Charting the course to a net-zero maritime future through pilots and trials

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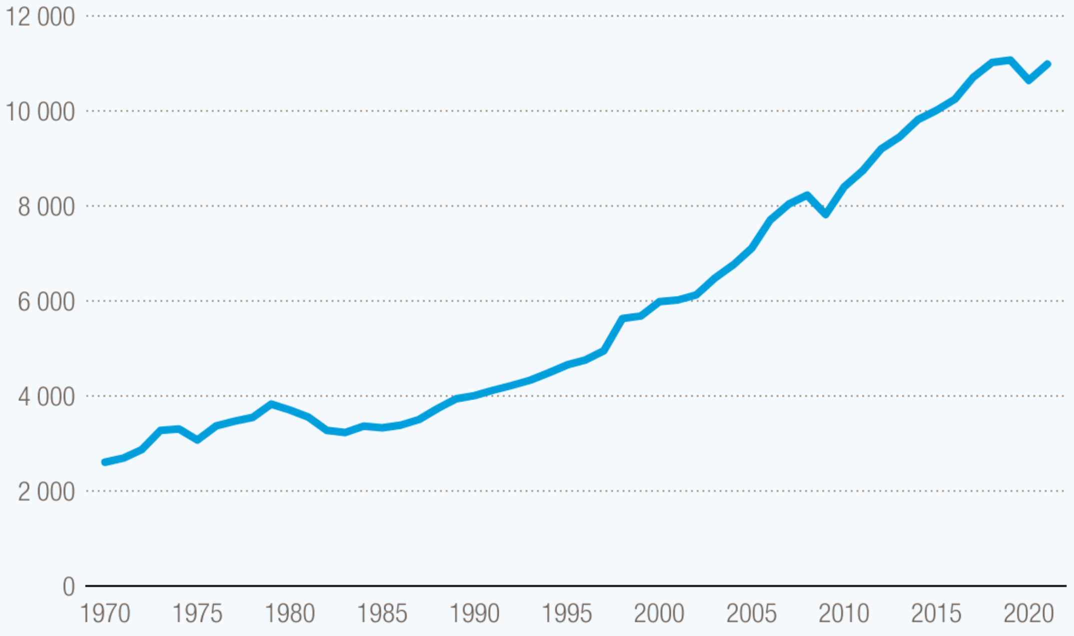
Shipping is a global industry

The rising tide of seaborne trade over the decades

Total goods loaded in world seaborne trade, millions of metric tons, 1970–2021



Source: UNCTADstat

+ Responsible for transporting **11B tons** of goods annually, or **80%** of global trade

+ Contributes to **2.5%** of global GHG emissions, greater than the emissions of the sixth largest emitter (Germany)

+ IMO targets (2023 revised strategy)

  Targeting **20%**, striving for **30%** emissions reduction by **2030**

  Targeting **70%**, striving for **80%** emissions reduction by **2040**

  Net zero around 2050

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Shipping's emissions are difficult to abate

Shipping is **heterogeneous,** requiring a heterogeneous set of solutions

5,855 container

13,182 bulk / cargo carriers

20,553 general cargo

12,309 crude oil tankers

54,816 others

Source: unctadstat.unctad.org (2023)

Ecosystem for maritime decarbonisation **not mature**

Existing solutions cannot get shipping to net-zero

Alternative fuels not available at cost or scale

5% of shipping's **fuel** must have zero emissions by 2030

15.8M tons
heavy fuel oil

must be replaced with

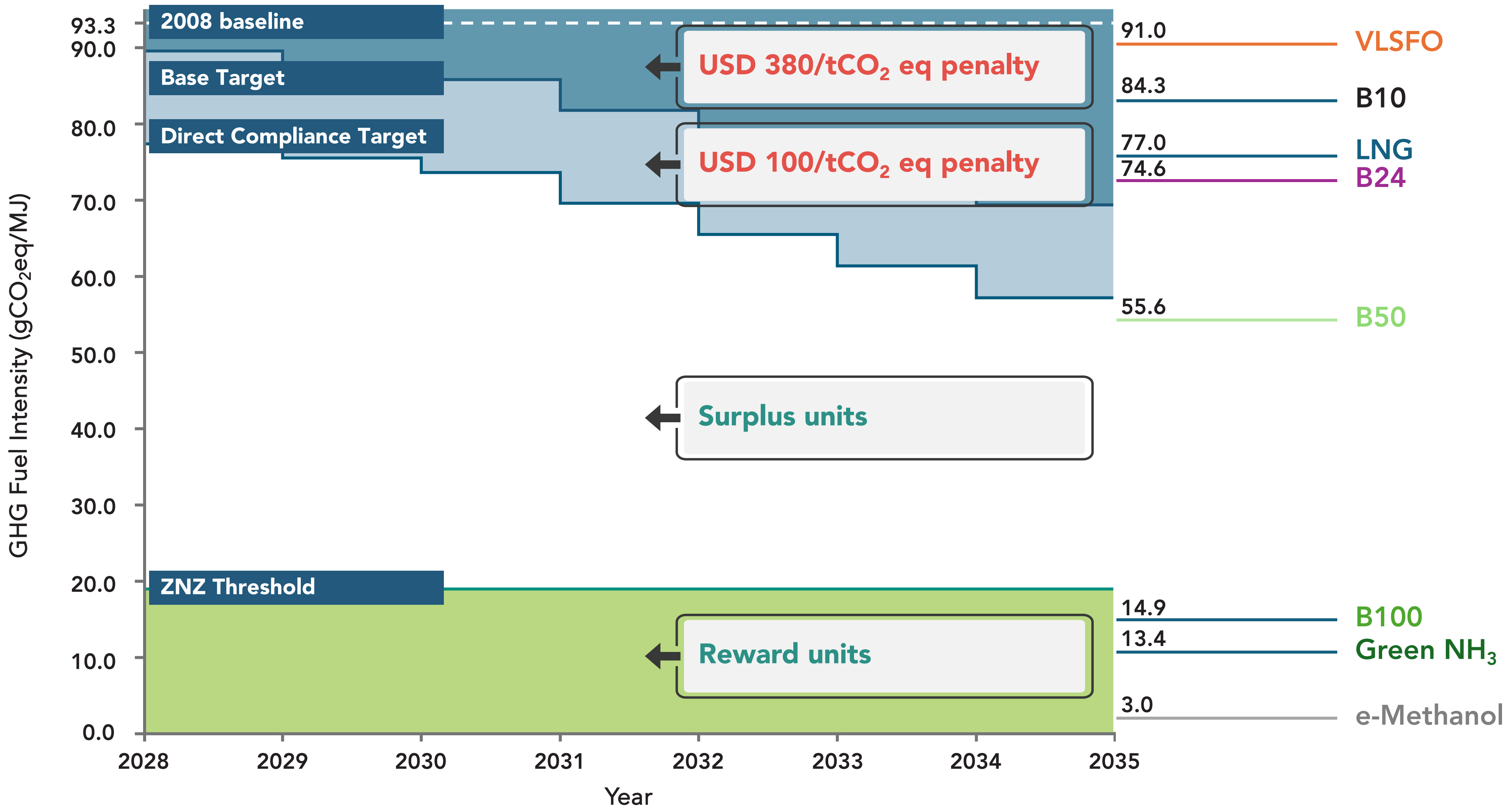
≈ 36.5M tons
ammonia/ methanol

NH_3 CH_3OH

Source: GMF, 2021, Getting to Zero Coalition

IMO's adopts landmark measure to price GHG emissions

Clearest signal yet: Switch fuels to minimise operations cost



Energy source + savings impact emissions penalties

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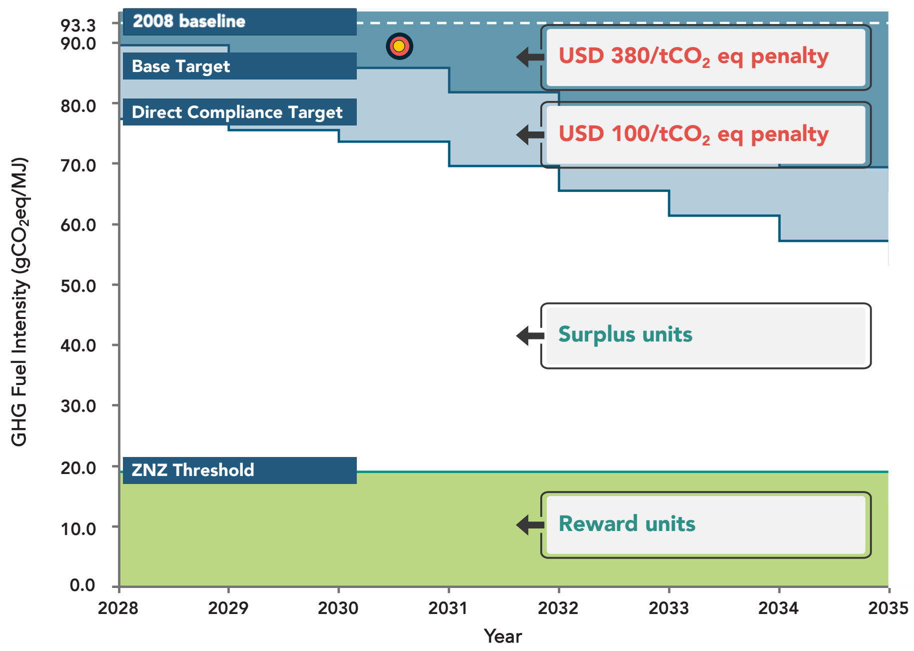
01 Energy savings

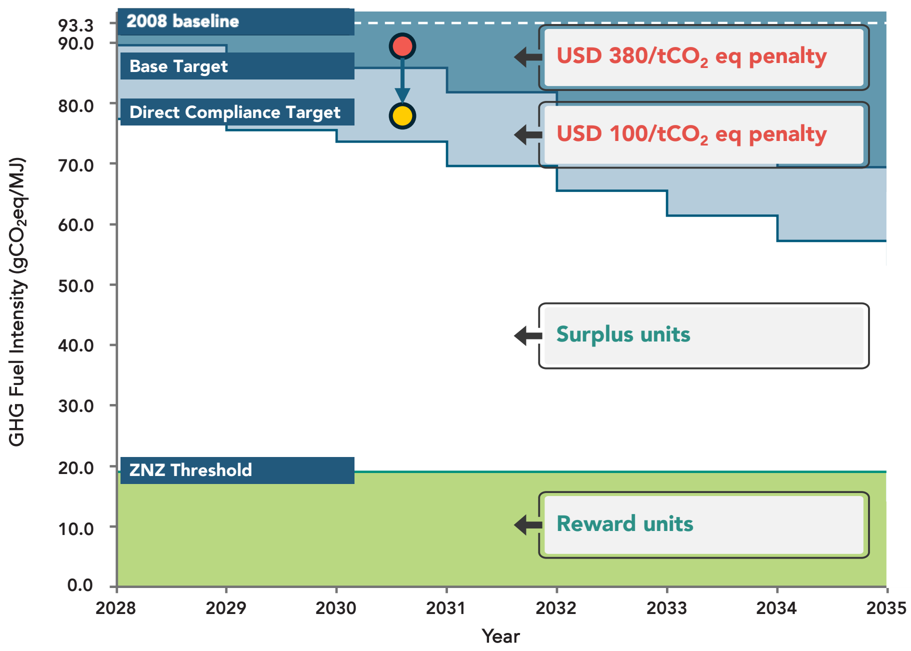
- Advanced hull coatings
- Air lubrication
- …



Energy savings lower penalties **linearly**

02 GFI of energy used

- Fuel switch
- Drop-in fuels
- Wind and solar energy



Reduction in **GFI** lowers penalties **disproportionately**

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Implications of IMO's GFI framework

Existing vessels can minimise fuel and compliance costs by progressively introducing drop-in fuels
Transition to new builds that consume ZNZ fuels hinges on price of Reward units

Drop-in fuels

Bio-diesels will be adopted sooner and more widely; **bio-methane** a pathway for LNG-fuelled vessels

Penalties + rewards

Price of **Surplus units** will set ceiling price for alternative fuels; need appropriately priced **Reward units** to spur ZNZ fuel adoption

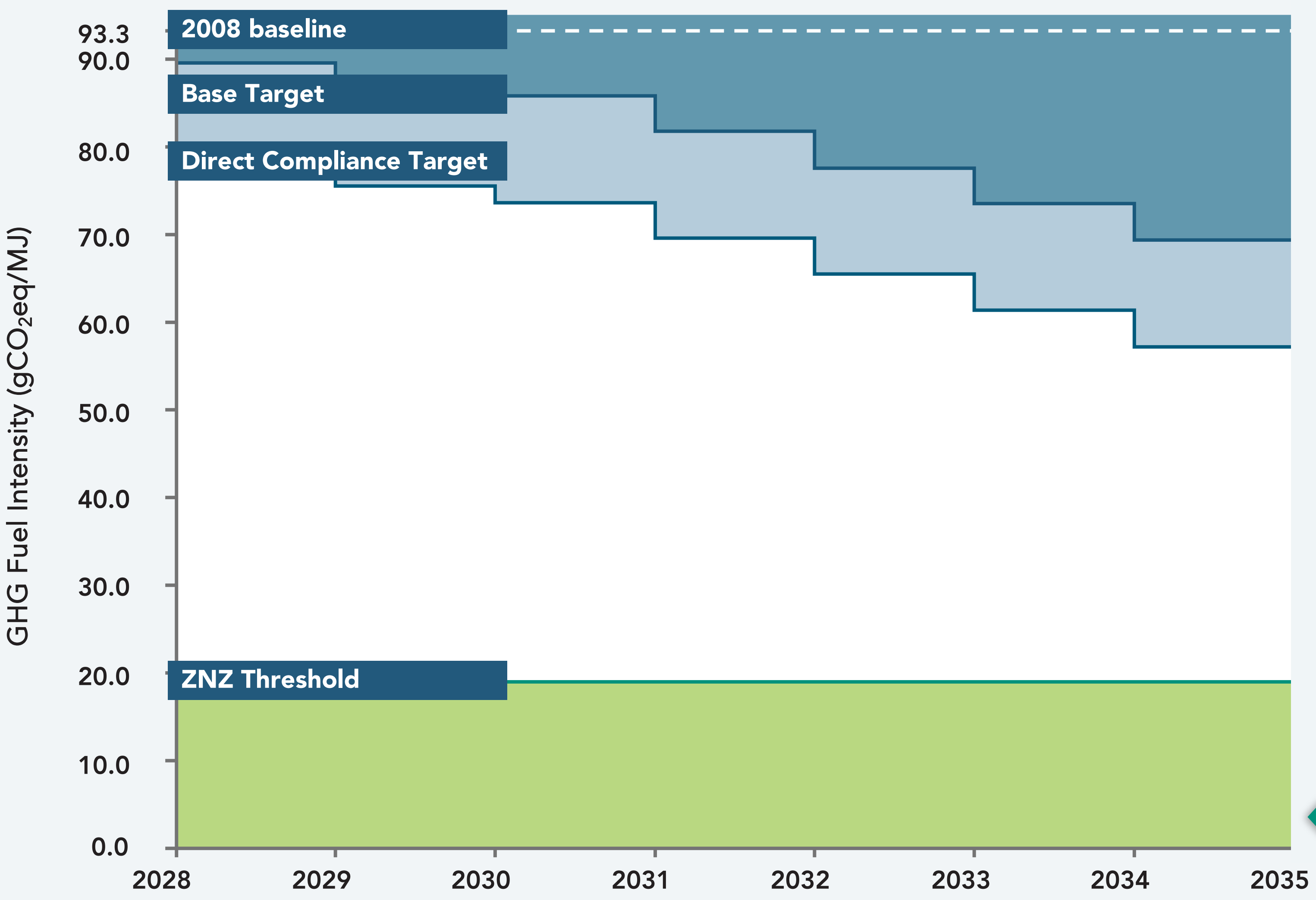
Other energy inputs

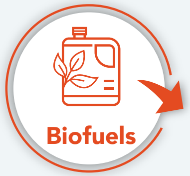
Wind and **solar** treated as energy inputs; outsized impact to reduce penalty cost

Timing

Timing is everything! Pricing may encourage demand; **supply, infrastructure, ecosystem** need to keep up

Contextualising GCMD's efforts





Biofuels:
Bolster supply chain **integrity** and increase **user confidence** with assurance framework

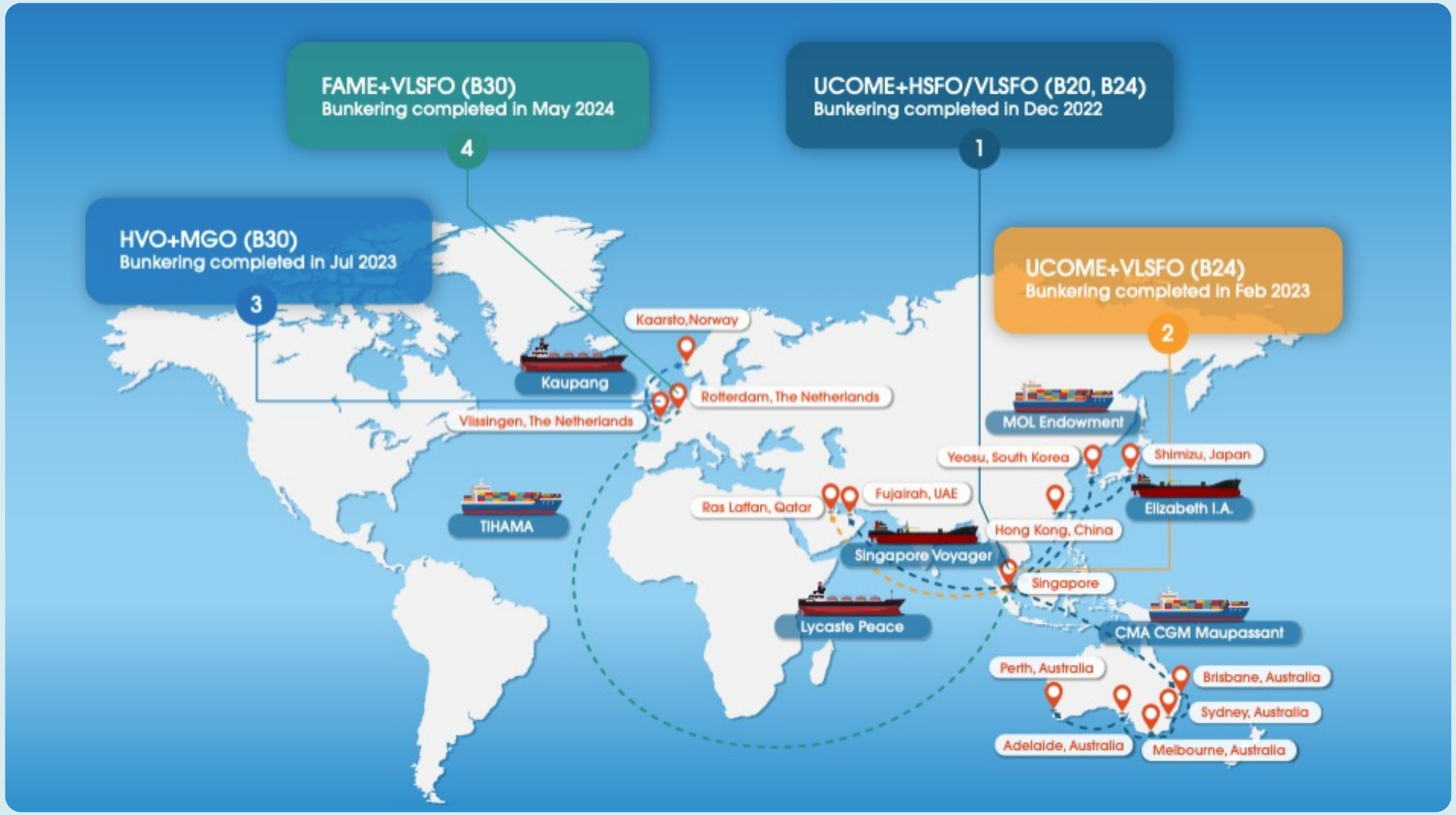
EETs:
Spur adoption of EETs, including those with **outsized impact** on emissions penalties

OCCS:
Demonstrate pathway for onboard **emissions removal** on a lifecycle basis

Ammonia
Readying the ecosystem for green ammonia, a ZNZ fuel

GCMD biofuels end-to-end supply chain trials

*9,400 MT of biofuel blends bunkered on seven vessels; **24% reduction** of GHG emissions*



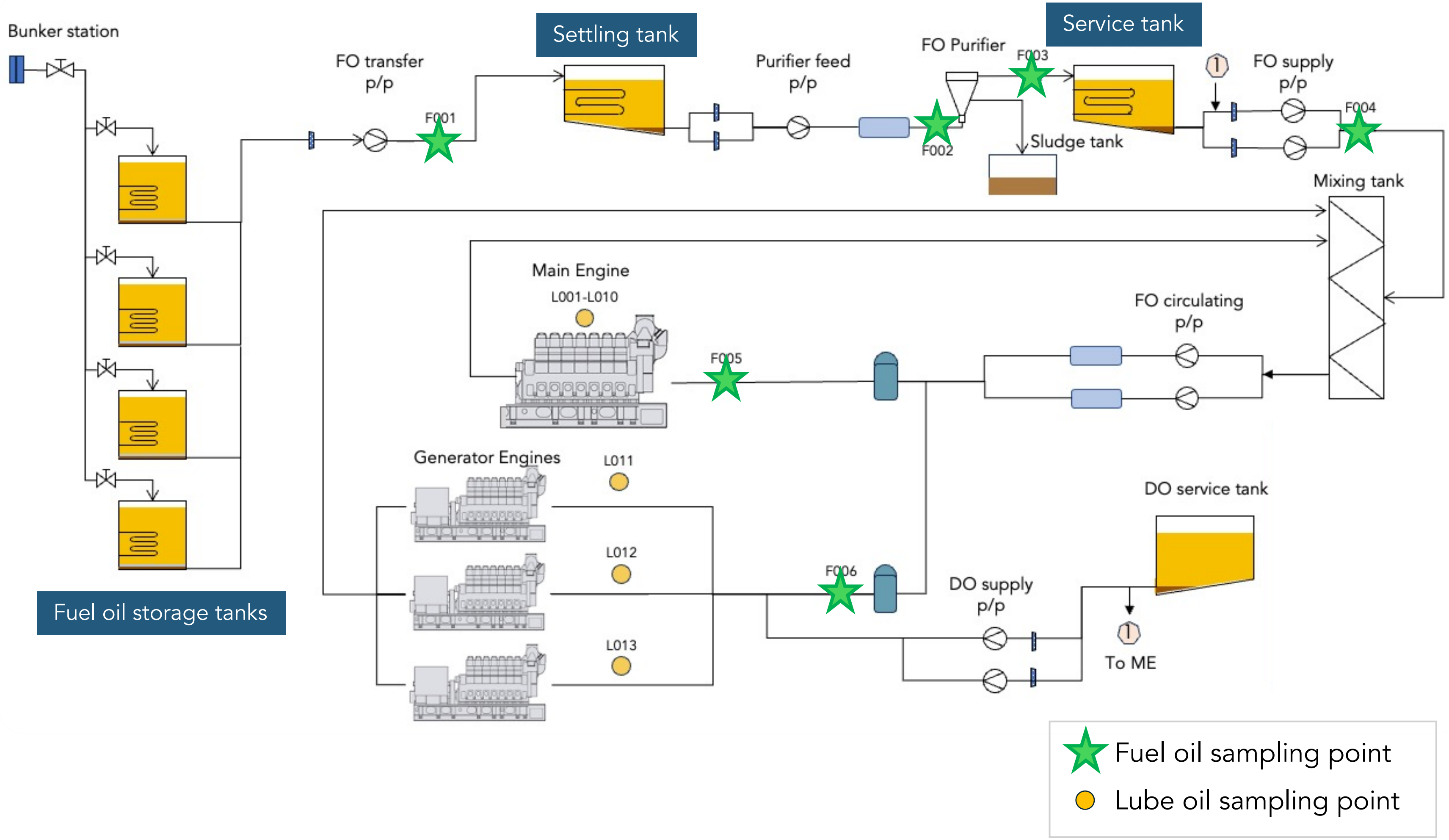
CAO: Crude Algae Oil
FAME: Fatty Acid Methyl Ester
HVO: Hydrotreated Vegetable Oil
HSFO: High Sulfur Fuel Oil
MGO: Marine Gas Oil
VLSFO: Very Low Sulfur Fuel Oil
UCOME: Used Cooking Oil Methyl Ester

Project partners

Angelicoussis Group, AngloAmerican, Astomos Energy, Authentix, BHP, BCG, bp, BunkerTrace, Chevron, CMA CGM, Control Union, Eastern Pacific Shipping, FincoEnergies, Hapag-Lloyd, IDS Group, MAN Energy Solutions, MTM Maran Tankers Management Inc., NYK Line, ONE Ocean Network Express, PIL, Saybolt, Stena Bulk, Swire Bulk, TotalEnergies, VPS, Viswa Group

Impact of continuous biofuels use on vessel operations

Four bunkerings of 1,000 MT each into two onboard storage tanks over six months



Project specifications

Vessel type	RORO car carrier
Vessel route	Southeast Asia
Biofuel blend	B24 (UCOME + VLSFO)
Vol. bunkered	4,000 MT
Fuel + lube oil sampling	Before + after each bunkering
Monitoring hours	+ Main engine: **2,947 hours** + Generator engine: **1,813 hours** + Fuel oil purifier: **> 3,000 hours**

Project partners

In operando sample monitoring + post-trial inspection revealed **no** major issues

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Engine inspection with OEM and classification societies

Engine performance

Main engine: **No significant issues detected**

+ Comparable to VLSFO at maximum continuous rating

Generator engines: **No significant degradation in performance**

Fuel delivery system

Fuel and lube oil samples: **No anomalies**

Purifier efficiency & filter change frequency: **Unchanged**

Fuel quality under long-term stowage (6 months)

ISO 8217 tests: **Within specs**

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Crude algae oil (CAO) engine compatibility tests

Results from Chevron's 4-stroke engine test; testing on 2-stroke engine ongoing

Key findings

B30 (CAO+VLSFO) is **stable**; no precipitation

No handling issues; water and sediments effectively separated via centrifugation

Compatible with 4-stroke engine; no observable increase in deposit formation compared to VLSFO

Project partners

AVL

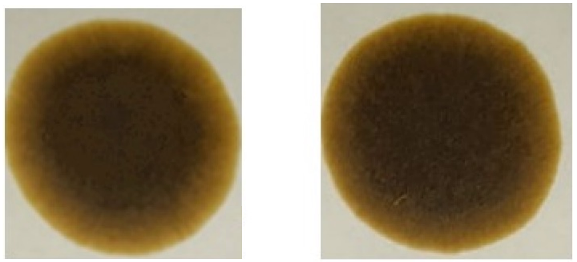
Chevron

FincoEnergies

汇盛生物 HUiSON

Saybolt
A CORE LABORATORIES COMPANY

Spot test: B30 and VLSFO

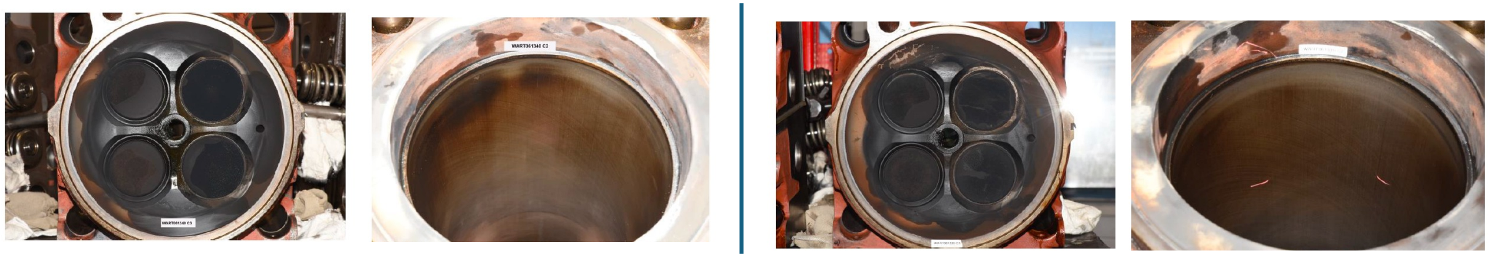


B30 VLSFO

Injector tip: After 120 hours of continuous operation

B30 VLSFO

Cylinder cover and liner: After 120 hours of continuous operation



B30 VLSFO

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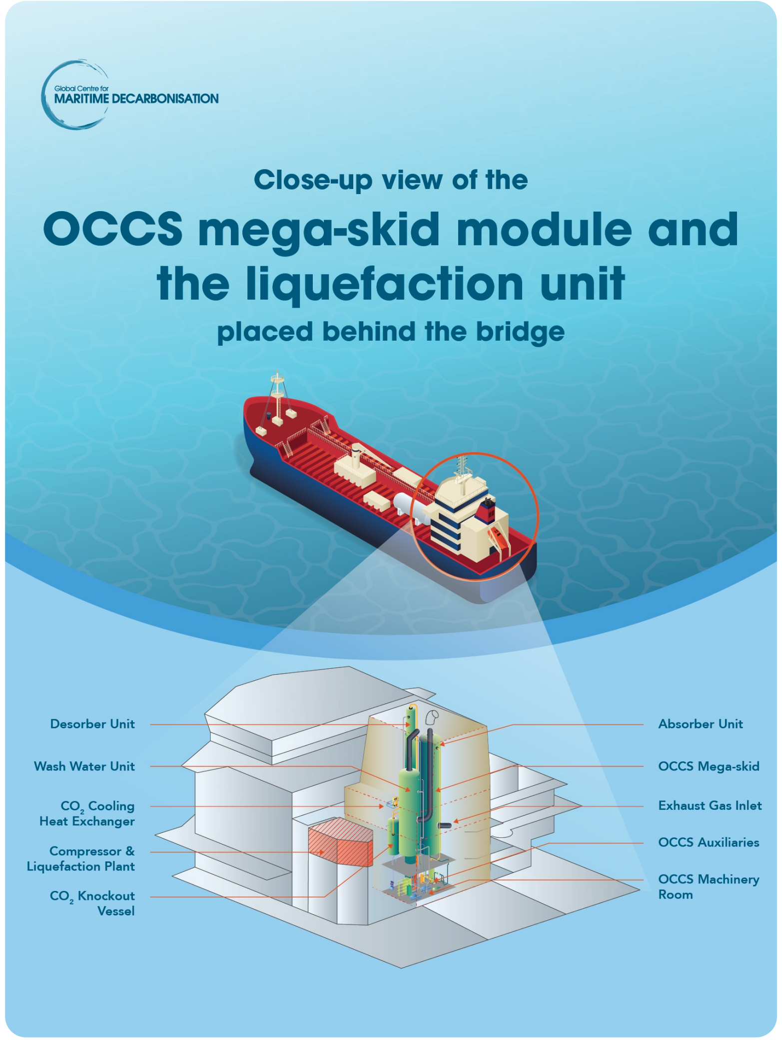
Project REMARCCABLE

Retrofitting an OCCS system on the Stena Impero



Analysis carried out on the

Stena Impero, a Medium Range tanker

Vessels of similar size contribute 17% of shipping's emissions

Emissions analysis

CO_2 emissions can be reduced by as much as **24% per year**

With fuel consumption penalty of under 10%

Cost analysis

CAPEX
USD 13.6M (+/-15%)
OPEX
USD 830K per year
Total abatement cost
USD 769/tCO_2

Carbon intensity indicator (CII) analysis

Extends CII rating of "C and better" for the **remaining nine years** of vessel life[1]

With OCCS retrofit

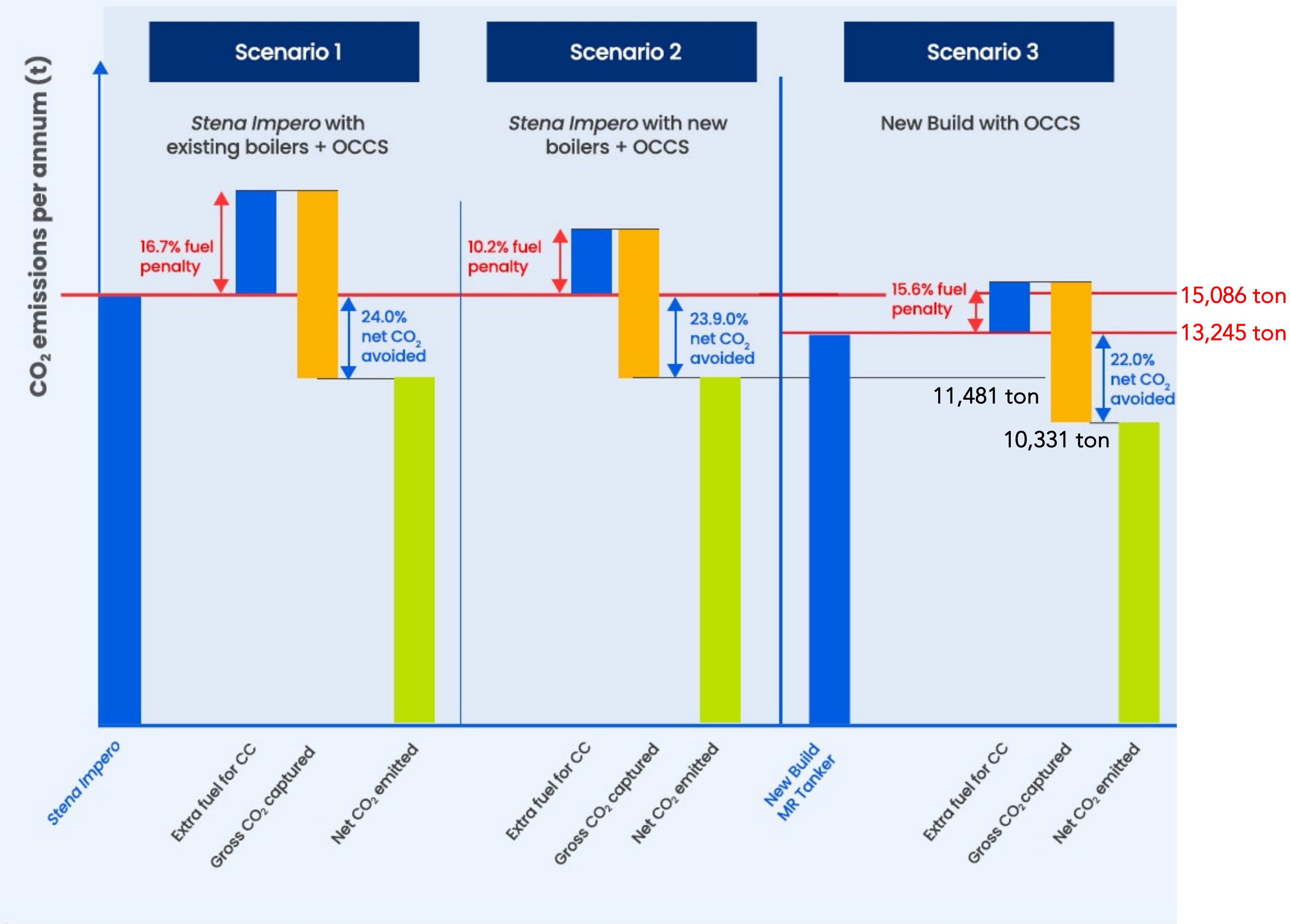
[1]Assuming a Carbon Intensity Indicator (CII) reduction factor of 2% from 2027 onwards

Project partners

OGCI – Oil and Gas Climate Initiative
Stena Bulk
TNO innovation for life
Alfa Laval
Deltamarin
ABS
LR
Seatrium

Energy needs for OCCS: an opportunity for re-optimisation

OCCS requires ***1250 kWth*** *and* ***200 kWe****; electrical power adequately supplied by auxiliary engine(s)*



Existing boilers

- Waste heat from main engine already being recovered and used; **no excess thermal energy**
- **16.7% fuel penalty** to general thermal energy for OCCS

With steam economiser + 2x microboilers

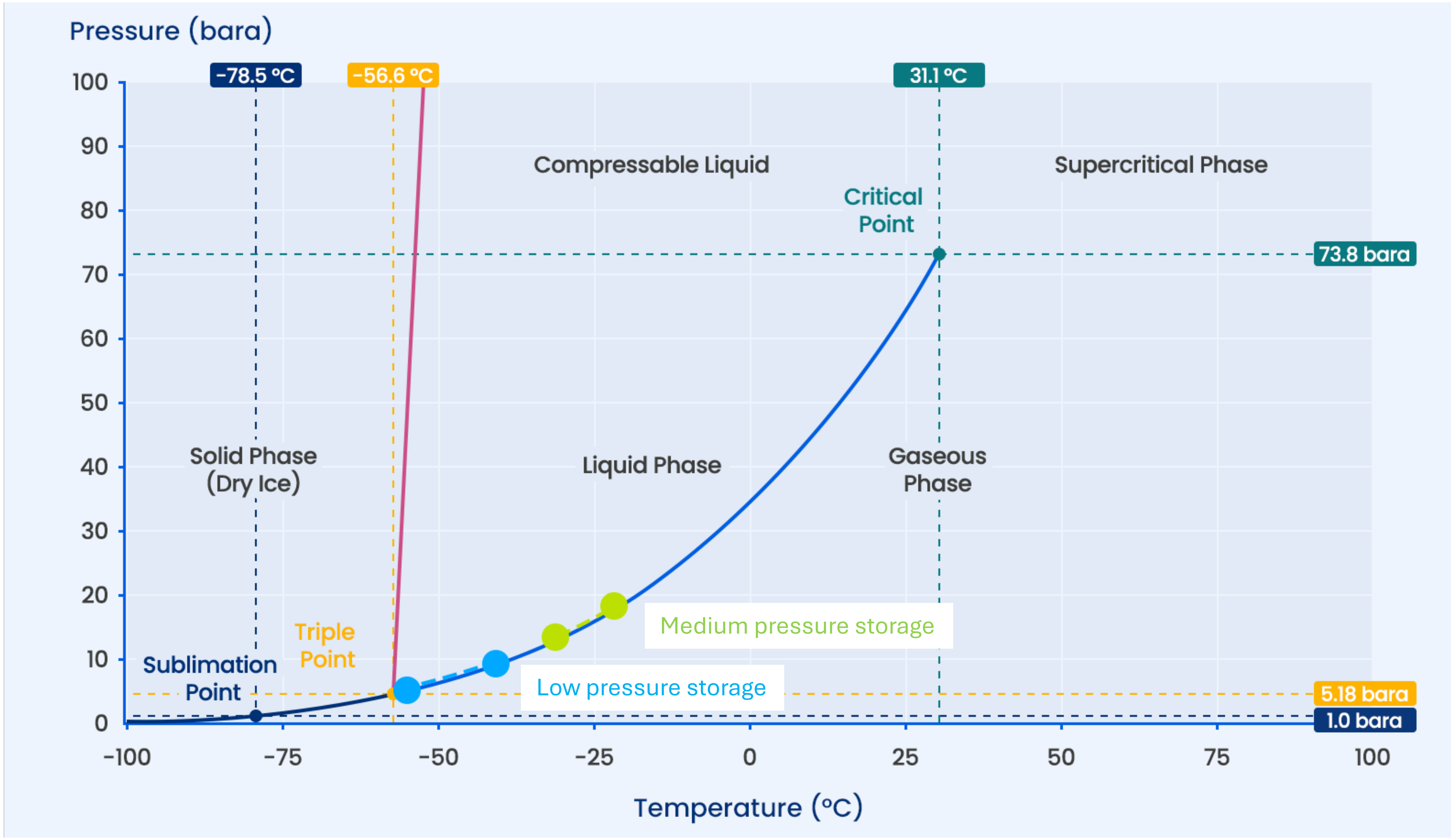
- Waste heat recovery makes up **34.5%** of thermal energy needed; remaining **820 kWth** to come from using more fuel
- **10.2% fuel penalty** to provide thermal energy for OCCS

New build with heat pumps

- New vessel **12%** more fuel efficient
- **15.6% fuel penalty** to generate thermal energy for OCCS
- **1.5% fuel penalty** relative to *Stena Impero*; or **10%** of original fuel penalty

Onboard storage of CO_2 has unique safety challenges

Impurities and small changes in T, P can impact phase boundaries; risk of hitting triple point



* Adapted from The Engineering ToolBox. Carbon Dioxide - Thermophysical Properties. Jan 2024 https://www.engineeringtoolbox.com/CO2-carbon-dioxide-properties-d_2017.html

Potential first mover in green ammonia

Bulk carriers delivering iron ore from point to point between Western Australia-Northeast Asia

A Potential Port for Ammonia

- **5%** of all tradeable ammonia are currently supplied through Dampier
- Start of the busiest iron ore route
- About **7,700** vessel calls in the Pilbara Ports for 2023
- Potential demand of **1-1.5** million tonnes of bunker by 2035

Source: Kpler, 11 Oct 2024

Vessel traffic for iron-ore carrying capesize and newcastle max bulk carriers

Successful ship-to-ship ammonia transfers

In the anchorage of Port of Dampier; in collaboration with and with approval from the Australian Maritime Safety Authority

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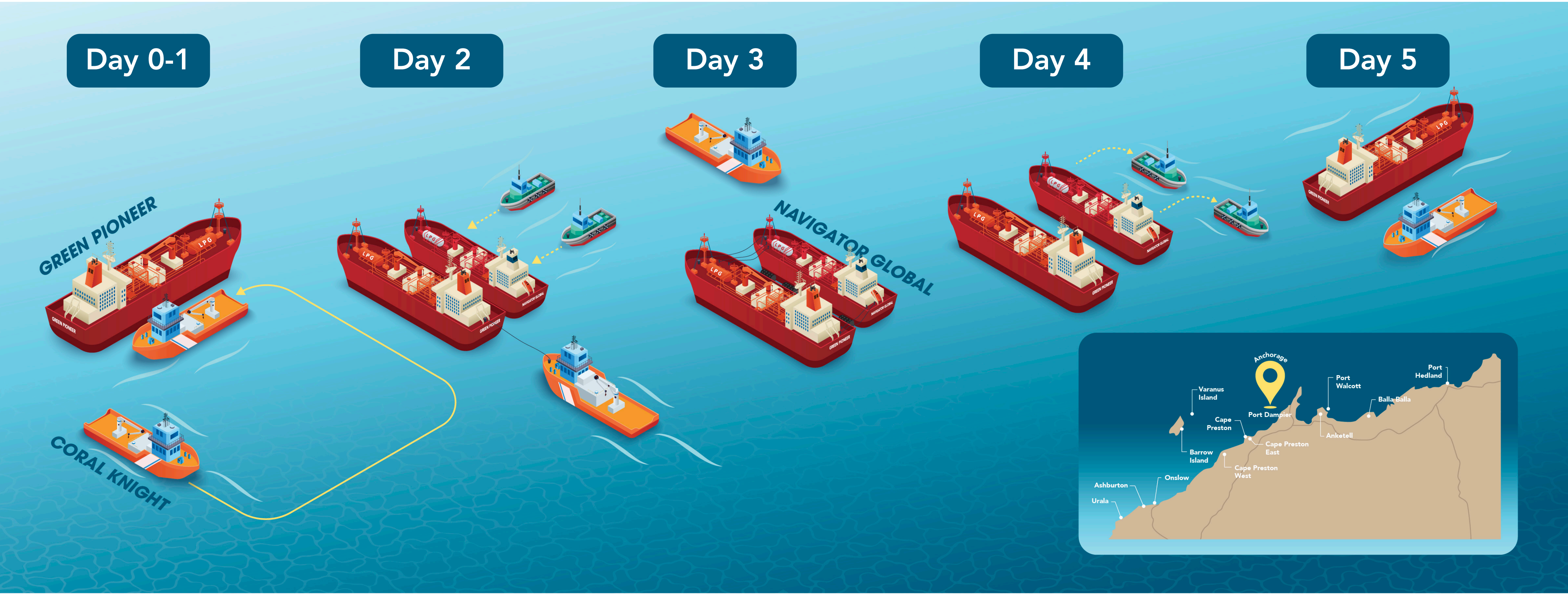

PILBARA PORTS | Yara Clean Ammonia | MOL Mitsui O.S.K. Lines | NAVIGATOR GAS | BHP | bp | DNV | EASTERN PACIFIC SHIPPING | gard | James Fisher Fendercare | OSRL | RioTinto | TCOMS

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Goal of our pilot

*To showcase **lightering** and simulate **bunkering** operations before ammonia-fueled vessels are available*

Four areas of focus:

- **01** | Safety + risk assessments
- **02** | Operational procedures
- **03** | Safety protocols
- **04** | Emergency response protocols

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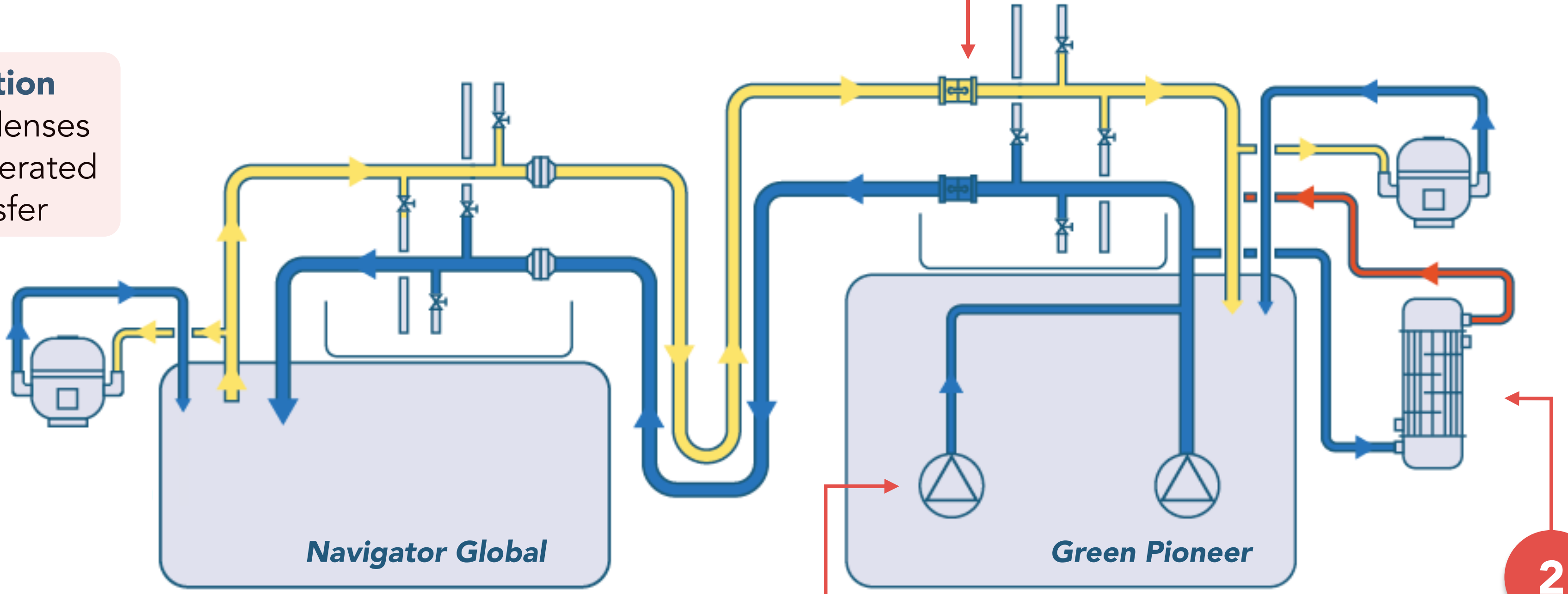
Liquid ammonia transferred between vessels

4,000 cbm *(2,700 tonnes) transferred @* ***700-800 cbm/hr***

4 **Emergency release couplings,** auto-seal hoses to prevent or minimise release

3 **Reliquefaction plant,** condenses vapour generated during transfer



2 **Vapouriser,** to maintain positive tank pressure and manage back pressure in lines

1 **Pumps,** each with a maximum flow rate of 400 m³/hr

- Ammonia (-33 degree C)
- Ammonia (20 degree C)
- Vapour return
- Closed valve

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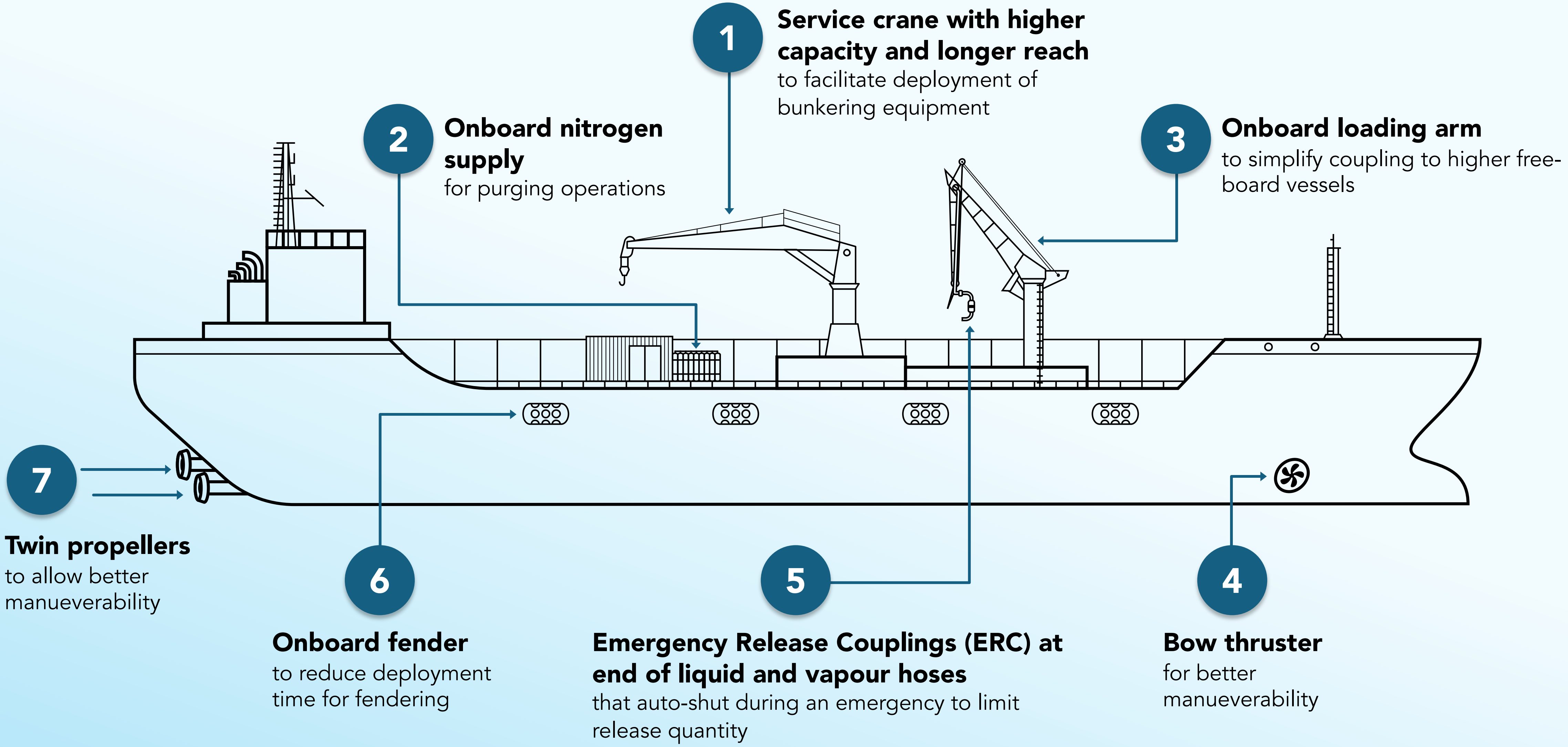
Elements to facilitate ammonia bunkering



All images used are for illustrative purposes only. Individual features, as well as sizes and fittings, are not drawn to scale and will vary.

Engine community at frontline of maritime decarbonisation

New fuels + cargo bring new considerations that impact hardware design, materials selection, equipment operations and interoperability

Properties

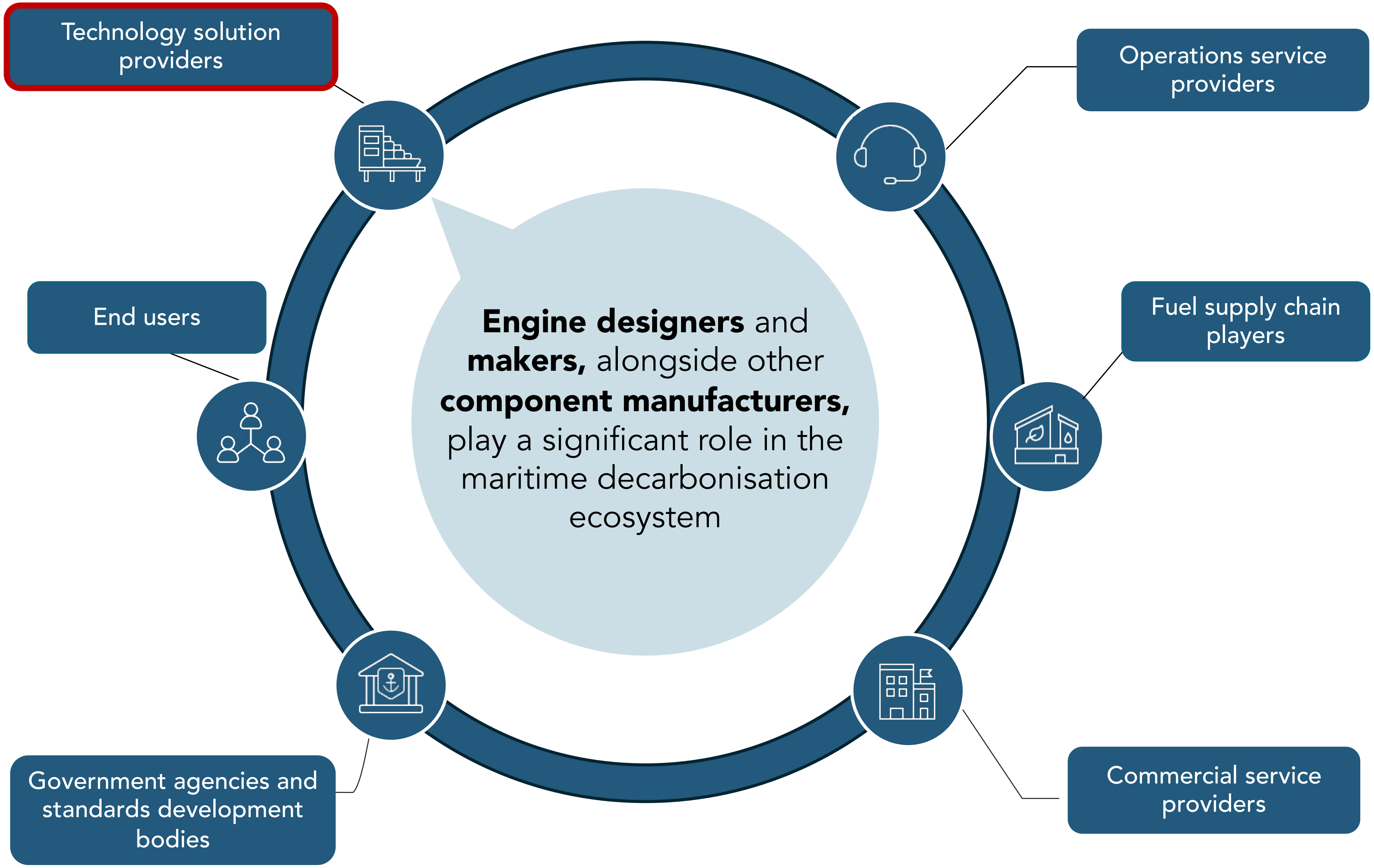
+ Combustibility
+ Toxicity
+ Corrosiveness
+ Viscosity

Phases

+ Liquid
+ Gas

Contaminants

+ Moisture
+ Phosphorus
+ Nitrogen oxides
+ Free fatty acids, …



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Partner with us to accelerate maritime decarbonisation

Founders/ Strategic partners

Coalition partners

Knowledge partners

Enabling partners

Impact partners

And ~100 project partners

Enabling ammonia as a marine fuel*

Assuring the quality, quantity and emissions abatement of drop-in green fuels*

Unlocking the carbon value chain

* *Initiatives partially funded by MPA; partners for the initiative "Scaling the Adoption of Energy Efficiency Technologies" will be announced soon*

Thank you!

Scan the QR code to download GCMD reports and papers

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