CO_2 Shipping Interoperability Industry Group (CSIIG)

3rd CSIIG Workshop – 12 February 2025

EverLoNG project, WP2

Please mute microphones and cameras

This workshop will be recorded

The EverLoNG project is funded through the ACT programme (Accelerating CCS Technologies, Horizon2020 Project No 691712). Financial contributions have been made by the Ministry of Economic Affairs and Climate Policy, the Netherlands; The Federal Ministry for Economic Affairs and Climate Action, Germany; the Research Council of Norway; the Department for Business, Energy & Industrial Strategy, UK; and the U.S. Department of Energy. All funders are gratefully acknowledged.

Agenda 1030-1230 / 0930-1130 (all times approx. CET / UCT)

Introduction: The EverLoNG project & WP2 overview (1030-1035 / 0930-0935)

1. *Welcome*: Richard L Stevenson, Project & Research Analyst, SCCS/The University of Edinburgh
2. *EverLoNG project & WP2 OCC in the full CCUS chain*: Ragnhild Skagestad, Senior Research Scientist, SINTEF

Part 1: Ports and OCC (1035-1135 / 0935-1035)

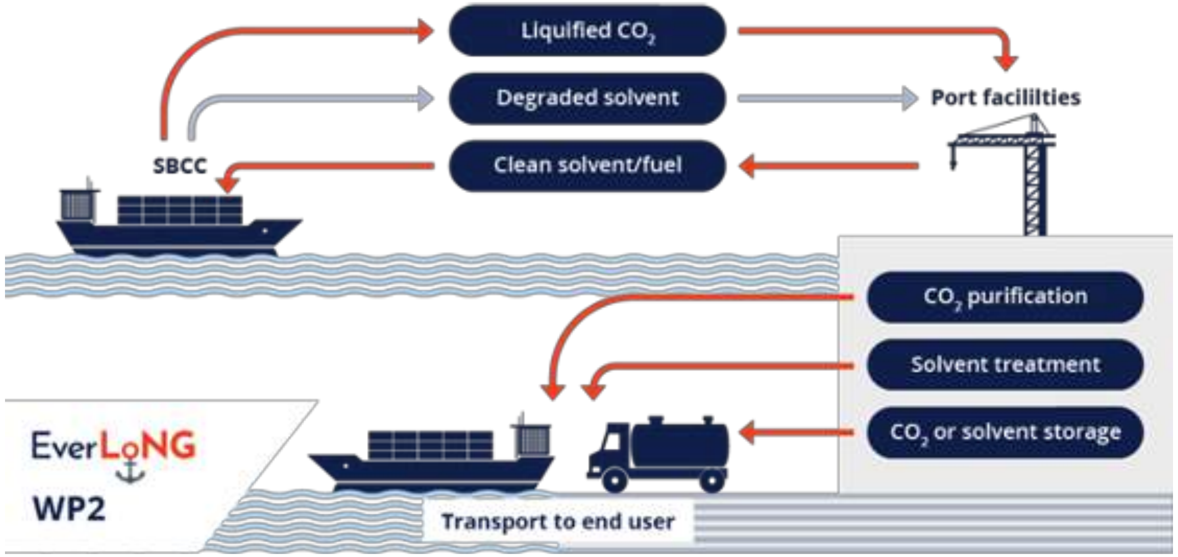
3. *Port of Rotterdam: Onboard Carbon Capture*: Steven Jan van Hengel, Sr. Business Development Manager Sustainable Transport, Port of Rotterdam
4. *Port of Antwerp-Bruges: CCUS hub in Europe*: Arne Strybos, Program Manager Fuel Transition, Port of Antwerp-Bruges
5. *Greenhouse gas emissions of OCC under the FuelEU Maritime regulation*: Donghoi Kim, Research Scientist, SINTEF
6. *Q&A/Discussion*

Part 2: EverLoNG CO_2 Offloading Roadmap & Port Readiness Tool (1130-1230 / 1030-1130)

7. *Roadmap of a European offloading network*: Ragnhild Skagestad, Senior Researcher, SINTEF
8. *Port Readiness Tool for CO_2 (PRT-CO_2)*: Richard L Stevenson, Project & Research Analyst, SCCS
9. *Q&A/Discussion*

What is the CSIIG?

- CO_2 Shipping Interoperability Industry Group
- Develop offloading strategies and establish guidelines for CO_2 shipping interoperability, port readiness, port infrastructure, CO_2 specifications, and solvent handling



The EverLoNG project- introduction

CSIIG #3 Webinar
12.2.25

Ragnhild Skagestad, SINTEF AS, NORWAY

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Introduction

The shipping industry is responsible for around **1000 million tonnes of CO_2** annually, which is around **3%** of global GHG emissions.

Maritime transportation was included in the EU ETS from 2024.

The International Maritime Organization has set a target to **have net zero GHG emissions by 2050**

Ship-Based Carbon Capture (SBCC) is one possible solution to decarbonise the maritime sector

Photo by Ian Taylor on Unsplash

The EverLoNG project

- Demonstrate onboard carbon capture (OCC) on LNG-fuelled ships
- Evaluate impact of OCC on ship infrastructure, stability and safety to guarantee technical feasibility of SBCC technology
- Evaluate cost and technical options of offloading, transport, utilisation and/or storage in different CCUS chains

16 partners from
NL, NO, GE, UK, USA
2021-2025
Lead by TNO

Partners

TNO

CONOSHIP INTERNATIONAL

carbotreat CO_2 SOLUTIONS

VDL AEC Maritime

HEEREMA

MAN Energy Solutions MAN

JÜLICH Forschungszentrum

TotalEnergies

SINTEF

BUREAU VERITAS 1828

akp

SCCS

Lloyd's Register

Los Alamos NATIONAL LABORATORY EST. 1943

DNV

ANTHONY VEDER

Objectives

Objective of EverLoNG is to accelerate the implementation of Onboard Carbon Capture (OCC) technology by:

(i) demonstrating OCC on-board of two LNG-fuelled ships (WP1)

(ii) facilitating the development of SBCC-based full CCUS chains (WP2)

(iii) optimising OCC integration to the existing ship infrastructure (WP3)

(iv) perform life cycle assessment and techno-economic evaluation: to show the impact of this technology, from both economic and environmental viewpoints (WP4)

(v) facilitating the regulatory framework for the technology (WP5)

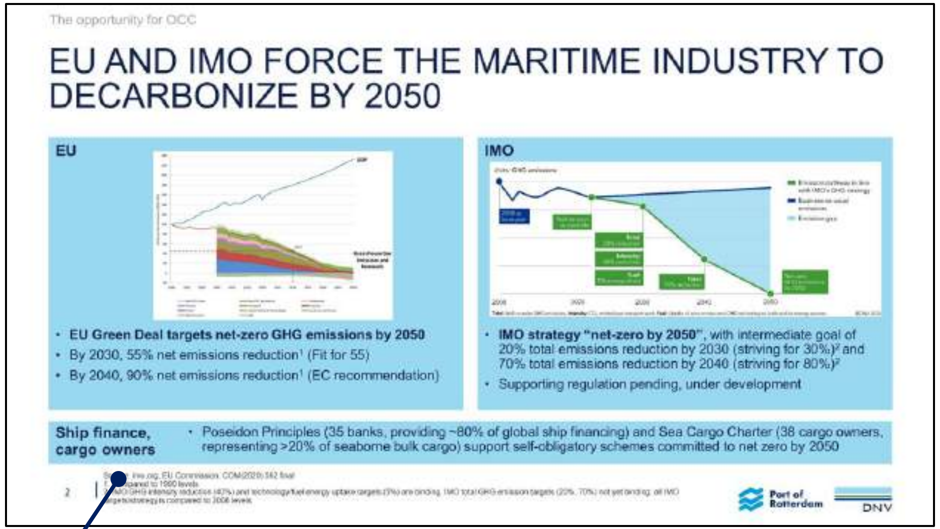
Port of Rotterdam
Onboard Carbon Capture (OCC)

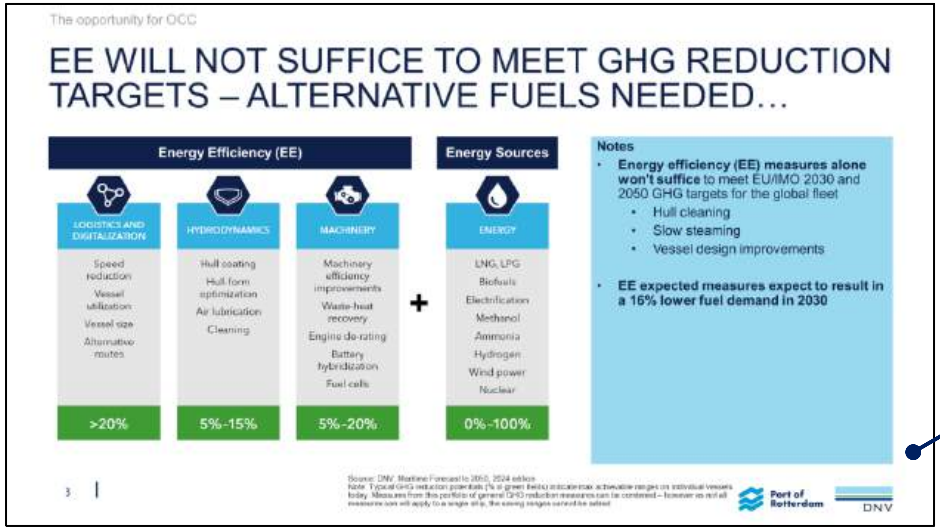
Steven Jan van Hengel

Port of Rotterdam

Port of Rotterdam

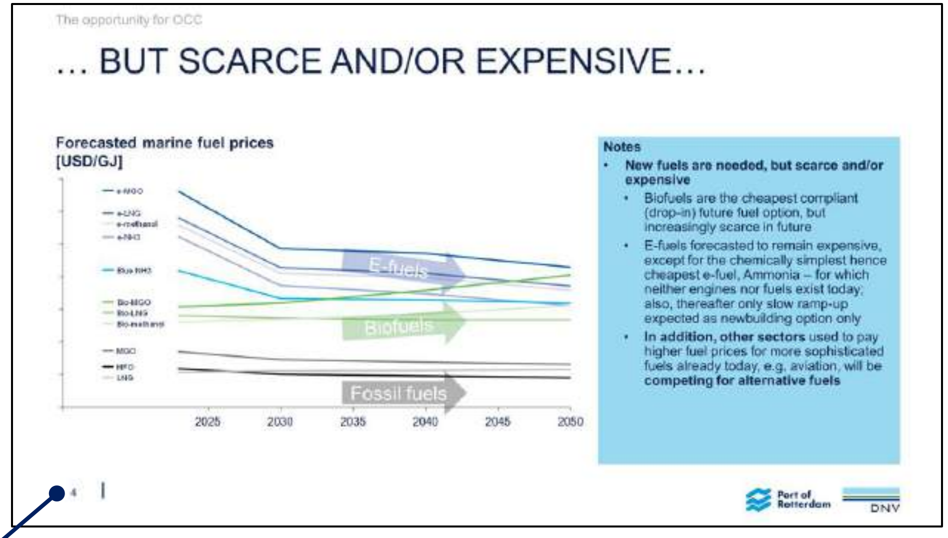
OCC – A SOLUTION IN A PORTFOLIO OF OPTIONS

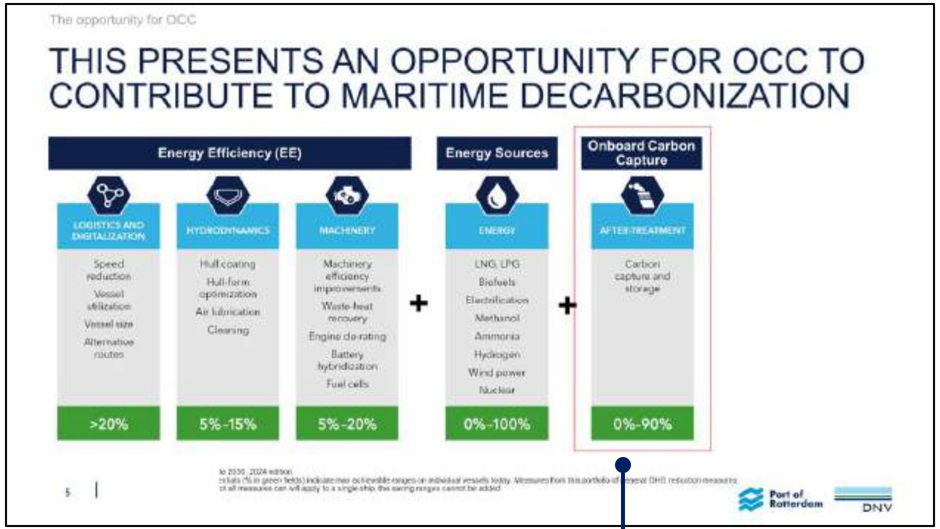




Energy Efficiency: A first step but will not suffice alone

Legislation and society is pushing decarbonisation; time is ticking towards 2030…





Alternative fuels remain scarce and expensive

It will be: Energy Efficiency & Alternative Fuels & OCC

Port of Rotterdam

ANALYSES AND INTERVIEWS SUGGEST THAT OCC WILL BE A PERMANENT SHIPPING TECHNOLOGY UNTIL AND BEYOND 2050

Bottom-up business model

Top-down analysis (DNV's MF 2050[1])

Interviews with 14 stakeholders

Interviewees	DNV evaluation
Shipping companies (liners, gas carriers, barge operator)	***Ship owners are positive about OCC being a potential decarb solution*** due to lack of alternative fuels and flexibility of vessel operation. Some are in already demonstration/ pilot stage of implementing OCC onboard ships whereas some are in the early stage of finding the correct solution
CCS Ecosystem Rotterdam	**Reception facilities are neutral about the source of CO2 received and would be ready to accept CO2** from shipping provided they form a considerable portion of the total CO2 received from different industrial sector
OCC solution provider	OCC provider has shown statistically that the **number of ship owners looking into the OCC products or going for pilot products have considerably increased**

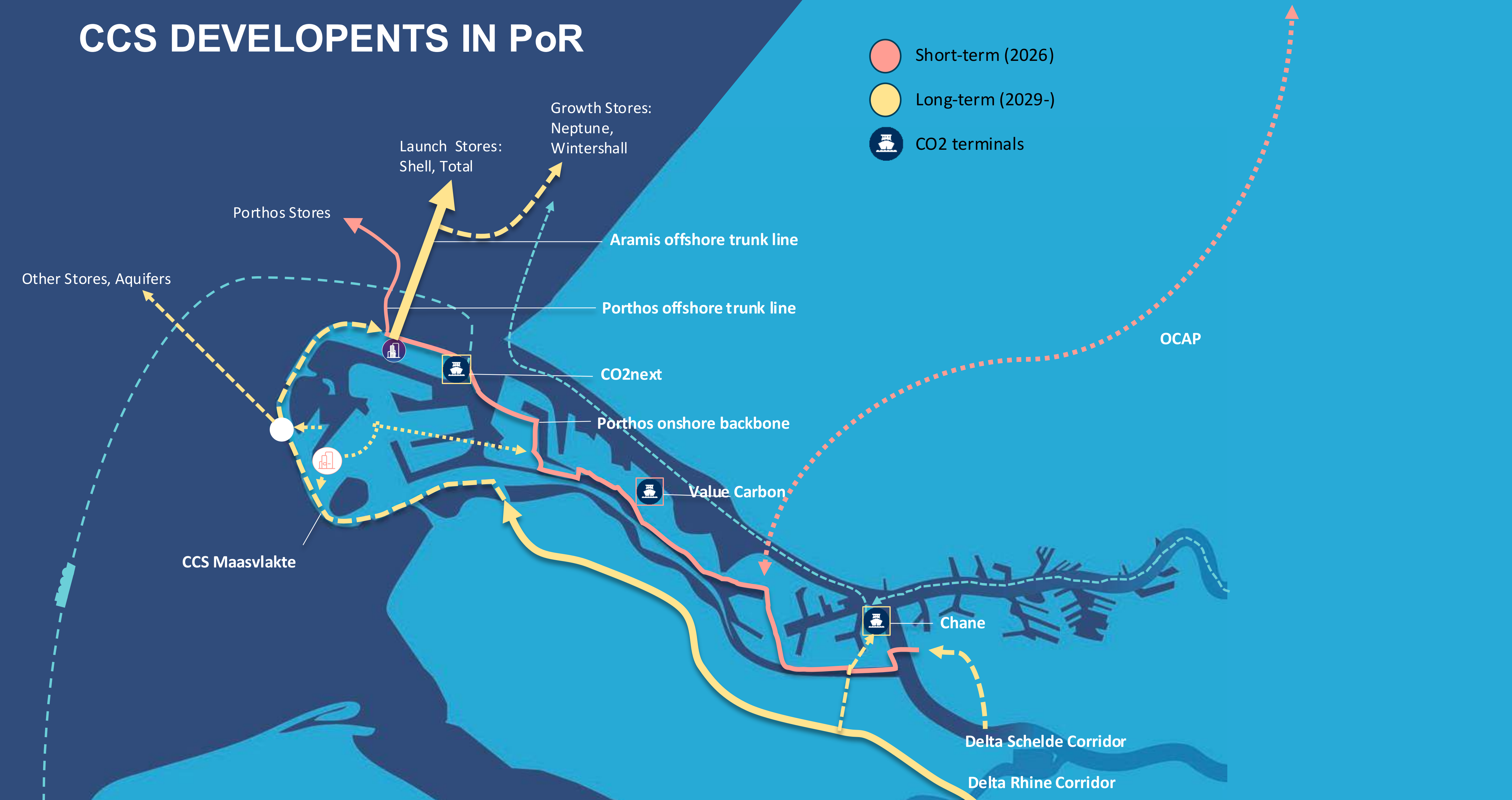
"OCC is here to stay" – bottom-up business model, DNV's MF 2050 analysis and stakeholder interview suggest OCC will be a permanent solution for decarbonization in shipping until 2050 and beyond

- Both bottom-up business model and top-down MF 2050 analysis show OCC's cost competitiveness as a potential decarb solution in shipping
- In interviews, shipping companies, Rotterdam's CCS ecosystem and a OCC solution provider see OCC as a viable decarb solution due to the scarcity of alternative fuel and cost competitiveness and flexibility of vessel operation

1. DNV Maritime Forecast to 2050, 2024 edition

Port of Rotterdam

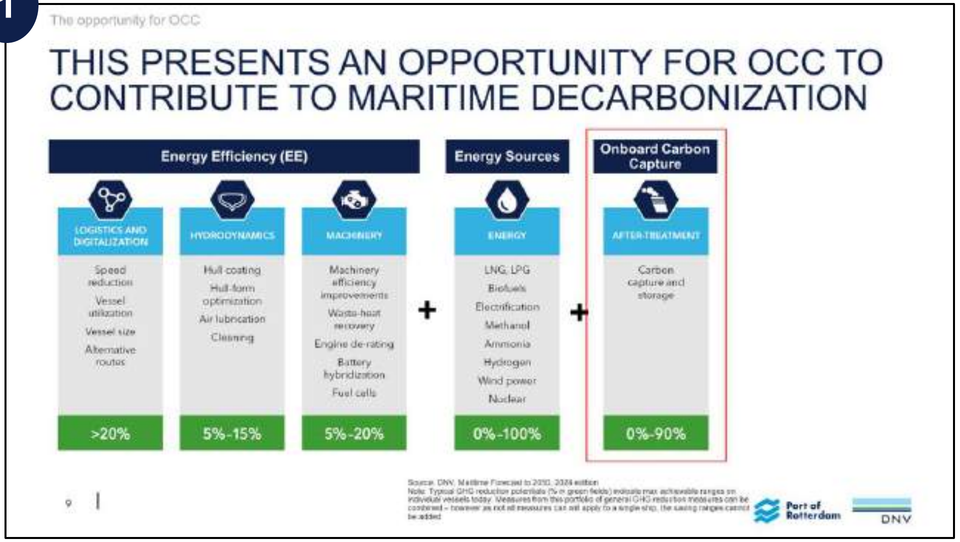
CCS DEVELOPENTS IN PoR



Key Conclusions

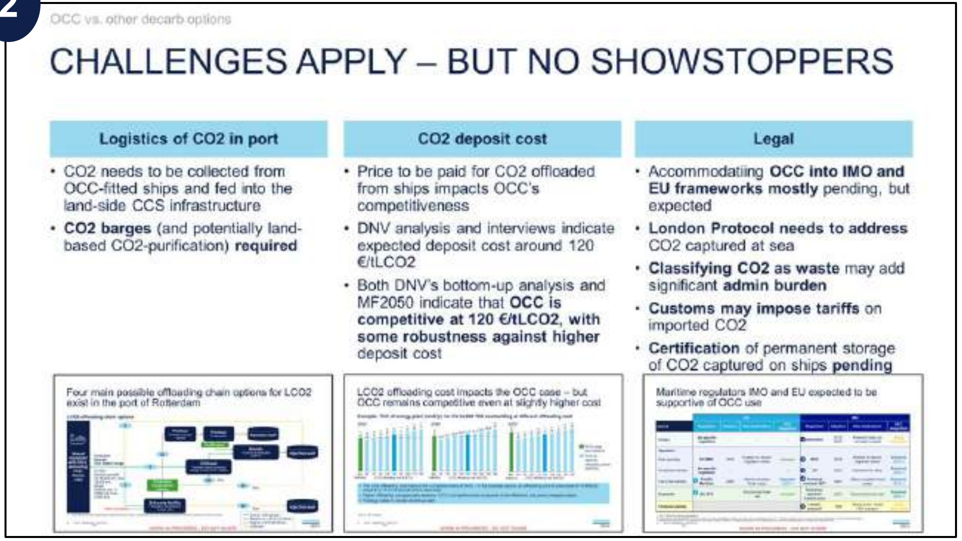
OCC to play a role in portfolio of decarb. options…

1



…Challenges apply, no showstoppers.

2



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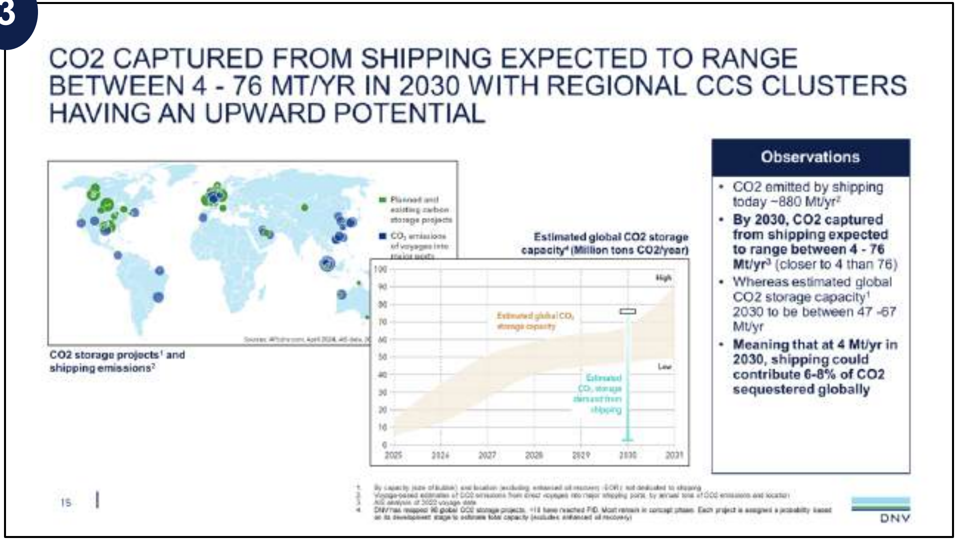


Demand for global 'offloading hubs' from shipping…

4

…Rotterdam is developing CCS infrastructure and preparing for OCC volumes.

EVERGREEN
OCC PILOT a/b EVER TOP IN EXECUTION

22/01/2025
Arrival @ ECT
Euromax

EVER TOP

- Evergreen
- 14k TEU container vessel
- 368m x 51m
- First DS container vessel with full-scale OCC
- OCC unit manufacturer: SMDERI

Port of Rotterdam

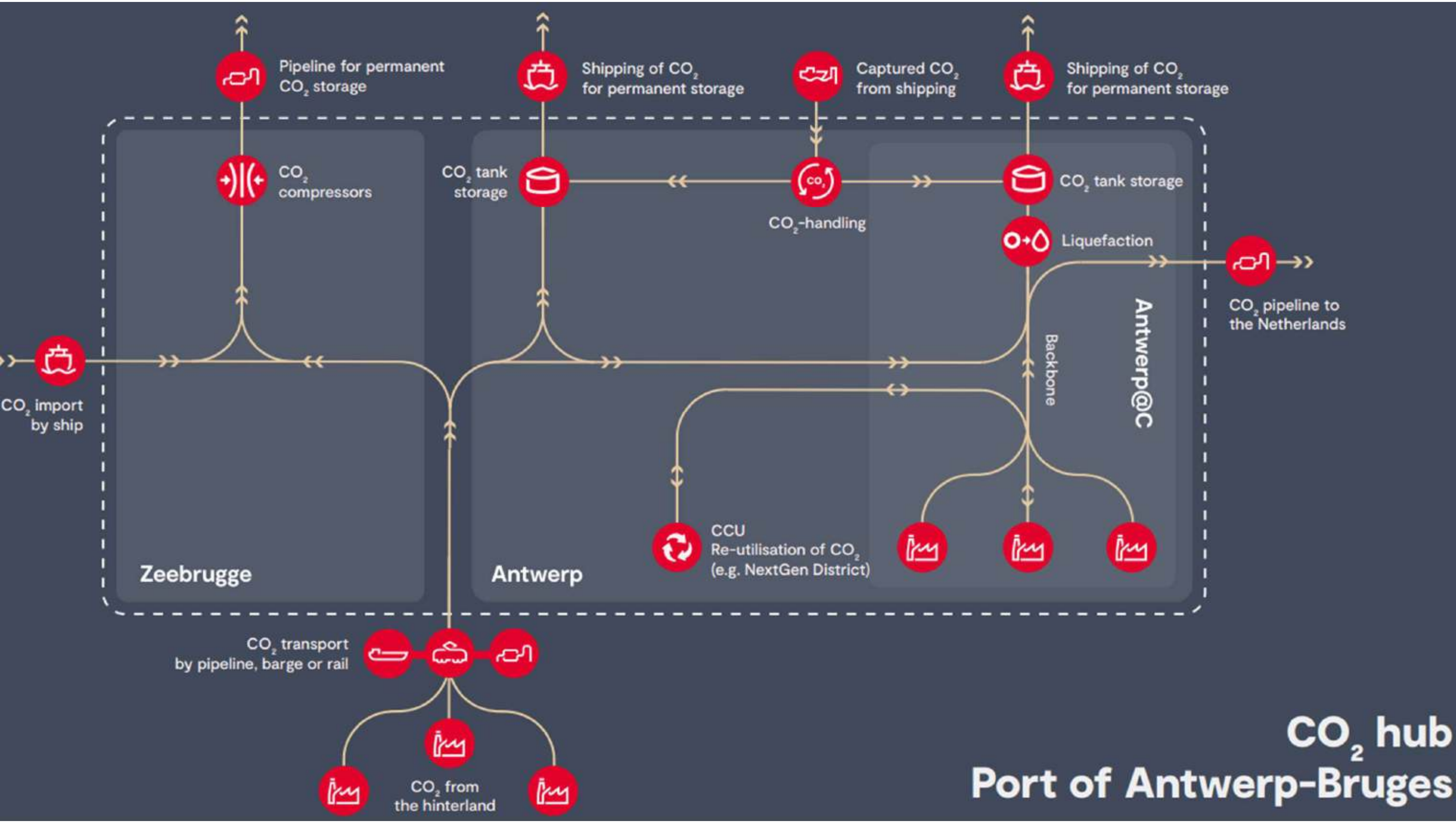
Thank You

Port of Rotterdam

Port of Antwerp-Bruges

CCUS hub in Europe

Port of Antwerp Bruges


Pipeline for permanent CO_2 storage
Shipping of CO_2 for permanent storage
Captured CO_2 from shipping
Shipping of CO_2 for permanent storage
CO_2 compressors
CO_2 tank storage
CO_2-handling
CO_2 tank storage
Liquefaction
CO_2 pipeline to the Netherlands
Antwerp@C
Backbone
CO_2 import by ship
CCU
Re-utilisation of CO_2
(e.g. NextGen District)
Zeebrugge
Antwerp
CO_2 transport by pipeline, barge or rail
CO_2 from the hinterland
CO_2 hub
Port of Antwerp-Bruges

Onboard Carbon Capture (OBCC)

Status and port's perspective

Port of Antwerp Bruges

Status of OBCC

A Port's Perspective on Challenges

CO_2 capturing on board of vessels

1. Maritime Policy (IMO/EU)
2. Technology & BUCA
3. Quality of CO_2
4. Expected volumes
5. Contract sinks or valorisation

CO_2 offloading at the port

1. Legal status of CO_2 in relation to waste legislation
2. Customs reporting & taxes
3. Location & permitting
4. Debunkering & risk profile

CO_2 handling in/through the port

1. Temporary storage
2. Purification
3. Re-use
4. Other related services

Port of Antwerp Bruges

In tune with the world

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Program Manager Fuel Transition

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Port of Antwerp Bruges

CCShip project: GHG emissions of OCCS under FuelEU Maritime

[1]Donghoi Kim*, [1]Sai Gokul Subraveti,
[1]Rahul Anantharaman, [1]Simon Roussanaly

[1]SINTEF Energy Research

EverLoNG CSIIG online workshop
2025.02.12

The CCShip project

Holistic assessment with cost, legal and regulatory aspects

Different CO_2 capture technologies
(Heat, electricity, material-driven systems)

+

Retrofit vs newbuilding
(utility/hull extension, engine type, fuel type,…)

Bulk/oil carrier from Klaveness

Identify the true potential of onboard CCS

Alternative fuels


Courtesy: Klaveness

CCShip: steppingstone

- Screened next-generation technologies to identify the most promising option.
- Identified challenges for the design and operation of onboard CCS.
- Validated emission reduction potential of onboard CCS for EU regulations.

- CCShip as the steppingstone for
  - Pilot test and validation for capture and liquefaction from Wartsila (LINCCS).
  - World-first full-scale demo for onboard capture from Wartsila (ENOVA).

CO2 capture test facility at Wartsila Moss

Courtesy: Wartsila

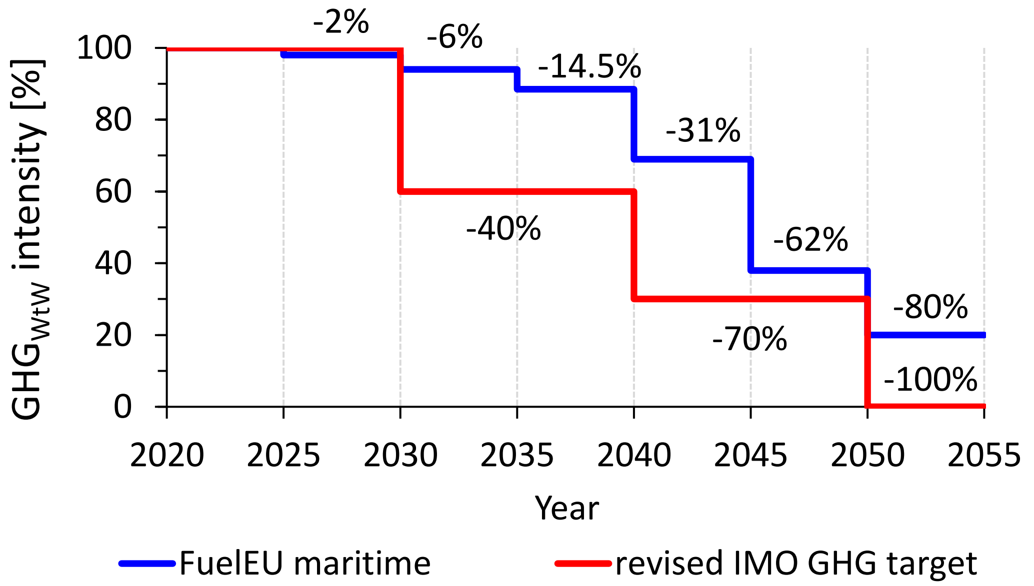
Full-scale onboard CCS demo by Wartsila Moss and Solvang

Courtesy: Solvang

Courtesy: Solvang

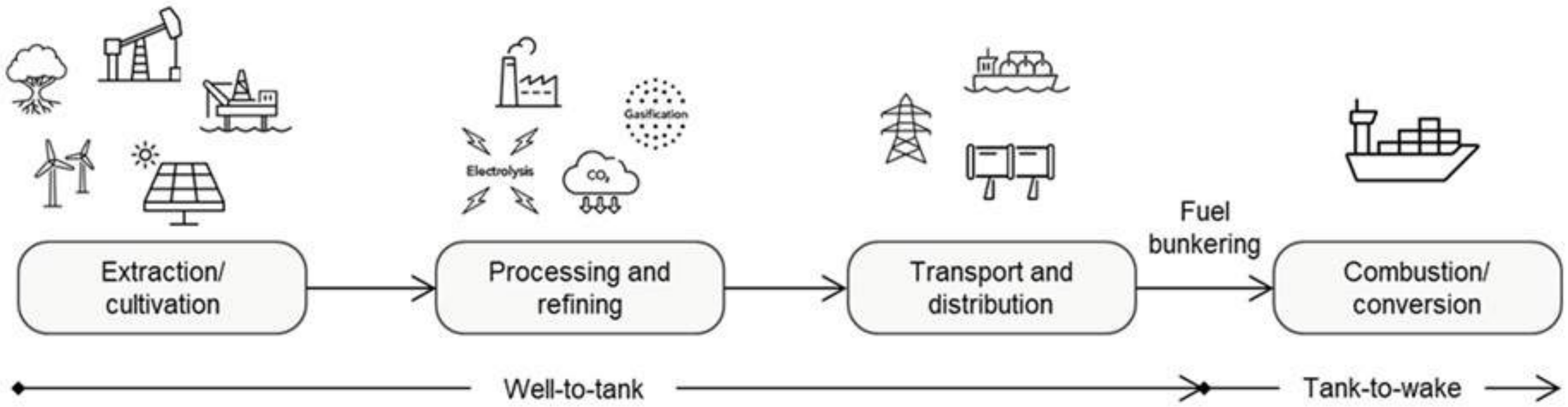
FuelEU Maritime

- FuelEU Maritime: based on EU Renewable Energy Directive (RED-II).
- Reduction in well-to-wake (WtW) greenhouse gas (GHG) intensity including CO2, CH4, N2O.
- GHG_{WtW} intensity for fuel energy used onboard.
- FuelEU Maritime starting from 1 January 2026.



FuelEU Maritime – WtW approach

- Well-to-wake (WtW) = Well-to-tank (WtT) + Tank-to-wake (TtW)
  - WtT: Lowering CO_2 intensity of fuel production.
  - TtW: Use of low-carbon fuels or OCCS.



*LCA guidelines, IMO 2023

FuelEU Maritime - GHG intensity values

- The default values for GHG_{WtT} must be used in FuelEU Maritime.
- However, actual GHG_{WtT} is varied with the origin of fuels and changed over time.-> no incentives in FuelEU.

Category	Unit	FuelEU Maritime		
		GHG_{WtT}	GHG_{TtW}	GHG_{WtW}
HFO	gCO_{2eq}/MJ	13.5	78.24	91.74
LFO	gCO_{2eq}/MJ	13.2	78.19	91.39
MDO/MGO	gCO_{2eq}/MJ	14.4	76.37	90.77
LNG otto (DF medium speed)	gCO_{2eq}/MJ	18.5	70.70	89.20
LNG otto (DF slow speed)	gCO_{2eq}/MJ	18.5	64.37	82.87
LNG Diesel (DF slow speed)	gCO_{2eq}/MJ	18.5	57.58	76.08
LBSI (Lean-burn spark ignited)	gCO_{2eq}/MJ	18.5	68.44	86.94

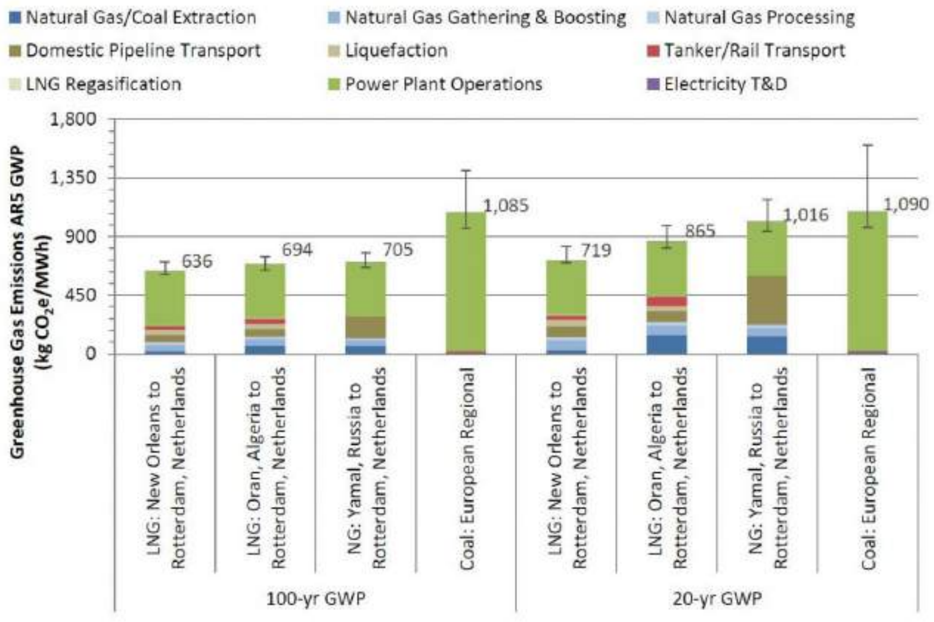


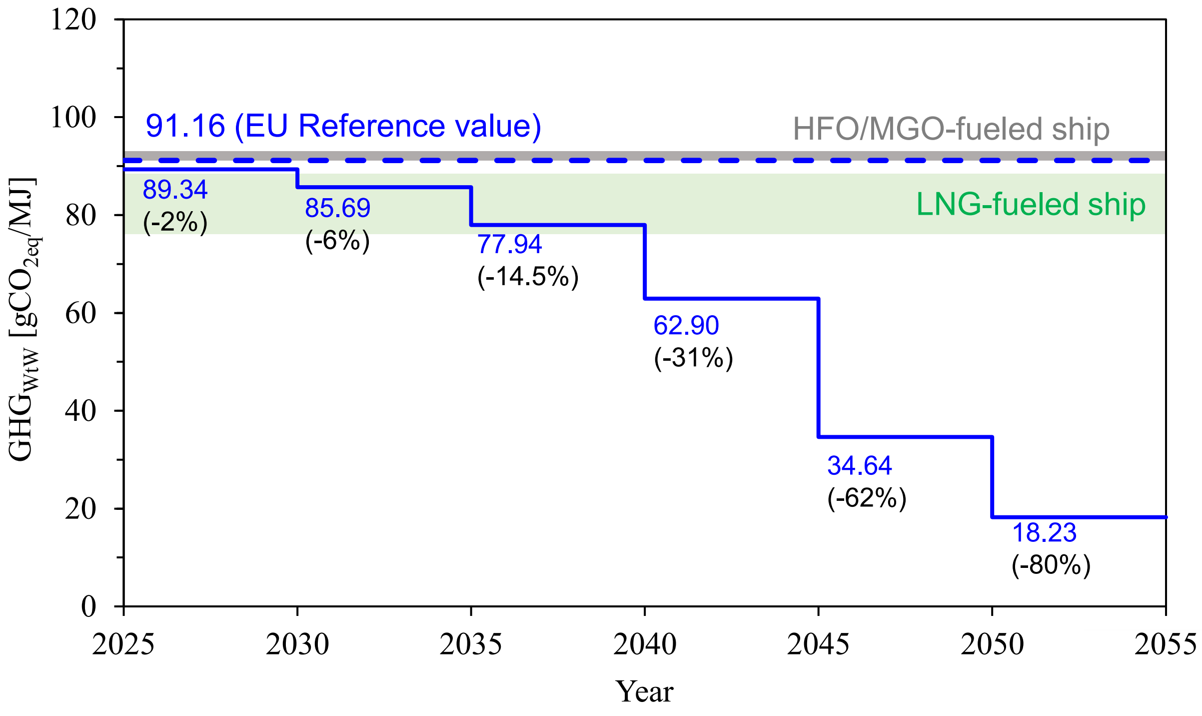
Figure 1: Life Cycle GHG Emissions for Natural Gas and Coal Power in Europe[71]

NETL, 2019

FuelEU Maritime - GHG intensity target

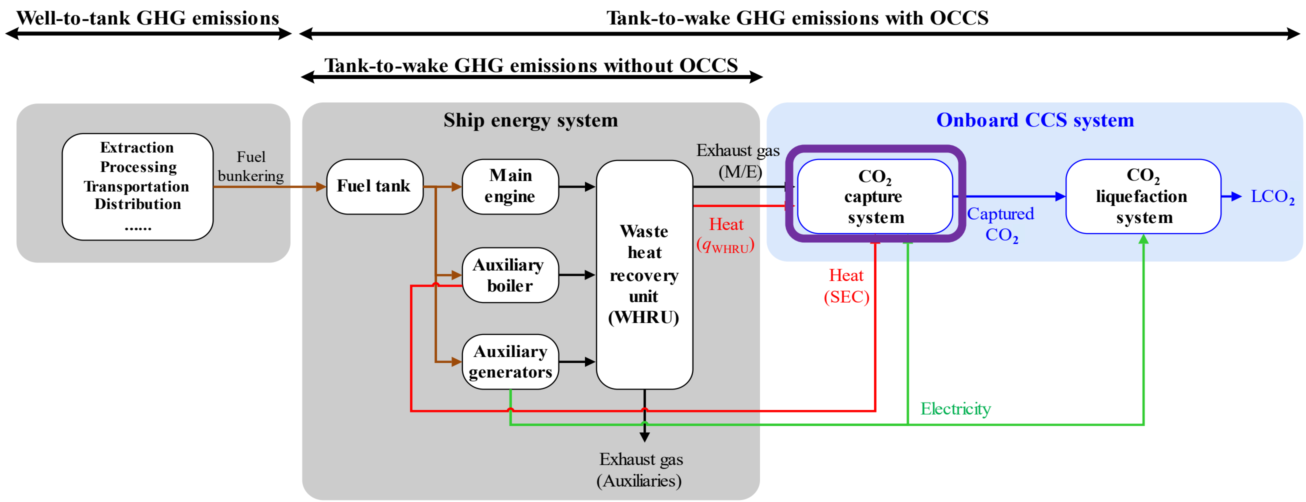
- HFO/MGO: Penalty from 2026.
- LNG: Penalty from 2040.

- FuelEU Maritime may not pose significant challenges for LNG despite concerns over methane leakages.
- Oil fuels need OCCS to meet FuelEU maritime targets.

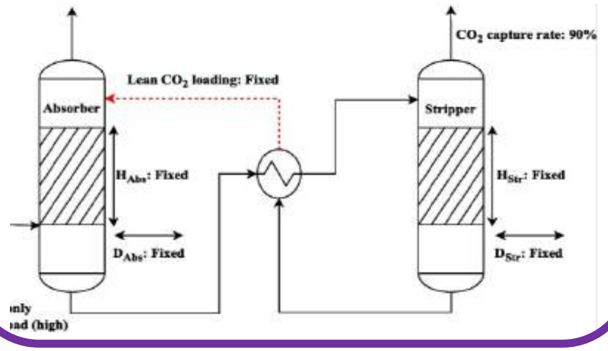


Methodology

- Ambition of the work has been to:
  - Understand the WtW GHG emissions of a relevant set of “ships scenarios” with OCCS
  - Understand how these scenarios would perform economically under the FuelEU Maritime Framework
  - In this work, OCCS from only the Main engine has been considered (which limits the CO2 avoidance rate)

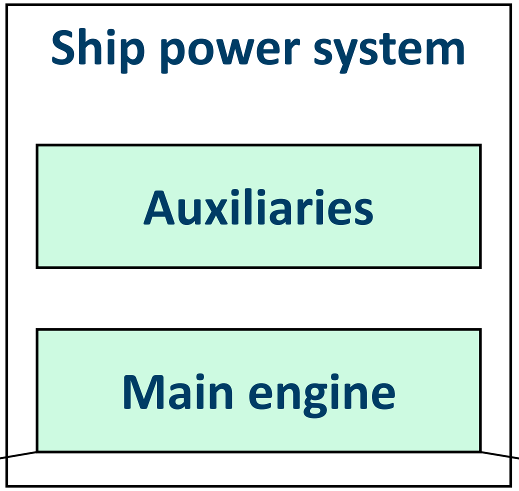


MEA-based capture

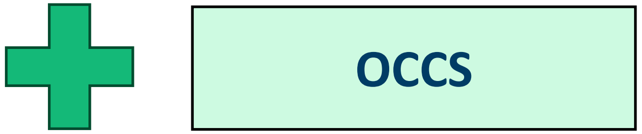


Methodology - Scenarios considered

- A wide range of fuel and engine types explored



Fuel type	Engine type			Scenario
	Stroke	Injection	Type	
HFO	4-stroke	Low-pressure	MSD	Scenario 1
MGO/MDO	2-stroke	Low-pressure	LNG-Otto-SS	Scenario 2
	2-stroke	Low-pressure	LNG-Otto-SS	Scenario 3
	2-stroke	High-pressure	LNG-Diesel	Scenario 4
	4-stroke	Low-pressure	LNG-Otto-MS	Scenario 5
	4-stroke	Low-pressure	LNG-Otto-MS	Scenario 6
LNG	2-stroke	Low-pressure	LNG-Otto-SS	Scenario 7
	2-stroke	High-pressure	LNG-Diesel	Scenario 8
	4-stroke	Low-pressure	LNG-Otto-MS	Scenario 9



SINTEF

Methodology - Scenarios considered

Category	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Fuel	HFO	MGO	MGO	MGO	MGO	MGO	LNG	LNG	LNG
Main engine	MSD-4S	SSD-2S	LPDF-2S	HPDF-2S	MSD-4S	LPDF-4S	LPDF-2S	HPDF-2S	LPDF-4S
$MCR_{M/E}$ (kW)	9,100	18,200	18,200	18,200	9,100	6,000	18,200	18,200	6,000
No. of main engines	2	1	1	1	2	2	1	1	2
Main engine load (%)	50	50	50	50	50	75	50	50	75
$SGC_{M/E}$ (g/kWh)	-	-	-	-	-	-	143.1	130.6	144.4
$SFOC_{M/E}$ (g/kWh)	177	160.5	177.4	157.8	174.3	181.9	1.3	3.9	5.8
Methane slip (gCH_4/kWh)	-	-	-	-	-	-	2.1	0.25	5.5*
Exhaust gas flowrate (tonne/h)	62	71	103	80	62	69	91	80	54
Exhaust gas CO_2 fraction (mol%)	5.3	4.2	3.2	3.7	5.2	4.8	2.6	2.7	4.5
Exhaust gas temperature (℃)	296	242	201	225	296	285	212	217	340

Methodology - WtW GHG intensity equation

$\text{GHG intensity}\left[\frac{gCO2eq}{MJ}\right] = f_{wind} \times (WtT + TtW)$ Equation (1)	
WtT	$\frac{\sum_i^{n\,fuel} M_i \times CO_{2eq\,WtT,i} \times LCV_i + \sum_k^c E_k \times CO_{2eq\,electricity,k}}{\sum_i^{n\,fuel} M_i \times LCV_i \times RWD_i + \sum_k^c E_k}$
TtW	$\frac{\sum_i^{n\,fuel}\sum_j^{m\,engine} M_{i,j} \times \left[\left(1 - \frac{1}{100} C_{slip\,j}\right) \times \left(CO_{2eq,TtW,i,j}\right) + \left(\frac{1}{100} C_{slip\,j} \times CO_{2eq\,TtW,slip,i,j}\right)\right]}{\sum_i^{n\,fuel} M_i \times LCV_i \times RWD_i + \sum_k^c E_k}$
f_{wind}	Reward factor for wind-assisted propulsion

Methodology – Economic viability

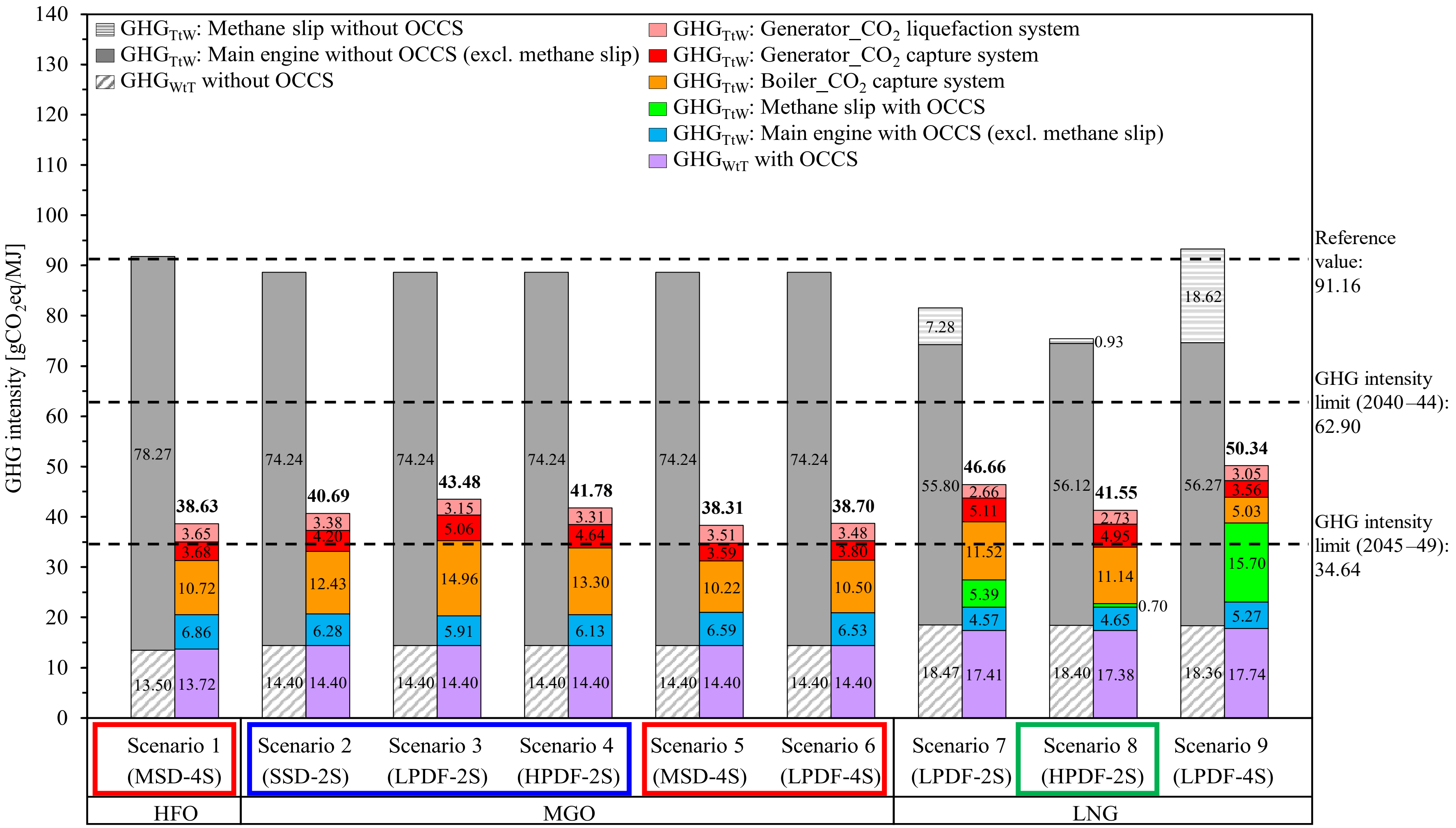
FuelEU Penalty =	$\frac{\lvert \text{Compliance Balance} \rvert}{\text{GHGIE}_{\text{actual}} \times 41000} \times 2400$

Compliance balance: GHG_{WtW} target - GHG_{WtW} attained.

GHGIE_actual (GHG_{WtW} attained), 2400 EUR, 41000 MJ (equivalent to 1 metric ton of VLSFO)

- If excess savings in GHG_{WtW} is sold to others, pooled, or banked. Higher GHG_{WtW} cut will be beneficial.
- Higher GHG_{WtW} cut could be achieved by OCC on the whole onboard energy systema and capture rates.

Results - GHG intensity with OCCS



4-stroke oil

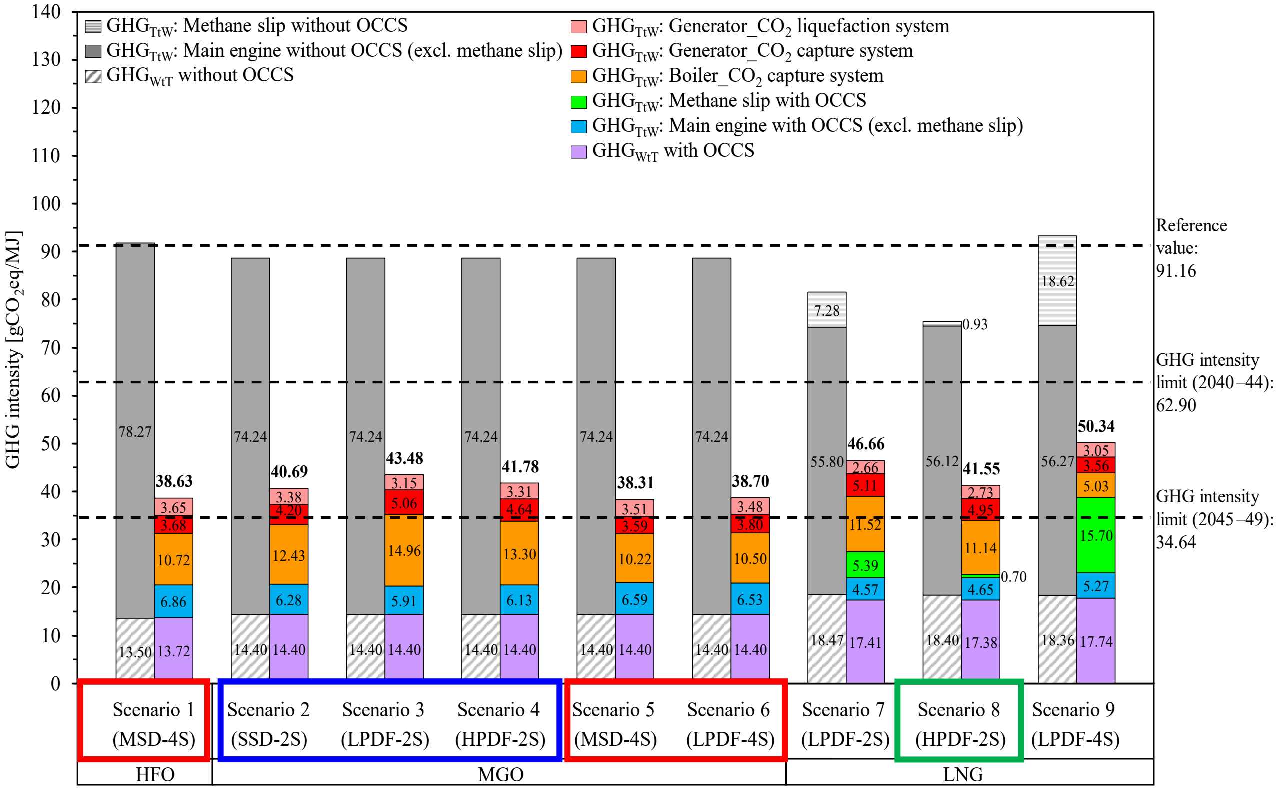
2-stroke oil

high-p LNG

low-p LNG

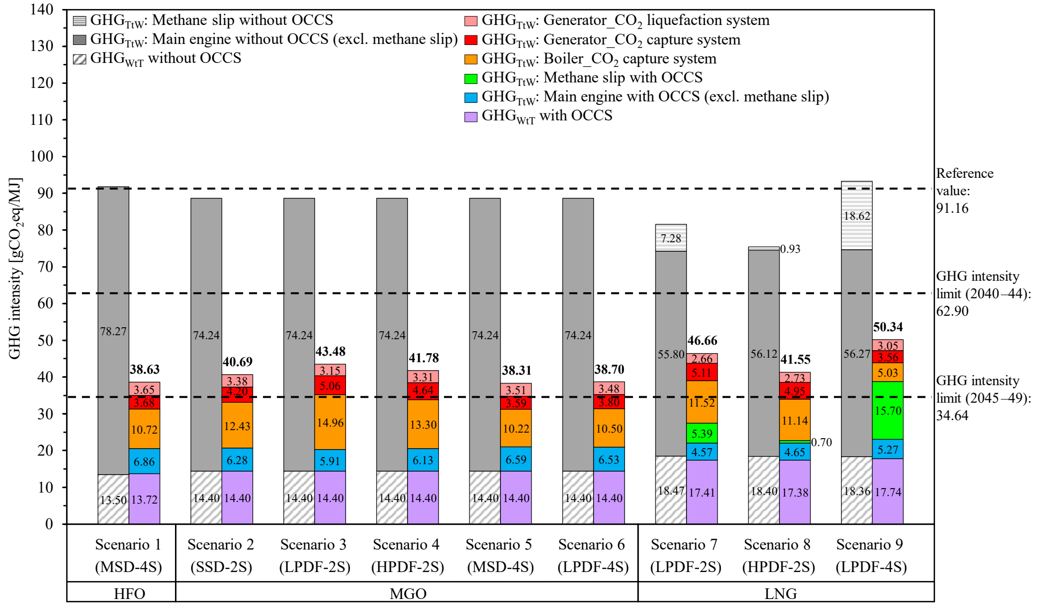
Results - GHG intensity with OCCS

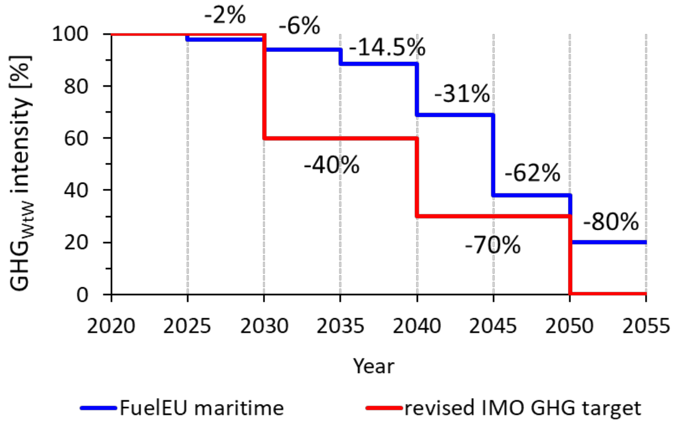
- GHG_{WtW} intensity: 4-stroke oil < 2-stroke oil < high-p LNG < low-p LNG.



Mid-size onboard CCS	→	Meeting 2040 target
GHG intensity with OCCS	→	Oil ≤ LNG
LNG	→	Upstream emissions & CH4 slip

Results - GHG intensity with OCCS

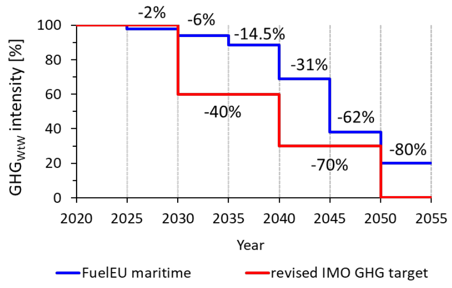


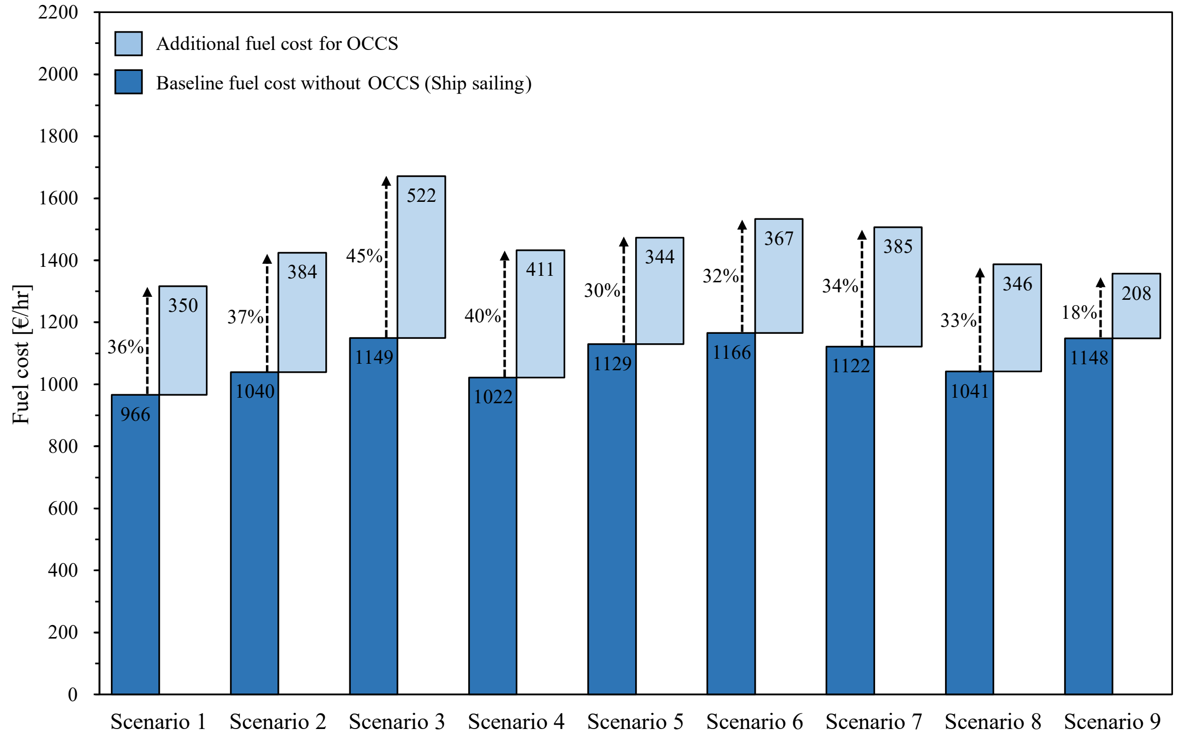


- With reduced upstream emissions and LNG cold energy for CO_2 liquefaction, LNG could reach similar levels of GHG intensity as oil engines.
- For the 2050 target, deep CO_2 reduction is needed
  → capturing CO_2 from the auxiliaries for higher capture rates
  → reducing WtT GHG emissions.

Results - Fuel cost with OCCS

- Up to 45% increase in fuel consumption with OCCS.
- Weak motivation to capture more than what is required in FuelEU maritime?

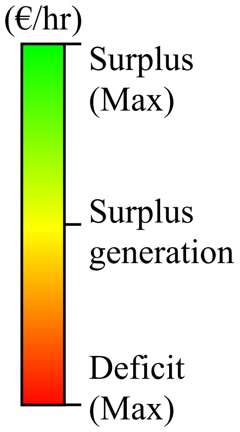




Results
- Fuel cost + FuelEU penalty

- Fuel cost (sailing and OCCS) + FuelEU penalty with 90% CO_2 capture for main engine.
- If excess savings (surplus) in GHG is sold to others, higher GHG_{WtW} cut is always beneficial.

	Unit	S. 1	S. 2	S. 3	S. 4	S. 5	S. 6	S. 7	S. 8	S. 9
		HFO-MSD-4S	MGO-LP-2S	MGO-LPDF-2S	MGO-HPDF-2S	MGO-LP-4S	MGO-LPDF-4S	LNG-LPDF-2S	LNG-HPDF-2S	LNG-LPDF-4S
GHG_{WtW}	gCO_{2eq}/MJ	38.6	40.7	43.5	41.8	38.3	38.7	46.7	41.6	50.3
CO_2 avoidance rate	%	60	53	45	50	60	59	44	46	66
2025-29	EUR/hr	5,310	4,554	4,518	4,293	5,417	5,507	3,241	4,110	2,257
2030-34	EUR/hr	4,833	4,106	4,026	3,854	4,925	5,000	2,836	3,690	1,919
2035-39	EUR/hr	3,821	3,154	2,980	2,921	3,878	3,923	1,974	2,799	1,201
2040-44	EUR/hr	1,855	1,306	949	1,110	1,847	1,831	300	1,069	-193
2045-49	EUR/hr	-1,837	-2,167	-2,865	-2,293	-1,968	-2,098	-2,843	-2,182	-2,812
2050-	EUR/hr	-3,981	-4,183	-5,080	-4,269	-4,184	-4,379	-4,669	-4,070	-4,333
2025-2054 (avg.)	EUR/hr	1667	1128	755	936	1652	1631	140	903	-327



Reflections

- OCCS from ship main engine can allow fossil-fuelled power ship to comply with the FuelEU maritime for the next 20 years.
  - Investing now could thus (likely) ensure economic viability.
  - Further compliance could be achieved through capturing CO_2 from the auxiliaries, higher CCR, and reducing WtT GHG emissions.
- In terms of scenarios: 4-stroke oil < 2-stroke oil < high-p LNG < low-p LNG

***FuelEU Maritime, EU**

(33) In the event of technological progress concerning new GHG abatement technologies, such as onboard carbon capture, the Commission should assess the possibility to reflect, in the GHG intensity and compliance balance formulas set out in Annexes I and IV respectively, the contribution of such technologies to lowering the GHG direct emissions on board ships.

SINTEF

Associated paper published

Contents lists available at ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Greenhouse gas emissions of shipping with onboard carbon capture under the FuelEU Maritime regulation: A well-to-wake evaluation of different propulsion scenarios

Juyoung Oh [a], Donghoi Kim [b], Simon Roussanaly [b,*], Youngsub Lim [a,c,d,*]

Acknowledgements

- This work was also supported by the KSP project CCShip under the MAROFF program of the Research Council of Norway (RCN project number 320260). The authors would like to acknowledge the following partners for their support: the NCCS Research Centre and its partners (Aker Carbon Capture, Allton, Ansaldo Energia, Baker Hughes, CoorsTek Membrane Sciences, Equinor, Fortum Oslo Varme, Gassco, KROHNE, Larvik Shipping, Lundin Norway, Norcem, Norwegian Oil and Gas, Quad Geometrics, Stratum Reservoir, Total, Vår Energi, Wintershall DEA), Calix Limited, Klaveness, Wärtsilä, and the Research Council of Norway (257579).

SINTEF

Technology for a better society

Onboard carbon capture – port infrastructure and roadmap

CSIIG #3 Webinar

12.2.25

Ragnhild Skagestad, Anette Mathisen, Kristian L. Aas, Sumudu Karunarathne

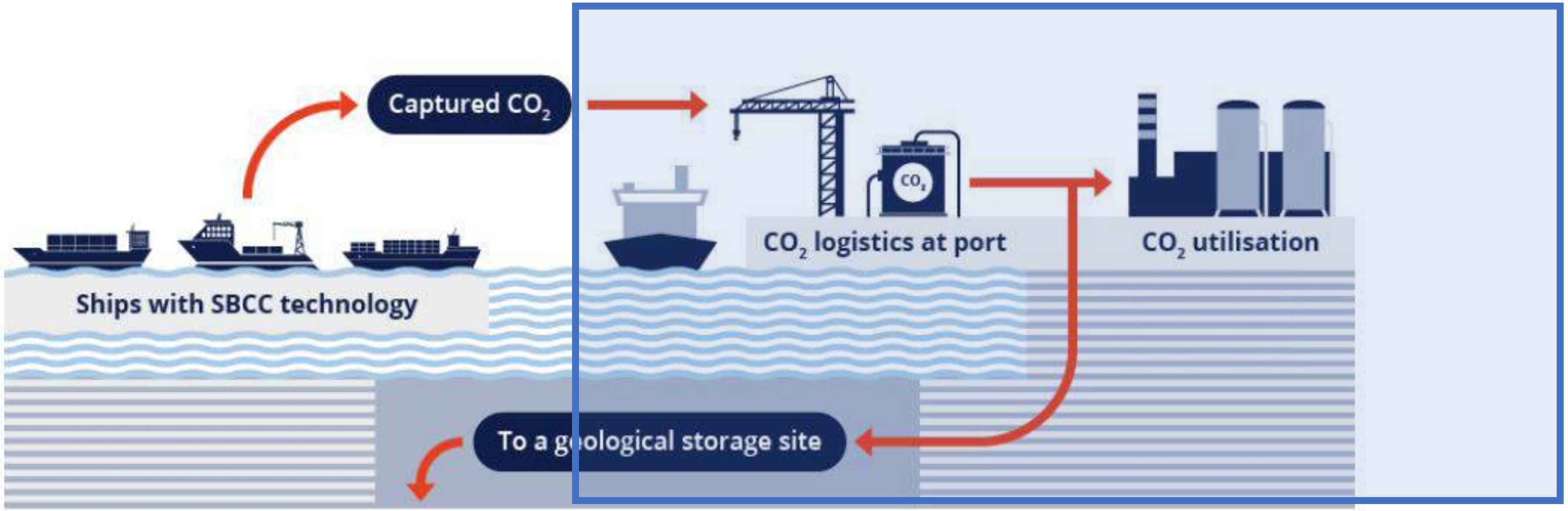
SINTEF Industry, Hydrovegen 69, Porsgrunn, Norway

The EverLoNG project is funded through the ACT programme (Accelerating CCS Technologies, Horizon2020 Project No 691712). Financial contributions have been made by the Ministry of Economic Affairs and Climate Policy, the Netherlands; The Federal Ministry for Economic Affairs and Climate Action, Germany; the Research Council of Norway; the Department for Business, Energy & Industrial Strategy, UK; and the U.S. Department of Energy. All funders are gratefully acknowledged.

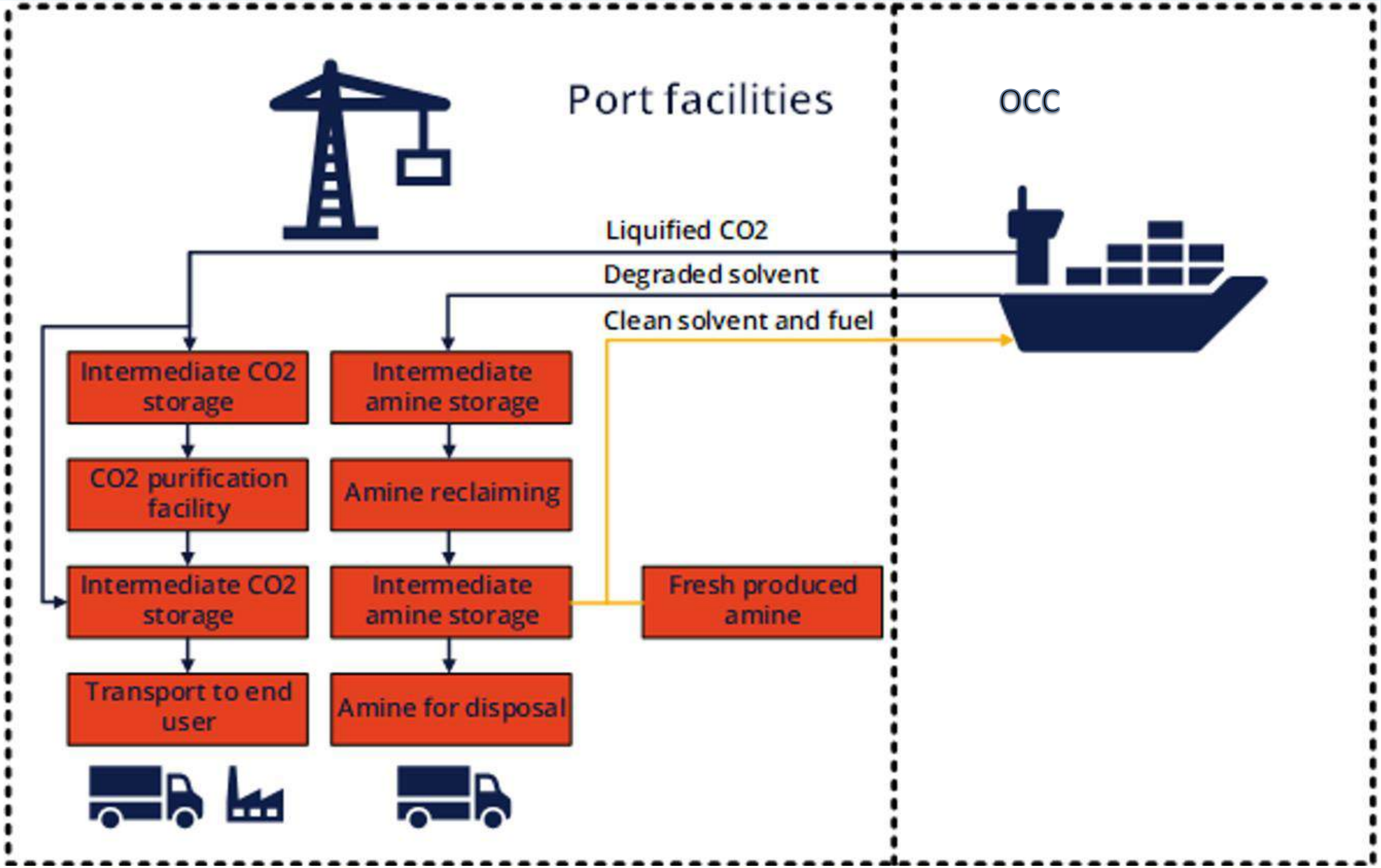
EverLoNG- logistics

After all the effort of capturing the CO_2 onboard the vessel - it is paramount that the CO_2 remains captured and stored/utilized.

To enable this, a CO_2 handling infrastructure needs to be in place that can receive this CO_2 in such a way that it has little impact on the normal operation of the vessel



Port facilities



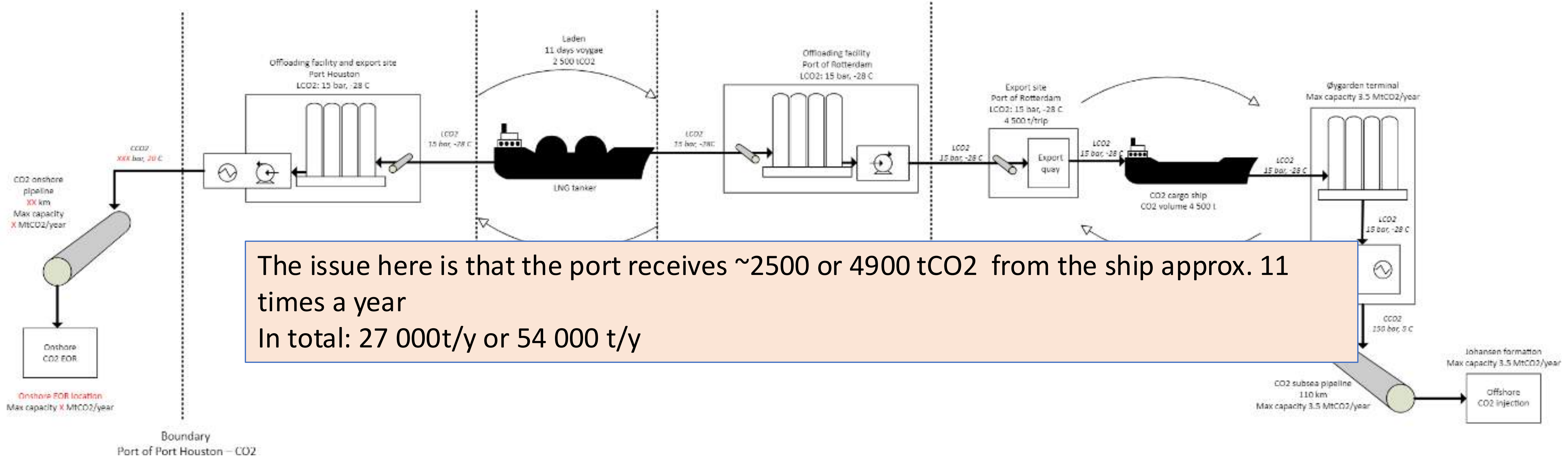
Capture at a LNG vessel

	Data/value
Vessel	A LNG vessel
Mode of operation	LNG transport from Houston to Rotterdam
Voyage duration (port to port)	11 days
CO_2 offloading port	Port of Rotterdam
CO_2 captured on voyage	2500 t /2400 t
CO_2 condition at unloading to port	Liquid @ 15 bara, -28 °C
CO_2 destination	Permanent storage – Northern Lights

TOTAL's LNG carrier *

*Not a spesific LNG ship, but based on several ships

LNG vessel- port to port in 11 days



The issue here is that the port receives ~2500 or 4900 tCO_2 from the ship approx. 11 times a year
In total: 27 000t/y or 54 000 t/y

Scale up- more ships with SBCC to the port!

+Then we can utilize the infrastructure better, and reduce the cost per tonn handeled ☺

But;

- Does the CO_2 come in the same condition, pressure/temperature?
- Require different purification facilities?
- Solvent handling-different types of solvent/capture technologies
- Can they use the same offloading facilities?
- Potential mixing several impurities/streams with the return gas line
- Sizing of the equipment

Roadmap to 2050 – how to scale up?

- Startup volumes ; from one to several ships
- Several ports-make a network
- Different types of ship; container, bulk cargo, tankers ect
- Different capture technologies, conditions and impurities

Port of Houston (photo: Kristian Aas, SINTEF)

Key challenges

- The nature of shipping
  - Chartering – unpredictable routes and time in actual service
  - Low volumes per ship pose a challenge for further transport/storage
  - Long time between offloading
  - Unpredictable volumes –short contracts
- It is very difficult to predict the type and number of ships/vessels that will select SBCC as decarbonisation method
- A port of a certain size will have several different terminals serving different type of vessels – a flexible receival facility is needed
- Access to CO_2 infrastructure for further handling
- In case of large-scale deployment of SBCC
  - Quality of CO_2 - strict CO_2 stream purity demands – mixing of different qualities?
  - For absorbent-based systems with need for reclaiming – mixing of different solvents should be avoided

Start up – first port

- A port with CO_2 infrastructure for access to storage/utilization
  - either ships, pipeline, railway

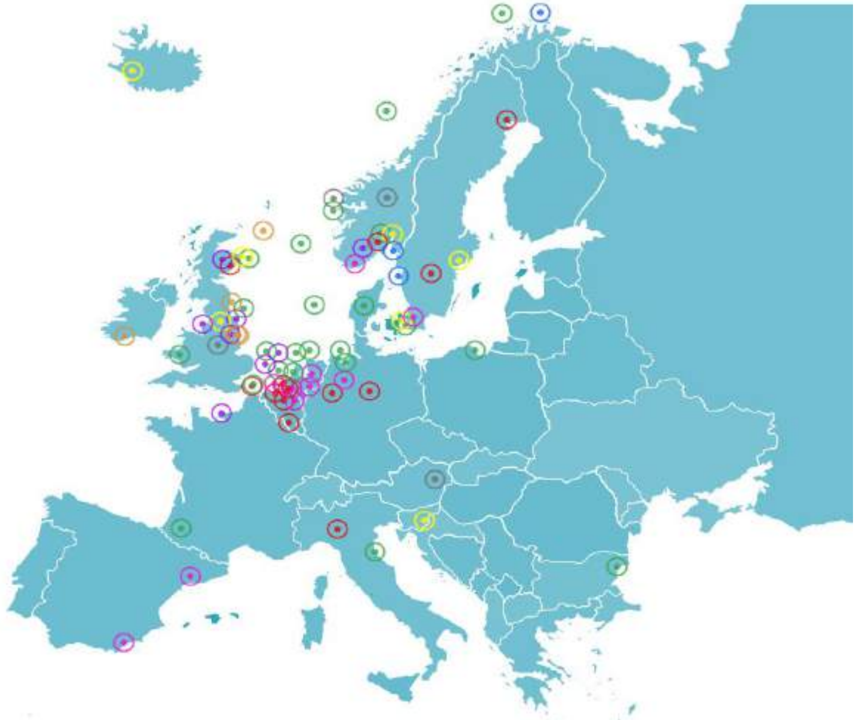
- Ships with regular access to the port
  - Long term obligations

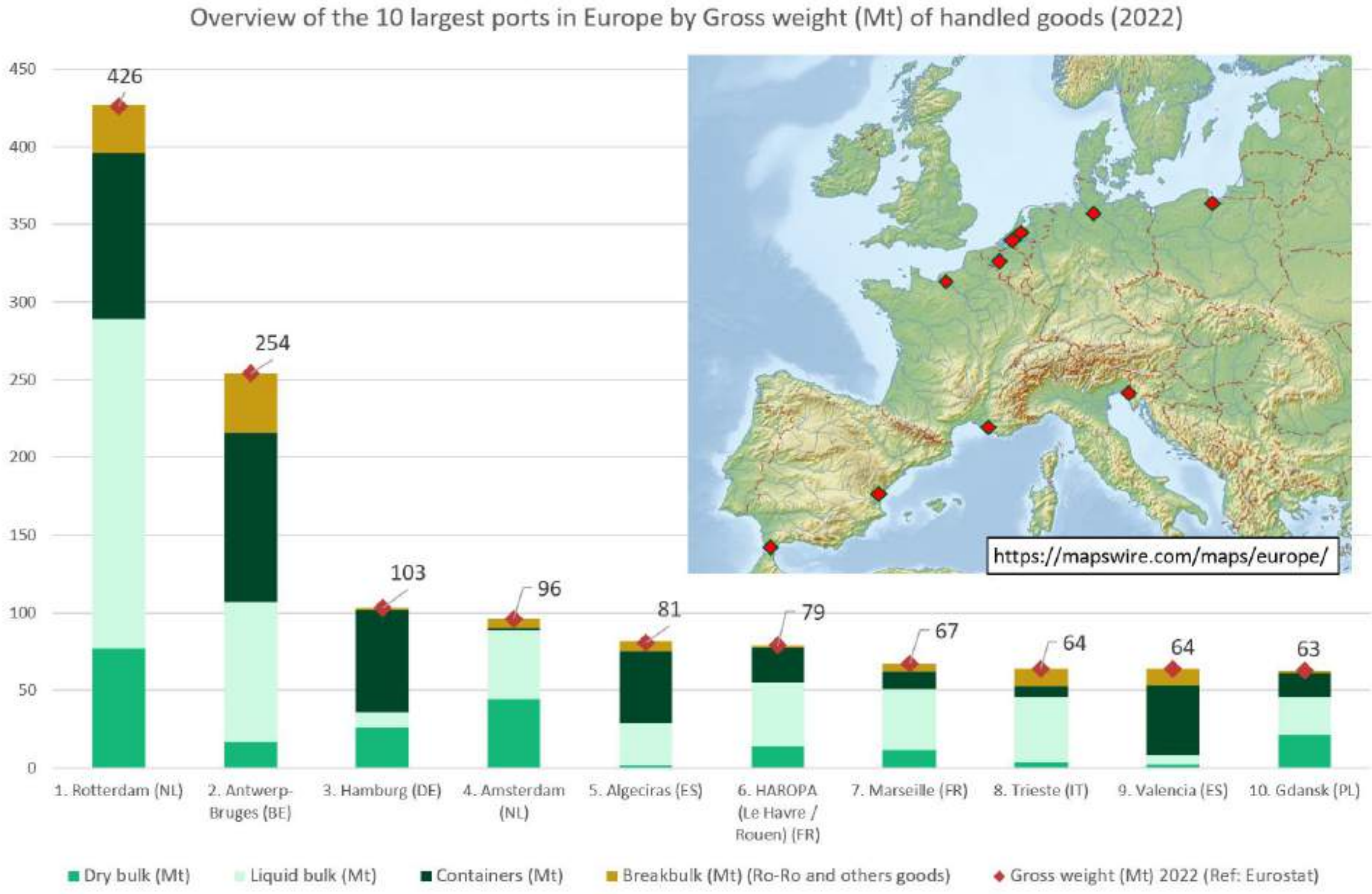
- Several ships with the same type of capture system and conditions of the CO_2

- Flexible loading/unloading equipment (to be able to handle several ships)

Roadmap pathways to 2050- network of ports

Start with some large ports with access to CCS projects





CCS/CCU projects map from ZEP platform: https://zeroemissionsplatform.eu/about-ccs-ccu/css-ccu-projects/

Key takeaways

- Implementation of OCC is a decarbonising measure that can be implemented today, demonstrated in the EverLoNG project
- Port infrastructure is a challenge
    - Low volumes per ship pose a challenge for further transport/storage
    - Long time between each offloading
    - Unpredictable volumes –short contracts
- Start with a large port with possible infrastructure for further transport
- A flexible offloading system at port that can handle several types of ships/sizes is desired

Acknowledgements

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EverLoNG

Thank you for listening

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Port Readiness Tool for CO_2 (PRT-CO_2)

3rd CSIIG Workshop – 12 February 2025

Richard L Stevenson, Dr Erika Palfi

SCCS, The University of Edinburgh

The EverLoNG project is funded through the ACT programme (Accelerating CCS Technologies, Horizon2020 Project No 691712). Financial contributions have been made by the Ministry of Economic Affairs and Climate Policy, the Netherlands; The Federal Ministry for Economic Affairs and Climate Action, Germany; the Research Council of Norway; the Department for Business, Energy & Industrial Strategy, UK; and the U.S. Department of Energy. All funders are gratefully acknowledged.

What is the PRT-CO_2?

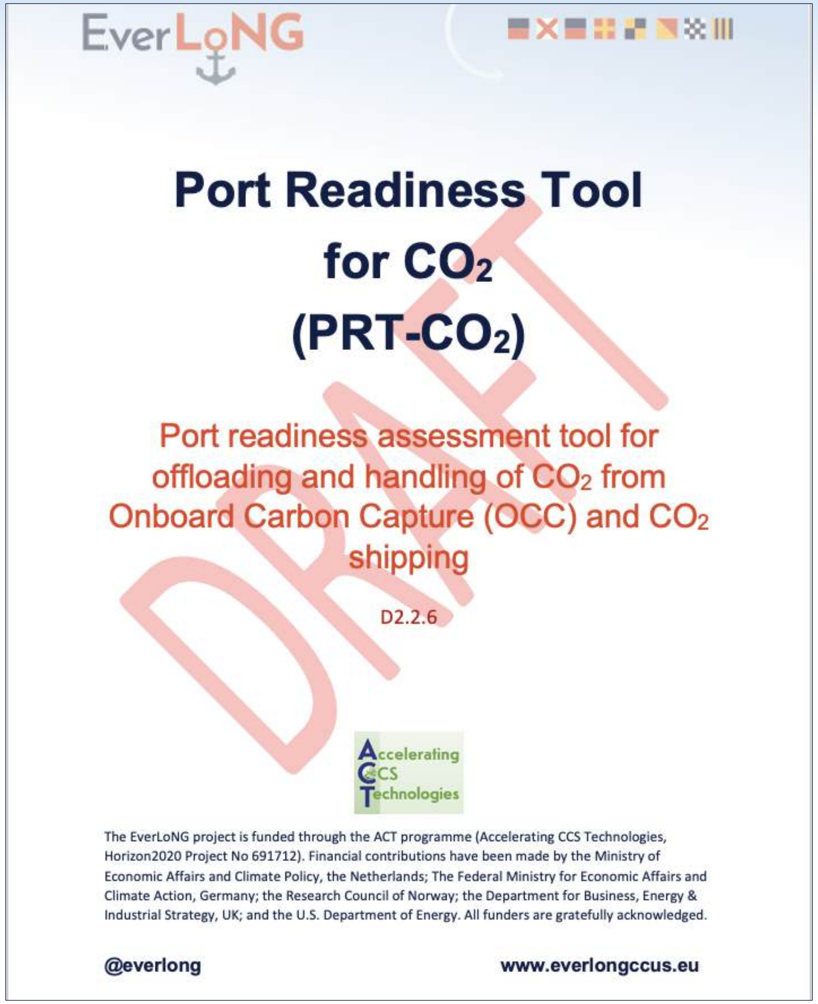
- Onboard Carbon Capture (OCC) CO_2
- CO_2 transport by ship

- Literature survey, industry engagement, CSIIG, EverLoNG WPs

- Support decarbonisation of the maritime sector
- Support decarbonisation of the wider economy

- Structured checklist supporting self-assessment
- Starting point for CO_2 handling preparedness

- Publicly available with accompanying report guidance
- Complementary contribution to wider sector efforts


EverLoNG

Port Readiness Tool for CO_2 (PRT-CO_2)

Port readiness assessment tool for offloading and handling of CO_2 from Onboard Carbon Capture (OCC) and CO_2 shipping

D2.2.6

DRAFT

Accelerating CCS Technologies

The EverLoNG project is funded through the ACT programme (Accelerating CCS Technologies, Horizon2020 Project No 691712). Financial contributions have been made by the Ministry of Economic Affairs and Climate Policy, the Netherlands; The Federal Ministry for Economic Affairs and Climate Action, Germany; the Research Council of Norway; the Department for Business, Energy & Industrial Strategy, UK; and the U.S. Department of Energy. All funders are gratefully acknowledged.

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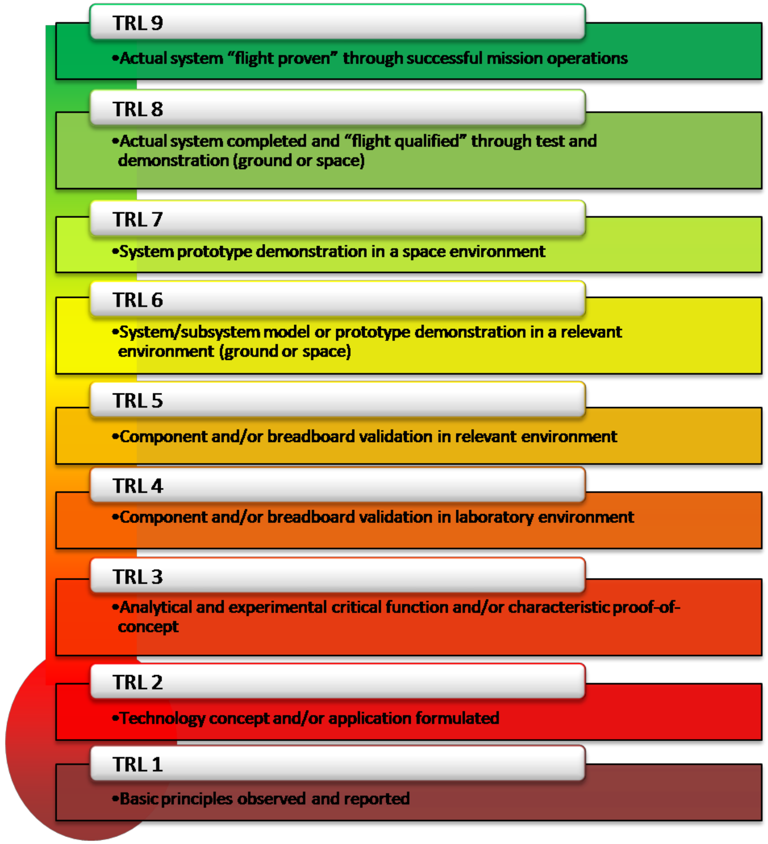
Objectives

- **Evaluate** port readiness to support OCC offloading and CO_2 transport by ship operations
- **Identify** gaps in infrastructure, such as offloading systems, CO_2 storage capacity, and scalability
- **Support** adherence to safety and regulatory standards specific to CO_2 handling
- **Facilitate** integration into regional and international CCS networks
- **Provide** flexibility to accommodate the diverse requirements of OCC and CO_2 transport by ship operations

Who are the intended users of the PRT-CO_2?

- All relevant stakeholders of a port community and CCUS stakeholders:
  - Port authorities
  - Port service providers
  - Shipping companies
  - Industrial emitters
  - CO_2 transport & storage operators
  - CCUS projects
  - CCU service providers
  - Regulatory authorities (local, national)
- Collaborative exercise

How does the PRT-CO_2 work?



NASA TRL framework

Readiness Level	Phase
PRL-CO_2 9	Phase 3: Deployment
PRL-CO_2 8	
PRL-CO_2 7	
PRL-CO_2 6	Phase 2: Development
PRL-CO_2 5	
PRL-CO_2 4	
PRL-CO_2 3	Phase 1: Research
PRL-CO_2 2	
PRL-CO_2 1	

PRL-CO_2 framework

What does the PRT-CO_2 look like? (1)

- Key areas of relevance: Governance, Safety, Infrastructure, Market

Level 1: Information on OCC offloading technologies and processes

Infrastructure

- ☐ Research the requirements necessary to serve as a port of call for vessels to offload on board captured CO_2 and regenerate/reload the solvent used for onboard capture.
- ☐ Conduct high-level assessments of existing infrastructure to determine compatibility with OCC offloading systems.
- ☐ Identify space availability for potential OCC-related infrastructure, including solvent handling systems and temporary CO_2 storage facilities.
- ☐ Research technical requirements for connecting OCC equipment to port systems (e.g., pipelines, berths).
- ☐ Assess the availability of space in the port for future expansions or upgrades to accommodate OCC-related operations.

Level 1: Information on CO_2 shipping technologies and processes

Infrastructure

- ☐ Research the requirements necessary to serve as a port of call for vessels to load and/or offload transported CO_2.
- ☐ Map existing infrastructure capabilities for CO_2 transport by ship, including berths, storage, and pipelines.
- ☐ Identify space availability for potential CO_2 transport by ship infrastructure, including temporary CO_2 storage facilities.
- ☐ Research technical requirements for connecting ship equipment to port systems (e.g., pipelines, berths).
- ☐ Identify potential upgrades needed to accommodate CO_2 vessels and associated systems.
- ☐ Assess geographical and logistical advantages for integrating the port into CCS supply chains.
- ☐ Evaluate opportunities for infrastructure co-development with CCS partners.
- ☐ Explore temporary storage solutions for CO_2 awaiting onward transport.
- ☐ Assess the availability of space in the port for future expansions or upgrades to accommodate CO_2 transport by ship related operations.

What does the PRT-CO_2 look like? (2)

- Key areas of relevance: Governance, Safety, Infrastructure, Market

Level 3: Research, analysis and evaluation of OCC readiness

Governance

- ☐ Develop an initial policy framework for OCC integration into port operations.
- ☐ Establish governance structures and assign responsibilities for regulatory compliance.
- ☐ Define legal and administrative requirements for OCC offloading operations.
- ☐ Initiate discussions with policymakers to develop clear regulatory pathways for OCC adoption.
- ☐ Compile evidence from research reports and scientific papers to supplement information already gathered.
- ☐ Develop partnerships with key stakeholders to participate in research programmes, consortia and other initiatives to supplement information already gathered and facilitate knowledge exchange.
- ☐ Collaborate with policymakers to refine OCC regulations at national and international levels.
- ☐ Explore potential incentives to encourage shipping companies to adopt OCC solutions.
- ☐ Assess legal precedents from early adopters of OCC technologies.

Level 3: Research, analysis and evaluation of CO_2 shipping readiness

Governance

- ☐ Establish a regulatory roadmap for integrating CO_2 transport into port operations.
- ☐ Define compliance measures and reporting obligations for CO_2 shipping activities.
- ☐ Develop collaborative agreements with government agencies and CCS stakeholders.
- ☐ Work with legal experts to outline liability and contractual considerations for CO_2 transport.
- ☐ Compile evidence from research reports and scientific papers to supplement information already gathered.
- ☐ Develop partnerships with key stakeholders to participate in research programmes, consortia and other initiatives to supplement information already gathered and facilitate knowledge exchange.
- ☐ Advocate for consistent regulatory standards across national and international jurisdictions.
- ☐ Assess potential tax or financial incentives for CO_2 transport investments.
- ☐ Explore the creation of regional regulatory working groups for CO_2 shipping.

Q&A/Discussion

- Status of OCC CO_2: Ship-based waste or something else?
- CO_2 specification and standards
- Mixing conditions (pressure, temperature) and different capture technologies - how should ports prepare for that?
- Development timeframe for OCC and OCC-ready ports
- Large scale implementation of OCC: Who goes first? Ship with OCC or ports ready to receive the CO_2?
- What is needed to accelerate the use of OCC?

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Thank you for listening

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