Onboard carbon capture

IMO meeting, 11th September 2025

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Agenda

- EverLoNG goals
- Demonstration results
- Full scale design
- Business Case
- Way forward

The EverLoNG project (2021 – 2025)

Goals: **Demonstrating Onboard Carbon Capture (OCC) on LNG-fuelled ships.**

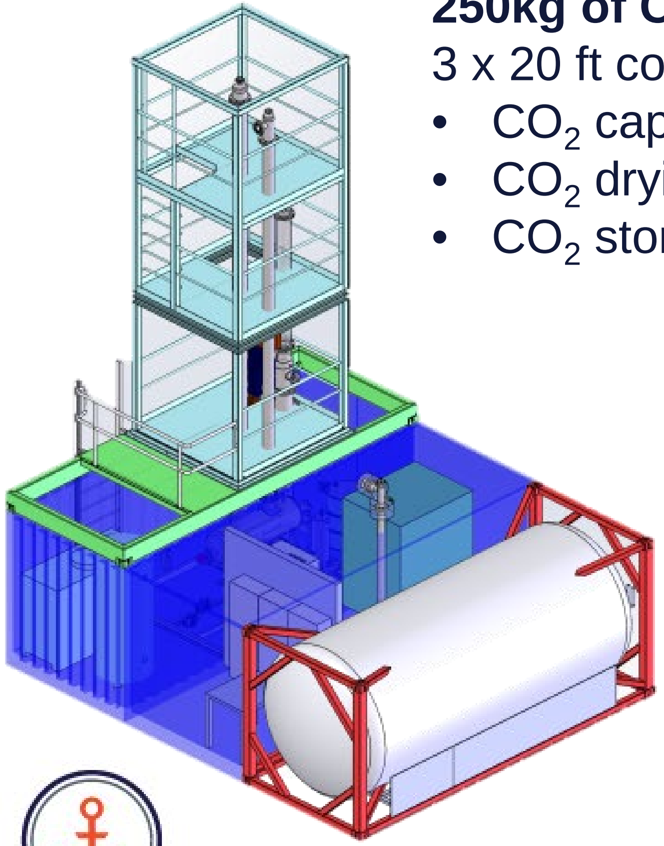
Design full scale OCC system.

- 16 partners from NL, NO, GE, UK, USA
- Total budget: M€ 4.9 (funding: M€ 3.5)

Everlong's demonstrations

	LNG carrier	Crane vessel
Engine	Wartsila 12V50DF (4-stroke)	MAN 8L51/60DF (4-stroke)
Operation	Capture only	Capture + liquefaction
Fuel	LNG + pilot	LNG + pilot

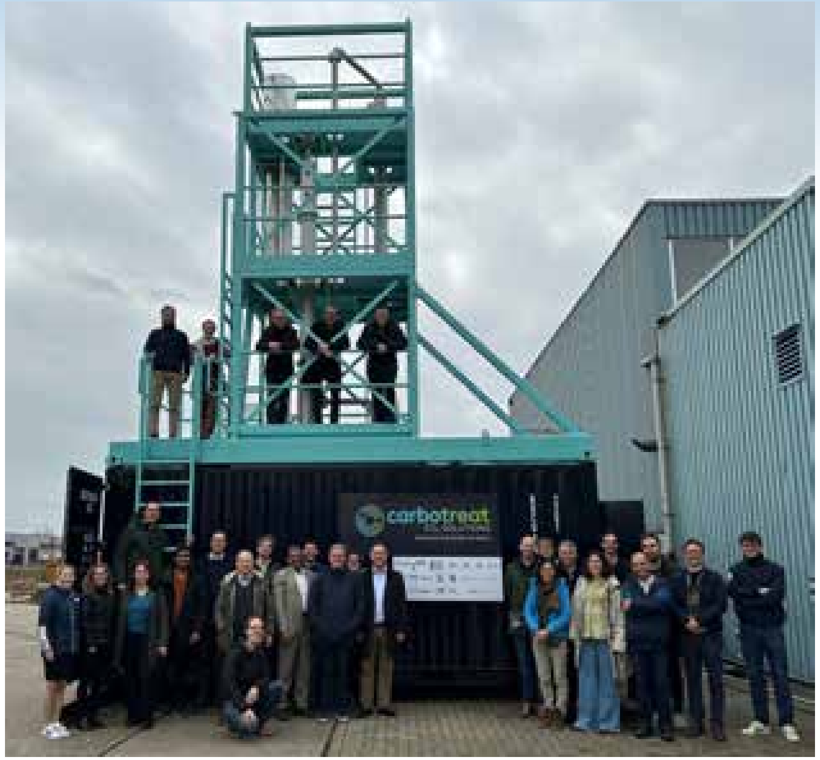
EverLoNG's OCC prototype



250kg of CO_2 per day

3 x 20 ft containers

- CO_2 capture with 30 wt% MEA
- CO_2 drying and liquefaction
- CO_2 storage at 15 bar, -27.7°C



Demonstration results

Seapeak Arwa Campaign

- MEA solvent concentrations tested: 5–7% (low), 16–18% (medium), and 30% (target)
- **Capture rate:**
  - Low concentration: ~23%
  - Intermediate: ~54%
  - High concentration: ~79%
- **1500+** operational hours

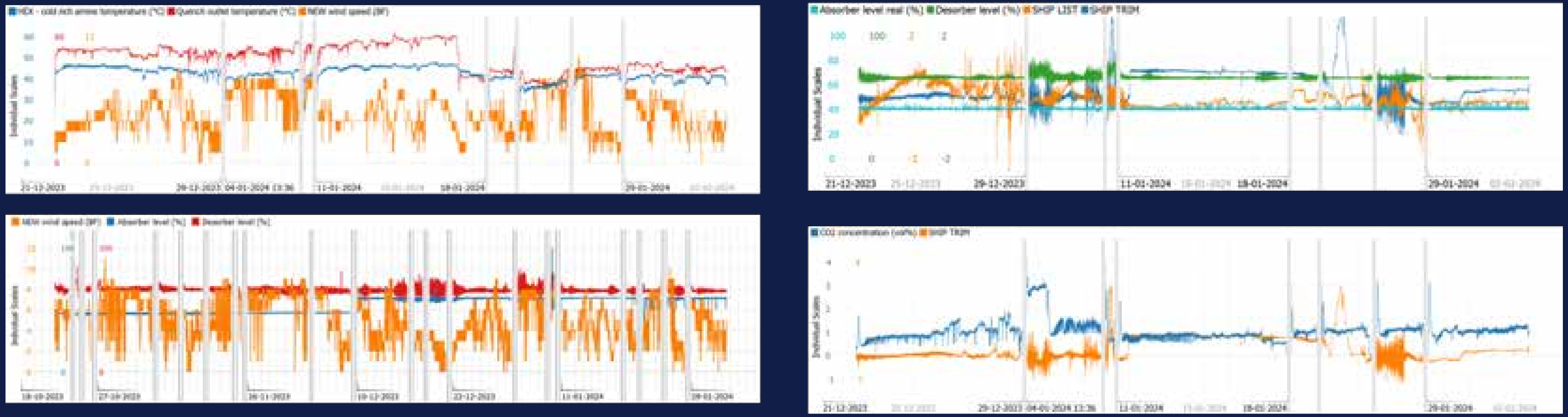
Sleipnir Campaign

- **Capture rate:** ~98% (due to low exhaust flow)
- **CO_2 captured:** ~4200 kg
- **400+** operational hours

Demonstration lessons learned (1)

Ship motion doesn't seem to be a point of concern

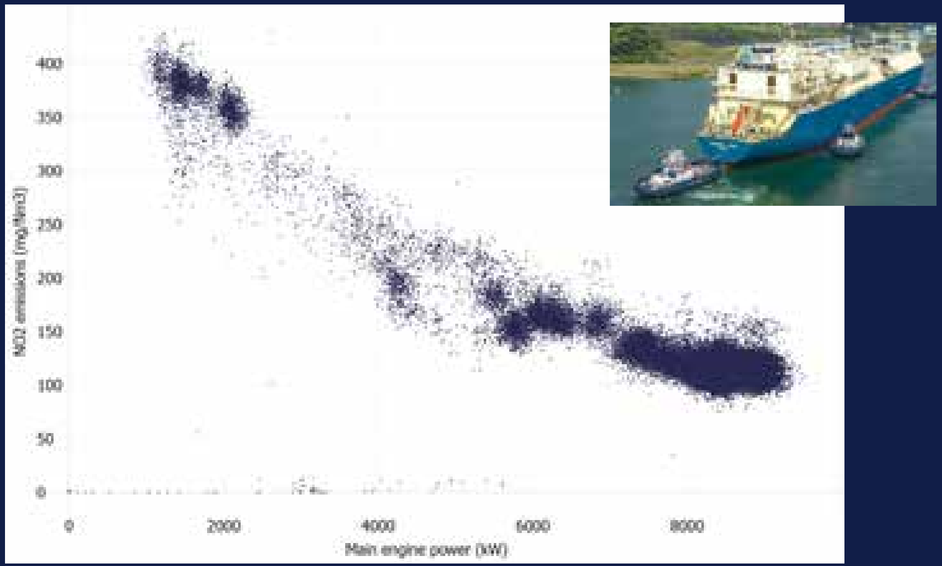
Ship sea movement or rolling evaluated throughout the campaign
Periods with strong wind speed (up to Beaufort 10, or above 24.5 m/s)



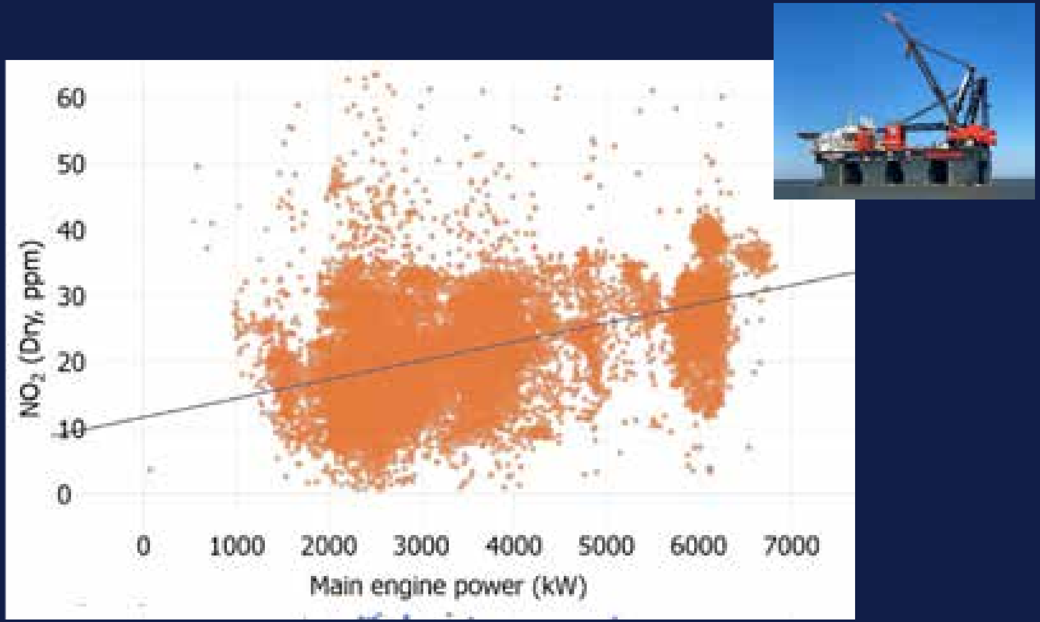
Ship motions had **no measurable effect** on CO_2 capture rate or other process parameters

Demonstration lessons learned (2)

High NO_2 content in exhaust gases



50-200 ppmv



10-30 ppmv

Onshore pilot references: below 5 ppmv

Demonstration lessons learned (2)

High NO_2 content in exhaust gases → high oxidative degradation rate

Component	Unit	TCM MEA	EverLoNG TotalEnergies
Formic acid	mg_L/Nm^3	2.0	6.2
Acetic acid	mg_L/Nm^3	0.3	2.9
Oxalic acid	mg_L/Nm^3	0.9	3.0

Onshore pilot benchmark

Demonstration lessons learned (2)

High NO_2 content in exhaust gases → high oxidative degradation rate

Component	Unit	TCM MEA	EverLoNG TotalEnergies	EverLoNG Sleipnir
Formic acid	mg_L/Nm^3	2.0	6.2	1.8
Acetic acid	mg_L/Nm^3	0.3	2.9	0.4
Oxalic acid	mg_L/Nm^3	0.9	3.0	0.5

NO_2 100% removed

Demonstration lessons learned (2)

High NO_2 content in exhaust gases → high oxidative degradation rate

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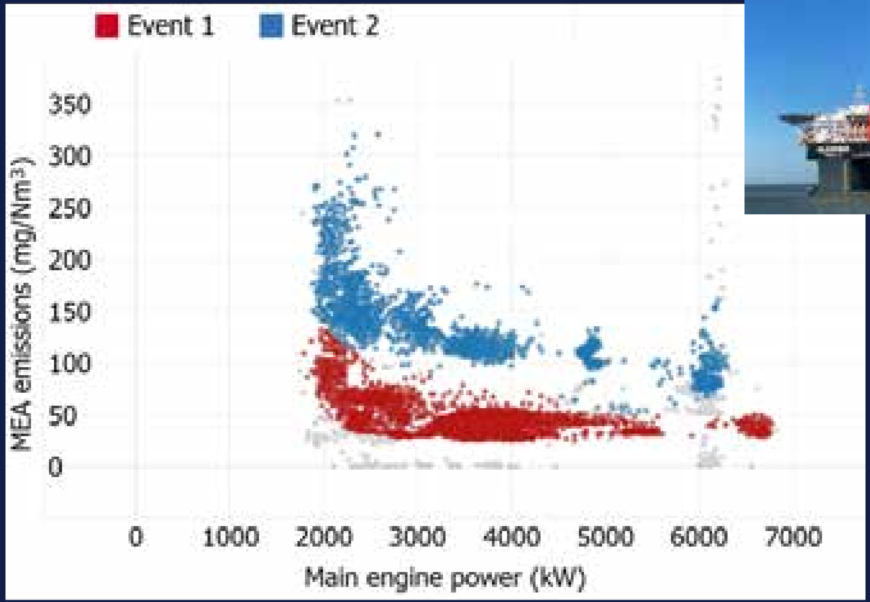
Oxalic acid	mg_L/Nm^3	0.9	3.0	0.5

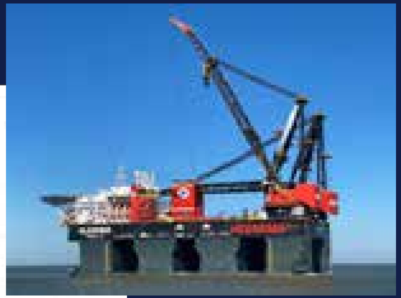
2 pathways: remove NOx (e.g. SCR) or allow higher degradation rate

Demonstration lessons learned (3)

Potential for aerosol-based emissions

Volatile emissions dominate
Average: 2.1 mg/Nm^3
Standard deviation: 14.8 mg/Nm^3





Aerosol emissions dominate

Demonstration lessons learned (3)

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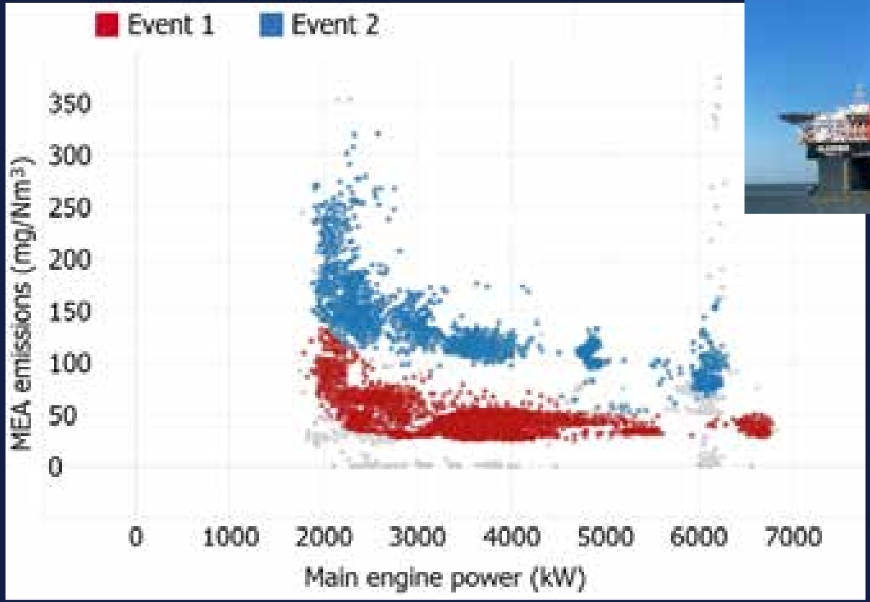


Aerosol emissions dominate

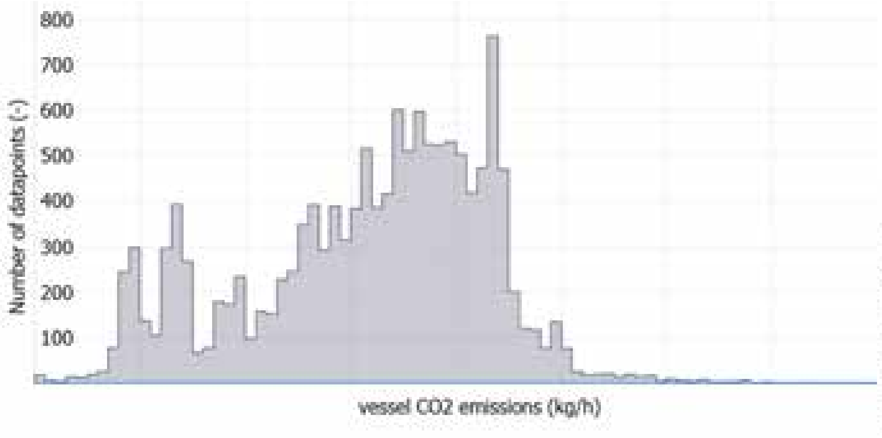
Particle measurements onboard & integrate countermeasure in OCC design

Design of full-scale OCC systems

- Two cases:
  - Sleipnir (Heerema Marine Contractors)
  - LNG carrier (TotalEnergies chartered)

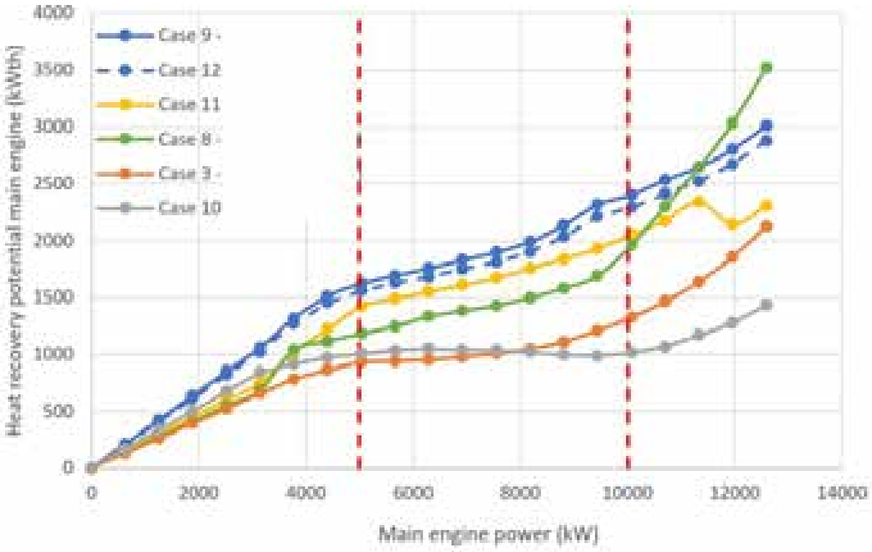
- Target: 70+% reduction of CO_2 emissions (tank to wake)

Capture system design: “digital cousin” approach

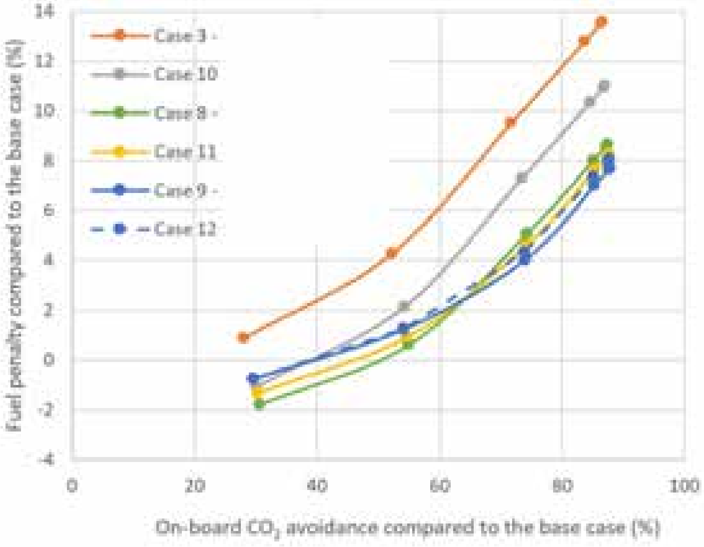


Real operational profiles

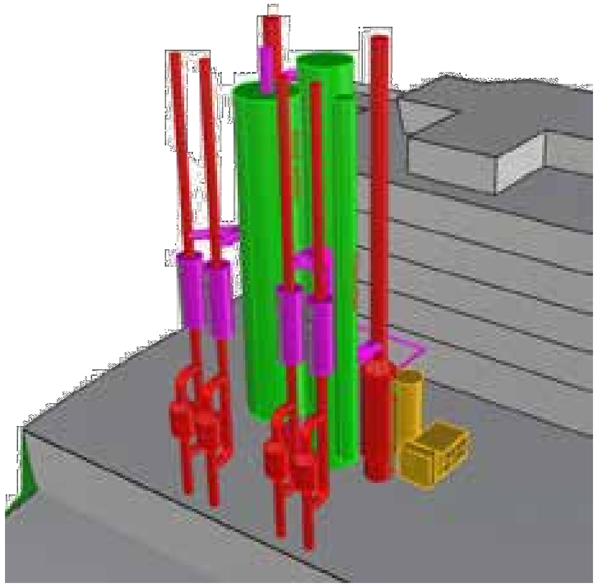
Heat recovery potential

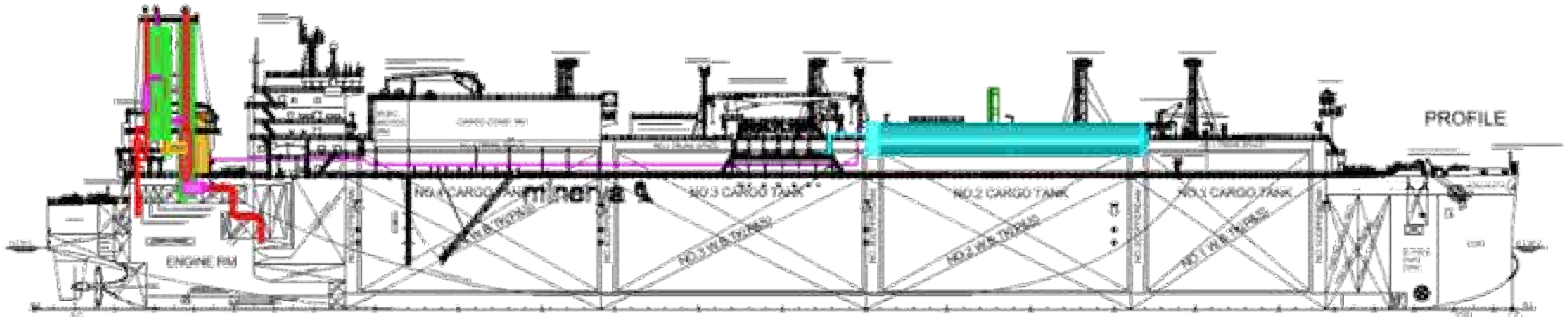


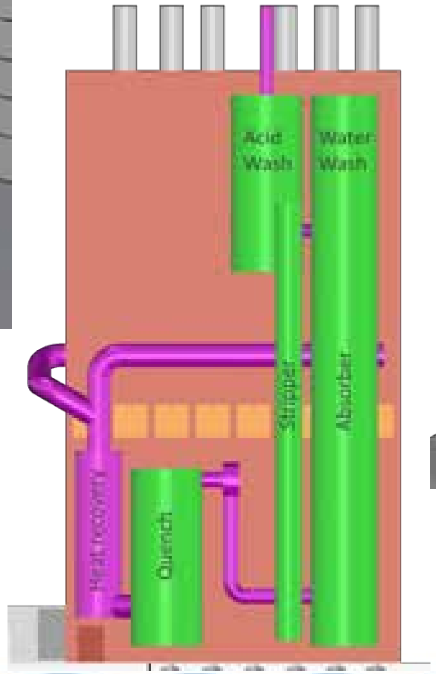
Fuel penalty

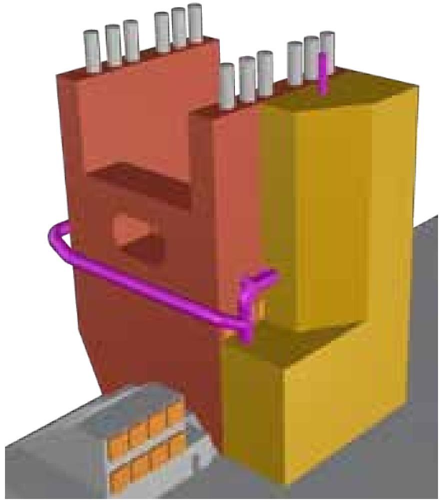


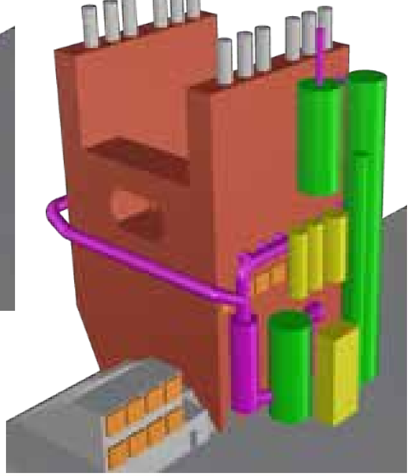
Design and integration











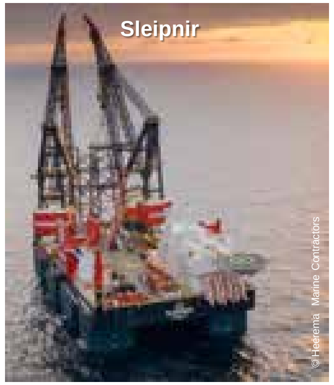
Design lessons learned: heat recovery

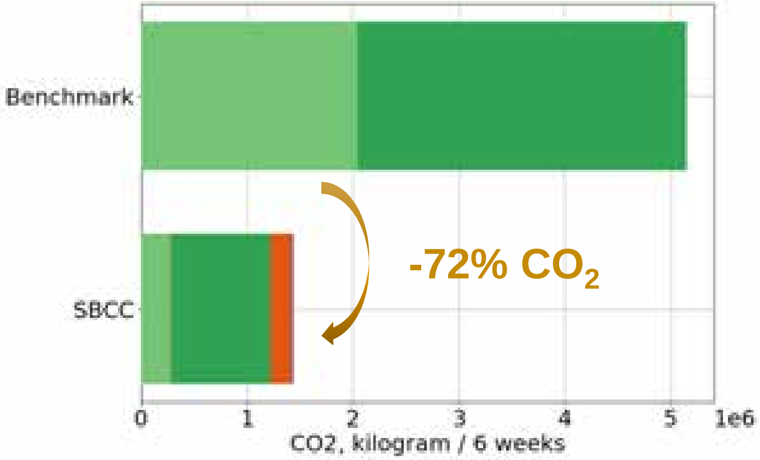
- Heat availability for four-stroke engines is typically sufficient for high capture rates (up to 95%)
- For two-stroke engines, additional heat is required to enable high capture rates
- HFO has a high heat demand, hence heat not available for carbon capture: if possible, avoid HFO

Design lessons learned: standardisation

- For high capture rates, a tailor-made design can provide significant benefits
- Standardisation becomes easier with a lower design capture rate (smaller fraction of treated exhaust gas)

On-ship (tank to wake) emissions

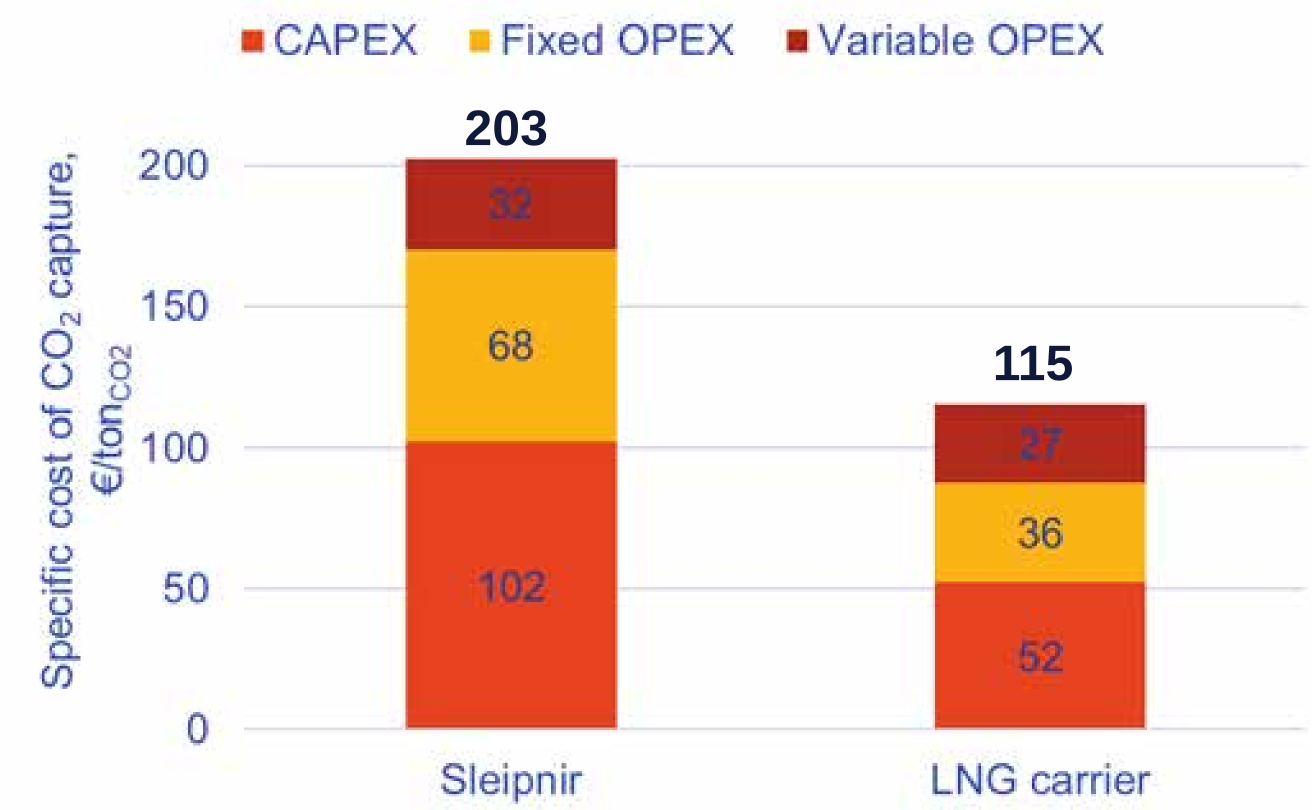


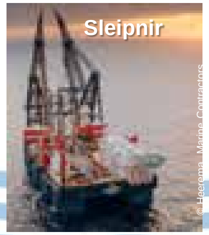


70% CO_2 reduction target achieved

-84% CO_2

Cost of CO_2 capture





Main differences Sleipnir vs. LNG carrier

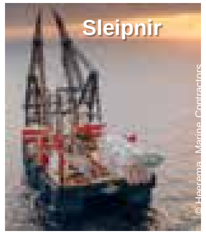
1) Retrofit vs. New-built

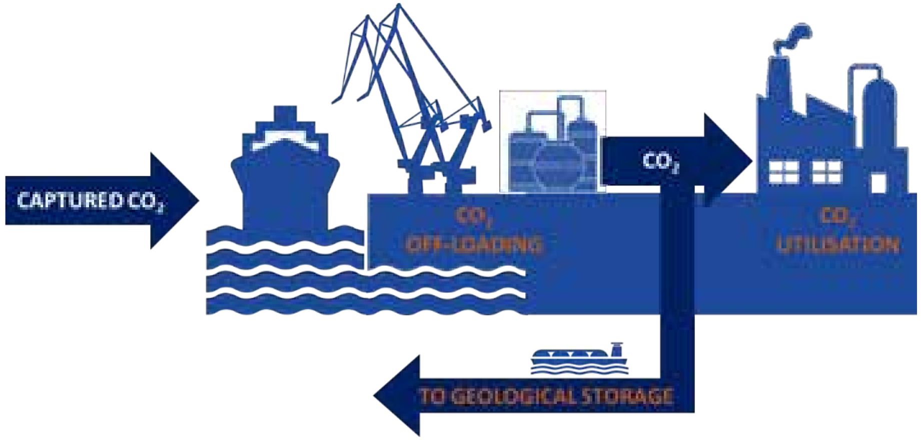
2) CO_2 storage tanks (42 vs. 16 days)

3) Capacity factor

→ CAPEX doubles
→ variable OPEX is comparable (+20%)

Full-chain costs: capture, transport and storage





Cost element	€/t_{CO2} captured
On-board carbon capture	115 - 200
Receival facility	20
Cost of transport, pipeline	20
Cost of storage	40
Total	**195 - 280**

TEA lessons learned

- Methane slip hinders further emissions reduction → improvements potential on engine and gas-treatment level.
- Increased heat recovery efficiency can attenuate fuel effects.
- Onboard CO_2 storage effects ship design in more than just cost.
- Value of carbon is potential for business case success.

Way Forward “LNG Zero”

Continue development of full design.

Full supply chain development.

including ship to ship logistics.

Partners

Acknowledgement

- ACT funding partners

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U.S. DEPARTMENT OF ENERGY

Thank you for listening

For questions, please contact:

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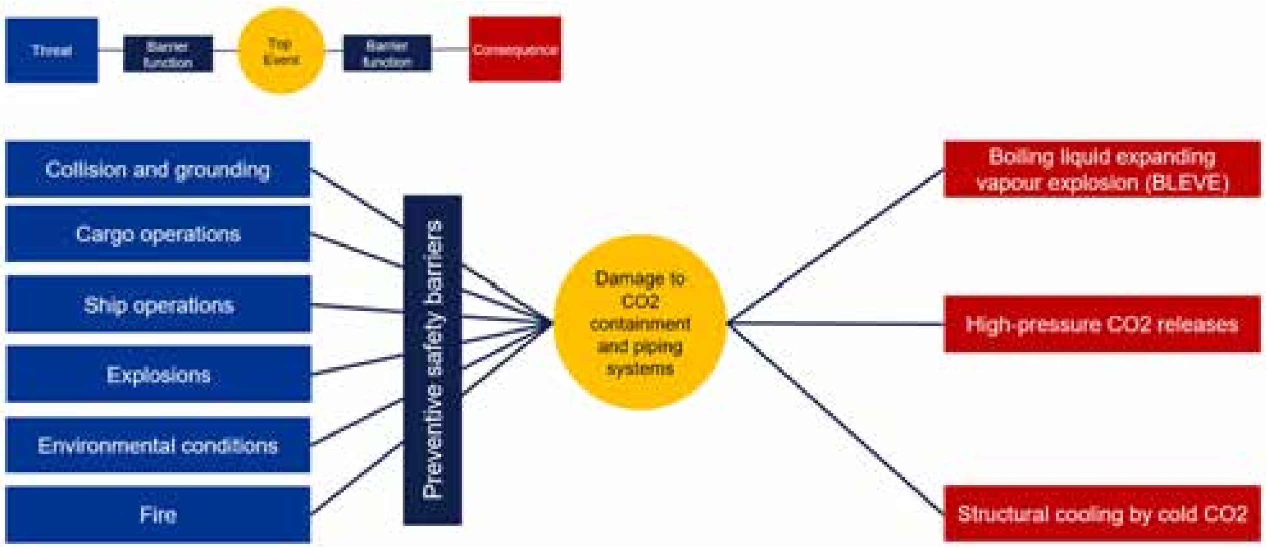
Additional slides

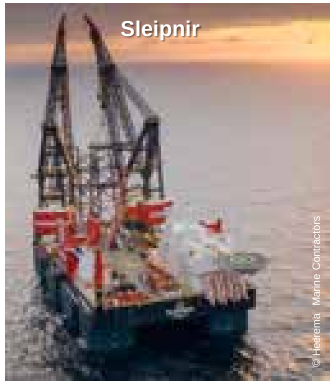
Lessons learned on safety aspects

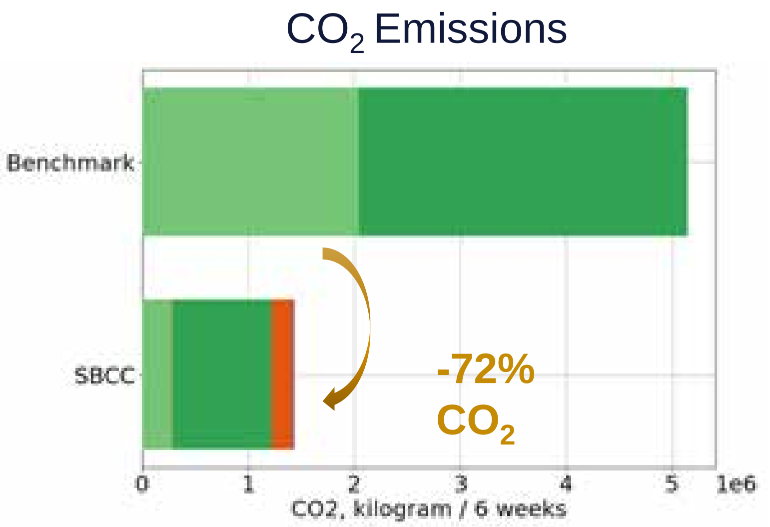
Generic safeguards:

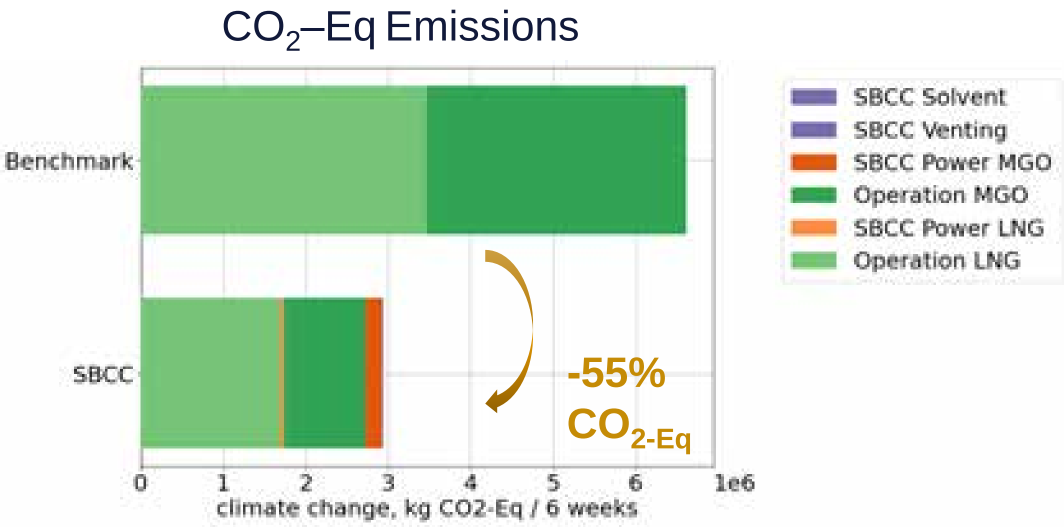
- Derived from the full scale HAZID workshops
- Organised by SBCC safety risks and comprehensively explained
- Report on the generic safeguards is available to the public and be downloaded here: https://everlongccus.eu/about-the-project/results



On-ship (tank to wake) emissions





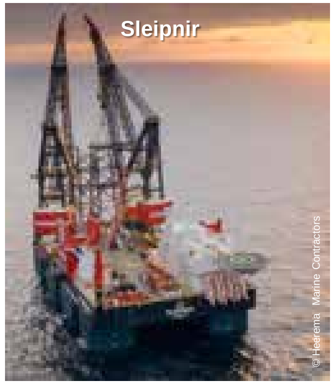


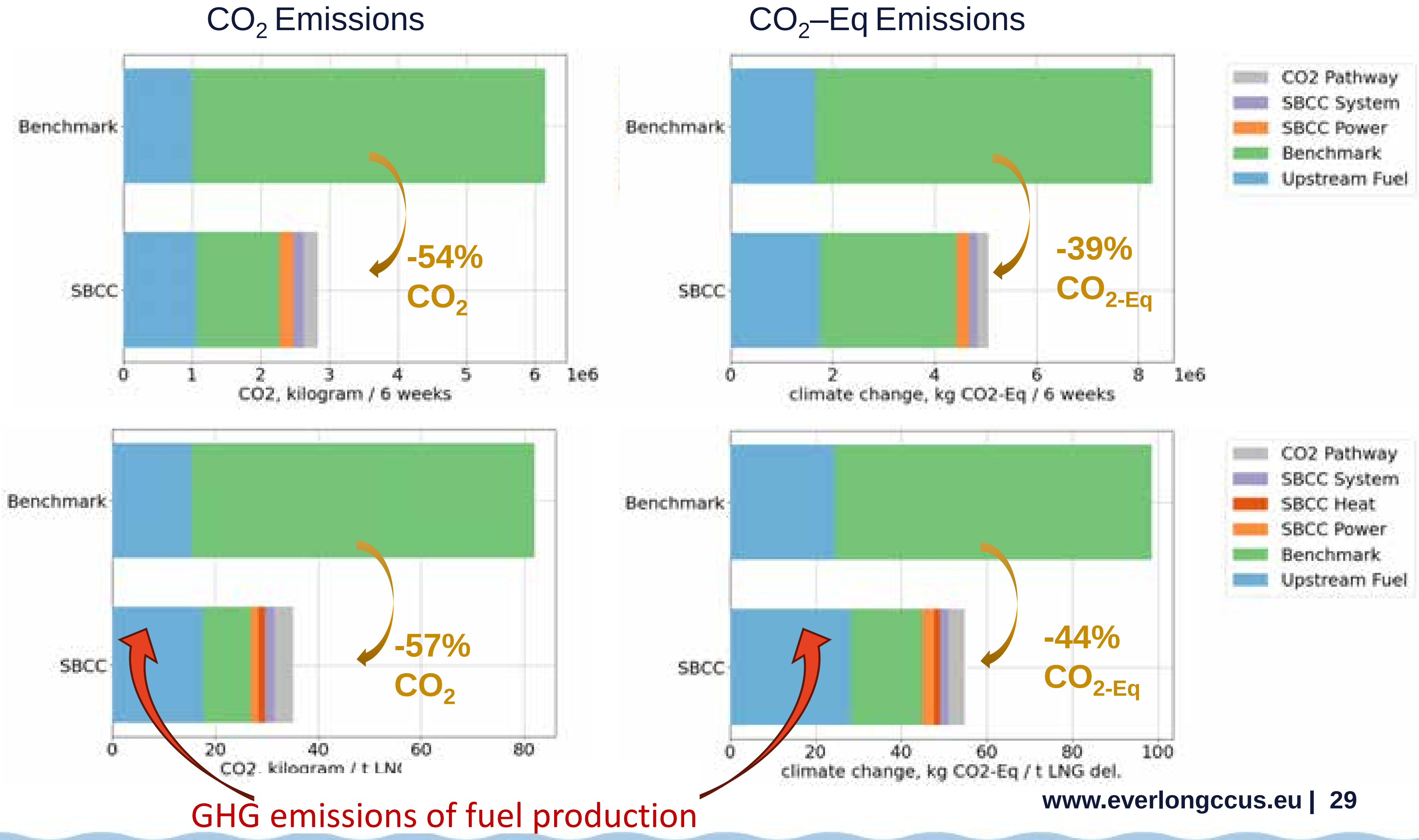
-84%
CO_2

-75%
$CO_{2\text{-}Eq}$

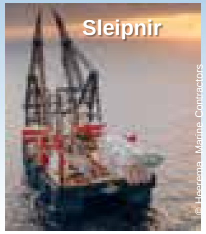
Methane slip adds to the emissions and are not abated by OCC

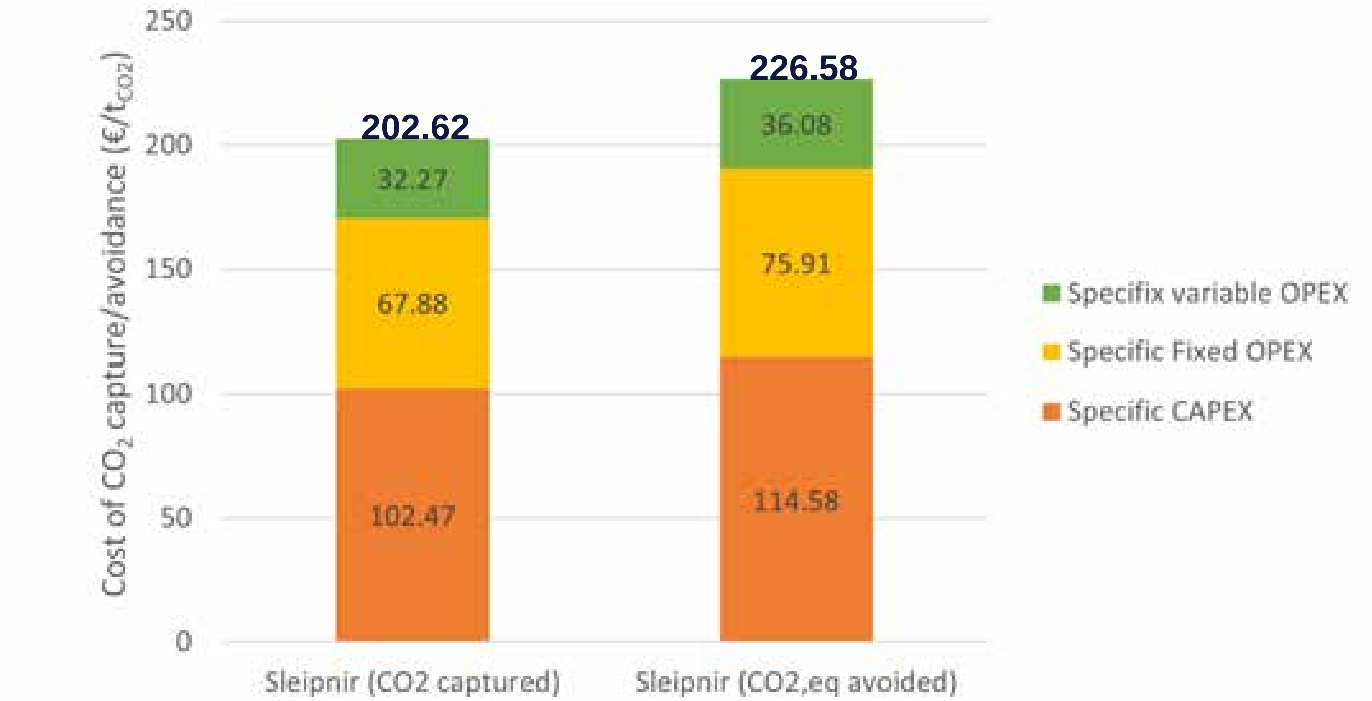
Full Life Cycle incl. CO_2 Pathway



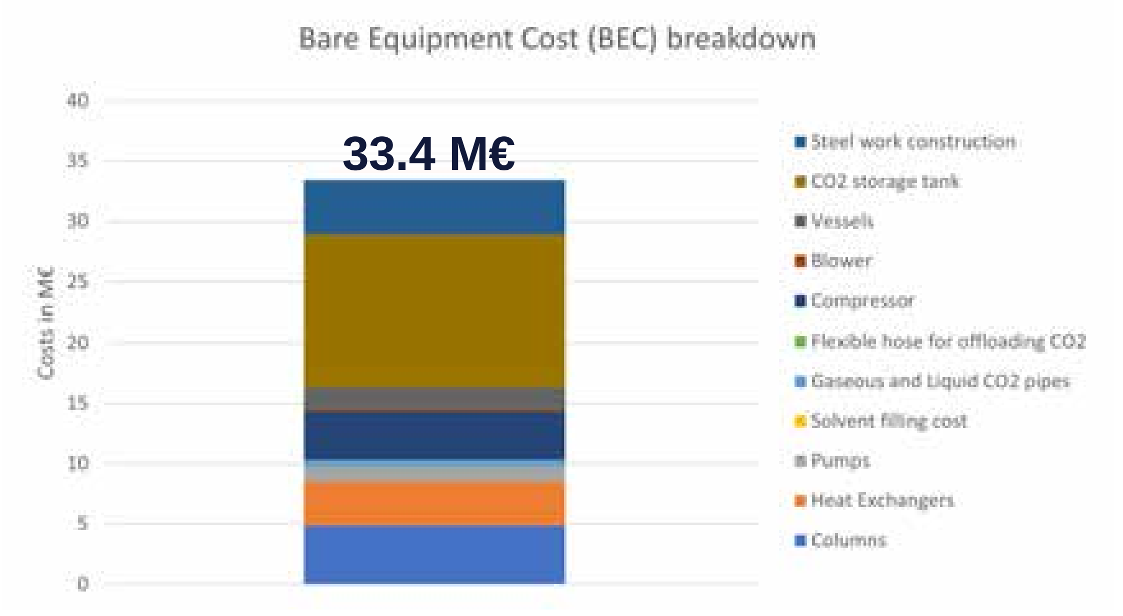


TEA - Sleipnir Case



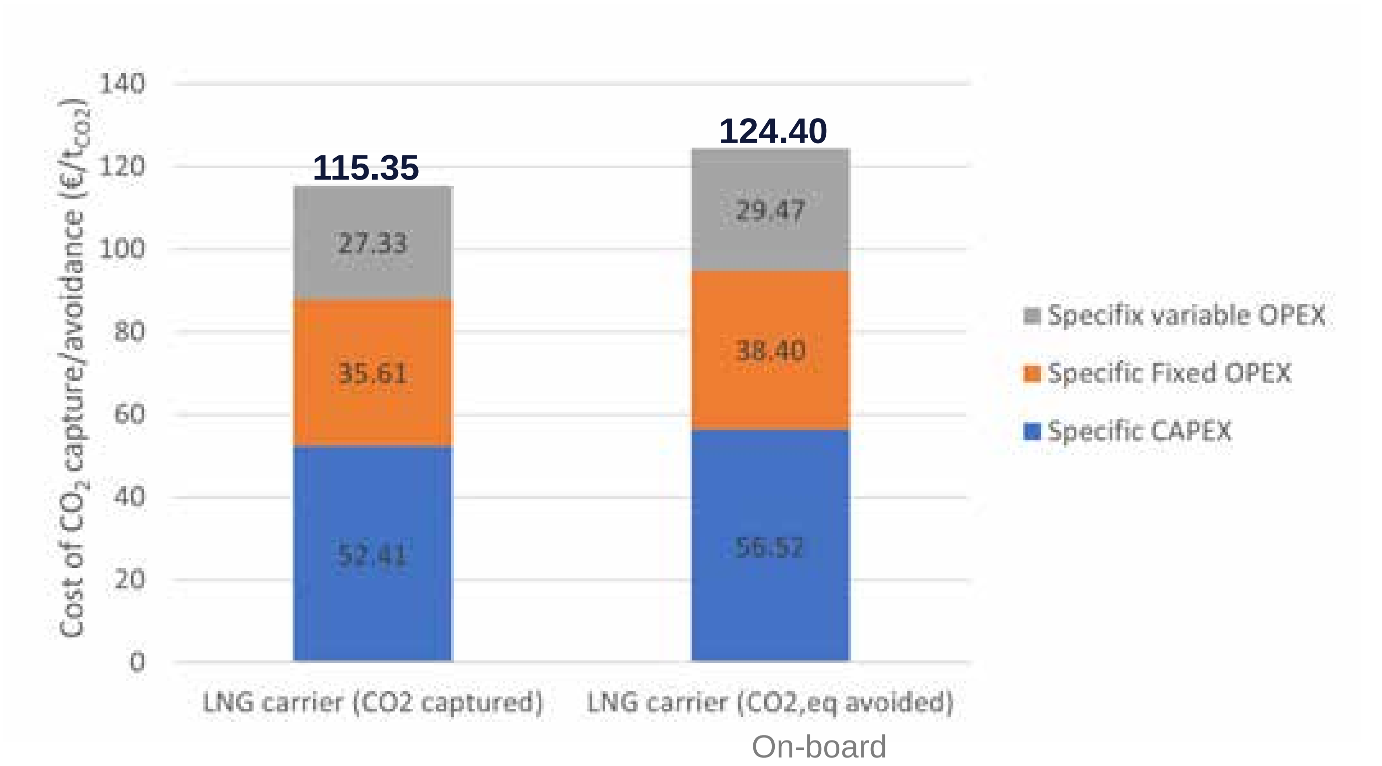


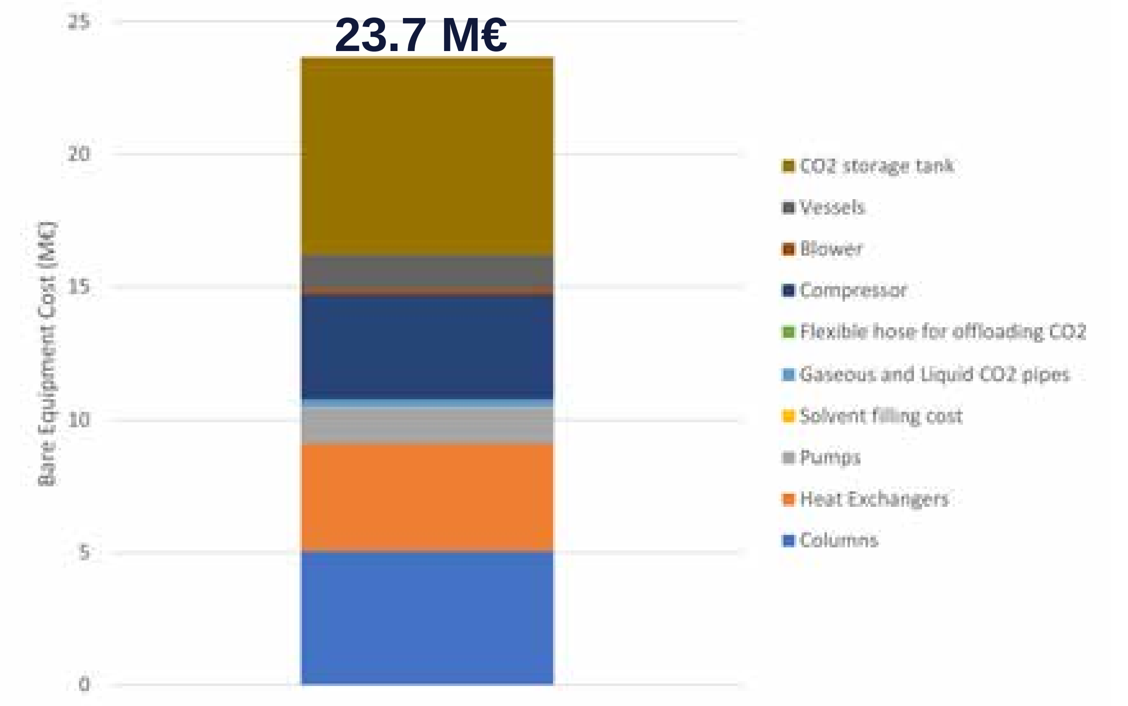
On-board



- **CO2 storage tank cost** is the major equipment cost driver**.**
- Since this is a retrofit case, steel work construction costs are considered.

TEA - Tanker Case





- CO2 storage tank cost is the major equipment cost driver but lower than Sleipnir.
- Since this is a **new-built case, steel work construction costs are NOT considered**.
- **The capacity factor of the capture system is higher** here thereby giving **lower specific total costs.**

Roadmap for OCC implementation in Europe

OCC contributes to net zero emissions in 2050

2030

Implementation in Ports of Rotterdam and Antwerp

2035

Implemenation in several ports
50 ships with OCC

2040

OCC in all major ports
New ships on alternative fuels

2045

75% alternative fuels
No fossil fuel without OCC

2050

OCC on all C-containing fuels (including carbon-neutral)
700 ships with OCC
35 Mt CO_2