1. The challenge

The shipping sector is responsible for approximately 80 percent of global trade, and the demand for shipping is expected to continue to grow in line with global economic growth over the next three decades.

Although it is less intensive than other freight transport modes in terms of CO_2 emissions per tonne-kilometre, shipping represents about 3 percent of total global CO_2 emissions—a share that is likely to increase as other sectors decarbonise. Without concerted collective effort, emissions from the sector could rise by as much as 50 percent by 2050.[4]

Demand-management levers, such as curtailing traffic volumes, together with improvements in optimising logistics, could reduce the sector's emissions by between 4 and 5 percent. A further opportunity to improve vessels' energy efficiency by upgrading ship design and propulsion systems could theoretically reduce emissions intensity by between 15 and 55 percent. However, a decarbonisation strategy focused on these levers alone would not be sufficient to meet the targets set by the International Maritime Organization (IMO)—much less the goal of full decarbonisation by 2050, set out in the Call to Action issued by 200 industry leaders in September 2021.[5] To meet these goals, the maritime industry requires the deployment of vessels using zero-GHG-emitting fuels.

Zero-emission fuels currently cost significantly more than conventional fuels, and fuel makes up a comparatively large portion of the overall costs of deep-sea shipping. Actions to lower fuel costs are made more difficult by split incentives, such as shipowners paying for efficiency improvements and charterers paying fuel costs. As the sector faces the need to develop entirely new zero-emission value chains, it also faces a chicken-and-egg problem, with each party's investment decisions dependent on another party's choices.

Technologies to achieve zero-emission shipping are becoming increasingly commercially available—but they need to be deployed at scale to unlock cost reductions and be adopted at a faster pace in the coming decade. The piloting and demonstration of these technologies has already begun; however, scaling these initial efforts into industry-wide solutions will be challenging, given the heterogeneous and complex nature of the global shipping industry.

2. Why green corridors matter

The creation of green corridors—defined as a shipping route between two major port hubs (including intermediary stopovers) on which the technological, economic, and regulatory feasibility of the operation of zero-emissions ships is catalysed through public and private actions—offers the opportunity to accelerate progress in tackling the challenges of decarbonising shipping described earlier.

For one thing, green corridors provide sufficient scale and volume for impact as they are large enough to include all the essential value-chain actors needed to scale zero-emission shipping, including fuel producers, vessel operators, cargo owners, and regulatory authorities. Green corridors also provide offtake certainty to fuel producers, allowing for additional scaling of zero-emission fuel production concentrated in one location. And they can generate strong demand signals to vessel operators, shipyards, and engine manufacturers to scale and catalyse investments in zero-emission shipping.

Green corridors also offer specificity and can leverage favourable conditions for accelerated action. Like special economic zones, they allow policy makers to create an enabling ecosystem with targeted, fit-for-purpose regulatory measures, financial incentives, and safety regulations. At the same time, corridor-specific arrangements can make actions to mobilise demand—such as aggregating demand through pre-competitive coalitions or creating a transparent and standardised registry for tracking—more manageable and acceptable for the stakeholders involved.
Creating green corridors will lower the threshold for action by industry and policymakers, but these corridors are unlikely to emerge organically: key stakeholders will need to contribute to the analysis, evaluation and planning that could underpin their development. In the following chapters we introduce some important considerations by examining a few example corridors.

3. Corridor selection

The selection process for initial green corridors is crucial. It is important that the routes selected as green corridors are feasible from an implementation viewpoint, and capable of generating lessons that can be applied to other routes. Selected corridors should be promising candidates for large-scale decarbonisation and ideally for generating spill-over effects that will reduce shipping emissions in a material manner elsewhere.

Ten corridors were pre-selected for either impact or feasibility and then tested based on an in-depth, multi-criteria analysis.[i] Impact and feasibility were further defined to create a set of nine key indicators (Exhibit 1).

Exhibit 1: Analysis of 10 shortlisted corridors against impact and feasibility criteria

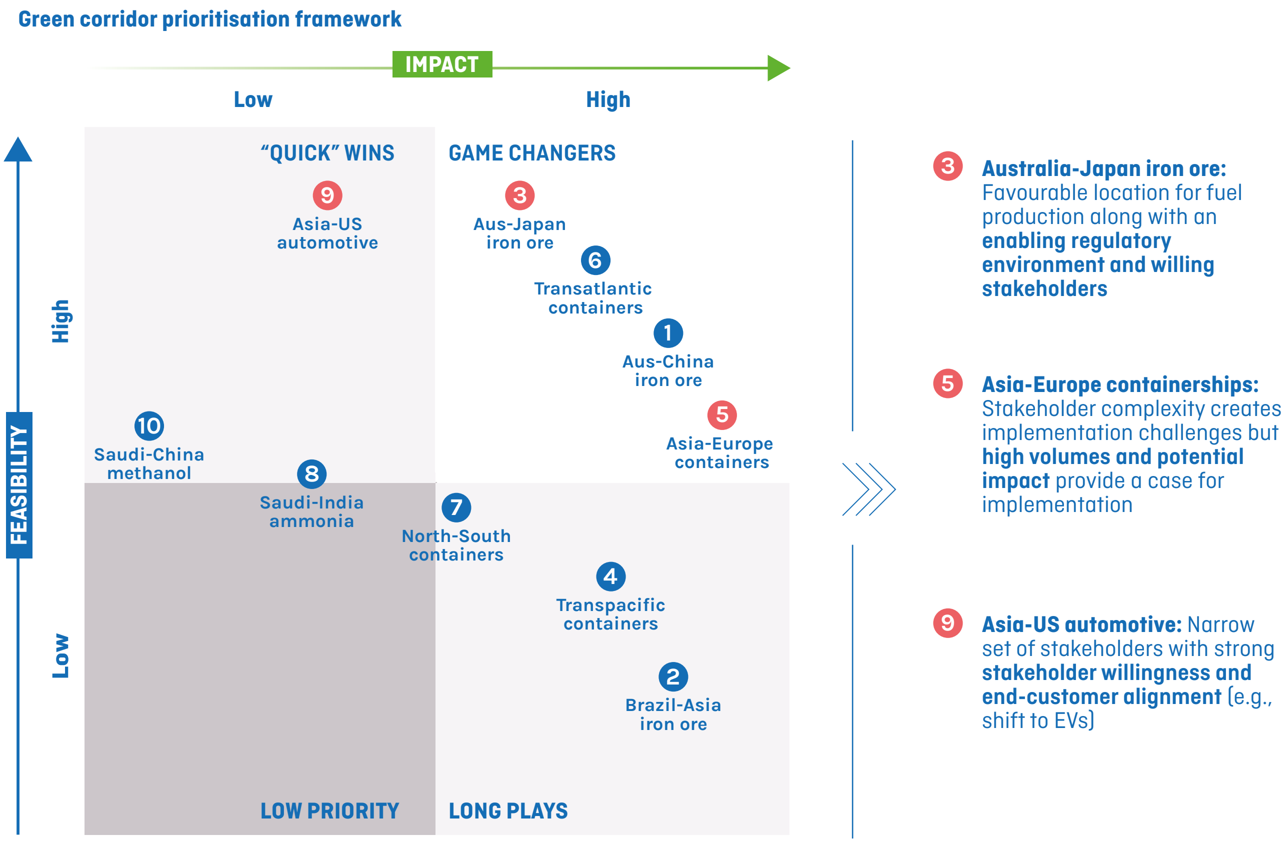
● High volume routes (1–7)
● Rapid decarbonization routes (8–10)

	Metric		1 **Aus-China iron ore** Large volumes, fewer policy enablers	2 **Brazil-China iron ore** High volume, with higher shipping costs	3 **Aus-Japan iron ore** Lower volumes with committed stakeholders	4 **Transpacific containers** Major mainline route	5 **Aus-Europe containers** Long, high-emission mainline route	6 **Transatlantic containers** Small volumes, more policy enablers	7 **North-South containers** Low volumes, limited ability to pass on costs	8 **Saudi-India ammonia** Potential future fuel, small traded volumes	9 **Asia-US automotive** Low volume, high value, and carbon intensive	10 **Saudi-China methanol** Potential future fuel, small traded volumes
IMPACT	**A. Trade and logistics**											
	Share of global trade volume	Basis points	650	195	60	181	210	52	14	2	4	1
	Expected future growth, CAGR 2021-2025	%	4%	3%	3%	2%	3%	3%	8%	5%	2%	6%
	B. Emissions											
	Carbon intensity on route	kgCO2e/tonne cargo	28	48	29	61	93	56	99	104	197	137
	Current carbon emissions on corridor	tonne CO_2e	20,200,000	10,500,000	1,900,000	12,300,000	21,700,000	3,200,000	1,500,000	300,000	900,000	160,000
FEASIBILITY	**C. Value and cost pass-through**											
	Relative price increase of traded good	%	11%	28%	11%	3%	2%	2%	12%	4%	1%	4%
	Scope 3 importance for traded good sector	1=low, 5=high	3	3	3	2	2	4	2	1	3	1
	D. Zero-emission fuel supply											
	Delivered cost of zero-emission fuel in 2025	$/GJ	35	37	35	38	30	40	35	30	38	30
	E. Stakeholder readiness											
	National policies/regulations (net zero, green H2)	1=low, 5=high	2	2	4	1	3	3	4	1	3	1
	Ease of stakeholder environment	1=low, 5=high	2	5	4	1	1	1	2	4	5	4

i Further details on the selection process can be found in Appendix 1.

The impact and feasibility analysis highlighted two routes that were particularly interesting for in-depth study, with an additional third corridor that was determined to be interesting enough to feature as a case study (Exhibit 2).

Exhibit 2: Evaluation of three routes based on impact and feasibility parameters



Of the three iron ore routes examined, the focus of the analysis landed on the Australia-Japan iron ore route. While Brazil-China iron ore routes showed higher decarbonisation potential than the Australia-Japan route, the significant distance between Brazil and China means that transportation costs were found to be more sensitive to increased fuel cost on the corridor. Australia-China iron ore routes also had significantly higher decarbonisation potential, but from a feasibility viewpoint, the Australia-Japan route was assessed to have greater potential for an enabling regulatory environment. Given that both routes have the same origin point and many overlapping stakeholders, successful implementation of the Australia-Japan route could result in significant spill-over effects for the Australia-China route.

Despite the inherent stakeholder complexity of containership routes, the low delivered cost of fuel, through potential bunkering in the Middle East, and enabling regulatory environment on the European leg of the route made a compelling case for the selection of the Asia-Europe containership route as the second green corridor considered in this report.

Additionally, of the rapid decarbonisation routes that were assessed, North-East Asia-US automotive carrier corridor was chosen as a case study given its relative impact, the strong alignment between trends in the customer segment (such as the move toward electric vehicles), and commitment to decarbonisation of shipping on the route.

4. The building blocks of zero-emission shipping

The following four critical building blocks need to be in place to establish a green corridor:

1. **Cross-value-chain collaboration:** A green corridor requires stakeholders that are committed to decarbonisation and are willing to explore new forms of cross-value-chain collaboration to enable zero-emission shipping from both the demand and supply side.

2. **A viable fuel pathway:** Availability of zero-emission fuels, along with bunkering infrastructure to service zero-emission vessels, are essential factors.

3. **Customer demand:** Conditions need to be in place to mobilise demand for green shipping and to scale zero-emission shipping on the corridor.

4. **Policy and regulation:** Policy incentives and regulations will be necessary to narrow the cost gap and expedite safety measures.

Fostering cross-value-chain collaboration

The traditional maritime value chain has three core industrial actors—marine fuel producers, ship operators, and cargo owners—all of whom need to be committed to decarbonisation and willing to collaborate to make green corridors a reality.

The maritime value chain has an established industry, infrastructure, and operational practices around existing fossil fuels. A zero-emission vessel pilot will likely require the creation of a parallel value chain that involves new actors and new contractual relationships, develops new production facilities and infrastructure, and alters vessel operations. Therefore, cross-value-chain collaboration is essential to enable zero-emission shipping from both the supply and demand sides.

These collaborations will be necessary to integrate new knowledge from other sectors, for example expertise related to production and handling of fuels, and to distribute risks faced by first movers.

Determining the fuel pathway

Several fuel pathways for zero-emission vessels are being considered by the industry—and uncertainty persists at the global level. While biomass-based fuels can be used on ships, there are concerns about the long-term scalability of biofuels, given major supply constraints on the truly sustainable and low-emissions provision of biomass globally. While biomass-based marine fuels could in principle be used as transition fuel in shipping over the next decade, it is likely that they will not be a scalable solution for the industry in the long term.[6]

There are four other fuel pathways[ii] to be considered, in line with the Getting to Zero Coalition's framework for zero-carbon energy sources (Exhibit 3):[7]

- **Green ammonia:** Green ammonia, produced using renewable hydrogen, is attractive as it has no carbon in its molecular structure and is the most likely marine fuel to be adopted in the long-term, and based on today's techno-economic modelling has potential for future cost reductions. Green ammonia also has scalability advantages because it is also likely to be produced and exported for other energy and industrial uses. While ammonia is currently shipped in large volumes as cargo, fuel safety standards, particularly for port infrastructure and bunkering hubs, would need to be developed. From a vessel-technology standpoint, there are currently no ammonia internal combustion engines (ICEs) commercially available, but the first available engines are expected in Q4 2024.[8]

- **Green methanol:** Green methanol, produced from a combination of green hydrogen and CO_2, is considered to be the most advanced solution from a vessel-technology standpoint as methanol ICEs are already commercially available. To be considered as zero-emission, however, the CO_2 used to produce the fuel must originate from net-zero biogenic sources—resulting in potential long-term challenges for the scaling of production and for the fuel's dependency on the cost of carbon capture technologies.[9] Direct air capture as an alternative carbon source is currently not cost-competitive but presents a future opportunity space for synthetic fuels.

- **Green hydrogen:** Green hydrogen is produced through electrolysis, utilising carbon-neutral electricity. It can be used as a marine fuel but is considered technically challenging to store onboard vessels. The use of liquid hydrogen can overcome fuel-storage challenges, but the liquefaction process and cryogenic storage requirements increase costs.[10] Green hydrogen has scalability advantages as the use of green hydrogen is a route for decarbonisation in other sectors.

- **Synthetic diesel:** Synthetic diesel, produced from a combination of green hydrogen and CO_2, can be "dropped in" without requiring any changes to engines or storage tanks. As with methanol, to be considered zero-emission, CO_2 feedstock for synthetic diesel must originate from non-fossil sources, resulting in potential long-term challenges for carbon feedstock procurement. Synthetic diesel production is also more expensive than competing options.[11]

ii While synthetic liquefied natural gas (LNG) is—in theory—a potential fuel pathway, it has not been considered for the purposes of this report due to the high methane slip associated with LNG that limits its GHG-mitigation potential.

Exhibit 3: Zero-emission fuel pathways at different technology readiness and TCO pathways

Technology[1]	Long-term potential	TRL fuel prod.	TRL engine	TRL vessel	TCO 2030[2] $m/year	TCO 2050[2] $m/year
Green ammonia	Zero-emission fuel with existing infrastructure, possibility of hydrogen transport and increasing price competitiveness due to independence from carbon feedstock requirement	8	7	3	19	17
Green methanol	Considered the most advanced fuel with solutions already in use; long-term challenges for carbon feedstock procurement from non-fossil sources	8	8	8	23	20
Green hydrogen[3]	Technically challenging and **cost intensive storage** on ship due to fuel properties	9	7	2	24	22
Synthetic diesel	**Scalability challenges** due to carbon feedstock procurement from non-fossil sources; **higher electricity demand** results in greater production costs	7	9	9	24	20

[1]Numbers based on direct air capture technology (DAC) for green methanol and synthetic diesel
[2]Based on a bulk iron carrier +200,000DWT with a speed 12 knots and 200 days at sea; green ammonia with 95% ammonia and 5% LSFO; green methanol with 97% methanol and 3% LSFO
[3]Assumes liquid hydrogen

Sources: Getting to Zero Coalition (2020), TRL: Lloyd's Register and UMAS (2020), TCO: Team analysis based on the Maersk Mc-Kinney Moller Center for Zero Carbon Shipping NavigaTE model

In addition to zero-emission fuel production being available, green corridors need to have the necessary vessels and technologies, and appropriate bunkering infrastructure, such as storage tanks and vessels for refuelling purposes.

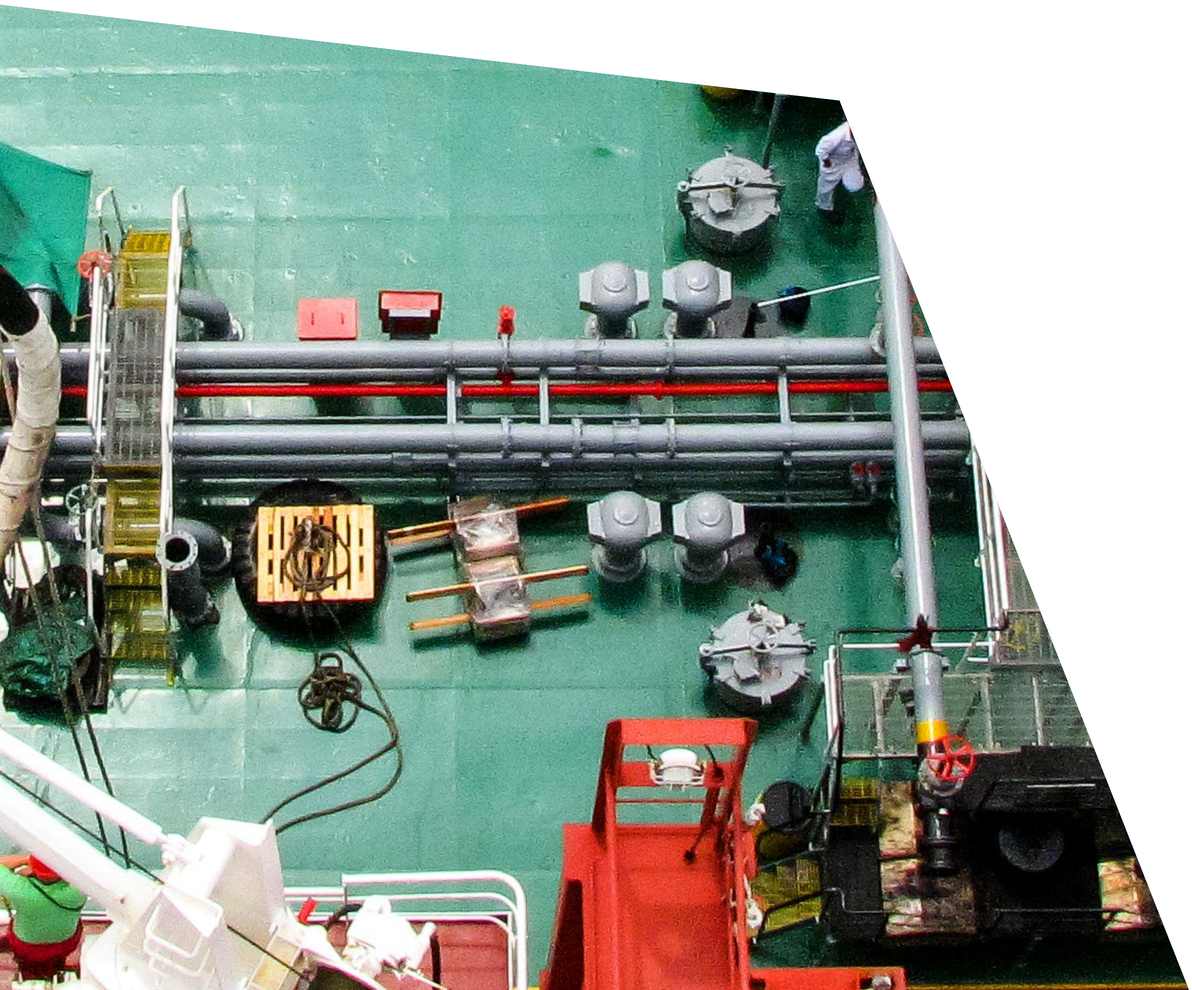
This analysis is focused on the fuel pathways with the highest potential to supply a large share of the global maritime sector's fuel demand, considering cost and scalability. While technology development could make other green fuels (such as green hydrogen) viable in the future, green ammonia and green methanol are the primary options considered in our deep dives on specific corridors. We expect, however, that the approach, analysis, and recommendations will be transferrable to a wider range of potential fuel and technology pathways.

Mobilising demand

There is increasing demand for green shipping from charterers seeking to decarbonise their operations, cargo owners seeking to reduce the Scope 3 emissions of their supply chains, and individuals looking to buy products with a reduced carbon footprint.

Decarbonisation initiatives between cargo owners and vessel operators are emerging. For example, the Clean Cargo Initiative, a collaboration between cargo owners, shippers, and freight forwarders, provides transparency around the environmental performance of the container sector. Cargo owners and shipping lines/freight forwarders have also collaborated on pilots that blend biofuels with fossil fuels to reduce emissions. Such collaborations include CMA CGM and Ikea; and Maersk, Wallenius Wilhelmsen, and customers such as H&M, Levi's, and Marks and Spencer.[12]

However, to accelerate decarbonisation in the container sector, bulk sector, and beyond, the demand from customers for zero-emission shipping will need to be mobilised and aggregated to turn individual initiatives into commercial-scale action that can advance the industry's transition.
Mobilising demand for more expensive zero-emission transport will likely require customers to bear part of the cost of zero-emission fuels. On certain corridors there is greater potential for end customers to share these costs. End customers may need to guarantee offtake commitments to de-risk ship owners' investments in zero-emission-fuelled vessels.



Developing policy and regulation

Given its geographically dispersed nature, governance of the global shipping industry is primarily the domain of international regulations and policies set by the IMO. In relation to decarbonisation, the IMO has set an aspirational goal of emission reductions of 50 percent for all vessels by 2050.[13] The target is not net-zero aligned and there have been calls from industry for the IMO to set more ambitious reduction goals.[14] There have also been several calls by industry to accelerate decarbonisation through the introduction of some form of global carbon taxation or levy on the shipping industry.[15] Such measures would be the most powerful driver of industry decarbonisation, but their prospects remain uncertain, and first movers on zero-emission shipping will have to manage this uncertainty.

This analysis is specifically aimed at catalysing green corridors, irrespective of the global framework. The focus of the analysis will be on regional, and potentially route-specific, policy and regulatory measures that will be essential for the creation of green corridors.

The IMO is also a key player in determining future fuel pathways for international shipping based on its ability to approve global fuel standards and safety regulations. Of the fuel pathways that have been introduced, methanol has been given interim approval by the IMO for use as a safe ship fuel.[16] Other fuels, such as synthetic diesel, could require a new certification process since additives or different sealings in the engine system might be needed for safe operation.

The IMO has not yet approved safety and fuel handling guidelines for ammonia and hydrogen, however, and use of either as a marine fuel requires special approval from the relevant regional regulatory authorities—as further discussed during the deep dives on specific corridors.

5. The Australia-Japan iron ore route

In 2019, some 65 million tonnes of iron ore were exported from Australia to Japan, making the passage between the two countries the third largest dry-bulk trade route in the world.[iii] Approximately 75 percent of this iron ore was shipped directly from the Pilbara region to Japan, while the remaining 25 percent involved intermediary stops at other ports, in Korea in particular.[17] Ships carrying iron ore between Australia and Japan, both directly and with intermediary stops, burned approximately 550,000 tonnes of fuel oil in 2019—equal to 1.7 million tonnes of CO_2 emissions.[18]

The route has strong potential to be a first-mover green corridor. For one thing, there is growing momentum among stakeholders on this route to decarbonise iron ore shipping. For instance, 90 percent of the Australian iron ore exported to Japan is mined by players committed to net-zero.[19]

Moreover, there are favourable conditions, and significant planned capacity, for zero-emission fuel production in the region. In Australia, green hydrogen production capacity is expected to reach 29 GW by 2030—which will be approximately 25 times the amount needed to decarbonise shipping on the route.[20]

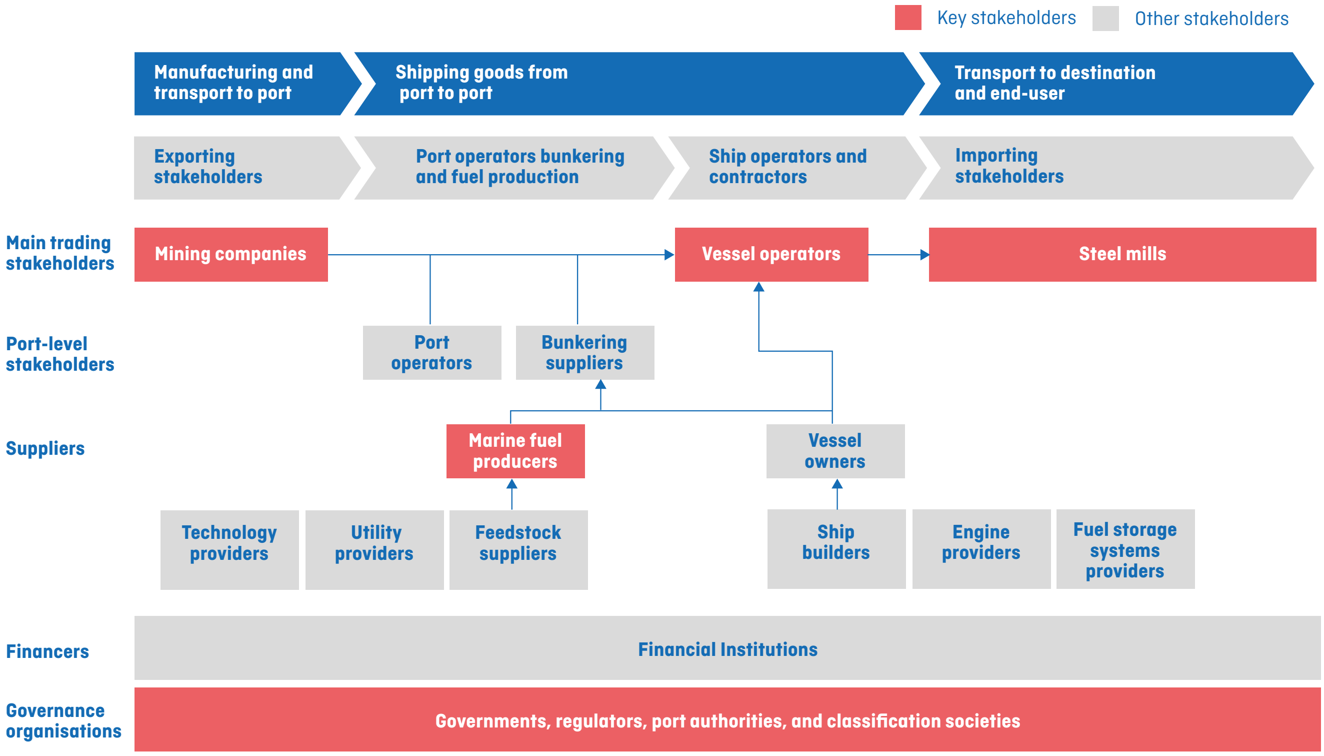
Additionally, there is potential to lower risks and costs for stakeholders in both countries—both by taking a collaborative approach to various policies that support lower fuel costs, and by working across the value chain to pool demand.

iii The Australia-China and the Brazil-China iron ore routes are the first and second-largest dry bulk trade routes respectively.

Potential for cross-value-chain collaboration

Creating a green corridor will require new forms of collaboration between key stakeholders. Exhibit 4 maps the major stakeholders across the Australia-Japan iron ore route's value chain.

Exhibit 4: The set of core actors needed for decarbonising the Australia-Japan iron ore corridor



A set of five key stakeholders have already set ambitious decarbonisation targets:

- **Mining companies:** The exporting stakeholder group for the route is comprised of three major mining companies—Rio Tinto, BHP, and Fortescue Metals Group (FMG)—that are responsible for approximately 90 percent of iron ore exported from Australia to Japan.[21] Rio Tinto and BHP have committed to net-zero targets by 2050 that include all shipping-related emissions.[22] FMG has committed to net-zero for all Scope 3 emissions by 2040.[23]

- **Vessel operators:** Five ship owners cover 56 percent of the route's capacity and four of these have set commitments on carbon-intensity reduction beyond IMO requirements.[24] Furthermore, in September 2021, Nippon Yūsen Kabushiki Kaisha (NYK) and Mitsui O.S.K. Lines (MOL) supported the Global Maritime Forum's Call to Action for Shipping Decarbonization by 2050, signalling a commitment to target net-zero emissions by 2050.[25]

- **Steel mills:** Japanese steelmakers are exploring how to transition to decarbonised production with a focus on reducing Scope 1 and Scope 2 emissions.[26] In addition to their 2050 decarbonisation commitments, several steel makers have set ambitious 2030 decarbonisation targets.

- **Fuel producers:** Australian fuel producers are planning to scale up their production facilities to produce green hydrogen and sustainable shipping fuels. By 2030, these planned or installed project could comprise close to half of the world's new green hydrogen electrolysis capacity.[27] Among them is the world's largest green energy hub with an eventual planned capacity of 50 GW that aims to produce green hydrogen and green ammonia in Western Australia.[28]

- **Governance organisations:** Regulatory bodies on both ends of the corridor have a crucial role to play in the uptake of sustainable shipping for iron ore. While they are less likely to be involved in cross-value-chain collaboration, they can play an important role as mediators between the different stakeholders, and meaningfully guide stakeholders' levels of ambition through interlocking targets. For example, the target set by the Japanese government to source three million tonnes of ammonia fuel per year by 2030[29] can be aligned with Australia's aim to become one of the top-three exporters to Asia.[30]

The deployment of zero-emission vessels, globally, will require the creation of a new green shipping value chain, involving both old and new stakeholders. This will likely be underpinned by new forms of contractual business relationships—a topic further covered in the "Shared demand for decarbonisation across the corridor" section of this chapter that deals with mobilising demand.

Significant capacity for zero-emission fuel

Given its rich renewable resources, Australia has favourable production conditions for the production of zero-emission fuel in the region. Considering the capacity already announced, green ammonia is likely to be the fuel of choice for the corridor, with bunkering located in North West Australia for the initial zero-emission vessels.

Vessel requirement

In 2019, a total of 111 bulkers travelled directly between Western Australia and Japan, transporting approximately 50 million tonnes of iron ore.[31] An additional 15 million tonnes of iron ore were traded with intermediary stops at other ports.[32]

Due to the ad hoc scheduling of the bulk carrier market, the majority of the 111 bulkers only conducted one trip on the Australia-Japan iron ore route.[33] While this is currently in line with standard bulker market practice, decarbonising the route may require vessels that are dedicated to full-time service on the corridor. If the Australia-Japan iron ore trade were consolidated into purpose-built vessels, it would take 41 fully dedicated vessels to decarbonise all iron ore trade between Australia and Japan.

Zero-emission fuel availability

Decarbonising the Australia-Japan iron ore route will require zero-emission fuels derived from green hydrogen, with the first vessel requiring approximately 40 MW of electrolyser capacity to produce the equivalent of a year's supply of zero-emission fuel.

Providing fuel production for the 41 fully dedicated zero-emission iron ore vessels will require approximately 1.7 GW of electrolyser capacity. The estimated capital expenditure (capex) requirement for this would be between $3.7 billion and $5.2 billion[iv] for electrolysis, hydrogen storage, the ammonia production process, and the investment costs for renewable electricity production.[34]

Given Australia's location, and the fact that it is blessed with rich renewable resources, the country is well-placed to produce green hydrogen for the corridor at low cost. This is reflected by the recent spate of producers announcing their intentions to scale up green hydrogen production. In fact, the Hydrogen Council projects that there will be 29 GW of electrolyser capacity online in Australia by 2030, with the majority located in Western Australia (Exhibit 5).[35]

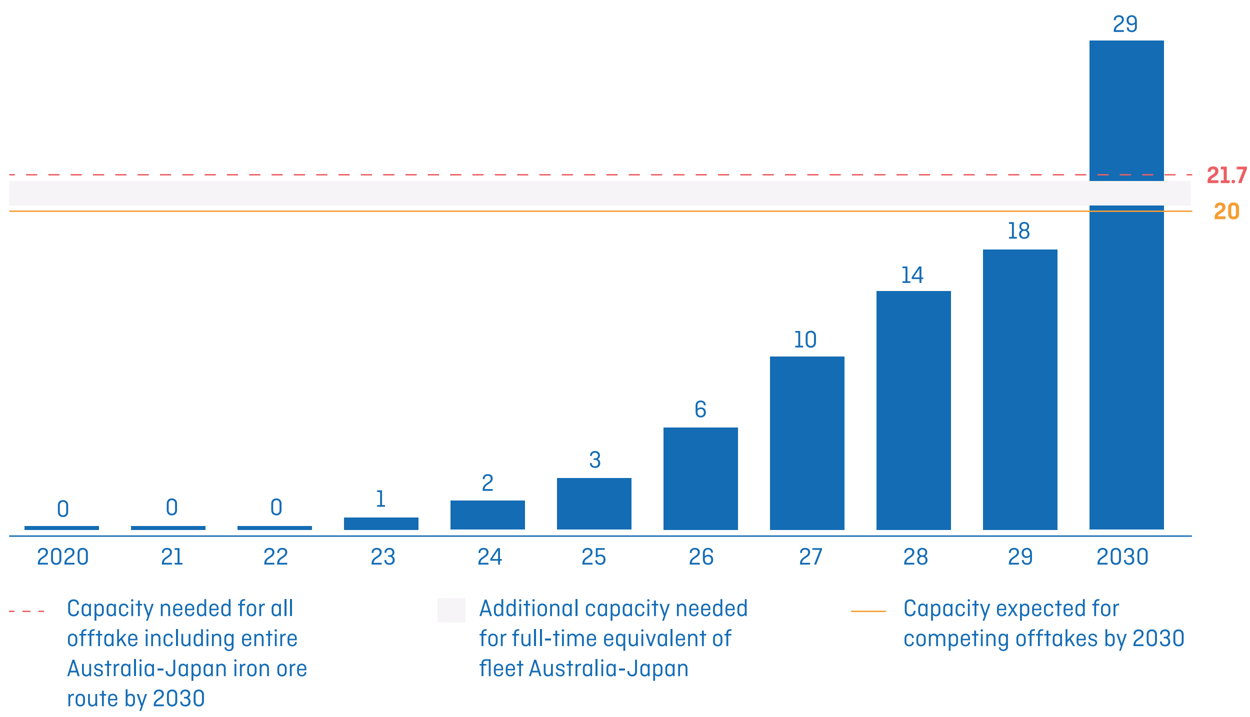
iv See further details in Appendix 3

Demand from China, Japan, and Korea for green hydrogen and derivatives—as well as demand from key domestic end-use sectors such as refining, fertiliser, and other industrial feedstock—is estimated to correspond to approximately 70 percent of the projected electrolyser capacity in Australia.[36] This leaves, on current projection, supply "headroom" of 9 GW by 2030—more than four times the electrolyser capacity needed to decarbonise the Australia-Japan iron ore route.

Current projected capacity for Australian green methanol is 60,000 tonnes—which would decarbonise less than 5 percent of the Australia-Japan iron ore trade.[37] Additionally, Australia has limited amounts of biogenic CO_2 available, severely reducing its ability to scale green methanol production. Given the supply dynamics and long-term cost advantage, it is likely that green ammonia will be the zero-emission fuel of choice for the corridor.

Exhibit 5: Announced production capacity in Australia

Projected cumulative capacity ramp up from announced projects, *electrolyser capacity (GW)*



Source: ETC analysis based on Deloitte (2019); capacity analysis by Hydrogen Council (2021)

Bunkering

The three Pilbara ports (Port Dampier, Port Hedland, and Cape Lambert) are expected to be the primary bunkering ports for the route. Bunkering at traditional hubs such as Singapore with zero-emission fuels sourced from other low-cost fuel production locations such as Chile or China is a possibility.

But transporting the fuel would incur an additional initial cost of between 5 and 15 percent per tonne of fuel—making bunkering at non-Australian ports an economically unsound option in the short-term. In the long term, once critical mass has been achieved, it is possible that bunkering at ports such as Singapore could provide access to cheaper sustainable shipping fuels as many other segments of shipping including deep-sea container trades pass by Singapore.[38]

Bunkering infrastructure needs for the corridor are relatively small, with one bunkering vessel and one onshore tank facility required per port for initial ramp-up. Bunkering infrastructure for a fully decarbonised corridor would require two bunkering vessels and one onshore tank facility per port (Exhibit 6).
While the capex requirements would be relatively small (between $42 million and $72 million) compared to investment needs for fuel production, the cost of bunkering per tonne is significant at smaller scales. This would add approximately 5 percent to the cost of fuel. As the corridor decarbonises, the cost of bunkering per tonne will reduce significantly.[39]

Exhibit 6: Scenario analysis on scale of ammonia use on the Australia-Japan iron ore corridor

Scenario analysis, scale of ammonia use on the Australia-Japan iron ore route	Scenario A **1 vessel**	Scenario B **3 vessels**	Scenario C **Full-time equivalent of fleet (direct to Japan)**	Scenario D **Full-time equivalent of fleet (all trade to Japan)**
Vessels in fleet, # Number of vessels required based on current fleet	1	3	30	41
Hydrogen capacity needed, MWe MWe electrolyser capacity based on 65% operation	41	123	1,235	1,675
Bunkering facilities[1] Type of bunkering needed in the port in Australia	← **1 bunkering vessel** per port needed to bring ammonia from the terminal to the vessels, and 1 onshore tank facility per port. Total capex of $14million per port →		← **2 bunkering vessels per port**[1] and 1 onshore tank facility per port. Total capex of $24million per port →	
Cost of bunkering per tonne bunkered, USD	64	21	4	3

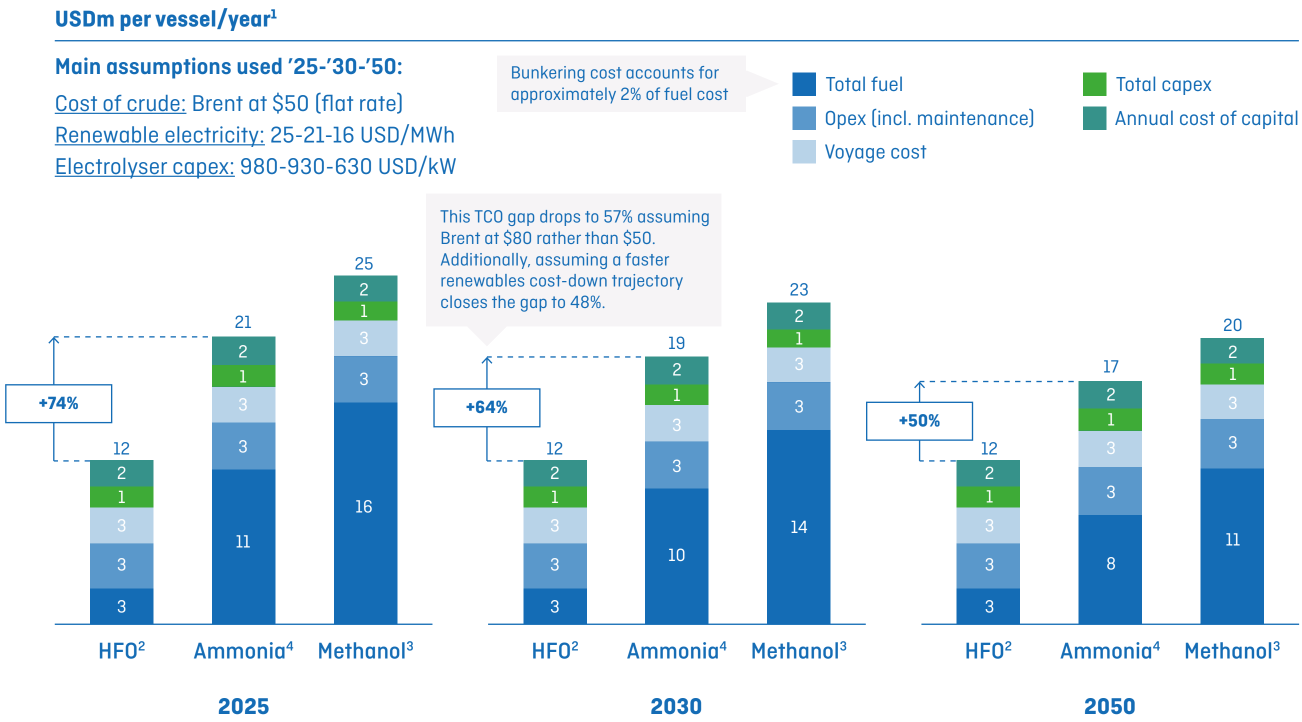
[1]Pending peak capacity of ports; based on 10 hour fuelling (5,000 tonnes per ship at 500 tonnes per hour) and 241 trips per year across three ports in Western Australia (Dampier, Port Hedland and Cape Lambert). Based on an investment of $10 million per LPG bunker vessel (lifetime 25 years) and 20,000 tonnes onshore tank capacity at $600/tonne (lifetime 30 years) distributed across number of bunkering events during lifetime

Source: based on AIS data (2020); International Maritime Organization (2020).

Total cost of ownership

Despite a significant drop in zero-emission fuel costs, a gap of 65 percent of the annualised end-to-end total cost of vessel ownership is forecast to remain by 2030. While this is primarily driven by additional fuel cost, there are smaller additional costs in certain components of the total cost of ownership. These include the vessel capex and the potential opportunity cost from lost cargo capacity due to the larger space requirements for zero emission fuel tanks.[v] With less conservative assumptions–Brent Crude at $80/bbl, not at $50/bbl; and average renewable electricity prices dropping below $20/MWh by 2030—the cost gap closes to 50 percent (Exhibit 7). This persistent gap indicates the importance of new policies and regulations to ensure competitiveness, as well as new business arrangements allowing the cost gap to be shared between stakeholders.[40]

Exhibit 7: Total cost of ownership pathways for iron ore bulk carriers



[1]Based on a bulk iron ore carrier +200,000 DWT with a speed 12 knots and 200 days at sea; Engine pro-rating on fuel cost in ratio 14kW (+80,000DWT) vs 20kW (+200,000DWT)
[2]ICE HFO with LSFO as fuel (100%)
[3]ICE methanol with 97% e-Methanol fuel use with Direct Air Capture (DAC) and 3% LFSO
[4]ICE ammonia with 95% ammonia (green) and 5% LFSO

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

v See detailed assumptions in Appendix 5

Shared demand for decarbonisation across the corridor

Demand for decarbonisation is shared end-to-end on this corridor. Shipowners, for whom the majority of emissions are Scope 1, have set targets for decarbonising their fleets. For mining majors committed to reducing their Scope 3 emissions, zero-emission shipping is a key part of their decarbonisation pathways, with downstream transport representing approximately 20 percent of their pre-processing Scope 3 emissions.[41]

Partnerships, joint ventures, or systems for sharing credits for emissions reductions would likely help mobilise demand in the value chain, which includes shipowners and both steelmakers (who account the scope 3 emissions from these journeys) and iron ore suppliers. As the Australia-Japan green corridor scales up, we would expect there to be spill-over effects on these other routes, further accelerating the miners' decarbonisation pathways.[vi]

New mechanisms or partnerships may be required to ensure that the cost gap is shared between stakeholders that are willing to pay for the increased costs of green fuels in the early years of the green corridor.[vii] Partnerships—potentially including joint ventures, limited chartering arrangements, or other forms of collaboration—will be particularly important to catalyse demand. Any potential partnership aimed at scaling shipping's decarbonisation could include two key elements:

- Stakeholders would need to bridge the cost gap for higher costs of zero-emission fuel, and guarantee the minimum use of those zero-emission vessels that would be potentially dedicated to the Australia-Japan iron ore corridor.
- Shipowners, steelmakers, and miners could form partnerships to de-risk the capex required to build the new zero-emission vessels.

In addition to these partnerships, establishing an "insetting" mechanism [viii] is another way to mobilise demand. In this system, purchasers of green fuel would receive zero-carbon compliant carbon credits on purchase.[42] Other value chain players could agree to buy these carbon credits from the fuel purchasers to "inset" their Scope 3 emissions from the iron ore shipped on this corridor. In this way, the cost of decarbonisation would be shared across the value chain, thereby mobilising demand.

vi See Appendix 2 for further details

vii Research indicates that the iron ore freight rate historically has been sensitive to bunker prices, although the likely price trajectory is subject to how any cost gap is shared by stakeholders on this route.

viii Insetting refers to the process by which a company offsets the emissions or other environmental/ social impacts of another company within its own supply chain. New mechanisms or partnerships may be required to mobilise demand for green shipping where there is willingness to pay. As well as establishing partnerships to support dedicated vessels, an "insetting" mechanism can be established and initially launched on a green corridor. Under this mechanism, vessel operators could buy green fuel from the green fuel producers and in turn receive SBTi-compliant carbon credits. Other value chain players agree to buy these carbon credits from the vessel operators to cover iron ore shipped on this corridor. See Clark et al, "Zero-Emissions Shipping: Contracts-for-difference as incentives for the decarbonisation of international shipping," Smith School, University of Oxford, June 2021.

Potential of policy and regulation to reduce cost and create an ecosystem

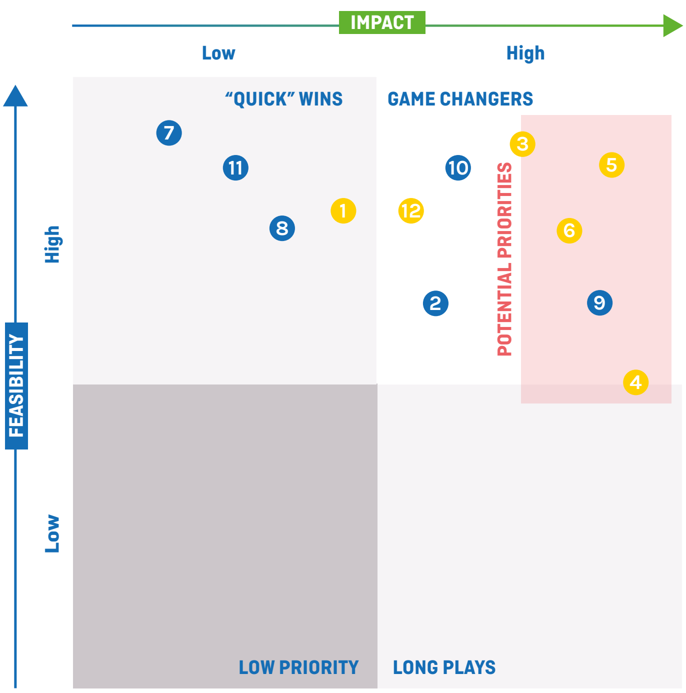
Using green ammonia as a sustainable fuel on the Australia-Japan iron ore route requires an integrated policy approach to overcome initial hurdles and reach a minimum threshold for market penetration. As the main barrier to the greater use of green ammonia is cost, the primary role of policy makers is to set the policy framework to narrow the cost gap and create an enabling ecosystem in the near term. In addition, long-term signals, such as national commitments to net-zero, can play a part in offering certainty to the private sector and improving the business case for green hydrogen—producing positive spill-over effects for other shipping decarbonisation efforts.

In total, 12 supporting regulatory levers have been identified which reduce fuel cost and create an enabling ecosystem for green corridors (Exhibit 8).

Exhibit 8: Policy options to reduce fuel cost and create an enabling ecosystem for the Australia-Japan iron ore corridor

NOT EXHAUSTIVE

Green corridor policy framework



Main level of governance[1] > **Policy options**

- Fuel cost reduction (yellow)
- Enabling ecosystem (blue)

Federal governments

1. Provide public investment through credit guarantees, anchored blended finance and grant finance to lower cost of capital
2. Mandate zero-emissions fuel supply targets for domestic shipping
3. Provide compensation for use of electrolysers for grid-firming services
4. Implement (reverse auctioned) CfDs[2] for zero-emissions fuels
5. Extend fossil fuel subsidies to zero-emission fuels
6. Facilitate permitting the use of natural storage for H2 storage

State governments

7. Best practice guidelines to accelerate fuel production project development

Government research agencies

8. Develop 'Guarantees of Origin' (GO) schemes for green H2

Classification societies

9. Expedited standards on safety requirements (e.g., bunkering at ports)

Port authorities and state controls

10. Funding for additional bunkering capacity at ports
11. Implement crew safety training for handling of zero-emission fuels and workforce retraining
12. Reduce port fees for zero-carbon vessels

[1]Examples of key players; most policy actions require collaboration across governance levels
[2]Contract-for-Difference

Source: based on ARENA (2021) and CSIRO (2018)

Based on a qualitative assessment of impact and feasibility, there are three categories of policies that can accelerate the creation of a green corridor:

- **Policies to lower costs of zero-emission fuel production:** Key policies and regulations can lower the cost of zero-emission fuel for the green corridor by encouraging both the supply and demand sides. Policies and regulations include faster permitting procedures for green hydrogen projects, loan guarantees, capex subsidies, facilitating the use of natural salt caverns for affordable hydrogen storage, and compensating electrolysers for potential grid stabilisation services.

- **Policies to create an enabling ecosystem:** Enabling ecosystems can be created by providing funding for additional bunkering capacity at ports—for example, ammonia storage terminals—and expediting safety measures for the use of green ammonia.

- **An incentivisation scheme for zero-emission fuels, such as Contract-for-Difference:** A fuel-based Contract-for-Difference (CfD)[ix] for the iron ore route could create a level playing field for zero-emission shipping fuels on the route. Decarbonising new zero-emission vessels on this corridor via CfD would cost taxpayers between $250 million and $350 million a year up until 2030.[x] Such a system would create benefits in both Japan and Australia. Japan would benefit from sustainable fuel uptake that would be synergistic with the country's target for ammonia energy. Australian producers would gain a secure offtake, de-risking investment, and be incentivised to reduce production costs for what could become a strong export industry.

In addition to lowering the costs of zero-emission fuels, it is also imperative that zero-carbon fuels are put on a level playing field with fossil fuels. To do so, current schemes such as concessional port charges for liquefied natural gas (LNG) vessels in the Pilbara by the Western Australian government should be extended to zero-carbon fuels such as green ammonia.[43]

ix See Appendix 2 for further details

x This calculation uses a reference price of $450-650 per tonne, based on fossil fuel costs projections for 2025 and a strike price of around $1,300 per tonne, based on the Maersk Mc-Kinney Moller Center for Zero Carbon Shipping NavigaTE model and on "Shipping bunker cost risk assessment and management during the coronavirus oil shock," MDPI, April 29, 2021, mdpi.com.

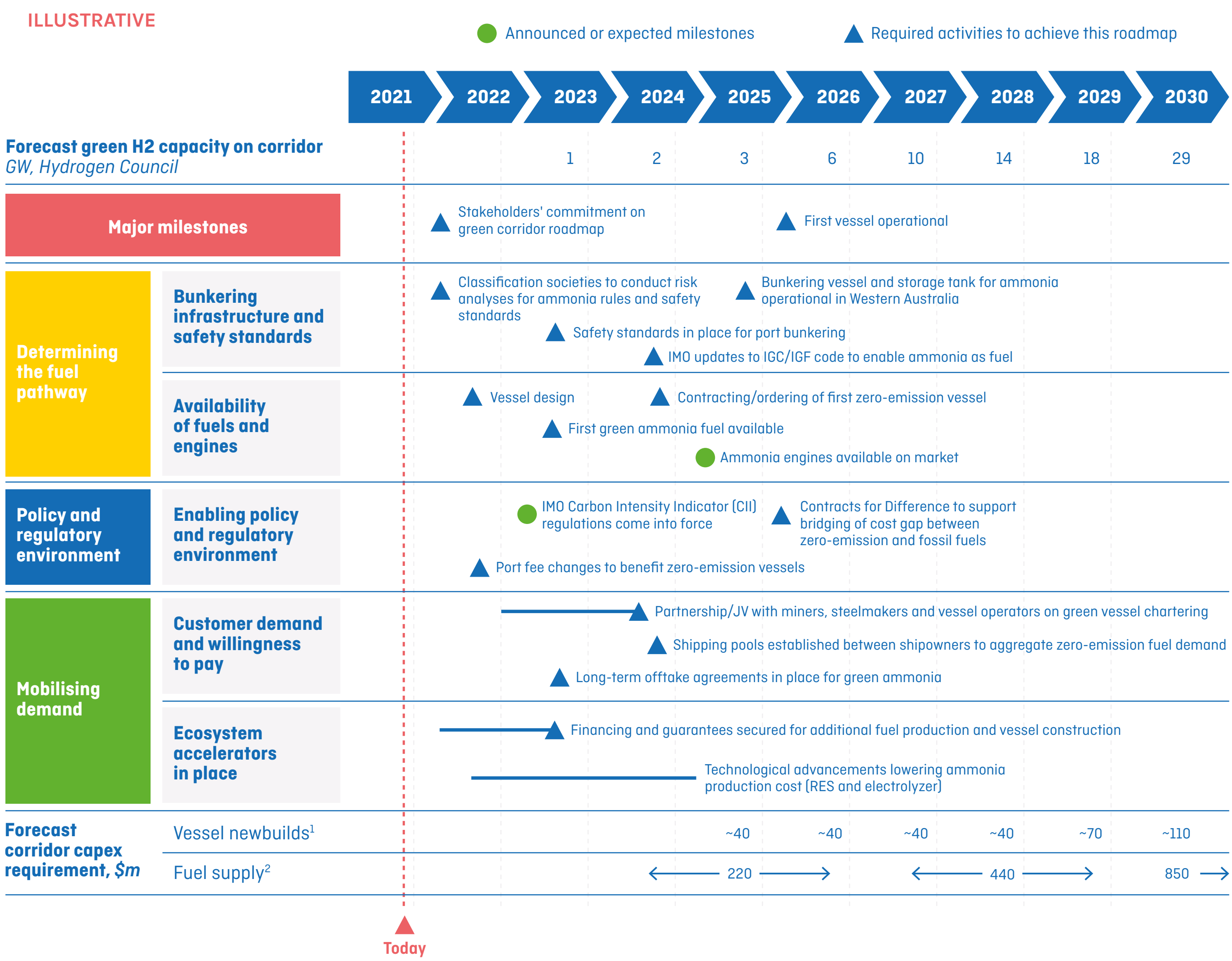
A roadmap for decarbonisation

Turning the Australia-Japan iron ore route into a green corridor will require stakeholders to align around a credible but ambitious roadmap for introducing zero-emission shipping at scale.

Ammonia engines are expected to be available in 2024, with the first vessel potentially operational in 2025.[44] Ahead of this milestone, it will be important for safety standards to be in place for port bunkering, and bunkering infrastructure (e.g., a bunkering vessel and ammonia storage tanks) to be operational in Western Australia. A partnership or joint venture potentially including miners, vessel operators, fuel producers, and steelmakers would need to be established in the coming years to meet this ambitious timeline.

Early commitments to such a roadmap would give each stakeholder the confidence that is needed to invest, co-ordinate, and deliver the solutions required to catalyse a green corridor by 2030 (Exhibit 9).

Exhibit 9: A potential credible, ambitious roadmap for decarbonisation of the iron ore corridor



[1]Total capex for ZEV newbuilds slightly more than capex for newbuild HFO vessels
[2]Capex required for production of green ammonia required to meet corridor demand, including renewable energy production

6. The Asia-Europe container route

This route is the largest of the three major East-West containership routes and offers the largest potential to reduce emissions. In 2019, approximately 24 million twenty-foot container equivalent units (TEUs) were traded on the route, carried by 365 vessels. The vessels burned approximately 11 million tonnes of fuel, releasing the equivalent of 35 million tonnes of CO_2, accounting for roughly 3 percent of global shipping emissions.[45]

Vessels on the route operate on a schedule with a fixed port rotation at fixed frequency. Shanghai is the largest port on the Asian side and Rotterdam is the largest port on the European side. Singapore acts as the primary transhipment port on the route.[46]

The route has significant potential to become a green corridor, for several reasons. First, there is growing momentum among players on the route to decarbonise container shipping as many cargo owners have set Scope 3 reduction targets.[47] Second, the pipeline of announced green-hydrogen projects—which amounts to 62 GW of hydrogen electrolyser capacity by 2030 in Europe, the Middle East and Australia (for bunkering in Asia)—is likely to be more than sufficient to serve the greening of the corridor.[48]

However, despite significant reductions in zero-emission fuel costs, a gap of 25 to 45 percent on a total cost of ownership (TCO) basis is forecast to remain by 2030.[49]

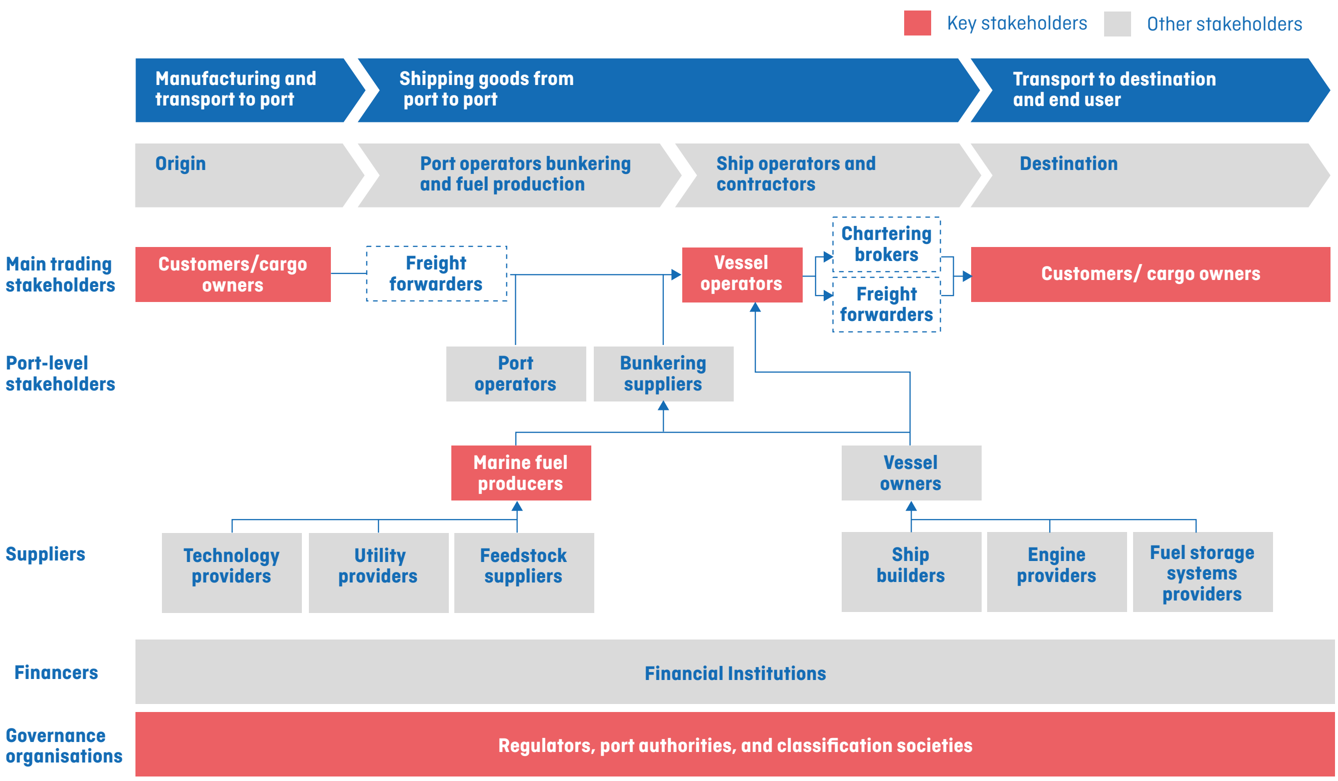
Actions already under consideration by policymakers—for example the EU's Fit for 55 package for shipping[50]—could reduce the cost gap entirely if revenues generated are recycled into providing a Contract for Difference (CfD) mechanism for initial zero-emission vessels on the corridor.

In addition, the Asia-Europe corridor offers the opportunity to establish demand coalitions from cargo owners, as well as to create book-and-claim systems that would allow them to aggregate efficiently and benefit from zero-emission fuel use. These are key levers for greening container shipping; establishing them in this corridor could set the stage for global adoption.

Momentum for decarbonisation across the value chain

The Asia-Europe container route has a relatively complex stakeholder environment, given the significant number of vessel operators involved on the route. Additionally, the nature of container shipping, where one vessel can be carrying cargo from a myriad of cargo-owners creates an additional layer of complexity in creating cross-value-chain collaboration. Exhibit 10 sets out all stakeholders across the Asia-Europe container route's value chain.

Exhibit 10: The set of core actors needed for decarbonising the Asia-Europe containership corridor



Despite the complex environment, the key value chain actors on the route have demonstrated significant interest in decarbonising the route:

- **Customers/cargo owners:** A diverse set of cargo owners employ containerships to carry their products. Approximately 33 percent of trade on the Asia-Europe route consists of products in categories that are "close to the customer" such as furniture, apparel and fashion accessories.[51] Many of these cargo owners are seeking ways to significantly reduce their supply-chain related carbon emissions and have set ambitious targets for reducing Scope 3 emissions, including a 100 percent reduction in some cases.[52] Both factors should allow for cargo owners to be able to share some of the marginal cost increases to the end-product, owing to decarbonisation, with their customers.

- **Vessel operators:** Most vessel operators on the route have made decarbonisation commitments.[53] As much as 70 percent of the total TEU capacity deployed on the route is covered by five shipping lines—MSC, Maersk, CMA CGM, COSCO Shipping, and ONE.[54] All five shipping lines have committed to reducing GHG emissions by 50 percent by 2050, in line with the IMO targets. Maersk[55] and CMA CGM[56] have committed to being carbon-neutral by 2050.

- **Fuel producers:** Fuel producers across the world have committed to significant scaling of green hydrogen production, allowing for sustainable shipping fuels to be available on the route at several bunkering locations including Europe, the Middle East, and Singapore (through low-cost production locations such as Australia). Additionally, the Neom project located in Saudi Arabia could play a key role in providing initial supply, with 4 GW of electrolyser capacity expected to be available by 2025.[57]

- **Governance organisations:** Given the recent momentum towards decarbonisation from most nations, governance organisations will likely have a key role to play in the decarbonisation of this route, regardless of the initial or final location of the bunkering hub. The European Union (EU) in particular has prioritised decarbonisation for all sectors including shipping, and recent legislative proposals make it likely that all international vessels entering the EU will have to face some form of carbon taxation.[58] Additionally, ship classification societies and port authorities will be key players in ensuring that safety standards are developed, and suitable infrastructure is in place for the green corridor.

- As is the case with the Australia-Japan iron ore route, cross-value-chain collaboration will be essential to catalyse the green corridor. The number of stakeholders involved, as well as the logistical make-up of the containership sector means collaboration will likely require unique mechanisms—as covered in the "Coalitions and agreements that can mobilise demand" section of this chapter.

Sufficient supply of zero-emission fuel

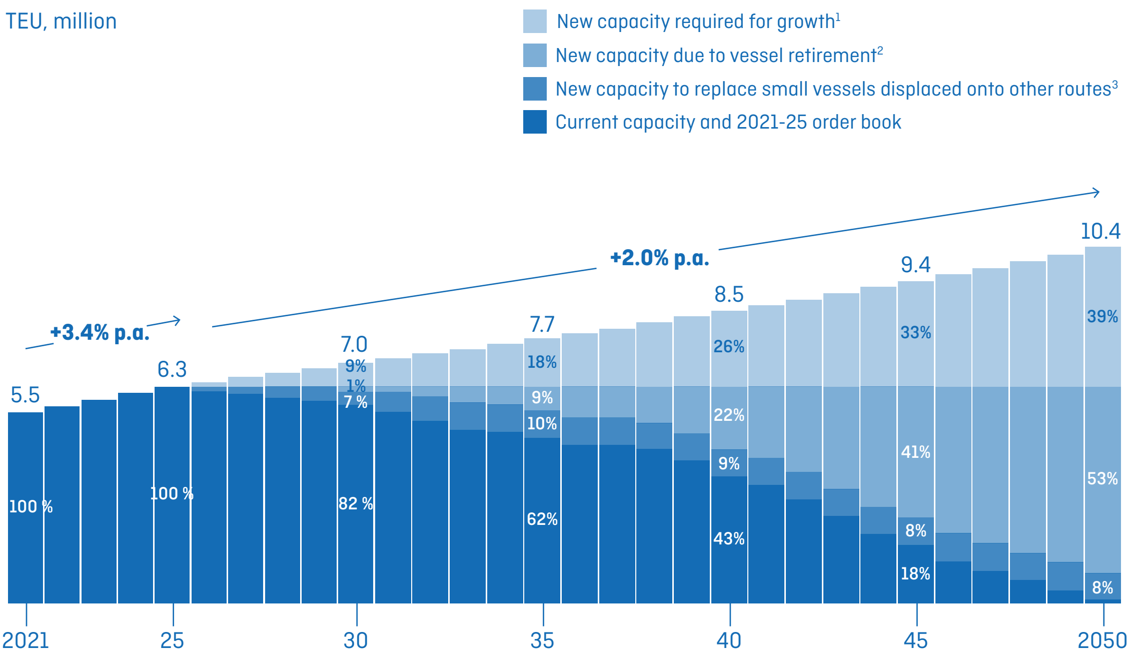
Given the ports schedule frequented by vessels on the route, sources of zero-emission fuel production on the corridor are likely to be Europe, the Middle East, or Australia (for bunkering in Asia). Green methanol is the most advanced zero-emission fuel option on the route, with methanol engines available today. Additionally, methanol has handling and operating requirements that make it easier to use as a marine fuel compared to other zero-emission fuels. Green ammonia has the long-term cost advantage on this route, with the lowest-cost fuels on this corridor likely to be produced in the Middle East.[59]

Vessel requirements

In 2019, 365 containerships were active on the Asia-Europe mainline route—equal to approximately 5.5 million TEUs of available capacity—conducting approximately four round trips per year.[60] Containerships on the route are typically the largest class size available, with an average vessel size of 15,000 TEU.[61]

Assuming that zero-emission vessels deployed on the corridor up to 2030 are all new builds, up to 17 percent of TEU capacity on the route could be zero-emission by that point. This would be limited by the fleet turnover rate. Some new vessels would replace retirements, but most would be deployed to meet growing demand or replace smaller ships moved off the route for efficiency reasons (Exhibit 11).

Exhibit 11: Vessel retirement curve by capacity on the Asia-Europe containership corridor



[1]Based on Drewry Shipping Consultants: (2020) capacity growth of 3.4% until 2025 and OECD GDP growth of 2% from 2025-2050
[2]Assuming an average vessel lifetime of 25 years
[3]Assuming 5% of the portion of the fleet <15,000 TEU are displaced onto other routes each year and replaced with new, larger vessels. The impact is that the average size of vessels increases from 15,000 TEU to 24,000 TEU over this period.

Source: based on Drewry Shipping Consultants (2020) and Alphaliner (2020)

These dynamics could lead to approximately 50 zero-emission vessels, providing 1.2 million TEUs of green container shipping, on the route by 2030.

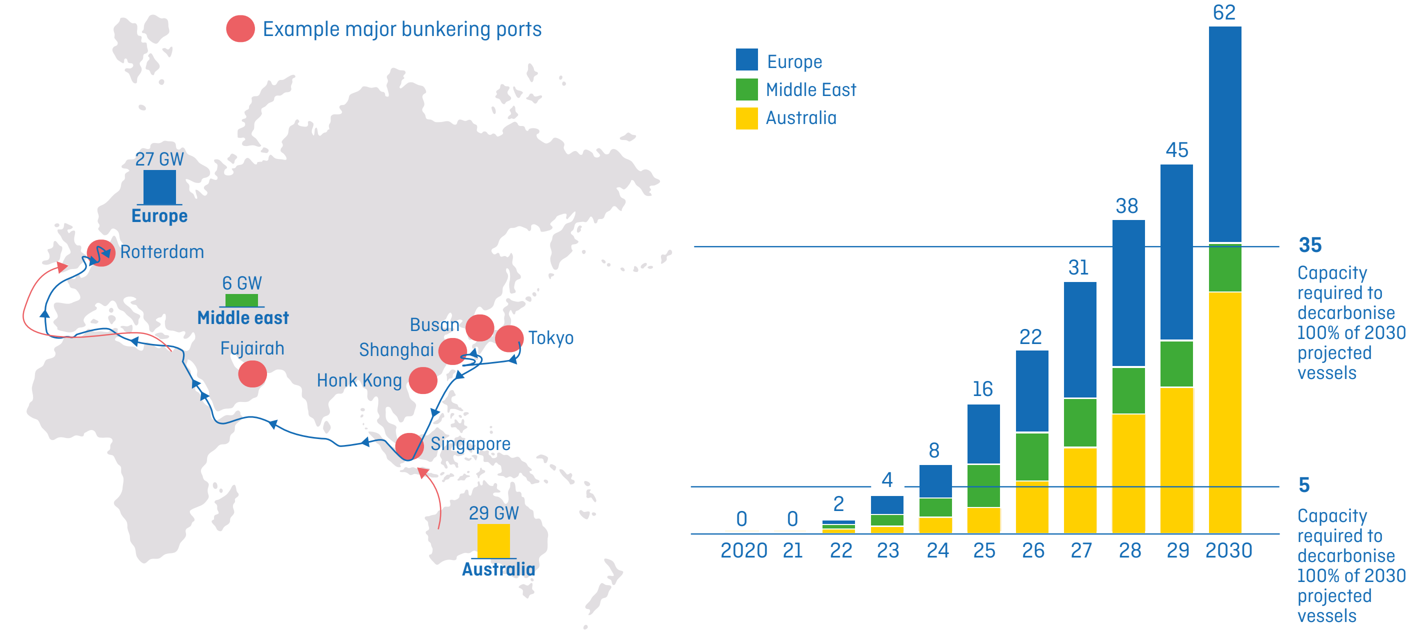
Zero-emission fuel availability

Announced green hydrogen production capacity, in the regions relevant to bunkering, amounts to 62 GW by 2030 (Exhibit 12).[xi]

Exhibit 12: Announced global green hydrogen electrolyser capacity by 2030

Announced green hydrogen electrolyser capacity by 2030 and current bunkering locations on route, *electrolyser capacity (GW)*

Projected cumulative capacity ramp up from announced green hydrogen projects, *electrolyser capacity (GW)*



Source: Ship & Bunker (2021); Hydrogen Council estimates of hydrogen capacity ramp up (2021)

xi While blue hydrogen could be also be used to produce sustainable shipping fuels, recent research indicates that only regions with strict methane leakage standards can consider blue hydrogen to be low carbon. See Robert W. Howarth and Mark Z. Jacobson, "How green is blue hydrogen?" Wiley Online Library, August 12, 2021, onlinelibrary.wiley.com. Europe produces sustainable blue hydrogen but incremental capacity from blue hydrogen projects in Europe is less than that for green hydrogen: 243 kt pa in 2025 and 1,100 kt pa in 2030 for announced blue hydrogen projects, compared to 917 kt pa in 2025 and 2,810 kt pa in 2030 for green hydrogen. Depending on the supply-demand dynamics, green hydrogen is likely to be the feedstock for shipping fuels moving forward.

Decarbonisation of the entire container fleet (based on 2030 projections) would require approximately 35 GW of electrolyser capacity. This equates to 55 percent of the 62 GW capacity of projects in Europe, the Middle East and Australia that are expected to be available by 2030. While it is likely that there will be demand for hydrogen from other end-use sectors, production in both the Middle East and Australia is geared towards meeting international demand for large offtake industries such as shipping. Additionally, given strong decarbonisation demand signals, it is likely that additional production capacity beyond what has been announced will be added towards 2050.[62]

Producing sufficient sustainable shipping fuel for the potential 50 zero-emission new-build vessels on the corridor would require approximately 5 GW of electrolyser capacity, just 7 percent of hydrogen capacity expected to be available on the route by 2030. The estimated capex requirement for this would be $14 billion for electrolysis, hydrogen storage, the ammonia production process, and the investment costs for renewable energy production.[63] The estimated capex requirement to decarbonise the entire corridors (including fuel production and renewable energy supply) would be $150 billion.[xii]

Hydrogen derived zero-emission fuel production is unlikely to be a major blocker, given the likely demand from ships by 2030 and the clear availability of supply.

Bunkering

Moving forward, ports with close access to low-cost green hydrogen along this route (e.g., Iberia, North Africa and Middle East, India, Australia) are potential bunkering ports. In addition, EU policies and targets aimed at achieving 10 million tonnes of green hydrogen production by 2030 could give Europe a potential advantage as a bunkering hub for the green corridor.[64]

However, initial vessels on the route will likely need a mid-way refuelling point on both legs of the journey given the characteristics of the zero-emission fuels likely to be used.[xiii] This would provide the Middle East with a geographical advantage as a bunkering hub.

Furthermore, bunkering will likely shift to ports that can provide the lowest delivered cost of fuel, giving the Middle East an additional advantage as a bunkering hub for the route in the long term—if the region is able to scale green production sufficiently to meet long-term demand. Singapore could also act as an alternative if it is able to secure sufficient supply from low-cost production locations such as Australia.

Initial bunkering infrastructure needs for the corridor would be relatively small, with one bunkering vessel and one onshore tank facility required per port for initial ramp-up. Given the implications of permitting timelines, it will be important for strong signals to be sent ahead of time to ensure that bunkering infrastructure is in place. Bunkering infrastructure for a fully decarbonised corridor would require anywhere from 10 to 15 bunkering vessels and four onshore tank facilities per port.[xiv]

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xii See Appendix 3 for further details.

xiii Lower volumetric density of ammonia and methanol results in more than twice as much fuel volume being required to travel the same distance when compared to fuel oil.

xiv Assumption based on LPG bunkering vessels with a capacity of 500 tonnes of ammonia per hour, 40 percent operational efficiency, and a 1.2 peak demand factor.

While the capex requirements would be relatively small (estimated at $130 million to decarbonise the route fully), especially compared to investment needs for fuel production, the cost of bunkering per tonne is significant at smaller scales. If one single vessel was absorbing the cost, it would add 5 percent to the cost of fuel. As the corridor decarbonises more broadly, the cost of bunkering per tonne will reduce significantly (Exhibit 13).

Exhibit 13: Scenario analysis on scale of ammonia use on the Asia-Europe containership corridor

Scenario analysis, scale of ammonia use on the Europe-Asia container route	Scenario A **1 vessel**	Scenario B **15% of fleet**	Scenario C **50% of fleet**	Scenario D **100% of fleet**
Vessels in fleet, # Number of vessels required based on current fleet	1	50	187	374
Hydrogen capacity needed, GWe GWe electrolyser capacity based on 65% capacity factor	0,1	5	17	35
Bunkering facilities[1] Type of bunkering needed in the port	**1-2 bunkering vessels** needed to bring ammonia from the terminal to the vessels		**10-15 bunkering vessels** needed to bring ammonia from the terminal to the vessels	
Cost of bunkering per tonne bunkered, USD	59	8	7	6

[1]Assumption based on LPG bunkering vessels with a capacity of 500 tonnes of ammonia per hour, 40% operational efficiency (percentage of time active bunkering – other time spent refuelling, idling and traveling to and from ships), and 1.2 peak demand factor; Based on an investment of $10million per LPG bunker vessel (lifetime 25 years) and four 20,000 tonnes onshore tank capacity at $600/tonne (lifetime 30 years) distributed across number of bunkering events during lifetime

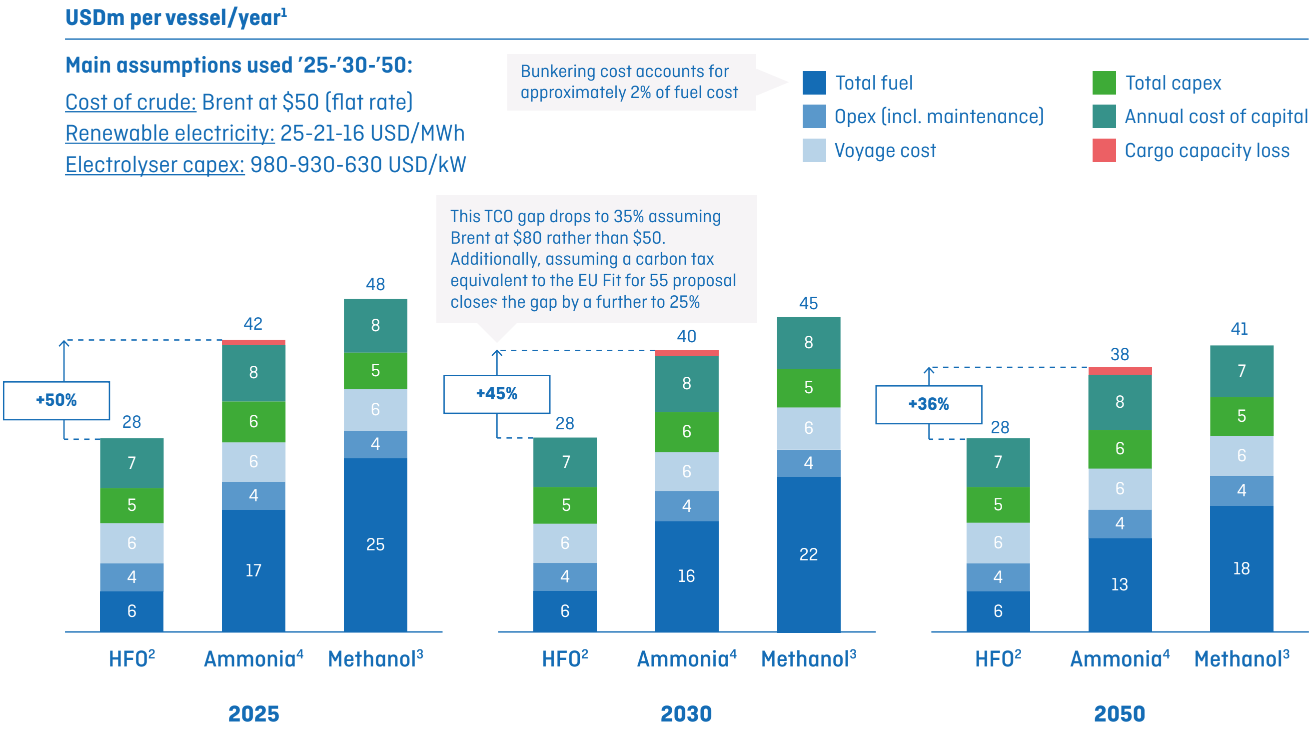
Source: based on Alphaliner (2020); International Maritime Organisation (2020); Hydrogen Council (2021)

Total cost of ownership

Despite significant drops in zero-emission fuel costs, a gap of 45 percent on TCO is forecast to remain by 2030, with additional fuel cost being the primary driver for the cost gap (Exhibit 14).[xv]

Certain measures could result in further reductions in the cost gap, including fuel efficiency savings and investor mobilisation to assess carbon penalties on loans. Even in a best-case scenario, however, there remains a cost gap of approximately $5 million annually per vessel by 2030—indicating the importance of demand mechanisms as well as policy and regulation to ensure that zero-emission shipping is competitive on the route.[65]

Exhibit 14: Total cost of ownership pathways for containerships



[1]Based on vessel >15,000 TEU with bunkering in Middle East; Typical speed of 18 knots and 8 annual canal transits (Suez)
[2]ICE HFO with LSFO as fuel (100%)
[3]ICE Methanol with 97% green methanol fuel use with Direct Air Capture (DAC) and 3% LFSO
[4]ICE Ammonia with 95% green ammonia and 5% LFSO

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

xv See detailed assumptions in Appendix 5

Coalitions and agreements that can mobilise demand

Cargo owners can expect relatively small price increases on their end products shipped on this route, making cost pass-through a powerful lever for green shipping on this route. Cargo owners can potentially generate value from sustainable shipping and use this to differentiate their offerings from competitors. However, this value can only be captured if the reductions are seen as credible and material by end consumers. While cargo owners cannot be expected to bear the entire extra cost of zero-emission shipping, a clear demand signal can help enable action from the rest of the value chain and policymakers.

For the initial vessels, multi-year offtake agreements between cargo owners and ship owners could provide this signal, cascading via shipowners' offtake agreements to de-risk fuel producers' investments on the corridor.

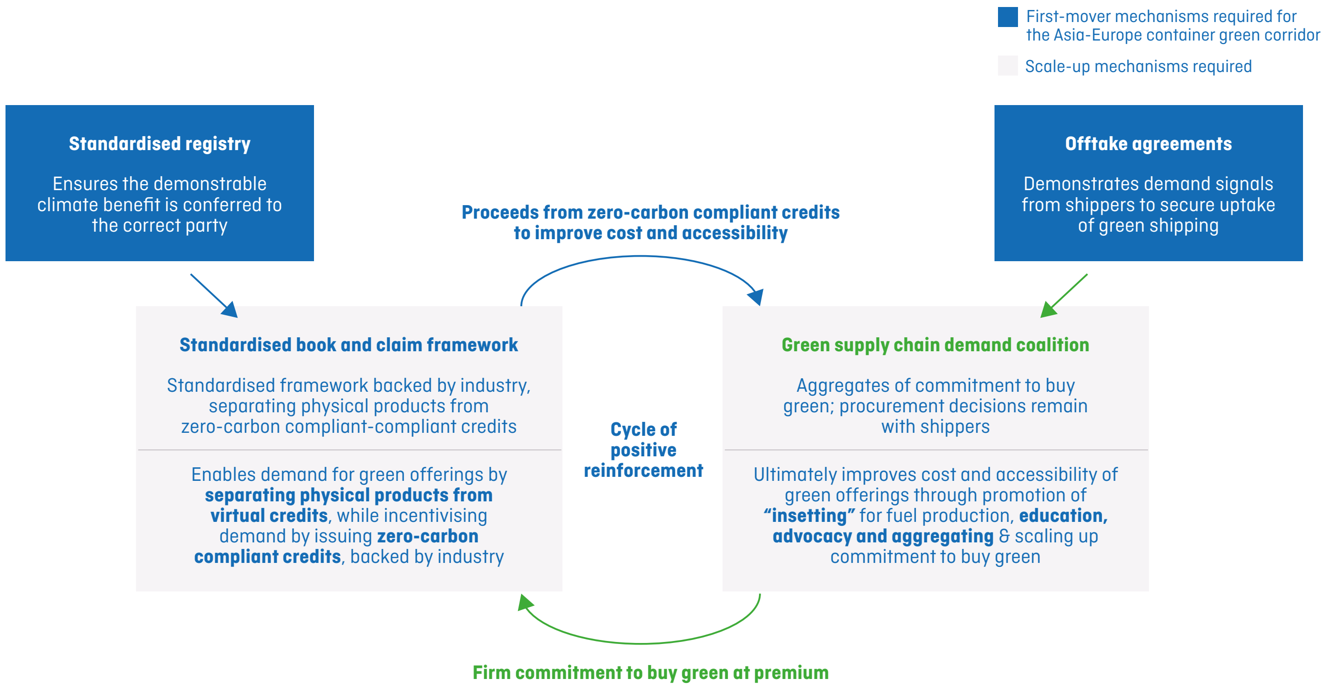
Design parameters for the offtake agreements could include the following five factors:

- Alignment on the definition of zero-emission fuel (for example, lifecycle assessment of GHG reduction)
- Agreement on sharing the cost of the premium for green shipping
- Flexibility to manage changes in the regulatory environment
- The option to include additional value-chain actors such as fuel producers in agreements.[66]

Multi-year offtake agreements can be complemented by the formation of pre-competitive demand coalitions. This will allow cargo owners to aggregate their commitments to buy green while keeping full autonomy over their purchasing decisions. When developing such agreements, a standardised registry system should be considered from the very beginning to ensure that demonstrable climate benefit is defined and conferred to the correct party. Because of its size, this corridor is uniquely positioned for initiating this system that can then serve as the basis for a global standardised book and claim framework (Exhibit 15).[xvi]

xvi A book and claim framework separates physical products from virtual credits, allowing for the creation of a disaggregated marketplace. Ensuring that any book and claim system has credits that are zero-carbon compliant and backed by industry can further incentivise demand for green offerings.

Exhibit 15: Mechanisms to aggregate and mobilise demand both for first movers on the green corridor and for the scale-up



Source: Based on World Economic Forum (2021)

Additionally, a corridor-based book and claim system would allow participants to ensure system boundaries and conditions for booking/claiming that meet their thresholds for quality and credibility. For instance, the system could exclude near-shore shipping or limit which fuels qualify. The success of a corridor-based book and claim system can then be used as a starting point for a universal one.

It is important to note that while some cargo owners will seek to maximise the credibility of claimed emissions reductions by securing containers on vessels that use green fuels, logistical complexity will likely require a book and claim system as participation in the corridor scales up.

Potential policy levers to close the cost gap

Policy and regulatory levers have the potential to both reduce the cost gap and create an enabling ecosystem for the route.

The containership corridor is uniquely positioned to benefit from forthcoming policy interventions in Europe. Compared to other regions, these could come into effect more quickly in Europe and will affect the entire route. For example, the EU Fit for 55 package includes shipping in the Emission Trading Scheme and is expected to be ramped up by 2026.[67]

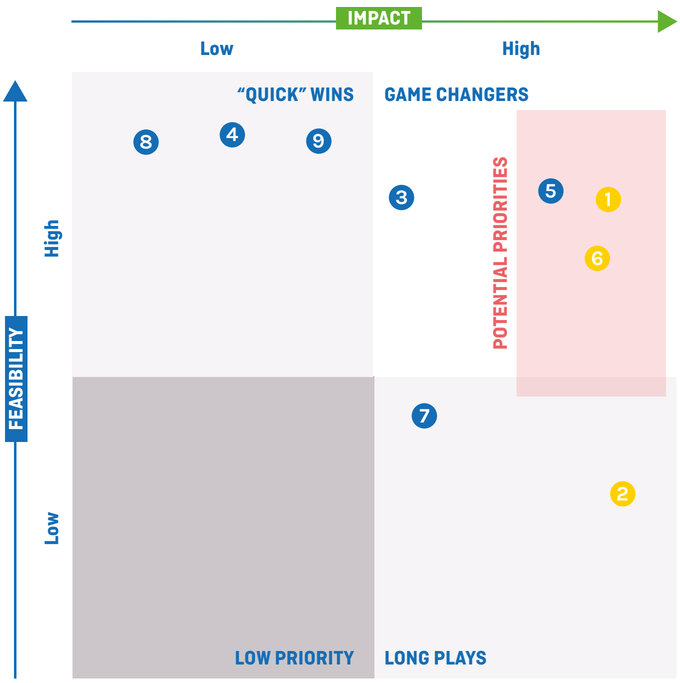
Governments in the Middle East can further support the uptake of sustainable fuel production and bunkering, for example by providing hydrogen storage to accelerate the cost-reduction trajectory for green hydrogen.

In total, eight supporting regulatory levers have been identified which further reduce the cost gap and create an enabling ecosystem on the container corridor in the near term. Three of these measures specifically help to reduce the cost gap and five further support the creation of an enabling ecosystem on the route (Exhibit 16).

Exhibit 16: Potential options to reduce fuel cost and create an enabling ecosystem for the Asia-Europe containership corridor

NOT EXHAUSTIVE

Green corridor policy framework



Fuel cost gap reduction (yellow)
Enabling ecosystem (blue)

Organisation[1]	Policy options
Governments and EU	1 Expand EU ETS to shipping into or out of EU (Fit for 55)
	2 Implement Contract-for-Difference for zero-emission fuels
	3 Secure natural hydrogen storage to accelerate cost-down trajectory for green hydrogen
	4 Support development of 'Guarantees of Origin' (GO) schemes for green H2 (aligned with CertifHy)
Classification societies	5 Develop required class notation for the safe use of sustainable marine fuels e.g., green ammonia
	6 Reduce port fees for zero-emission vessels
Port authorities	7 Develop infrastructure and guidelines for sustainable marine fuel bunkering
	8 Implement crew safety training for handling of zero-emission fuels
	9 Ensure adequacy of green fuel bunkering through the appointment of sufficient bunker suppliers

[1]Not exhaustive: examples of key players, most policy actions require collaboration across governance levels

Source: Based on Transport & Environment (2021) and Maritime and Port Authority of Singapore (2021)

Two sets of policies can reduce the cost gap and create an enabling ecosystem for green shipping:

- **Policies to reduce the cost gap:** Various policies are in place, or are being explored, that can reduce the cost gap on the route. For instance, under the EU Fit for 55 legislative package, the Emissions Trading Scheme would apply to 50 percent of the shipping into and out of the EU.[68] This could be expected to reduce the 2030 cost gap between fossil fuels and zero-emission fuels on this route to 25 percent. In the short term, revenues for containerships could be recycled back to provide funds for a Contract for Difference (CfD) mechanism.[xvii] The CfD could be used to benefit new-build zero-emission vessels on the route. Carbon related revenues generated from the route between 2025-2030 would be two to three times greater than the estimated CfD cost (between $0.5 billion and $0.7 billion annually) of 50 first mover zero-emission vessels. Additionally, port incentive programs, for example the reduction of port fees for containership vessels that use zero-emission fuels, can help close the cost gap. Several ports are already exploring such incentive schemes.[69]

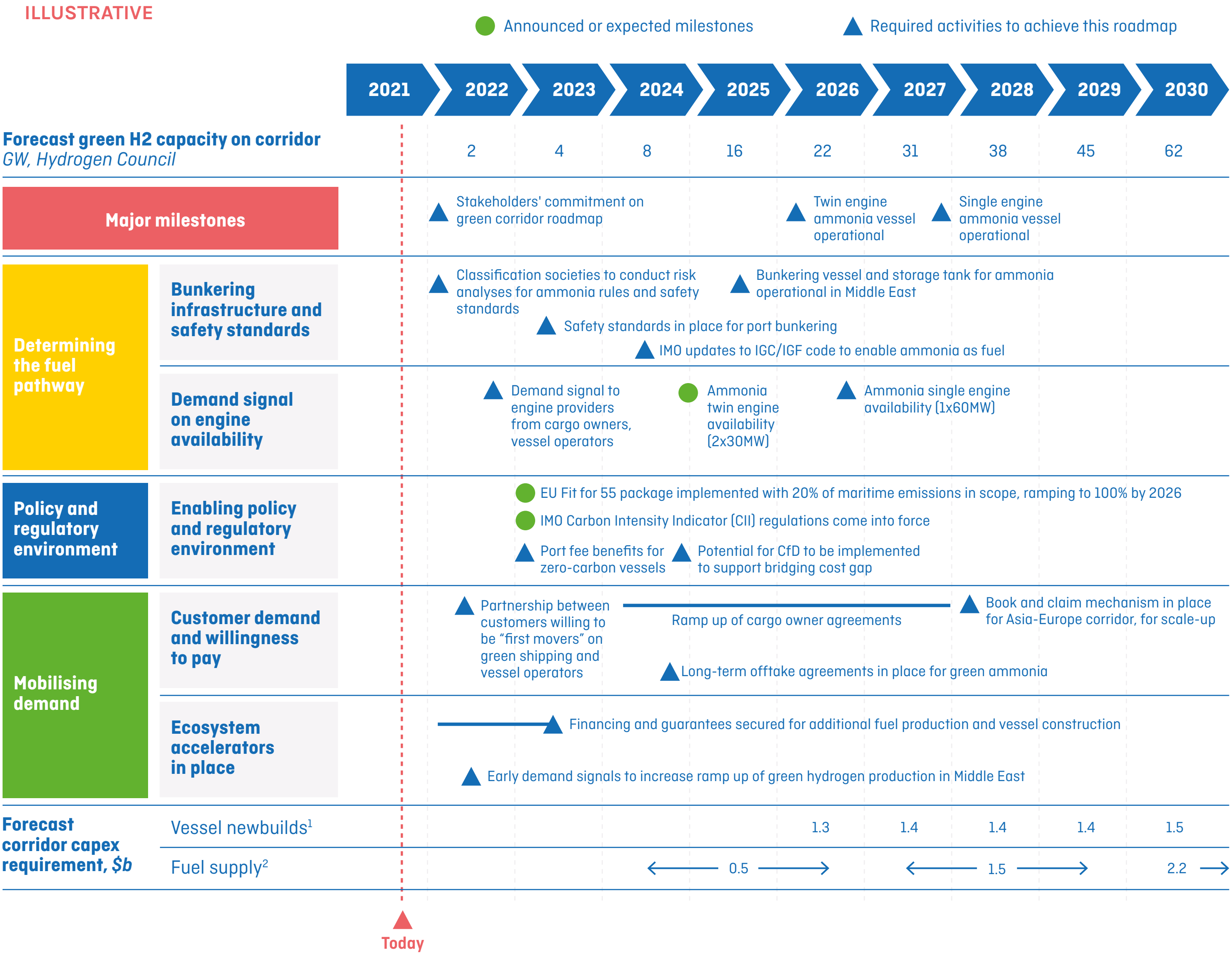
- **Policies to create an enabling ecosystem:** There are policies that governments and ports could use to create an ecosystem that enables green shipping. The development of guarantees of origin schemes should be aligned with EU procedures such as CertifHy[70] to facilitate smoother integration of non-EU bunkering hubs for the route. In addition to these government efforts, port authorities can further catalyse the uptake of sustainable shipping by ensuring safe bunkering of zero-emission fuels and by providing the required infrastructure. This is of relevance for all stakeholders, including ports, given the limits for hazardous fuels that can be stored close to populated areas. Overall, an alignment will be required across the regulatory landscape to ensure the safe handling of sustainable fuels.

xvii See Appendix 2 for further details

A roadmap for decarbonisation

Aligning on a credible but ambitious roadmap will enable all stakeholders up and down the value chain to move to action with confidence. In the near term there will need to be a demand signal from ship owners and cargo owners. Partnerships would need to be established between first movers on the corridor to establish long-term offtake agreements for green ammonia ahead of the first vessel becoming operational (Exhibit 17).

Exhibit 17: A potential credible, ambitious roadmap for decarbonisation of the containership corridor



[1]Total capex for ZEV newbuilds slightly more than capex for newbuild HFO vessels
[2]Capex required for production of green ammonia required to meet corridor demand, including renewable energy production

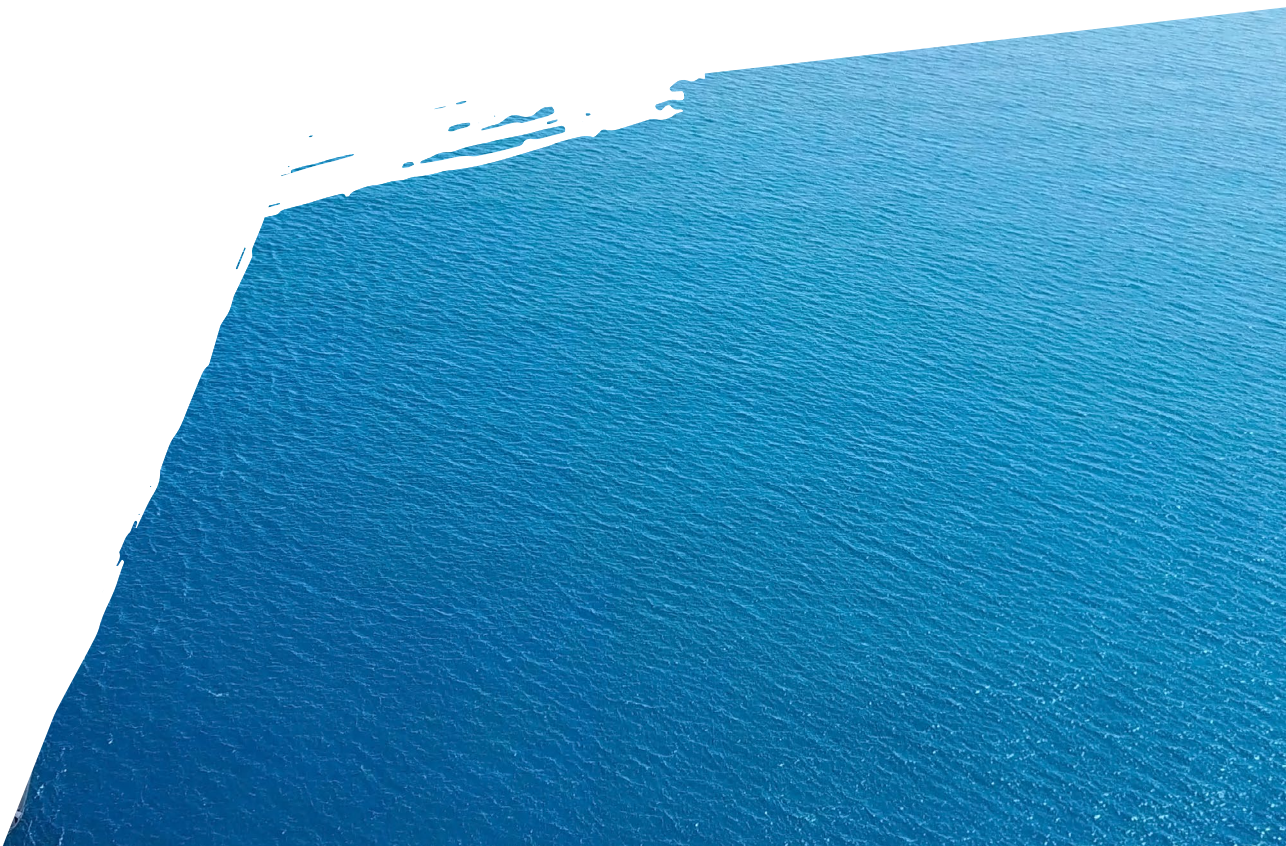
7. Case study: Northeast Asia-US car carriers

In addition to the two previously discussed high-volume routes, smaller-volume shipping routes may also prove prime candidates for becoming green corridors. On these routes, the smaller number of vessels, operators, and shipping customers may increase the feasibility of becoming a green corridor.

A prime example of such a route is the corridor transporting finished vehicles on specialist pure car carrier (PCC) RoRo vessels from factories in Japan and Korea across the Pacific to ports on the US West Coast. Several stakeholders on the route have made commitments to decarbonisation and there is a move to electrification in the automotive industry to reduce carbon emissions—so transporting cars in a more carbon neutral way would be a natural extension of this ambition.

Based on vessel voyage data from 2019, there are approximately 60 PCC vessels that make the Transpacific journey from terminals used by car factories in Japan or Korea to terminals used by import dealers in the US.[71] Often these PCCs will call on intermediary ports and may be in ballast (travelling empty) on the return journey to Northeast Asia. These vessels burn approximately 670,000 tonnes of heavy fuel oil (HFO) each year, generating 2.2 million tonnes of CO_2 emissions.[72] Most PCC vessels globally are not dedicated to a fixed corridor, but instead are on flexible deployments that include multiple continents. However, the Transpacific corridor probably has the highest number of dedicated ships compared to other routes.

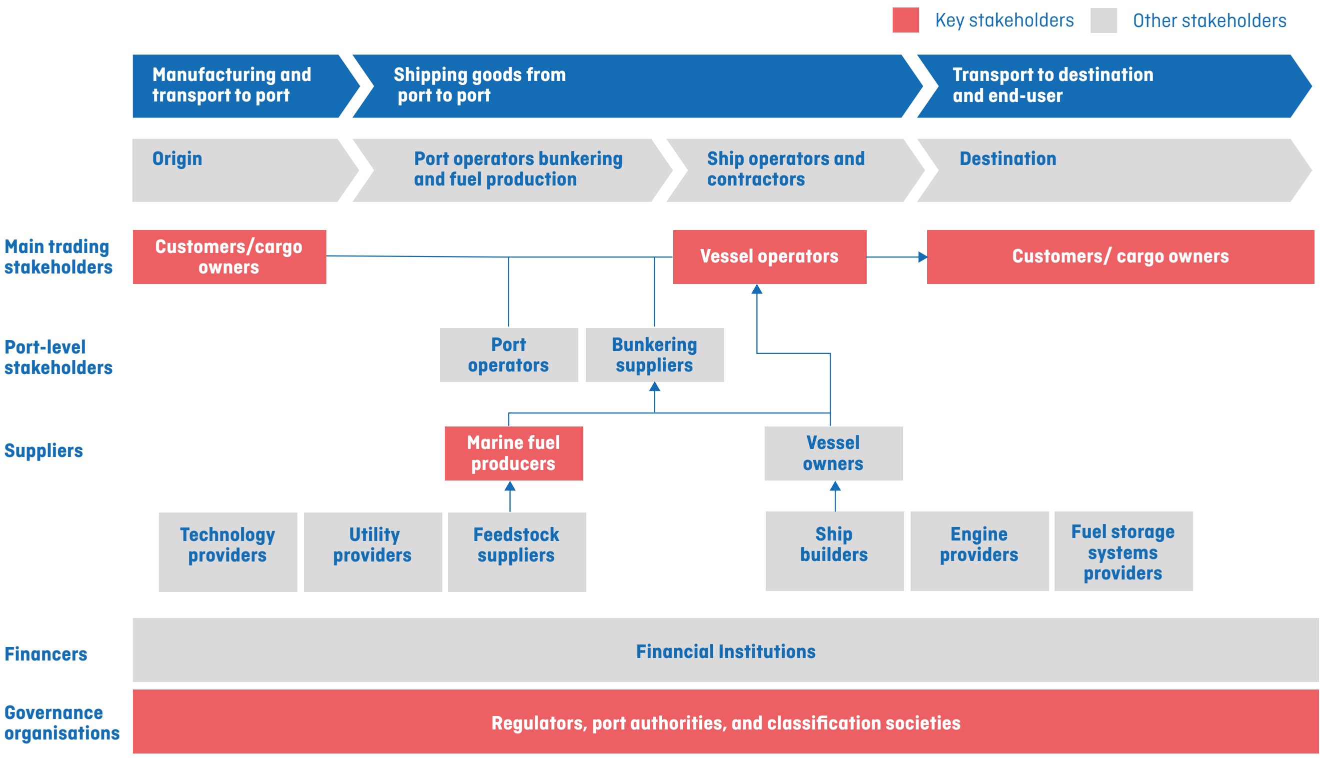
There are some additional complexities involved in decarbonising this corridor, including securing bunkering infrastructure and fuel supply on both sides of the Pacific—since neither region is home to locally produced, affordable low-carbon fuel. There is also the related issue of the size of the fuel tanks, and a potentially significant opportunity cost from lost cargo, in addition to the more expensive cost of green fuel.



Interest in decarbonisation across the value chain

In advance of measures to decarbonise the route, cross-value-chain collaboration between green bunker suppliers and automotive Original Equipment Manufacturer (OEM) customers would be required to mobilise demand for more expensive zero-carbon shipping. Exhibit 18 sets out the stakeholders across the Asia-US car carrier route's value chain.

Exhibit 18: The set of core actors needed for decarbonising the PCC corridor from Japan/Korea to US



There is significant interest from stakeholders in decarbonisation, with many European and Japanese PCC operators committing to decarbonisation in line with, or ahead of, the IMO's targets. For example, Hoegh Autoliners and Wallenius Wilhelmsen have made announcements about low/ zero-carbon ships. Hoegh Autoliners announced that its Aurora class vessels with multi-fuel ability will transition to zero-carbon fuels, such as green ammonia, when available and commercially viable.[73] Wallenius Wilhelmsen has introduced the Orcelle Wind concept, where a significant portion of the propulsion will come from wind power.[74]

Japanese car manufacturers have also set clear targets for GHG emission reduction throughout the lifecycle of the cars, supported by upcoming regulation on electrification in the US and Europe.

There is a relatively small set of stakeholders involved in the Japan/Korea-US PCC route. The five largest PCC operators cover 70 percent of the trips made and just five car manufacturers ship two-thirds of the volumes on this route.[75]

True cross-value-chain collaboration between shipping customers, automotive OEMs, PCC operators, and automotive dealers will be especially critical for this corridor, because—unlike container shipping—a single customer may have a significant majority of the cargo onboard any particular shipment.

A potential fuel pathway

Green ammonia is expected to be the zero-emission fuel with the greatest cost advantage. As technology options are still being developed there are uncertainties in the assumptions and TCO modelling will become more reliable as projects progress and learning are incorporated in the modelling.

Regardless of fuel choice, a cost gap between fossil fuels and zero-emission fuels is expected to persist, estimated at approximately $6 million, or 40 percent, on an annualised total cost of ownership basis.[76]

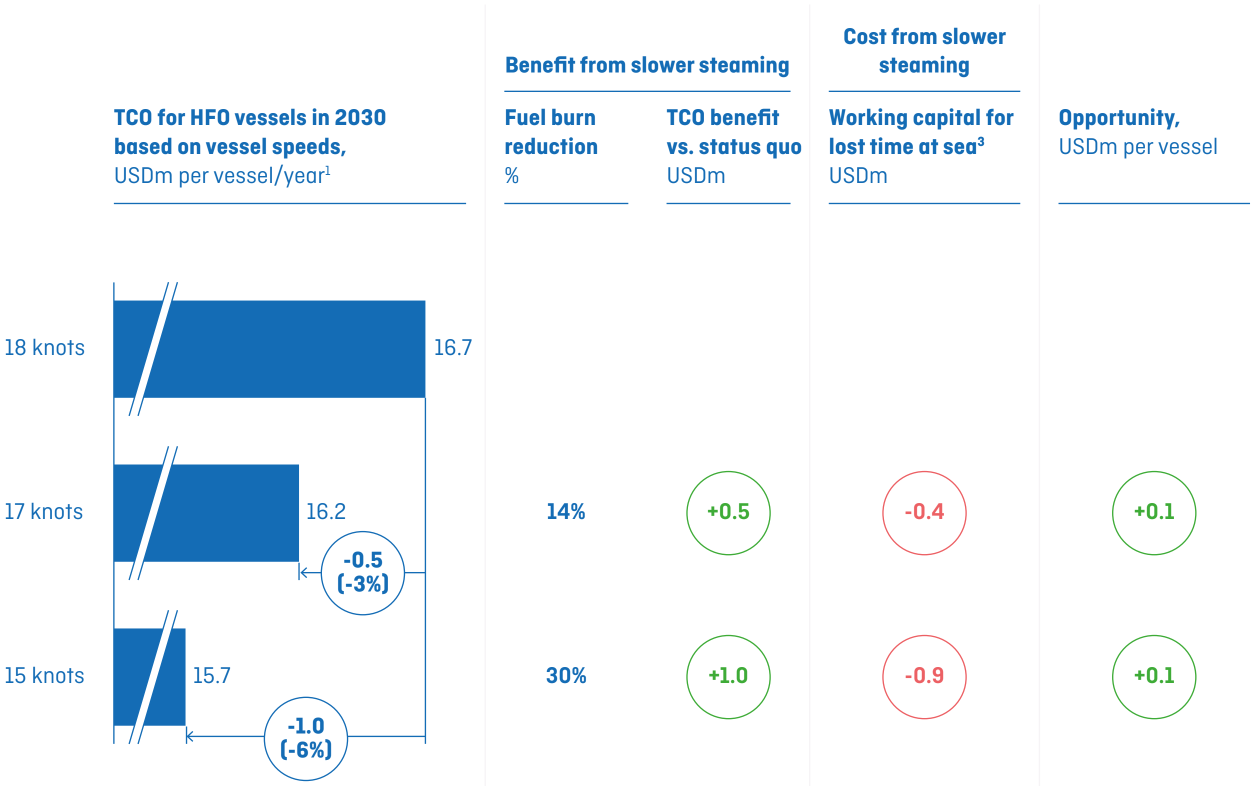
Ammonia is approximately half as energy-dense, by weight, as HFO, and 50 percent more voluminous. Therefore, the fuel tanks—which are currently in the void spaces in the ships' hulls—would need to be enlarged, creating an opportunity cost from lost cargo space that is more pronounced in the PCC segment than other shipping segments (such as container or dry bulk) given the high value add embedded in the cargo. Assuming that a sufficiently large ammonia tank could enable a standard PCC range on a dual-fuel vessel, this opportunity cost could be approximately $2 million, or 9 percent of the cost gap. The cylindrical or prismatic tank required may also obstruct the front-to-back flow of the PCC carriers, increasing loading/unloading time and risks.

Reducing the tank size mitigates these costs, but it also introduces potential operational inefficiencies. Smaller tanks constrain PCC vessel deployment to specific routes and distances, creating a less flexible fleet. On this route for example, a smaller tank size would require green ammonia bunkering facilities in both Northeast Asia and the US West Coast. The limited network of bunkering facilities would constrain the route and deployment possibilities even further and would certainly require long-term agreements with customers.[xviii]

Partnerships to mobilise demand

Even before zero-emission fuels become available at commercial scale, there are significant opportunities for industry players to collaborate end-to-end across the value chain to reduce emissions. For example, cars are currently transported at high speed across the Pacific, only to wait for several weeks at the port of arrival before being delivered to dealers. Industry estimates indicate that cars spend between 25 and 40 percent of the total journey parked at port terminals.[77] This high-speed journey wastes fuel and emissions, as engines burn significantly more fuel when travelling at speed. Reducing the speed from 18 knots to 15 knots could reduce fuel burn, and therefore emissions, by 30 percent—without lengthening the time that the inventory is in transit or reducing time to market (Exhibit 19).

Exhibit 19: Lowering the speed of PCC vessels as a cost-effective opportunity to lower emissions



[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]Based on trip of 4,842 nautical miles between Yokohama, Japan and Long Beach United States
[3]$210m cargo value (6,000 cars at $35,000 value) for 2 days longer at sea, 12 trips per year and 5% interest rate

xviii See Appendix 4 for more details

Of course, slowing the voyage in this way would reduce the carrying capacity of the total fleet, and increase the working capital requirement for car manufacturers due to holding the cars as inventory for an additional 2.5 days.

Depending on the assumptions, abating carbon in this way should approximately pay for itself because less fuel would be used. The opportunity could be greater should green trade financing be able to lower the cost of capital further.

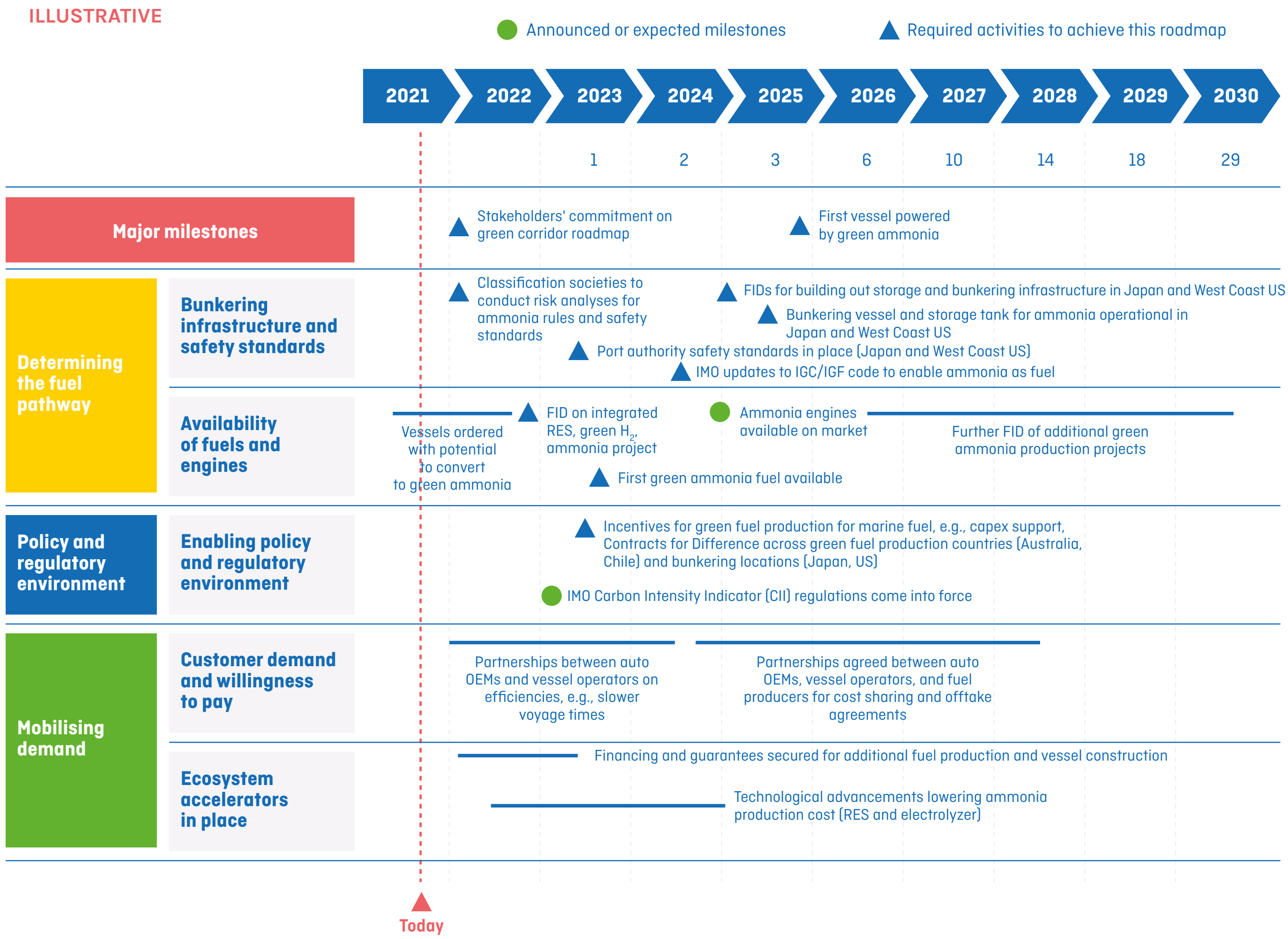
Partnerships on emission reduction through commercial levers such as this could pave the way for joint ventures or other forms of partnership between automotive OEMs and shipping lines to bridge the potential cost gap once zero-emission fuels and vessels are available in the mid-2020s.

Policy and regulation that can help bridge the cost gap

Policy and regulation have a role to play in reducing the cost gap between green fuels and fossil fuels on the route. For instance, a CfD across multiple potential green-fuel production countries such as Australia and Chile, and multiple bunkering locations such as Japan and the US (perhaps even as bonded zones where no import tax needs to be paid on the fuel), could accelerate the transition to green shipping.[78]

A potential roadmap towards decarbonisation, using ammonia as fuel, is suggested in Exhibit 20. The most significant constraining factor on this roadmap could be the readiness of the engine supply and fuel supply in the Northeast Asian and US West Coast markets. Fuel supply would need to be secured in the next two to three years to meet the ambition to scale up decarbonisation of the corridor in the latter half of the decade. Partnerships between automotive OEMs and vessel operators could begin now by reducing emissions through operational measures such as slower sailing speed. These could form the foundations of partnerships to share the costs and risks of the shift towards zero-emission ships by 2025.

Exhibit 20: A potential credible, ambitious roadmap for decarbonisation of the PCC corridor



8. The path forward

Green corridors could help the shipping industry reach its goal of full decarbonisation by 2050. The two feasibility studies, and one case study, presented in this report demonstrate that stakeholder collaboration to deliver green corridors is feasible and credible. The following actions would accelerate the development of the corridors:

- **Identify key success factors when prioritising green corridors:** Successful initiatives will be built on credible fuel pathways, the potential for value chain initiatives, and the feasibility of policy action.

- **Prepare to move forward together:** The entire value chain—including cargo owners, fuel producers, and vessel operators—needs to come together to establish new partnerships based on a shared commitment to zero-emission shipping. These partnerships may need to evolve into new institutional models, such as joint ventures, to solidify commitments and mitigate first-mover risk.

- **Send the market signals to ensure zero-emission fuel supply:** The promising developments in green hydrogen production can be consolidated to the benefit of the maritime ecosystem if offtake agreements can be put in place on green corridors.

- **Mobilise customer demand for carbon-neutral supply chains:** Cargo owners and freight forwarders can mobilise the demand for green shipping—from companies seeking to minimise their Scope 3 emissions, and individuals looking to buy goods with a reduced carbon footprint—by seeking zero-emission alternatives for their goods. Working with shipping operators on a corridor-wide zero-carbon compliant verification mechanism could accelerate these solutions and be a testing ground for global implementation.

- **Deploy targeted, corridor-specific policies that enable early action today and also make zero-emission vessels the default choice on specific corridors by 2030:** This includes catalysing the green hydrogen economy in likely locations for zero-emission fuel production, for example in Australia and Middle East; utilising mechanisms to bridge the gap between fossil fuels and zero-emission fuels in the short term, for instance through carbon pricing, Contracts for Difference, and differential port fees; and creating an enabling ecosystem for the use of new marine fuels by putting in place safety measures and handling regulations.