Paths Towards Decarbonisation of Shipping: Critical Levers and Scenarios

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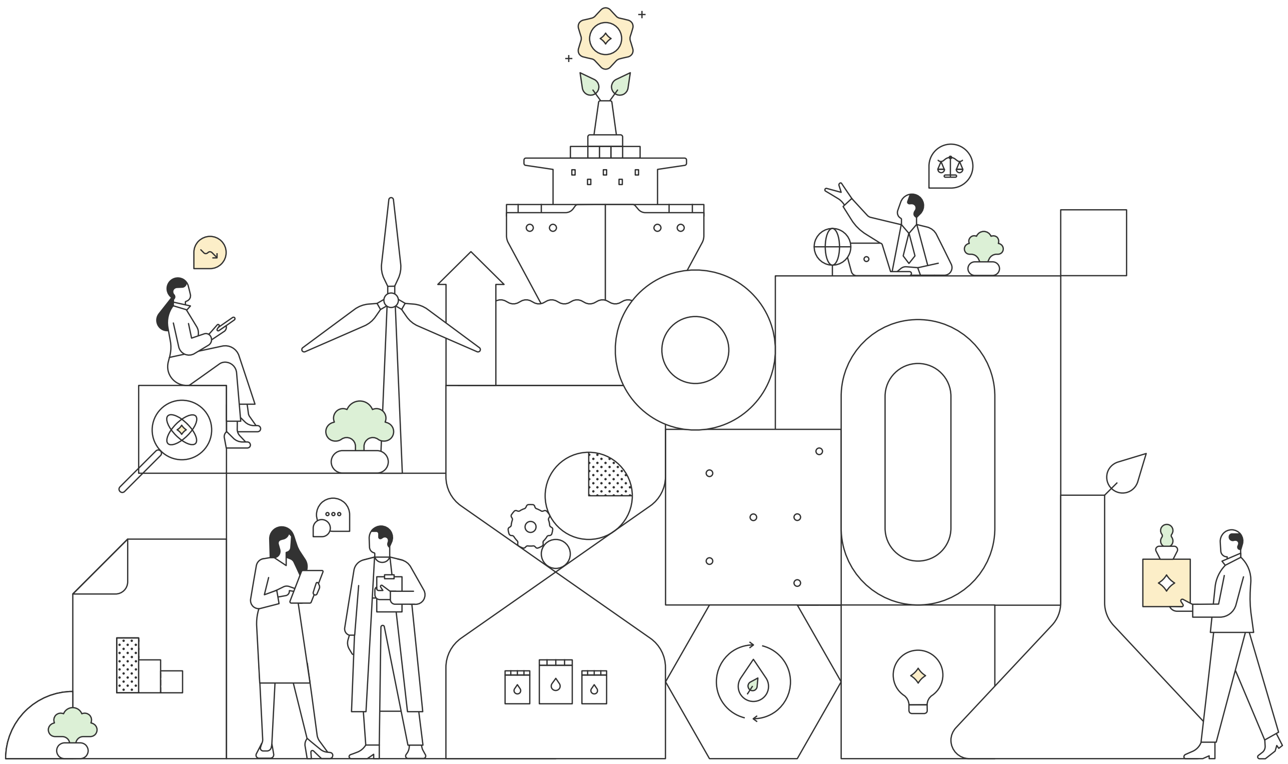
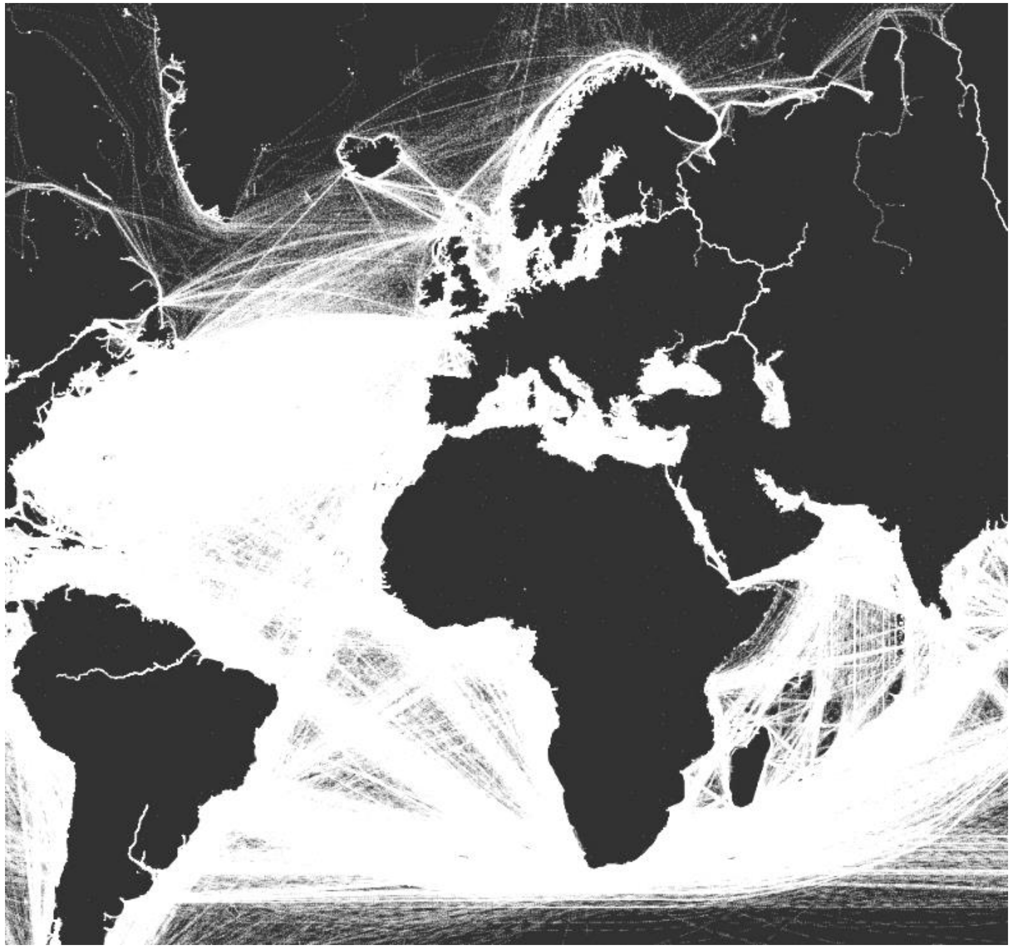


EUROPEAN COMMISSION
DIRECTORATE-GENERAL
MOBILITY & TRANSPORT
CLIMATE ACTION

Sub-group on:
Sustainable Alternative
Power for Shipping

Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping

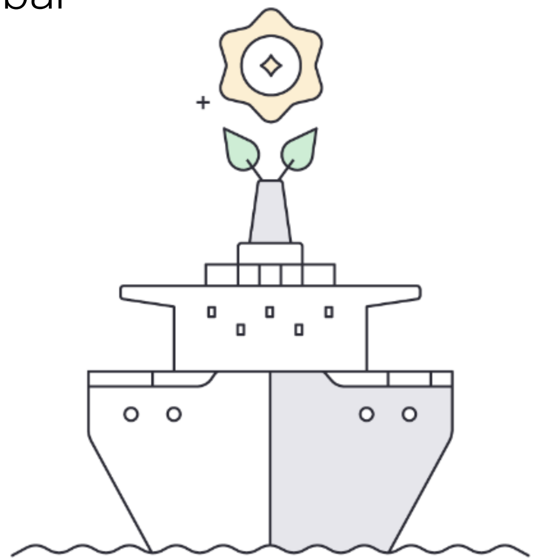
With **~100.000** commercial vessels globally consuming **m300Tons fuel** p.a. the shipping-sector accounts for around **3%** of global CO_2 emissions.



The Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping - we show the world it is possible

Our vision
A decarbonization of the global maritime industry by 2050

Our mission
To be a visible and significant driving force in the global maritime decarbonization journey



Not-for-profit
Money earned by or donated to the Center is used in pursuing our mission

Independent
We operate in a pre-competitive environment bringing together key players across the value chain

Science-based
We explore viable decarbonization pathways by assessing available data and developing own energy and technology solutions

Our Partners share the zero-carbon vision and are committed to collaborative climate action

19 Strategic Partners

ABS
Alfa Laval
bp
Cargill
DP World
Haldor Topsøe
John Swire & Sons
Maersk
MAN Energy Solutions
Mitsubishi Heavy Industries, Ltd.
Mitsui & Co.
Norden
NYK Line Nippon Yusen Kaisha
Seaspan
Siemens Energy
Stolt Tankers
Sumitomo Corporation
TotalEnergies
V.Group

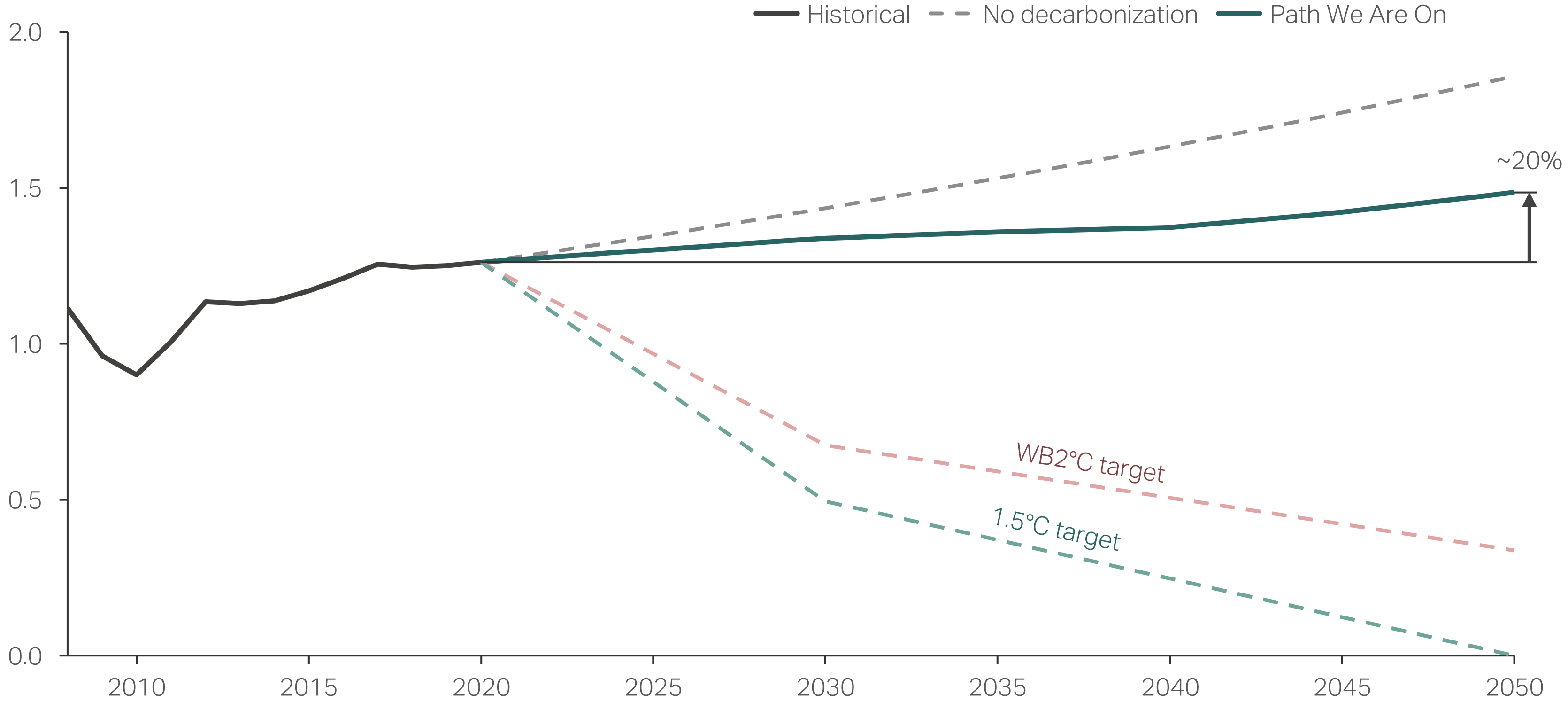
7 Knowledge Partners

BCG
Danish Shipping
EDF Environmental Defense Fund
Global Maritime Forum
Maritime and Coastguard Agency
McKinsey & Company
The Royal Institution of Naval Architects

Decarbonizing the Maritime Industry

The path we are on leads to increased GHG emissions

WTW Maritime emission pathways[1]
$GtCO_2$-eq/year



- The path we are on may lead to more GHG emissions in 2050 compared to today
- Industry leadership on its own cannot drive the transition and must be supported by regulation and customers´ willingness to pay more for zero-carbon transportation

Sources: IMO, IEA, Clarksons, NavigaTE Techno-economic model MMM Center for Zero Carbon Shipping
1 WTW = well to wake.

Three segments contribute to most maritime emissions and volumes are expected to grow towards 2050

Global volumes, 2018 / Emissions and intensity, 2020

Segment	Billion ton-miles	2020-50 CAGR %	$GtCO_2$-eq/year (well-to-wake)	gCO_2 -eq/ton-km
Total	58,932	1.3	1.26	~12
Bulk carrier	25,050	1.0	0.24	~5
Tanker	14,090	0.1	0.28	~11
Container	13,046	2.4	0.29	~12
Gas carrier	2,987	2.3	0.08	~15
Other cargo	2,146	2.2	0.09	~22
RoRo/Car carrier	607	2.0	0.06	~52
Ferry	135	2.0	0.06	~223
Cruise	130	4.0	0.04	~115
Others[1]	740	2.3	0.12	~89

Supported by a positive World GDP outlook and historic data, maritime volumes are expected to continue to grow. Three segments - bulk, tanker and container - account for ~90% of industry volume and ~65% of emissions, making them the key focus areas for future emission reduction pathways.

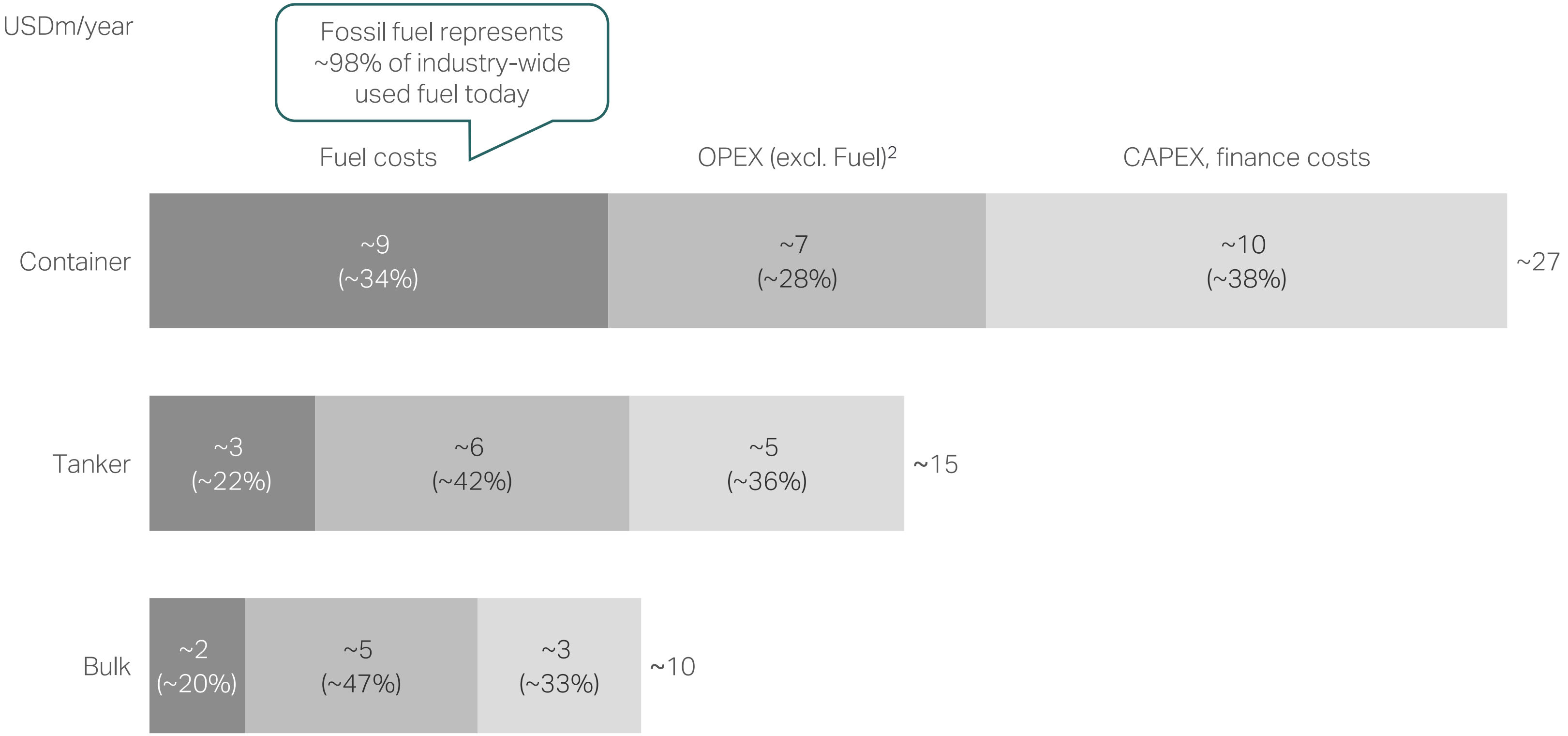
Growth will not be stable. Technological disruptions, population growth, macro-economic, environmental and geopolitical events will continue to impact trade and challenge the maritime industry with some vessel segments being more impacted than others. For example, a global push for CO_2 abatement will most likely mean less oil and coal transported, growing populations will most certainly increase demand for container cargo and regionalization or pandemics such as CoVID-19 will affect global trading patterns.

Source: IMO 4th GHG study (2020), McKinsey&Co. (2021), Clarksons (2021), NavigeTE Techno-economic model MMM Center for Zero Carbon Shipping
1 Others include offshore, tugs and non-specified ships
2 Exports of goods and services (% of GDP) | data (worldbank.org)

The challenge

Fuel represents ~20-35% of total annual costs with almost the entire industry consumption being fossil-based

Total cost of ownership for various vessel types[1] in 2020



Source: NavigaTE Techno-Economic model MMM Center for Zero Carbon Shipping
1 Typical vessels refer to: Container- 8,000 TEU capacity; Tanker - LR2 85-125k DWT; Bulk carrier - Panamax 70-99k DWT ; All vessels are assumed to have a 25-year lifetime. Typical operational profiles have been assigned to each vessel type.
2 Maintenance, crew, port call fees and other operating costs not including fuel costs

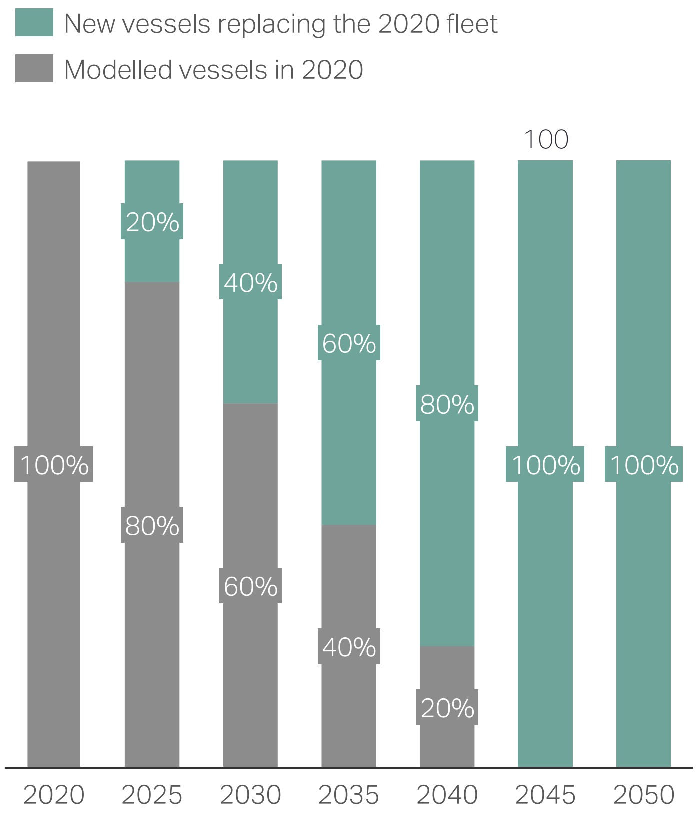
Shipowners and managers understand the importance of looking beyond purchase price and considering the total cost of ownership (TCO) of their vessels. Acquisition costs, operation and personnel costs all factor into the full expense of owning and operating a vessel.

In maritime, fuel is a significant proportion of the overall cost. Firstly, there is the direct fuel purchasing cost and secondly, the quality of fuel affects cost related to vessel maintenance and performance.

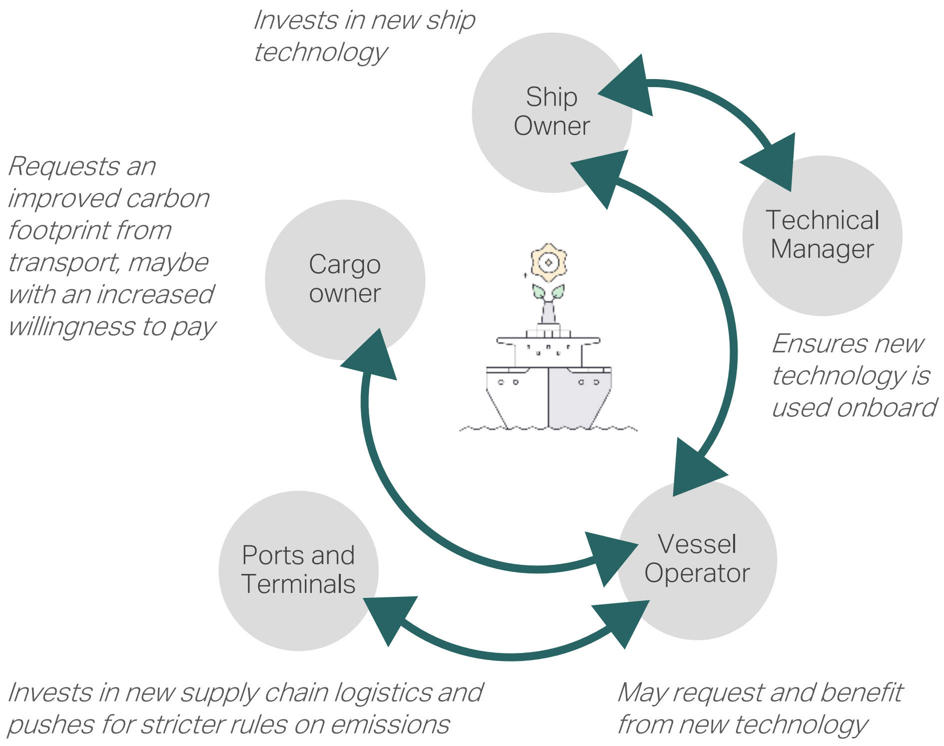
Maritime fuel costs make-up 20-35% of annual TCO, with container vessels having the highest proportion of fuel cost.

...and the current fleet composition and industry structure challenge the decarbonization path even further

Natural replacement of existing fleet[1]



Complex commercial structures



Decarbonization via fleet replacement takes time; a ship's average lifetime is ~25 years. Key drivers of global fleet replacement are current age distribution, global trade capacity needed, vessel scrap prices and the concept of total cost of ownership (TCO). Thereby, retrofitting the existing fleet with new and existing technology may accelerate the transition beyond the natural replacement rate.

Commercial structures in the maritime industry today can also be seen as an impediment to decarbonization. Lack of mutual attractiveness to save fuel and cut emissions do not incentivize everyone in the business model. This often slows down adoption of new and capital-intensive projects. Current business model also doesn't emphasize on the cleverness of vessel routing, and Just in Time principles among others, which could be used as operational tweaks unlocking the emissions reduction potential.

Source: MMM Center for Zero Carbon Shipping

1 Illustrating the impact of an expected vessel lifetime of 25 years and a 4% yearly scrap rate of fleet.. New vessels is the number needed to maintain the same fleet size as per 2020

What does it take ?

Activating critical levers across five categories can drive reduction of maritime emissions

1 Policy and regulation

National and regional regulation is of great importance, but we need global regulation. IMO can level the playing field by introducing maritime **CO_2 pricing and tighter energy efficiency regulations**

2 Tech advancements on ship

Existing efficiency technologies are technically mature but not universally adopted. We need better sharing of operational best practices, and **new efficiency solutions**

3 Energy & fuel advancements

Accessibility and availability of alternative fuels will **be largely dependent on scaling** of known, but not yet commercially scaled, technologies

4 Customer demand/pull

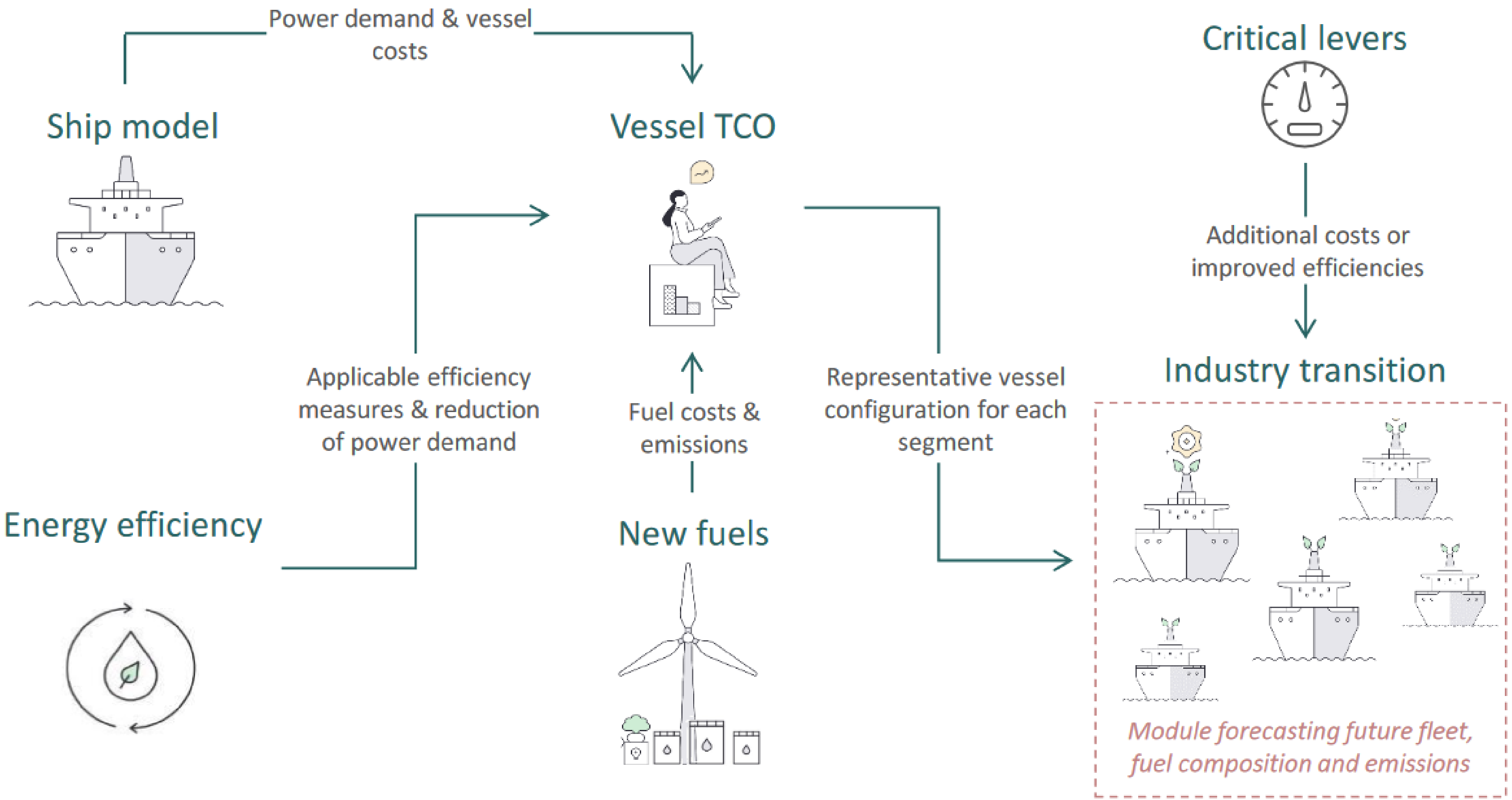
End-product-buyers are willing to change purchasing habits to show climate action. The pace of maritime decarbonization will increase if more consumers **demand zero-carbon transportation and are willing to pay a premium**

5 Finance sector mobilization

Green financing is already widely used by other industries and is now gaining momentum in the maritime industry as well. **Lower finance cost** can support and accelerate decarbonization

Source: MMM Center for Zero Carbon Shipping

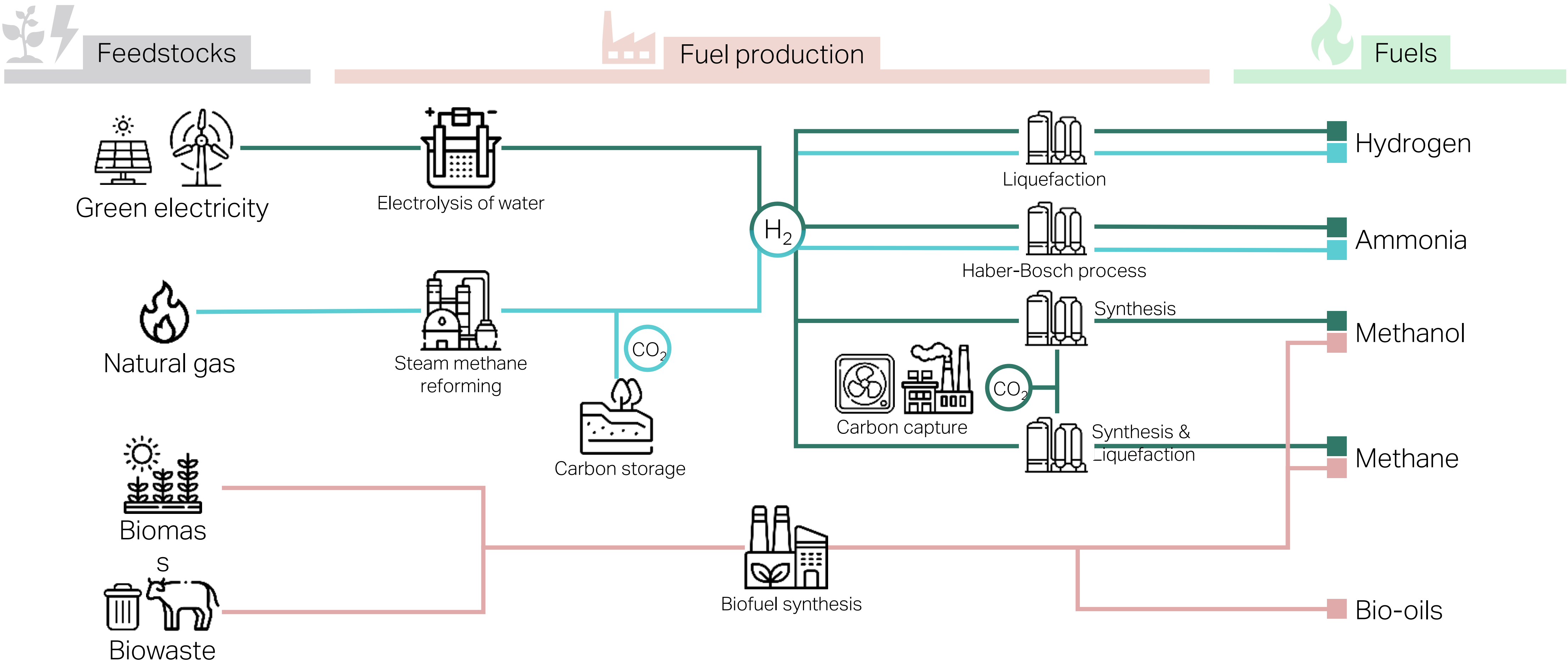
We model paths towards 2050



- The Industry Transition model enables fleet projections based on TCO comparisons, trade growth and fleet turnover.
- The two key input is the TCO comparison and the swing factors.
- The TCO model enables diligent ship level comparison of fuel and energy efficiency setup across ship types, sizes and over time based on the ship model, energy efficiency and new fuels
- The Critical Levers can change a key assumption such as the price of renewable electricity for fuel production and the regulatory efficiency demands or adding a price on CO_2.

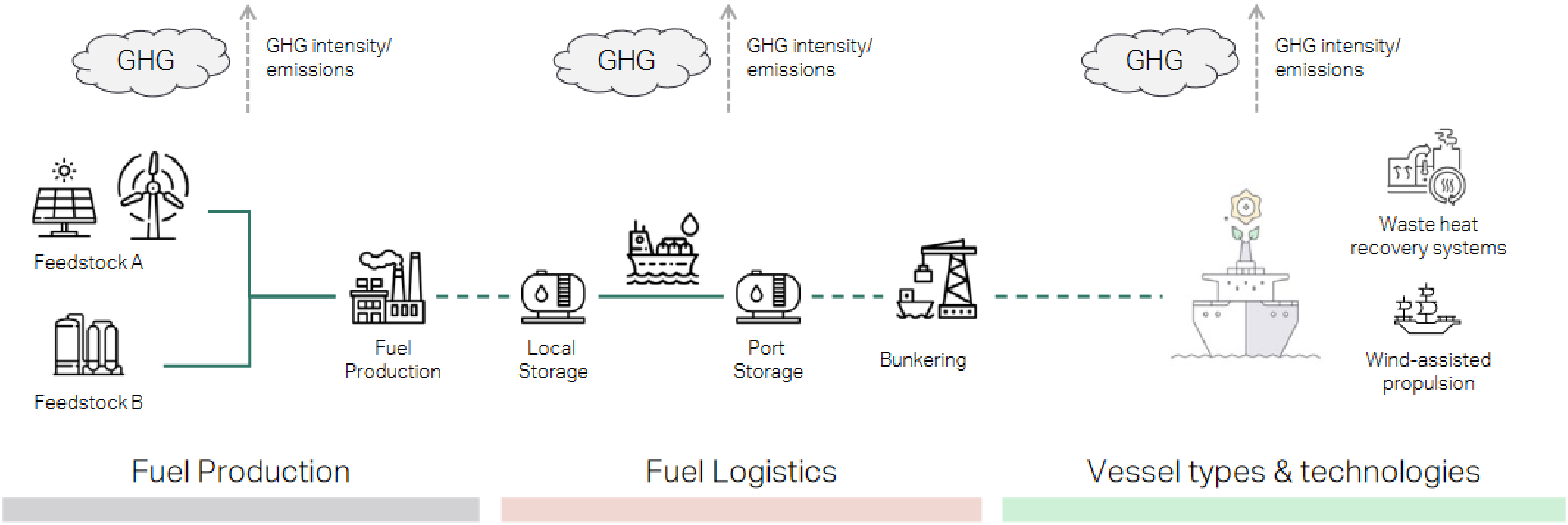
Source: "NavigaTE to Zero", https://cms.zerocarbonshipping.com/media/uploads/documents/NavigaTE_Whitepaper_final.pdf

Some of the fuel pathways in our transition model

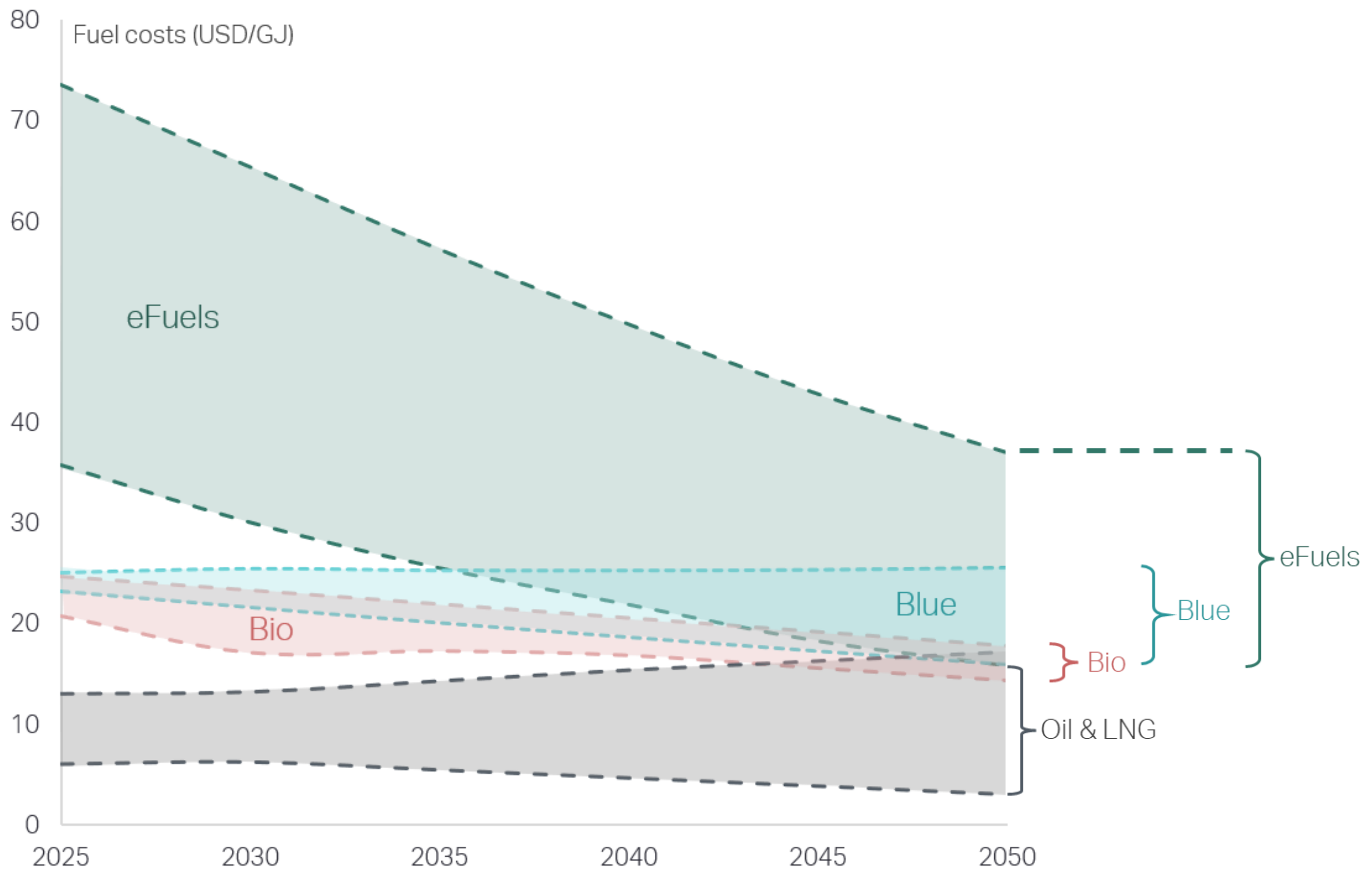


Parameters for *Well-to-Wake* are included in the model

– Primarily adressing CO_2, CH_4 and N_2O:



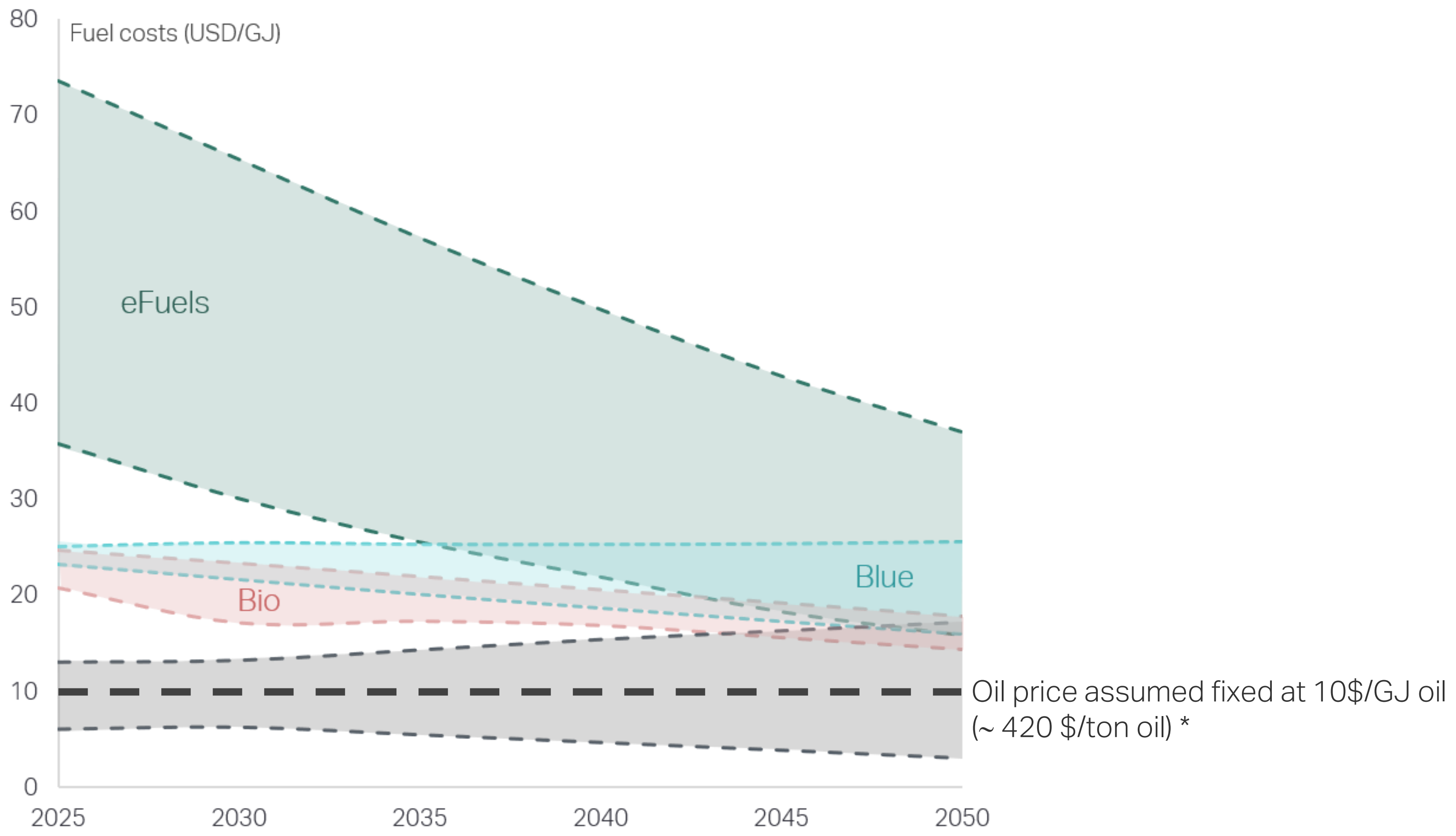
Challenge of significant cost gaps – particularly in the beginning of the transition



Source: MMM Center for Zero Carbon Shipping

- High carbon price is needed to bring fossil fuels on part with best alternative fuel options.
- But a high CO_2 price is difficult to obtain broad acceptance and implementation.

Illustrating different carbon price levels on the fuel cost graphs (I)

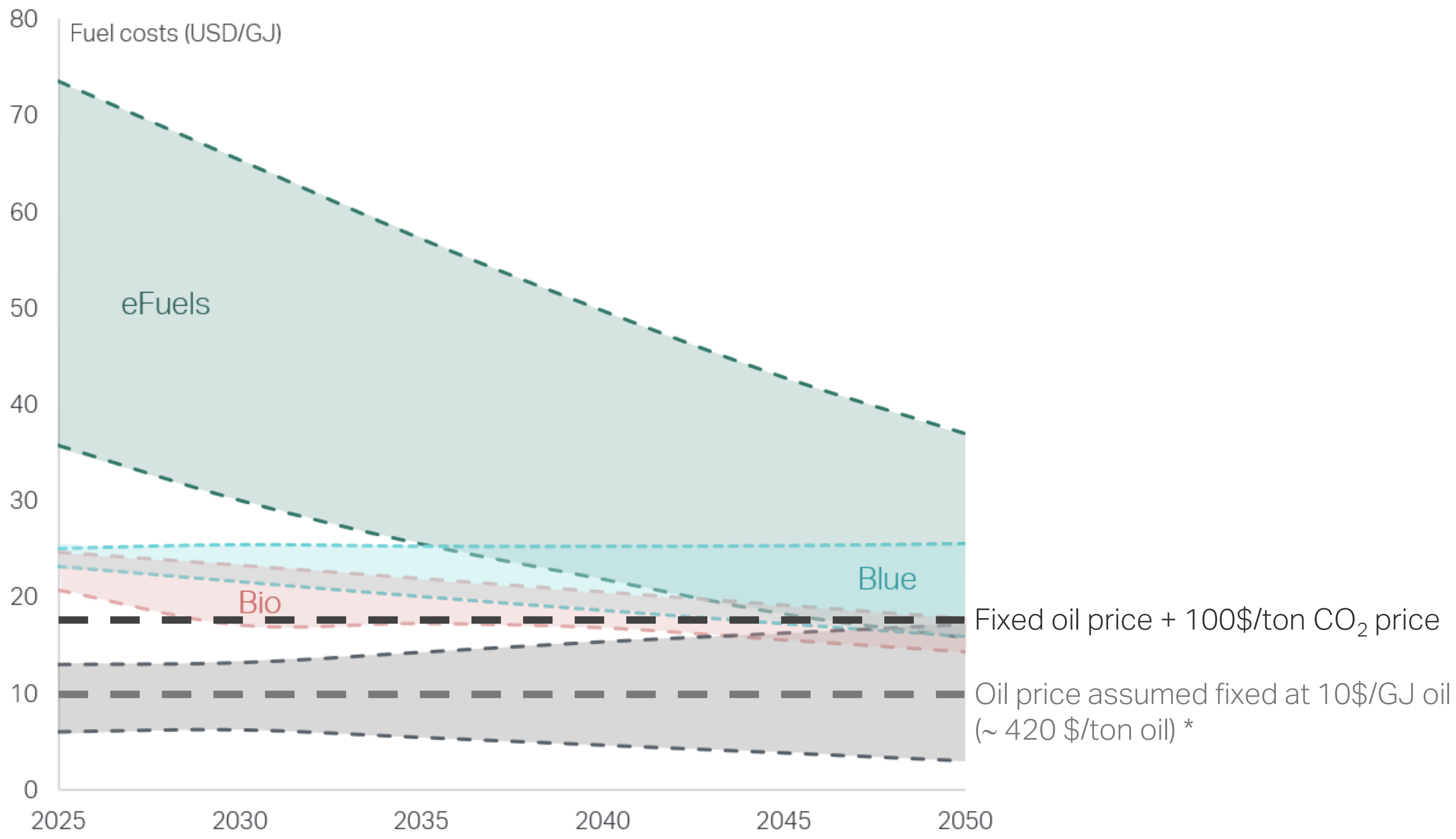


Source: MMM Center for Zero Carbon Shipping

(*Calculation example:

- Assumed oil price: **420 $/ton oil**
- One ton oil contains approximately 42 GJ (giga joule) per ton oil → **10 $/GJ oil**
- One ton oil releases approximately 3.2 ton CO_2 when combusted → 1/42*3.2 = 0,076 ton CO2/GJ oil.
- A carbon price of **100 $/ton CO_2** gives an adjusted oil price of: 10 $/GJ oil + 0.076 ton CO2/GJ oil * 100 $/ton CO_2 = 10 + 7.6 = **17,6 $/GJ oil.**

Illustrating different carbon price levels on the fuel cost graphs (II)



Source: MMM Center for Zero Carbon Shipping

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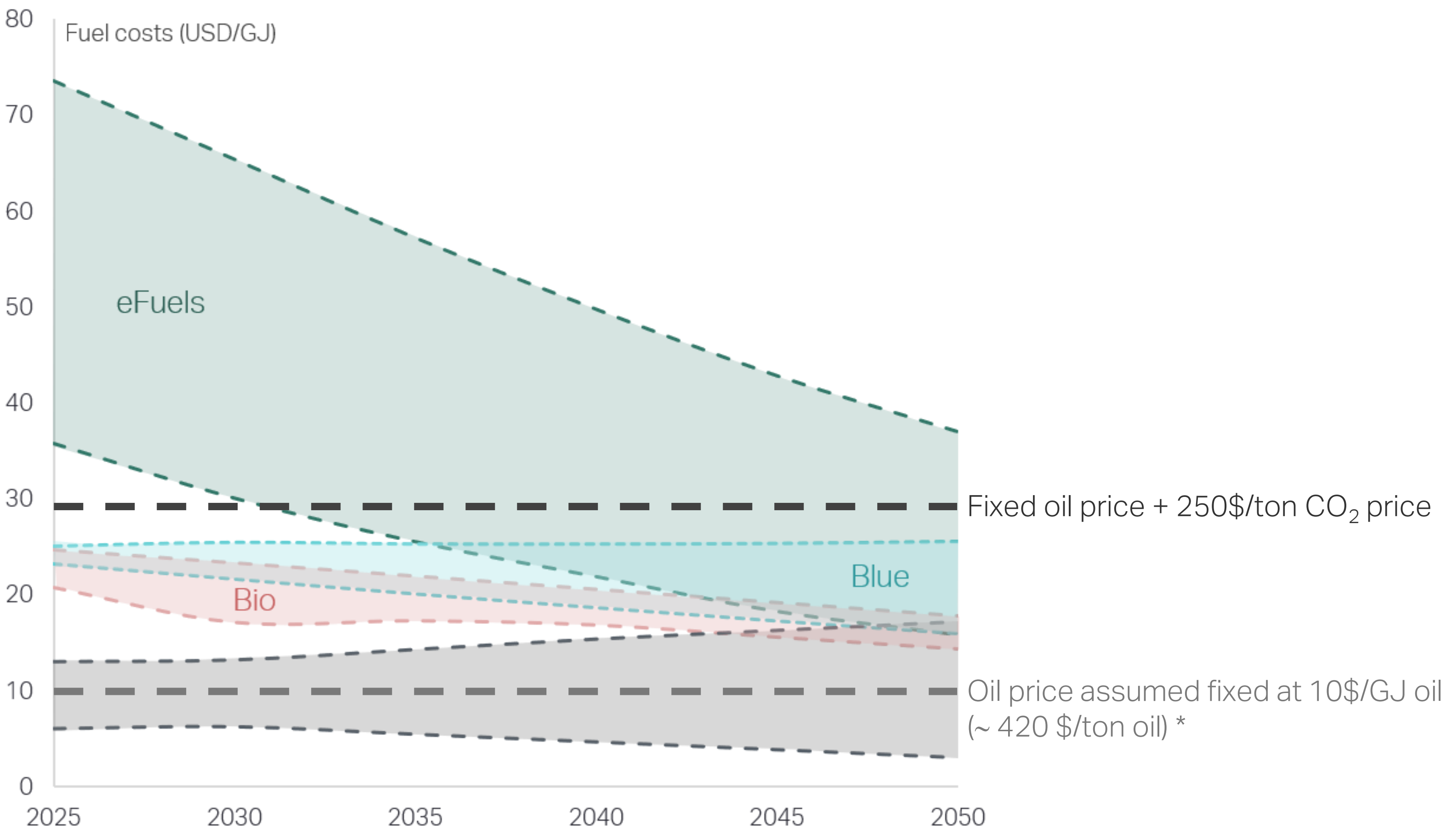

Source: MMM Center for Zero Carbon Shipping

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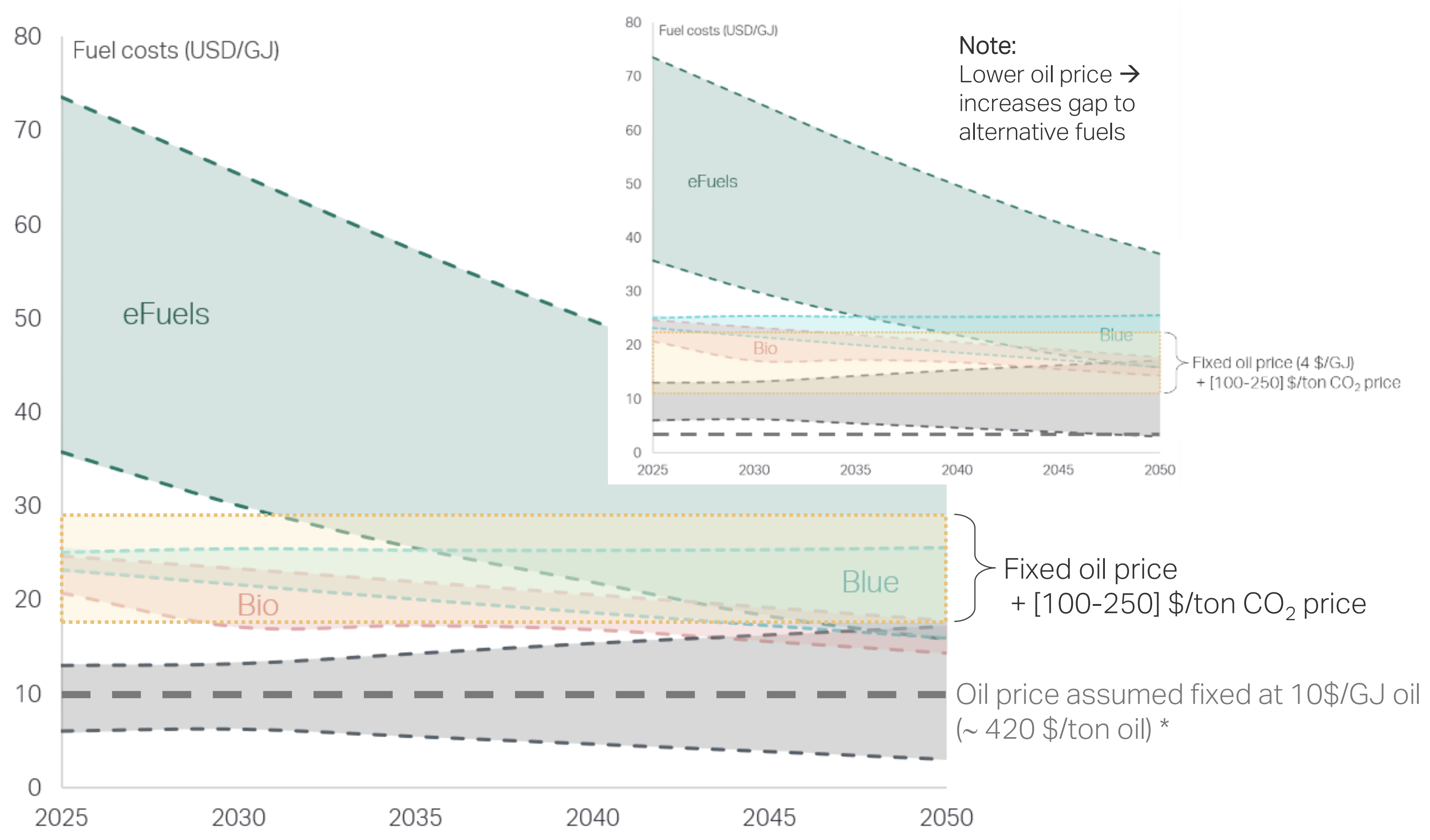
Illustrating different carbon price levels on the fuel cost graphs (IV)



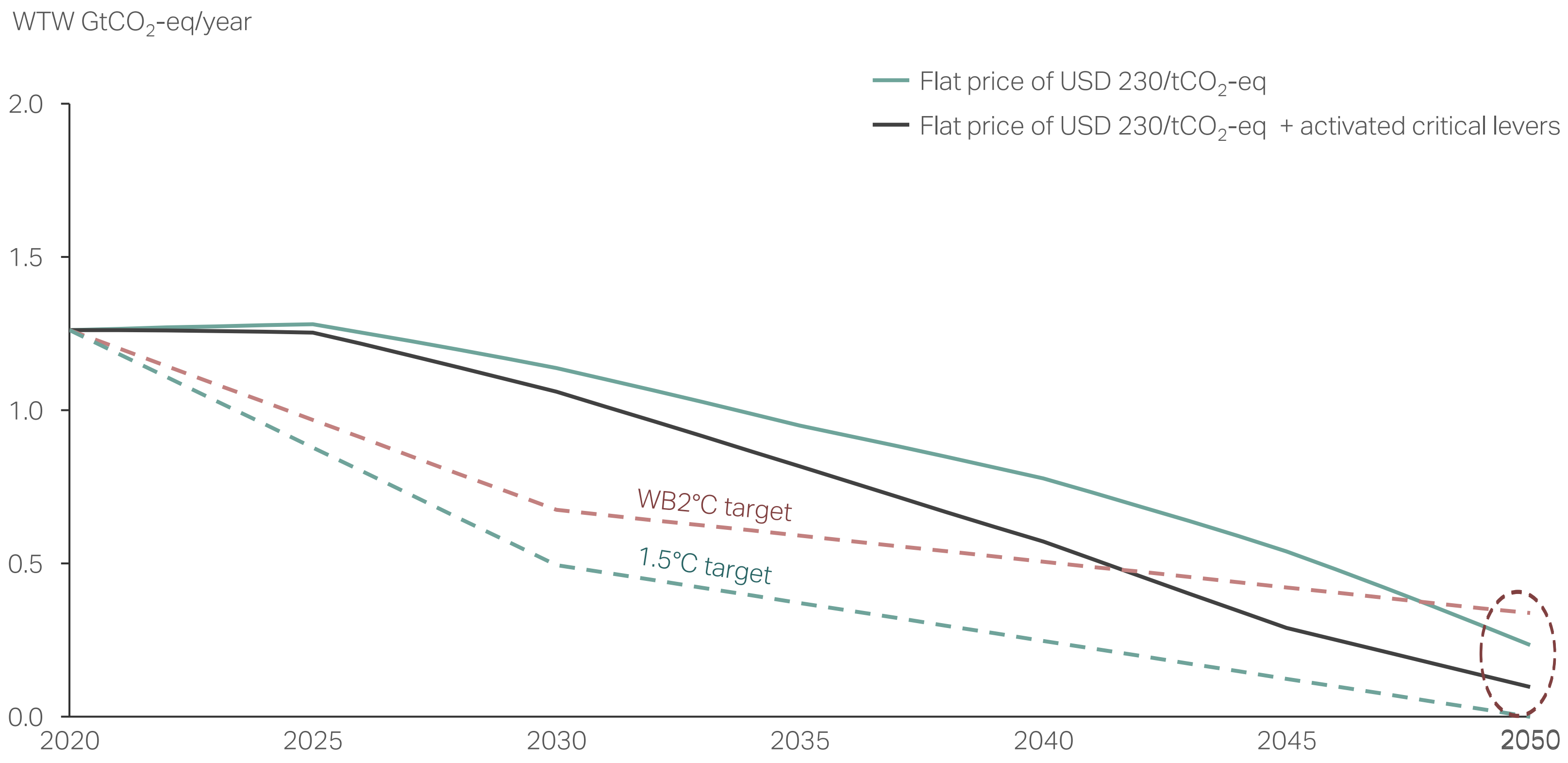
Source: MMM Center for Zero Carbon Shipping

Hard-to-abate
→ high price on CO_2 needed

In particular in the first phase of the transition where the cost gab is highest

Scenarios and impact of energy efficiency requirements

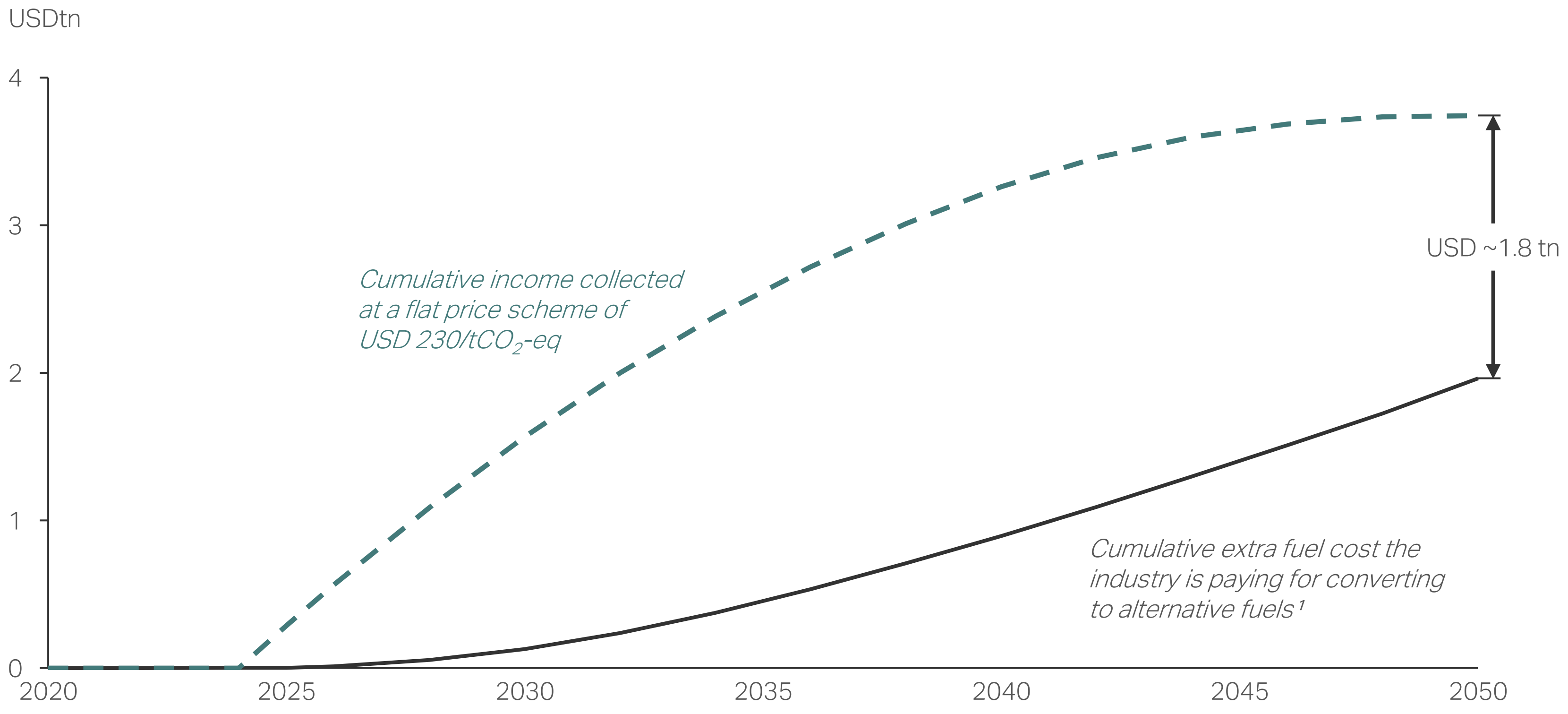
Global carbon pricing can be an effective regulatory measure on a Path to Zero



Source: MMM Center for Zero Carbon Shipping

- 61 emissions trading schemes are now in place or scheduled globally covering around 22 percent of global emissions but with no significant coverage of maritime transport
- Our analysis shows that a flat price on CO_2 of USD ~230/tCO_2 -eq by 2025, in combination with activated critical levers, results in the abatement needed towards 2050.

A high, flat carbon price will generate a much higher revenue than needed to bridge industry's fuel cost gaps

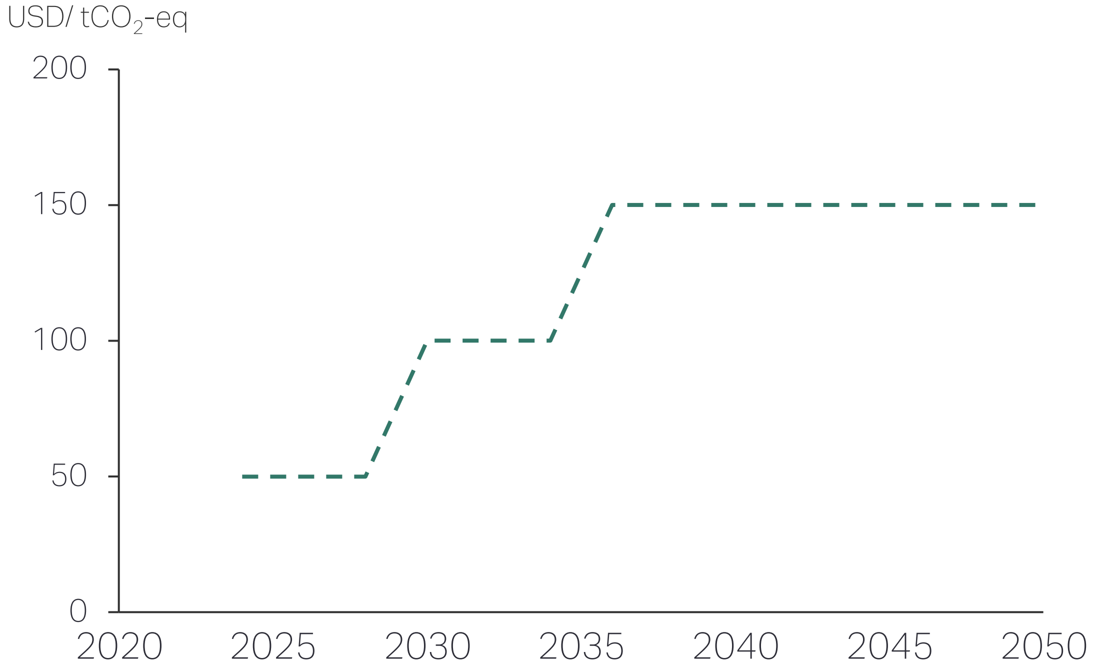


- A flat price of ~ USD 230/tCO_2-eq sufficiently penalizes fossil fuel usage by bringing costs up on par with the alternative fuels.
- With most vessels operated on fossil, the cumulative CO_2-eq income collected from a price will quickly grow large while tapering off further into the transition (green dotted line).

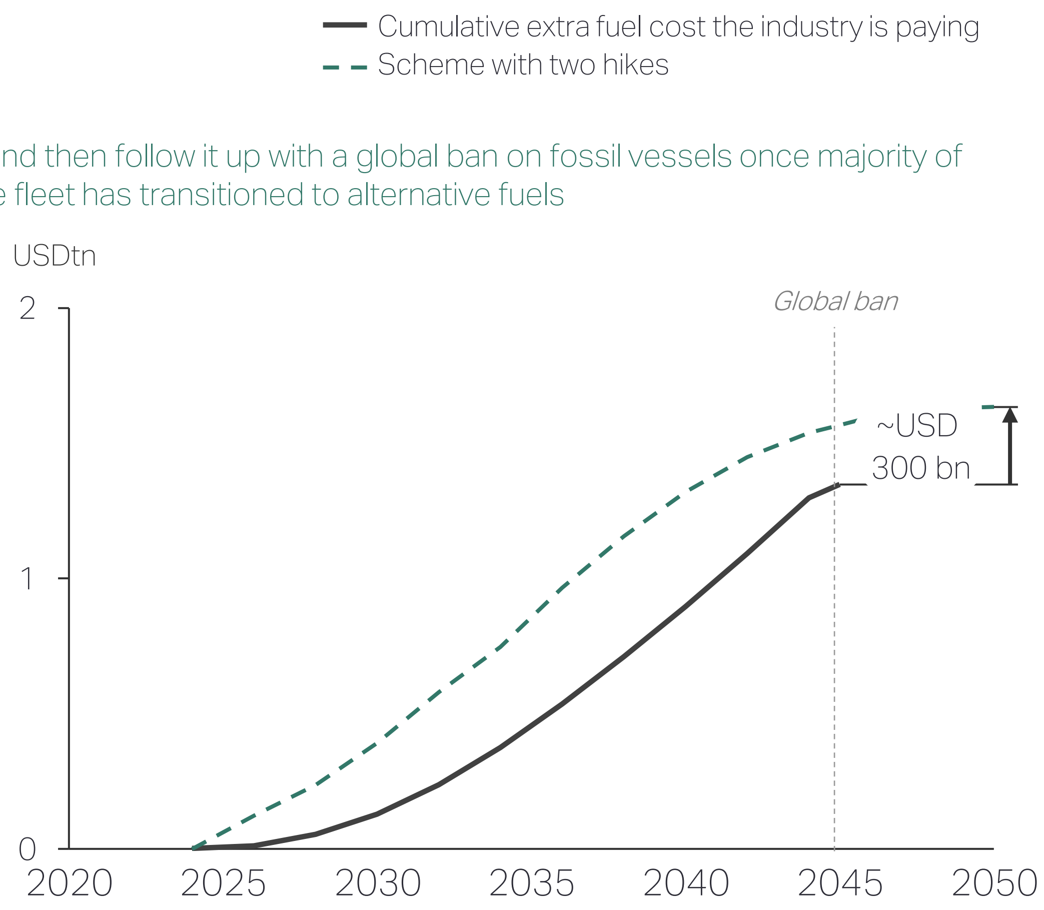
Source: MMM Center for Zero Carbon Shipping.

Alternatively, an earmark and return carbon pricing scheme sequenced with a ban can motivate lower levies

The regulator can start by imposing an "earmark and return" global carbon price system...

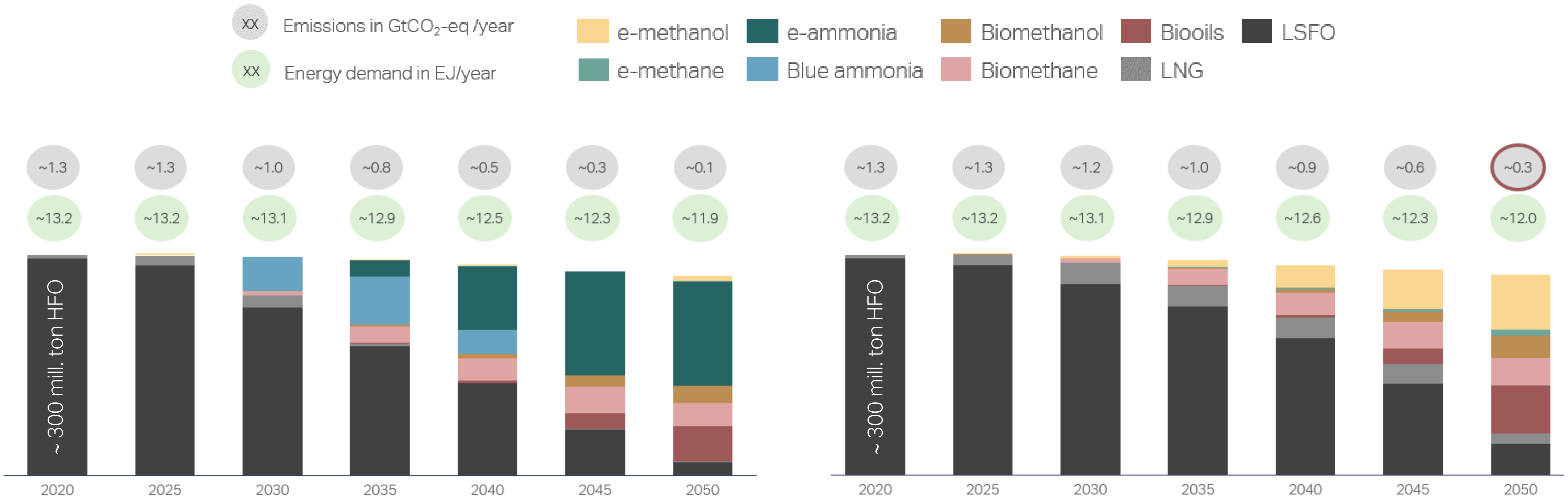


...and then follow it up with a global ban on fossil vessels once majority of the fleet has transitioned to alternative fuels



Source: MMM Center for Zero Carbon Shipping.

Different scenarios may play out subject to cost, feedstock availability, scale and required legislation getting in place



Reference scenario(*)

Activating all critical levers and introducing a flat global carbon price of USD 230/tCO2-eq

"What if no ammonia" scenario(#)

Source: NavigaTE Techno-Economic model MMM Center for Zero Carbon Shipping

(*) https://cms.zerocarbonshipping.com/media/uploads/documents/MMMCZCS_Industry-Transition-Strategy_Oct_2021.pdf

(#) https://cms.zerocarbonshipping.com/media/uploads/documents/Fuel-Options-Position-Paper_Oct-2021_final.pdf

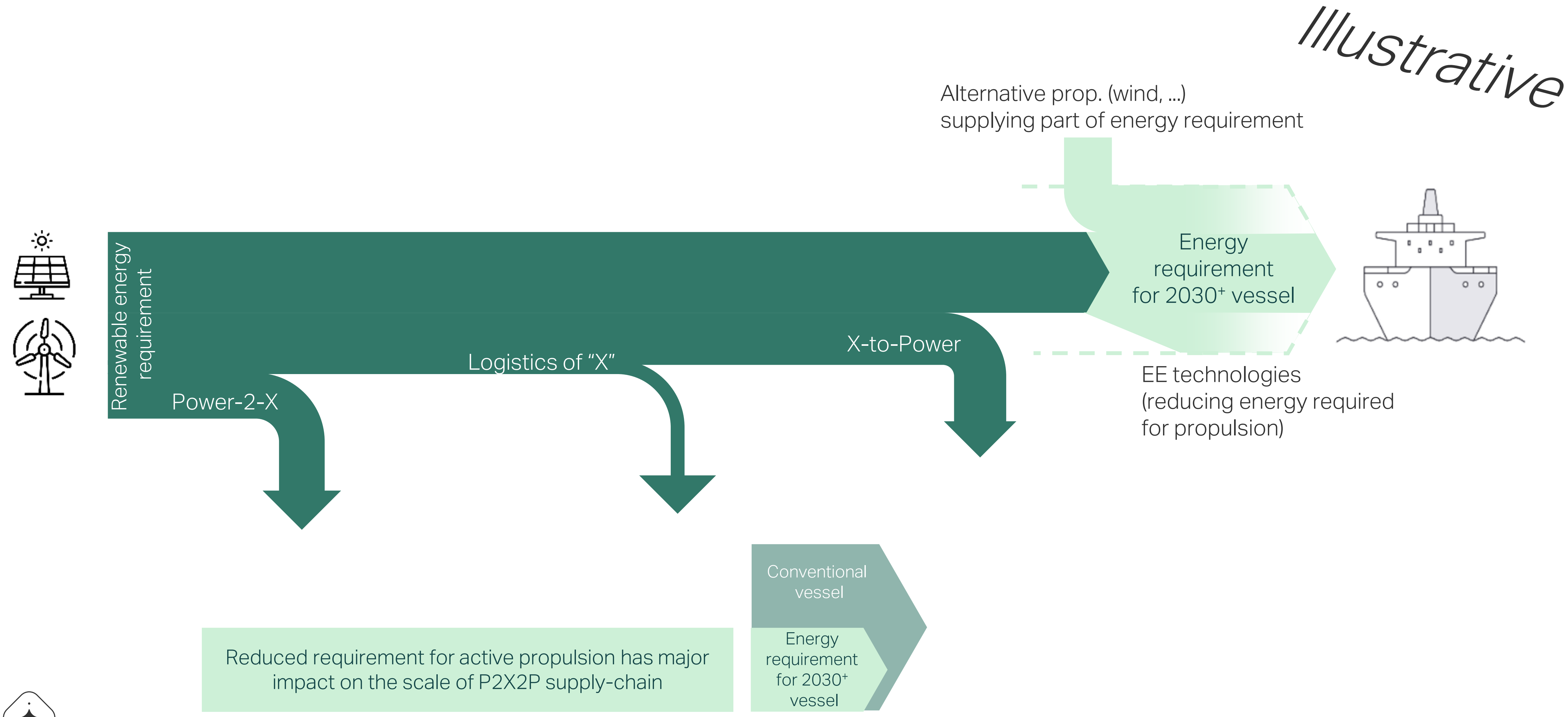
Confirming the high value in a strong link between alternative fuels and EE

Decarbonisation in Shipping – ESSF Expert Groups

ESSF sub-group on Ship Energy Efficiency – ESSF SEE	ESSF sub-group on Alternative Power Systems for Ships – ESSF SAPS
Expert Group addressing challenges related to the **Energy Efficiency**	Expert Group addressing challenges related to the **use of Alternative Power in shipping**
- EEDI, EEXI, CII - IMO DCS - Wind Assisted Propulsion	- Life Cycle Analysis/ WtW - Low GHG Fuel Pathways - Gaps/ Barriers to uptake of Alternative Fuels

European Commission

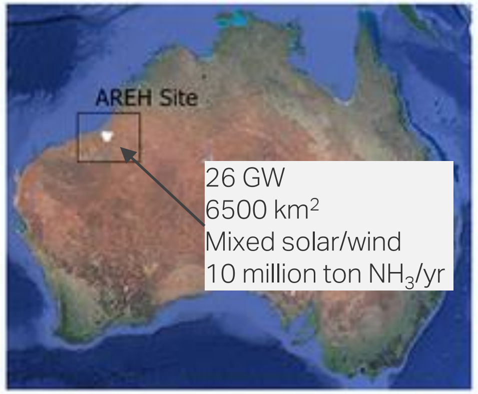
Energy efficiency & alternative propulsion matters



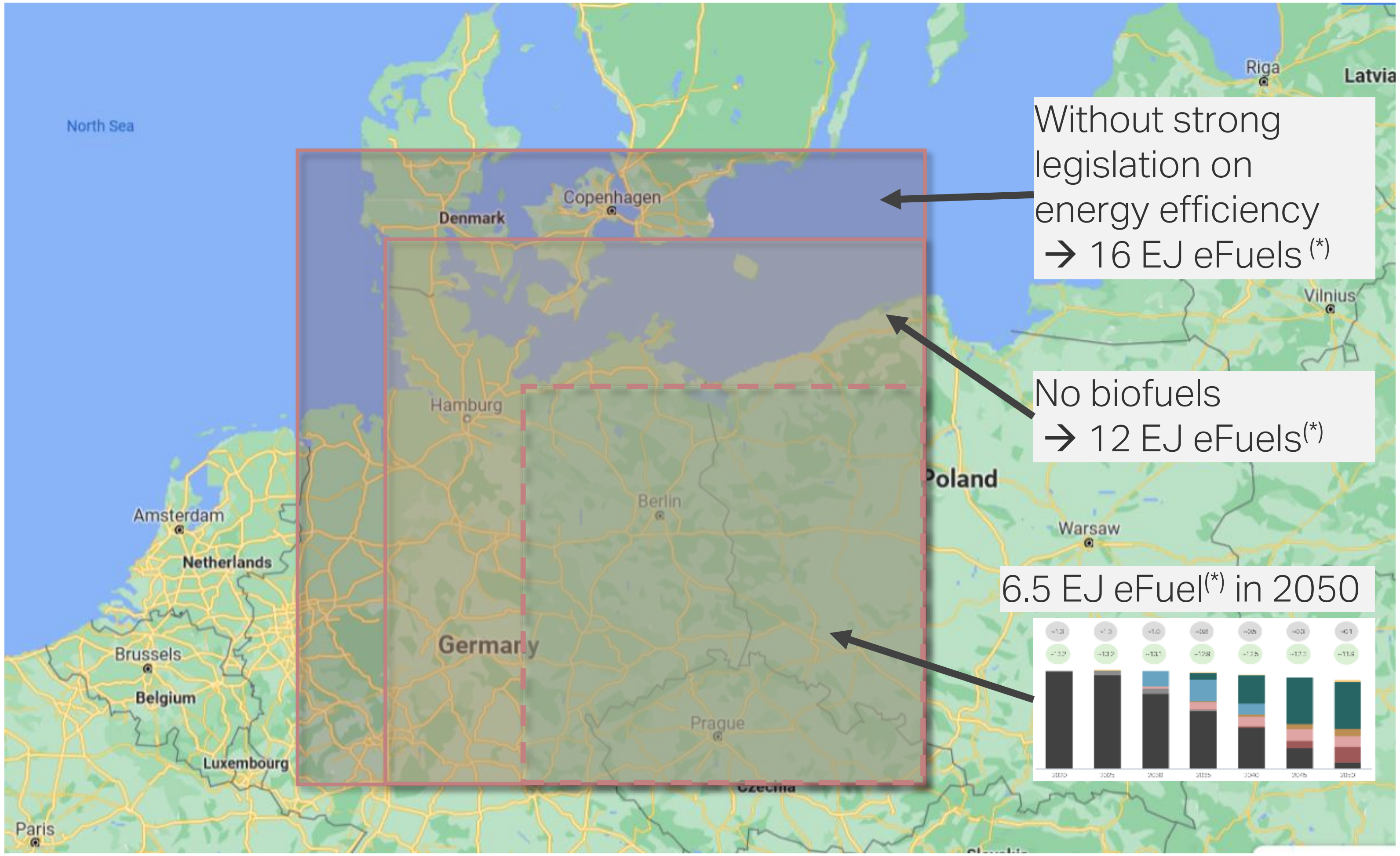
How much renewable power required?
We must use the renewable electricity respectfully…

Scaling of development “Down Under”

The Asian Renewable Energy Hub
Nyangumartamili wangal pa janyja



https://intercontinentalenergy.com/asian-renewable-energy-hub



(*) For simplicity assumed to be e-ammonia. Assuming e-methanol from DAC, the area for renewable power will be considerably larger

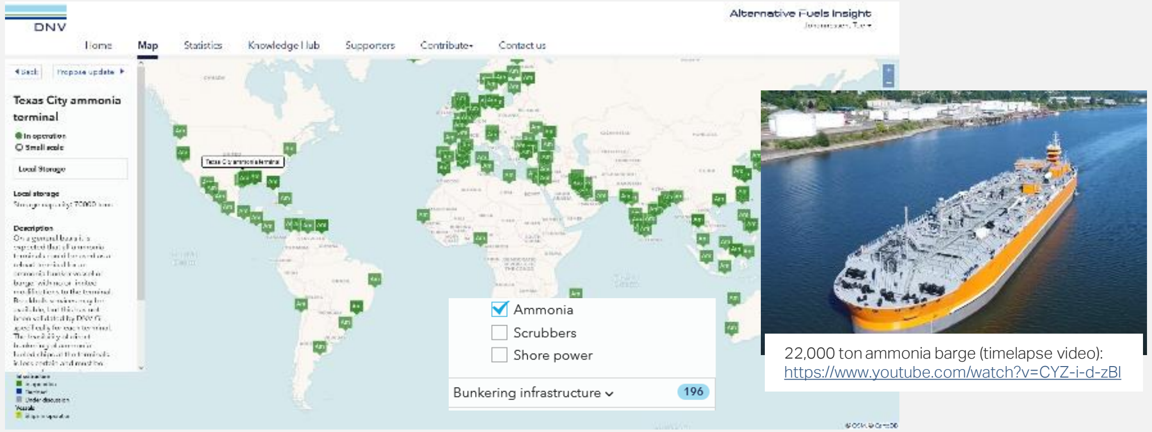
Urgent need for actions:
Renewable/green fuel production, infrastructure and new vessels

Two of the front runners: Methanol and ammonia

Current level of chemical production capacity, infrastructure and handling

Ammonia

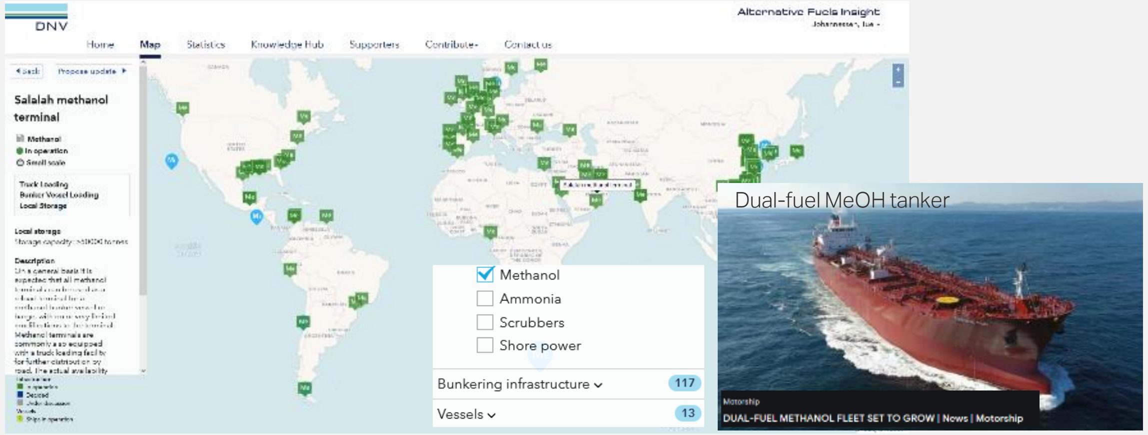
- 180 million tons per year | 20 million ton traded/shipped
- Ammonia port terminals: ~ 200. Not yet NH_3-powered vessels in op.
- Massive build-out of terminal capacity and bunkering equipment needed.



22,000 ton ammonia barge (timelapse video): https://www.youtube.com/watch?v=CYZ-i-d-zBI

Methanol

- 110 million ton/yr. Millions of tons shipped in chemical tankers.
- Methanol port terminals: ~ 200; 13 tankers operating on methanol
- Massive build-out of terminal capacity and bunkering equipment needed



Terminal locations: DNV AFI website

* https://shipandbunker.com/news/world/151813-maersk-to-order-12-methanol-fuelled-15000-teu-boxships-report https://theloadstar.com/x-press-feeders-orders-green-boxship-fleet-that-can-run-on-methanol/

Accelerating port infrastructure: Example of initiatives (I)

– MAGPIE Ambition*:
Our project has the ambition to force a breakthrough in the supply and use of green energy carriers in transport to, from and within ports. We will create energy efficiencies and support developments that make green energy carriers available to the users.

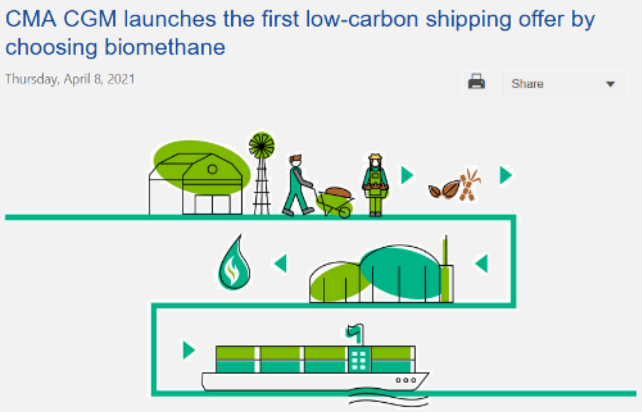
– MMMCZCS is leading a bunker feasibility work package.

https://www.magpie-ports.eu/agenda-directory/magpie-start-conference/

* https://www.portofrotterdam.com/en/news-and-press-releases/eu-awards-nearly-eu-25-million-funding-green-port-project-rotterdam

First-mover initiatives

– CMA CMG & biomethane



https://www.cma-cgm.com/news/3643/cma-cgm-launches-the-first-low-carbon-shipping-offer-by-choosing-biomethane?cat=corporateinformation

– NYK and ammonia

https://www.offshore-energy.biz/nyk-project-to-commercialize-ammonia-fuelled-ships-set-to-begin/

– Maersk and methanol:

"Designing the future of our customers' supply chains with carbon-neutral methanol vessels"
15 kTEU container vessels

https://www.maersk.com/news/articles/2021/12/08/designing-the-future-of-our-customers-supply-chains

Urgent need for scale-up of green fuel production capacity. An example:

Recent announcements for green/bio methanol:

– Maersk container vessels

– X-Press Feeders

These announced vessels would need in the order of 4-500,000 ton of methanol pr. year.

Example of ramping up:

Liquid Wind Flagship One (50,000 ton/year)

https://orsted.com/en/media/newsroom/news/2022/01/orsted-partners-with-liquid-wind-and-expands-presence-in-green-fuels-with

In summary, accelerated progress is needed in four areas during the next decade to meet 2050 target

A level playing field
with global regulation

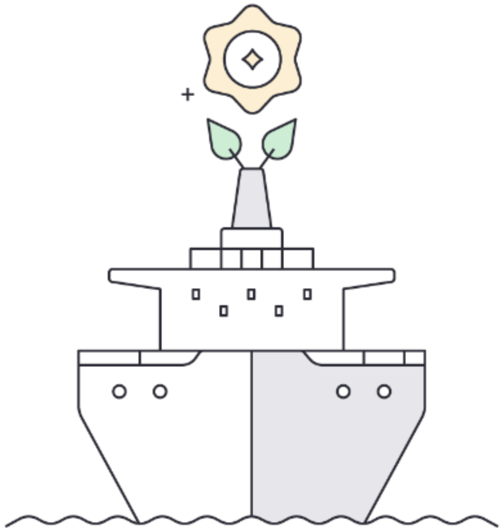
Alternative fuels
available at scale

Energy efficiency support
across the value chain

Support to first
movers

The full strategy document including detailed deep dives on each priority can be found on
www.zerocarbonshipping.com

Source: MMM Center for Zero Carbon Shipping



Thank you

Learn more on www.zerocarbonshipping.com

Links to our recent publications:

- Industry Transition:
  - https://cms.zerocarbonshipping.com/media/uploads/documents/Fuel-Options-Position-Paper_Oct-2021_final.pdf
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