Appendices

Appendix 1: Corridor selection

The green corridor selection process followed a stepwise filtering process, designed to narrow down the entire universe of shipping routes to ten likely green corridor candidates that could be further analysed.

The first step in the corridor selection process was the shortlisting of every global shipping corridor that comprises more than 0.1 percent of global trade by volume. Next, all routes trading fossil fuels, such as oil and coal, were filtered out based on the logic that there would not be significant motivation for fossil-fuel cargo owners to decarbonise the transportation of their products.

That left approximately 23 corridors that each make up more than 0.1 percent of global trade by volume. Of these 23 corridors, seven corridors were selected across two major vessel sub-categories: containerships and dry bulk (Exhibit 21).

Exhibit 21: Corridor selection shortlist

We shortlisted 7 of the 23 corridors with >0.1% of global trade by volume

Vessel type	**Goods**	**Route**	**Volume** (m tonnes, 2019)
Container-ships	Diversified - mainline	Transpacific mainline	202
		Asia-Europe mainline	234
		Translatlantic mainline	58
	Diversified – non-mainline	Non-mainline East-West	193
		North-South	89
		South-South	144
		Intra-regional	405
Dry bulk	Iron ore	Australia-China	689
		Brazil-China	212
		Australia-Japan	62
		Australia-South Korea	53
		Brazil-Malaysia	29
		South Africa-China	17
		Brazil-Japan	13
		Brazil-Netherlands	11
	Soyabeans	Brazil-China	58
		United States-China	23
	Bauxite	Guinea-China	38
		Australia-China	31
	Manganese	South Africa-China	11
	Nickel Ore	Philipines-China	25
		Indonesia-China	18
	Forestry products	New Zealand-China	14
Dry cargo	No routes > 0.1 % of global trade		
Liquid bulk	No non-fossil fuel routes >0.1% of global trade		

...and a further 3 based on potential ability to decarbonise rapidly

Automotive RoRo, e.g., Asia-US
3 pilots ongoing. Manufacturers have significant incentives to decarbonise supply chains

Methanol tanker, e.g., Saudi Arabia-China
Dual fuel tankers already in fleet, methanol potential zero-emission marine fuel

Ammonia tanker, e.g., Saudi Arabia-India
Ease of retrofit creates attractive opportunity from technical feasibility standpoint

Source: Based on Clarksons Research (2020), UNCTAD data on non-mainline containership routes (2021), Drewry Shipping Consultants (2020)

In the containership category, three major mainline corridors—Trans-pacific, Asia-Europe, and Transatlantic—were selected due to the volumes traded and the fact that they are clearly defined shipping liner routes. To add further diversity to the selection process, a non-mainline corridor, North-South, was also included.[xix]
In the dry bulk category, iron ore was by far the most significant commodity traded from a volume perspective and all three corridors selected were iron ore routes.

In addition to the seven corridors selected based on impact, three corridors were selected based on their potential to decarbonise rapidly. Ammonia and methanol tankers, traveling from Saudi Arabia to India and China, were selected according to a hypothesis that both vessel types can be more easily converted to run on zero-emission fuels due to their ability to use existing vessel-based storage facilities.

Automotive roll-on/roll-off (RoRo) vessels that travel from Asia to the United States, were selected based on the hypotheses that (i) value chain actors would have significant incentive to decarbonise their supply chains, and (ii) given the high-value nature of automotive as a traded good, higher transportation costs would not have a material impact on the final retail price.

xix Non-mainline containership corridors are aggregates of several liner routes. Compared to main-line containership corridors, they are not clearly defined from a shipping liner route perspective. The non-mainline East-West category, for example, is made up of multiple shipping liner routes including Asia-Middle East and Asia-South Asia.

The final ten corridors were then assessed on a set of nine qualitative and quantitative indicators, covering impact and feasibility (Exhibit 22).

Exhibit 22: Key indicator assessment criteria

Category	Metric	KPIs [Unit]	Assessment	Data analysis[1]	Source
Impact	A. Trade and logistics	Share of global trade volume [Bps]	Proportion of global trade in tonnes per route	Qualitative	Based on Clarksons Research (2020), UNCTAD data (2021), Drewry Shipping Consultants (2020)
		Expected future growth [%]	CAGR 2021-2025	Quantitative	Based on Clarksons Research (2020), UNCTAD data (2021), Drewry Shipping Consultants (2020)
	B. Emissions	Carbon intensity on route [kgCO_2e/tonnage cargo]	CO_2/ tonne	Quantitative	IMO (2020)
		Current carbon emissions on corridor [Tonne CO_2e]	Tonnage on route	Quantitative	IMO (2020)
Feasibility	C. Value and cost pass-through	Relative price increase of traded good [%]	Increase in transportation cost of product/retail price of good	Quantitative	Multiple sources for average value of good on the route (e.g., insurance marine.com); fuel delta estimates based ETC analysis (2021)
		Scope 3 importance for traded good sector [Scoring 1-5]	Top 3-7 largest producers of commodity/product (by value) : • Commitment to net zero or tackling scope 3 • Which faced a sustainability scandal in the last 5 years • Whose products have high visibility to end consumers	Qualitative	Multiple sources including annual reports of largest companies active on the route
	D. Supply of zero-emission fuel	Delivered cost of zero-emission fuel [$/GJ]	Delivered cost of zero-emission fuel based on ammonia cost calculation for a specific route	Quantitative	Analysis based on ETC (2021)
	E. Stakeholder readiness	National policies/regulations [Scoring 1-5]	Status on net-zero goal setting (relevant for specific route) on regional/ governmental level	Qualitative	Energy&Climate Intelligence Unit (2021)
		Ease of stakeholder environment [Scoring 1-5]	Hydrogen strategy planned or in place	Qualitative	Multiple sources including national hydrogen roadmaps published by governments
			Number of import/export parties involved	Qualitative	Multiple sources including AIS data (2020) and Alphaliner (2020)

For impact, along with share of global trade volume, the expected future growth of the route, the carbon intensity of the route, and the current carbon emissions on the corridor were assessed. For feasibility, indicators were chosen to assess the additional cost of zero-emission fuel, the value and ability for additional transportation cost to be passed through, and stakeholder willingness to create an enabling ecosystem for green corridors.

Appendix 2: Contracts for Difference

A Contract-for-Difference (CfD) is a fixed-term contract between two parties, usually referred to as the "buyer" and the "seller". In a CfD contract, the buyer pays the seller the difference between the current value of an asset and its value at the time the contract was concluded. The reverse is also true.

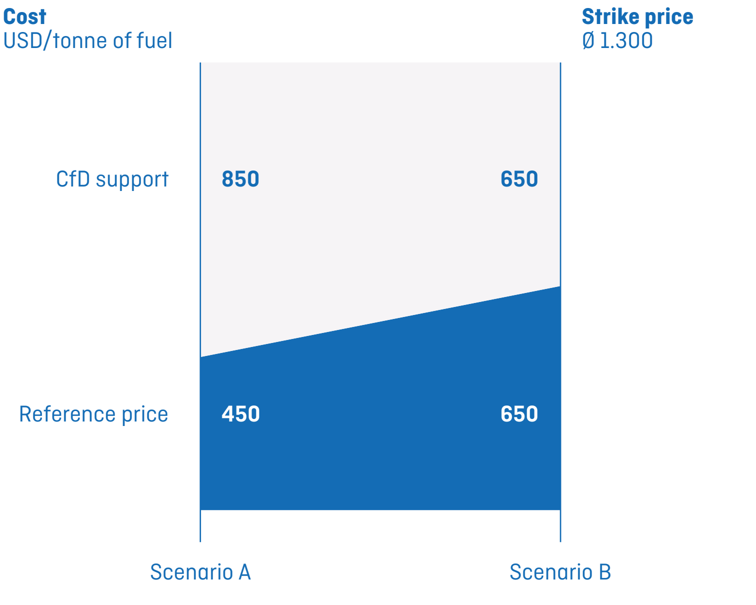
The purpose of a CfD is to ensure investment in new technologies, accelerate their deployment, and reduce costs and uncertainty to the point where they become economically competitive without further support. At the same time, it is important to ensure the greatest possible flexibility for the contract participants.

In the context of green shipping, the public sector represents the buyer. The seller may be, for example, a fuel supplier, but depending on the contract any shipping firm may participate under the condition that zero-emission fuel will be used on a zero-emission vessel. The public sector can either set the strike price administratively or consider an auction mechanism where suppliers bid against each other to determine the "winning" strike price.

In addition, there are two options for designing green shipping CfDs where the structure of the reference price is different. The first option is a fuel-based CfD which means the reference and strike price are only based on the cost of the fuel. The second option is a total-cost-of-ownership-based CfD where the strike and reference price relate to the cost of building and operating a qualifying vessel (Exhibit 23).

Exhibit 23: Fuel-based CfD mechanism

Fuel-based CfD mechanism



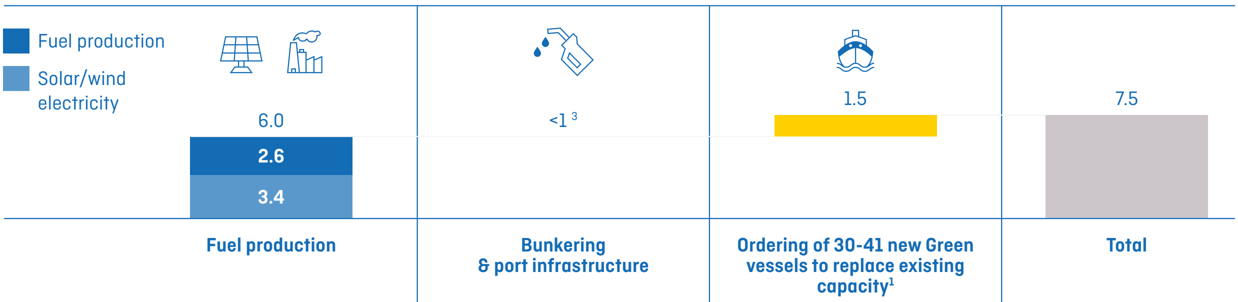
Source: Based on Han&Wang (2021)

Appendix 3: Capex breakdown for the iron ore and containership corridors

Exhibit 24: End-to-end capex requirement to decarbonise the iron ore corridor

Total end-to-end capex requirement to build 100% of the decarbonised route
USD, billion

ASSUMING CURRENT FLEET CAPACITY ON ROUTE AND FULL TIME EQUIVALENT VESSELS ONLY



Assumptions used

Fuel production

- 1.5 per MW of wind/solar capacity
- 1.2-1.7 GW of green H2 electrolyser capacity at investment of $980/kW capacity ($1.2-1.6bn)
- Hydrogen storage of ~$0.4-0.5bn based on 48 hour buffer at $29 /tonne[2]
- Ammonia plant – $300-400mn at $400/ton of ammonia production capacity and 1.0m tonnes of ammonia per year required

Bunkering & port infrastructure

- 1 storage tank per port of 20,000 tonne ammonia capacity each with investment of $600/tonne
- 2 bunker vessels per port required at $10m/vessel

⚠ Safety requirements for bunkering ammonia may require additional port infrastructure to mitigate risks, but are not expected to be significant

Ordering of 30-41 new Green vessels to replace existing capacity[1]

- 1 storage tank per port of 5,000 tonne ammonia capacity each with investment of $600/tonne
- 2 bunker vessels per port required at $10m/vessel

⚠ Note: Not additional capex; Total capex for ZEV newbuilds only slightly more expensive than newbuild HFO vessels

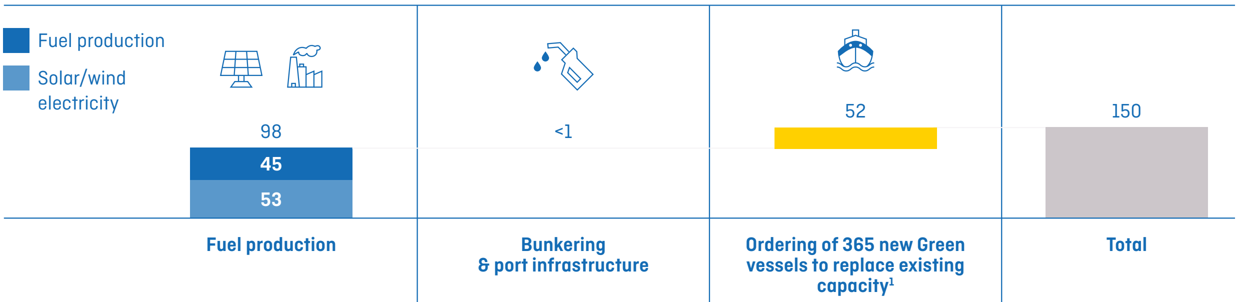
[1]Based on replacement of vessels with capacity 150,000-200,000 dwt on route (assuming capacity of route remains constant)
[2]On a 24 hour basis the hydrogen storage cost capex would become $187m
[3]Bunkering infrastructure capex estimated at $69m for the iron ore corridor

Source: Team analysis based on the Maersk Mc-Kinney Moller Center for Zero Carbon Shipping NavigaTE model

Exhibit 25: End-to-end capex requirement to decarbonise the Asia-Europe corridor

Total end-to-end capex requirement to build 100% of the decarbonised route
USD, billion

ASSUMING CURRENT FLEET CAPACITY ON ROUTE



Assumptions used

Fuel production

- 1.5 per MW of wind/solar capacity
- 35 GW of green H2 electrolyser capacity at investment of $980/kW capacity
- Hydrogen storage of $2.3bn based on 24 hour buffer at $29 /tonne
- Ammonia plant – $8bn at $400/ton of ammonia production capacity and 20m tonnes of ammonia per year required

Bunkering & port infrastructure

- 4 storage tanks of 20,000 tonne ammonia capacity each with investment of $600/tonne
- 10-15 bunker vessels required at $10m/vessel

Safety requirements for bunkering ammonia may require additional port infrastructure to mitigate risks, but are not expected to be significant

Ordering of 365 new Green vessels to replace existing capacity[1]

- $142m capex required for single vessel with lifetime of 25 years

Note: Not additional capex; Total capex for ZEV newbuilds only slightly more expensive than newbuild HFO vessels

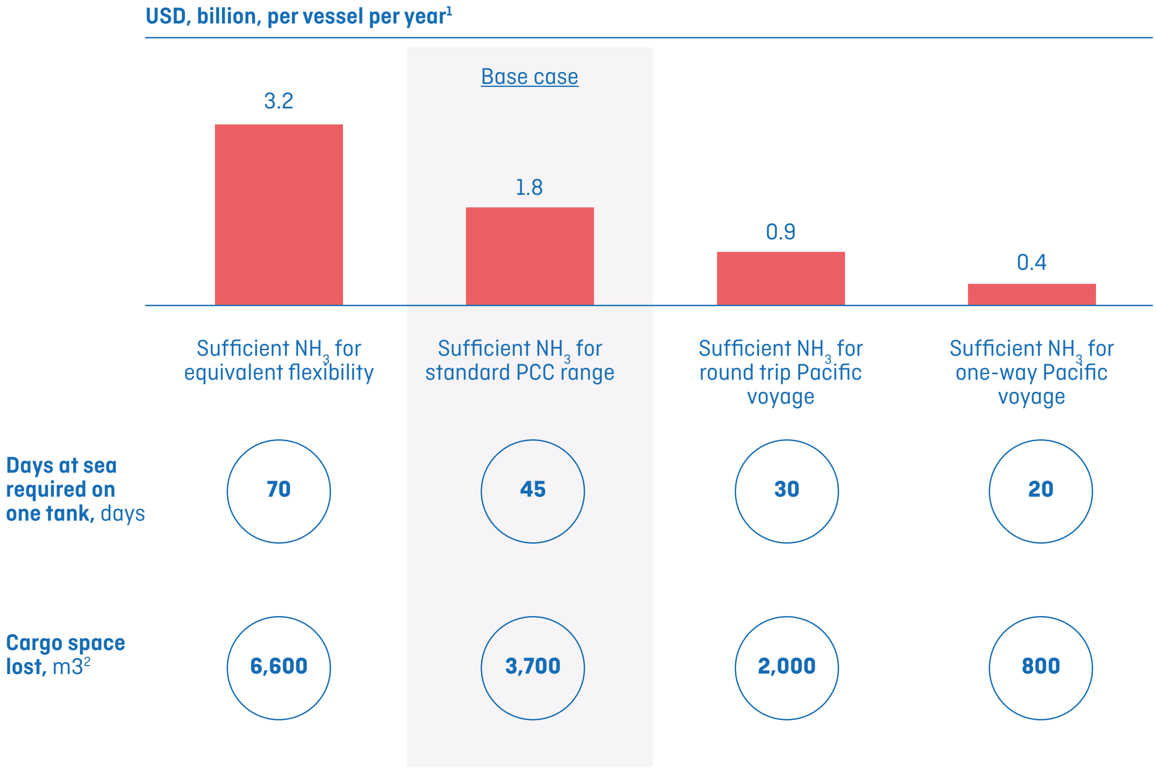
[1]Based on replacement of vessels with capacity of 24,000 TEU vs current fleet average of 15,000 TEU on route (assuming capacity of route remains constant)

Source: Team analysis based on the Maersk Mc-Kinney Moller Center for Zero Carbon Shipping NavigaTE model

Appendix 4: PCC—Reducing tank size to mitigate costs

In our base case, we assumed a range of 45 days at sea which would result in 3,700 CBM of space lost to accommodate the fuel—which is the equivalent of 300 cars. A leaner tank set-up would require refuelling at both sides of the Pacific and only result in lost cargo space of 800 CBM, or 67 cars (Exhibit 26).

Exhibit 26: Cargo capacity loss for dual-fuel PCC carriers under different ammonia fuel tank assumptions



[1]Based on PCC vessel >25,000; typical speed of 17 knots; bunkering in West Coast US (fuel from Chile) or Japan/Korea (fuel from Australia)
[2]Assuming all ammonia-powered vessels also have a 1,200 m^3 HFO fuel tank to maintain dual-fuel capability. Based on standard tank of 3,000m^3 and 250m^3 penalty for spherical ammonia tank

Appendix 5: Assumptions used for calculations

Assumptions for Total Cost of Ownership estimates

Assumption	Unit	2030	2050
Renewable electricity feedstock (Middle East/Australia)	USD/MWh	21	16
Capacity factor including balancing	%	90	90
Cost of debt	%	5	5
Green ammonia (Middle East / Australia production)	$/GJ	28	18
Green ammonia (Europe production)	$/GJ	37	20
Green methanol (DAC, Middle East/ Australia production)	$/GJ	40	26
LSFO	$/GJ	8	8

Assumptions for globalised weighted average fuel production costs for non-subsidised commercial scale plants

Fuel	Unit	2030	2050
Green ammonia	$/GJ	30-43	16-23
Green methanol (DAC)	$/GJ	47-64	25-35

Source: Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping, Position Paper Fuel Options Scenarios

Vessel assumptions

Assumption	Unit		Source
Iron ore bulk carrier size	DWT	200,000	
Iron ore bulk carrier HFO burn/vessel/year	tonnes	13,241	IMO (2020)
Iron ore bulk carrier CO_2 emissions/vessel/year	tonnes	42,636	IMO (2020)
Containership size for current fleet	TEU	14,450-20,000	
Containership size for zero-emission fleet	TEU	24,000	
Containership HFO burn/vessel/year	tonnes	29,826	IMO (2020)
Containership CO_2 emissions/vessel/year	tonnes	96,040	IMO (2020)
Pure car carrier size	Gross tonnage	50,000	
Pure car carrier HFO burn/vessel/year	tonnes	11,106	IMO (2020)
Pure car carrier CO_2 emissions/vessel/year	tonnes	35,934	IMO (2020)

Assumptions for capex requirement for newbuild vessels

Vessel type	Unit	HFO vessel	Ammonia vessel	Methanol vessel
Iron ore bulk carrier	$ million	34.8	36.5	33.8
Containership	$ million	126.8	143.0	136.5
Pure car carrier	$ million	97.3	99.5	97.5

Assumptions used to calculate bunkering requirements

Vessel type	Unit	
Ammonia required/tonne of NH_3/HFO conversion factor	tonne	2.07
Hydrogen required/tonne of ammonia	tonne	0.176
Capex/bunkering vessel	$ million	10
Ammonia storage capex	$/tonne	600

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