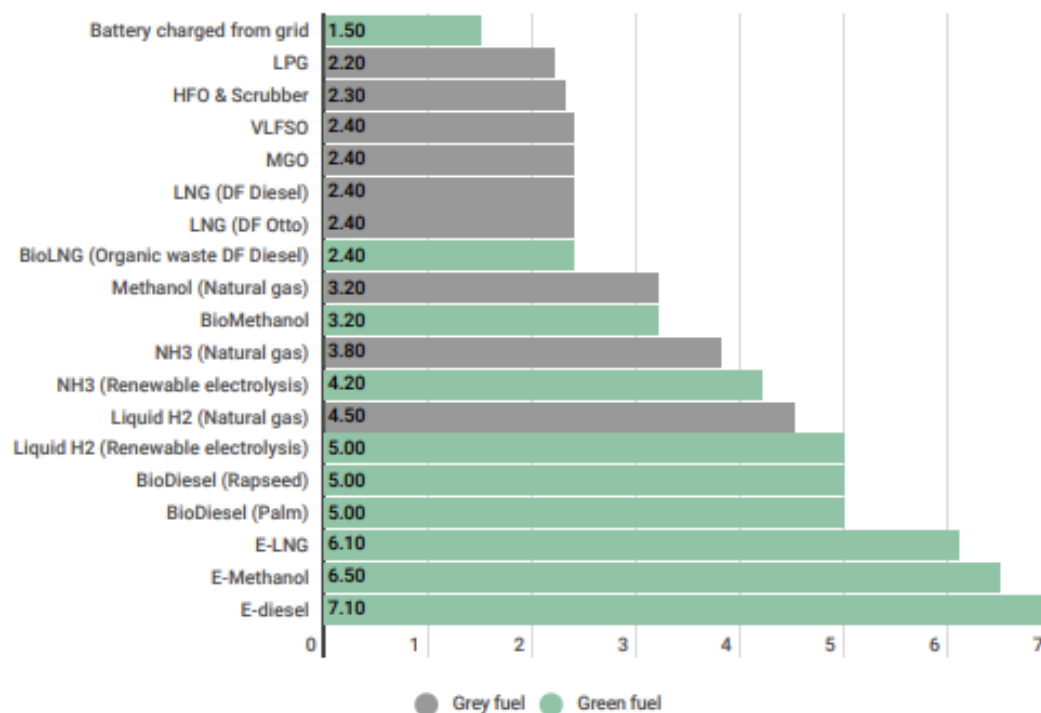
- 2010 “Make our Blue Logo Green” program.
- 2013 Delivery of the world's first ECO LPG Carrier with EGC with water treatment in open loop.
- 2015 Development of LP EGC + scrubber (NO<sub>x</sub>/SO<sub>x</sub> control) on an ethylene carrier.
- 2019 4 ECO Ethylene and 1 ECO Panamax VLGC newbuilds (EGC + LP EGR (NO<sub>x</sub>/SO<sub>x</sub> control)).
- 2021 Launches carbon capture project with Wärtsilä.
- 2023 Orders 7 VLGCs, OCCS-ready.
- 2024/2025 Installing and running the world's first full-scale OCCS system onboard the pilot vessel.

# GHG emissions vs. energy needed for propulsion

**Well-to-wake fuel emissions**  
in gram CO2 per kWh - GWP100



**Total energy input WTW / Delivered propulsion energy**



All e-fuels have a large energy loss during production. The global lack of GHG-neutral electricity from renewable sources also make e-fuels unfit for deep sea shipping today.





# CCS project goals and status

## Project status & timeline;

- LOI signed October 2021
- On-shore test started mid Feb2022
- Install WESP filter 2024 (5 vessels)
- Full CCS installation Q4 2024 (DD)

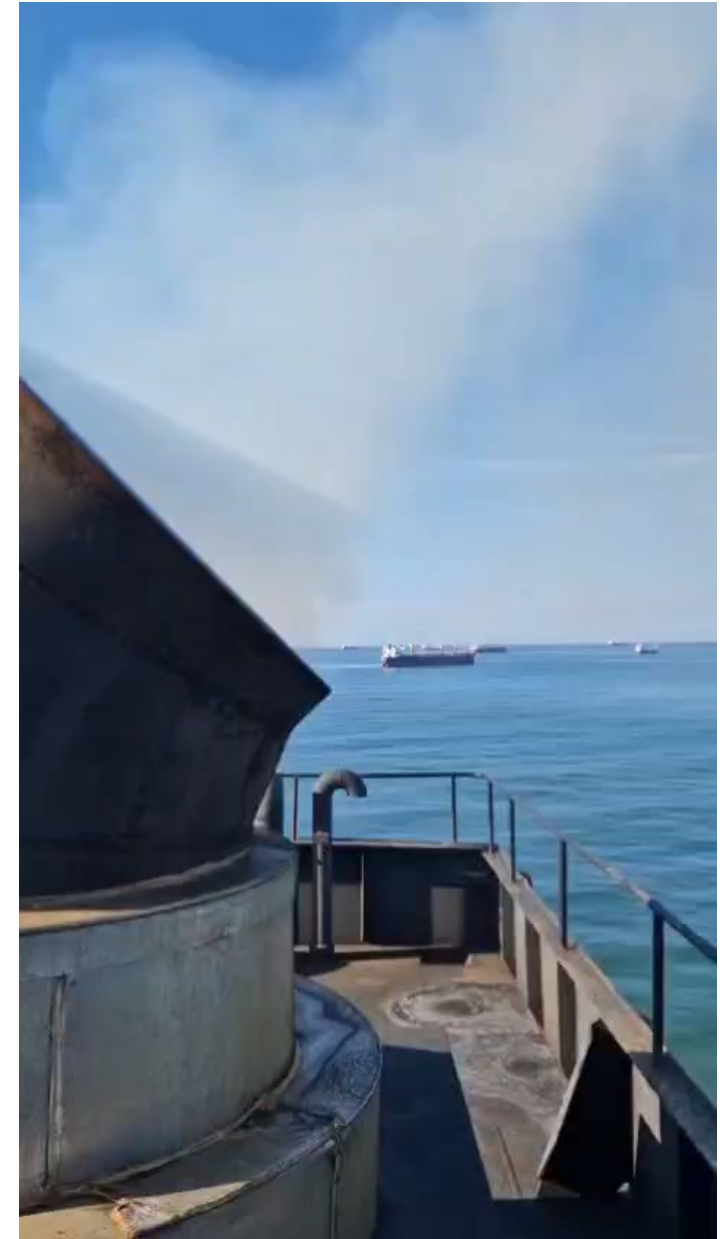
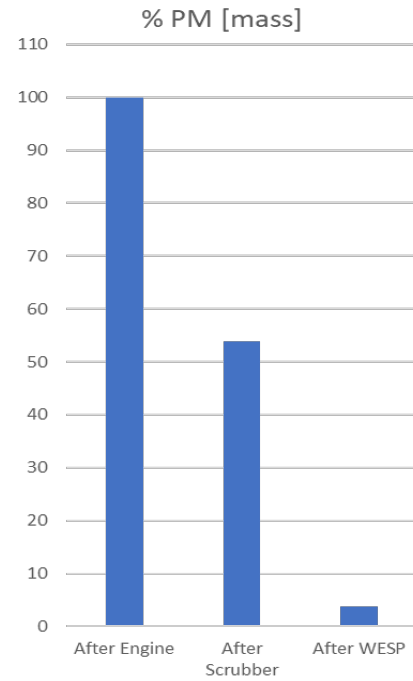
## Deliverables;

- To demonstrate that CO<sub>2</sub> can be captured and stored as liquid CO<sub>2</sub> in the deck tank
- Gain real experience of operation of an onboard CCS plant;
- Energy consumption
- Cost (CAPEX and OPEX)
- Maintenance requirements
- Input to Flag state and IMO and
- Find possible receivers of the captured CO<sub>2</sub>





# WESP (wet electrostatic precipitator) installation

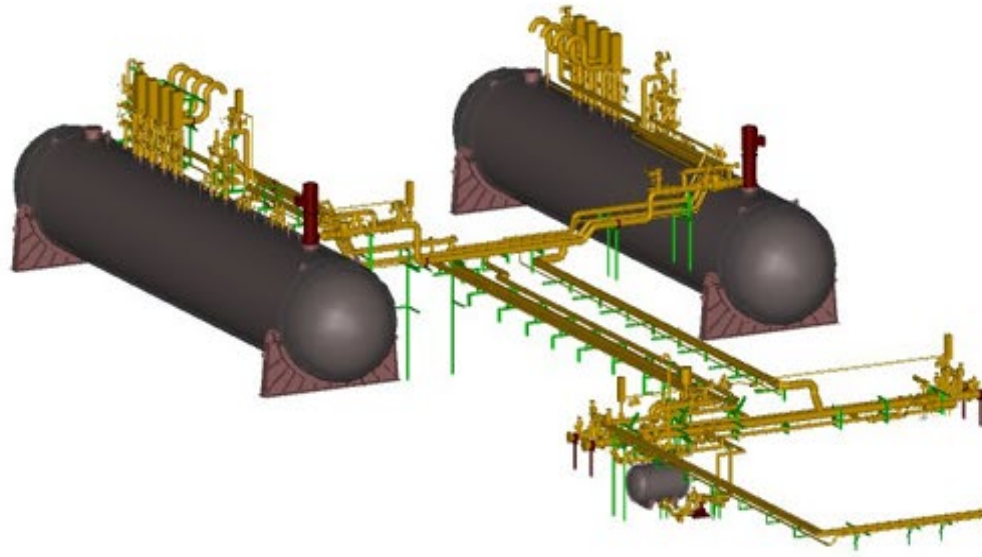


## Soot collected from WESP/water treatment after 12 hours operation.

- Automat filter for soot handling.
- Previous SYSTEM, filter bags



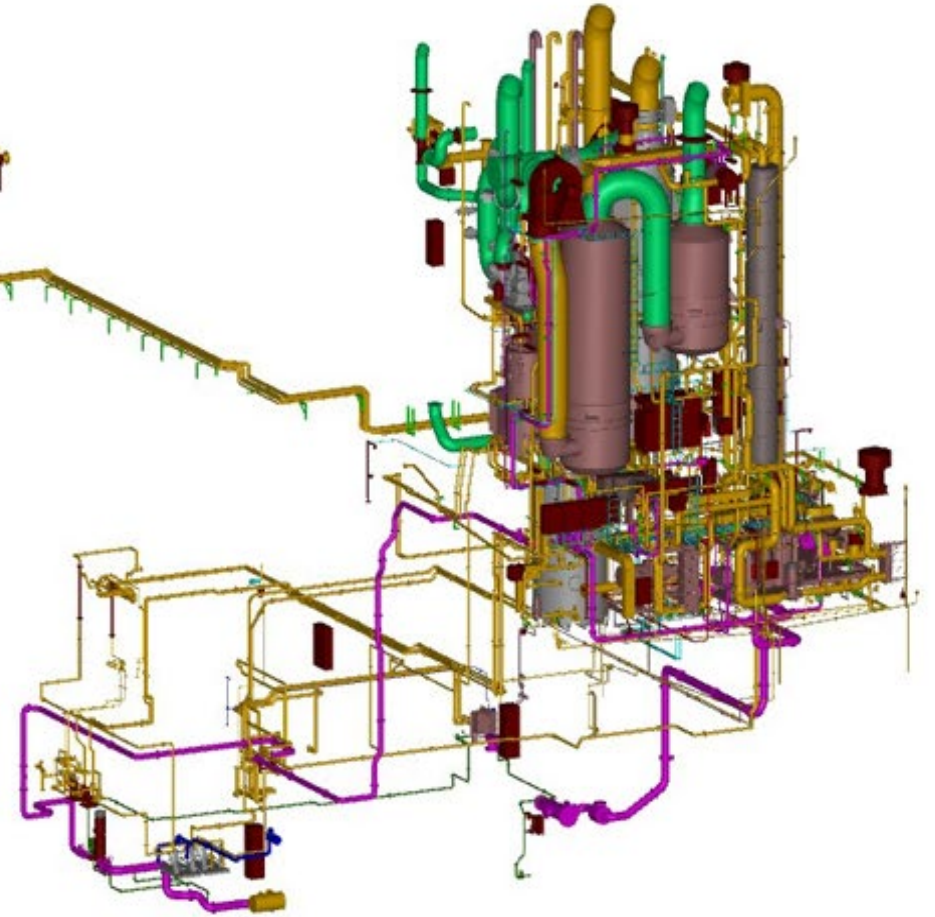




# OCCS installation on Clipper Eris

## Design

- Combination of EGC with water treatment + WESP + LP EGR
- Conventional HFO
- Transatlantic with offloading in both end
- 75 % capture rate ~ 50 tons CO<sub>2</sub> pr day
- 2 x 350 m<sup>3</sup> CO<sub>2</sub> tanks ---> 14 days sailing
- Collecting CO<sub>2</sub> from ME, AE and boilers



# Key Milestones



Feasibility Studies

26 Oct 23

◆ **Contract Award**  
03 Feb 24



**Basic & Detailed Engineering Commencement**  
06 Jan 24

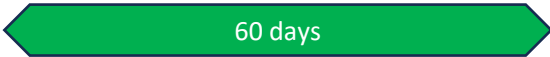


**Procurement Commencement**  
29 May 24

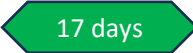


**Prefabrication CCS Equipment Room & CO2 Handling Room**  
20 Jul 24

◆ **Vessel Arrival**  
21 Nov 24



**Construction and Integration**  
21 Nov 24



**Vessel Dock**  
16 Dec 24

**Vessel Undock**  
02 Jan 25

**Inclination Test**  
19 Jan 25



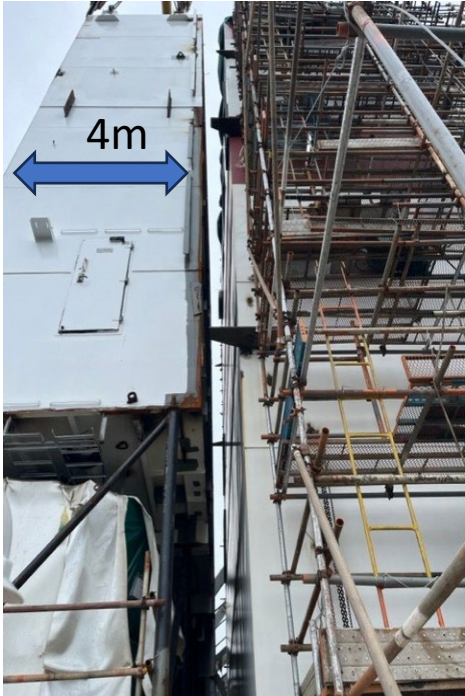
**Start Commissioning**  
20 Jan 25



**Sail for Gas Trials**  
06 Feb 25



10 Dec 24 – Block Installation



11 Dec 24 – LCO<sub>2</sub> Tanks Installed



02 Jan 25 – Undock





# THE GREEN FUTURE OF CONVENTIONAL FUELS



After 12 years of experimentation, research and development, Solvang and partners present a game changing technology: The shipboard carbon capture system.



The abatement systems onboard will provide the following emission reductions:

- **SOx:** >97% reduction (EGC)
- **NOx:** >80% reduction (EGR)
- **PM:** ~90% reduction (EGC+WESP)
- **CO2:** >70% reduction (CCS)

# Status today + further work

- Ready for first off-loading of CO<sub>2</sub> (300 tonn today).
- Tuning of engine and CCS plant finding optimum operation parameter with and withouth Solvang EGR.
- Tuning main engine and CCS plant together, total emission controll + waste heat.
- More testing of CO<sub>2</sub> purity (From lab 99.9? % CO<sub>2</sub>)
- Measurement and verfication by third party (Sintef)
  - Energy consumption, partikel emissions ++



# OCCS: The Scalable, Fuel-Flexible Solution for Immediate Impact

- The main benefit with the onboard CCS is that this system can be implemented as a retrofit and newbuilding.
- It can handle all fossil fuels + biofuels; it would only be a cost issue.
- It can be done in massive scale if/when shore terminals are available and several are under construction.
- Compared to the other decarbonization solution this can be done very fast. Ref number of scrubber vessels.
- A combination of Exhaust gas cleaning, EGR and CCS reduce all harmful emissions to air.

# Key parameter to consider for successful implementation of OCCS

- Technology neutrality:
  - Reducing GHG emissions require more energy, whether this come from fossil energy or renewable is irrelevant if the total GHG emissions is reduced.
- All part of the value chain must take care of their own GHG emissions.
  - As the regulation are today there is no reason for reducing up stream fuel emissions.
  - Well to tank emissions must be real values, not fixed factors based on worst case production path. I.e. Well to tank emission need to be handled of fuel producer with CCS or renewable and emission related to CO<sub>2</sub> handling after discharging very small compared to the actual values (efficient and low emission value chain).
- Regulation needs to simple and predictable.





[www.solvangship.no](http://www.solvangship.no)