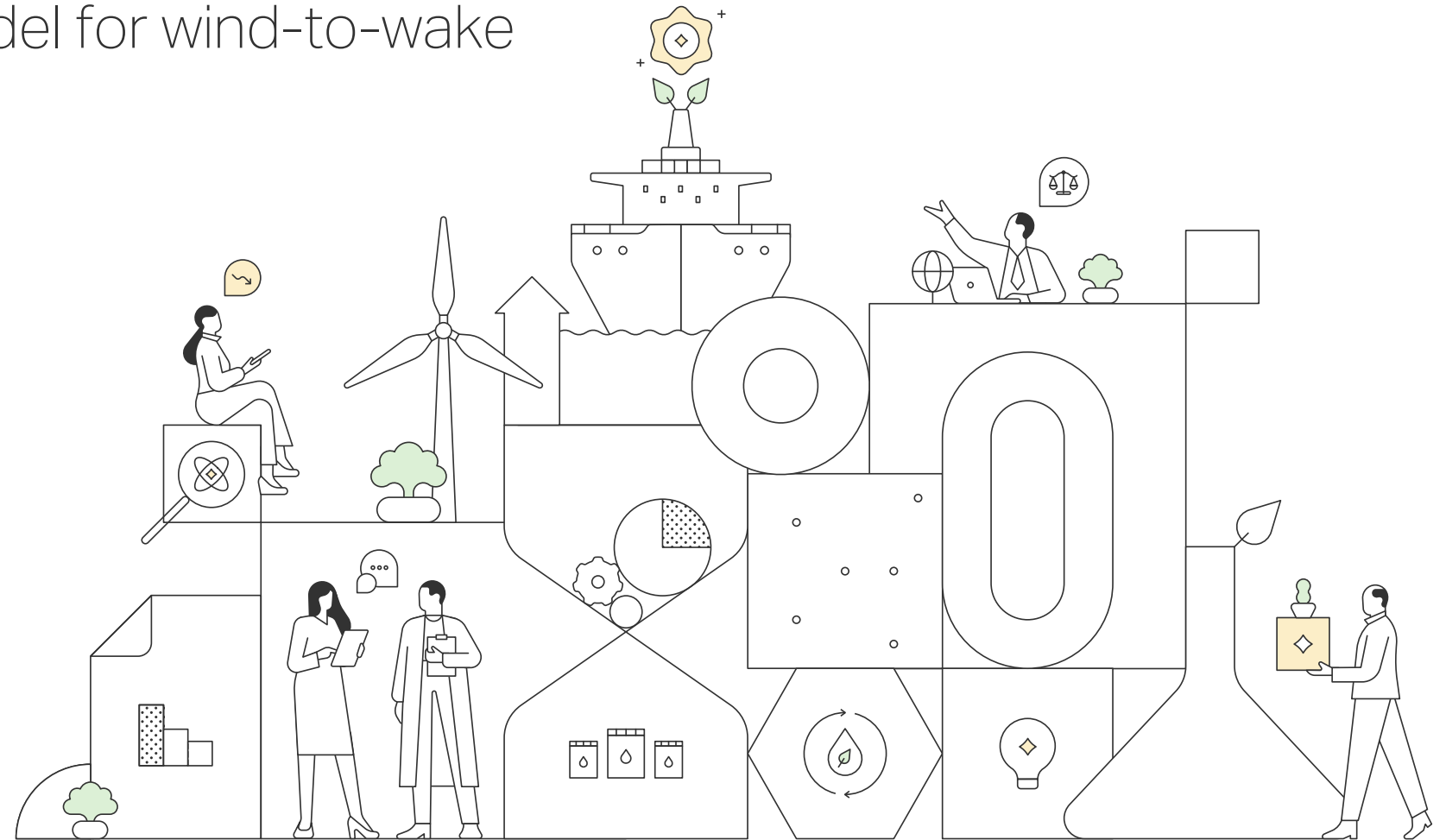


Paths for alternative fuels: Techno-economic model for wind-to-wake

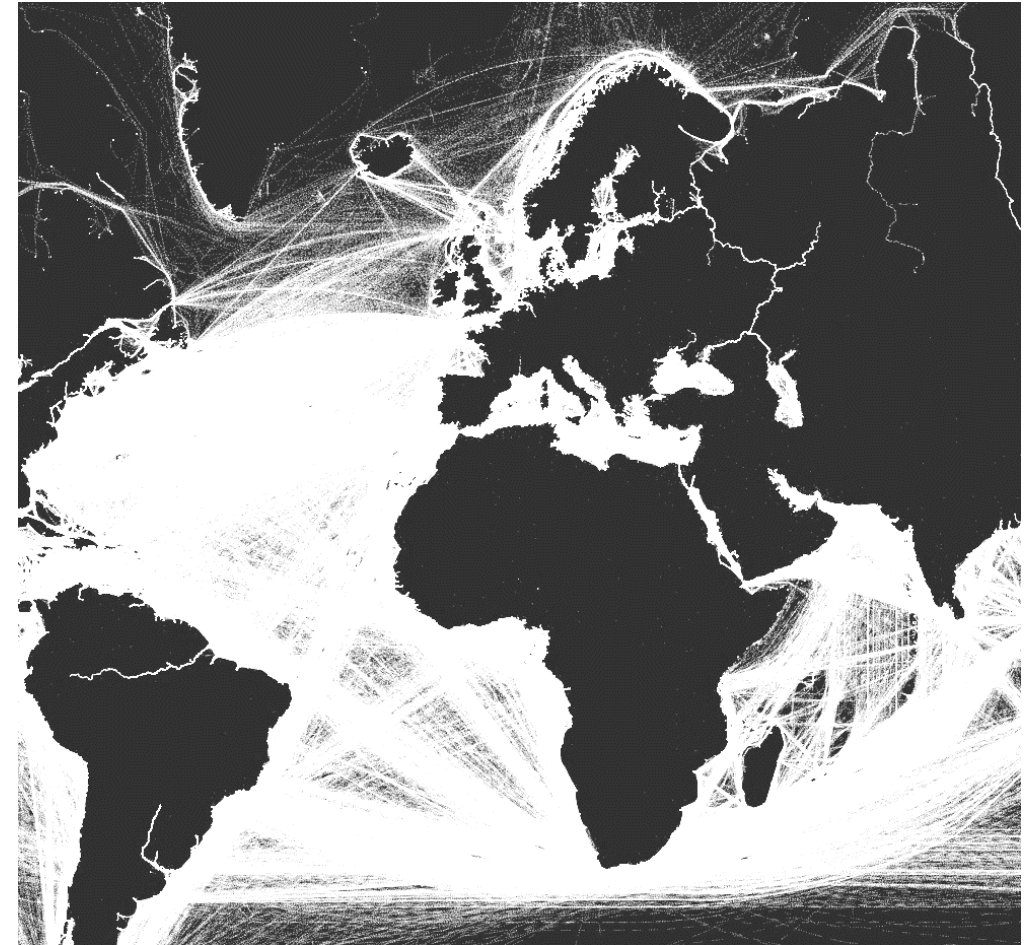
Dr. Tue Johannessen
Head of Maritime Application and Viability

GreenLab Summit 2021
Kulturcenter Skive
28/10-2021



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 CO₂ emissions.



The Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping

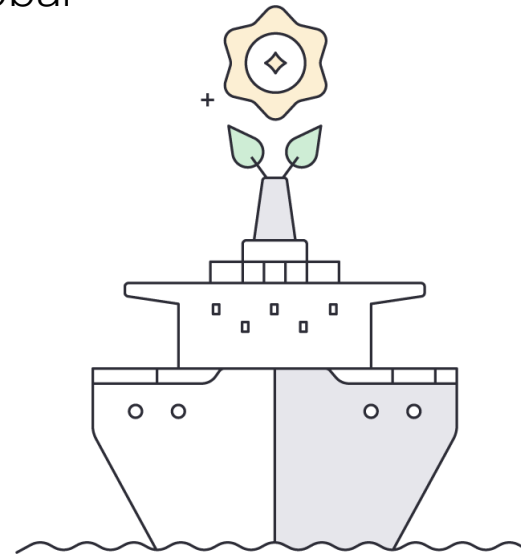
- we show the world it is possible

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



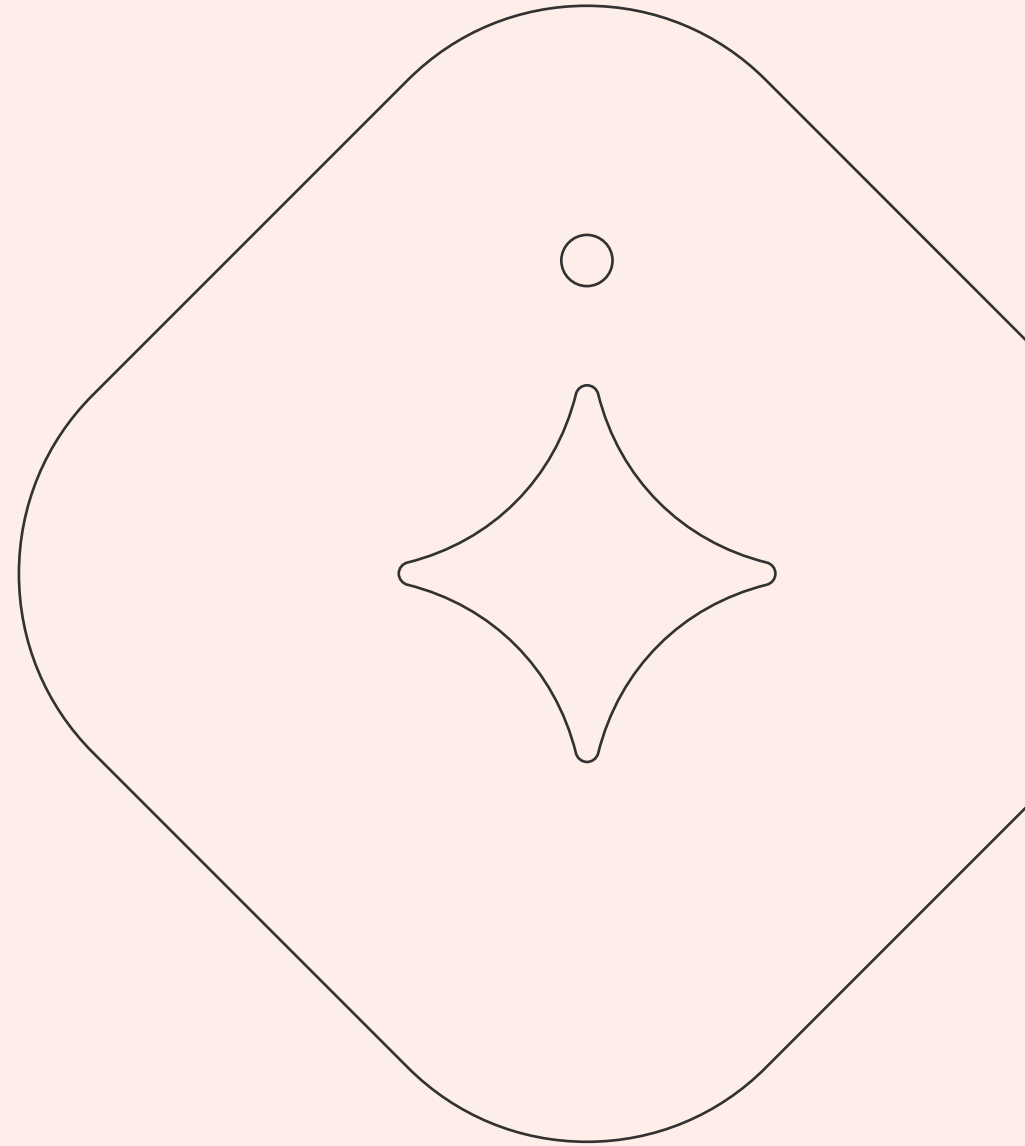
Our Partners share the zero carbon vision and are committed to collaborative climate action



-
- 17
Corporate Partners
 - 5
Knowledge Partners
 - 800+ bn
US\$ annual revenue
 - 900+ k
Total employees
 - 460+ bn
US\$ listed marketcap
 - 3,250+
Vessels operated

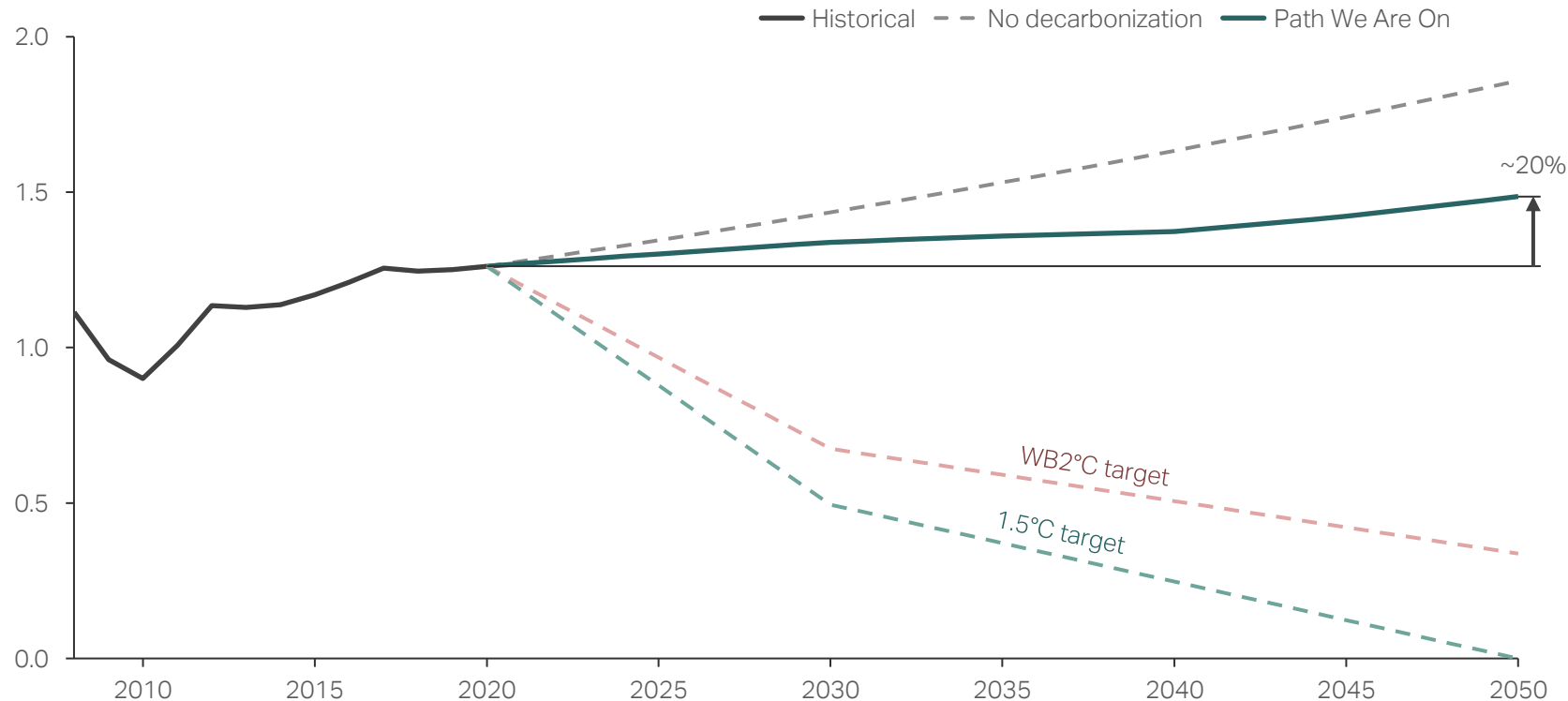


Decarbonizing the Maritime Industry



The path we are on leads to increased GHG emissions

WTW Maritime emission pathways¹
GtCO₂-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



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

Global volumes, 2018

	Billion ton-miles	2020-50 CAGR %
Total	58,932	1.3
Bulk carrier	25,050	1.0
Tanker	14,090	0.1
Container	13,046	2.4
Gas carrier	2,987	2.3
Other cargo	2,146	2.2
RoRo/Car carrier	607	2.0
Ferry	135	2.0
Cruise	130	4.0
Others ¹	740	2.3

Emissions and intensity, 2020

	GtCO ₂ -eq/year (well-to-wake)	gCO ₂ -eq/ton-km
Total	1.26	~12
Bulk carrier	0.24	~5
Tanker	0.28	~11
Container	0.29	~12
Gas carrier	0.08	~15
Other cargo	0.09	~22
RoRo/Car carrier	0.06	~52
Ferry	0.06	~223
Cruise	0.04	~115
Others ¹	0.12	~89



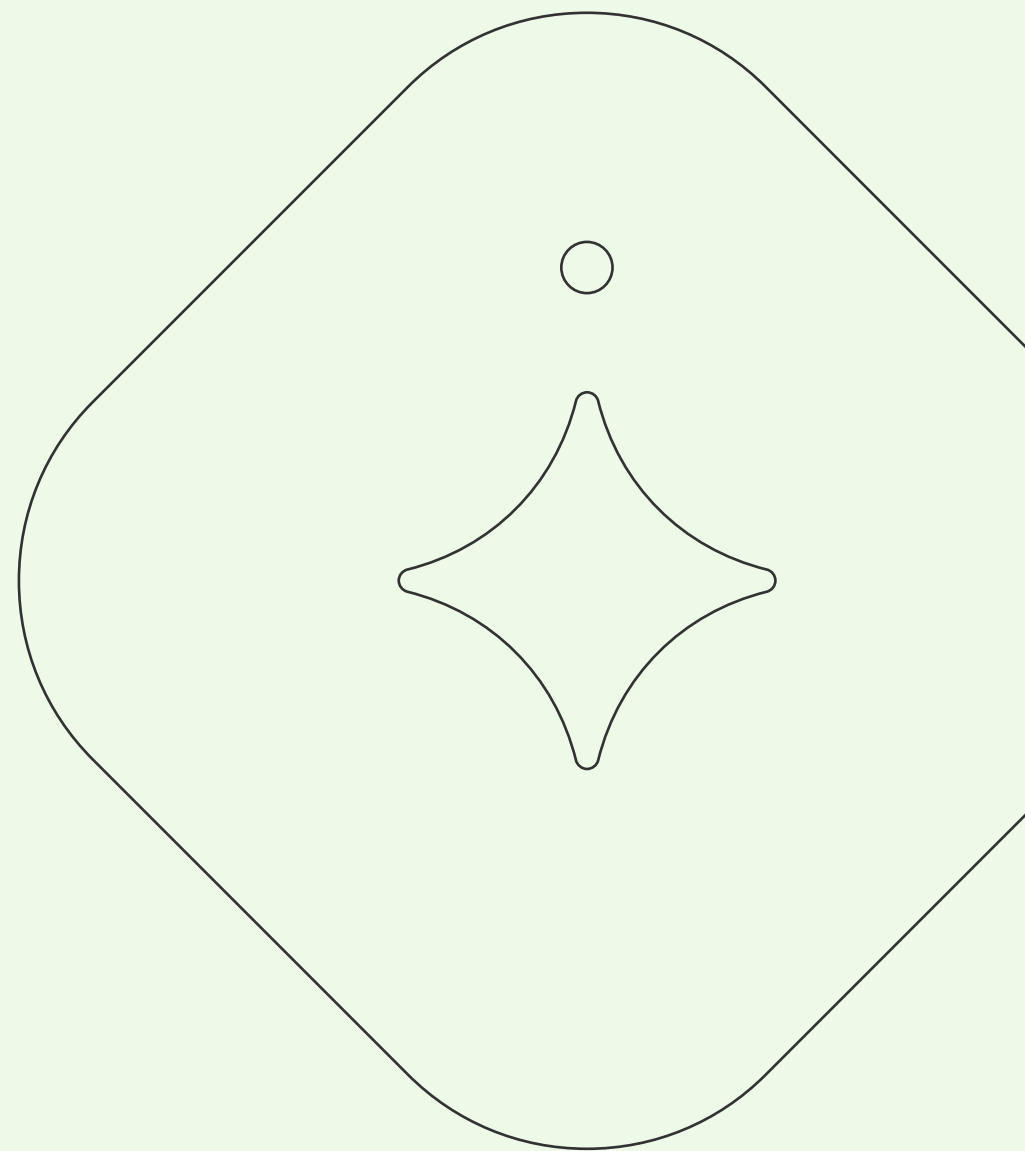
Supported by a positive World GDP outlook and historic data, maritime volumes are expected to continue to grow. Three segments - bulk, tanker and container - account for ~90% of industry volume and ~65% of emissions, making them the key focus areas for future emission reduction pathways.

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 CO₂ 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.



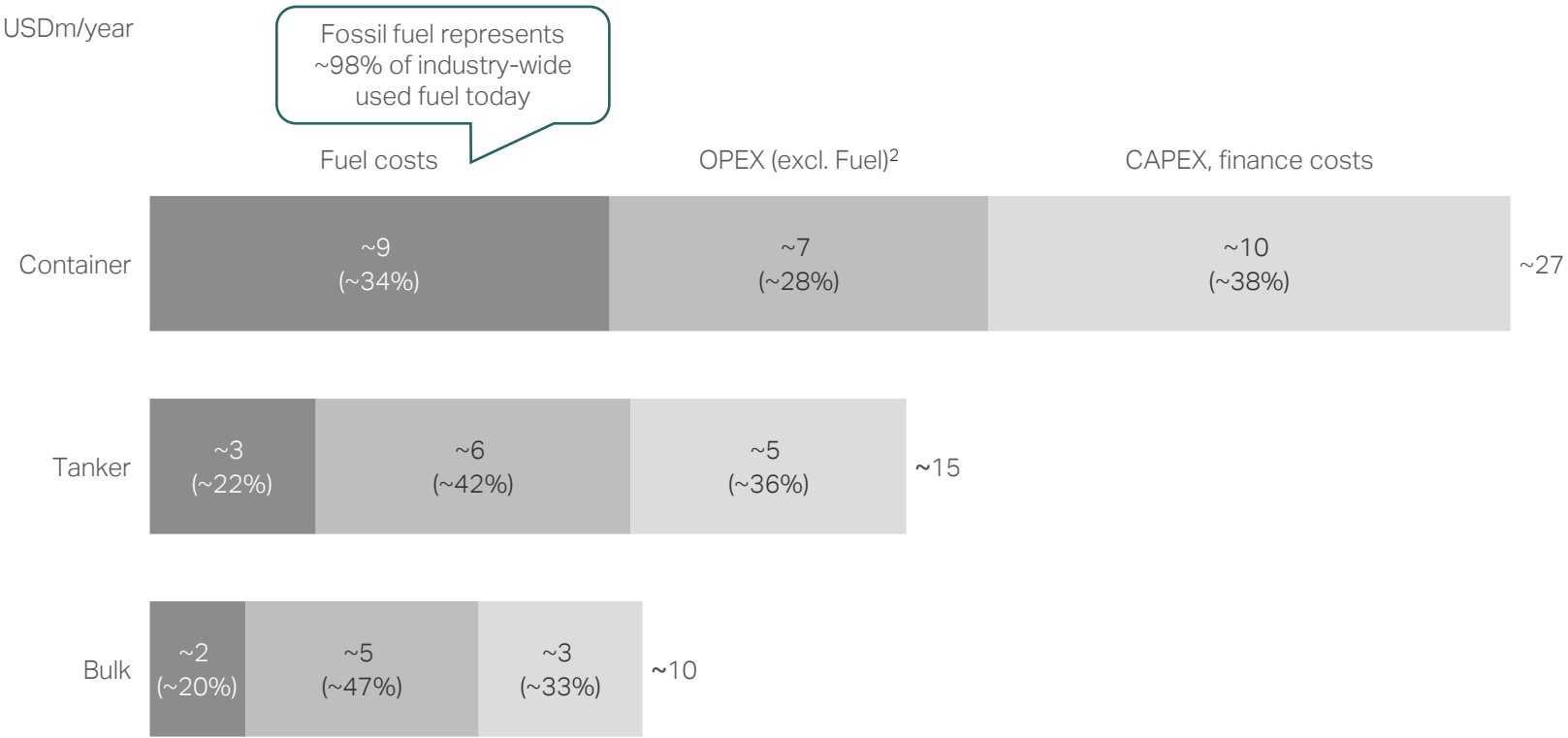
Source: IMO 4th GHG study (2020), McKinsey&Co. (2021), Clarksons (2021), NavigeTE Techno-economic model MMM Center for Zero Carbon Shipping
1 Others include offshore, tugs and non-specified ships
2 Exports of goods and services (% of GDP) | data (worldbank.org)

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 types¹ in 2020



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.

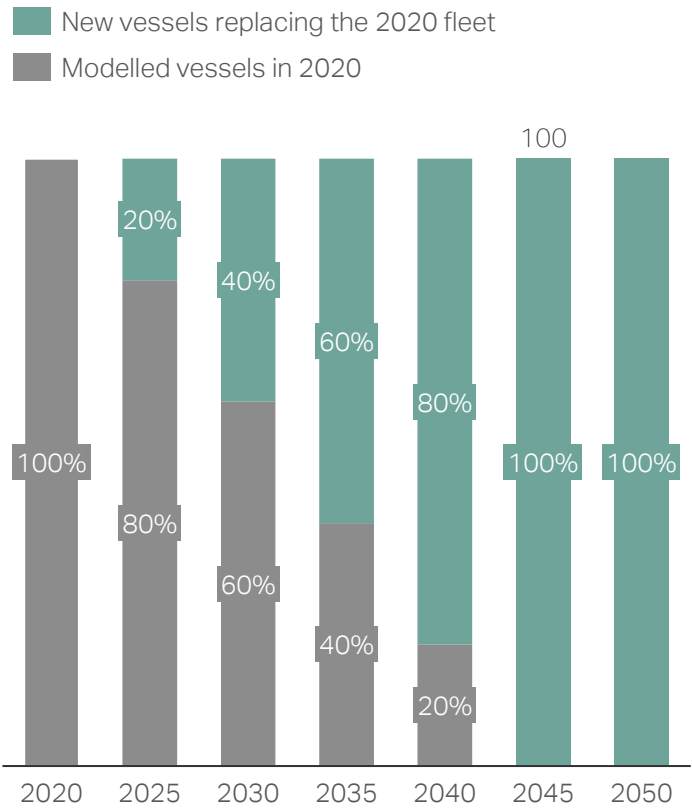
In maritime, fuel is a significant proportion of the overall cost. Firstly, there is the direct fuel purchasing cost and secondly, the quality of fuel affects cost related to vessel maintenance and performance.

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

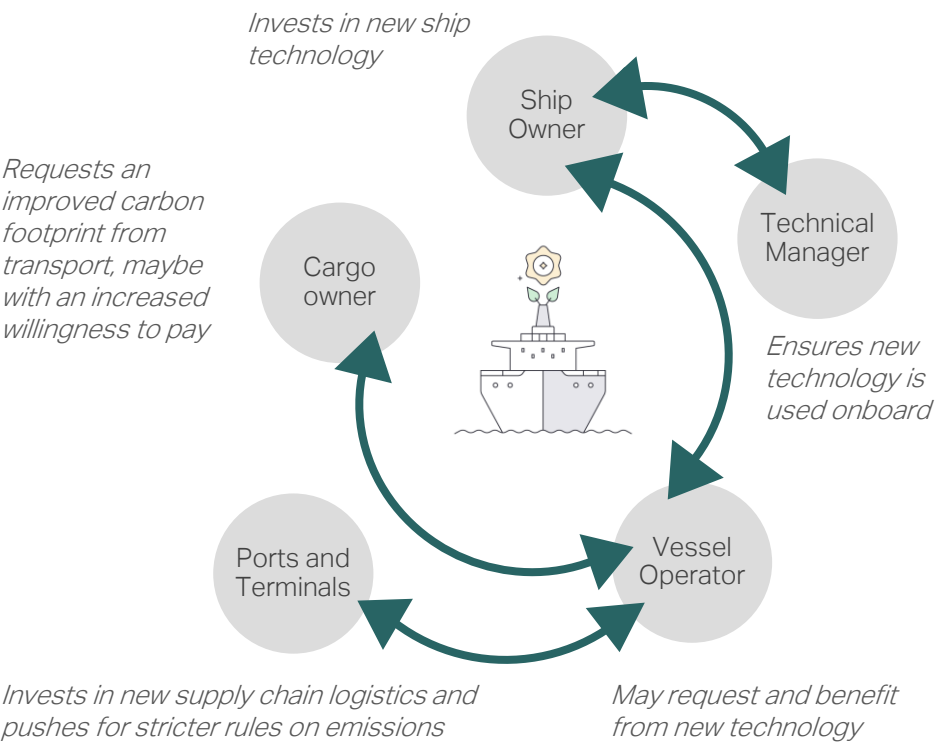
Source: NavigaTE Techno-Economic model MMM Center for Zero Carbon Shipping
1 Typical vessels refer to: Container- 8,000 TEU capacity; Tanker - LR2 85-125k DWT; Bulk carrier - Panamax 70-99k DWT ; All vessels are assumed to have a 25-year lifetime.
Typical operational profiles have been assigned to each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

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

Natural replacement of existing fleet¹



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


Alternative fuels have varying maturity levels and challenges in the early years of transition

Alternative fuels for decarbonization

Energy Carrier	Feedstock availability	Fuel production	Fuel storage, logistics, bunkering	Mature and proven	Solutions identified	Major challenges remain
				Onboard fuel conversion ¹	Onboard safety and fuel management ²	Regulation ³
Fossil fuels						
e-hydrogen						
Blue hydrogen						
e-ammonia						
Blue ammonia						
e-methanol						
Bio-methanol						
e-methane						
Bio-methane						
Bio-oils						

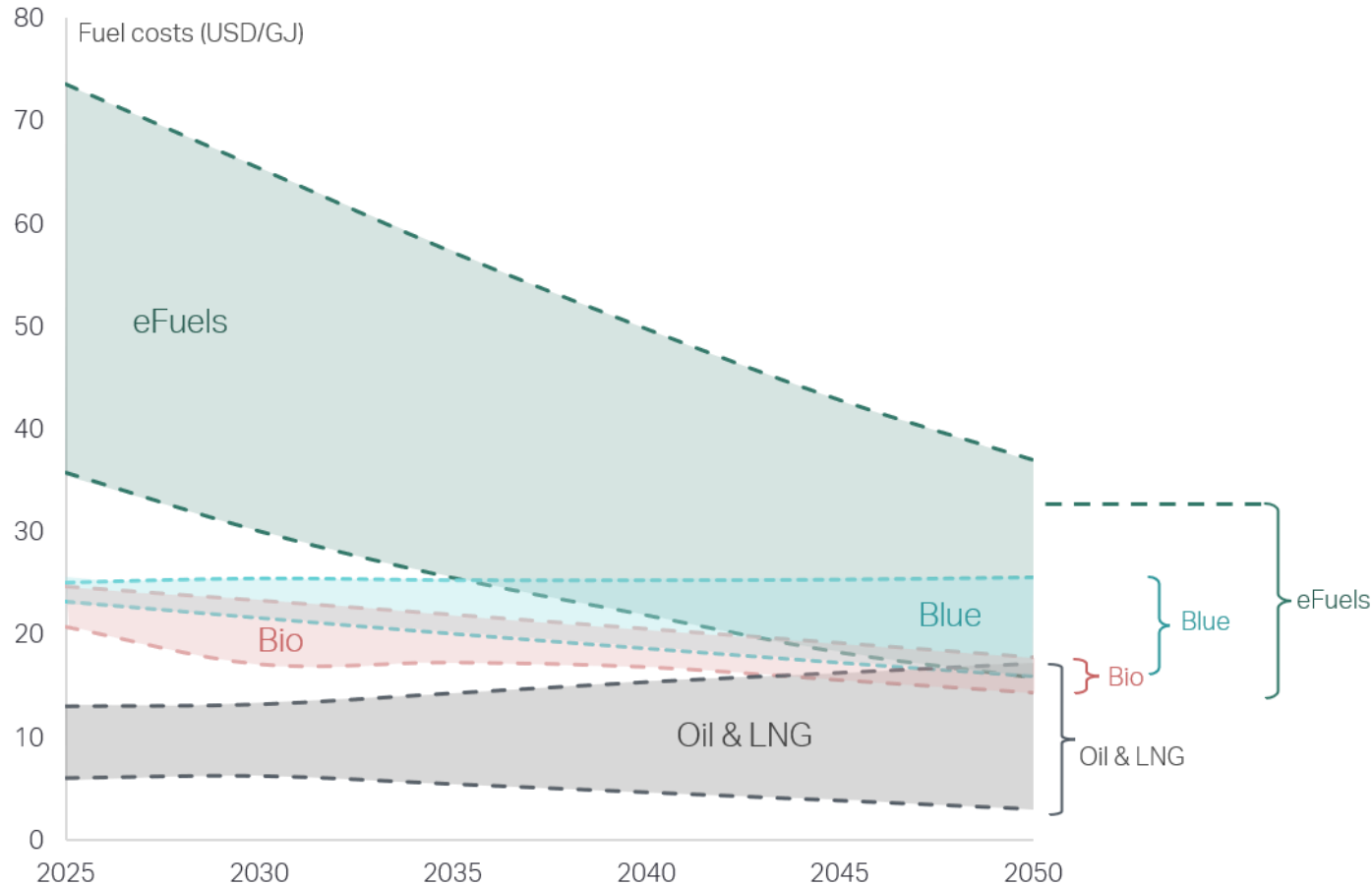


- The future fuel pathways will include more options than we know today
- Each pathway has different challenges in terms of scalability, cost and technology maturity and safety
- Alternative fuels will be in competition, when the sectors and nations progress through the green transformation.



The center tile map will be updated regularly

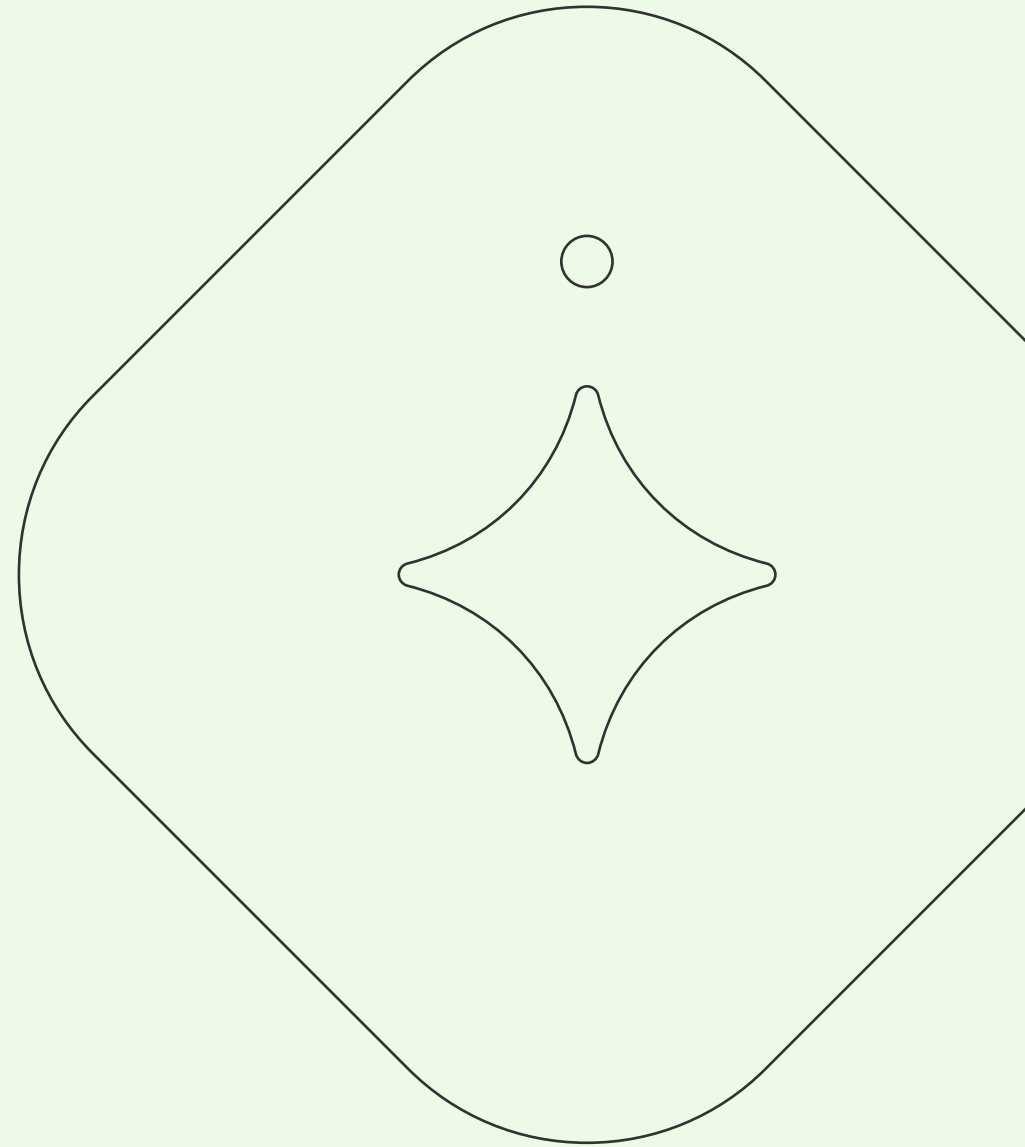
... and there are significant fuel cost gaps – particularly in the beginning of the transition



- Very high carbon tax is needed to bring fossil fuels on par with best alternative fuel options.
- But high tax levels are difficult to implement



What does it take ?



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



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 **CO₂ pricing and tighter energy efficiency regulations**



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**



Energy & fuel advancements

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



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**

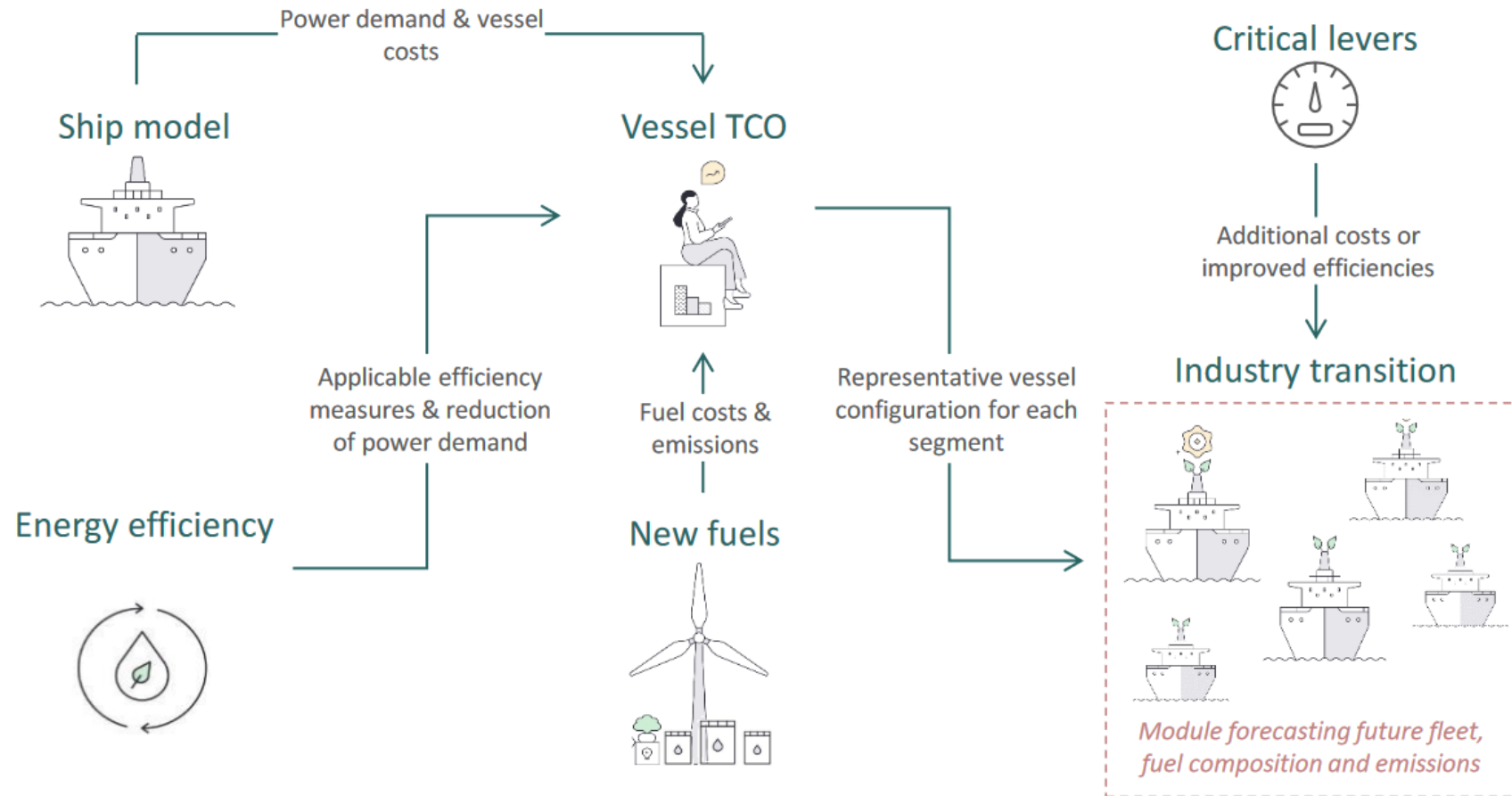


Finance sector mobilization

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



We model the path towards 2050

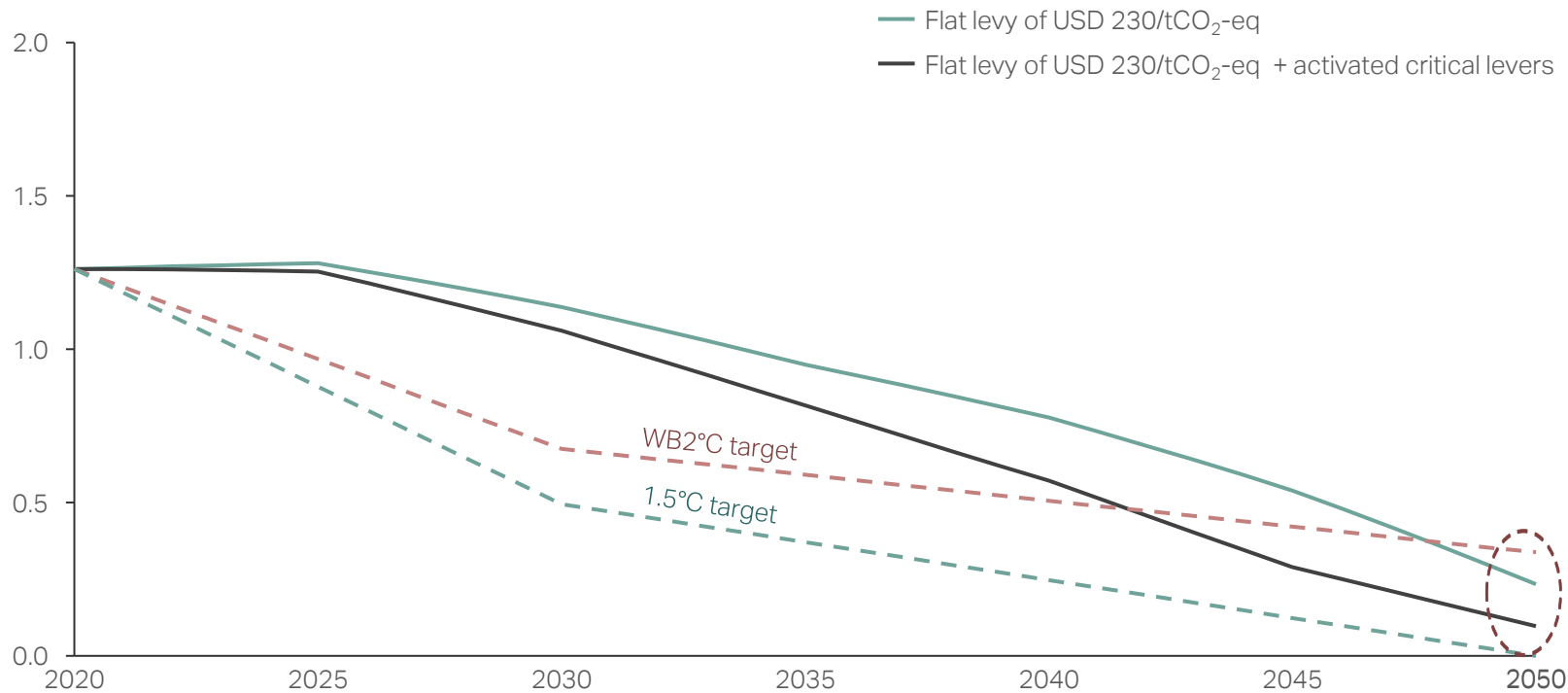


- The Industry Transition model enables fleet projections based on TCO comparisons, trade growth and fleet turnover.
- The two key input is the TCO comparison and the swing factors.
- The TCO model enables diligent ship level comparison of fuel and energy efficiency setup across ship types, sizes and 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 CO₂ taxation.



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

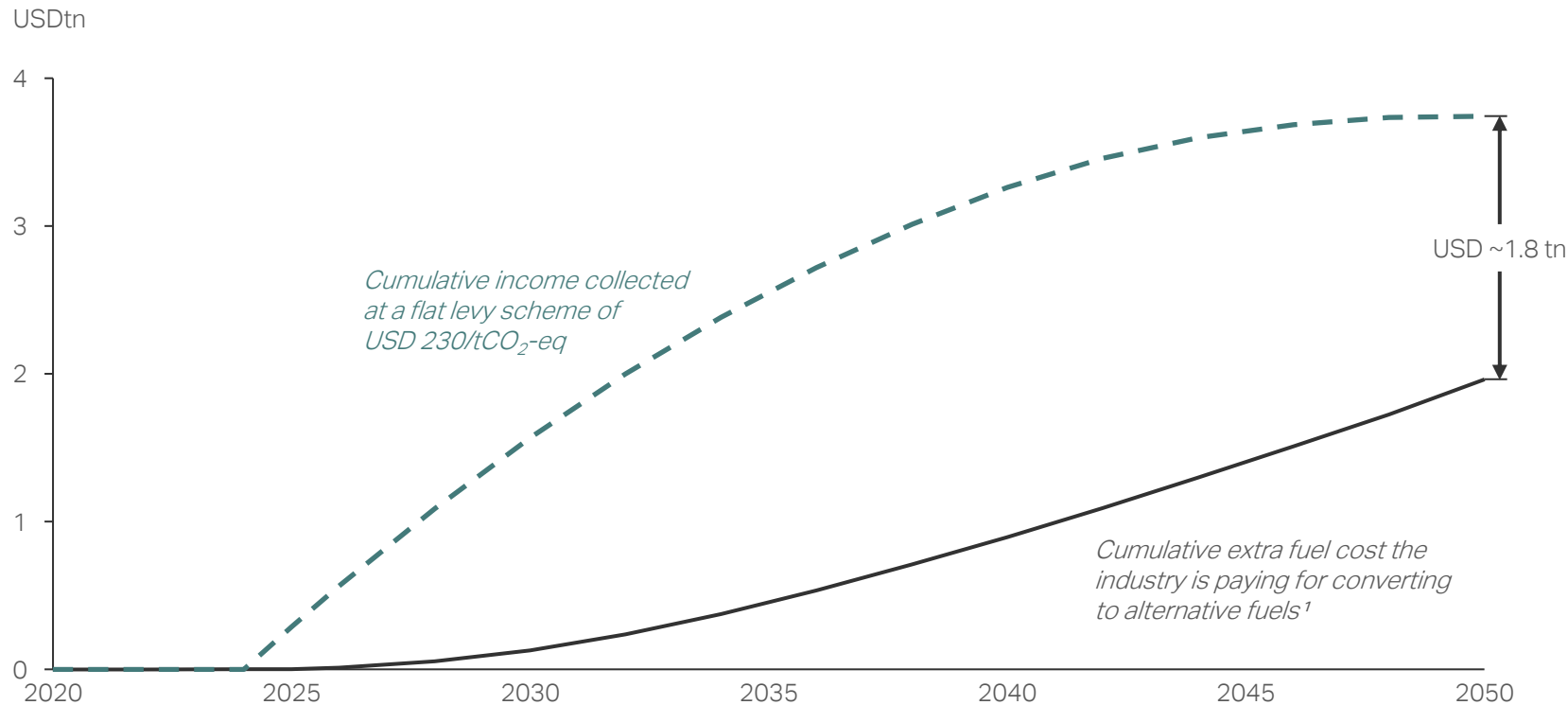
WTW GtCO₂-eq/year



- 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 levy of USD ~230/tCO₂-eq by 2025, in combination with activated critical levers, results in the abatement needed towards 2050.



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



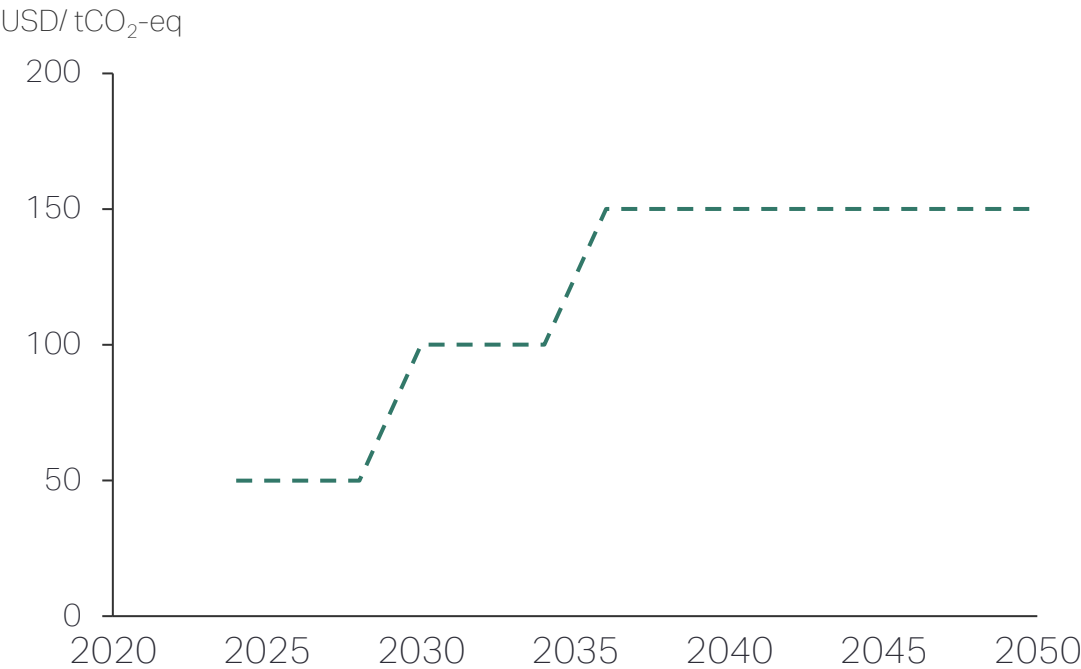
- A flat levy of ~ USD 230/tCO₂-eq sufficiently penalizes fossil fuel usage by bringing costs up on par with the alternative fuels.
- With most vessels operated on fossil, the cumulative CO₂-eq income collected from a levy will quickly grow large while tapering off further into the transition (green dotted line).



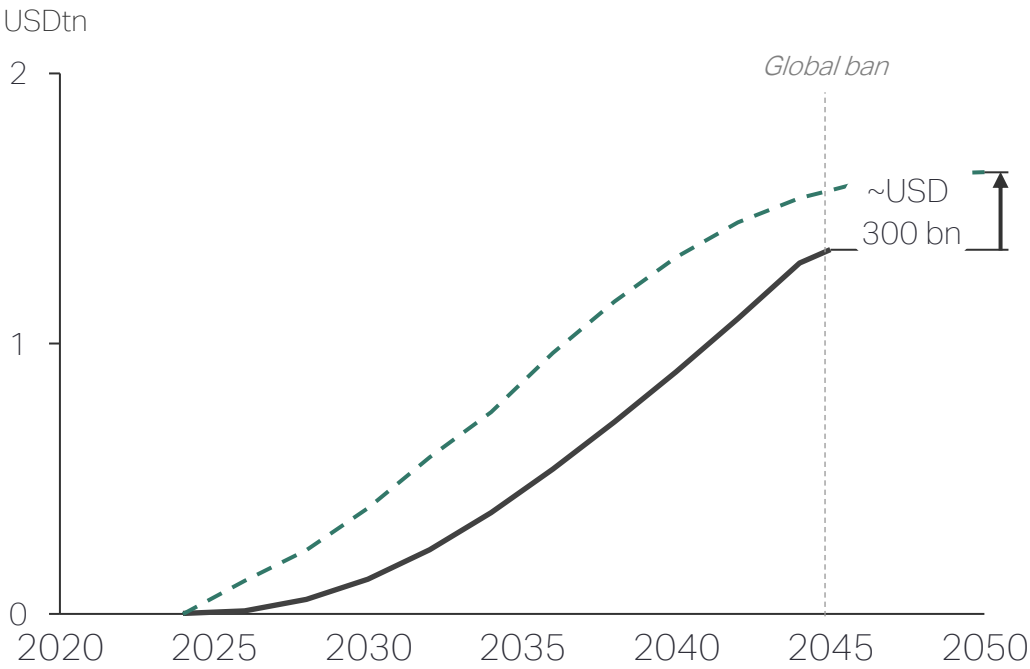
Alternatively, an earmark and return carbon pricing scheme sequenced with a ban can motivate lower levies

— Cumulative extra fuel cost the industry is paying
- - - Scheme with two hikes

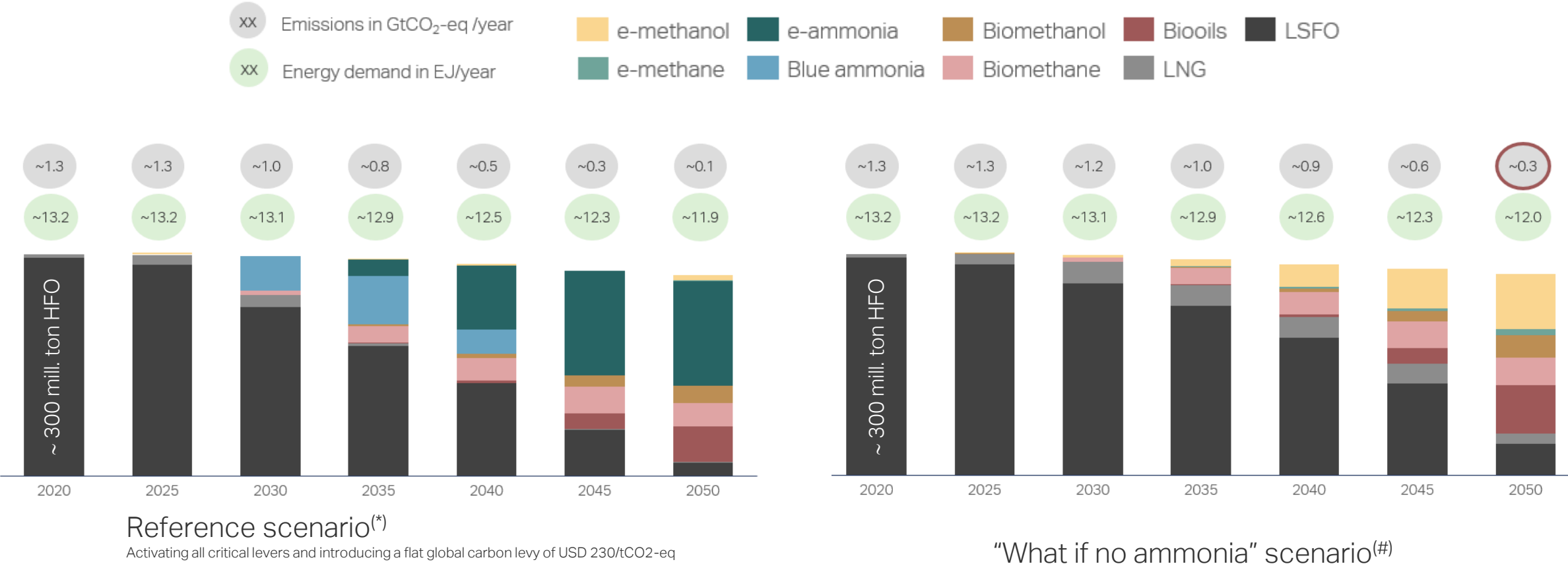
The regulator can start by imposing an “earmark and return” global carbon levy system...



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



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

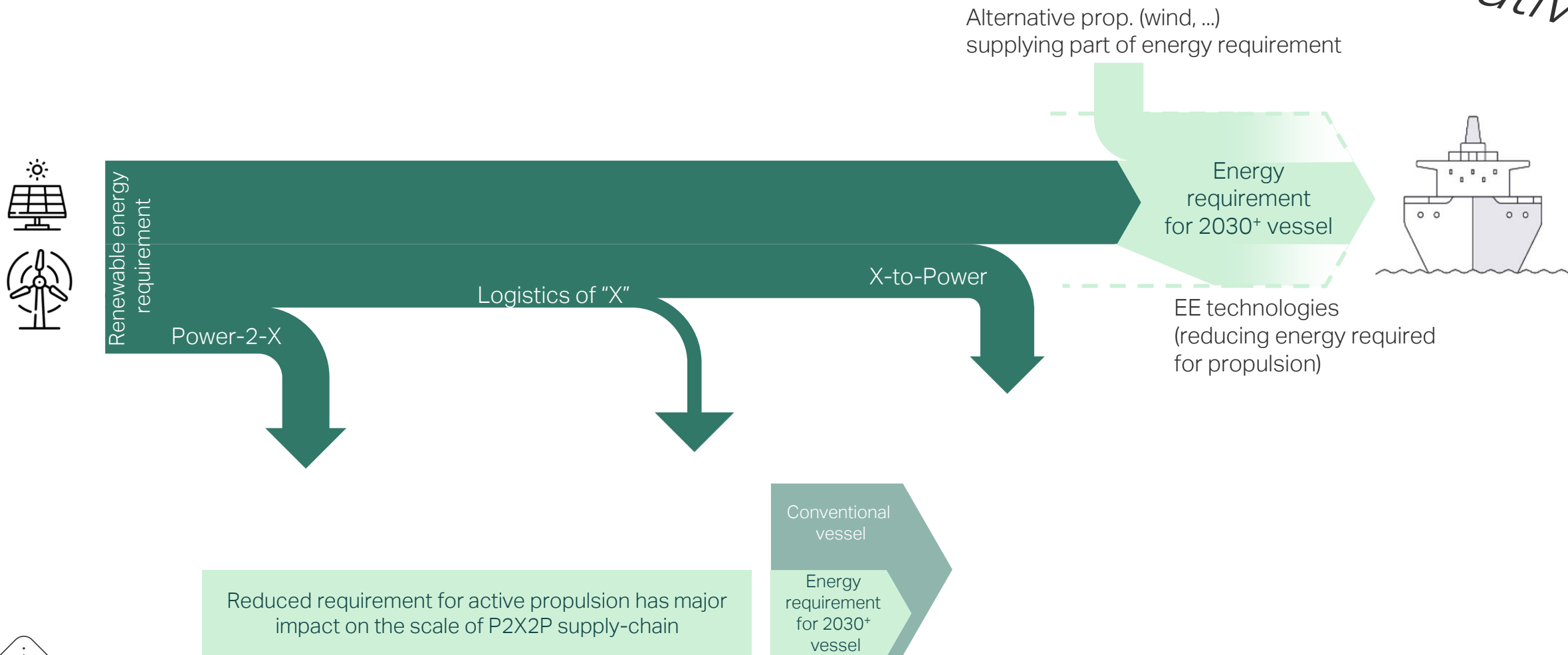


Source: NavigaTE Techno-Economic model MMM Center for Zero Carbon Shipping

(*) https://cms.zerocarbonsshipping.com/media/uploads/documents/MMMCZCS_Industry-Transition-Strategy_Oct_2021.pdf
(#) https://cms.zerocarbonsshipping.com/media/uploads/documents/Fuel-Options-Position-Paper_Oct-2021_final.pdf

Energy efficiency & alternative propulsion matters

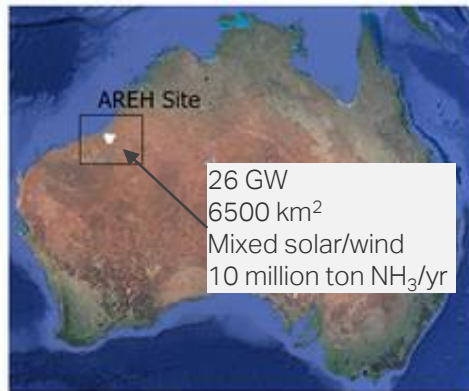
Illustrative



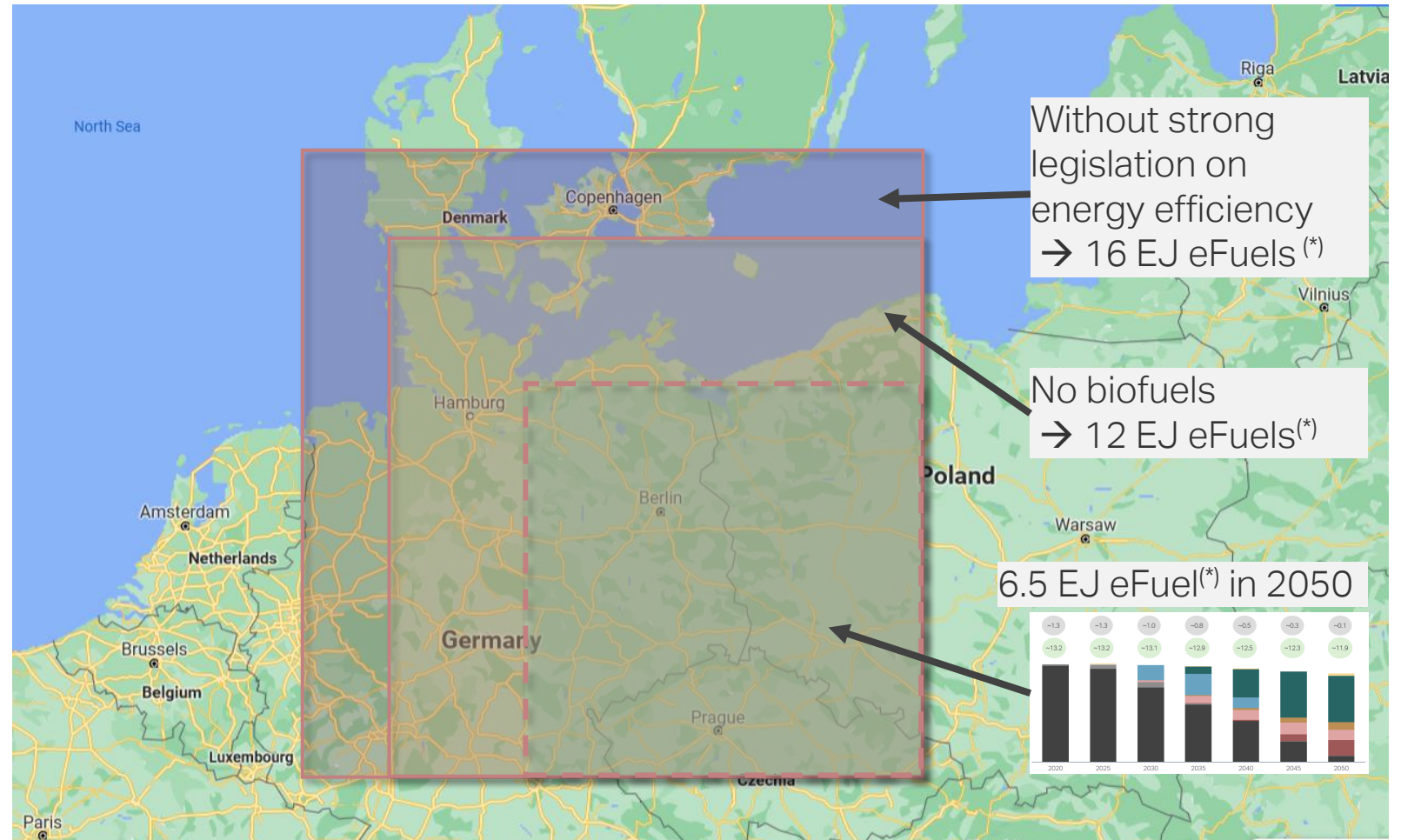
How much renewable power required?

We must use the renewable electricity respectfully...

Scaling of development "Down Under"



<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

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



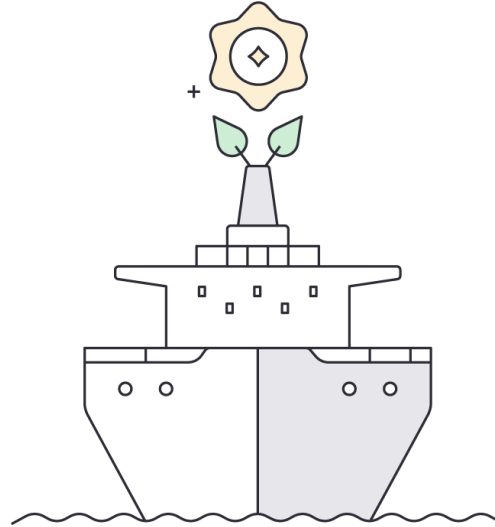
Support to first
movers



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

– Fuel Options:

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

– NavigaTE to Zero:

- https://cms.zerocarbonshipping.com/media/uploads/documents/NavigaTE_Whitepaper_final.pdf