MARITIME DECARBONISATION
Pathways & Alternatives

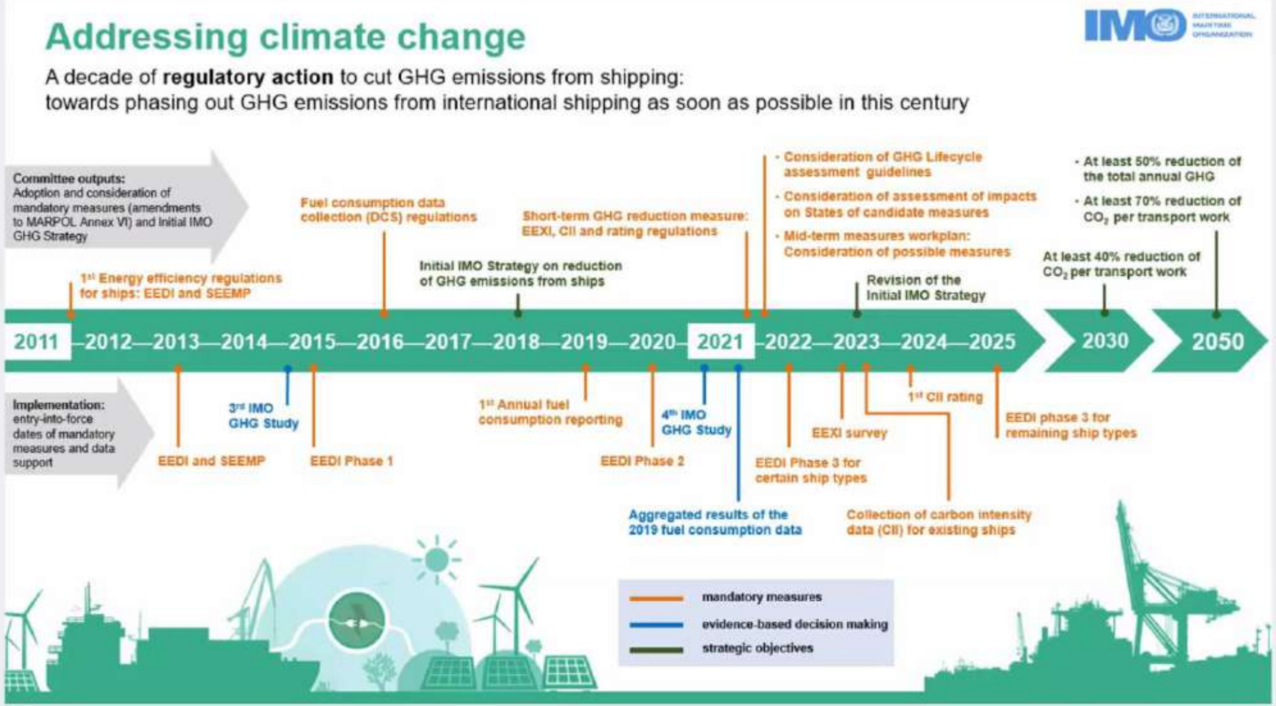
Singapore, October 6TH 2021

Martial CLAUDEPIERRE
Sustainable Shipping

AGENDA

- Emissions regulation background
- EEXI and CII future impact on shipping
- Alternative fuels and propulsions
- Q/A

Context: a decade (2011-2021) of mandatory IMO energy-efficiency requirements in MARPOL



See: https://www.imo.org/en/MediaCentre/HotTopics/Pages/Cutting-GHG-emissions.aspx

SUSTAINABLE SHIPPING FOR A SUSTAINABLE PLANET

01 Emissions regulation background

GHG reduction in shipping – IMO Timeline 2021 – 2050

2021

IMO NOx
North Sea & Baltic Sea ECA enters into force on 1 Jan (tier III)

2022

IMO EEDI phase 3
Phase 3 enters into force on 1 Jan (up to 30% reduction)

2023

IMO SEEMP
Enhanced plan

IMO EEXI and CII
for existing ships

IMO RATING MECHANISM

2025

IMO EEDI phase 4
Under discussion

2030

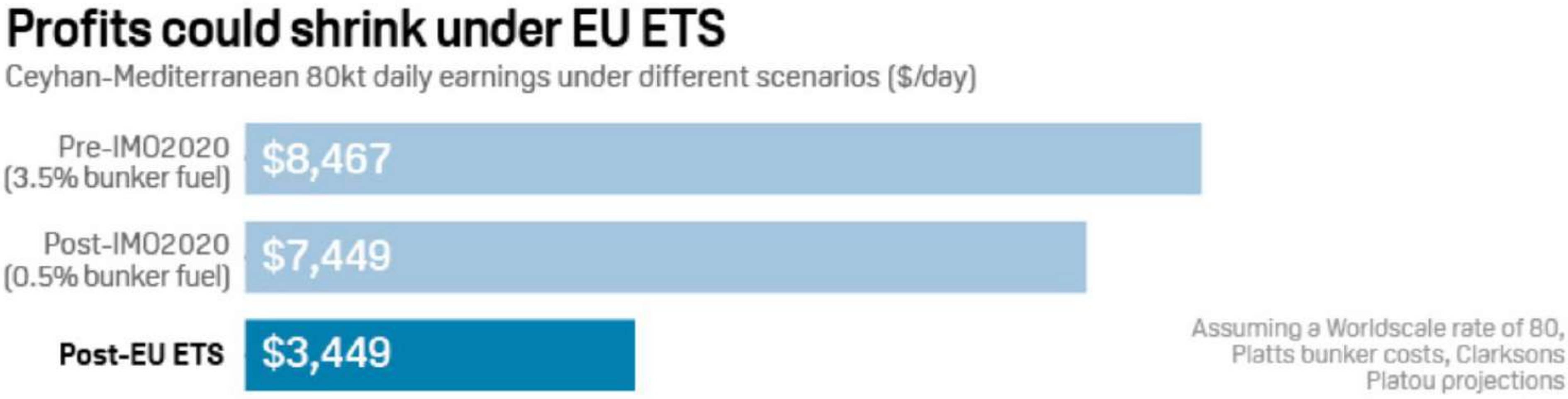
IMO CO2
Reduction of CO2 emissions per transport work "intensity" by at least 40% compared to 2008

2050

IMO GHG
Reduction of the total annual GHG emissions by at least 50% by 2050 compared to 2008 and CO2 reduction by 70%

EU Emissions Trading Scheme

Impact on industry might be significant



(source S&P Global Platts)

The shipping industry, which represents 13% of total EU greenhouse gas emissions, is likely to be under EU ETS rules as early as 2024.

02 EEXI and CII

Adoption of CO_2 reduction measures - MARPOL Annex VI Ch4

1) **Technical** : EEXI for existing ships calculation similar to EEDI formulae and same scope of ship types, passengers and cargo ships above 400 GT

- Attained EEXI < Required EEXI (=EEDI phase 2 or 3 depends on ship type and GT).
- Applicable at first annual intermediate or rebnewal IAPP survey after 1st Jan 2023.

2) **Operational :**

2.1) Enhanced "decarbonation" SEEMP with mandatory reduction target to reduce emissions diuring operations for all ships above 400 GT. (Ship management plan to improve energy efficiency)

2.2) Carbon Intensity Indicator CII; apply to passenger and cargo ships above 5000 GT. Rating scheme from A to E, one year E or three consucutuve D ratings require implementation of corrective action.

MARPOL ANNEX VI CHAPTER IV

MEPC75 outcome:
extension of EEDI
to existing ships

MARPOL ANNEX VI
chapter 4

Application 19
19A, Goal
19B, Functional Requirement

MEPC75 outcome:
Mandatory reduction target for operational emissions (CII, CII rating)
Enhanced SEEMP

TECHNICAL
Carbon Intensity Requirement by Design

OPERATIONAL
Carbon Intensity Requirement In Operations

Regulation 22
SEEMP

NewBuilt

Regulation 20
Attained **EEDI**

Regulation 21
Required **EEDI**

Ships in Service > 400 GT

Regulation 22A
Collecting & reporting of ship fuel oil consumption

Regulation 22B
Operational Carbon Intensity **CII**

Ships in Service > 5000 GT

Ships in Service > 400 GT

Regulation 20A
Attained **EEXI**

Regulation 21A
Required **EEXI**

Part I: Ship management plan to improve emergency efficiency **(SEEMP)**

Part II: Ship fuel oil consumption data collection plan **(DCS)**

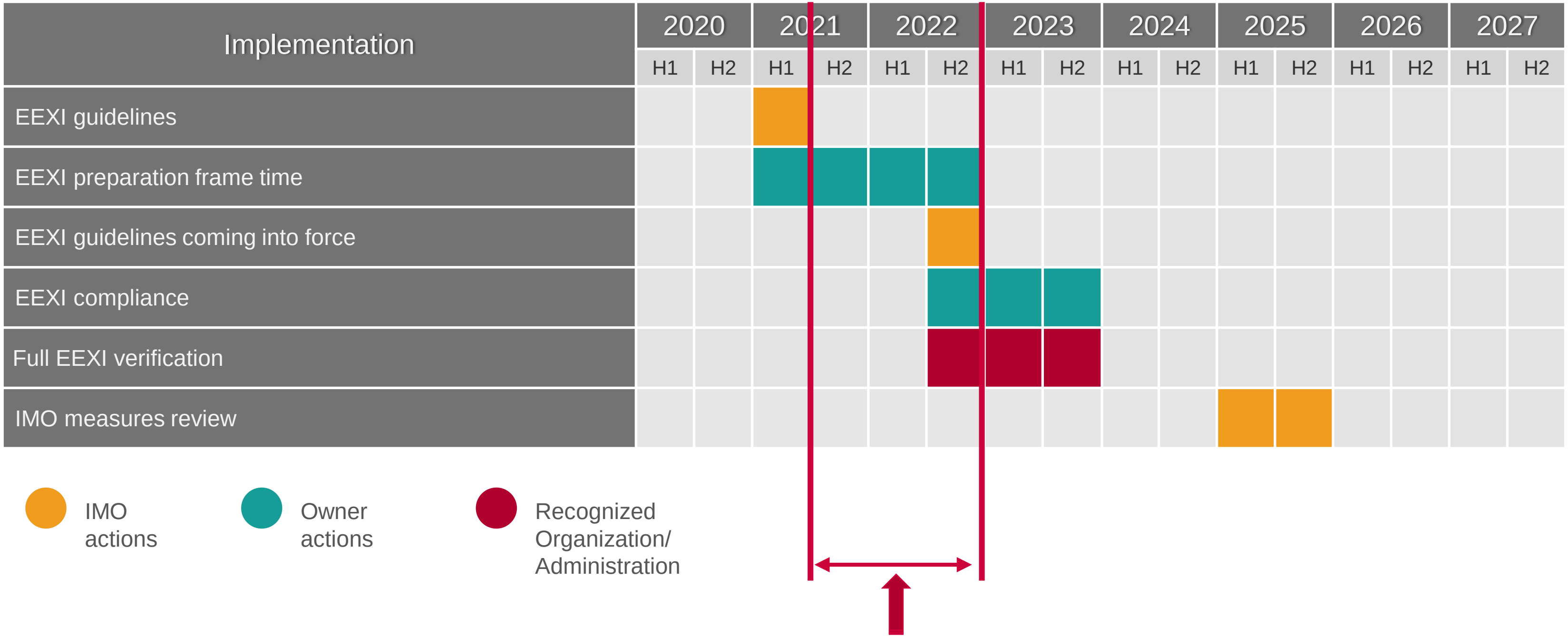
-Attained annual **CII**
-Required **CII**
-Operational **CII rating** (A,B,C,D,E)
-Corrective action and incentives

INTERNATIONAL ENERGY EFFICIENCY CERTIFICATE (IEEC)

EEXI – SUMMARY

- Overall **~70% post EEDI ships are expected to be compliant « as is »**
- For non-compliant ships, **EPL/ShaPoLi is likely to be the easiest compliance option**
  - The required engine power limitation (EPL) to achieve compliance is **in most cases above the actual engine load factors that are currently common in practice**
- **Efficient designs** will have some **competitive edge** if chartering requirements request increased speed compared to current practice
- **ESDs may be beneficial** for cases of small EEXI exceedance **and more complicated retrofits hull/machinery** may offer increased benefit
- Potential for **disruption to the LNG Carrier** market exists as **Steam turbine** driven vessels (1/3rd of total fleet) are seriously affected

EEXI APPLICATION TIMELINE
PREPARATION IN 2021-2022, VERIFICATION IN 2023



Important to be prepared and have EEXI technical file ready for submittal

CII FORMULA
(OPERATIONAL) CARBON INTENSITY INDICATOR

Actual annual CO_2 Emissions (DCS)

$$CII = f\frac{CO2\ Emissions}{CapacityxDistance}$$

Actual annual Transport work

$$AER = \frac{\sum CO_2}{DWT_{max} \times Distance}$$

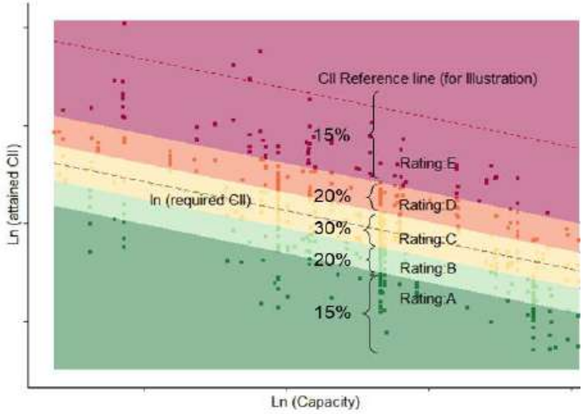
AER = supply (capacity) based CII,
EEOI = demand (cargo weight) based.

For a containership it is hard to define EEOI in terms of actual transport work, as the cargo in containers for example can be volume limited or weight limited, or even empties.

By using AER, the industry is seen to have been less effective in comparison to 2008 than is the case when considering EEOI. As a consequence cargoships will have to reduce CII by a substantial amount

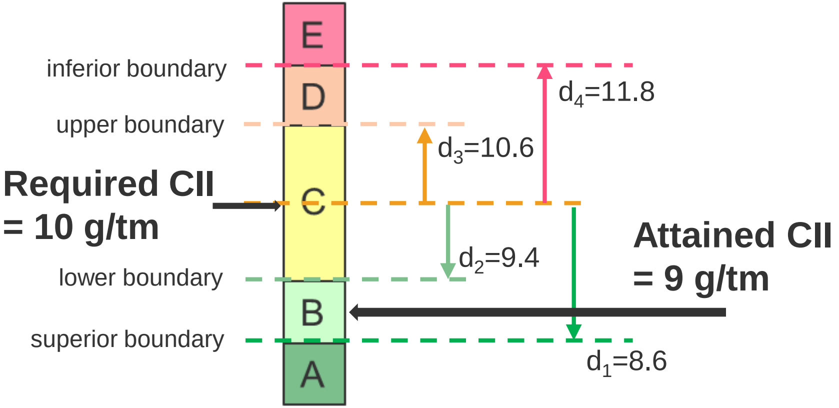
CII RATING METHODS
PRINCIPLES AND EXAMPLE ILLUSTRATION

Principles



- Symmetry in C rated vessels
- Differences amplified in the smaller vessels
- The distribution is skewed towards the C, D & E rated ships

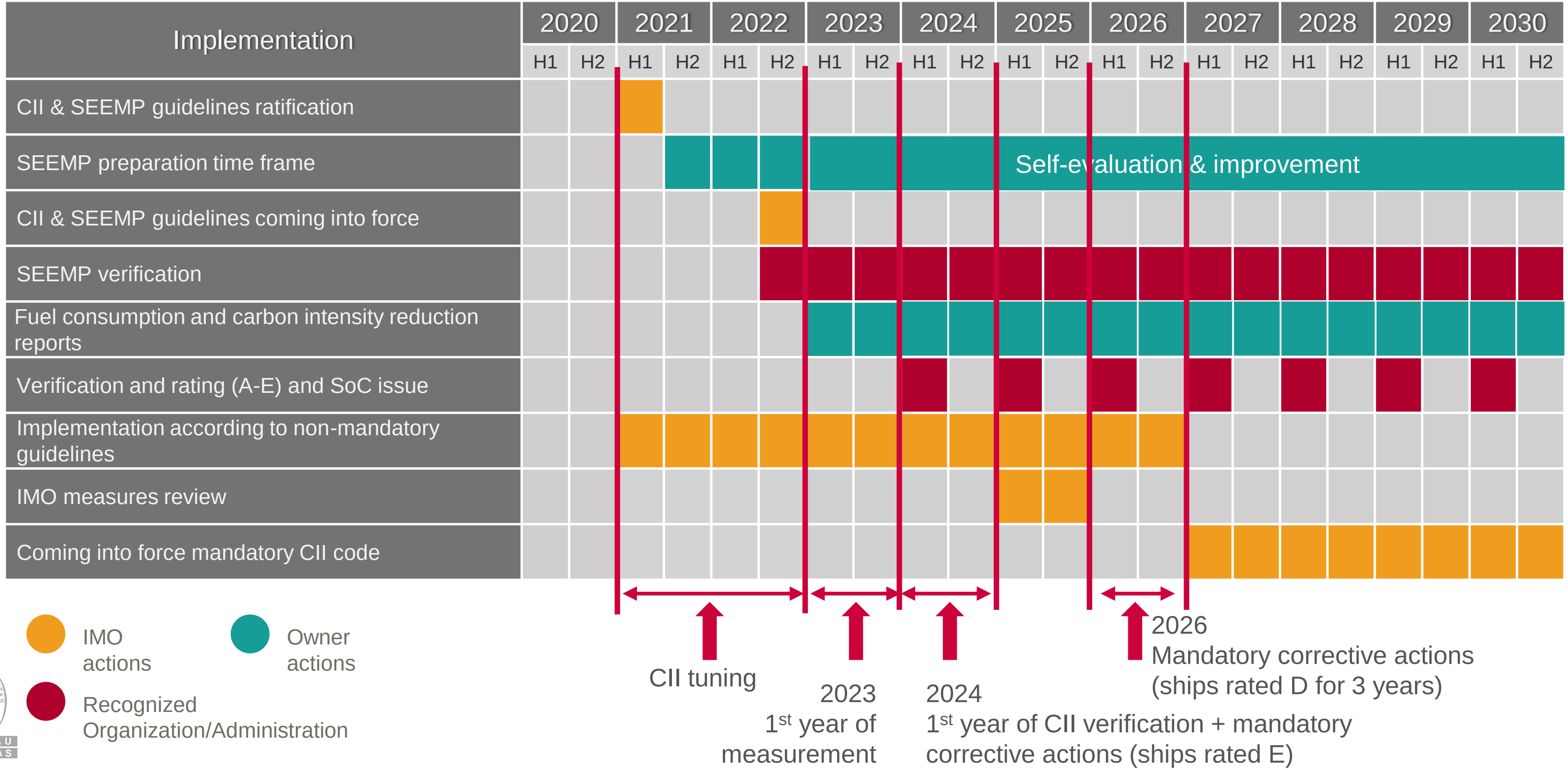
Worked example for "B" bulk carriers:



$exp(d_1)$	$exp(d_2)$	$exp(d_3)$	$exp(d_4)$
0.86	0.94	1.06	1.18

CII APPLICATION TIMELINE: VERIFICATION IN 2024

CORRECTIVE ACTIONS IN 2025



CII EXEMPTIONS FOR SPECIFIC VOYAGES

- Sailing in **ice conditions**

- **No transport work or distance travelled for a prolonged period** such as
  - Lay-up
  - Drydock or stop for technical repairs
  - Waiting time due to port congestion.

- Sailing in **sea states** at or more severe than Bf 7 or Bf 8.

- **Dynamic positioning operations** of shuttle tankers during cargo loading at offshore locations

CII TAKEAWAYS

Scenario for Reduction Rate still under discussion – **with impact x2** between the 2 combinations

If ship performance remains unchanged, **5%-10% is expected to shift to non-compliance by 2023 and 15-30% by 2030** assuming **demand-based rating** scenario.

The latter figure could be increased to **55%** if the **supply-based rating** scenario will prevail.

Specific exemptions are planned to account for **specific sea conditions** (ice, severe weather) and **ship operations** (cargo handling, DP, port waiting time, etc.)

Many options exist to reduce CII (both design and operational). They will require careful consideration of their suitability and ROI.

BUREAU VERITAS

Additional medium-term measures at IMO

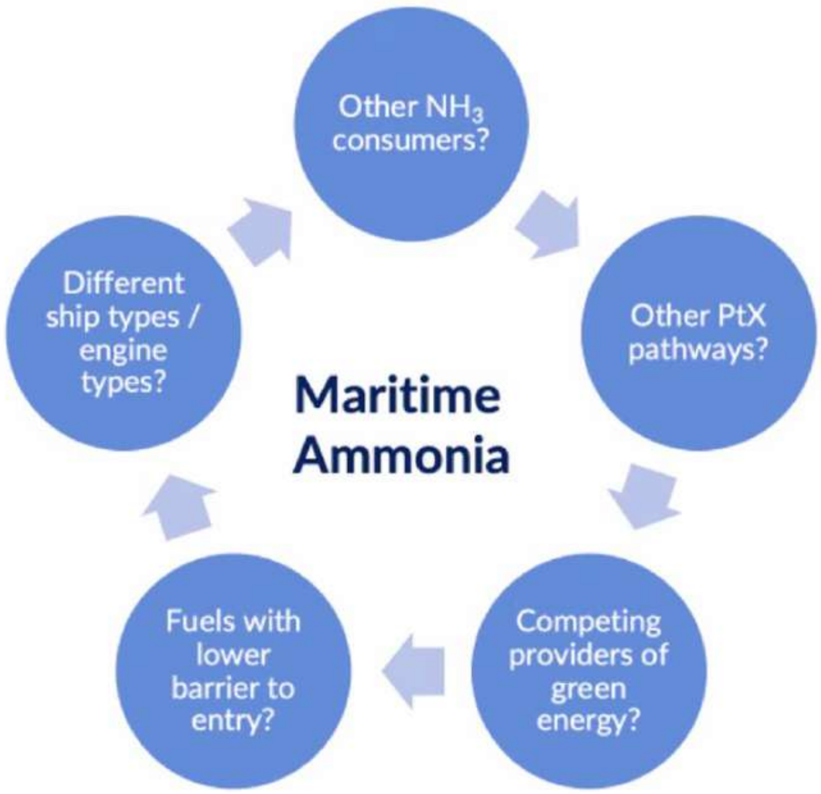
- Proposed the establishment of an International Maritime Research and Development Board (IMRB), a non-governmental R&D organization that would be overseen by IMO Member States.
- GHG and carbon emission factors for fuels in units of carbon dioxide equivalent (CO2e). Gases are converted to CO2e by multiplying by their global warming potential (GWP)
- LCA application with specific carbon factors (WtW)
- New methane emission regulations
- Possible phase 4 of EEDI requirements

03 Alternative fuels and propulsions systems

SOME RECENT ANNOUNCEMENTS …

zero carbon fuels as ultimate fuels of choice ?

The overall energy transition is mobilising all industry sectors. For green ammonia, as a maritime fuel, and as an energy carrier or industrial ingredient carried on ships, how is this opportunity enabled or challenged by the external perspective?



Alternative fuels energy density and storage characteristics

Fuel type	Mass energy density LHV [MJ/kg]	Volumetric energy density LHV [GJ/m3]	Storage pressure [bar]	Storage temperature [°C]	Relative tank volume (without insulation)
Marine Gas Oil	42.8	36.6	1	20	1
Liquid methane LNG	50.0	23.4	1	-162	1.6
Ethanol	26.7	21.1	1	20	1.7
Methanol	19.9	15.8	1	20	1.7
Liquid Propane	50.3	26.7	1 to 7	-42	1.4
Liquid Ammonia	18.6	12.7	1 to 10	-34	2.9
Liquid Hydrogen	120	8.5	1	-253	4.3
Compressed Hydrogen	120	7.5	700	20	4.9
LNG and Carbon Capture Storage Onboard	50.0	23.4	1	-162	3.2 (1.6 + 1.6)

Alternative fuels – pricing

Green ammonia and grey ammonia as shipping fuel are non -existing markets, so a price/value is difficult to estimate.

Fuel type4	US$/To n	$/cbm	MWh/T on (LHV)	US$/MWh (LHV)	Logistic cost US$/MWh	Total cost US$/MWh
HFO 180 (+scrubber)	450		11.2	41	1.8	36
MGO	800		11.9	54.0	1.7	56
LSFO 0.1%	600		11.25	52.1	1.8	54
LNG (TTF) long term contract	-		13.7	19.5	6.5	26
Bio LNG	-		13.7		6.5	80
Ammonia (grey)	450		6.25		12	82
Ammonia (green)	800		6.25		12	162
Methanol			5.5		unknown	90
LH2			33		unknown	92

LNG is a viable and effective low carbon marine fuel as of today

LNG is fully compliant with all global Emission Control Areas (ECAs) and the IMO's global sulphur cap, and future-proofs ship owners against more stringent local emissions regulations.

The use of LNG cuts greenhouse gases (GHGs) by up to 20% on a tank-to-wake basis and it offers a **potential decarbonisation pathway** for shipping via liquefied biomethane, produced from biomass, or liquefied synthetic methane, produced from renewable electricity.

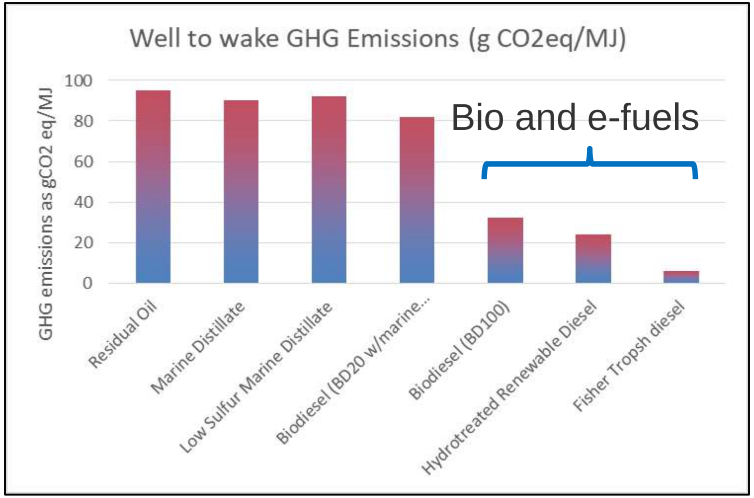
Chronology of LNG bunker vessels projects

LNG Bunkering in Singapore

Singapore is one of the largest fuel bunkering hubs in the world as a result of its location on several major shipping routes, the efficiency of its bunkering operations, the attractiveness of prices and the availability of products. To be ready and maintain this competitive edge in LNG and other aternative fuels it is of utmost importance to test and engage feasibility of bunkering.

Building the LNG transition CMA CGM JACQUES SAADE and TOTALENERGIES GAS AGILITY

“Drop-in” bio fuels and e-fuels - Lifecycle CO2 (WtW) emissions



Source: US ORNL Biofuels for Marine Shipping 2018

“ElbBLUE“ is the world’s first ship using **synthetic natural gas (SNG)** when it received approx. 20 tons of the fuel in the Elbehafen in Brunsbüttel. The bunkering is a joint project of MAN Energy Solutions, the shipowner Elbdeich and the charterer Unifeeder. The trio aims at demonstrating the potential for the use of climate neutral fuels in shipping.

Onboard Carbon Capture Systems (CCS) – A transition technology ?

Involvement in EU funded R&D project

- Total E & P Norway AS
- TNO, Conoship, etc., BV and other class societies
- Project involves among other ships an existing LNGc

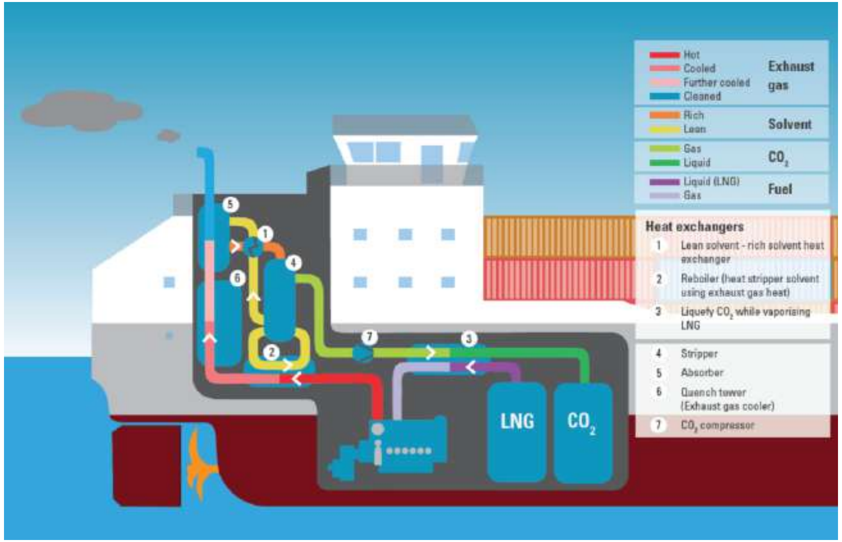
BV presently in JDP specific for new LNG carrier design

Some hurdles may be

- Required extra space and weight
- Energy efficiency of the overall system
- Storage of the CO_2 and disposal to shore

In principle CCS seems to be simple, but

- No experience in ships yet
- Few companies involved
- Korean yards developing their own concept



Ammonia as fuel VLCC JDP

Pursuance of technical feasibility based on NR671

BUREAU VERITAS

→ Risk based feasibility study

- Identify safety & operational hazards associated with ammonia fuel storage and propulsion engine on VLCC
- Determine safeguards & recommendations
- Study scope
  - NH_3 storage space & bunker stations
  - NH_3 fuel treatment/HP fuel pump room
  - Engine room (gas-safe)
  - Vent/safety system, incl. vent mast

MAN Energy Solutions, SAMSUNG HEAVY INDUSTRIES, TotalEnergies, GASLOG, Stena Bulk, STOLT-NIELSEN, MÆRSK, STAR BULK, equinor, CAPITAL, GTT Expert in LNG, DFDS, MTG, NYK LINE, ALFA LAVAL, sgmf, CMB, EXMAR, EURONAV, ENGIE, TORM, C-JOB, MOL

→ Next projects engaged

- Design concept evaluation of VLCC DF AIP

Methanol as fuel and NI670

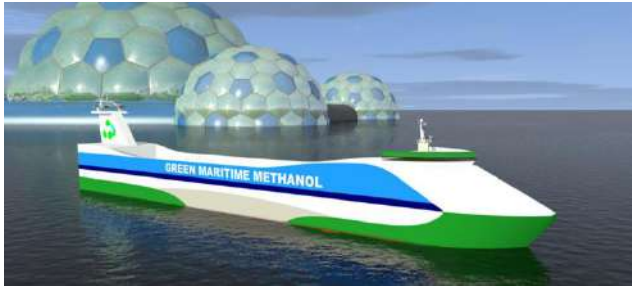
project consortium green maritime methanol

→ Methanol as marine fuel

- Experience of use of black methanol onboard ships, either ferries or methanol carriers.

→ Renewable methanol as low carbon marine fuel

- Applied R&D for 9 selected ships
  - New designs, newbuildings & existing ships
  - Cargo ships, ferries, dredgers & coastal (offshore) support vessels
- Ship owners
  - Boskalis
  - Van Oord
  - Royal Netherlands Navy
  - Wagenborg Shipping
- Vessel ranges:
  - 40 – 160 m Loa
  - 300 – 23,000 GT
  - 1 – 12 MW installed power
- 26 partners, including Bureau Veritas



Hydrogen as fuel value chain

H2 Offshore Production

Hydrogen Production:
- Renewable Hydrogen,
- Low-carbon Hydrogen
- Fossil-based Hydrogen with CCS
- Fossil based Hydrogen

H2 Marine Storage

Hydrogen storage on-board:
- Gas
- Liquid

H2 Marine Transport

Hydrogen transport :
- CH2 carrier
- LH2 carrier
- Subsea pipelines

H2-as-Marine-Fuel Bunkering

Bunkering station on-board

Bunkering ship

Other bunkering onshore infrastructures

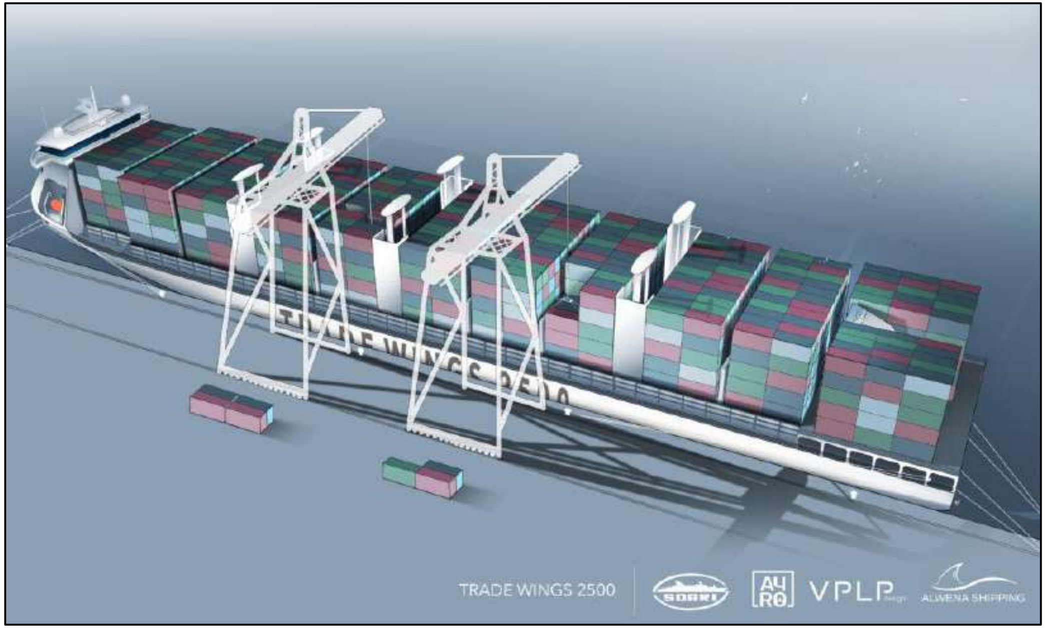
H2-As-Marine-Fuel Usage

Energy converter:
- Fuel cell
- ICE

Hydrogen usage:
- Essential services
- Non-essential services

For the avoidance of doubt the services performed by either BV or BVS shall be delivered through separate contracts, delivery teams and legal entities in order to clearly differentiate the services rendered by BV from the services rendered by BVS and presented herein

Wind assisted propulsion



→ Technology options

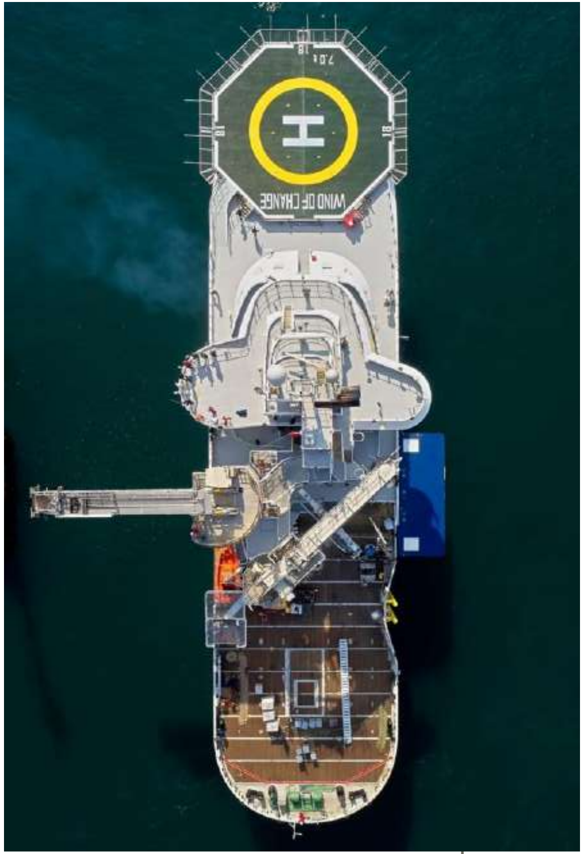
- Sails, rotors, kite sails
- Main propulsion, assisted main prop
- Foldable, rigid
- Come with weather routing for trade route optimisation
- In service, at test level, on design

→ Challenges

- Testing, qualification, how to reflect in EEDI or EEXI ?

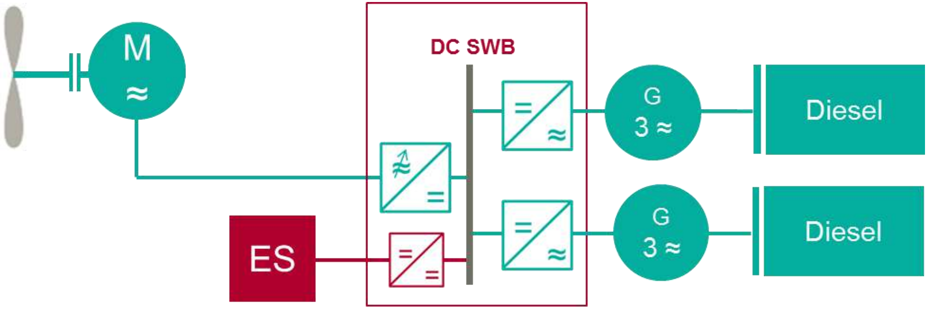
Hybrid and full electric ships

Energy storage systems (ESS) key to success



→ Electric ships with batteries

- Minimize fuel consumption/emissions over operating range
  – Efficient for ships with high load variations (e.g. OSV, tug)
  – Suitable for “plug-in” additional power sources (e.g. wind, solar, fuel cells)
- Operational modes:
  – Power back-up (PB mode)
  – Zero-emission (ZE mode)
  – Power management (PM mode), e.g. peak shaving
- BV class notations **ELECTRIC HYBRID()** & **BATTERY SYSTEM**



Strategy on reduction of GHG emissions from ships

Hydrogen will be the backbone of ultimate decarbonization

- Hydrogen (compressed or liquefied) in a multi fuel approach firstly– later main fuel

- –Ammonia as hydrogen carrier for large ocean going vessel easier to handle (ICE firstly – later large SOFC)

We are still at the learning curve : concept design, approval, guidance, pilots projects,

There are a lot of niches and pressure is **increasing on sustainability** thus creating opportunities.

MOL Wind Challenger

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