

**World Ocean Forum 2024**  
**Sustainable port for Green Shipping Corridors**  
***New maritime fuels and their impact on port operation***

**25 September 2024**  
**Klaipeda University**  
**Kang-Ki LEE**



# Content

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1

**Maritime Fuels and Environment**  
**Conditions to be maritime fuels and its evolution**

2

**A Future Scenario for Fuels on Green Shipping Corridor**  
**Gap between production/supply versus demand for Sustainability**

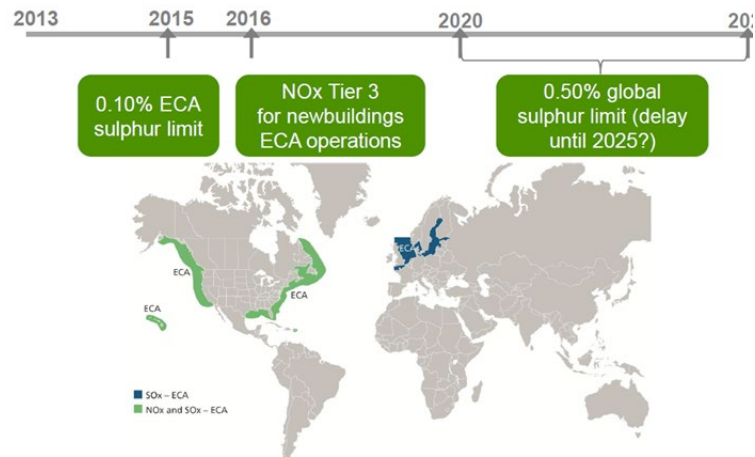
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**Sustainable Port**  
**How/what to be managed**

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# Fuel Sustainability Evolution of Maritime Fuels

Price-Competitiveness, Safety and Availability + Environment



• 7,000DWT Cargo & Passengership (M/V Selandia)  
- 2 x 8cyl., 4cycle, 1,250hp

2 TOTE 3,100teu Container ship by 8L70ME-C8.2-GI  
2 Teekay 173K LNG Carrier  
Powered by 2 x 5G70ME-C9.2-GI



- Only 1 Oil Station  
- Ship Dieselization: ~20years

1812 – steam (reciprocating) engine  
(cf: 1894- World first steam turbine-powered steamship: Turbine)



World first diesel engine ship : M/S Selandia

- Several Gas Stations  
- Innovative Technology on S, T, L & E  
- Electronic Engine  
- Scale Economy on Ships in Number.

World first LNG fuelled container ship designed by DSEC

# Environment & its Sustainability: What do we have to deal with ?

## Decarbonization vs GHG → Strategy towards GHG

### → Greenhouse Gases

50% reduction in 2050



40% reduction in 2030

70% reduction in 2050



Global fuel limit of 0,5% in 2020

### Heavy Fuel Oil

Ban on the use and carriage of heavy fuel oil (HFO) in the Arctic

DCS: Fuel consumption data collection by authorities started in 2019



Trade off efficiency vs **NOx**



Ammonia slip



### → Particulate Matter

Under heavy discussion at IMO  
(expected ~2025)

### Black Carbon

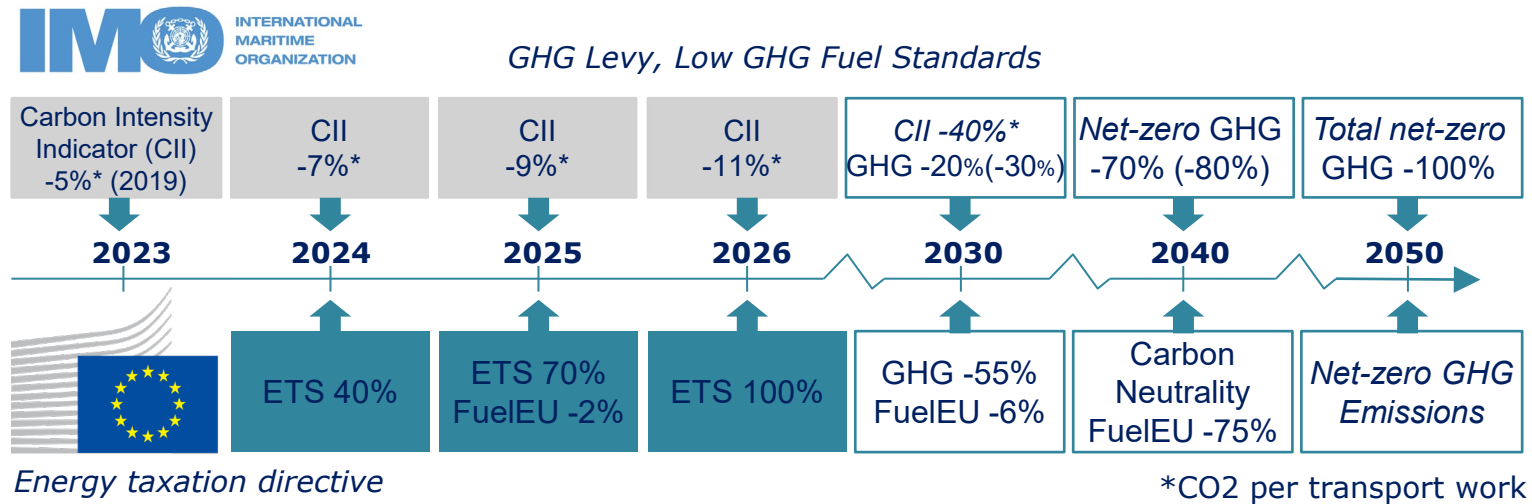
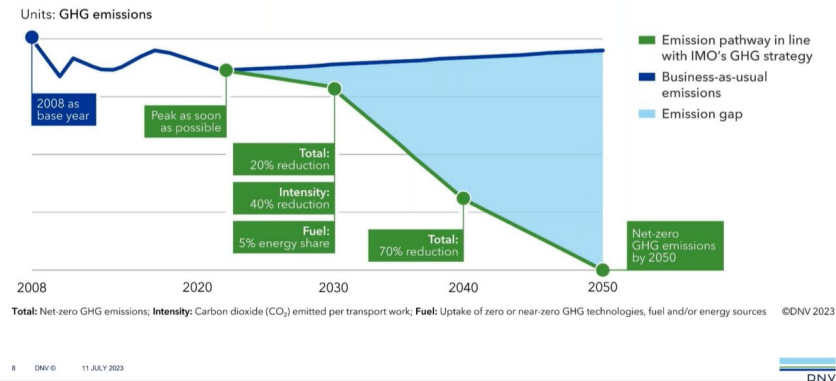
Under heavy discussion at IMO  
(expected ~2025), encourage LNG

### Under Water Noise

Under heavy discussion at IMO  
(expected ~2025)

# IMO and EU Regulations Towards Net-zero GHG Emissions

## Strengthened IMO strategy on GHG reductions



Adapted from Hellstöm, M. et.al.; CIMAC 2023|048 and Nyhus, E., Longva, T.: MEPC 80, DNV Webinar, July 11th, 2023

## → Carbon Zero !



**Ambitious Target vs Reality**

**Gap → Sustainability/LCA**

**Strategy of**

**GHG vs CO<sub>2</sub>**

# Future Fuels for Sustainability

Production | Properties | Applications

Source: AVL List GmbH

## Carbon-free Fuels

**Hydrogen**  
H<sub>2</sub>



**Ammonia**  
NH<sub>3</sub>



- + Production Efficiency
- + Flexibility: Engine; PEM FC
- + Future Availability (Industry)
- + Good Fuel Properties

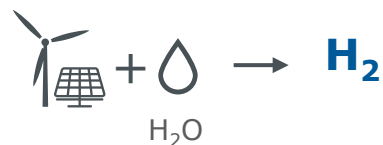
- + Storage as Liquid Gas
- + Best Carbon free H<sub>2</sub> Carrier

- Storage Density
- Safety due to high Reactivity

- Toxic
- Corrosive
- Poor Fuel Properties

### Electrolysis

Electricity



### Haber-Bosch Process



## Carbon-neutral Fuels

**Methane**  
CH<sub>4</sub>



- + Available Technologies and Infrastructure

- Upstream Emissions (CH<sub>4</sub>)
- Energy Demand in case of Liquefaction (LNG)

### RNG: Methanation



### BNG: Bio-Fuel Production



**Alcohols**  
CH<sub>3</sub>-(CH<sub>2</sub>)-OH



- + Liquid → Acceptable Storage Density

- Ethanol: Dependance from Bio-Source

### Bio Alcohol / Synthesis



Methanol: Gasification of biomaterial + Synthesis or Methanol synthesis  
Ethanol: Sugar Fermentation

**Paraffins**  
C<sub>n</sub>H<sub>2n+2</sub>



- + Available Technologies and Infrastructure
- + Best Storage Density
- + Highest Engine Efficiencies

- Poor Production Efficiency

### E-Fuel (e.g. Fischer Tropsch)

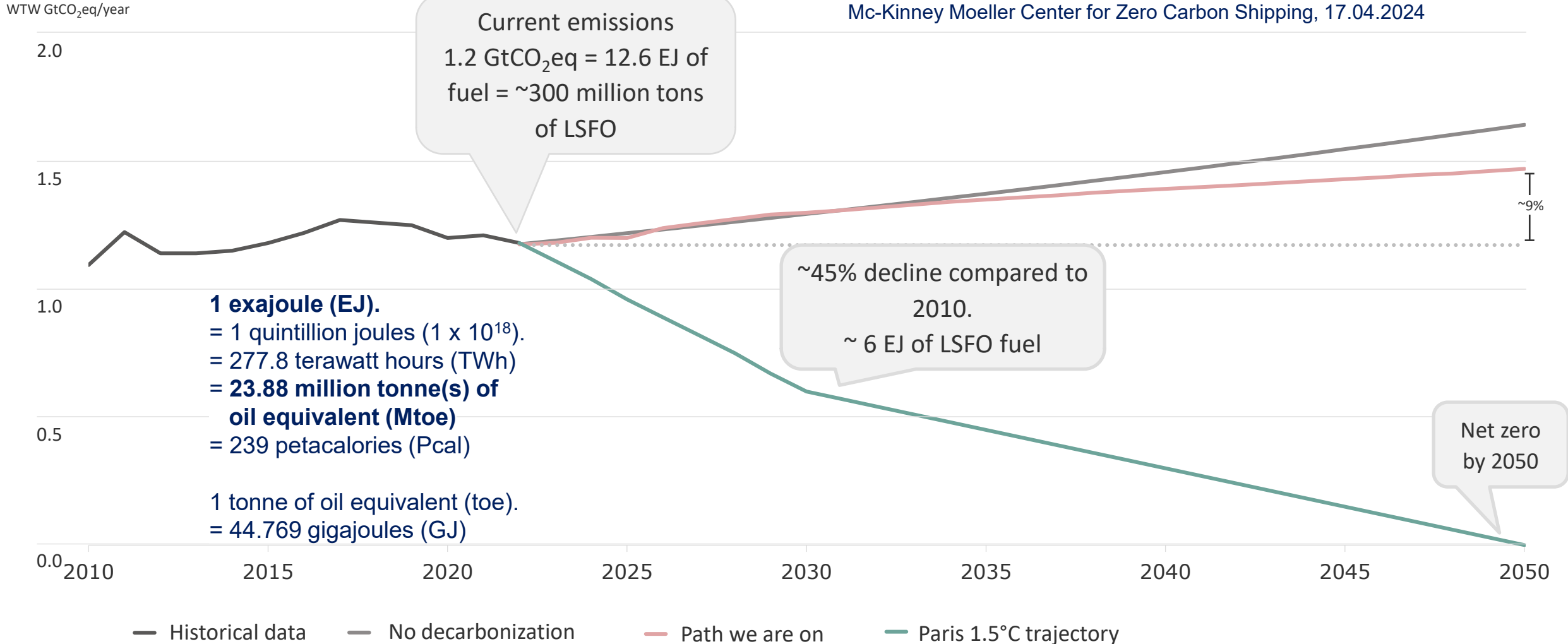


### HVO: Isomerization



# The challenges remain – we are not on track. Collaborative action is needed!

Source: HPSC 2024 Graz, Keynote Speech by Mr. Claus Graugaard, Maersk Mc-Kinney Moeller Center for Zero Carbon Shipping, 17.04.2024



# Market Observation on **Transition** Methanol on Spotlight



Maiden voyage and arrival at Copenhagen for namegiving of Laura Maersk, the world's first methanol fuel-enabled container ship. Image, courtesy A.P. Møller - Maersk A/S.

**MAN Energy Solutions developed the ME-LGIM dual-fuel engine for operation on methanol, as well as conventional fuel (source: MAN ES)**

MAN wins Maersk methanol engines contract

18 Oct 2022 by Jamey Bergman

MAN Energy Solutions will supply the engines for Maersk's latest six methanol-ready, dual-fuel newbuilding box ships

Hyundai Heavy Industry's (HHI) shipbuilding division has ordered six MAN B&W G95ME-C10.5-LGIM dual-fuel main engines in connection with a recent ship order from container shipping giant Maersk.

In early October 2022, [Maersk announced a six-vessel order](#) for 17,000-TEU container vessels with HHI.

## DFDS

Copenhagen-headquartered freight and passenger ferry operator DFDS is evaluating a system that injects methanol and hydrogen as a solution for its conventional four-stroke engines.

Source: DNV "Maritime Transition Outlook 2050" published in 2023 and press release by HD KSOE and public media

MAN wins retrofit contract on 22 June 2023 2 min read

11 container ships to be outfitted with engines capable of using methanol.

Maersk Line recently signed a Letter of Intent (LOI) with China's Yangzijiang Shipbuilding Ltd. for the construction of eight 8,000 TEU methanol-powered container ships. (22 June 2023)

METHANOL ENGINE, FUEL CELLS, HYBRID SYSTEMS - ROLLS-ROYCE PRESENTS NEW MTU PROPULSION SOLUTIONS FOR SHIPS AT SMM

Posted on September 06, 2022

- Launch from 2026: Methanol engines based on [mtu Series 4000](#)
- Launch from 2028: [mtu fuel cell systems](#)
- Available from 2023: [mtu Hybrid PropulsionPack for mtu Series 2000 and 4000](#)

Rolls-Royce will be showcasing new sustainable [mtu](#) marine solutions for propulsion, automation and service at SMM, the international maritime industry trade fair, in Hamburg, Germany, from 6 – 9 September 2022, under the slogan 'Pioneering the journey to Net Zero'. At booth 307 in Hall 3A, Rolls-Royce will present methanol engines, fuel cell concepts, hybrid systems, diesel engines with exhaust aftertreatment and for use with sustainable fuels, as well as [mtu NautIQ](#) marine automation products.

**Market launch from 2026: Methanol engines based on the [mtu Series 4000](#)**

**COSCO splashes \$2.87 bln on twelve methanol-powered 24,000 TEU mammoths**  
October 31, 2022, by Jasmina Ovcina Mandra

**Hong Kong-listed shipping major COSCO Shipping Holdings has placed an order for the construction of twelve 24,000 TEU methanol dual-fuel containerships worth \$2.87 billion.**

The construction contract was signed by the company's subsidiaries Orient Overseas Container Line (OOCL) and Cosco Shipping Lines with Nantong Cosco Khi Ship Engineering (NACKS) and Dalian COSCO KHI Ship Engineering Co. (DACKS).

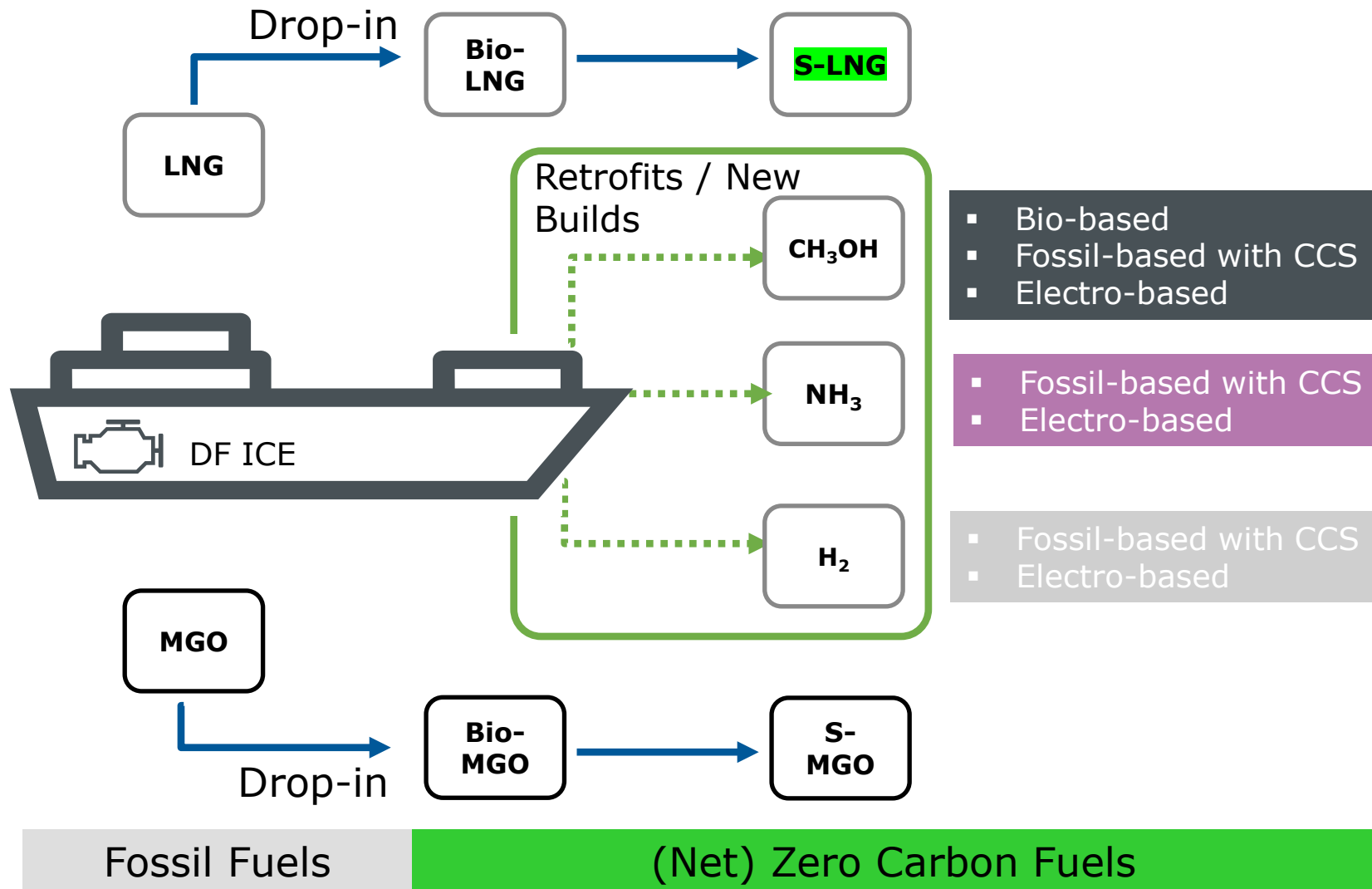
Under the contract, NACKS, a joint venture between Kawasaki Shipbuilding Corporation and COSCO Shipping, will be entrusted with building seven units from the batch, while DACKS shipyard, another JV between COSCO Shipping and Kawasaki Shipbuilding, will be entrusted with the construction of the remaining five ships.

**Wavelength secures methanol fuel supply deal in China**

October 17, 2022, by Fatima Bahtić

Portugal-based energy and tech company Wavelength Technology Center has secured a contract for a methanol marine fuel supply system.

# Bridging Technologies Fuel Flexibility



Now is the time to act to be able to meet the IMO's strategy

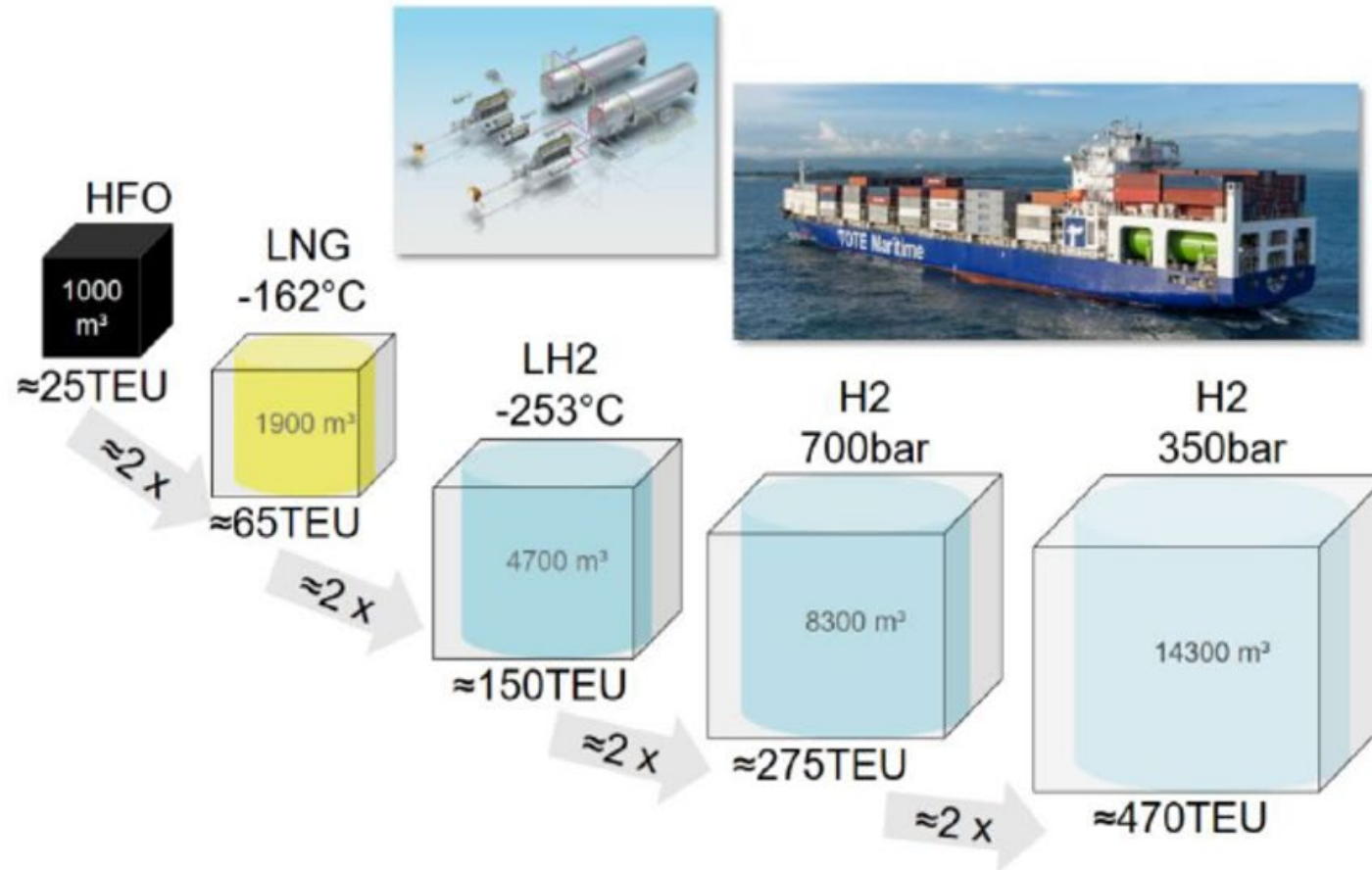
To reach it, the first net-zero ships will need to start entering the global fleet by 2030

There is a real sense of urgency in the industry!

Source: Based on DNVGL Report of Maritime Transition Outlook 2050

# Sustainable Port Policy - Port Operation and Management

## Storage & Handling: Volume Increase for Hydrogen and Cryogenic (H<sub>2</sub> -253 deg.C)



H<sub>2</sub>: Increased room for storage

– LNG (fossil or synthetic) needs more storage room than conventional liquid fuel

– Even more storage room for LH<sub>2</sub> due to its lower density

– Stored gaseous, tank volume further increases





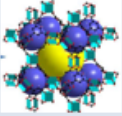



→ LNG/LH<sub>2</sub> for deep sea shipping

→ cH<sub>2</sub> maybe option for coastal shipping or temporary H<sub>2</sub> operation

Source: MAN E.S. Webinar, 39 June 2020 by Dr. A. Knafl

# Sustainable Port Policy - Port Operation and Management

## Logistics: Operation of Cryogenic material

Hydrogen			Ammonia	Methanol	SynLNG
<b>Compressed</b>	<b>Liquid</b>	<b>Solid</b>	<b>Liquid</b>	<b>Liquid</b>	<b>Cryogenic</b>
<p>CGH<sub>2</sub></p> 	<p>LH<sub>2</sub></p> 	<p>LOHC (Liquid or-ganic H2carrier)</p>  <p>V=5.6-6.1x HFO</p> <p><u>Metal Hydrides</u></p>  <p><u>MOFs</u> (Metal organic framework)</p> 	<p>NH<sub>3</sub></p> 	<p>CH<sub>3</sub>OH</p> 	<p>SynLNG</p> 
<p>Type III, IV pressure vessels</p> <p>P = 350/500 or 700 bar</p> <p>V=14.5 x HFO</p>	<p>Vacuum insulated low-pressure cryo tank</p> <p>P = 2-5bar</p> <p>T =-253°C</p> <p>V= 4.7 x HFO</p>	<p>LOHC Loading</p> <p>η~65-75%</p>	<p>Low-Pressure storage tank</p> <p>P = 7.5bar or T = -33°C</p> <p>V=3.5 x HFO</p>	<p>Low-Pressure storage tank</p> <p>P = 2-5bar</p> <p>T = ambient</p> <p>V=2.6 x HFO</p>	<p>Insulated low-pressure cryo tank</p> <p>P = 2-5bar</p> <p>T =-162°C</p> <p>V= 2.3 x HFO</p>
<p><u>Pressurization</u></p> <p>η~88%</p>	<p><u>Liquification</u></p> <p>η~80%</p>		<p>N<sub>2</sub> from air NH<sub>3</sub> Synth.</p> <p>η~70%</p>	<p>CCU from biomass + hydrogenation</p> <p>η~50-75%</p>	<p>CCU from biomass + methanisation</p> <p>η~50-70%</p>
Zero Carbon Pathway				Net-Zero Carbon Pathway	

Source: AVL



# Sustainable Port Policy - Port Operation and Management Risk Management: Sophisticated Technology & sensitivity

Source: Busan Port Authority

# Sustainable Port Policy - Port Operation and Management

## Risk Management: example – Scrubber vs Impact on Port, if harsh climate



### Harsh Weather

**Logistics:** Supply of chemicals, H<sub>2</sub>SO<sub>4</sub>  
**Risk management:** how to secure the safety from **toxic materials**



**SOx Emission in Shipping**

**Primary Measures**

**Very Low Sulphur Fuel**

**LNG Fuel**

**Alternative Fuel**

**Secondary Measures**

**Wet Scrubber**

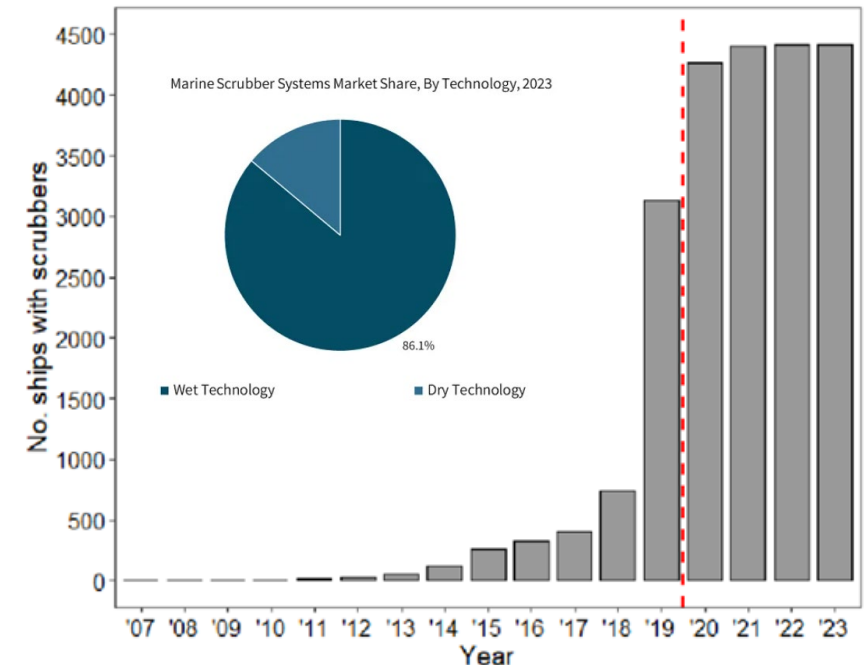
**Dry Scrubber**

**Non-thermal Plasma**

**Open Loop  
(sea water)**

**Closed Loop  
(fresh water & chemicals)**

**Hybrid  
(open/closed switchable)**

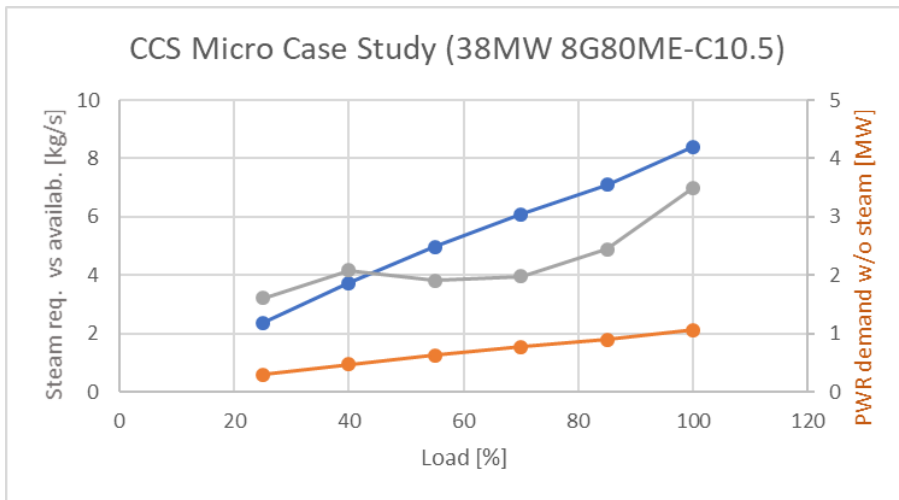


Source: The number of ships with scrubbers (in operation and on order) worldwide increased following reduced IMO limits on Sulphur emissions (1 January 2020; red line). Source: DNV-GL Alternative Fuels Insight. 6 July 2020. <https://afi.dnvgl.com/>, MAN E.S. [Marine Scrubber Systems Market Size, 2024-2032 Growth Analysis \(gmainsights.com\)](https://gmainsights.com/)

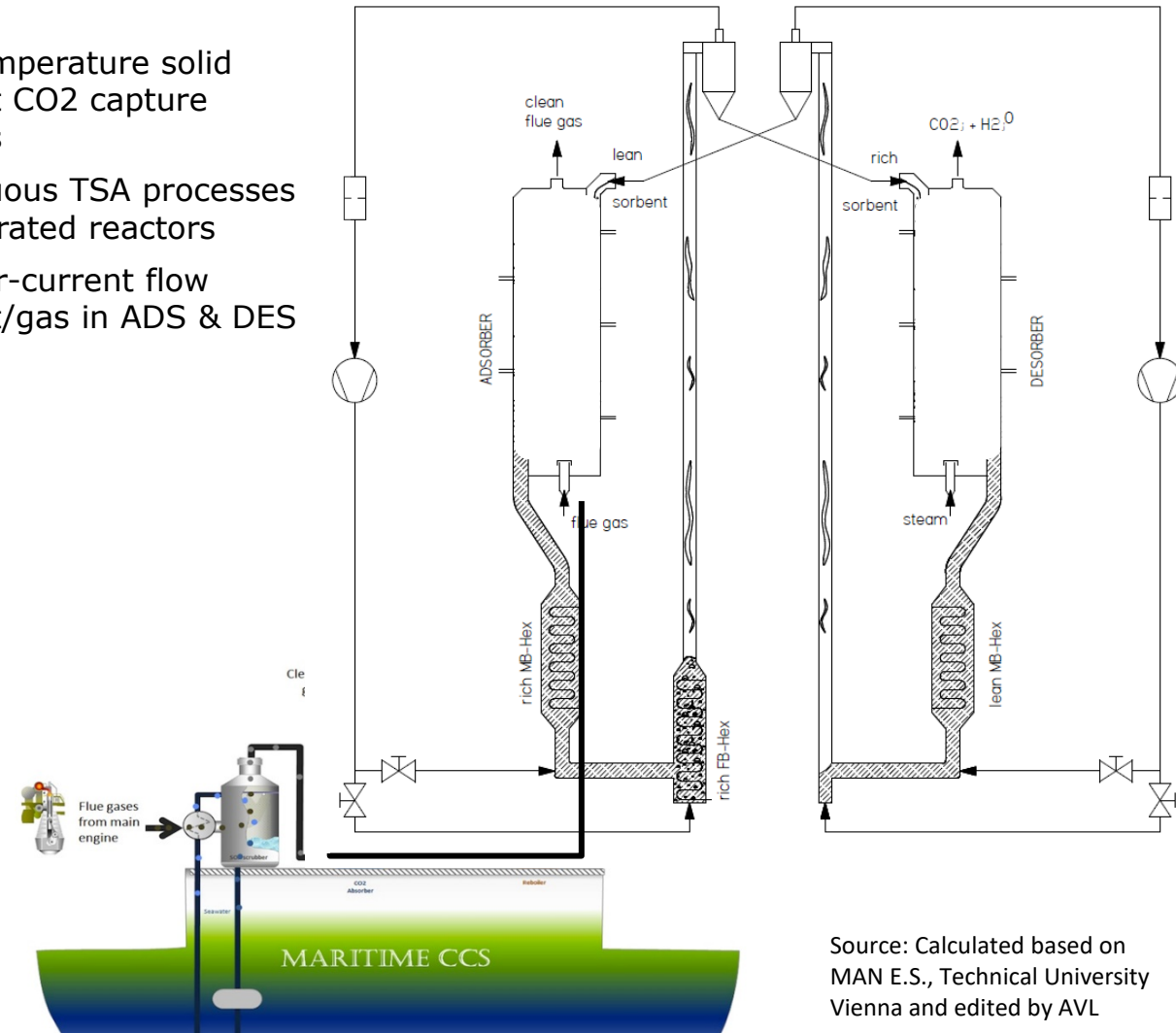
# Sustainable Port Policy - Port Operation and Management

## Logistics: Carbon Capture & Storage: Micro Case Study

- Engine: 8G80ME-C10.5-LPSCR (38MW)
- Solid amine based CO<sub>2</sub> adsorption system
- CO<sub>2</sub> capture rate = 90%
- 85% MCR: Exh\_MF = 70kg/s (~390t CO<sub>2</sub>/day)
- **Space requirements: 40m2x15m**
- Amine mass: 42t (+10t @1500h)
- Energy demand 0,2GJ/tCO<sub>2</sub>
- Steam demand: 3,7GJ/tCO<sub>2</sub>
- Cost\*: 75-125€/tCO<sub>2</sub> (\* based on land based EPG and depending on energy cost and depreciation)



- Low temperature solid sorbent CO<sub>2</sub> capture process
- Continuous TSA processes in separated reactors
- Counter-current flow sorbent/gas in ADS & DES



# A Future Scenario for Fuels on Sustainable Shipping Complexity and Flexibility but already NOW!



## Sailing on Solar

Could green ammonia decarbonise international shipping?

With Ammonia, There's No "Chicken or Egg" Dilemma

Bio-fuel

Ammonia

LNG

Ammonia

Hydrogen

In Depth: Interview: Hydrogen Is the Ideal Zero-Emissions Fuel

LNG

Methanol

New fuel rules push shipowners to go green with LNG

Ethanol

LPG

In Depth: Methanol Is Ready for Use as Marine Fuel

BW LPG to Retrofit 4 Ships to LPG-Propelled Dual-Fuel Engines

Source: HD KSOE, EEC, Presentation by Mr. Kjeld Aabo/MAN E.S. at The Maritime Hydrogen Conference at NorShipping 2022, Oslo | G. Stiesch – Decarbonization – Large Engine TechDays – ©2021

Thank you