UK Domestic Shipping

Mobilising Investment in Net Zero

November 2022

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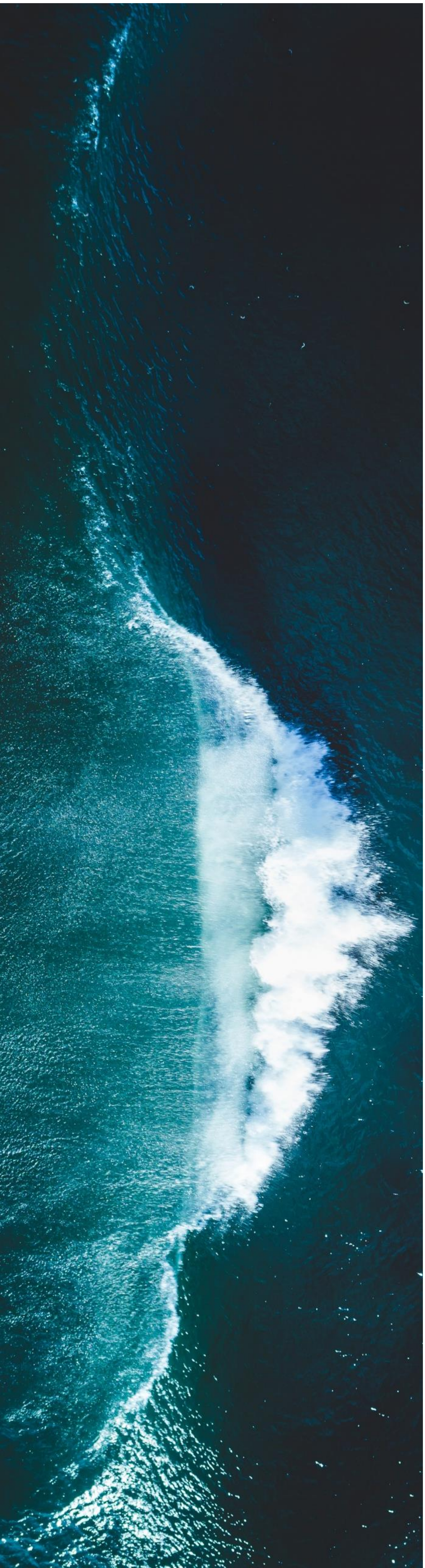


Executive Summary

The UK has committed to reaching net zero by 2050, and this target extends to domestic shipping. The maritime sector is complex and diverse, and there are no simple solutions. The challenges also bring opportunities, but investment is needed.

Access to capital is a critical hurdle, but there are funding models that could help channel investment into the sector.

In 2019, the UK became the first major economy in the world to legislate to reach net zero by 2050[1], a bold commitment which extends to the maritime sector and domestic shipping. Investment will be a key catalyst for decarbonisation. Over the coming three decades, an estimated £75 billion will need to be invested in the domestic maritime sector for it to transition to net zero. Approximately half would be spent on replacing the domestic and short sea fleets with lower and (eventually) zero emission vessels; the remainder covers investment in related shoreside infrastructure, including the provision of zero emission fuels and shore power at UK ports.

Currently, however, there are headwinds to such investment. The complexity of the domestic maritime sector is one. There is a large number of diverse stakeholders (many of them small or medium-sized) across the domestic shipping, port, and associated maritime industries. Despite the interdependency of these players, many operate in a siloed manner, magnifying the challenges that need to be overcome for the sector to decarbonise.

Uncertainty is another impediment to investment. This includes the current ambiguity regarding future demand for and supply of clean fuels, and the lack of clarity over the evolution of the policy and regulatory environment (including targets and timelines). Limited access to funding by many of the stakeholders in the sector also stymies investment, particularly for smaller shipowners where decarbonisation may necessitate a shift away from a business model built around the acquisition of second-hand vessels, which are cheaper to buy and easier to finance than new vessels.

The scale of investment needed to fund decarbonisation cannot be sourced from within the industry or through its traditional lenders (commercial banks). Institutional investors, who together represent more than $80 trillion of asset value, could help bridge this funding gap. However, there are currently various barriers preventing these providers of capital from entering the domestic maritime sector. These include a lack of familiarity with the industry and the reluctance to assume the risks associated with the early stages of the decarbonisation transition.

To mobilise investment into the domestic maritime sector from external sources of capital, a coordinated approach is required by government and industry stakeholders. This study presents three case studies illustrating funding solutions that could be used to finance the decarbonisation of the domestic and short sea fleets. These models do not require upfront funding by government, but support will be needed to unlock private sector investment, particularly to finance large-scale fleet replacement.

The transition to net zero will be a complex process. Government will have a critical role to play in terms of support and intervention, through policy and regulatory tools, to ensure that this pathway is navigated successfully. Areas of priority need to be identified to ensure support is targeted appropriately and effectively. However, domestic and short sea shipping fulfils a large range of functions, the vessels are very diverse, and the technical and operational constraints are highly varied. Different approaches will be needed in different segments.

Ferries and Ro-Ros are a significant and concentrated source of emissions: this segment accounts for 10% of vessels but 50% of emissions from the domestic and short sea fleets. The average age of these vessels is 23 years, and more than half will need to be replaced over this coming decade. Given the long working life of these vessels, any fleet renewal programme that does not incorporate emissions reduction and/or adaptability for future conversion to zero emission fuels will equate to a lost opportunity. However, as these vessels consistently operate on regular routes, this segment offers opportunities to establish domestic and/or regional zero emission shipping routes (also known as green corridors).

Collectively, offshore service vessels (which support offshore energy industries such as oil and gas, and increasingly, the offshore wind sector) account for the second largest source of emissions. This segment also presents opportunities for decarbonisation. Vessels that service the offshore oil and gas industry are typically built to generic designs and therefore can be bought and sold more easily on the second-hand market. This means that the replacement with new lower or zero emission vessels will not necessarily be dependent on the lifespan of the existing fleet. Industry-specific emissions reduction targets and government support could be introduced accordingly.

Decarbonising offshore wind service vessels (in alignment with the Operation Zero initiative[2]) also presents an ideal opportunity for targeted measures. Given the UK's planned expansion in offshore wind projects over the coming decades, early decarbonisation of this segment would prevent a potential future source of emissions from ever becoming established.

As evidenced by approaches taken by other countries, governments play a pivotal role in enabling domestic maritime decarbonisation. Different support will be required at different stages of the transition, and as demonstrated in comparative regimes, the role of Government is likely to evolve alongside the decarbonisation trajectory. Support could be provided through a variety of measures, including economic instruments (either involving revenue generation or support schemes) and direct regulation. Government will also need to ensure that regulatory safety and technical compliance issues are also resolved, and that new skills are developed across multiple sectors such as shipyards, shipowners, seafarers, ports, and Classification Societies.

Although challenging, the decarbonisation of the domestic maritime sector also offers opportunities for the wider UK economy. Clean maritime technology entails a step up in technical complexity that ostensibly aligns with the UK's competitive advantage. This could deliver increased demand throughout the UK's maritime supply chain, from maritime equipment manufacturers to domestic shipyards and boatbuilders. As well as capturing a share of the growing domestic market for clean maritime projects, there may be enhanced opportunities for clean maritime technology-related exports.

Coordination between government departments will be crucial to ensure that the measures enacted are effectively implemented. The decarbonisation of domestic shipping needs to be viewed in the context of a wider transport strategy, both nationally and regionally, to ensure transport demand is not inadvertently shifted away from shipping (as the most emissions-efficient form of transport). Similarly, the approach to maritime decarbonisation must also align with strategies that map the broader energy transition: shipping is just one source of demand for low/zero emission fuels and the provision of shore power at ports needs to be coordinated with the national energy strategy.

Close interaction and clear communication with industry stakeholders is essential to laying the foundation for closer collaboration between the different stakeholder groups, which will be a crucial component for success. This could be achieved, in principle, through a single unit such as UK SHORE which could be responsible for coordinating, communicating and delivering packages of complementary regulatory and policy tools along with clearly defined targets and timelines.

PART I: SCALE OF THE CHALLENGE

Introduction

Since the UK government committed to reaching net zero by 2050, there has been increasing focus on how the domestic maritime sector can reach this goal.

How much investment is needed to fund this transition and how could external capital be mobilised?

1.1 What is the domestic maritime sector?

The UK's maritime sector encompasses multiple industries including shipping, ports, marine engineering, and professional maritime services such as ship surveying and classification, as well as finance, insurance, and legal services. The sector is a key enabler of trade, with ports handling almost half a billion tonnes of commercial cargo every year, representing approximately 95% of the UK's trade in goods. The maritime sector is also a substantial contributor to the UK economy, directly supporting £17 billion in Gross Value Added (GVA) and over 200,000 jobs[3].

The UK shipping industry owns and operates a large, diverse domestic and international fleet. At the end of 2021, UK entities were the beneficial owners of almost 2,400 vessels greater than 100 gross tonnes, totalling 25 million gross tonnage[4]. The UK's domestic shipping industry is a subset of this fleet, and although it accounts for a small proportion of the overall gross tonnage (as large vessels typically trade internationally), it comprises almost half of the vessels.

1.2 Working towards a net zero strategy

In 2019, the UK became the first major economy in the world to legislate to reach net zero by 2050[1]. This bold commitment extends into all facets of the UK's energy, industry, and transport landscape, including the domestic maritime sector. In the same year, the UK government published Maritime 2050[5], a strategic vision for the future of the UK maritime sector, and subsequently, its Clean Maritime Plan[6], which outlined a high-level route map for the UK's transition to zero emission shipping.

There is clear ambition from government for the UK to be a world leader on clean maritime innovation, and this has been supported by action. In 2021, the Clean Maritime Demonstration Competition (CMDC) distributed £23 million in grant funding across 55 projects involving feasibility studies on renewable energy based fuel solutions and clean maritime technologies[7].

The CMDC will be a multi-year programme, overseen by a new unit within the Department of Transport. Launched in March 2022, the UK Shipping Office for Reducing Emissions (UK SHORE) has been allocated £206 million to fund research into clean maritime technologies, develop the infrastructure to produce zero emission fuels and vessels, build maritime manufacturing hotspots and support the creation of skilled jobs[8].

This is intended to develop the domestic manufacturing capacity and capabilities needed to secure competitive advantage in the rapidly evolving global clean maritime industry, an ambition furthered by the simultaneous release of a refreshed National Shipbuilding Strategy. This outlines a vision to create a globally successful, innovative and sustainable shipbuilding enterprise, and offer support for the domestic maritime sector through a proposed credit guarantee scheme to level the playing field for domestically owned vessels constructed in UK shipyards[9].

As well as pursuing opportunities to lead globally on clean maritime technologies, the UK government is also firm in its commitment to decarbonise domestic shipping. A refreshed version of the Clean Maritime Plan is due to be published in Autumn 2023 and proposes to offer a clearer view of indicative targets and policy measures that will help the domestic shipping industry reach net zero[10].

1.3 Aim and approach of the study

For the domestic maritime sector to reach net zero by 2050, the rapid development and commercialisation of zero emission fuels and vessel technology is needed. This will require collaboration between all major stakeholders across the maritime sector, as well as support by government. Although technological innovation will be critical, innovative business and funding models that overcome investment barriers will be key to propelling those solutions to commercial scale in the necessary timeframe. However, the level of investment that will be needed to reach net zero is too large for the maritime sector to fund alone. External providers of capital must be mobilised, and this too will require government support.

This study seeks to identify solutions that have the potential to facilitate the investment needed to fund the transition to a zero emission domestic and short sea fleet. The approach taken is technology and fuel agnostic, and instead focuses on how the commercial barriers that impede investment decisions can be overcome and how new sources of capital can be unlocked.

The first step towards achieving this aim was the identification of the UK's domestic and short sea commercial fleets. This covers trading vessels that carry cargo and/or passengers, and service vessels that undertake activities (e.g. workboats, tugs, dredgers). The dataset used in this study also includes larger fishing vessels, and although detail on these vessels has been presented, the specific challenges facing that industry have not been addressed.

The identification of the domestic and short sea fleets was followed by an assessment of the level of investment needed for these fleets to transition to net zero. To determine the specific challenges that decarbonisation-related investment presents to the UK's domestic shipping industry, extensive interviews were conducted with stakeholders from across the domestic maritime sector.

Potential approaches to domestic maritime decarbonisation seen employed in maritime sectors and comparable transitions elsewhere in the world were investigated, alongside the current and prospective policies implemented by regulatory regimes affecting the sector.

Key areas of priority for decarbonisation were then identified, and potential approaches to overcoming investment hurdles and mobilising investment were considered. A working group was formed with members drawn from the financial and legal sectors, including banking, investment/asset management, and legal and tax advisory services. This working group assessed how funding models could be implemented and what policy support would be necessary to help ensure success.

Domestic Maritime Landscape

The domestic maritime sector is a complex network of diverse stakeholders operating across the shipping, port, marine engineering and professional services industries.

Domestic shipping emissions are currently estimated from vessel voyages. The overlap between domestic and international shipping means that what constitutes a domestic vessel needs to be clearly defined.

Understanding how these vessels operate on a commercial basis informs of the challenges and opportunities for decarbonisation faced by the fleet.

2.1 Sector overview

The domestic maritime sector is a complex ecosystem of organisations and assets which together fulfil a variety of functions supporting the transportation of goods and people, plus a range of other services, at sea, along the coast and on inland waterways. The sector can be split into four broad industries, plus a non-commercial segment (leisure marine) which is outside the scope of this study. The functions of each industry, and the key stakeholders involved, are summarised in Table 2.1.

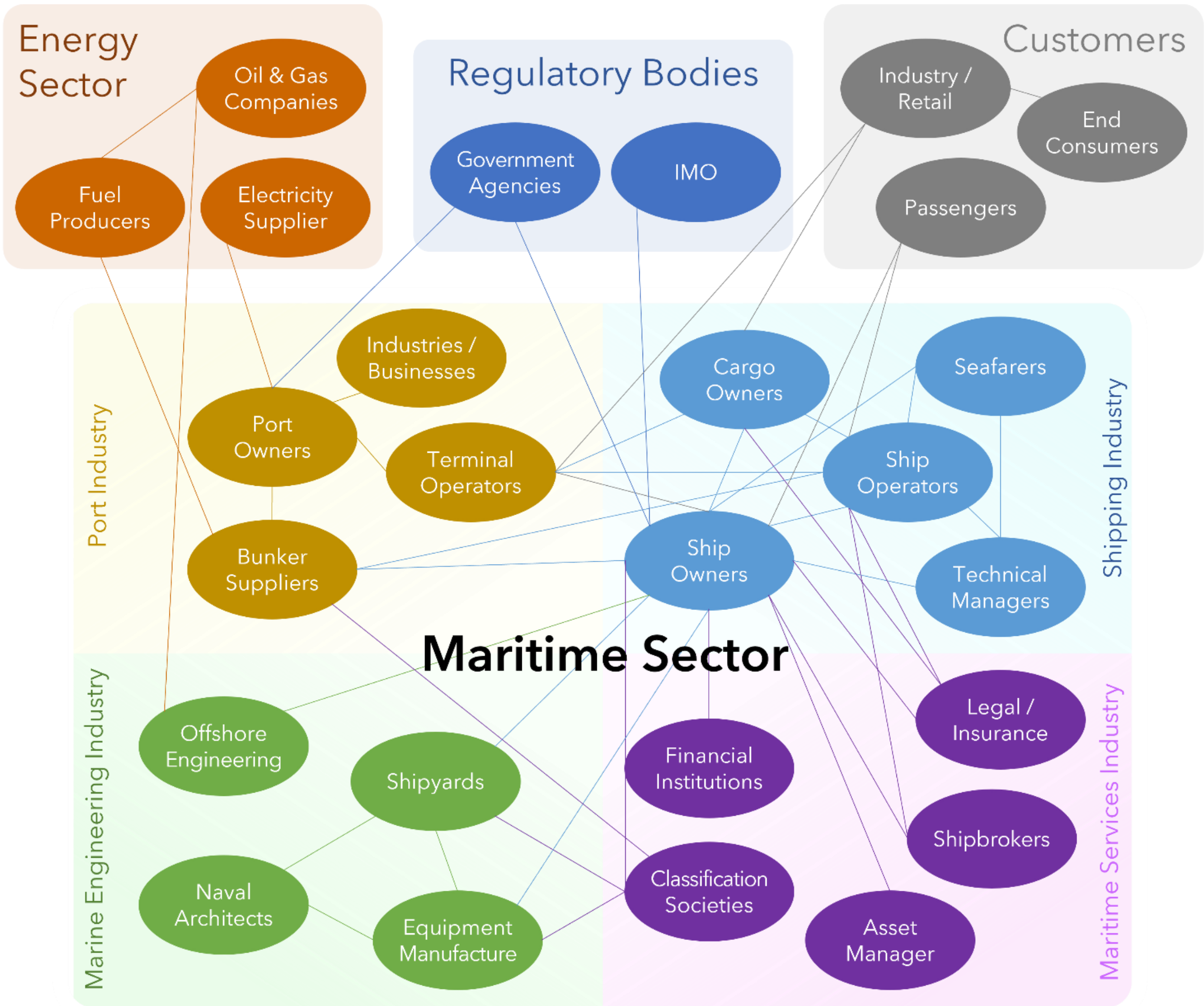
Table 2.1: The functions and key stakeholders of each industry in the maritime sector

Industry	Functions	Key stakeholders
Shipping	Covers all activities that directly involve the commercial use of vessels, including: - transportation of goods and passengers - activities such as fishing, towing, and dredging - support for offshore industries such as the oil and gas sector and wind farms (e.g. survey, installation, supply, maintenance)	- Shipowners - Operators (charterers) - Technical managers - Seafarers - Cargo owners - Passengers - Regulatory bodies - Trade bodies and associations
Ports	Ports and harbours function as the shoreside intersection between: - ships, cargoes and passengers - border and customs control - inland transport networks - energy infrastructure	- Port owners - Terminal operators - Firms operating within the ports - Marine fuel bunker suppliers - Local authorities - Government agencies - Trade bodies and associations
Marine engineering	Maritime engineering and construction services that relate to marine assets and projects carried out at sea/on waterways, including.: - vessel building (and extended maritime equipment supply chain) and maintenance - marine engineering and construction projects - engineering and support for offshore industries	- Shipyards - Naval architects and engineers - Maritime equipment manufacturers - Marine engineering/construction firms - Offshore industry engineering/support firms - Trade bodies and associations
Professional maritime services	A diverse industry of professional services that facilitate the functioning of the entire maritime sector	- Classification societies - Financial institutions - Shipbrokers - Maritime asset/fund managers - Legal and accounting service providers - Insurance providers - Maritime consultants

Source: Based on Cebr definitions[3]

These industries do not operate discretely; there are multiple interactions between internal and external stakeholders and many points of overlap with other systems. Ports act as critical nodes where vessels, cargoes and passengers, inland transport networks, and energy infrastructure intersect. However, there are many other connections between stakeholders, particularly within and across the shipping and professional maritime services industries (Figure 2.1).

Figure 2.1: Map of key stakeholders and interconnections between them



Source: Marine Capital

All components of the maritime sector are represented within the UK, but with differing degrees of scale and areas of specialisation. The ports, shipping and marine engineering industries are highly fragmented, largely made up of thousands of small and medium-sized businesses (Table 2.2). This has reinforced a tendency for stakeholders to operate in a siloed manner, where interactions along the maritime value chain are on a functional rather than strategic basis, and little cooperation is seen across the stakeholder network.

Table 2.2: Number of UK enterprises by turnover band in 2021

Industry	Micro <£2m	Small £2m - £10m	Medium £10m - £50m	Large >£50m	Total
Marine fishing and aquaculture	3,665	90	20	5	**3,780**
Shipyards and repair	850	55	15	10	**930**
Sea and coastal transport	965	90	35	30	**1,120**
Inland water transport	235	10	0	0	**245**
Total	**5,715**	**245**	**70**	**45**	**6,075**

Source: VAT and/or PAYE based enterprises by SIC class and turnover size bands, from ONS[11]

Many parts of the maritime sector span both the international and domestic markets, and the boundaries between them are not always explicit. For instance, there is a large pool of professionals and businesses in the UK that offer their services (especially in maritime law, insurance, shipbroking, and technical management) worldwide[12]. There are also UK-based shipowners engaged solely in international shipping, and conversely, shipowners that are not based in the UK, but which operate vessels in domestic waters (particularly in the oil and gas sector).

The complexity of the maritime sector and the mobility of vessels makes determining the domestic element more challenging than in other industries. Clear definition is therefore required when referring to the domestic maritime sector, domestic shipping and a domestic fleet.

2.2 Ringfencing the domestic and short sea fleets

2.2.1 International versus domestic shipping

International shipping is defined as shipping between the ports of different countries; domestic shipping is shipping between ports in the same country[13]. For the UK, domestic shipping includes voyages made between ports in Great Britain, Northern Ireland, the Isle of Man and Channel Islands, in and out of the same port (such as travel to and from offshore oil and gas installations) and on inland waterways[14]. Voyages to and from (or between) the UK and the Crown Dependencies are included, but voyages to ports in Overseas Territories are excluded from the definition of domestic shipping in this study.

The UK adopts different approaches to estimating international and domestic shipping emissions. For the former, the reported sale of international marine bunker fuels by UK providers is used; for the latter, a voyage-based approach is employed, utilising location-tracking data from the Automatic Identification System (AIS) transponders on board vessels. The emissions from smaller commercial domestic vessels that do not carry AIS transponders are captured within the assessment made for vessels on inland waterways and is based on reported fuel sales and port traffic statistics[15].

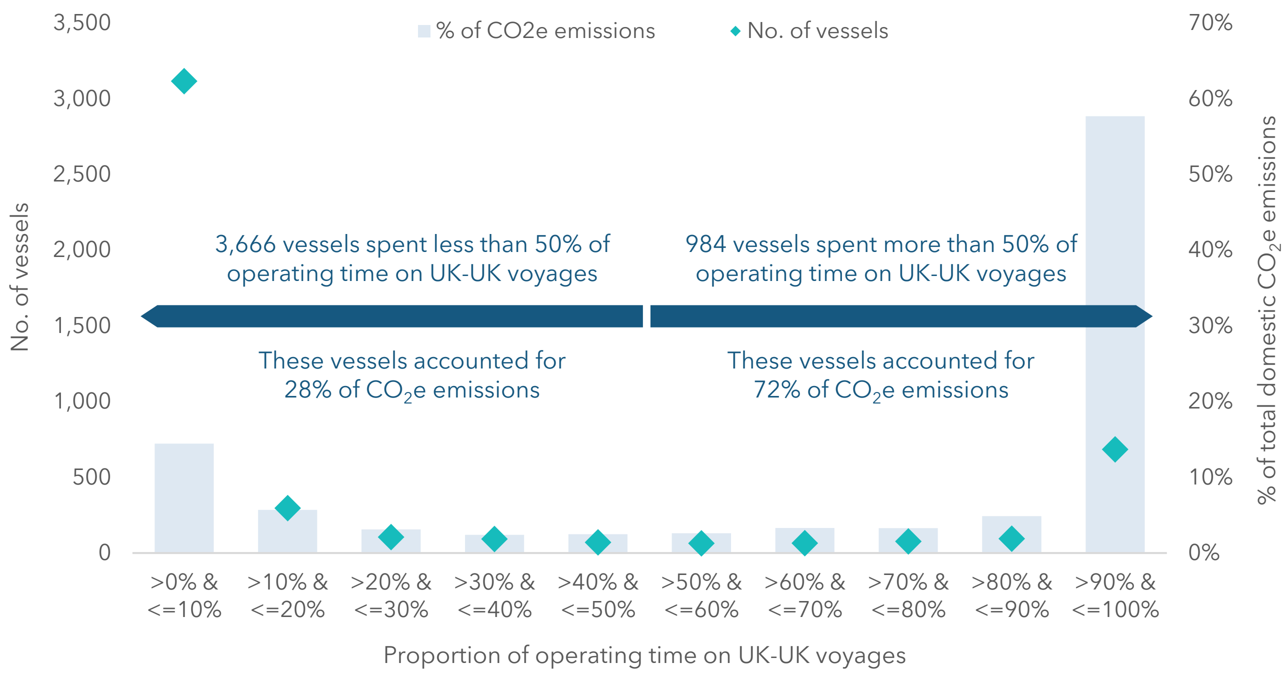
The use of AIS data enables the emissions from vessels making domestic voyages to be estimated with greater certainty. However, this approach also captures the domestic voyages made by vessels that trade more widely. Many vessels undertake both international and domestic voyages; the inherently peripatetic nature of shipping presents a challenge when attempting to ringfence a domestic fleet.

Sometimes the country of ownership or registration is used to represent a domestic fleet. However, there is no fixed link between where a vessel is owned, where it is registered, where it is managed from and where it sails. Vessels owned by companies registered in the UK or those that operate under the UK flag may not necessarily trade in or around the UK.

International and domestic shipping are also sometimes differentiated by function. The primary role of international shipping is to facilitate trade by transporting commodities and finished goods. In contrast, domestic shipping fulfils a more diverse role: as well as cargo and passenger transport, a domestic fleet carries out other commercial non-trading activities such as fishing, dredging and marine construction, and supports offshore energy industries such as the oil and gas sector and wind farms.

A more granular approach is to define a domestic vessel as one that spends most of its time in domestic waters. AIS data can be used to translate from a voyage-based representation of domestic shipping into a vessel-based classification of the domestic fleet by setting a minimum hurdle for operating time spent on domestic voyages. This study uses AIS-based data from UMAS's Fuel Use Statistics and Emissions (FUSE) model (see Appendix I for more detail) to identify the vessels that made voyages between UK ports in 2018[16]. The model estimates fuel consumption and emissions from voyages based on factors such as speed, draught, and engine type. In total, 4,650 individual commercial vessels were detected, collectively emitting 3.9 million tonnes of CO_2e on voyages between and whilst berthed at UK ports (Figure 2.2).

Figure 2.2: Percentage of greenhouse gas emissions from vessels on UK-UK voyages, grouped by proportion of operating time spent on UK-UK voyages



Source: Based on UMAS FUSE[16] data

The profile of these emissions shows that the highest proportion (58%) came from 685 vessels that spent more than 90% of their operational time on UK-UK voyages. This indicates there is a core set of vessels that operate almost exclusively in UK inland and domestic waters, and these are collectively responsible for over half of domestic shipping emissions. At the other end of the spectrum, 14% of greenhouse gas emissions came from over 3,100 vessels which spent less than 10% of operating time on UK-UK voyages.

There is no universally agreed benchmark for ringfencing a domestic fleet based on the proportion of operating time spent in domestic waters. Norway, which has gone through a similar process as a basis for developing a decarbonisation strategy, uses a hurdle of 80%[17]. In this study, to ensure coverage of the UK's North Sea oil and gas industry, the hurdle has been set at a minimum of 50% of operating time spent on UK-UK voyages. By this metric, 984 commercial vessels qualify for the domestic fleet, together accounting for 72% of total domestic shipping emissions (2.8 million tonnes of CO_2e).

However, the dataset used by the FUSE model does not include smaller vessels due to the lack of legal requirement for vessels smaller than 300 gross tonnes to install AIS transponders and the limited availability of technical specification data below this threshold. This omission underrepresents the total number of smaller vessels by several thousand, particularly in the workboat and fishing segments. For instance, 532 fishing vessels were, according to 2018 data, identified by the FUSE model as undertaking UK-UK voyages, of which, 300 were UK flagged. However, at the end of 2018, there were 5,354 fishing vessels registered and licenced in the UK, only 490 of which were over 100 gross tonnes[18].

2.2.2 Broadening the scope to include short sea shipping

In addition to domestic shipping, voyages to and from the UK and the nearby short sea countries shown in Figure 2.3 have been evaluated in a similar manner to determine the short sea fleet.

Figure 2.3: Short sea countries included in scope, 2020 trade volumes in millions tonnes (both directions)

Short sea country	2020 trade (m tonnes)
Netherlands	56.7
France	29.7
Belgium	25.5
Norway	24.8
Irish Republic	18.4
Germany	12.0
Spain	11.0
Sweden	10.1
Denmark	4.3
Portugal	4.0
Total	**196.5**

Source: Trade volumes from Department of Transport Statistics[19]

Short sea shipping is defined as shipping between countries not separated by an ocean. For the UK, this covers all countries in Europe, the Mediterranean, North Africa, and Russia[20]. In selecting this smaller group of short sea countries, a trade-off has been made between the expanse of the geographical area covered (and thus size of the short sea fleet captured) and the focus on pinpointing the vessels that make regular voyages on consistent routes.

Almost 8,450 vessels were identified as having sailed between UK ports and/or between the UK and any of the chosen short sea countries in 2018 (i.e. 3,800 vessels did not call between UK ports, but did travel between the UK and a country on the short sea list). These vessels collectively emitted 14.7 million tonnes of CO_2e, 10.8 million tonnes of which came from voyages between the UK and short sea countries.

To ringfence the short sea fleet, a hurdle of 50% of operating time has again been applied. Any vessel which spent more than half of its operating time sailing between ports in the UK and/or between the UK and any of the short sea countries is classified as part of the domestic and short sea fleets. In this manner, 835 vessels qualify for inclusion in the short sea fleet, collectively accounting for an additional 4.9 million tonnes of CO_2e emissions (Table 2.3).

Table 2.3: Number of vessels and emissions from domestic and short sea voyages

Ringfenced fleet	Metric	UK-UK voyages	UK-SS voyages	UK-UK & UK-SS voyages
All vessels	No. of vessels	4,650	3,812	8,479
	Emissions	3.9	10.8	14.7
Domestic fleet	No. of vessels	984		
	Emissions	2.8	0.2	3.0
Short sea fleet	No. of vessels		835	
	Emissions	0.4	4.5	4.9
Domestic and short sea fleet	No. of vessels			1,824
	Emissions	3.2	4.7	7.9

Source: Based on UMAS FUSE data[16]

2.3 Shipping through a commercial lens

2.3.1 Linking shipping activity to commercial models

The technical challenges faced in developing zero emission solutions for shipping vary across different vessel types. However, it is the nature of a vessel's activity that has a greater bearing on the commercial barriers to decarbonisation faced by its owners. Therefore, the domestic and short sea fleets have been grouped according to how the vessels usually trade. By extension, this typically defines the common operational traits, prevailing market structures, exposure to commercial pressures and approaches to ownership seen in those groups (Table 2.4).

Table 2.4: Characterisation of the domestic and short sea fleets

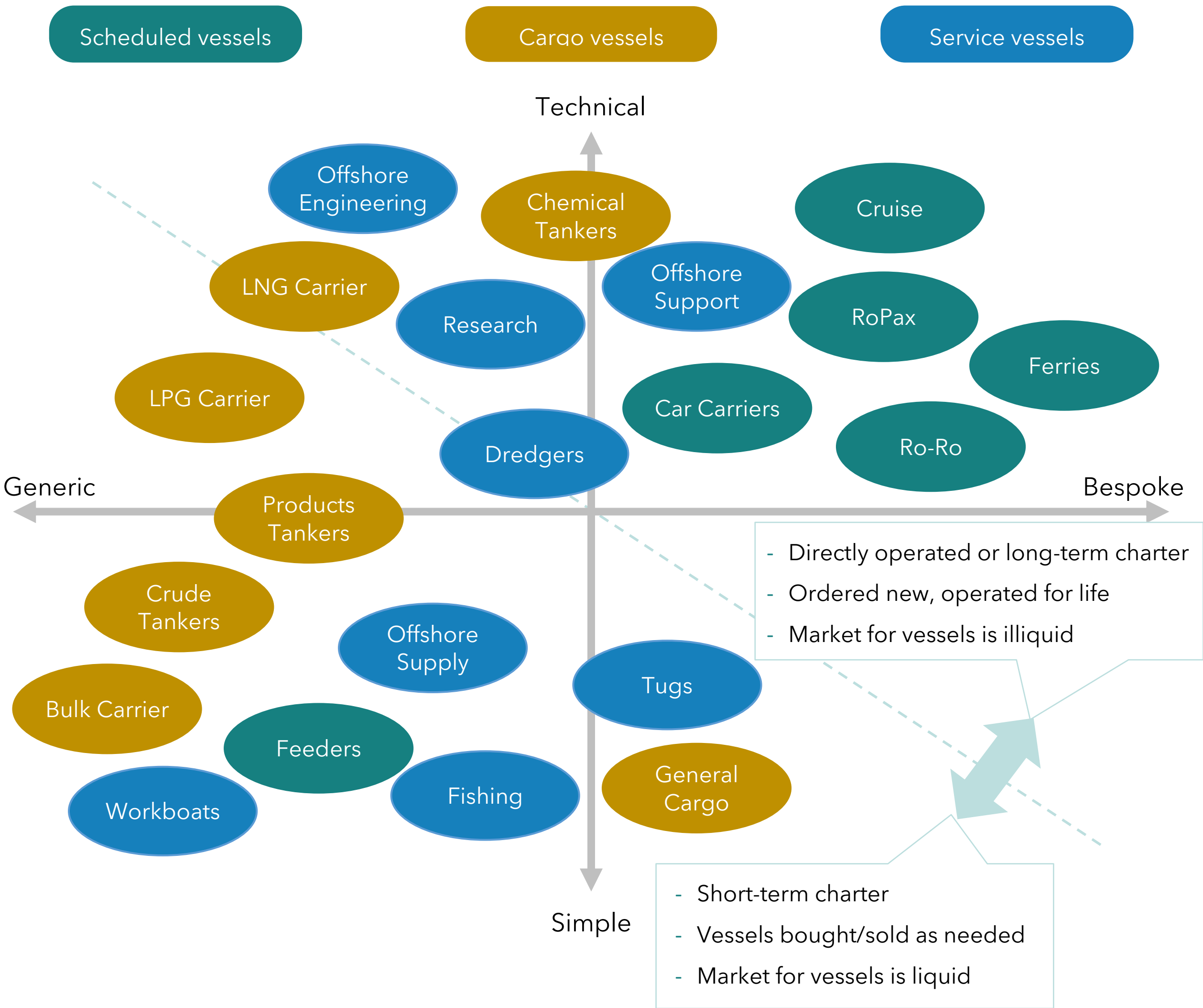
	Scheduled vessels Vessels that operate on fixed scheduled routes	Cargo vessels Vessels that carry bulk cargoes	Service vessels Vessels that perform a service or activity
Types of vessels	- Ferries - Ro-Ro, RoPax - Container ships (feeders) - Car carriers - Cruise ships	- Tankers (crude, products and chemical) - Gas carriers (LPG, LNG) - Bulk carriers (dry bulk, cement, aggregates) - General cargo ships	- Offshore support vessels - Offshore engineering vessels - Dredgers - Tugs - Workboats - Research vessels - Fishing vessels
Function of vessels	- Transports passengers and non-bulk goods on scheduled routes between fixed ports - Some vessels act as lifeline services to islands	- Transports bulk commodities - Trading patterns are random, vessels call at many ports	- Broad range of activities at sea and on inland waterways - Some vessels are specialised, others multi-functional with broad operational capability
Commercial operation	- Most owners operate in market directly, either selling a logistics service or providing shipping services to retail customers - Long-term charters can be found in car carrier sector	- Often chartered under short-term contract by cargo owner to deliver commodities - Some long-term charters or direct ownership for oil transport or distribution (e.g. shuttle and bunker tankers)	- Often chartered under short-term contract - Long-term charters seen in offshore wind service sector - Some vessels directly owned by industrial firms for specific role (e.g. dredgers collecting sand)
Specialisation and value of vessels	- Often built to specific route/port constraints (e.g. draft limitation) - Even when not custom built, tend to be heterogenous - Often large and very expensive	- A few are built for specific trades/operating conditions - Largely generic and technically simple vessels with price dependent on size	- Vessels under long-term charter built to charterers' spec - Vessel price linked to size and technical complexity; most are small and low cost
Types of owners	- Small number of large owners - A few small owners that operate short, local routes	- Varies, but typically fewer UK owners (majority are European shipowners)	- Fragmented market, mostly small/medium-sized owners - A few large global companies (in offshore and tugs)
Vessel acquisition	- Bespoke vessels are built to spec and operated for life - Container ships more likely to be actively traded	- Generic vessels are easily traded on international market - Many small owners buy/sell second-hand vessels	- Many small owners buy/sell second-hand vessels - Large owners can shift vessels around world as needed
Relationship with ports	- Strategic relationships common given the permanent presence of owners and the major source of income for ports	- Random trading offers little opportunity to build relationships - Owners that operate regularly from a port and/or own/rent shoreside facilities have stronger relationships	- Smaller owners can be overlooked as not a major source of revenue - Some owners consistently operating in a port have forged stronger relationships

Source: Marine Capital

The key commercial differentiators can be broadly split along two lines: the degree to which a vessel is able to function in a wider market and its technical complexity. The more specialised the vessel (either technically or operationally), the narrower its scope. Such vessels are usually either owned and operated directly over their entire economic life or are chartered out by shipowners under long-term contracts. The second-hand market for these vessels tends to be illiquid, and the vessels difficult to price. The owners of these vessels bear the risk that the demand for the specific route, trade or activity will change in future.

The more generic and/or technically simple vessels tend to be employed under shorter-term charters. These vessels operate more widely across the world and so can be bought and sold freely. Therefore, owners of generic vessels are not constrained by the economic life of the vessel and are able to manage their fleet profile in a more flexible manner. These owners bear the risk that the balance of supply and demand for the vessels in the international market dictates vessel earnings and prices (Figure 2.4).

Figure 2.4: Indication of the relative technical complexity and operational specialisation of the vessels in the domestic and short sea fleets



Source: Marine Capital

These are broad characterisations and there is variation within each group and overlap across them. For instance, not all vessels sailing on fixed schedules are custom-built for a specific route and trade. Feeders (small container ships), which deliver containerised trade from regional transhipment hubs (where large vessels offload cargo for onwards transportation), exhibit a wider range of design and dimension than larger container ships, but are ubiquitous.

2.3.2 Profiling the domestic fleet

The UK domestic fleet is summarised in Table 2.5, grouped by category. The table shows the number of vessels in each category, those which are UK-owned, the median age, and the total and median emissions from those vessels on domestic voyages (i.e. excluding emissions from voyages that do not both start and end in the UK).

Table 2.5: Summary of vessels in the domestic fleet

Sector	No. of vessels	of which are UK-owned	Median age (years)	Total emissions ('000 tonnes CO_2e)	Median emissions ('000 tonnes CO_2e)
Ferry/Ro-Ro	89	84	21	1,060	4.7
Cruise	9	8	36	26	1.2
Car carrier	0	-	-	-	-
Container ship	2	0	21	5	2.4
Tanker	36	21	15	202	4.7
Gas carrier	0	-	-	-	-
Dry bulk	24	12	37	37	1.2
Offshore engineering	10	3	11	24	2.0
Offshore support	237	125	9	638	2.2
Survey/research	17	12	19	17	0.9
Dredger	34	30	30	113	3.1
Tug	148	113	16	185	0.8
Workboat	48	39	12	86	1.4
Fishing	330	288	28	419	1.1
Total	**984**	**735**	**19**	**2,813**	**1.4**

Source: Based on UMAS FUSE[16] and IHS Markit[21] data

The scheduled vessels mainly comprise those providing ferry and Ro-Ro services in Scotland, between mainland UK and Northern Ireland, and to other UK islands. There are also a small number of coastal and river cruise ships. All these vessels operate exclusively in UK waters and those travelling to island communities are often lifeline services. Most are UK-owned, and almost 40% are over 25 years old.

There are fewer cargo vessels that operate consistently in the UK. These consist of a few large shuttle tankers, alongside smaller bunker, products and chemical tankers, and in the dry bulk segment, small general cargo vessels and aggregate carriers. The age profile of the tanker fleet is far lower than seen for dry bulk vessels, where 75% of vessels are over 25 years old.

The service vessel segment is very diverse, particularly the offshore support sector where vessels differ greatly in terms of specification and function. The offshore support fleet has the youngest age profile; however, the UK-owned vessels (just over half of the fleet) are, on average, older than those owned by non-UK companies (median age of 11 years versus 7 years). Dredgers and the fishing fleet are far older, with more than half over 25 years old. Given the omission of sub-100 gross tonne vessels from the dataset, it is likely that the degree to which the age profile is skewed towards older vessels has been underestimated in these fleets.

Overall, almost 40% of the domestic fleet is older than 25 years, indicating the urgent need to plan for vessel replacement. The issue is particularly acute in the ferry, Ro-Ro, cruise, dry bulk, dredger and fishing vessel segments. Most ferries and Ro-Ros are also large vessels and so are high emitters of greenhouse gases: in terms of vessel numbers, this segment accounts for less than 10% of the domestic fleet, but it accounts for almost 40% of total emissions from the domestic fleet.

2.3.3 Profiling the short sea fleet

The short sea fleet is summarised in Table 2.6. Greenhouse gas emissions are from domestic and short sea voyages only (i.e. exclude emissions from voyages that do not either start and/or end in the UK).

Short sea ferries and Ro-Ros are typically larger than those that operate exclusively in domestic waters and so, on average, emit more greenhouse gases. These vessels operate between the UK and all short sea countries other than Portugal which does not have a direct ferry service with the UK. Although the age profile of these vessels is slightly younger than the domestic ferries/Ro-Ros, a quarter of these vessels are over 25 years old.

There are also regular services for containerised freight from Europe. The majority of this trade is with the Netherlands, which is a large transhipment hub for containers, but there are also routes from the UK to France, Belgium, the Irish Republic, Spain and Portugal. Most of these vessels are owned and operated by European companies.

The short sea fleet has four times the number of non-containerised cargo vessels than the domestic fleet as the transport of bulk cargo is more commonly related to imports/exports than to cabotage. In the tanker segment, three quarters of the fleet is made up of small chemical tankers and a sixth are large shuttle tankers. These vessels primarily sail between the UK, Norway, and the Netherlands. The gas carriers are mainly small LPG carriers, with diverse trading patterns throughout Europe. The dry bulk fleet is similarly small and diverse, but skews towards an older age profile.

Given that offshore and fishing activities reach into international waters, the spread of these vessels into the short sea fleet is expected, as is the similarity to the age profiles found in the domestic fleet. A portion of the dredger fleet also operates on an international basis, transiting between the UK and Europe as required (although this may have changed post-Brexit). Tugs are less mobile, with the domestic fleet almost exclusively operating in UK waters, with only a few tugs operating more widely.

Overall, just over a quarter of the short sea fleet is over 25 years old (although this falls to a fifth when the fishing fleet is excluded). As seen in the domestic fleet, the need to replace vessels in the ferry, Ro-Ro, dry bulk, dredger and fishing segments of the short sea fleet will become acute over this decade.

Table 2.6: Summary of vessels in the short sea fleet

Sector	No. of vessels	of which are UK-owned	Median age (years)	Total emissions ('000 tonnes CO_2e)	Median emissions ('000 tonnes CO_2e)
Ferry/Ro-Ro	89	20	18	2,914	30.1
Cruise	1	1	31	17	16.7
Car carrier	7	0	20	61	7.8
Container ship	27	6	16	236	9.0
Tanker	75	7	12	525	6.5
Gas carrier	33	2	11	162	4.4
Dry bulk	142	20	19	371	1.9
Offshore engineering	17	8	9	30	1.5
Offshore support	139	35	10	292	1.5
Survey/research	12	4	8	18	1.1
Dredger	13	2	17	39	2.1
Tug	24	14	13	16	0.6
Workboat	9	2	9	4	0.4
Fishing	247	51	25	228	0.8
Total	**835**	**172**	**17**	**4,915**	**1.7**

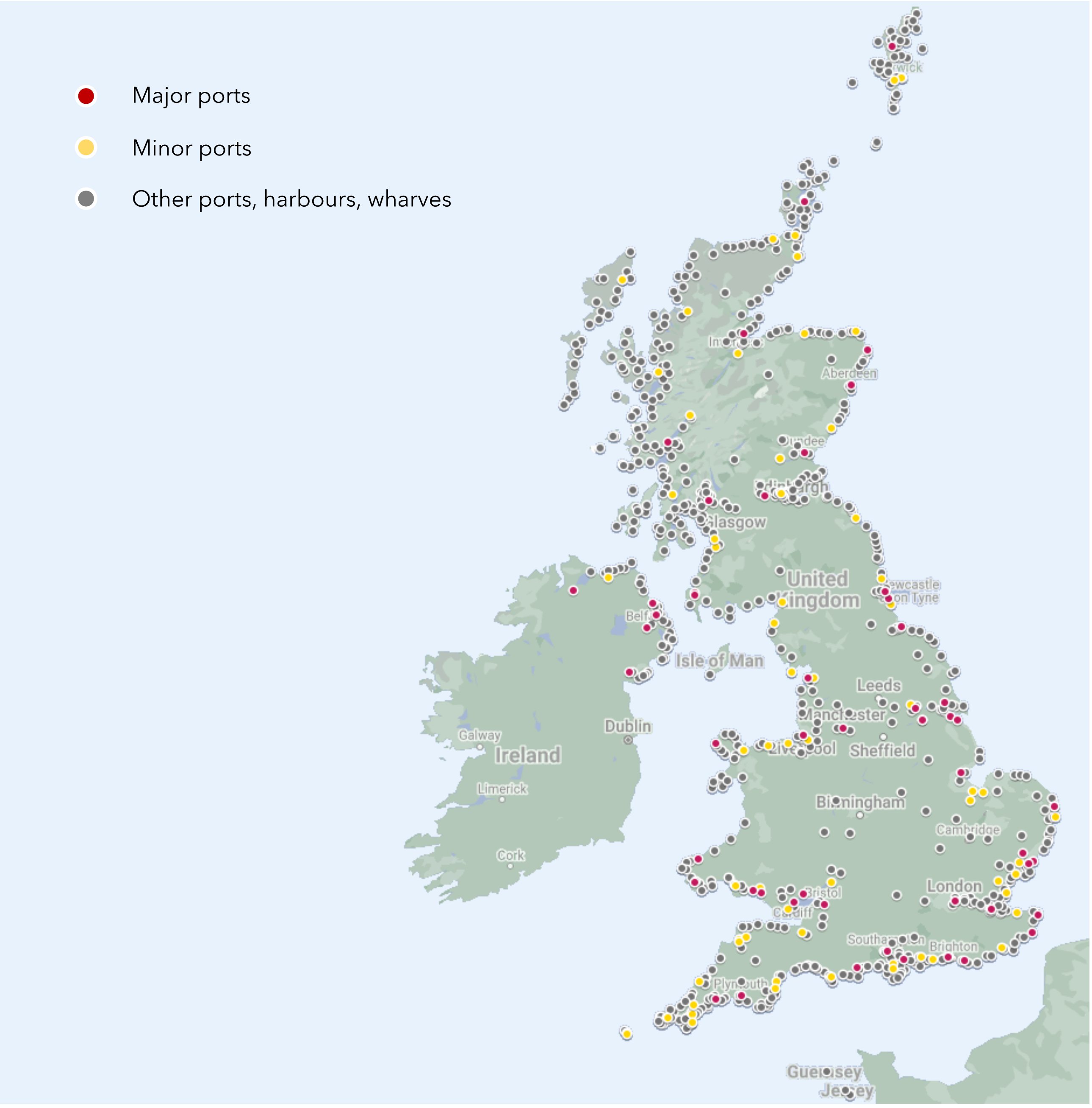
Source: Based on UMAS FUSE[16] and IHS Markit[21] data

2.4 UK port landscape

2.4.1 Dispersion of ports and harbours

There is considerable variety in the type, size and function of ports and harbours across the UK. Larger ports are categorised by cargo throughput: there are 51 'major' ports that each handle more than 1 million tonnes of cargo per annum, and a further 63 ports classified as 'minor' commercial ports[20]. Major ports are key trade nodes, handling approximately 98% of the UK's total seaborne trade[19]. There are also many smaller ports, harbours and wharves that cater to small commercial non-cargo vessels (such as workboats and fishing vessels) and leisure craft. The voyage-based AIS dataset used by the UMAS FUSE model identified over 800 discrete locations along the coast and inland visited by the domestic and short sea fleets. These are mapped in Figure 2.5 alongside the UK's major and minor ports.

Figure 2.5: Map of UK ports, harbours and wharves; major and minor ports highlighted



Source: Based on UMAS FUSE[16] and DfT[20] data

2.4.2 Range of port ownership and business models

As well as ranging in size and function, ports in the UK also vary in terms of ownership structure and operating model. Three different types of port ownership have evolved in the UK over time: privately owned, controlled by a local authority, or run as a trust port (Table 2.7). All three models operate on a strictly commercial basis with no reliance on government funding, but each has a distinctive approach to governance and focuses on different stakeholders.

Table 2.7: Characteristics of the three port ownership models found in the UK

Ownership model	Characteristics
Private ports	- Almost two thirds of the major ports are privately owned - Some are held as private companies (e.g. Port of Bristol), some ferry ports are owned by ferry companies (e.g. Port of Holyhead by Stena and Port of Larne by P&O), and others are held by larger, often global, conglomerates (e.g. ABP, Peel Group, CK Hutchison Holdings) - Operating on a commercial basis, these ports are accountable to their owners/shareholders and may have access to funding from their parent to invest in port facilities and infrastructure
Municipal ports	- These are ports owned by local authorities - Municipal ports tend to be smaller, but there are five major ports owned by local authorities (including Portsmouth Port, and ports in Shetland and Orkney) - These ports operate on a commercial basis but are accountable to a wider set of stakeholders, including the local community
Trust ports	- These are not-for-profit, independent statutory bodies led by independent boards which are accountable to their stakeholders (including government) - There are over 100 trust ports (including approximately a quarter of the major ports) and some trust ports are large hubs for domestic and short sea traffic (e.g. Port of Aberdeen, Belfast Harbour, Port of Dover) - Trust ports operate in a commercial manner without subsidy and with all profit reinvested for the benefit of stakeholders - Although not owned or funded by government, the eight largest trust ports are classified as public corporations which means any private borrowing by these ports is reflected in the DfT's capital expenditure budget

Sources: DfT[22, 23], British Ports Association[24], Monios[25]

When compared with port ownership models found elsewhere in the world, the UK's adoption of the private port model is highly uncommon. In Europe, most ports are public: municipal ports are widespread across north-western Europe and state ownership predominates in southern and eastern Europe[26]. The landscape is similar in the US, where most ports are owned by city, county, regional or state authorities[27]. The global port industry has received almost $100 billion in structured private investment over the last 30 years[28], but public ownership has been largely retained using a landlord model[29].

In public-private partnership port projects, the public sector typically acts as the planner and regulator, and ensures hinterland connectivity, while the private sector acts as service provider, operator, and sometimes, developer. The land and elements of port infrastructure remain in public ownership and are leased to private companies to operate. This private-public partnership model has increased access to capital and spread investment risk. It has enabled ports to revitalise outdated infrastructure, pursue growth opportunities and has also driven the trend towards specialisation[29].

The fully privatised port model, where the land and infrastructure are privately owned and the port is self-regulating, is mainly found in the UK and New Zealand. During the 1980s and 1990s, the UK privatised several trust ports to enable funding to modernise very dated infrastructure and increase local labour participation[29]. Currently, almost two thirds of the UK's major ports are in the hands of private companies.

Commercial ports and harbours are typically capital-intensive businesses needing long-term planning and budgeting cycles, particularly for infrastructure investment. Larger ports and harbours work to a rolling master plan which maps the port's strategic direction over a period of 20 to 30 years. These outline how the port plans to grow and adapt to meet future demand and what investments are required to fulfil its vision. The masterplan also links into local and regional planning for transport infrastructure, i.e. roads and rail networks[30].

Regardless of ownership or business model, all ports are commercially motivated. Although municipal and trust ports may assess a business case for investment under a wider set of criteria than private ports (e.g. to include public benefits), and may accept a longer payback period or lower return, all investment decisions will only proceed on a commercial basis. This has fostered a competitive environment across the UK port landscape and even when ports are not directly competing, there can be little communication or cooperation. Commercial information is highly sensitive and there is no requirement for private and trust ports to publish their annual reports or disclose greenhouse gas emission figures.

2.4.3 Ports as key enablers of maritime decarbonisation

Ports will play a crucial role in decarbonising domestic (and international) shipping by providing the infrastructure to supply vessels with low and zero emission fuels and, where needed, access to renewable shore power. However, the business case for investment in this type of infrastructure must compete with other funding needs a port may have, such as investments to increase or improve cargo handling capacity or decarbonise direct emissions from shoreside operations. In most cases, however, the greenhouse gas emissions from vessels at berth will be greater than those from port operations (e.g. the Port of Aberdeen estimates that 78% of emissions at the port are from berthed vessels[31]) and vessel emissions can also have significant impacts on local air quality.

Low and zero emission fuel supply

At present there is a limited selection of marine fuels on offer to the maritime industry, almost all of which are produced from fossil fuels (fuel oil, diesel oil and gasoil refined from crude oil or LNG from natural gas). Most domestic vessels use either diesel oil or gasoil. The only renewable fuel currently available for marine use is a biofuel, hydrotreated vegetable oil (HVO). This fuel is compatible with existing marine diesel engines and supply infrastructure and so is relatively easy, from a technical standpoint, to adopt[32].

Some owners of vessels on inland waterways have trialled HVO, and a few have switched, but the current cost premium and concerns over future costs and availability (given expected competition from aviation and road transport) have limited wider uptake. The reversal in 2021 of the decision to withdraw the entitlement to rebated gasoil (red diesel) for vessels on inland waterways cemented the cost differential between gasoil and HVO for those vessels[33].

Currently, depending on the type and location of the port, vessels can be refuelled from road tankers, shoreside storage, fixed pontoons, or mobile bunkering vessels. International vessels often refuel from bunker vessels that operate on a regional or national basis, but many ports have bunker barges as a flexible fuelling option. Smaller harbours and wharves may have fixed bunkering facilities either shoreside or on fixed platforms for smaller vessels, with road tankers offering remote fuelling.

Many ports will need to invest in new bunkering infrastructure, including those that do not currently have bunkering facilities, as the lower volumetric energy density of fuels such as ammonia, hydrogen and methanol means that vessels will need to refuel more often[34]. This will present a challenge to ports that have limited free land available. Ports are also beginning to invest in onsite renewable energy generation such as rooftop solar panels and/or onsite wind turbines. Those with access to large sources of renewable energy may eventually develop onsite electrolysers to fuel shoreside equipment and potentially vessels.

Shore power

Some ports will also invest in infrastructure to provide berthed vessels with electricity. This can serve two functions. Firstly, it allows the vessel to turn off its auxiliary engines and draw on shore power for lighting and other electrical uses (called 'cold ironing'). This reduces emissions of greenhouse gases and other pollutants at port, improving local air quality, and thus is an option well suited to ports near densely populated areas[35]. Secondly, it can be used to recharge onboard batteries in fully electrified vessels. This demand will primarily stem from smaller domestic vessels, and therefore the requirement for shore power may extend more widely across smaller ports and harbours.

The power requirement of small vessels is low and relatively easy to supply. Many ports and harbours in the UK provide low-voltage shore power connections for leisure craft and small commercial vessels, but larger vessels have far greater power demand (particularly cruise ships and container ships with refrigerated cargoes) and will need high-voltage connections and transformers[36]. At present, there are only two large commercial ports offering shore power in the UK (Southampton and Orkney)[35]. In addition to supplying power from the grid, in the future, shore power could also be supplied from an off-grid renewable source such as a wind turbine located either onsite or nearby.

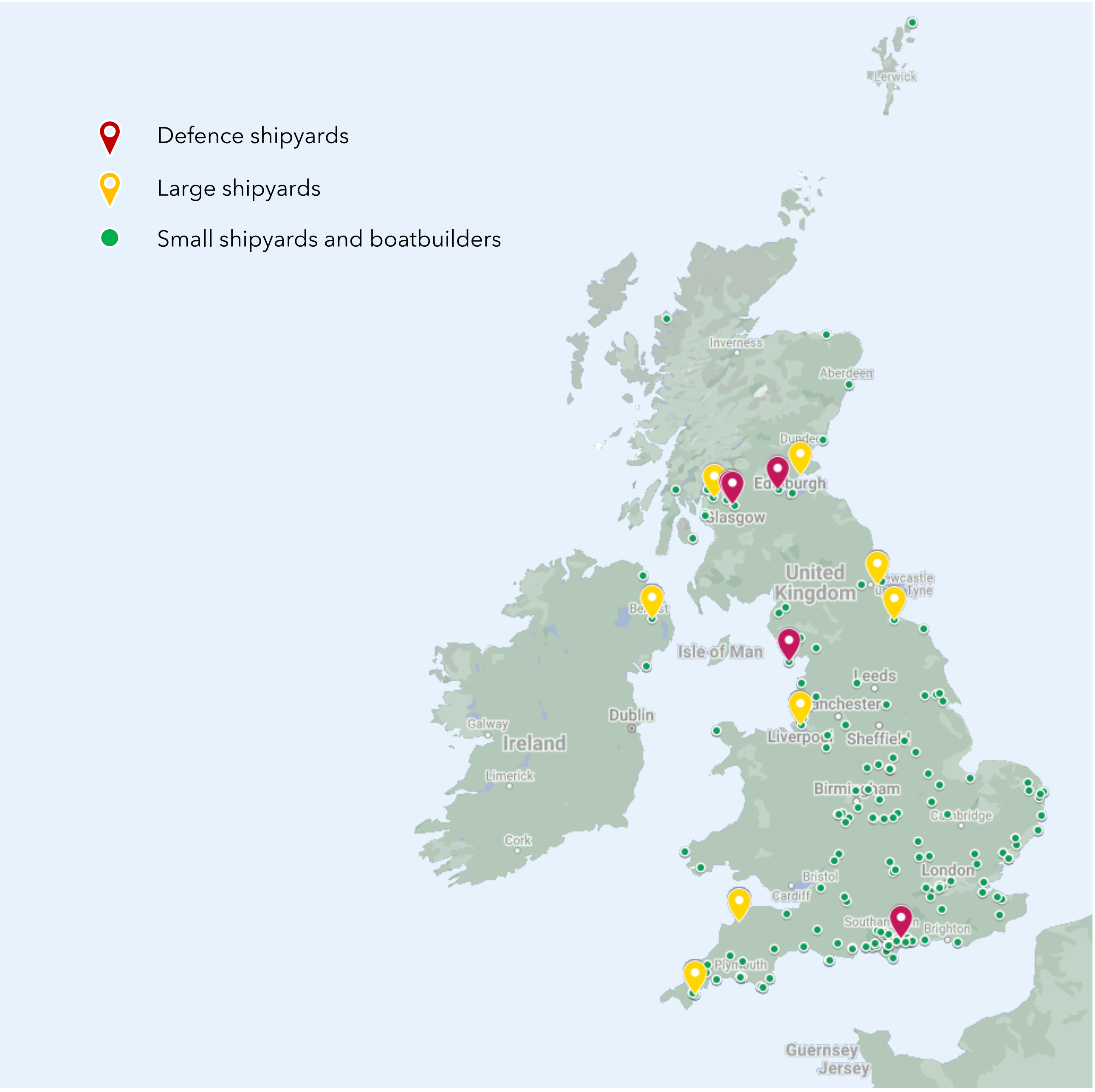
2.5 Wider UK maritime supply chain

The domestic maritime supply chain includes shipyards and boatbuilders which build and repair vessels, and the manufacturers of equipment used on vessels and in ports. There are only a few shipbuilders in the UK that can construct ocean-going vessels, and these either exclusively build naval vessels (e.g. BAE Systems and Babcock International) or more commonly take on projects to convert, retrofit or repair both naval and commercial vessels (e.g. Harland and Wolff, A&P and Cammell Laird). At the other end of the spectrum, there are around 200 small shipyards and boatbuilders (Figure 2.6) that construct and maintain small vessels (primarily leisure craft, but also some small commercial vessels such as fishing vessels and workboats).

Currently, the UK builds few of the vessel types found in the domestic or short sea fleets. Larger shipyards are mainly focused on converting and retrofitting high-value, complex vessels, and when compared with shipyards in Europe and beyond, are not competitive in building commercial domestic vessels. However, maritime decarbonisation will entail a step up in technical complexity that ostensibly aligns with the UK's competitive advantage. Given the pressing need for fleet replacement and the potential for demand to emerge for emissions-related retrofits, there is an opportunity for UK shipyards and boatbuilders to capture part of a growing domestic market for clean maritime projects in the coming decades. This ambition is backed by the proposed Home Shipbuilding Credit Guarantee Scheme which could guarantee up to 80% of the purchase price of a UK built vessel for a domestic shipowner[9].

As well as facilitating the decarbonisation of domestic shipping, increased output of low and zero emission vessels from UK shipyards would also channel demand up through the domestic maritime supply chain. This would support innovation in clean maritime technologies and deliver clearer pathways to commercialisation for manufacturers. Companies in the UK are also innovating in digitalisation and autonomous shipping. Here too, domestic fleet renewal can act as a testbed, providing the opportunity for the UK to grow its skills base and capabilities, enhance its competitive advantage and position itself to export into growing international markets.

Figure 2.6: Map of UK shipyards and boat builders



Source: Public sources

Getting to Net Zero

Investment decisions are key catalysts for decarbonisation. To anticipate how the transition to net zero may evolve, a nuanced understanding of the drivers and impediments to investment must be understood.

The age of domestic vessels and the prevailing commercial environment will play a large role in dictating how and when decarbonisation will occur. However, there are clear priority areas, whether due to the size or geographical concentration of emissions.

The investment needed in vessels and shoreside infrastructure over the next thirty years is likely to be in the region of £75 billion.

3.1 Why are investment decisions so important?

Domestic shipping currently accounts for approximately 1% of the UK's total greenhouse gas emissions and is included within the UK's ambition to reach net zero by or before 2050[6]. The domestic fleet is responsible for the bulk of these emissions and given the vessels operate consistently in and around the UK and are mostly UK-owned, they are the logical target of policies and measures intended to support domestic maritime decarbonisation.

Numerous factors will influence how and over what timescale the domestic fleet reaches net zero. New low and zero emission fuels must be developed and delivered; clean power must be supplied by ports where needed; steps must be taken to reduce emissions from existing vessels, and more efficient (eventually zero emission) vessels must replace them. However, the heterogeneity of the fleet, the wide range of activities undertaken, and the differing technical, operational, and commercial conditions faced by individual businesses mean that it will be far from a uniform or seamless process.

Progress may be slowed or accelerated by specific technological or operational factors, through the interactions of stakeholders, or due to business models and access to funding. However, the key advances towards net zero will be crystalised through investment decisions: the direction, level, and timing of which will be influenced by the wider commercial and regulatory environment. In some cases, the urgent need for fleet renewal will dictate the pace of investment and thus emissions reduction; in others, regulatory pressure may compel action.

In an industry where the assets are so long-lived, investment decisions made in the coming decade are likely to still influence the level of emissions by 2050. Different stakeholders in the maritime sector face different opportunities and challenges, and a nuanced understanding of how this could shape their investment decisions will better inform how the pathway to net zero might evolve in practice.

The end goal is set, but to determine what needs to happen when in order to reach it, the composition of the fleet and the distribution of greenhouse gas emissions must be understood at a granular level. In doing so, the areas of priority for decarbonisation (whether because investment is compelled by renewal, or because conditions are particularly conducive, or simply because the emissions are so large) can be identified. Segments where decarbonisation will be more challenging and in need of more support, can also be highlighted.

To decarbonise domestic shipping, significant levels of investment will be needed in shore-side fuel and infrastructure, in retrofits to existing vessels, and in new vessels. Such investment is most often viewed in terms of the incremental cost attributable to a business as usual approach (i.e. the cost of building zero emission fuel infrastructure, or the marginal cost of building a vessel that runs on zero emission fuels versus one that uses conventional fuel).

However, this does not take into account how decarbonisation could oblige market participants (primarily shipowners) to change their business models entirely. For instance, a shipowner whose usual business model is to acquire second-hand vessels, may need to invest in a new low or zero emission vessel. For this reason, it is valuable to assess the entire level of investment that is needed to decarbonise the domestic fleet, not just the incremental portion.

3.2 Commercial drivers of investment decisions

3.2.1 Considerations for shipowners

There are currently a number of options available to shipowners seeking to reduce emissions and build transition resilience into their fleets. However, the factors that drive such investment can differ between the international and domestic arenas.

Current options for reducing emissions

Shipping is widely acknowledged to be a hard-to-abate industry given its reliance on the high energy density of fossil fuels. This is certainly the case in international shipping where deep-sea cargo vessels require large quantities of fuel to transport goods across the globe. For these vessels, electrification is not an option and full decarbonisation awaits a zero emission fuel produced from renewable energy. These fuels are not yet commercially available and are not likely to be until the 2030s[37].

However, the challenges and opportunities faced in domestic maritime are distinct. Domestic and short sea shipping involves a more diverse group of vessels, performing a wider range of activities, often under operational parameters that differ from those faced by the international fleet. The smaller vessels and shorter distances involved could offer opportunities to deploy a wider range of solutions (including electrification), potentially over faster timescales than will be seen in international shipping.

Currently, all shipowners, whether in the international or domestic sectors, are focusing on:

1) Making existing vessels as energy efficient as possible through:
    a. Operational adjustments (e.g. sailing more slowly or routing to avoid bad weather)
    b. Technical improvements (e.g. cleaning hull, modifying engine or propeller)
    c. Installing new equipment (e.g. wind-assist technology and/or solar panels)
2) Building new or converting existing vessels to run on lower carbon energy sources (e.g. LNG)
3) Building new vessels capable of being converted to run on zero carbon energy sources in future (e.g. with additional space for zero emission fuel storage)

Although zero emission versions of some of the types of vessels found in the UK's domestic and short sea fleets are already being constructed, these are typically standalone projects that deliver both the vessel and the fuel/energy source (e.g. battery-powered ferry and onshore charging system[38], or hydrogen-powered ferry and contracted fuel supply[39]), and the vessels involved tend to be small and operate on very short routes. More commonly though, lower rather than zero emission vessels are being constructed (e.g. hybrid diesel-electric ferries[40]) and those that are capable of future conversion to zero emission fuels (e.g. LNG-powered ferries able to switch to biomethane or green methane[41]).

Not all of these efficiency technologies and fuel solutions will be technically and/or operationally viable for every vessel; suitability will vary by vessel type and efficacy will depend on trading pattern. Even where a zero emission fuel is viable, it may not eventually become commercially feasible and/or scalable. The uncertainty surrounding the development of future fuel pathways presents a challenge to current investment decision-making.

Energy efficiency technologies

All vessels will need to become more fuel-efficient but the scope for improvement in the domestic fleet could be more limited when compared with international vessels. Smaller vessels may not have room for equipment such as onboard batteries or wind-assist technologies to be fitted and reducing speed to save fuel may not be a tenable solution for scheduled vessels. Also, efficiency measures (both operational and technological) are primarily effective when a vessel is sailing. Such measures are well suited to international shipping where a large proportion of time is spent at sea but are less beneficial for domestic and short sea vessels which spend a lot of time at berth[42].

Investments in energy efficiency measures are recouped through the saving in fuel costs (or through higher charter rates if the shipowner does not directly pay for the fuel). These technologies vary greatly in cost, and although this is typically lower for smaller vessels (see Appendix III), the relationship between the capital outlay and the amount of fuel saved may not be directly proportional. Investments in such technologies are more likely to be cost-effective on larger vessels which consume more fuel.

When considering whether to invest in energy efficiency technology, the shipowner's decision will hinge on an assessment of his expected return on capital expenditure, achieved either through a saving in fuel costs or by earning higher charter rates. This will depend on the volume of fuel saved, wider commercial factors (fuel prices, strength of the chartering market, customers' willingness to pay for green shipping), and the vessel's age (the older the vessel, the shorter the remaining life over which an investment can be repaid).

Split incentives issue

Under some types of chartering agreements, the vessel charterer (who may be the cargo owner or an intermediary such as a trader) is responsible for fuel costs. As the shipowner derives no direct benefit from the fuel savings that result from investments in fuel efficiency technology, this issue is called a 'split incentive'. The charterer may agree to pay the shipowner a premium in return for such investment, but in commoditised markets where generic vessels operate (particularly dry bulk), charters tend to be of short duration (less than two years) which makes the potential return on investment uncertain for the owner[43]. In the domestic and short sea sectors, this issue is more prevalent in the cargo and service vessel sectors, whereas ferries/Ro-Ros tend to be directly operated by owners.

Capital costs versus fuel costs

Investment decisions involving vessels that use low or zero emission fuels will not solely be based on the capital outlay. The cost of producing these fuels is likely to be several multiples of that of conventional marine bunker fuels, particularly early on in the transition before economies of scale are achieved[44]. In this period, the price gap between conventional and alternative fuels will be a critical hurdle.

Over time, however, as fossil fuels are edged out of the energy system, the relative costs of different low and zero emission fuels will become more relevant. Over the course of the energy transition, a multi-fuel landscape could develop across the maritime industry. This trend is already seen with the growing number of vessels that can run on both fuel oil and LNG. As zero emission fuels are added to the mix, the commercial operation of shipping markets will become more complex, and the availability of certain fuel types will become another factor to be assessed in the investment decision.

Fuel costs usually represent a material component of a vessel's operating expense (which also includes crew costs, insurance, spares and repairs, and management costs), although the proportion varies with vessel type and size, activity undertaken, and the price of fuel. Vessels that are large, carry cargo, or sail further consume more fuel, typically making it a higher proportion of operating expense.

For example, in 2019, for a global container shipping company, the cost of fuel as a proportion of total vessel operating expense was 45%-50%[45]. In comparison, the proportion for three shipowners operating in the UK in 2019 was:

- 25%-30% for a ferry and Ro-Ro owner[46]
- 10%-15% for an owner of tugs[47]
- 5%-10% for an owner of offshore service vessels[48]

While the relative proportion of the fuel cost to total operating cost is not necessarily reflective of the absolute volume of fuel used (e.g. highly skilled crew on offshore service vessels may account for a large portion of operating costs), this does indicate that the impact of any fuel savings on operating profit will vary according to the sector/activity.

Vessels which carry cargo or people will be more exposed to the differences in fuel price and so may find it more difficult to switch away from conventional fuels. Owners of these vessels will focus on improving efficiency to reduce fuel consumption. On the other hand, service vessels may be less sensitive to the higher cost of zero emission fuels and may find switching to zero emission vessels easier to justify.

Although the future price of all (including conventional) marine bunker fuels is highly uncertain, it is clear that fuel costs will be higher. Thus, the pressure to find incremental improvements in energy efficiency will continue to propagate through vessel design, even when these vessels run on zero emission fuels. New vessels can utilise the same energy efficiency technologies as existing vessels (and in many instances, installation will be easier during the construction process), but once again, compared with international shipping, it may be more difficult to deliver design efficiencies if the vessels operate out of domestic ports and on inland waterways with draught restrictions.

When a shipowner converts or builds a vessel that uses a zero emission fuel, the investment is ultimately recouped from customers paying more for green shipping, either directly for shipowner-operators or indirectly via higher charter rates. In the latter case, the split incentives issue still applies and shipowners will seek certainty (e.g. via longer-term charters) that 1) the investment will be repaid and 2) the future employment of the vessel will not be adversely affected, either as a result of being uncompetitive due to higher fuel costs or by limiting where the vessel can trade due to fuel availability.

3.2.2 Fuel provision: the chicken and egg dilemma

The investment hurdles faced by shipowners are mirrored by fuel producers, leading to a 'chicken and egg' scenario that could slow the development and adoption of zero emission fuels. Investment decisions by fuel suppliers to build production facilities and supply infrastructure will be guided by an outlook on future demand; but investment decisions by shipowners to construct or upgrade vessels to run on those fuels will await clarity on the fuel types and confidence in the availability and security of supply.

This challenge is heightened in international shipping where much of the fleet does not operate on fixed routes. This means that a widespread supply of zero emission fuels will be needed before large-scale uptake can take place. Green corridors, which are being structured as bilateral or multilateral agreements between major ports and/or major stakeholders to establish zero emission shipping routes, have been proposed as a key first step to overcoming this supply-demand stalemate.

These routes have the potential to deliver measurable reductions in greenhouse gas emissions and help accelerate decarbonisation across wider regions through the establishment of clean fuel hubs and development of associated supply chains. Given the higher cost of zero emission fuels, particularly in the early stages of the energy transition, these initiatives will need a number of supportive elements in place. This includes access to a zero emission fuel source, collaborative partnerships between stakeholders across the value chain, customers willing to pay for green shipping, and a helpful regulation/policy environment[49].

The corridors will also need to run along routes with regular trade flows, preferably carried by consistently calling vessels. Container shipping, which operates on fixed and scheduled routes, is one target sector, as are ferries, cruise ships and large bulk carriers that exclusively transport iron ore on fixed routes (Figure 3.1). All of these proposed green corridors are in the early planning stages, and it will likely be five years or more before any are fully operational. Momentum in these initiatives may need to be catalysed through the investment commitments of individual stakeholders (e.g. by shipowners committing to constructing zero emission vessels or operators contracting zero emission fuel supply).

Figure 3.1: Green corridors initiatives announced as of August 2022

Source: Maritime UK[50]

There is clear potential for the ferry/Ro-Ro segment to support the formation of green corridors on a domestic or regional basis given the vessels typically operate on fixed routes and the shipowners tend to have strong relationships with the ports these vessels call at. These ports could then develop into clean maritime hubs that eventually service a wider fleet (domestic, short sea and international vessels).

3.3 Mapping emissions

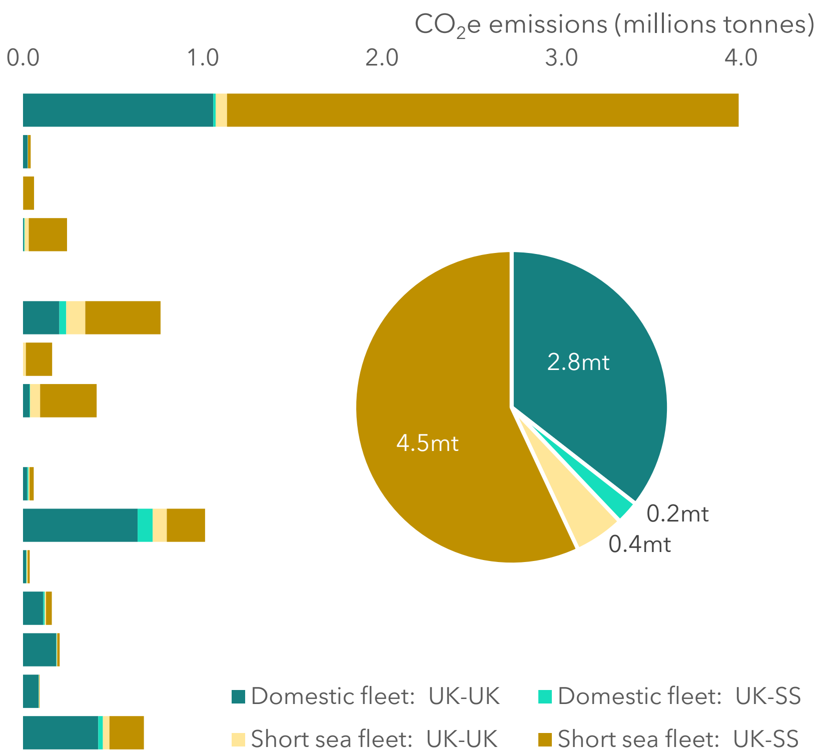
3.3.1 Emissions from the domestic and short sea fleets

In total, the 984 vessels in the domestic fleet emitted 2.8 million tonnes of CO_2e on voyages between UK ports based on 2018 data. This represents 72% of total domestic emissions from all the UK-UK voyages tracked by the UMAS FUSE model. These vessels (primarily offshore support vessels and tankers) emitted a further 0.2 million tonnes of CO_2e on voyages between the UK and short sea countries. In total, the 835 vessels in the short sea fleet emitted 4.9 million tonnes of CO_2e, of which, 0.4 million tonnes resulted from UK-UK voyages. Collectively, the domestic and short sea fleets account for 82% of all emissions from UK-UK voyages.

Figure 3.2 shows emissions from UK-UK and UK-short sea voyages by segment, split into the domestic and short sea fleets. Ferries and Ro-Ros generated 50% of overall emissions, with the short sea fleet accounting for one third of the total. Although relatively few in number, these vessels are typically large (particularly in the short sea fleet), carry containerised cargo and passengers, and are used intensively so as to maximise revenue generation. In contrast, a much larger number of smaller cargo and service vessels, each with lower emissions intensity, were responsible for 45% of overall emissions in aggregate. In the domestic fleet, emissions were concentrated in service vessels, while the short sea fleet delivered a higher proportion of emissions through bulk cargo vessels.

Figure 3.2: Number of vessels in the domestic and short sea fleets, greenhouse gas emissions by voyage type; inset pie chart shows aggregate emissions from the domestic and short sea fleets by voyage type

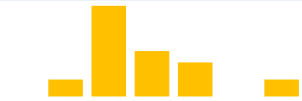
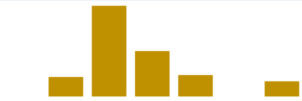
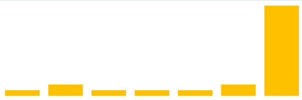
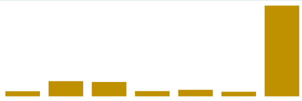
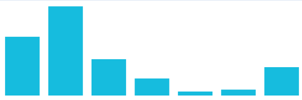
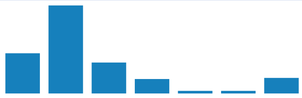
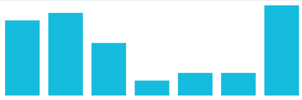
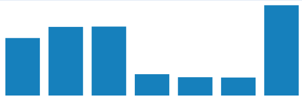
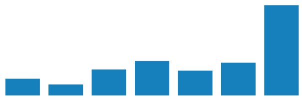
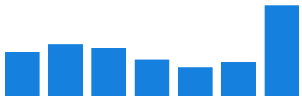
	UK fleet	SS fleet
Ferry/Ro-Ro	89	89
Cruise	9	1
Car carrier	0	7
Container ship	2	27
Tanker	36	75
Gas carrier	0	33
Dry bulk	24	142
Offshore engineering	10	17
Offshore support	237	139
Survey/research	17	12
Dredger	34	13
Tug	148	24
Workboat	48	9
Fishing	330	247



Source: Based on UMAS FUSE[16] data

The distribution of vessels and emissions by age highlights which segments are under the most pressure to replace vessels and indicates how this might influence emissions reduction (Table 3.1 and Table 3.2). These charts reflect vessel ages as at the end of 2018 and therefore vessels older than 20 years can be considered to be due for replacement in the near-to-medium term.

Table 3.1: Vessel number and emissions by age (5 yearly intervals) in domestic fleet

<table>
<tr><th>Sector</th><th>No. of vessels</th><th>No. of vessels by age profile
<5 | 10 | 15 | 20 | 25 | 30 | 30+</th><th>Total emissions ('000t CO_2e)</th><th>Emissions by age profile
<5 | 10 | 15 | 20 | 25 | 30 | 30+</th></tr>
<tr><td>Ferry/Ro-Ro</td><td>89</td><td></td><td>1,060</td><td></td></tr>
<tr><td>Cruise</td><td>9</td><td></td><td>26</td><td></td></tr>
<tr><td>Container ship</td><td>2</td><td></td><td>5</td><td></td></tr>
<tr><td>Tanker</td><td>36</td><td></td><td>202</td><td></td></tr>
<tr><td>Dry bulk</td><td>24</td><td></td><td>37</td><td></td></tr>
<tr><td>Offshore engineering</td><td>10</td><td></td><td>24</td><td></td></tr>
<tr><td>Offshore support</td><td>237</td><td></td><td>638</td><td></td></tr>
<tr><td>Survey/research</td><td>17</td><td></td><td>17</td><td></td></tr>
<tr><td>Dredger</td><td>34</td><td></td><td>113</td><td></td></tr>
<tr><td>Tug</td><td>148</td><td></td><td>185</td><td></td></tr>
<tr><td>Workboat</td><td>48</td><td></td><td>86</td><td></td></tr>
<tr><td>Fishing</td><td>330</td><td></td><td>419</td><td></td></tr>
<tr><td>Total</td><td>984</td><td></td><td>2,813</td><td></td></tr>
</table>

Source: Based on UMAS FUSE[16] data

The heterogeneity in vessels can be seen clearly in the ferry/Ro-Ro segment of the domestic fleet where vessels older than 20 years account make up half the fleet but only 20% of emissions from the segment. These vessels will need to be replaced soon, likely before equivalent zero emission vessels are available. However, given the lower emissions intensity of these, building low emission rather than zero emission replacements will still be beneficial. More critical are the vessels in the 15-to-20-year age range which account for 15% of emissions from the entire domestic fleet; unless their replacements are built to run, or can be later converted to run, on zero emission fuels, the opportunity to eliminate a large portion of domestic shipping emissions will have been missed.

The offshore support segment is the second largest source of emissions, but the age profile of the vessels is much younger. This could be partly due to the emergence of the offshore wind industry in the UK, but the vessels servicing the offshore oil and gas industry still constitute a much larger portion (estimated to be over 90%) of this segment. Given the decline in domestic oil and gas production since the early 2000s[51, 52], it is likely that offshore service providers employ relatively young vessels for this industry, and these vessels are either sold or transferred to operate in another jurisdiction later in life. Therefore, while existing vessels could reduce emissions by improving energy efficiency, more significant reductions could also be seen through fleet replacement before these vessels reach the end of their life.

The same scenario seems plausible in the workboat segment given potential overlap in activities and the profile of vessel ages/emissions. On the other hand, a steady renewal of the tug fleet is likely given the even spread of ages. In the dry bulk, dredger and fishing segments the advanced age of vessels means that replacement is pressing and investment to improve efficiency is unlikely (given the short payback period).

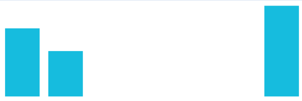
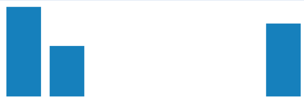
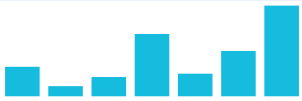
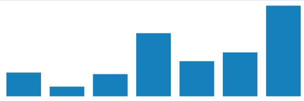
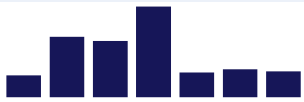
A similar picture emerges from the distribution of vessels and emissions by age in the short sea fleet (Table 3.2), but overall, the fleet is younger, and so is the profile of emissions. Vessels below 20 years account for 75% of emissions from the short sea fleet. Ferries and Ro-Ros are the largest source of emissions, and these are again concentrated in the 15-to-20-year age range. The replacement of these vessels could tie in with the formation of green corridors in the second half of the 2020s. There is a similar opportunity from replacement container ships in the 2030s.

The vessel and emission profiles of tankers and gas carriers suggest that a combination of efficiency improvements in younger vessels and eventual replacement of older vessels with lower emission alternatives will be needed. However, these are generic vessels, and thus able to work in different parts of the world. Therefore, emissions reductions may again be accelerated before vessel replacement dictates, particularly for vessels large enough to be subject to international maritime emissions-related regulation.

The dry bulk segment is mainly comprised of smaller general cargo and multi-purpose vessels that carry a wide range of cargoes. These are technically simple vessels which tend to be used well beyond the 25 years of economic life seen in other segments (the average age of the global multi-purpose vessels fleet is 19 years[53]). Most are too small to be affected by regulation and so scrapping ages may not be brought forward. Conversely, however, measures to improve efficiency may be more acceptable in older vessels.

In the service vessel segments, offshore support and fishing vessels are the largest sources of emissions. The age profile of the offshore support vessels in the short sea fleet is very similar to that of the domestic fleet (which is unsurprising given vessel activity for the oil and gas sectors in both the UK and Norway overlaps), but the age profile of fishing vessels is younger.

Table 3.2: Vessel number and emissions by age (5 yearly intervals) in short sea fleet

Sector	No. of vessels	No. of vessels by age profile <5 | 10 | 15 | 20 | 25 | 30 | 30+	Total emissions ('000t CO_2e)	Emissions by age profile <5 | 10 | 15 | 20 | 25 | 30 | 30+
Ferry/Ro-Ro	89		2,914	
Cruise	1		17	
Car carrier	7		61	
Container ship	27		236	
Tanker	75		525	
Gas Carrier	33		162	
Dry bulk	142		371	
Offshore engineering	17		30	
Offshore support	139		292	
Survey/research	12		18	
Dredger	13		39	
Tug	24		16	
Workboat	9		4	
Fishing	247		228	
Total	**835**		**4,915**	

Source: Based on UMAS FUSE[16] data

3.3.2 Emissions at UK and short sea ports

In 2018, emissions from the domestic fleet at ports constituted 17% of total emissions from domestic voyages; as short sea shipping involves longer distances, the overall proportion is only 12% (Table 3.3).

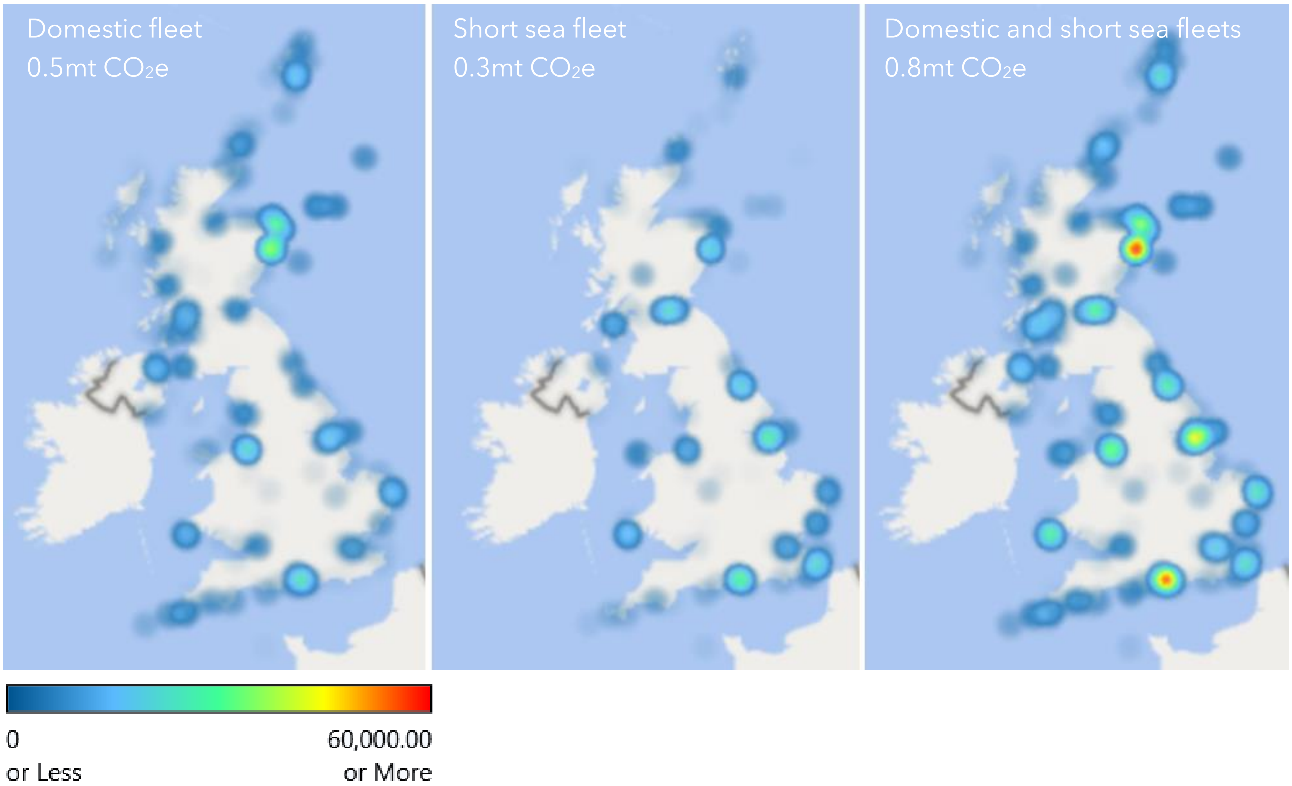
Table 3.3: Emissions by vessels on domestic and short sea voyages at sea and at ports

CO_2e million tonnes	All UK-UK voyages	of which from domestic fleet	All UK-UK and UK-short sea voyages	of which from domestic and short sea fleets
Emissions at sea	3.2	2.4	12.9	6.9
Emissions at UK ports	0.7	0.5	1.3	0.8
Emissions at short sea ports	-	-	0.5	0.2
Total	**3.9**	**2.8**	**14.7**	**7.9**

Source: Based on UMAS FUSE[16] data

The level of emissions from vessels berthed at ports does not directly correlate with emissions from voyages to and from those ports or quantify the potential demand for marine bunker fuels at those sites. However, it does indicate the relative intensity of fuel consumption in different regions and so highlights where zero emission fuel supply (and possibly shore power) for the domestic and short sea fleets will be needed in future. Figure 3.3 shows the emissions at UK ports from the domestic and short sea vessels.

Figure 3.3: Heat map of emissions (tonnes CO_2e) at UK ports from domestic and short sea fleets



Source: Based on UMAS FUSE[16] data

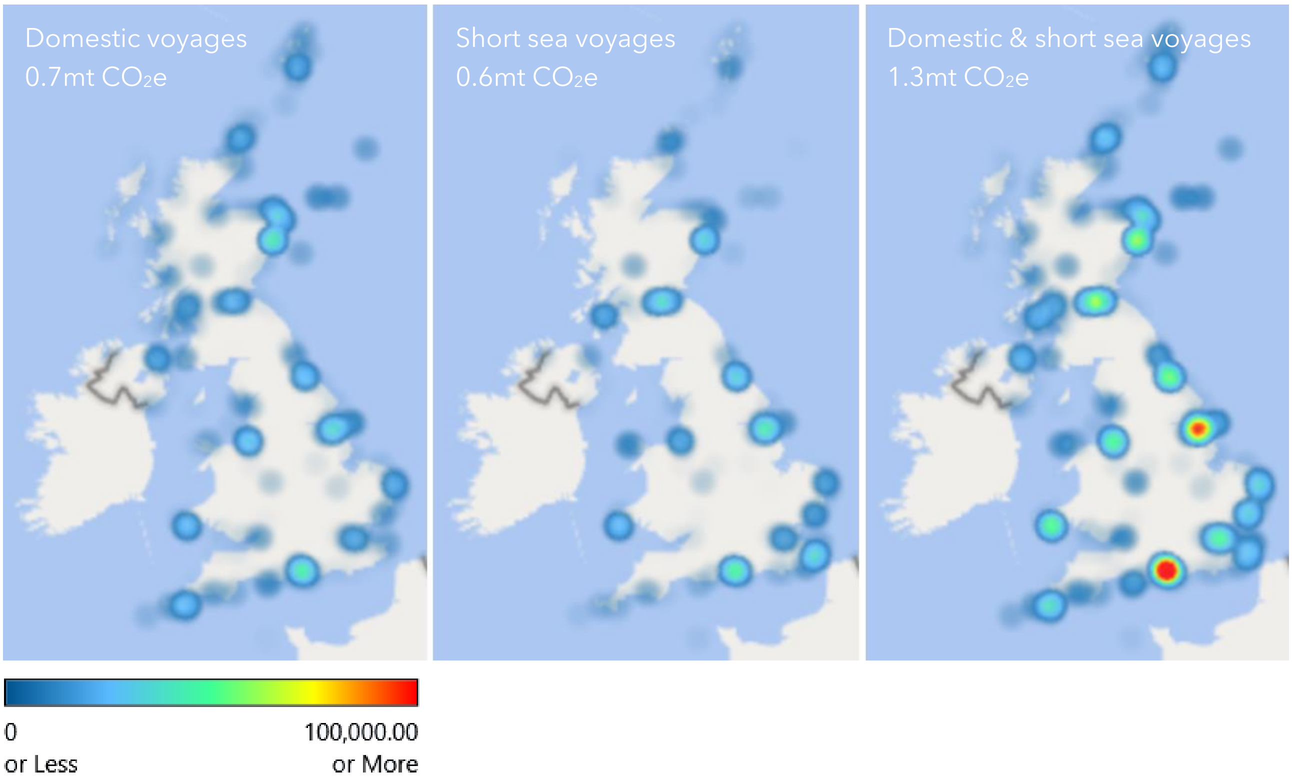
As these vessels consistently travel to and from UK ports, they constitute a source of regular demand that is supportive of the formation of early clean energy clusters and possibly green corridors. The overlap in emissions from the domestic and short sea fleets, principally from vessels servicing the offshore oil and gas industry, forms a hot spot on the northeast coast of Scotland (Aberdeen, Peterhead and Fraserburgh). Similar concentrations in aggregate emissions are seen around Southampton and Portsmouth (ferries), Immingham (Ro-Ros and tankers), Liverpool (ferries and Ro-Ros) and Great Yarmouth (offshore vessels).

Recent studies have been made to determine where demand for new fuels and shore power overlaps with areas where generation of these is possible. For example, both Aberdeen and Liverpool have been identified as ports that have the capacity to form a shore power and/or hydrogen cluster due to potential access to renewable electricity generation[54]. However, given the range in technical solutions the shipping industry is likely to adopt, multiple energy solutions will be needed in key ports across each region.

Assessments which consider aggregate demand at the port or cluster level from all vessels indicate the potential level of demand for clean fuels and/or power, but more sophisticated modelling based on discrete vessel voyages allows for better evaluation of the type of consistent and regular demand that supports early decarbonisation projects and green corridors[55].

Clean maritime hubs need to be formed where they can eventually supply the wider fleet, so the overlap with international shipping must also be considered. Although energy demand stemming from the international fleet has not been assessed, port emissions from all voyages between the UK's ports and between the UK and short sea countries highlights the regions where energy demand overlaps between vessels that regularly make domestic and short sea voyages and those that do not (Figure 3.4).

Figure 3.4: Heat map of emissions (tonnes CO_2e) at UK ports from all domestic and short sea voyages



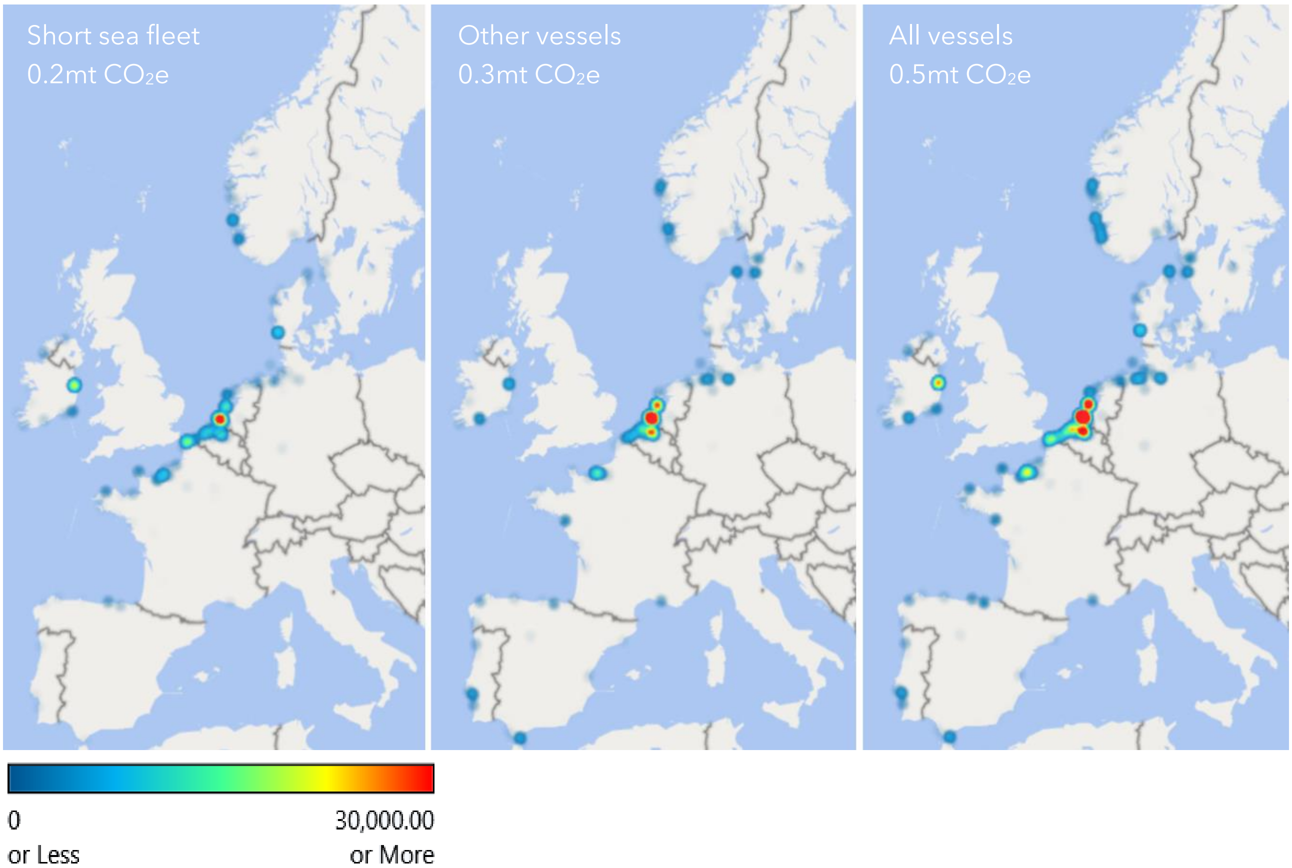
Source: Based on UMAS FUSE[16] data

These heatmaps reflect a shift in emissions intensity to Southampton and Portsmouth, Immingham and Grangemouth, primarily due to voyages from large numbers of oil and chemical tankers, which do not trade consistently enough to the UK to qualify for the short sea fleet.

Lastly, the concentration of emissions at European ports by the short sea fleet can indicate which locations could offer routes suitable for green corridors. Again, by seeing how those points of demand overlap with wider (irregular) shipping activity to and from the UK, potential sites for future clean maritime hubs can be discerned.

The vessels sailing between the UK and the ten short sea countries visited over 1,000 European ports in total, although the short sea fleet visited only two thirds of these ports (Figure 3.5). The heatmaps illustrate the concentration in voyage activity, with Rotterdam, Dublin, and Calais key ports for ferries, Ro-Ros and tankers. While the voyages of irregular vessels were more widely dispersed, port calls did coincide in some regions, particularly around Rotterdam and Le Havre.

Figure 3.5: Heat map of emissions (tonnes CO_2e) at short sea ports from all domestic and short sea voyages



Source: Based on UMAS FUSE[16] data

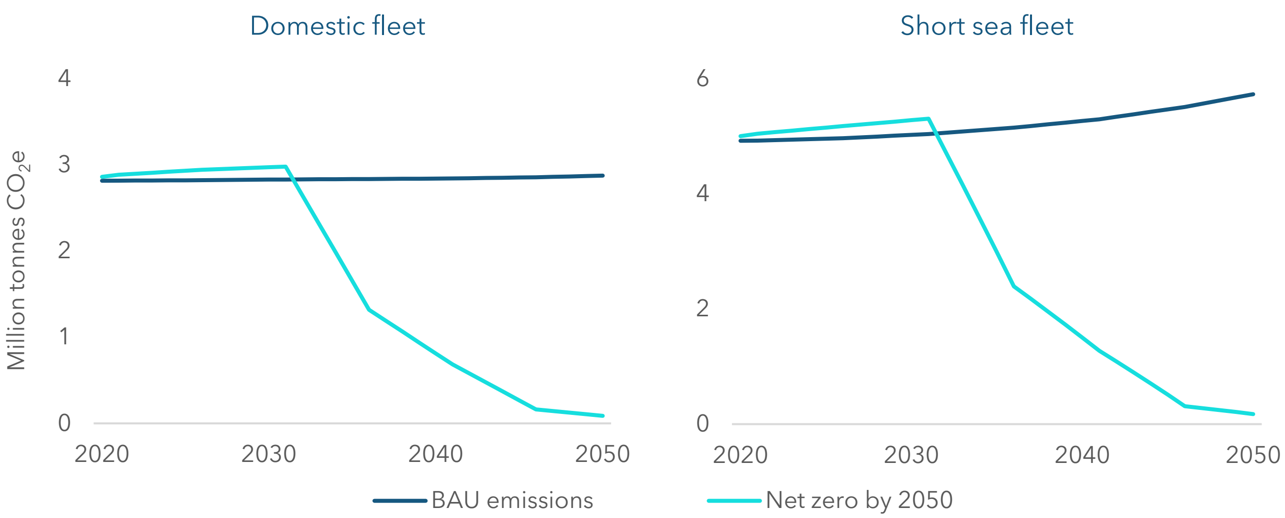
3.4 Investing in net zero

3.4.1 Investment required in vessels

In the analysis undertaken for the Clean Maritime Plan a range of potential trajectories for reductions in domestic shipping emissions were mapped. For each scenario, the marginal cost of abating greenhouse gas emissions as compared with a 'business as usual' approach was calculated[56]. This incremental cost represented the expected level of investment in vessel efficiency technologies and the additional cost of replacing end of life vessels with lower or zero emission alternatives. As well as the incremental capital requirement, the marginal operating cost (i.e. the projected spread in zero emission versus conventional fuel prices) was also calculated.

This analysis has been applied to the domestic and short sea fleets using trade/fleet growth projections generated by UMAS's Global Transport Model (GloTraM) to show emissions on a business as usual basis compared with a potential pathway to net zero by 2050 (Figure 3.6)[57]. In this scenario, emissions hold relatively flat until 2030 before falling (mainly due to a shift to zero emission fuels, with a smaller contribution from electrification and efficiency gains).

Figure 3.6: Projected emissions for the domestic and short sea fleets under business as usual and a net zero by 2050 pathway



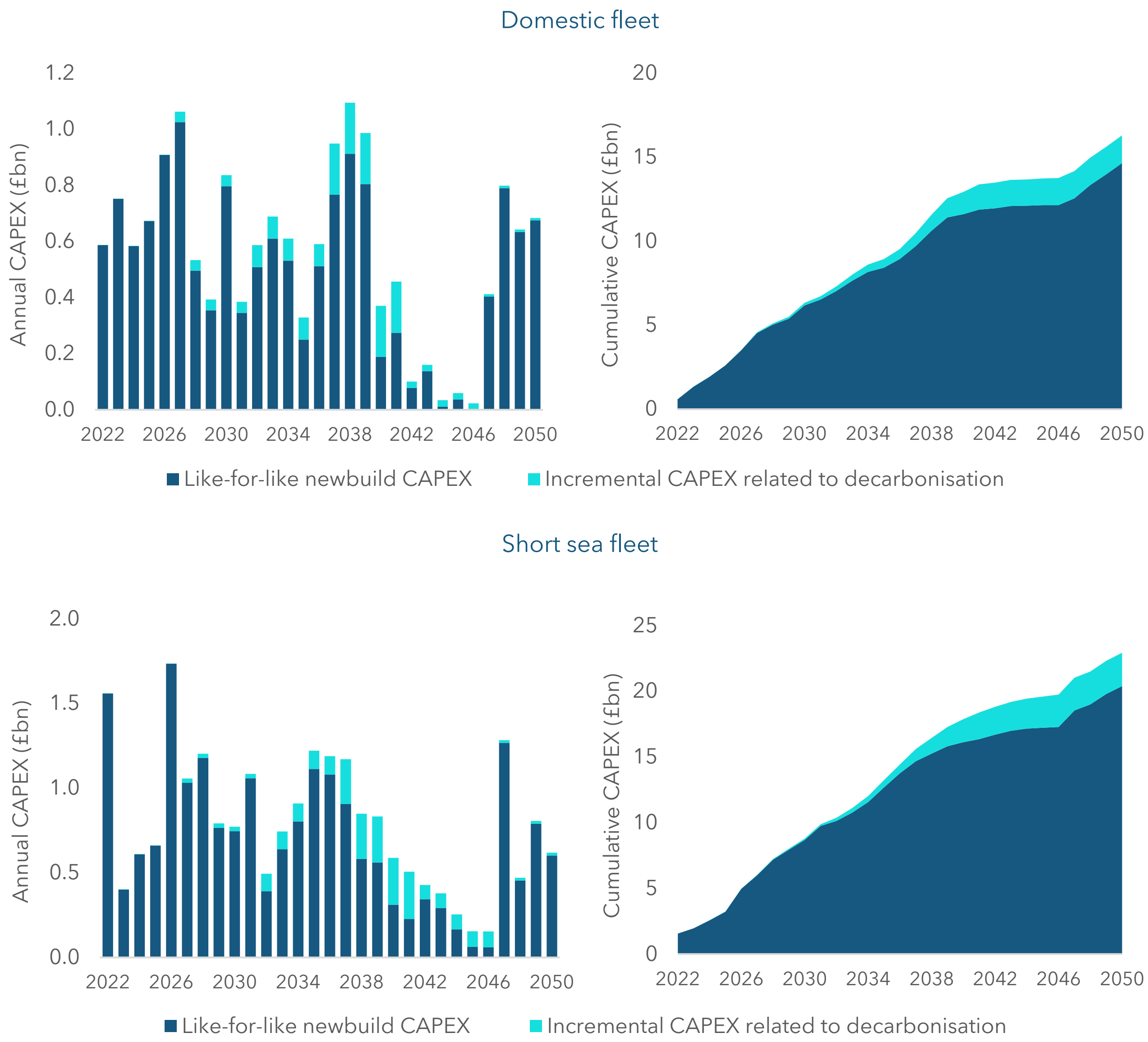
Source: Based on UMAS FUSE[16] and GLoTRaM[57] data

This is just one possible trajectory, and although the emissions reduction pathway eventually achieved may be similar, the mix of technologies and fuels used to reach it may differ from the above scenario. This uncertainty, plus the lack of clarity over the cost of future fuels and technologies, means that the marginal cost of abatement should be considered an indication rather than a projection.

Furthermore, the capital element of the marginal abatement cost does not represent the total investment that will be required to decarbonise the domestic and short sea fleets. Given the urgent need for renewal, which will include some owners who would otherwise have bought second-hand vessels, there will be a shift to a younger fleet. Therefore, it is important to recognise the overall level of investment needed.

To estimate the investment required to build the underlying vessel, a like-for-like replacement cost (based on January 2022 prices) has been calculated for each vessel (refer to Appendix II for more detail), and a projection for new vessel ordering has been formed from assumptions on fleet replacement and growth from the GloTraM model (Figure 3.7).

Figure 3.7: Indicative annual and cumulative capital investment (basis January 2022) in vessels, split by like-for-like newbuild cost plus incremental cost related to decarbonisation (net zero by 2050 pathway)



Source: Based on UMAS GLoTRaM[57] and Clarksons Research Services[53] data

The results indicate that approximately £40 billion will be needed over the next three decades to build new domestic and short sea vessels and install decarbonisation-related equipment, with the marginal cost of abatement accounting for just over 10% of the total cost. Again, this analysis is indicative rather than predictive (particularly as in many segments of the shipping industry, vessels are not typically ordered and then owned for life by a single shipowner). However, it does suggest the scale of funding that domestic and short sea shipowners will need to access in the coming decades.

3.4.2 Investment required in onshore infrastructure

Estimating the potential investment needed in zero emission fuel production and supply infrastructure for the domestic maritime industry is difficult. There is much uncertainty over what fuels will be needed in what quantities and by when. Even if costs can be estimated, it is far from certain if enough clean energy will be available in time, and to which sectors priority might be given if supply is not abundant. Therefore, at best, efforts to quantify cost are only likely to indicate the order of magnitude in investment required.

There is no universal agreement as to which zero emission fuel will be most commonly used in by the shipping industry in future, but it will most likely be a derivative of hydrogen, such as ammonia or methanol. Low carbon (blue) hydrogen can be made from natural gas using steam methane reforming in combination with carbon capture and storage; zero carbon (green) hydrogen can be produced from the electrolysis of water using renewable electricity.

One study estimated that by 2050, it could cost up to $1.7 trillion to build enough production capacity to supply ammonia to the entire international fleet[58]. Based on the proportion of fuel used by the domestic and short sea fleets on voyages between UK ports and between UK and short sea ports, compared with the consumption of the international fleet, this equates to cumulative investment in zero emission fuel production facilities of approximately $15 billion[59].

This estimate only covers the capital cost of the production facility and associated storage. Electrolysis is an energy-intensive and inefficient process, requiring plenty of renewable electricity. Therefore, further investment would also be needed upstream (in renewable energy projects to supply the electricity and in the transmission network) as well as downstream (to create a fuel distribution and delivery network). The investment needed for this is also likely to be in the tens of billions of pounds, but not all will necessarily be in the UK. It is likely that international trade in zero emission fuels will develop, and the UK may import a proportion of the fuels it needs.

Any provision of shore power at ports will also require investment. This can vary widely depending on the cost of grid connection or the cost of construction of onsite renewable power generation facilities. A recent study on the barriers to uptake of shore power in the UK assessed the capital costs of different shore power projects around the world, with nine examples from Europe from 2010 onwards. These projects ranged in size between 0.5MW and 33.5MW and the average cost per MW was £775,000. The study estimated that in the UK, grid connection and port infrastructure would cost up to £35 million for a 16MW connection, but as low as £2.5 million for smaller ports and/or lower power requirements.

There is no estimate as yet for how many ports may need to supply shore power. Long term there will likely be concentration in major ports servicing the international fleet, but in the shorter term more demand may be seen at smaller port catering to domestic vessels that are using batteries. Even so, the order of magnitude of investment is lower than will be needed for fuel production and supply.

As a rough approximation, the total investment required to decarbonise the domestic and short sea fleets (i.e. including the replacement of vessels and the provision of zero emission fuels and shore power) is likely to be in the region of £75 billion. In practice, the shoreside investment will extend beyond the domestic and short sea fleets to also fuel and power the wider international fleet.

Industry Views

Interviews with stakeholders from across the domestic maritime sector highlight the challenges currently faced and how these inform investment decisions related to decarbonisation.

There is much uncertainty, but there are also signs that opportunities are being sought and that collaboration is growing, both vertically and horizontally along the value chain.

4.1 Engagement with stakeholders

To understand the key challenges that stakeholders in the domestic maritime sector face, and to gain insight into the actions on decarbonisation they are, or are planning, to take, one-on-one interviews were held with industry participants across a wide cross section of the sector. This included UK shipowners, charterers and cargo owners, port owners and terminal operators, shipbuilders and maritime architects, trade associations, financial institutions, and experts in maritime law, insurance, and tax.

As shipowners and ports are the key stakeholder groups facing decarbonisation-related investment decisions, from these two groups, as wide a cross-section of businesses as possible (in terms of operational activity, size, and location) were interviewed. Although these views do not represent the experiences of all stakeholders in these two industries, other stakeholders were also interviewed and were able to contribute objective observations on how the domestic maritime sector is currently positioned on the journey to net zero. As a result, nuanced perspectives on the challenges and opportunities faced by stakeholders from across the breadth of the maritime sector were gathered.

Unsurprisingly, for an industry as diverse as the maritime sector, the feedback was similarly varied. However, while different parts of the sector, and even individual stakeholders, function within distinctive operational and commercial environments, many common themes were raised. These include views on investment decisions related to decarbonisation and the commercial pressures influencing these, the relationships between stakeholders, and thoughts on how government's approach to the decarbonisation of the domestic maritime sector can evolve.

4.2 Investment drivers for shipowners

4.2.1 Current action on existing vessels

Options currently available

Shipowners largely face two options, depending on the size of the vessels: 1) smaller vessels can use HVO as a drop-in fuel; 2) in larger vessels, owners can try to improve the energy efficiency, either by changing how it is operated or by installing energy efficiency technologies. The first option entails a higher fuel price, but otherwise no capital cost, and owners or charterers will typically seek to pass through the higher fuel cost to customers. Energy efficiency technologies, on the other hand, do require upfront investment and so decisions will revolve around the projected payback period of the investment, either through fuel saving or higher charter rates.

Uptake of HVO

Two owners interviewed (both tug owners) have switched a portion of their fleet to HVO. One is a large tug owner that viewed the rollout as a trial for its wider international fleet, and also considered it a possible source for carbon credits which could be sold on to customers in other parts of the world. A smaller tug owner undertook the move to HVO, in part, to secure its position as a supplier of the fuel to other users in the area.

However, the broad response on HVO was muted, particularly given the continuation of the rebate scheme for gasoil for commercial vessels on inland waterways ('red diesel'). Some shipowners who did express interest in the fuel were concerned about future availability and cost, given issues of competing demand from other sectors (particularly aviation).

Energy efficiency improvements

Most shipowners have assessed technical options for retrofits and operational efficiency improvements for existing vessels. However, lack of clarity from manufacturers (i.e. the absence of reliable data available on potential emissions savings for shipowners) and from Classification Societies (which consult on the suitability of these technologies for smaller, non-generic vessel types and the efficiency gains that could result), have hampered uptake. Until there is clarity, investment decisions are likely to remain challenging.

There was also concern by shipowners that the efficacy of any operational or technical options available could be constrained due to:

1) The size of the vessel (e.g. lack of space for onboard batteries)
2) The operational profile of the vessels (as energy efficiency technologies work when the vessel is underway rather than in port)
3) The trading profile (e.g. for ferries, schedules may mean that slow steaming is not an option, and recharging batteries in port may not be possible due to lack of time spent at berth)
4) Port/route constraints (e.g. draught restrictions) preventing efficiency gains in existing vessels

These last three issues will also limit the improvements in energy efficiency that can be realised through better designed replacement vessels, at least until zero emission solutions become available.

Shipowners that were assessing whether to invest in energy efficiency technology had spent considerable amounts of time weighing up the practicalities (how it could be fitted, what the ongoing operational or maintenance requirements were, what training staff might need). Ultimately, however, the decision rested on the calculated fuel savings, the age and suitability of the vessel, and the commercial outlook. For owner-operators this was based on assumptions about future fuel prices; for owners that chartered their vessels, the outlook of the wider chartering market.

None of the shipowners interviewed had considered installing multiple types of technologies. There is ambiguity about the fuel savings each of these technologies may achieve in practice, but shipowners pointed to even greater uncertainty about the potential efficiency gains when combined. In future, with the low hanging fruit already picked, shipowners may find additional investments increasingly difficult to justify.

Split incentives issue

This issue arises where the owner and charterer/operator are different stakeholders. The owner makes the initial investment to improve energy efficiency and the charterer/operator charters the vessel and pays for the subsequent fuel use. The rate the charterer pays may not be sufficient to allow the owner to see a return on, or even recoup, the investment. This rate will depend on the market at any point time and the price of fuel (greater fuel efficiency is of course more valuable when fuel costs are high), rather than reflect a return on overall capital cost.

This is clearly a greater challenge in markets where shorter-term charters prevail as long-term charters offer shipowners and charterers an opportunity to agree a rate that provides an acceptable return on an owner's upfront investment. In parts of the industry where generic vessels operate on short-term contracts, domestic shipowners reportedly found themselves unable to demand any premium for more efficient vessels. Nor were charterers prepared to pay for the additional cost of HVO fuels.

However, even in segments where longer-term charters are the norm and charterers and shipowners have established relationships, shipowners spoke about the difficulty in making investment in energy saving technologies and in agreeing cost-sharing rates, as well as the impact that new technologies could have on the contractual arrangements.

4.2.2 Outlook for fleet replacement

Cost gap in conventional fuels and zero emission alternatives

As yet, there are no zero emission fuels being produced at commercial scale for the maritime industry. However, future price curves have been estimated based on assumptions of the cost of production (which includes renewable electricity) and economies of scale increasing over time. The projected difference in cost between conventional fossil fuels and zero emission alternatives reflects the capital investment required by energy companies and marine bunker fuel suppliers to develop these alternative fuels, construct production facilities, and build the distribution infrastructure[44].

Although there is no clarity on when zero emission fuels will be widely available, or even what fuels will be available, all shipowners interviewed recognised that the cost would be greater than current conventional fuels. The perceived difference in cost was great enough for most shipowners to discount a switch, even should such fuels be available. However, one port owner interviewed was a partner in a local hydrogen project venture and had assessed the use of the fuel in the tugs it operated within the port.

Options for new vessels

As vessels are depreciating assets, planning for fleet replacement is a part of existing budgeting and investment cycles. All interviewed shipowners had given consideration to which efficiency improvements might be feasible for their fleet, and most had a view on their preferred option for replacement. However, which zero emission fuel or fuels will ultimately be adopted by the shipping industry (and when) is still unclear and there is too much uncertainty to allow for a meaningful volume of investment decisions on fleet renewal currently. Instead, owners are focusing on the emission reduction options that are feasible now and considering how redundancy for future adaptation can be built in.

Shipowners with bespoke vessels (i.e. built to particular specifications, such as to meet dimensional restrictions in regular ports of call) generally expressed a longer-term view of what future emissions regulation, fuel options and possible prices could be. Those in the ferry and Ro-Ro segment are generally focused on building new vessels that will be as efficient as possible, along with other options such as 1) adding onboard batteries so that main engines could be switched off during port manoeuvres; 2) installing dual-fuel LNG engines; or 3) building in redundancy (such as additional fuel storage space) to enable future adaptation to zero emission fuels. However, shipowners reported on the difficulty in getting approval from Classification Societies on novel vessel designs.

Similarly, owners of vessels on long-term charters have also been assessing options for longer-term solutions, for both new and existing vessels. One shipowner in the offshore wind sector voiced concerns about how choices made now could affect future operating expenses (i.e. the relative cost curves of different fuels and of electricity). There was also some concern that decisions made over the near term, could lead to vessels facing early obsolescence, either by becoming uneconomic (e.g. due to expensive mid-life battery replacement) or through increasingly stringent emissions regulation. Such stranded asset risk is magnified for vessels built specifically for certain routes or operating conditions.

Meanwhile, shipowners operating more generic vessels that are typically employed through short-term contracts (e.g. tugs, workboats), tended to take a near-term view of the solutions currently available and voiced a preference for the most efficient version of what is currently available.

Competitive market

For most shipowners and operators, the decision to switch to a higher-cost low or zero emission fuel rests on the customers' willingness to pay a premium. While there has been commitment by large international retailers such as Amazon and Ikea to move towards green shipping, no willingness to pay for this service was reported by shipowners at the domestic level[60]. However, a few shipowners did indicate that this could change in future as cargo contracts come up for renewal and as pressure from Scope 3 reporting grows.

Shipping is one link in an integrated logistics chain that has been built to operate efficiently and at low cost. Where there are alternative modes of transport available (e.g. rail, road, air), vessels that transport cargoes and people operate in a highly price-sensitive market and are at risk from intermodal shifts. Several ferry and Ro-Ro owners spoke of the challenges of passing through increased fuel costs to their customers due to the fierceness of competition and were worried that disjointed policies on fuel/carbon pricing across different transport modes might not only disadvantage them, but, as shipping is the lowest emitting form of transport per unit carried, ultimately also lead to greater emissions overall.

4.2.3 Funding investment

Access to capital

For shipowners, access to capital is correlated to the size of the company. Larger shipowners tend to have established relationships and facilities with commercial banks but reported that these banks are still very conservative when looking at funding ships using new, untested technologies. There are fewer funding options available to smaller domestic players.

This was confirmed through interviews with two commercial banks that together represent the largest source of lending to domestic shipowners. For shipowners with a corporate balance sheet, lending is based on credit quality. For smaller shipowners, financing is typically much easier for banks to provide when a long-term charter is involved, but this is relatively rare outside the offshore wind sector. For vessels operating in short-term charter markets, the loan terms (tenor, amortisation profile and interest rate) of financing were dependent on the vessel type. Modern, generic vessels that can operate across wider markets were generally given better lending terms, but the banks stated that they are very cautious about financing new vessel types without long-term charters attached.

Business models

For smaller shipowners, there were some concerns that decarbonisation could enforce a shift in their current asset ownership model. The owners of bespoke vessels built for specific routes or operating conditions are generally most likely to order new vessels and operate them until end of life. Fleet renewal will be carefully planned by these shipowners. However, in the domestic segments where more generic vessel types operate (e.g. workboats, offshore vessels), rather than build and hold for life, some owners will buy second-hand vessels and then possibly sell-on before end of life.

For a shipowner, there are two key differences between buying new and existing vessels. First, new vessels are more expensive and second, the shipowner must fund pre-delivery instalments while the vessel is being constructed. Both these factors can make the purchase of new vessels more difficult for smaller shipowners. Lenders are typically very reluctant to extend pre-delivery financing, meaning shipowners must fund payments to the shipyard from equity. Then, even if the owner is able to access finance for this vessel once it is delivered, the debt servicing costs will be higher than for a cheaper, second-hand vessel.

This liquidity in generic vessels presents challenges and opportunities for decarbonisation. On the one hand, if relying on second-hand zero emission vessels to percolate through the industry, it will likely take several decades to decarbonise the fleet. Alternatively, the ability to trade generic vessels means that zero emission vessels can be brought into the domestic fleet faster than would be seen through end-of-life fleet replacement. However, if domestic shipowners find they must switch from purchasing second-hand tonnage to ordering new vessels, there could be considerable implications for their business models in terms of funding, liquidity, and risk.

4.3 Investment drivers for ports

4.3.1 Priorities for decarbonisation-related investment

Business case for investing in decarbonisation-related infrastructure

Ports will need to invest in fuel storage and distribution systems, potentially for multiple fuel types, and possibly in shore power provision. As commercial enterprises, ports require that large-scale investment is recouped through either existing customers or new business opportunities. Given the high capital cost of new fuel infrastructure and shore power connections, the business case is challenging, particularly as the associated revenue streams may simply result from users switching from existing facilities rather than providing additional income.

Without clarity on which zero emission marine bunker fuels will be in demand (and when), ports will not consider investment in onsite storage due to the risk of low or no utilisation (i.e. stranded asset risk). Some ports confirmed that they view ammonia as a leading candidate, but few have started to assess how and where new, potentially multiple, zero emission marine bunker fuels could be stored on site, and the safety considerations associated with this. At some ports there are also limitations on the space available for new bunkering infrastructure.

The provision of shore power also presents a quandary for ports. Given the large investment required, the business case tends to be difficult to justify on a standalone basis. Only one port interviewed had installed shore power (for visiting cruise ships), but this was supported by a grant. However, the key driver for this investment was local air quality and a reduction in emissions of nitrogen oxide (NOx), sulphur oxides (SOx) and particulate matter (PM), rather than in greenhouse gas emissions.

Other ports interviewed were not actively planning investment in shore power provision, but several stated that they have been in discussions with their distribution network operator (DNO) to understand local grid capacity and the feasibility and potential cost of connection. The latter was usually high enough to dissuade further investigation. Some ports close to offshore wind projects were investigating direct power provision (dependent on cabling location). Although some ports were aware of mobile power solutions (e.g. for smaller ports/harbours or berths for smaller vessels), few had investigated this more closely (and lack of quay-side space was considered to be a potential constraint for this solution).

Decarbonising port operations takes precedence

Ports will need to decarbonise their own shoreside operations, and this generally takes precedence over investments that enable the decarbonisation of the vessels that visit. Some large ports are disclosing current greenhouse gas emission levels and stating targets for reduction. These targets are usually set by the port owner (particularly if it is an institutional investor like a pension fund), but ports that were most progressive in terms of planning and action were those that had full by-in from senior management.

In general, however, the focus by ports has been on tackling direct emissions from operations (Scope 1 and 2 emissions) which result from cargo handling equipment such as forklift trucks and reach stackers and electricity use onsite. The withdrawal of the gasoil rebate ('red diesel') for non-road mobile machinery (NRMM) in April 2022 has encouraged many of the ports interviewed to consider investment in electric port equipment (and some to investigate the use of hydrogen). However, ports that have made investments in decarbonising their own operations reported on the difficulty of passing through that cost to their customers.

Ports are also beginning to invest in onsite renewable energy generation such as rooftop solar panels and/or onsite wind turbines. Those with access to large sources of renewable energy (either onsite or through local sources) spoke of the possibility of eventually developing onsite electrolysers to fuel shoreside equipment and potentially vessels.

4.3.2 Access to capital

The ability of ports to raise finance depends on their size and ownership structure. Major ports, whether private, trust or municipal, typically have experience of large-scale investment and infrastructure planning, whether for harbour development, terminals, port equipment or energy systems, with funding sourced through owners (i.e. parent company or local authorities arranging finance) or directly from commercial banks.

Even smaller ports tend to adopt long-term views on investment based around the port masterplan, but access to private capital tends to be more limited. Public funding has been received, as part of packages earmarked for regional investment, as well as directly through EU grants (pre-Brexit) and allocations from the UK government's Port Infrastructure Fund to build new customs facilities post-Brexit.

4.3.3 *Stakeholder relationships*

Relationships with shipowners

The strength of the relationship between ports and shipowners varies by owner, port, and segment. Large owners tend to have stronger relationships and there tends to be greater effort by both parties to plan investment jointly (e.g. provision of shore power on fixed berths for battery hybrid ferries and cold ironing for cruise ships). This is understandable given that these shipowners generate significant income for these ports and the relationships are likely to be longstanding.

However, the owners of smaller vessels (tugs, workboats), which contribute a far smaller proportion of a port's revenue stream, reported struggling to obtain due consideration from ports. For example, such owners found being able to secure fixed berths difficult and ports generally seemed reluctant to invest in shore power for such small owners, making investment in battery technology challenging. One shipowner pointed out that as smaller ports can generate income through the provision of traditional marine bunker fuels, this can make them reluctant to switch to alternative fuel sources (particularly electric power).

Relationships with other ports

Ports operate in a highly competitive landscape and there is typically little communication between them, particularly on commercial matters; this siloed outlook tends to be breached only on issues relating to safety. However, there seems to be an increased willingness by some ports to cooperate with others on the subject of decarbonisation. In part, this seems to be linked to participation in the CMDC, but also through the activities of organisations like ORE Catapult and Connected Places Catapult across a range of ports. Although information related to decarbonisation can have commercially sensitive elements (e.g. power consumption, emissions from direct operations), this may lead to increased information-sharing on decarbonisation initiatives.

4.4 Views on regulation and government strategy

4.4.1 *Maritime decarbonisation strategy*

Relationship between government and industry

Stakeholders expressed their appreciation of the recent initiatives introduced by government. As the decarbonisation transition picks up pace, many expressed the desire for government to ensure that its maritime strategy is well coordinated and communicates clear direction and policy setting, while ensuring strong coordination between different government departments. The consensus was that across wider government, greater understanding of the sector and the challenges currently faced (not solely related to decarbonisation) would be beneficial.

Some stakeholders felt that some challenges are magnified by the current lines of communication between government and industry. Stakeholders in the maritime sector are represented by numerous trade associations which act as conduits to government. However, smaller ports pointed to a lack of representation through such bodies and shipowners indicated that different trade bodies representing different sections of the industry failed to speak with a single voice and suggested that this was detrimental to the quality of overall dialogue.

Government maritime decarbonisation strategy

Looking forwards, some stakeholders were hopeful that future efforts outlined in the Clean Maritime Plan would lead to a more coordinated approach, informed by a greater level of engagement with the industry. Some also felt that the funding from CMDC was a good first step which indicated that government was serious about delivering its vision of decarbonising shipping. Generally, however, the lack of clarity on future targets, mechanisms and further types of support that might be put forward by government added to the uncertainty currently hindering investment decisions, always remembering the long-term planning and budgeting cycles in both the shipping and port industries.

For example, ports were uncertain if shore power would be mandated, and if so, whether/how support would be made available. Larger shipowners involved in cargo and/or passenger transportation were very concerned about what any form of carbon pricing could mean for their fuel costs. Some small owners pointed to current policies potentially being divergent from decarbonisation objectives (e.g. the continued entitlement of commercial vessels to access red diesel disadvantaged those choosing to switch to HVO).

Some stakeholders also suggested that decarbonisation could be seen as an opportunity to rethink how demand for transportation would evolve in future and to structure long-term strategies and infrastructure accordingly. This point was raised by stakeholders in both the port and shipping industries, with the suggestion that, at a high level, policies on transport across the board would need to be linked to the government's overall strategy for the energy transition.

Stakeholders involved in lifeline services to islands gave examples of rethinking how demand for energy and transport could change for communities and visitors (e.g. by making electric vehicles available for hire on islands, demand for car carrying capacity on ferries could be reduced; or looking at how locally produced energy could power all modes of transport). Other stakeholders reflected on what the increase in electric vehicles could mean for both vessels (e.g. charging requirements) and ports (potential fuelling requirement for HGVs).

Intermodal shift

Another concern voiced by several stakeholders in the ferry/Ro-Ro segment, was the possibility that divergent policies across different modes of transport could discourage cargo and passengers away from vessels and onto less emission-efficient road and air transport. While some felt this issue of intermodal shift also presented an opportunity to reduce overall emissions by moving cargo transportation off roads and onto sea lanes and inland waterways, few could see this happening without commitment from cargo owners and pointed out that existing logistics and warehouse infrastructure acted as a drag on this.

Those stakeholders involved in cargo transportation were keen to see policies based on an end-to-end assessment of emissions over the whole logistics chain as a way to deliver a greater reduction in overall emissions and to ensure a level playing field. Along similar lines, some stakeholders raised the issue of considering lifecycle emissions when determining decarbonisation policies. This applies not only to the well-to-wake emissions of fuels, but also to the risk that enforced obsolescence would not take account of carbon emissions embedded in the manufacture of existing and new vessels. A requirement for companies to report on greenhouse gas emissions from supply chains (Scope 3 emissions) was suggested as an effective way to encourage increased emissions-efficiency across the logistics chain.

Clean Maritime Demonstration Competition

Feedback from domestic maritime stakeholders who participated in the first round of CMDC funding indicated that the collaborative nature of the projects had facilitated communication and helped build understanding between project participants, particularly between industry and academia (e.g. on the uses of big data in ports). However, others suggested that the remit of the CMDC was too narrow (not allowing already feasible solutions to have product trials funded), or too wide (scatter gun approach resulting in diluted effort).

Operation Zero

Despite the progress made by the industry coalition in understanding the issues involved and where potential solutions might lie, the stakeholders involved in the offshore wind industry reported that there was limited scope for progress without some form of support by government for existing vessels, and for clear targets to be set for new offshore wind farm tenders so that the cost of zero emission operation and maintenance could be budgeted within auction bids.

4.4.2 Regulatory friction

Stakeholders in the short sea shipping industry spoke of potential conflict resulting from operating under different regulatory regimes, and a clear desire to see cohesion between UK and EU regulation. For example, ensuring that any mandate for shore power on the UK side mirrors that of the EU to allow for a standardised approach, and that any inclusion of shipping in the UK ETS is aligned with the EU's approach to minimise the reporting burden and eliminate double counting.

4.4.3 Standards and safety issues

Stakeholders dealing with standards pertaining to smaller vessel segments pointed out that regulation moves slowly in shipping and lags behind other transportation industries. The lack of regulation for sub-500 GT commercial vessels (which are not covered by international maritime safety rules) was given as an example.

Some stakeholders in the port industry reported that they have already started assessing what the provision of new zero emission fuels (particularly ammonia) is going to entail. These stakeholders (particularly those located in densely populated areas) highlighted safety concerns and the need for government to establish safety standards as quickly as possible.

4.5 Challenges in the wider maritime sector

4.5.1 Supply chain

Shipowners interviewed generally had unfavourable views on UK shipbuilding capacity or capability for all but the small commercial vessel segment (e.g. workboats or crew transfer vessels). However, many are very happy to use UK shipyards for dry docking and maintenance, and possibly even future retrofitting opportunities.

Both ports and shipowners related difficulties in obtaining equipment (e.g. engines, replacement parts) from suppliers in the UK and from Europe. It was suggested that the market for manufacturing maritime equipment within the UK is not large enough to offer many options or to ensure timely delivery.

4.5.2 Skills gap

Many shipowners reported on the challenge of attracting and retaining staff and shared concerns about this challenge growing as new technologies came into use, requiring a whole set of different and higher skill levels than those currently needed. Across the wider group of stakeholders, there was an acknowledgment that decarbonisation of the domestic marine industry will require new skills and knowledge across multiple sectors: shipyards, Classification Societies, seafarers, ports, and shipowners. There was general concern about the time this would take to develop and whether the support infrastructure needed would be in place.

5

Funding Net Zero

The decarbonisation of the domestic maritime sector will be a complex and costly process. Existing funding channels will be unable to fill the gap and new sources of capital will be needed.

Institutional investors represent a huge pool of capital, but a nuanced understanding of their investment preferences and risk tolerance is the key to unlocking this source of capital.

5.1 Current funding models

5.1.1 How domestic maritime businesses access capital

The capital structure of most organisations in the domestic maritime sector is a mix of internal equity from the owner(s) and debt financing provided by commercial lending banks. Access to finance is generally determined by size. Larger companies with reliable (possibly diversified) revenue streams, and greater reserves and assets, are considered more resilient counterparties by commercial banks. This includes major ports, the largest shipbuilders, and a few domestic shipowners. Such entities can access debt at the corporate level, or on an asset or project basis (although a corporate guarantee may then be required). Some also have larger parents through which funding (either equity or debt) could be sourced.

For the small and medium-sized enterprises that predominate in the domestic maritime sector, the ability to raise debt finance is impeded by a lack of internal equity and the perception of lower credit quality. While lending or asset-based finance may be available to these businesses, there are fewer lenders, and the terms of debt tend to be more limited and costly.

There has generally been little recourse to public funds within the sector, other than by shipbuilders and ports which have seen different forms of support offered by government over time, including the procurement of newbuild naval or state-owned civilian vessels, export credit and guarantee facilities, direct loans and aid[61] and seed capital for Freeports[62]. More recently, innovation funding through the Clean Maritime Demonstration Competition has also been made available to the sector, and additional support for domestic shipyards (and by extension, domestic shipowners) through the Home Shipbuilding Credit Guarantee Scheme has been proposed[9].

5.1.2 Asset-based lending from commercial banks

Both international and domestic shipowners have traditionally financed vessels through a combination of equity and commercial bank debt where the loan is secured by a mortgage on the vessel and a set of covenants to ensure that the value of the security package is maintained. Only the largest shipowners have the balance sheet to access corporate borrowing facilities, and such firms are more commonly found in international shipping than the domestic market. The rest are more likely to borrow from asset-based lenders, who are less focused on a corporate balance sheet.

Asset-based lending is available for new and second-hand vessels. However, banks are reluctant to finance pre-delivery instalments to shipyards while a vessel is being built as there is no associated cash flow and no mortgageable asset (although, should a default occur, the lender may take over the shipbuilding contract if it is prepared to fund to completion). Pre-delivery payments, which can account for up to 80% of the capital cost of a vessel, are typically spread over a period of 1-2 years.

Reputable shipowners (with corporate balance sheets) may be able to negotiate pre-delivery debt facilities, but these are more expensive as the interest is capitalised until the vessel is delivered. Banks will want assurance that the owner has sufficient equity to contribute to the project and that profitable long-term employment has been secured for the vessel upon delivery. Smaller shipowners tend to rely on equity to fund shipyard instalments and will seek to reduce the amount of pre-delivery payments (which the shipyard will offset through a higher purchase price).

Compared with the economic life and consequent annual depreciation of a vessel, banks will typically demand a relatively fast amortisation schedule and short loan tenor that leaves them with little residual value exposure. As newbuild vessels usually cost more than existing vessels, the loan amount is higher and so repayments are larger than for a second-hand vessel. Smaller owners of generic tonnage, that would normally only buy in the second-hand market (e.g. ships in the middle of their lives) will naturally find financing newbuild vessels more challenging. Those operating bespoke vessels are less likely to have the choice between new and second-hand and will have to find ways to fund newbuildings.

The amount and cost of debt available to a domestic shipowner varies, depending on a number of factors: the type and age of the vessel, its underlying trade and related cash flows, the tenor of the loan, and the characteristics of the owner and charterer. Given the typical size of domestic shipowners, borrowing costs are generally higher than in international shipping, which also has access to a far wider pool of banks and leasing companies.

As well as the reluctance to take on residual value exposure, banks are also generally cautious with their assessment of credit quality, as default risk could leave them in the position of having to find solutions for the future operation or disposal of a vessel. This is even more of a concern in the domestic sector where the vessels are more often built for specific trades or routes and thus may not easily be sold or find alternative employment.

Although the professional maritime services industry includes large global banks, in some cases with sizeable UK-based shipping departments, these largely cater to clients in international shipping. There are few banks that finance domestic shipping businesses. NatWest is now the largest provider and there are a few other specialist financing institutions, but their market share is modest.

5.1.3 The current role of commercial banks

Out of all providers of capital, commercial banks have the lowest appetite for risk and offer a (relatively) low cost of debt in exchange for taking the most secured position in any funding activity. This security could be underwritten by an asset mortgage, a corporate guarantee, or a long-term contract or offtake agreement with high-quality counterparty, or any combination of these.

Commercial banks are hesitant to take on construction, technology or market risk, which will limit their involvement in the early stages of the energy transition. For example, a commercial bank may not offer project financing during the construction phase of a large-scale renewable energy project, but then may step in to refinance the project once operational. Major ports have received bank loans for expansion and infrastructure projects, but only when there is a strong business case for future growth in trade and/or revenue[63, 64]. It will be difficult to raise traditional debt finance for projects involving new zero emission fuel supply infrastructure or shore power provision that are unable to demonstrate enough additional revenue (or show revenue switching from other areas of port operation).

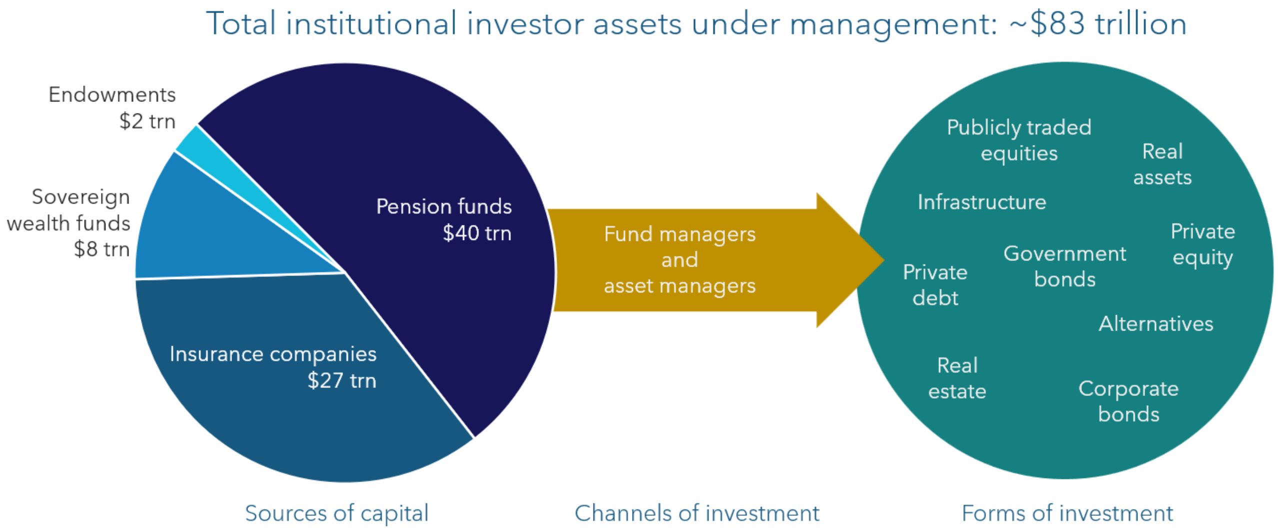
Banks may also struggle to bridge the incremental cost of zero emission vessels or lend on retrofitted equipment, particularly if such investment is not accompanied by certainty of increased revenues that cover the additional debt burden. Until there is more clarity on future fuels and technologies, banks will also be concerned with obsolescence risk and the residual value of the asset at the end of the loan term. The low credit quality of small shipowners is another factor that adds to the challenge, particularly if these owners must shift from purchasing second-hand vessels to building new vessels.

5.2 Finding new sources of capital

The decarbonisation of the domestic maritime sector will be a complex and costly process. Ultimately this cost will be borne by end consumers, but individual businesses will struggle to fund the level of upfront capital investment needed in zero emission fuel production and supply infrastructure, shore power at ports, efficiency improvements to existing vessels, and new vessels that use low or zero emission fuels. Existing channels of financing will be unable to fill the gap and so new sources of capital will be needed. Stakeholders speak consistently of the desire to attract institutional capital to fill this gap. Given this, it is important to understand the nature and potential role of these investors.

Institutional investors are entities that invest in financial and real asset markets on behalf of groups or individuals. Such entities include corporate and state pension funds, insurance companies, sovereign wealth funds and endowments. These investors represent one of the largest pools of capital, with global assets under management valued at over $80 trillion[65]. This capital is often channelled via large global fund/asset managers and smaller specialist fund/asset managers who then invest directly in public equities (stock markets), government and corporate bonds, real estate, infrastructure, and a range of other alternative investments in private markets (Figure 5.1).

Figure 5.1: Institutional investors, assets under management and participation in market



Source: PwC, Consulting UK, Preqin, OECD, Willis Towers Watson, Campden Wealth, P&I (January 2020)

These organisations represent a potential source of capital for projects related to the energy transition, including those in the maritime sector, and the characteristics of such projects *can* align well with the mandates of institutional investors. Investments in infrastructure and long-lived assets can generate returns (and, very importantly, cash flow) over timescales that match the investment horizon of institutional investors with long-term liabilities (e.g. pension funds, insurance companies)[65].

Institutional investors have become increasingly interested in sustainability and ESG-linked investing, and particularly in clean energy projects. There are a number of routes via which these investors can channel capital into green projects, and the manner of their participation varies depending on their mandate, time horizon, return target and risk tolerance.

5.3 How institutional investors deploy capital

5.3.1 Equity investments in companies

Institutional investors acquire equity in both public (via listed equities on publicly traded markets) and private (via direct acquisition) companies. Equity investments can deliver income (through dividends) and the potential for a return on investment gained through the appreciation in value of the company.

Publicly traded equity

Most institutional investors across the world are very large holders of publicly traded equities. This medium of investment benefits from the relative ease of trading, high liquidity, transparent pricing, fast transaction speed, and low internal oversight/resource requirement.

From a company's viewpoint, listing shares on a public stock exchange provides an opportunity to raise capital, but it also comes with some challenges and drawbacks. There are some very large public shipping companies (such as A.P. Moller–Maersk listed on the Danish stock exchange), but most are far smaller. This, plus limited investor appetite for shipping investment to date, means that most publicly listed shipping company shares tend to have low liquidity and usually trade below the value of the underlying assets (vessels). This makes attracting further capital through follow-on share issues (which is considered to be an ongoing benefit to listing) very challenging.

There are also public exchanges that cater to smaller companies and offer more flexible listing criteria and a lower regulatory burden (e.g. AIM in the UK). However, the amount of capital that is typically raised on these exchanges is relatively modest and liquidity can be even more challenging. In addition, the upfront cost of listing and the burden of ongoing public reporting also tends to dissuade shipping companies from this route. Public listing is therefore not a viable option for all but the largest domestic shipowners, but some private port owners (e.g. CK Hutchinson Holdings and, previously, PD Ports) and domestic shipyards (Harland and Wolff, BAE) do have a portion of their stock publicly listed.

Private equity

Institutional investors can acquire equity in a company directly through privately negotiated transactions. These take place across a range of markets, industries, and businesses, and across a wide risk and return spectrum. Investment may involve a complete buyout of ownership or a partial stake in the company. With the latter, the investor may exercise a degree of control over the strategy or operation of the company or elect to be passive. Such transactions are time consuming as the price must be evaluated and negotiated, and the risk is greater as the investor must secure an exit (either through sale or public listing) within their investment horizon. To compensate, the returns from these illiquid transactions tend to be higher.

International shipping companies have historically attracted very modest equity capital from institutional investors as the shipping markets tend to be little understood and therefore easily ignored as a 'niche' asset class. On the other hand, many private ports have been successful in attracting institutional investor capital as these are viewed as infrastructure investments with resilient cash flows and supported by underlying land values. Some of the largest pension funds in the world own several UK ports outright (either solely or in consortia) and other institutional investors have invested indirectly through co-mingled funds managed by fund/asset managers.

5.3.2 *Debt financing*

Institutional investors are also significant participants in debt finance which has historically taken the form of investing in sovereign or corporate debt issued in the form of bonds. However, over the past two decades, either directly or through intermediaries such as fund managers, some institutional investors have expanded into other forms of debt finance including direct lending activities (the form of which depends on their return requirements and risk appetite).

Non-bank debt

Given their long-term liabilities, pension funds and insurance companies are often willing to provide long-term debt finance on attractive terms to discrete projects and against assets which are deemed to have a low risk profile, such as loans to investment grade corporations, or to projects or assets associated with secure long-term cash flows either from an investment grade counterparty or sovereign entity (e.g. for national utilities such as water).

At the other end of the risk scale, the fund/asset managers through which this type of investment is often channelled, also have large pools of co-mingled funds which they deploy across a variety of strategies. They lend to a broader range of entities, assets and projects which are associated with lower credit quality or higher risk, and this is reflected in the lending rates, which tend to be well above those offered by banks.

This type of funding has increased in international shipping in recent years, particularly as the traditional ship-lending banks have reduced their exposure following coinciding downturns in several shipping markets (Figure 5.3). In the domestic sector, smaller ports and shipowners may access private debt (especially when refinancing older vessels by the latter), but uptake is likely limited.

Corporate bonds

Corporations can raise debt finance directly by issuing bonds. These are fixed-income instruments where (most commonly) interest (a coupon) is paid in regular instalments and the loan amount is repaid upon maturity, i.e. the debt is typically non-amortising. The interest rate is linked to the company's credit quality and any security that underpins the bond. Bond durations can range between short (1-3 years) and long (up to 60 years). Depending on credit quality, these instruments can provide a company with lower cost debt than can be accessed through banks, and less cash will be needed to service payments.

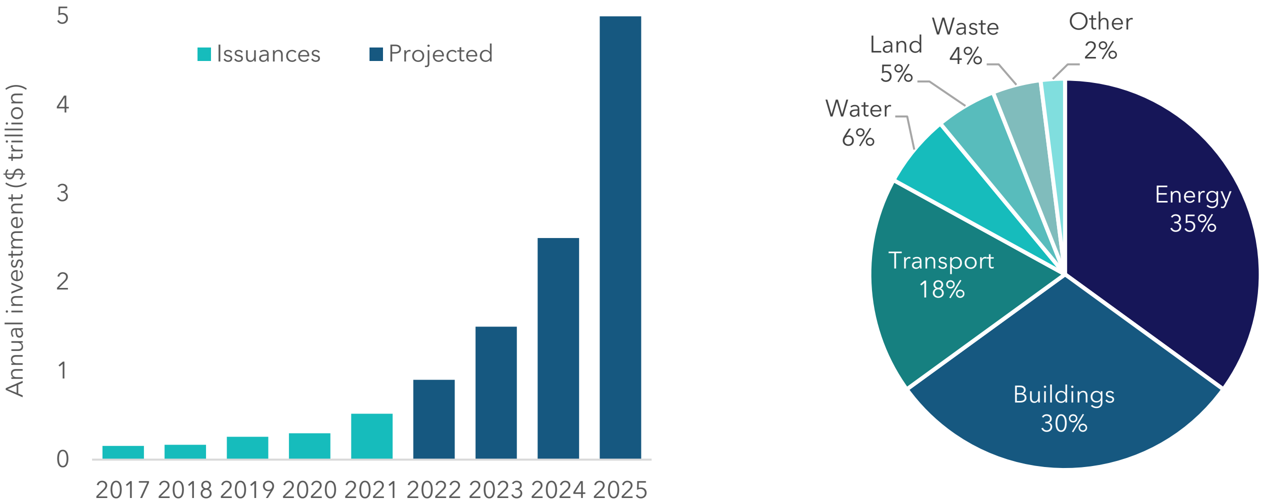
Large, investment grade companies can issue bonds without any associated security on publicly traded exchanges. Corporates of lower quality more often offer bonds secured against assets via a private placement through investment banks. Although these can be traded through secondary markets ('over the counter'), the coupon on these bonds incorporates an illiquidity premium. The stable cash flows associated with fixed income instruments make them attractive to institutional investors, and they typically participate in both types according to their risk appetite.

Given the cost of issuing bonds, in the maritime industry, they are limited to large ports and international shipowners, and are usually offered through private placements. The largest companies may be able to issue unsecured bonds on the strength of their balance sheets, but most will be secured against assets. In the UK, at least one private port (ABP) has issued corporate bonds[66], but this is not an option for all but the very largest ports and domestic shipowners and, even then, the overall cost of finance would be dependent on the underlying assets and security of cash flows.

Corporate green bonds

Green bonds are a form of bonds which can be issued to finance a project that meets specific 'green' criteria or a more general sustainability-linked overall corporate target. These bonds attract investors who have a desire for promoting higher environmental standards and so, in exchange, accept (at least in principle) a lower cost of debt. Green bonds have been very popular in recent years given the greater focus on climate change. In 2021, issuances totalled $517 billion, up from $297 billion in 2020, and are expected to exceed $1 trillion annually in 2023 (Figure 5.2)[67].

Figure 5.2: Historical and projected green bond issuances (left); use of proceeds in 2021 (right)



Source: Climate Bond Initiative[67]

To date, however, only three green bonds have been issued by international shipping companies, all of which have been by large corporate entities (Seaspan, Hapag-Lloyd and FSI). Given their current reliance on fossil fuels, and their role in the transportation of those fuels, shipowners can find meeting the qualifying criteria difficult, even if the funds raised will directly lead to reductions in fossil fuel use (e.g. through retrofitting green technologies). Furthermore, the difference in the cost of funding between green bonds and traditional shipping debt finance is relatively small, particularly when the cost and administrative burden of issuance is included, and this has limited uptake.

5.3.3 Public-private partnerships: funding infrastructure

Public-Private Partnerships (PPPs) are arrangements between a public body (typically government, but also could be a supranational, regional or municipal authority) and the private sector that involve the construction (and sometimes operation) of an asset or some form of infrastructure. There have been many projects, including in the energy and transportation sectors, that have used PPPs.

The arrangements can take a variety of forms, depending on the specifics on the project, but at the core is a mechanism through which a public body mitigates the potentially high risks which institutional investors may be unwilling to bear (e.g. construction, market or residual value risk). The mechanism through which this mitigation is delivered varies by project but could include financing during the construction period and/or guaranteed cash flows post-delivery.

Following construction, infrastructure investments can offer long-term, stable (and sometimes inflation-linked) cash flows. They can be low risk (depending on the counterparty and/or jurisdiction) and typically have low correlation to other assets classes. This makes them attractive to institutional investors, particularly some types of pension funds, given their long-term liabilities and yield requirements.

Institutional investors participate in infrastructure projects both directly and indirectly, via both debt and equity. Indirect investment, through unlisted infrastructure funds or through listed instruments (either listed infrastructure funds or public companies focused on the operation or provision of infrastructure), has historically been a more common investment route. However, in recent years, many of the larger investors have begun investing directly in projects as they have accumulated more experience[68].

Direct participation by institutional investors in renewable energy projects is growing, but such investors tend to be unwilling to commit the internal resources needed to fully understand a market for a one-off investment and will only do so if further opportunities and a pipeline of potential deals of sufficient scale can be seen[65]. Even then, the preference has usually been to avoid construction risk and only enter when the project is operational. However, declining bond yields over the past few years have seen some institutional investors more prepared to offer project-based finance over the construction phase[68].

In the UK, institutional investors participate both directly and indirectly in offshore wind projects. Given the scale and speed of funding needed by the energy transition, institutional investors will have a role to play in financing future renewable energy and zero emission fuel production projects. However, given their low risk tolerance, such transactions will need to be suitably structured and supported by other entities (which could include government) to mitigate the relevant commercial risks and thus enable investments to proceed.

5.3.4 Real asset ownership

As well as participation through debt financing and equity stakes in companies, institutional investors also invest in real assets. This can take the form of investment in vehicles that lease the asset to a company which then operates it, investment in vehicles that own and operate the asset, or the direct ownership (and potentially management) of the asset by the investor.

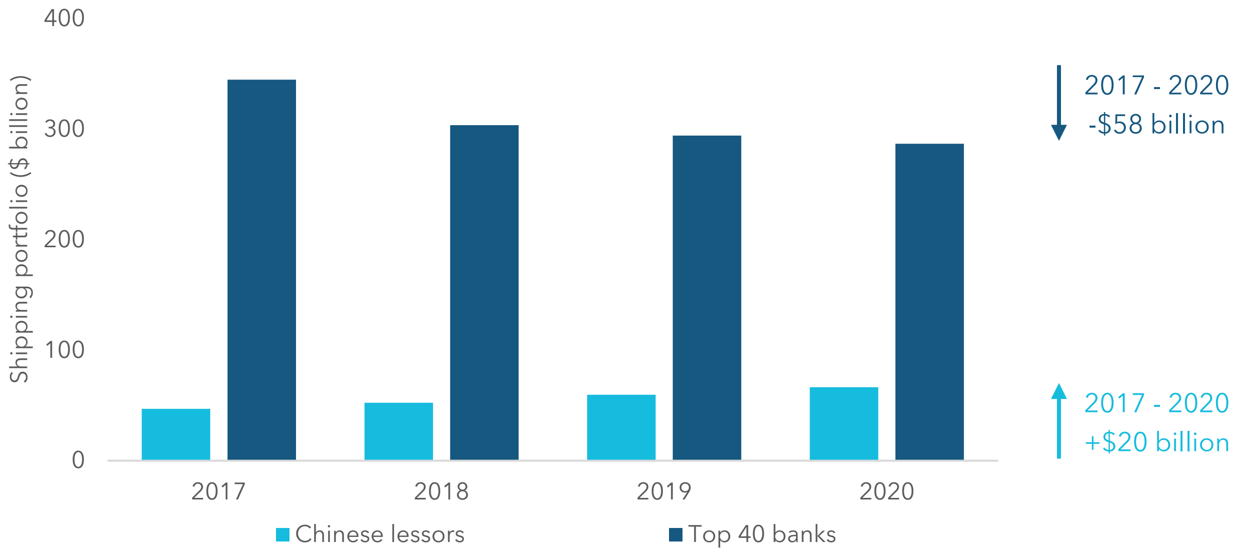
Asset leasing

Leasing is a financial tool which is used in many real asset markets including real estate, aviation and rolling stock. Rather than own an asset outright, a company (the lessee) will lease it from an owner (the lessor) for a period of time. This is an alternative source of finance, and the lessor is usually a financial institution such as a bank, fund manager or (increasingly) a specialist leasing entity. A lease can be used for both new and existing assets.

The lease is a long-term arrangement wherein the lessor finances the purchase of an asset and hands it over to the lessee who is responsible for its operation and maintenance. The lessee then pays the lessor a fixed payment to cover capital and interest on the finance over the duration of the lease. All the risks and rewards of ownership of the asset are transferred to the lessee and sit on the lessee's balance sheet (as a 'right-to-use' asset offset by a debt obligation). Such leases invariably contain a 'hell or high water' clause which means the lessee cannot terminate the lease or fail to make the lease payments. If the lease is terminated early, the lessee must compensate the lessor (in principle by reimbursing all future payments).

With the withdrawal of many traditional ship-lending banks, leasing, particularly from Chinese lessors, became more prevalent in international shipping (Figure 5.3). Depending on the security package (e.g. an associated long-term charter), the terms of leases can be very attractive. The leverage tends to be higher and the tenor longer (which can help mitigate debt servicing costs) than can be achieved through traditional banks. A 'sale and leaseback' is a common tactic through which companies can raise cash from existing vessels in their fleets, particularly during times of cyclical lows in the shipping markets. Leasing helps owners preserve liquidity and (re-)purchase options give them flexibility to (re-)acquire leased vessels or to invest in new projects by selling on the vessel at a profit.

Figure 5.3: Aggregate lending by top 40 ship-lending commercial banks and Chinese lessors, 2017–2020



Source: Petrofin Research[69]

The leasing market in international shipping is dominated by Asian lessors (particularly Chinese, and to a lesser extent, Japanese) and functions partly as support for domestic shipbuilding industries. There is also a small number of commercial shipping companies which specialise in leasing activity, sometimes operating the asset on behalf of the lessee.

Some countries have tax schemes which offer concessions to qualifying lessors such as deferring their corporation tax liability. Often these come with a range of strict qualifying criteria to provide some boost to the domestic market while trying to limit any potential abuse of the structure.

In domestic shipping, there is effectively no appetite from the existing lenders for commercial asset leasing. The most obvious exception, however, is seen in Scotland, where ferries are leased by an operating company (CalMac Ferries Ltd) from an asset-owning company (Caledonian Maritime Assets Ltd, CMAL). Both companies are owned by the Scottish government which ultimately subsidises the ferry services, but the ownership and operation of the vessels is split to facilitate a competitive tendering process (Serco Group plc operates ferries CMAL ferries from the north and north-east of Scotland to Orkney and Shetland)[70].

Elsewhere in the domestic fleet, there is some evidence of asset leasing to large shipowners for ferries, Ro-Ros, and offshore vessels, but it is more commonly seen in the short sea fleet. The very limited presence of asset leasing in the domestic fleet can be ascribed to the fact that the sector as a whole is small, and the individual companies themselves are too small and of too low credit quality (long-term charters to offer security are rare), to encourage traditional commercial banks to offer high-leverage leasing products or to attract specialist leasing companies to enter the market.

5.4 Mobilising institutional investor participation

5.4.1 Key barriers to participation

Institutional investors represent a huge pool of capital that is channelled into companies, infrastructure projects, and real assets, both directly and indirectly, through both debt and equity. This source of capital could help fund the investment that will be needed for domestic maritime, and the energy system that fuels it, to transition to net zero. However, there are numerous challenges in the domestic maritime sector that hinder the participation of institutional investors (Table 5.1). These will need to be overcome through appropriate government support to mobilise the inward flow of this capital. Helping this private capital to overcome these barriers will be a key factor in encouraging its participation.

Table 5.1: Barriers and risks to institutional capital providers participation in the domestic maritime sector

	Shipping	Ports	Clean maritime technologies
Familiarity with sector	Low familiarity and often negative impression	Large institutional investors more familiar with industry	Low familiarity
Access to sector	Medium in international shipping but low in domestic	High (many have invested directly or indirectly through investment funds)	Low
Ability to deploy significant capital (scale of market)	Depends on sector. Low in domestic market	High	Low initially but can increase over time
Risk premium sought	Yes	No	Yes
Residual value and stranded asset risk	Yes, given fuel and regulatory uncertainty	To some extent, but less acute than in shipping	Yes, given technologies and markets and are nascent
Credit risk	High as many companies are relatively small	Relatively low	High as many companies are relatively small/early stage

Source: Marine Capital

Familiarity with the sector

The maritime industry is generally poorly understood by the institutional investment community and most providers of private capital have little familiarity with the sector. The general impression of the industry is typically negative, informed by press articles which tend to focus on the more sensational stories from the shipping markets. This leads many capital providers to form an initial view that the entire industry is unsuitable for investment. Ports are the exception to this, and several institutional investors have made significant investments in major UK ports.

Access to the sector

None but the largest institutional investors have the capacity to build the internal resources and skills needed to oversee direct investment in specialist areas, and even then, a lack of day-to-day participation in those markets may mean they are unable to access investment opportunities. If there is an operational element to the investment, then the investor may need to engage an operational partner. Therefore, such investments are usually made indirectly via the fund/asset management industry which acts as a conduit to channel capital into asset classes such as 'alternative investments' (anything other than traditional equity and bond investments), real assets (including real estate), and infrastructure. This has helped fuel large-scale investment in ports and renewable energy projects.

Large, general fund/asset managers have invested directly in international shipping companies and assets (vessels), on both the debt and equity side, but few have in-depth, specialist knowledge of the industry and, again, may need to engage the services of an operating partner. There are some specialist shipping fund/asset management firms that operate globally, but they are relatively small and are focused on international shipping. It may be difficult for domestic shipping to attract the scale of private market investment that other real asset markets have achieved unless shipping as a whole can successfully develop in tandem its fund/asset management industry.

Scale of investment

Institutional investors are typically large and consequently will only consider individual investments in specialist sectors that are large enough in scale to justify the time and effort required to understand the investment opportunity, and for that investment to have a meaningful impact on their overall return. Investments in ports and renewable energy projects can provide this, but it is difficult to find that scale elsewhere in the domestic maritime sector as it is characterised by small shipowners whose individual projects are relatively modest. A pooled structure, if it could be developed, might provide a solution to this problem.

Undue risk premium

Lack of familiarity with the shipping markets leaves many private investors unable to accurately assess the risks associated with shipping investments relative to markets with which they are more familiar. As a result, investors tend to demand a 'risk premium' (i.e. require a higher rate of return) for participating in shipping investments and the underlying project (particularly in the domestic maritime sector) may be unable to support this cost of capital. This tends not to apply to port-related investments where institutional investors now have a high degree of familiarity with the market.

Residual value, stranded asset and technology risk

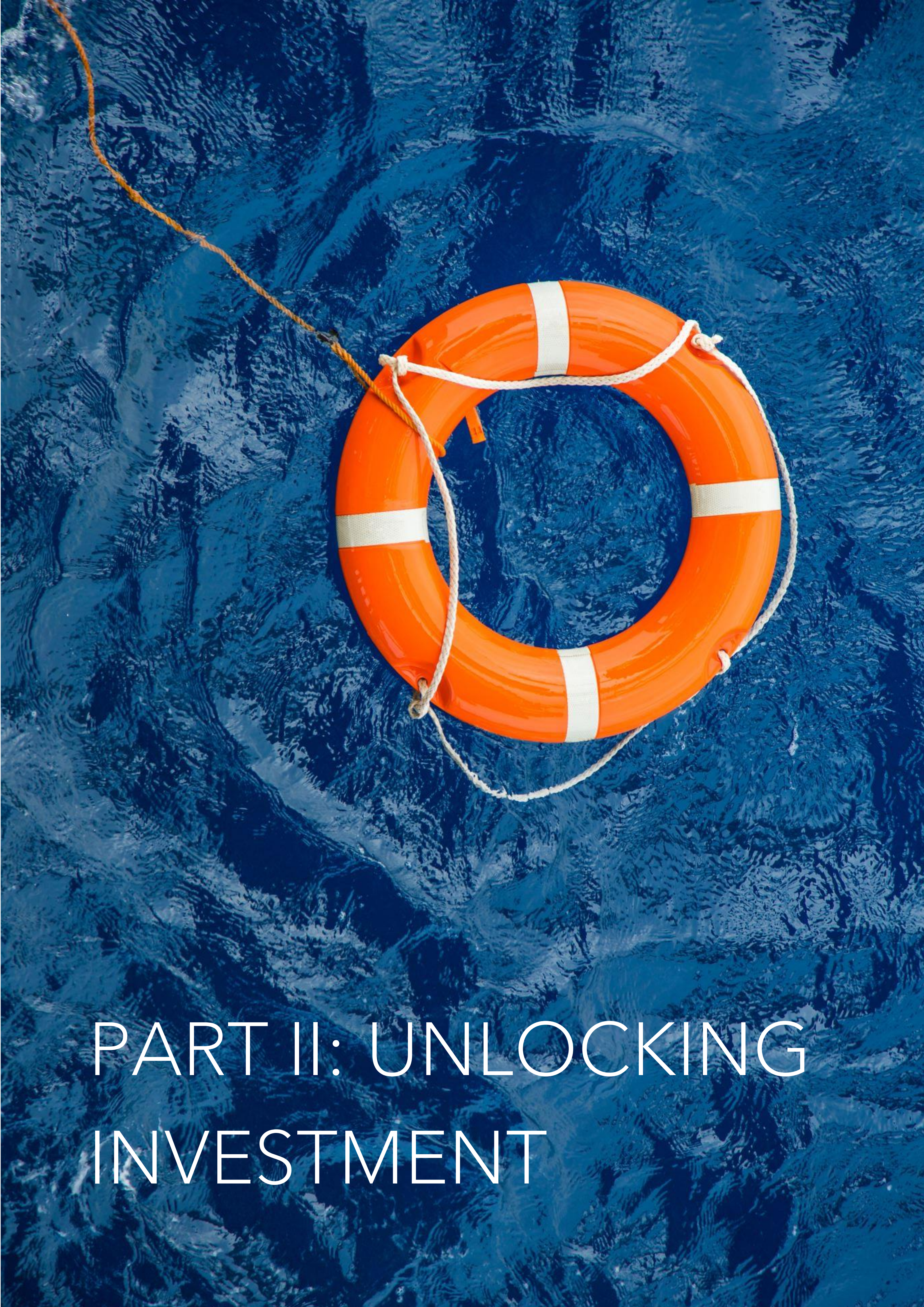
When investing in real assets and infrastructure, institutional investors favour investments with long-term secure cash flows and very little or no residual value risk, particularly in unfamiliar industries. In the domestic maritime sector, only a few segments have the security of long-term charters (e.g. government-backed lifeline ferry services or offshore wind farm maintenance vessels), but long-term employment is not available for most vessels.

Institutional investors will also be cautious about any potential exposure to stranded asset risk resulting from the energy transition. Given the uncertainties regarding future zero emission fuels and clean maritime technologies, the risk of an uneconomic operating environment may be perceived as higher during the energy transition. The risks inherent in new, early-stage technologies also make investment in companies producing innovative clean maritime technologies challenging.

Creditworthiness

Where the counterparty is the government (e.g. the Scottish government-backed lifeline ferries), then credit quality is assessed in terms of sovereign risk and the cost of capital is correspondingly low. Lower capital costs are also associated with projects underpinned by the UK government in some form (e.g. offshore wind farm tenders). Devolved governments and local authorities have stronger credit quality than corporations, so can also raise funds at lower cost.

However, the relatively small size of many domestic ports, shipowners, shipyards and maritime equipment manufacturing companies impairs their (perceived) credit quality. As a result, funding is harder to raise for these companies, and even when capital can be obtained, the cost of capital offered will be high. The predominance of small firms with poor credit quality is a key barrier to private capital entering the domestic maritime sector.



PART II: UNLOCKING INVESTMENT

Regulatory and Policy Environment

It is important to understand what influence each regulatory regime has and how policies related to decarbonisation may affect domestic and short sea vessels.

Vessels in the domestic and short sea fleets may be subject to different regulatory regimes: that of the International Maritime Organization, the EU, and the UK.

6.1 How is shipping regulated?

International shipping is overseen by the International Maritime Organization (IMO), a specialised agency of the UN with global responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by vessels. The IMO's main role is to create a regulatory framework for the shipping industry that covers the design, construction, manning, operation, and disposal of vessels. Governments that accept IMO legislation incorporate it into national law and then enforce as a Flag State (for vessels registered to that country), as a Port State (for vessels visiting that country), and as a Coastal State (within territorial waters).

The IMO's focus is directed at international shipping, leaving individual countries to regulate domestic vessels. Globally, over 70,000 vessels (more than 98% of the world's merchant shipping tonnage) are covered by some form of IMO regulation[71]. The IMO has estimated that approximately half a million vessels with AIS tracking operate domestically (although not all these will be commercial), and smaller vessels without AIS likely number several million[59].

Different IMO instruments apply to different vessels based on type and size (using metrics such as gross tonnage, deadweight tonnage, vessel length or passenger carrying capacity), but these criteria do not categorically define whether a vessel is international or domestic. Vessels that operate exclusively on domestic voyages are exempt from certain IMO instruments and national legislation fills in the gaps for these vessels, as well as the vessels that fall entirely out of the scope of IMO's remit.

In addition, the EU has been inserting its own maritime regulation between its member states' national legislation and the IMO's international rules and standards since the 1990s[72]. Therefore, depending on type, size, and trading profile, vessels in the UK's domestic and short sea fleets may be subject to IMO, UK-specific, and/or EU-specific maritime regulation. For shipowners caught by multiple regulatory regimes, the reporting burden and associated cost of compliance will be higher. For regulatory authorities, any disparity between the regimes could encourage regulatory arbitrage, particularly if cost avoidance is possible.

6.2 Measures to promote decarbonisation

There are a number of measures that policy makers can employ to compel and/or support the transition of the domestic maritime sector to net zero, and each tool offers a different approach to overcoming the barriers to decarbonisation (Table 6.1). These broadly split out into two types: direct regulation (also known as command-and-control measures) and economic instruments (also known market-based measures)[44].

Regulation can oblige stakeholders to take certain steps or to meet certain targets. It can be directed at the shipping industry, at maritime fuel suppliers, or at ports. Regulation is typically a blunt instrument, but as such, ensures a level playing field across a shipping sector or class of vessel.

Economic instruments can help overcome the critical commercial hurdles caused by market failures. These measures include fiscal incentives (subsidies, rebates) and disincentives (levies, ETS) that can contribute towards bridging the price gap between conventional fuels/technologies and zero emission alternatives, and subsidies that can offer targeted support where needed.

Table 6.1: Types of measures that could assist in decarbonising the maritime industry

Approach	Tool	Examples of types of measures
Direct regulation	Performance standards (mandate a particular goal but not approach)	- Technical efficiency targets on vessel designs - Operational efficiency targets for vessels/shipowners
	Technology standards (mandate a particular approach but not a goal)	- Mandating shore power usage - Banning or limiting use of certain types of fuels - Emission data collection/reporting requirements
	Product standards/specification	- Stipulating the carbon content of fuels
Economic instruments	Emission taxes and levies (price set by regulator; market determines emissions reduction)	- Fuel duties - Feebate system (a fee on emissions over a benchmark; rebates for emissions below the benchmark)
	Emission trading schemes (ETS) (emissions target set by regulator; price determined by market)	- Cap-and-trade schemes (emissions allowances capped and traded to set price; allowances reduced over time) - Baseline-and-credit schemes (credits which can be traded are issued when emissions are below a baseline)
	Subsidies	- R&D subsidies - Fuel subsidies - CAPEX subsidies (vessels or fuel/energy infrastructure) - Direct procurement/provision of public goods & services

Source: Based on the typology used by the Getting to Zero Coalition[44]

These tools can be used in combination (often described as a 'carrot and stick' approach) to ensure that the challenges to decarbonisation are tackled from multiple standpoints. Complementary measures can be introduced simultaneously to address demand and supply side issues. Policies can also be targeted so that segments that are harder to abate receive help to do so, thereby creating a more effective, efficient and equitable transition.

6.3 Policies proposed by the IMO and EU

6.3.1 IMO approach: improving technical and operational efficiency

In 2018, the IMO set out its initial strategy for cutting greenhouse gas emissions from international shipping. This was formed around the goals of reducing carbon intensity by at least 40% by 2030 and by at least 70% by 2050, and absolute emissions by at least 50% by 2050 (compared with 2008 levels). While the IMO had been mandating improved energy efficiency in the designs of new vessels since 2013, new measures were introduced in 2018 to improve the technical and operational efficiency of new and existing vessels (Table 6.2).

Table 6.2: IMO's mandatory measures on merchant vessels undertaking international voyages

IMO measure	Requirement	Effective	Applicable vessel size
Energy Efficiency Design Index (EEDI)	Requires that newbuild vessels meet minimum (and tightening) fuel efficiency standards	2013	Calculated > 400 GT but size at which applied varies
Data Collection System (DCS)	Requires that shipowners collect and report annual fuel consumption data to the IMO	2019	> 5,000 GT
Energy Efficiency eXisting ship Index (EEXI)	Requires that existing vessels meet a minimum energy efficiency standard	2023	Calculated > 400 GT but size at which applied varies
Carbon Intensity Indicator (CII)	Requires that vessels meet a minimum (and tightening) level of operational efficiency	2023	> 5,000 GT

Source: IMO[73]

These measures cover vessels carrying either cargo or passengers (called merchant or trading vessels) on international voyages. Domestic merchant vessels and all non-merchant vessels (such as offshore support vessels, fishing vessels, tugs, etc.) are exempt. So far, the primary target of these measures has been deep sea cargo shipping which, due to vessel size, distance sailed, and weight of goods carried, accounts for the largest proportion of greenhouse gas emissions. Smaller vessels, which are more likely to operate on short sea routes, are currently excluded based on vessel type and size[73].

The operational efficiency measure (CII) applies to vessels larger than 5,000 gross tonnes, a cut off which captures approximately 85% of total emissions from international shipping[71]. Although the technical efficiency measures (EEDI/EEXI) require vessels over 400 gross tonnes to calculate an energy efficiency value, only larger vessels are required to meet a target[73]. Figure 6.1 shows the estimated number of vessels from the domestic and short sea fleets that will be caught under these regulations, and the volume of greenhouse gases these vessels emit on domestic and short sea voyages.

As can be seen, there is little reach by IMO regulation into the UK's domestic fleet, but approximately 300 vessels (30%) of the short sea fleet will be affected, particularly in the ferry/Ro-Ro segment. For existing vessels, EEXI requires a one-off action to enable vessels to comply. However, EEDI will have an ongoing impact, requiring that new vessels are built to increasingly efficient standards over time. This could be an issue for Ro-Ros, given non-standardised vessel design (as each is typically built to optimise performance on a route-specific basis), meaning that achieving the emissions reduction targets through the technical improvements accepted by the current EEDI framework could be challenging[74].

Similarly, the ongoing improvement in operational efficiency mandated by CII could also prove difficult to implement for some Ro-Ros. Targeted levels of efficiency are based on the average of historical values from all applicable vessels, an approach that works well in segments with homogenous vessels. Given the diversity in vessel type and operating profile seen in the Ro-Ro segment, the wide dispersion in the efficiency of individual vessels means that there are many currently operating well above the average. Setting a uniform target across such a diverse segment will likely create a challenge for a portion of the fleet, particularly as the options to improve the operational performance of such vessels are relatively limited.

Figure 6.1: Estimated number of vessels and emissions affected by EEDI/EEXI or CII regulation in the domestic and short sea fleets

Source: IMO[73], UMAS FUSE[16] data
Note: Based on the assumption that vessels spending more than 90% of operating time on UK-UK voyages are exclusively domestic and thus are exempted from EEDI/EEXI and CII regulation

The IMO's current trajectory on EEDI and CII is set until 2026, whereupon it will review progress. In the meantime, other potential mid-term measures such as a fuel standard and economic instruments will be assessed[75]. The IMO's approach to decarbonisation thus far has followed its original mandate (i.e. drafting technical and operational regulation to improve vessel efficiency). Although the shift to developing and potentially deploying economic instruments would entail a change of that mandate, the organisation is increasingly focused on assessing such options and progress on a basket of mid-term measures is expected to be announced by mid-2023[76],

6.3.2 EU approach: proposed basket of policies to tackle range of barriers

A number of major accidents involving passenger and cargo vessels at the end of the 1990s and early 2000s prompted the EU to coordinate maritime safety policy across the region and introduce measures to bolster IMO regulation[77]. The European Maritime Safety Agency (EMSA) was established in 2002 to assist in this task. In 2007, the EU moved beyond aligning maritime safety policy and launched the Integrated Maritime Policy (IMP), a framework which integrated the national maritime policies of its member states and coordinated maritime and coastal initiatives across Europe[78].

In 2013, the European Commission set out a strategy to reduce maritime greenhouse gas emissions[79]. This led to the introduction of a data collection system (the EU Monitoring, Reporting and Verification system, EU MRV) which, from 2019 onwards, has required all merchant vessels over 5,000 gross tonnes calling at EU and European Economic Area (EEA) ports to report on greenhouse gas emissions. The EU MRV is similar to the IMO Data Collection System, but there is slight variation in the types of vessels covered and the data reported[80].

The 2013 strategy also signalled the EU's readiness to employ economic instruments on a regional basis, if not pursued by the IMO at the global level. This was realised in 2021 when the European Commission put forward the 'Fit for 55' package, so named for its aim to reduce greenhouse gas emissions in Europe by at least 55% (compared with 1990 levels) by 2030. Recognising that the maritime sector faces multifarious barriers to decarbonisation, the EU has proposed a basket of policies combining economic instruments and direct regulation to support the transition (Table 6.3).

Table 6.3: Proposed policies and intended start dates from EU's 'Fit for 55' package which affect maritime

EU policy	Summary	Effective
Inclusion of maritime in EU ETS	- The EU's 'cap and trade' system where shipowners will need to buy allowances to cover CO_2 emissions from vessels	2023
FuelEU Maritime	- Measure mandating a (reducing) limit to carbon intensity of marine bunker fuels and obliging the use of shore power	2025/2030
Alternative Fuel Infrastructure	- Targets for LNG supply infrastructure at major ports - Targets for shore power provision at all ports receiving large vessels	2025/2030
Renewable Energy Directive	- Targets reduction in greenhouse gas intensity from transport of 13% by obliging fuel suppliers to increase share of renewable sources - Allows for advanced biofuels and renewable fuels of non-biological origin used in maritime to be considered at 1.2x their energy content	2030
Energy Taxation Directive	- Aims to end tax exemption for conventional marine fuels within EU - Proposed tax exemption on electricity supplied from shore power	2023

Source: European Parliament[81]

While agreement on the general approach of the 'Fit for 55' package was reached at the end of June 2022, negotiations between the European Council, European Parliament and the European Commission must conclude before the legislation is adopted[82].

Inclusion of the maritime sector in the EU ETS

The EU's Emissions Trading System (EU ETS) is a 'cap-and-trade' scheme wherein companies must buy or trade allowances to cover their emissions each year. The cap on total allowances reduces year-on-year (currently by 2.2%) and market forces set the cost of the allowances (i.e. the carbon price)[83]. The system initially targeted power generation and energy-intensive industries, and later aviation (covering flights within the EEA). The extension of the EU ETS to cover the maritime sector will affect domestic, regional and international shipping to, from and within Europe.

Currently, the proposal covers carbon dioxide emissions from all merchant vessels above 5,000 gross tonnes on the following basis:

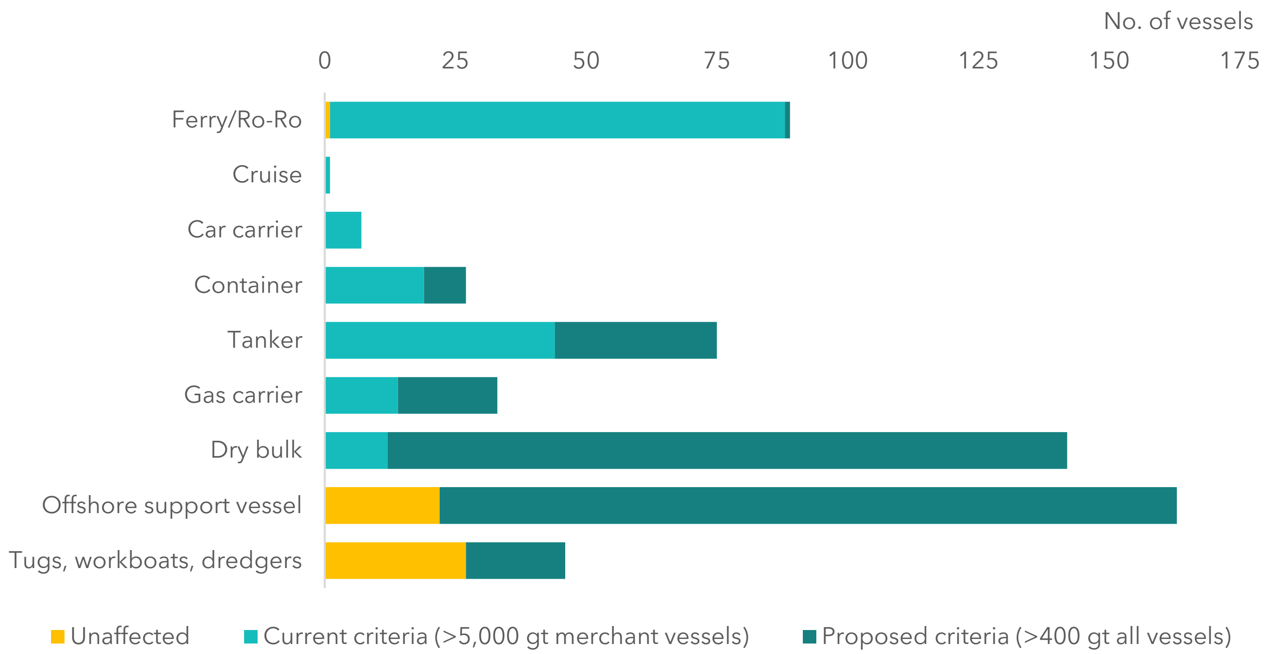
- 100% of emissions from intra-EU voyages and while berthed at port
- 50% of emissions from extra-EU voyages (i.e. to/from ports outside the EU)

The EU has proposed to phase the scheme in gradually, rising from 20% of emissions in 2023 to 100% from 2026 onwards. It has also indicated that 75% of revenues generated by the ETS from the shipping industry will be put into an Ocean Fund to support the decarbonisation of the maritime sector[84]. However, the policy is still being negotiated and adjustments are being considered, including:

1) Delaying implementation to 2024
2) Removing the phase-in period
3) Extending the EU ETS to cover 100% of extra-EU voyages
4) Including other greenhouse gases (e.g. methane) and possibly black carbon
5) Eventually requiring non-merchant vessels and vessels as small as 400 gross tonnes to participate (from 2027 has been suggested)

In its current form, the coverage of the EU ETS on the domestic and short sea fleet largely mirrors that of the IMO's CII regulation, mainly affecting the Ro-Ro and tanker segments. However, should the scope of the EU ETS be widened, more vessels will be caught by the regulation, particularly in the dry bulk (bulk carriers and general cargo ships) and offshore segments (Figure 6.2).

Figure 6.2: Estimated number of vessels in the short sea fleet affected by alternative proposals for EU ETS regulation (excluding fishing)



Source: European Parliament[84], UMAS FUSE[16] data

The extension of the EU ETS to vessels below 5,000 gross tonnes would cover a much wider group of owners. Although smaller vessels do not necessarily correlate to smaller owners, overlap is likely given the relationship between the size and the capital cost of vessels. These smaller shipowners will need to join the EU MRV system and participate in auctions and/or trade for allowances, bringing an unaccustomed administrative burden and unknown financial obligations.

Where the shipowner is not responsible for the operation of the vessel (i.e. when chartered by another entity), the EU has acknowledged the challenge of passing through the cost of allowances to the charterer and has proposed introducing binding clauses to allow shipowners to do so[85].

Impact of other EU Fit for 55 policies

The proposed FuelEU Maritime regulation will mandate the carbon content of marine bunker fuels used by vessels calling at EU and EEA ports. By setting a maximum limit on the carbon intensity of these fuels, the regulation aims to generate demand for renewable and low-carbon fuels. The limit will be reduced over time, starting with a 2% reduction in 2025 (compared with 2020), 6% by 2030 and 75% by 2050[81].

This regulation also stipulates that from 2030, container ships and passenger vessels not using zero emission fuels must use shore power while at berth *if available* (an exemption that will be curtailed from 2035). Penalties from non-compliance levied against shipowners will feed into the Innovation Fund and will be used to finance the production of renewable maritime fuels and other decarbonisation initiatives into the maritime sector[81].

To an extent, FuelEU Maritime mirrors the current scope of the EU ETS: it applies to merchant vessels above 5,000 gross tonnes and the carbon intensity target will apply to 100% of the fuel used on voyages between and at EU and EEA ports, and 50% of the fuel used by vessels arriving to/departing from the region[86]. However, the EU ETS assesses the carbon intensity of fuels on a 'tank-to-wake' basis, while FuelEU Maritime will adopt a full lifecycle approach ('well-to-wake'). The FuelEU Maritime regulation will also be a more challenging measure to implement as it will require the carbon intensity of marine bunker fuels acquired outside of the EU to be verified.

The 'Fit for 55' maritime policies have been devised to complement one another, obliging and supporting change on both sides of the supply-demand equation. For example, the Alternative Fuels Infrastructure Directive will require ports to provide the shore power that FuelEU Maritime dictates that vessels use. However, the interaction between these policies could potentially result in increased adoption of LNG as a marine bunker fuel due to combined pressure from the EU ETS, FuelEU Maritime and Alternative Fuels Infrastructure Directive.

That said, by introducing a comprehensive policy package, the EU will have the necessary tools in place, and these can be expanded in the future as needed.

6.4 Maritime decarbonisation initiatives in the UK

6.4.1 Development of a maritime decarbonisation strategy

At the start of 2019, the UK government published Maritime 2050, its strategic vision for the future of the UK's maritime sector. Recommendations included conducting assessments of 1) how economic instruments could support the transition to zero emission in the medium to long term, and 2) the merits of introducing a medium-term target for emissions of GHGs and air quality pollutants from UK shipping[5].

The Clean Maritime Plan, launched six months later, reiterated the commitment to explore the case for economic instruments and mandatory targets, with a review of progress to be delivered in an update of the Clean Maritime Plan in 2022 (now expected in 2023). It also drew a clear distinction between the role of decarbonisation-related regulation in domestic versus international shipping. While the use of direct regulation would be considered for the former, the UK government's preferred approach to promoting decarbonisation in international shipping is to advocate for ambitious targets and measures at the global level via the IMO[6].

Published in July 2021, the Transport Decarbonisation Plan made further commitments to help accelerate maritime decarbonisation[87]. These included the creation of the UK Shipping Office for Reducing Emissions (UK SHORE) to develop and oversee decarbonisation measures, and a consultation on shore power (steps to support and, if needed, mandate uptake). Another key commitment was the launch of 'Course to Zero', a broad consultation on the technical, operational and policy options available for government to achieve net zero by 2050. The outputs from this will feed into the refresh of the Clean Maritime Plan and help inform indicative targets to be introduced from 2030[10].

In March 2022, UK SHORE was launched in conjunction with a refreshed National Shipbuilding Strategy which seeks to create a 'globally successful, innovative and sustainable shipbuilding enterprise'. This strategy covers domestic shipbuilding and maritime supply chain, with policy aims to boost UK manufacturing capacity, skills, and competitive advantage (particularly in clean maritime technologies). A proposed Home Shipbuilding Credit Guarantee Scheme which could guarantee up to 80% of the purchase price of a UK built vessel for a domestic shipowner was announced as part of the strategy[9].

6.4.2 Inclusion of maritime in existing regulatory tools

Since the release of the Clean Maritime Plan, the UK government has consulted on the inclusion of domestic maritime in two existing regulatory tools: the Renewable Transport Fuel Obligations Order (RTFO) and the UK Emissions Trading Scheme (UK ETS).

Renewable Transport Fuel Obligations Order

The RTFO is an economic instrument that requires large fuel suppliers to prove that a proportion of the fuel they supply comes from renewable and sustainable sources (sustainably produced biofuels and synthetic fuels of non-biological origin made using renewable energy sources). Suppliers that comply claim a Renewable Transport Fuel Certificate (RTFC) which can be traded; those that do not must buy out their obligation. There is currently alignment between the RTFO and the EU's Renewable Energy Directive[88].

The findings from the consultation led to the decision in April 2021 to expand the RFTO to include renewable fuels of non-biological origin (RFNBO) such as hydrogen made from renewable energy for the maritime industry. Such fuels qualify for double the number of RTFCs. This measure is intended to support the development of fuels made from renewable energy, but in recognition that the ability of industry to provide such fuels is yet to be developed and that demand is currently very limited, it has not been accompanied by an obligation on marine fuel suppliers to supply a percentage of RFNBOs as part of their overall fuel mix[32].

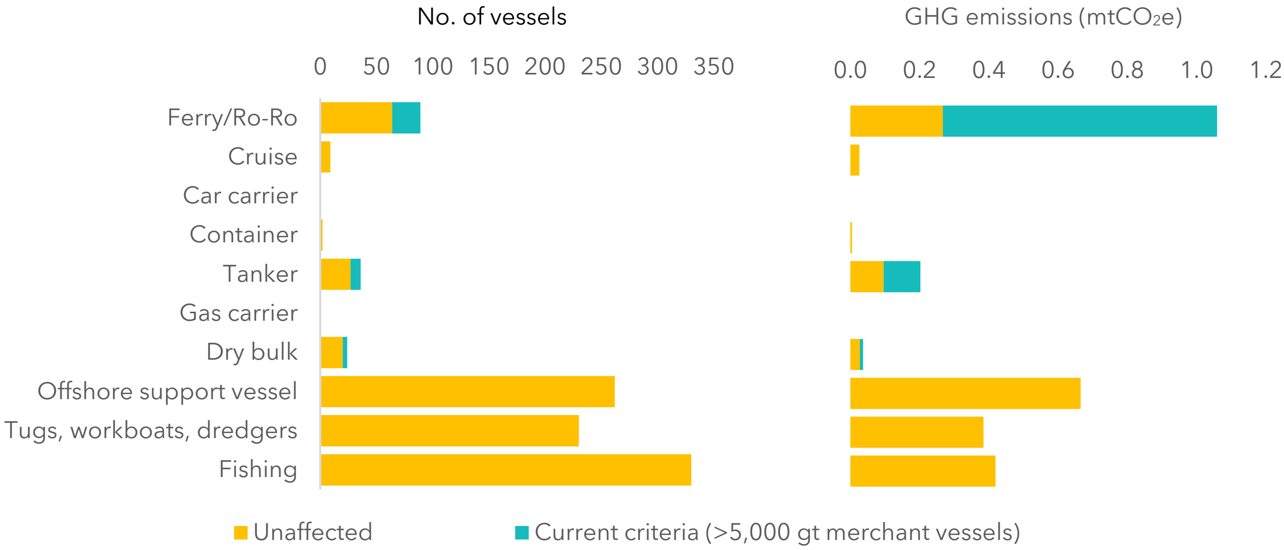
UK Emissions Trading Scheme

The UK ETS came into operation at the start of 2021 following the UK's departure from the EU ETS. The maritime sector is not currently covered by the UK ETS, but a consultation on its inclusion from the mid-2020s was launched in March 2022. The proposal is for the UK ETS to cover domestic shipping only, with emissions from international shipping addressed through support of the IMO's efforts.

Alternative methods of application have been suggested. The government's preferred option is to define domestic shipping on an activity basis (i.e. based on emissions from voyages between UK ports) and to target merchant vessels over 5,000 gross tonnes. This would align with the scope of the UK MRV which launched at the start of 2022. Alternative options being considered are to apply the UK ETS to the suppliers of marine bunker fuels to the domestic maritime sector, or a hybrid approach[89].

The preferred option would capture all merchant vessels larger than 5,000 gross tonnes sailing between UK ports, including vessels which spend less than half their operating time on those voyages (i.e. vessels that are not in the domestic fleet). Where such vessels are making stops at multiple UK ports as part of a longer haul route, the UK ETS may result in trade routes changing so that only a single port in the UK is visited. The domestic fleet, however, will be less able to avoid the UK ETS by shifting trading patterns. Although the UK ETS will affect relatively few vessels within the domestic fleet (approximately 40), it does cover almost half of the emissions (Figure 6.3).

Figure 6.3: Estimated number of vessels and emissions from the domestic fleet affected by current proposal for UK ETS regulation



Source: BEIS[89], UMAS FUSE[16] data

A small number of ferries/Ro-Ros and tankers will be the main vessels in the domestic fleet covered by the UK ETS under the preferred option, with the former accounting for the greatest proportion of greenhouse gas emissions. Most of these ferries and Ro-Ros operate in Scotland and between the UK mainland and Northern Ireland. This latter route could be put under pressure, with vessels potentially rerouting to the Republic of Ireland, if there is significant divergence between EU ETS and UK ETS prices.

The EU ETS and UK ETS, as currently proposed, differ on the inclusion of emissions from international voyages. As currently proposed, the EU ETS intends to cover 50% of emissions from international voyages (including to and from the UK); the UK ETS plans to exclude international voyages entirely. This means that vessels sailing between the UK mainland and Northern Ireland would be subject to 100% of the UK ETS, while those sailing to the Republic of Ireland would be subject to 50% of the EU ETS. The relative cost of the UK ETS and EU ETS will be only one of the factors determining the economics of trade flows, but it may lead to shipping capacity shifting away from routes to Northern Ireland.

If the UK ETS and EU ETS do not align with one another, wider shifts in vessel routing across Europe could be seen. This includes evasive port calls (i.e. using the UK as an initial/final stop on calls to EU and EEA ports to limit exposure to the EU ETS) and, if the EU ETS scope is widened to cover non-merchant and/or smaller vessels, a shift in vessel deployment on certain routes. Such regulatory arbitrage could lead to a rise in overall emissions by increasing sailing distances and/or result in more road traffic to redistribute trade if vessels reduce the number of port calls.

In response to any perceived potential gaming of the system, the EU could subject 100% of UK-EU voyage emissions to the EU ETS. However, while this would help prevent trade migration between the UK mainland and Northern Ireland/the Republic of Ireland (barring a material and persistent divergence in price between the EU ETS and UK ETS), it would not prevent the UK from being used for evasive port calls for avoidance of the EU ETS. This could be solved either by the EU extending its classification of qualifying voyages beyond last/next stop or by the UK extending its ETS to cover international voyages.

The UK's sixth Carbon Budget (which runs from 2033 to 2037) will include the UK's share of greenhouse gas emissions from international shipping for the first time[90]. While the UK's current position is to support IMO measures to reduce emissions from international shipping, depending on the regulatory trajectory of the IMO, the UK may consider including emissions from international voyages within the UK ETS in the lead up to 2033, or earlier if a phased-in approach is preferred.

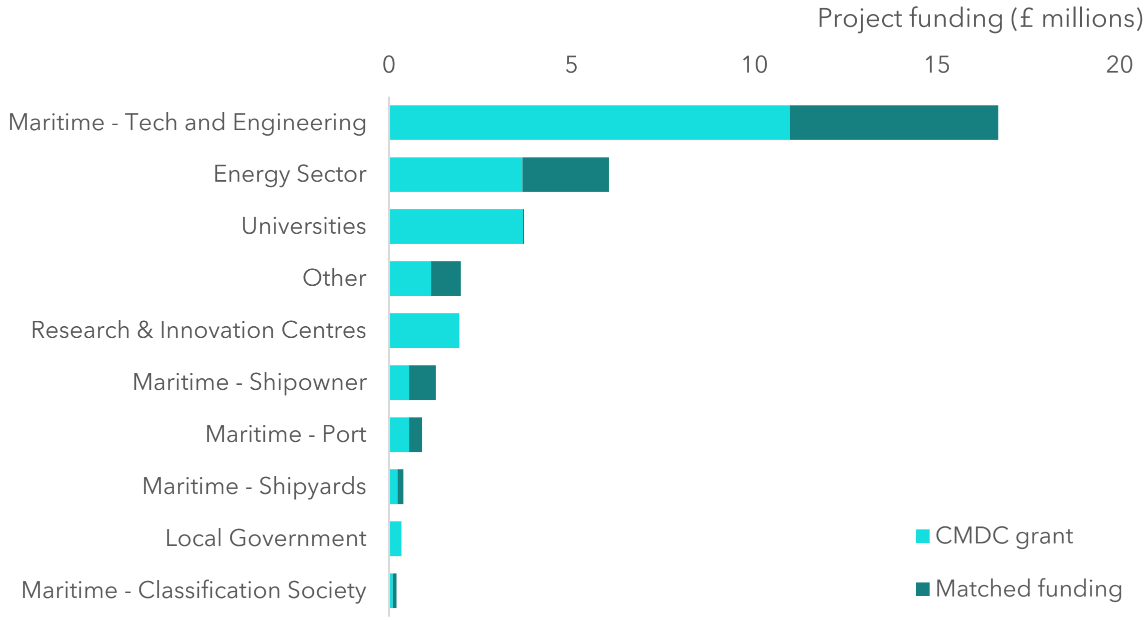
6.4.3 Other maritime decarbonisation initiatives

The UK government has also introduced a number of other initiatives and measures which could support the decarbonisation of the domestic maritime sector.

Clean Maritime Demonstration Competition

The Clean Maritime Demonstration Competition (CMDC) was launched in March 2021, offering grants for feasibility studies into innovative clean maritime technologies, smart shipping projects, and renewable energy solutions for vessels and ports. In the first round, £23.2 million was allocated to 55 projects involving over 200 participants from the maritime, engineering, and energy industries, universities, and local councils. This funding was matched by a further £10.3 million from industry (Figure 6.4)[7].

Figure 6.4: Round one CMDC project funding by type of recipient



Source: DfT[7]

The projects supported by the first round of the CMDC involved concept and design-stage feasibility studies. Each was required to outline a clear plan for advancing to a demonstration phase. The studies from the first round were delivered in March 2022 and a second round of funding for 2022/2023 was announced in May 2022, this time prioritising projects that specifically focus on one of the following themes:

- Technologies that eliminate the need for pilot fuels in hydrogen internal combustion engines used in maritime
- Demonstrating how multiple energy efficiency systems can be integrated into vessel design
- Overcoming the safety issues involved with the on-board storage of hydrogen and ammonia
- Designing larger (2.5 MW plus) fuel cell systems suitable for high power demand applications (e.g. tugs and larger vessels)
- Developing systems to refuel and charge small craft in ports and harbours
- Green shipping corridors both domestic and between the UK and other states including short and deep-sea routes

These projects are expected to deliver technical and economic feasibility studies which demonstrate the capability for commercialisation of the technology or product, substantiate the future benefit to the UK supply chain, and outline how a real-world demonstration could be operational by 2025.

The CMDC is intended to be a rolling programme of innovation funding, with an allocated budget of £206 million between 2022 and 2025[8]. This indicates that a subset of projects will be supported from feasibility through to demonstration stage.

COP26 declaration: Operation Zero

Launched by the DfT at COP26 in November 2021, Operation Zero is an industry coalition formed to 'accelerate the decarbonisation of the operations and maintenance vessels in the North Sea offshore wind sector'[2]. The vision is that zero emission vessels are deployed in the region by 2025, and the sector has certain advantages in being an early mover in this regard:

- It is a small community with strong relationships between shipowners, charterers (wind farm developers), equipment manufacturers and ports; this can help in overcoming the supply-demand challenge for fuel supply at ports
- The vessels are generally under long-term charter, which alleviates the split incentives issue
- There is an opportunity to utilise offshore charging for vessels

However, there are still challenges to realising this vision. The charter rates for the vessels are determined on the basis of the tenders won by the offshore wind farm developers. This usually involves very tight margins and competitive bids. For new wind farm tenders, unless a level playing field is provided by obliging that all wind farm developers bid on the basis that zero emission maintenance vessels must be chartered, the additional capital and operational cost will be hard to cover. For existing offshore wind maintenance vessels, support as well as targets may be needed to meet this ambition.

COP26 declaration: Clydebank Declaration for green shipping corridors

The Clydebank Declaration for green shipping corridors was also launched at COP26. This declaration was signed by 24 signatories, committing these countries to pursue efforts to establish at least six green corridors collectively by 2025, while aiming to scale activity up in the following years by supporting the formation of more routes, longer routes and/or having more ships on the same routes. These signatories have pledged to:

- Facilitate the establishment of partnerships, with participation from ports, operators and others along the value chain, to accelerate the decarbonisation of the shipping sector and its fuel supply through green shipping corridor projects
- Identify and explore actions to address barriers to the formation of green corridors. This could cover, for example, regulatory frameworks, incentives, information sharing or infrastructure
- Consider the inclusion of provisions for green corridors in the development or review of National Action Plans
- Work to ensure that wider consideration is taken for environmental impacts and sustainability when pursuing green shipping corridors.

This declaration, if supported as agreed by signatories, has the potential to accelerate most of the green corridor routes proposed thus far (Figure 6.5). This could have a significant impact on the decarbonisation of international shipping, and with potentially positive knock-on effects in Northwest Europe which is supportive of regional green corridors on short sea shipping routes.

Figure 6.5: Signatories of the Clydebank Declaration (highlighted in green) and proposed green corridor routes

Clydebank Declaration Signatories

Australia	Fiji	Japan	Palau
Belgium	Finland	Marshall Islands	Singapore
Canada	France	Morocco	Spain
Chile	Germany	Netherlands	Sweden
Costa Rica	Ireland	New Zealand	United Kingdom
Denmark	Italy	Norway	United States of America

Source: DfT[91]

UK Shipping Office for Reducing Emissions

Launched in March 2022, the UK Shipping Office for Reducing Emissions (UK SHORE) is a new unit in the DfT which will be responsible raft of initiatives (including a multi-year CMDC) aimed at decarbonising maritime. A first package of initiatives announced in May 2022 included[92]:

- Conducting feasibility studies for international green corridors (as part of the CMDC)
- Working with the devolved administrations to form domestic green corridors on intra-UK ferry routes
- Exploring initiatives on green shipbuilding in conjunction with the Department for Education, their UK Shipbuilding Skills Taskforce and the National Shipbuilding Office
- Setting up a Centre for Smart Shipping (CSmart) which will coordinate progress in new and emerging smart shipping systems and technologies
- Introducing grant schemes for early research projects from UK universities (in partnership with UKRI and marine industrial stakeholders) to create a pipeline of future technology solutions to decarbonise the maritime sector

Insights from Other Countries

Valuable lessons can be learned from approaches to domestic decarbonisation taken in other countries.

Key findings highlight how collaboration between competitive stakeholders can be encouraged; how government can support both the demand and the supply side of the equation for zero emission fuels; how the early participation of the investment community can lead to innovative funding solutions and open direct channels for investment.

7.1 Lessons from other regimes

Other countries around the world are also looking closely at ways to reduce emissions from domestic shipping. Some initiatives are led by government, others by industry coalitions. Each domestic maritime sector faces specific challenges and offers distinct opportunities to decarbonise, but many themes are universal, and the strategies adopted by regimes elsewhere can offer insight into alternative approaches which might be useful to the UK's situation.

Norway is a key case study for several reasons:

1) The Norwegian government has previously attempted to incentivise part of its domestic fleet to transition from conventional marine fuel bunkers to LNG
2) It has set targets for reducing emissions from domestic shipping and is looking closely, on a segment-by-segment basis, at policies that can enable this
3) It has an established green shipping programme that links government, industry, and financial institutions

There are other governments and industry groups across the world that have also launched national or regional programmes or projects to encourage their domestic maritime sectors to decarbonise. A selection of these (Table 7.1) were studied and representatives interviewed to understand the specific attributes of each domestic maritime sector (along with the attendant challenges and opportunities) and to gain insight into the approaches adopted to overcome commercial or investment hurdles, encourage participation from private capital providers, bring together stakeholders, and/or develop competitive advantage.

Table 7.1: Selection of domestic green shipping programmes and projects studied

Country	Programme	Summary
Denmark	Green Ship of the Future	- Industry-led coalition focused on collaborative studies looking at technological solutions
Netherlands	Maritime Masterplan	- Government-led programme funding: o Demonstration projects for commercial vessels o R&D funding zero emission fuel demonstration projects
United States and Canada	Blue Sky Coalition	- Industry-led coalition targeting collaborative projects involving stakeholders throughout value chain
Singapore	Maritime Singapore Green Initiative	- Government-led initiatives focused on ensuring that Singapore maintains its role as global bunkering hub throughout the transition to zero emission fuels
New Zealand	Port of Auckland Hydrogen Demonstration Project	- Early demonstration project for the production and use of green hydrogen

Source: Marine Capital

7.2 Norway's energy and maritime transition

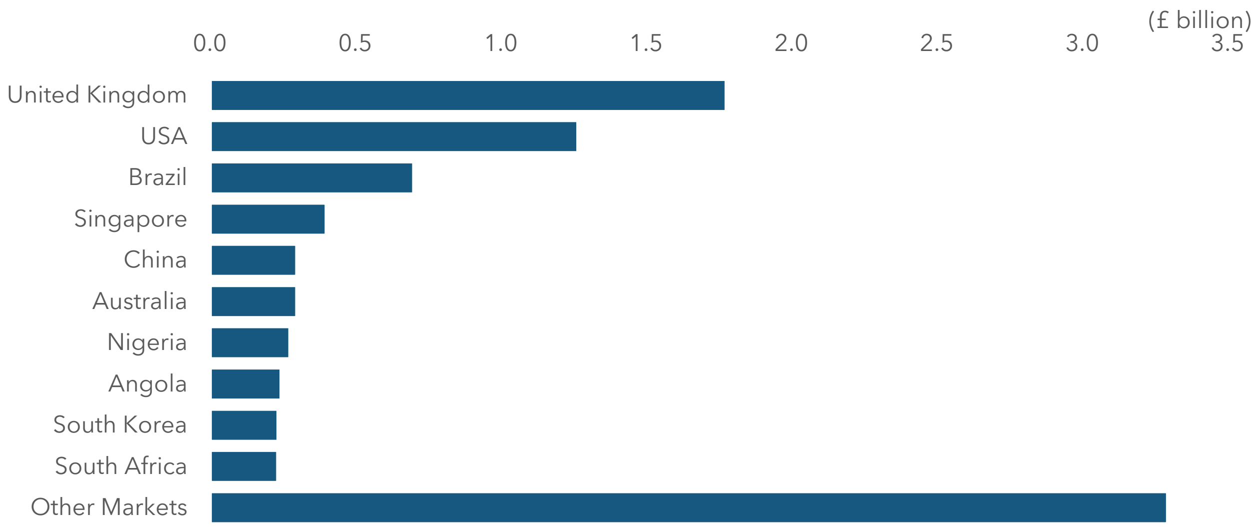
7.2.1 Co-evolution of Norway's energy and maritime sectors

Much like the UK, Norway has a long maritime history, and the sector remains an integral component of its economy to this day. Despite exposure to the same global competitive pressures in shipbuilding and shipowning as other traditional Western seafaring nations in the latter half of the twentieth century, the emergence of the offshore oil and gas sector and a proactive approach by government helped the Norwegian maritime industry adapt and thrive. Today, Norway has a large maritime cluster, directly contributing approximately £13 billion in GVA and employing around 85,000 people[17].

The development of Norway's offshore oil and gas sector has been instrumental in shaping the domestic maritime industry over the last 50 years. Since production began in the early 1970s, the oil and gas sector has grown into Norway's largest industry in terms of value added, government revenues, investments and export value[93]. In 2021, the sector contributed 20% of government revenue through taxation and direct interests, and accounted for 50% of total exports[94].

Oil and gas exploration and extraction centred on the Norwegian continental shelf, and this gave rise to a substantial domestic offshore service and supply sector. This sector is now Norway's second biggest industry in terms of turnover and is also a significant contributor to Norway's exports. In 2020, almost 30% of turnover from the offshore service and supply sector was generated overseas, the largest share of which (20%, £1.8 billion) came from the UK (Figure 7.1)[95].

Figure 7.1: Norway's 2020 exports from offshore service and supply industry



Source: Rystad Energy[95], Norwegian Petroleum Directorate[93]

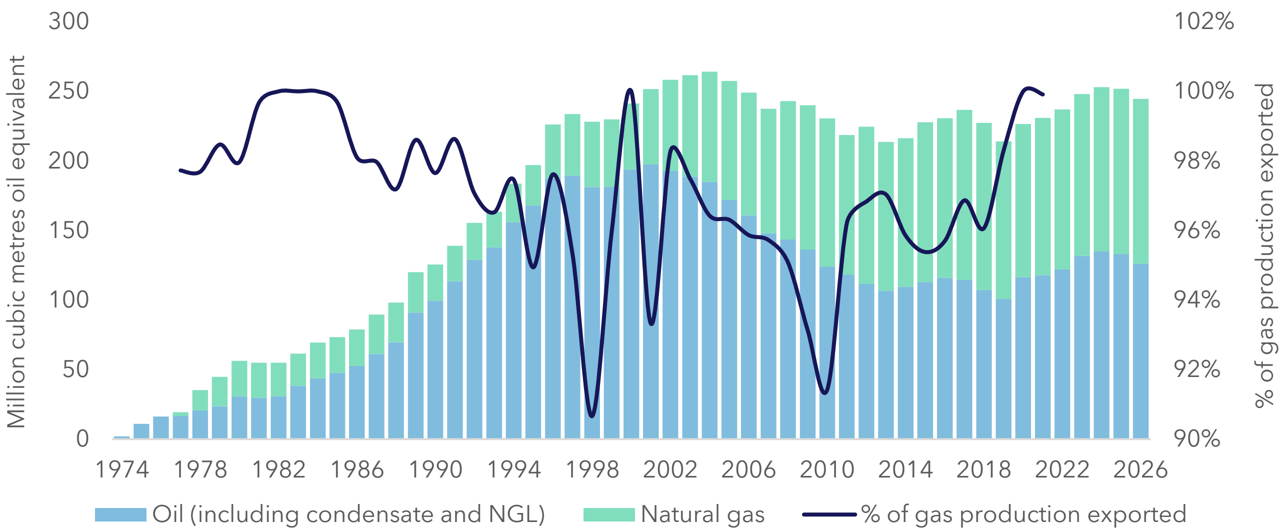
The genesis of the offshore sector helped safeguard Norway's maritime cluster from global competition, including its shipbuilding and equipment manufacturing base. Although the nation's international fleet sharply declined in the 1970s, its domestic offshore fleet grew and demand for increasingly complex offshore support and supply vessels enabled Norwegian shipyards to pivot away from building simpler vessels, helping to shield them from growing competition from shipyards in Asia.

However, government intervention was needed in the early stages. For shipowners, this took the form of vessel finance guarantees[96]; for shipyards, support was offered through contract subsidies, investments to alter production capabilities and even direct funding[97]. These protectionist policies gave the shipbuilding industry room to rationalise and specialise in technically advanced, high value-added vessel types in segments such as offshore, fishing, and ferries[98].

7.2.2 Strategy to stimulate use of LNG as a marine fuel

Given the interdependence of the offshore energy and maritime sectors, it is not surprising that the government has favoured correlative strategies where possible. As its national energy system was geared towards hydropower-generated electricity, Norway had limited internal demand for the natural gas it started producing in the late 1970s and most was exported via pipeline to Europe (Figure 7.2)[93].

Figure 7.2: Norway's historical and projected oil and gas production, and the proportion of gas exported



Source: Norwegian Petroleum Directorate[93], Statistics Norway[94]

Motivated by a goal to increase domestic use of gas, but also in a bid to reduce coastal emissions of nitrogen oxide (NOx) and other pollutants, the Norwegian government funded studies in the 1990s on the feasibility of using liquified natural gas (LNG) as a marine fuel[99]. Safety concerns emerged as a critical hurdle, particularly for vessels carrying passengers, slowing progress until standards were established (in conjunction with the Norwegian classification society, DNV) and safety reached an acceptable level[100].

Once the viability of LNG as a marine fuel was proven, successive initiatives were introduced to stimulate uptake in the domestic maritime sector over a period of about 15 years. The government remained the principal actor throughout, but it adopted different roles (through the relevant departments) at different points in the transition. Other stakeholders were brought into the process as needed, but each link in the supply chain assembled was represented by only one company, thereby reducing competitive tension[99].

As an initial step, the government financed a pilot project for an LNG-fuelled ferry which was constructed in a Norwegian shipyard and launched in 2000. Over the following 15 years, a further 25 LNG-fuelled ferries were built, subsidised via long-term government tenders[101]. This action ensured there was enough demand into an LNG supply chain, thus forming a nascent LNG fuel ecosystem[99].

The next step was to draw in commercial entities. In 2007, the Norwegian government introduced a tax on NOx emissions which covered offshore platforms and vessels making domestic voyages. A year later the NOx Fund was launched which offered subsidies up to 80% of the incremental cost of NOx-reducing technologies, including construction or conversion to LNG propulsion[102].

The clear and consistent policy direction set by government reassured shipowners that a viable LNG supply chain was being created, and this increased uptake by commercial entities. As a result, the pool of LNG-fuelled vessels widened to include general cargo vessels, ro-ro vessels, tugs, and offshore platform service vessels (the second most common vessel type after ferries)[99].

Currently, there are more than 60 LNG-fuelled vessels in Norway's domestic fleet. However, despite the subsidies, the adoption of LNG propulsion was far from universal. Less than 10% of Norway's domestic fleet is currently LNG-fuelled, and uptake is confined to the geographic areas covered by LNG supply infrastructure for ferries[101].

Decisions by shipowners not to invest in LNG-fuelled vessels was influenced by a growing split incentives issue. Oil and gas companies chartering platform service vessels grew less willing to pay a higher rate or offer longer tenors for LNG equivalents, particularly as conventional vessels became more fuel efficient over time. Shipowners were also reluctant to invest in LNG-fuelled ships due to the perceived risks of committing to the novel fuel due to the lack of clarity on LNG pricing in Norway and potential exposure to any future price differential between LNG and fuel oil[103].

Despite the challenges, Norway's efforts to establish an LNG supply chain did encourage adoption across the wider Baltic region. Its experience also provided other regimes with a valuable reference point when assessing the viability of LNG propulsion in their own domestic setting and several other jurisdictions have since developed hubs for domestic and regional LNG-fuelled vessels, largely based around emission control areas (ECAs)[101].

In recent years, there has also been growing investment in the wider international fleet, particularly in the container ship segment where the regularity of voyage routes makes LNG bunker provision easier to arrange. These vessels are typically dual-fuel (able to run on either LNG or fuel oil), allowing shipowners to adhere to ECA regulations where required and declare emissions reductions, while also providing an opportunity to arbitrage on fuel price spreads.

Norway's unique energy and maritime landscape, and the involvement of government in both, facilitated its role as a first mover in this LNG energy transition. However, this represents just one facet of the government's evolving maritime strategy.

7.2.3 Norway's green maritime strategy and action plan

In 2015, the Norwegian government launched its maritime strategy 'Blue Growth for a Green Future', which aimed to strengthen links between its maritime industries (oil and gas, fishing and shipping) and increase Norway's competitive advantage in innovative technologies through a focus on R&D and education[104]. Several measures were proposed for domestic and short sea shipping, including grants for low and zero emission solutions and a scrap and replace scheme offering innovation loans for new vessels to encourage fleet renewal with greener replacements[98].

In the same year, the transport sector was added to the remit of Enova, a state-owned organisation which promotes reductions in greenhouse gas emissions, develops innovation in climate technology, and strengthens energy security. Enova funding can support technology innovation from pilot phase through to market introduction. Between 2015 and 2020, Enova allocated almost £500 million to the transport sector, with maritime activities accounting for the largest share of this[105]. To date, more than £175 million has been spent on battery technology on vessels and shore power[17].

Domestic shipping was the focus of more substantive targets in the 2019 'Action Plan for Green Shipping', in which the government stated its ambition to halve emissions from domestic shipping and fisheries by 2030[17]. The plan described possible measures and policy instruments for different categories of vessels (Table 7.2) according to fleet structure and operating pattern (as determined by AIS data).

Table 7.2: Potential measures and policy instruments that are being assessed by the Norwegian government to reduce emissions from domestic shipping

Category	Proposed measure / policy instrument
Passenger vessels (ferries and cruise ships)	- Funding from Enova and NOx fund for upgrade/replacement - Prioritising R&D to abate vessels with high emissions intensity (e.g. fast passenger vessels) - Introducing environmental requirements in government procurement process (tenders for new ferries part or all electric) - Strict emissions standards and zero emission targets in sensitive areas (for cruise ships) - Onshore power (for cruise ships)
Cargo vessels	- Pilot schemes and grants to encourage modal shift of freight from road to sea (Norway's 2018 Transport Plan stated an ambition that 30 % of goods transported further than 300km be transferred from road to rail and sea by 2030) - Coordination with cargo owners for integrated approach to logistics chain - Discuss with industry partners possibility of drawing up letter of intent for green renewal of cargo fleet - Funding for green fleet renewal through instruments offered by Export Finance Norway and Innovation Norway - Include zero emission transport requirement in public procurement process
Offshore support vessels	- Funding from Enova and NOx fund for upgrade/replacement - Require offshore oil and gas production to use low or zero emission vessels (e.g. Equinor now requires that long-term chartered vessels are battery-hybrid and use shore power) - Encourage commercial agreements that overcome split incentives issue (e.g. Equinor has introduced incentive scheme whereby savings from reductions in fuel consumption are shared with the shipping company)
Specialised vessels (workboats, tugs, fishing and recreational craft)	- Funding from Enova for vessel and port energy technologies - Require low or zero emission service vessels in public procurement (including chartering) - Abolish carbon tax exemption and reduce tax rates for fishing vessels - Build knowledge base on emission reduction options for recreational craft

Source: Norwegian Ministry of Climate and Environment

7.2.4 Green Shipping Programme

Efforts to decarbonise domestic shipping have not solely rested with the Norwegian government. In 2015, the classification society DNV proposed that a public private partnership be formed between government and industry with the vision of establishing the world's most efficient and environmentally friendly coastal shipping fleet. Launched jointly with the Ministries of Climate and Environment, and of Trade, Industry and Fisheries, the Green Shipping Programme now has more than 100 partners, including shipowners, operators, cargo owners, shipyards and equipment manufacturers, financial institutions and academia[106].

Since inception, these partners have collaborated on initiating 42 pilot projects, 13 of which have been realised or are currently under construction. These include alternative fuel and energy efficiency projects for vessels and ports, digitalisation and autonomous shipping, and green funding solutions and standards[106]. Some partners operate in the international shipping markets but recognise that domestic and short sea shipping acts as a test bed for green technologies and commercial models, and thus value the knowledge base being created at the domestic level[107].

The programme played an important role in accelerating the adoption of battery use for ferries, securing Norway's current 40% market share in battery ships, and establishing an export-oriented supply chain. More recently, pilots have been proposed for ammonia-fuelled cargo and passenger ships, but the far higher cost (both in upfront capital expenditure and ongoing fuel cost) remains the principal hurdle to investment by shipowners, commitment by cargo owners and funding by financing institutions. However, perspectives are reportedly changing. Cargo owners are beginning to assess how their business models will be impacted by escalating carbon taxes; and they are acknowledging that long-term charters will be needed to overcome the split incentives issue to enable investment by shipowners[107].

Furthermore, the direct participation of several financial institutions (Scandinavian banks and institutional investors) has had dual benefits. First, early engagement with the finance community laid the groundwork in establishing standards and potential structures for funding green maritime initiatives[108]. Second, it familiarised these institutions with the maritime sector and increased awareness of the scope for funding green technologies, fuels and associated energy infrastructure. This has the potential to open channels of funding (particularly when investors have net zero targets or a clean energy focus themselves), and such partnerships allow for direct communication with government on the type and level of support needed.

For example, Norway's largest municipal pension fund, KLP, which is an active partner in the Green Shipping Programme, is currently exploring opportunities to finance a project to produce and distribute green ammonia as a zero emission marine fuel. As the technology is commercially unproven, KLP is investigating how government could step in to offset this risk within a PPP structure[109].

7.2.5 Support for decarbonising the maritime sector

In Norway, there are several sources of support for businesses seeking to reduce emissions from ongoing operations or to deliver new technologies or solutions into the maritime supply chain. Funding can be obtained through grants, soft loans or guarantees, depending on the lifecycle stage of the business or technology. The agencies supporting research and innovation often collaborate on programmes. For example, funding from Enova and Innovation Norway is being used to accelerate development of hydrogen technology. These sources are summarised in Table 7.3.

Table 7.3: Sources of support that can be accessed by the Norwegian maritime cluster

Entity	Role	Support
Research Council of Norway	Maritime research and innovation	Grants
Horizon Europe (Horizon 2020)	EU research and innovation funding programme	Grants
Innovation Norway	Development and innovation in the business sector; also offers: o scrap and replace scheme for short sea shipping o risk loans for short sea shipping and fishing fleets	Grants, loans and contract scheme
Loan scheme	Loan scheme targeting fleet retrofits and replacement in short sea shipping and fishing fleet (based on Innovation Norway loans)	Loans
Enova	Support innovation projects from pilot phase to market and support projects that build demand for climate and energy technology; goal is to promote permanent market change	Grants
NOx Fund	Fees paid by businesses for NOx emissions are funnelled into industry via funding for NOx-reduction measures	Grants of up to 80% of incremental CAPEX of NOx-reducing technology
Export Finance Norway (Eksfin)	Financing and guarantees for Norwegian exports (but can also be accessed by shipowners for domestic vessels built in Norway)	Long-term loans and loan guarantees
Gassnova	Funding for research related to CO_2 capture and storage (including transportation by shipping)	Grants

Source: Research Council of Norway[110]; European Commission[111]; Innovation Norway[112]; Enova[105]; NOx Fund[102]; Eksfin[113]; Gassnova[114]

For the wider maritime supply chain, Innovation Norway and Enova assist in reducing technology risk at the development and testing stage for new technologies. Innovation Norway also offers a contract scheme to develop innovative products, services and technologies in close cooperation with pilot customers. Enova's approach to stimulating the market means it supports both technology development and market introduction. For example, the agency has funded onshore power in Norwegian ports and electrification of vessels, thereby strengthening the value chain for battery technology[17].

Export Finance Norway supports the construction of ships at Norwegian shipyards (and abroad when using Norwegian equipment) through long-term loans and guarantees. In 2018, a credit guarantee scheme was launched for domestic vessels (ferries, well-boats, high-speed vessels, short sea vessels and fishing vessels) built in Norway. The reduced credit risk for the lending bank allowed Norwegian shipyards to access financing more easily, thereby increasing their competitiveness[17].

For shipowners seeking to upgrade or replace their vessels with low or zero emission technologies, direct support is typically accessed from the NOx fund, the loan schemes offered by Innovation Norway and Export Finance Norway.

7.2.6 Key insights from Norway

Norway offers many insights into different facets of domestic maritime decarbonisation. The Norwegian government's efforts to create a domestic LNG-fuelled maritime ecosystem offers a rare glimpse into the steps required to engineer an energy transition. The more recent focus of both government and the wide group of stakeholders involved in the Green Shipping Programme on decarbonising the domestic fleet also offers enlightening lessons that can help inform the UK's approach. These insights are summarised in Figure 7.3.

Figure 7.3: Summary of key insights from Norway's LNG transition, the government's approach to maritime strategy over the long term, and the industry-led Green Shipping Programme

LNG transition	Norwegian government's maritime strategy	Green Shipping Programme
- Government was a '**strong actor**' that initiated supply of and demand for LNG	- Long history of **coordination** between government departments on maritime strategy and policy initiatives	- Domestic shipping acts as a **test bed** to develop products and solutions for international maritime markets
- Government's **role evolved** during transition	- Maritime **strategy evolved** as domestic and international markets changed	- Stakeholder competition overcome by recognition that **entire industry benefits** by becoming market leaders
- Safety considerations slowed initial uptake; important to solve **safety issues** in parallel	- Regulatory targets and supportive **policies linked** (e.g. NOx tax and NOx Fund)	- Early participation of financial institutions helps create potential **funding solutions** and can open direct **investment channels**
- LNG uptake was not universal but stated goal (reducing NOx emissions) was achieved through **industry innovation**	- Government is willing to bear cost of being **first mover**	

Source: Marine Capital

7.3 National programmes and projects

7.3.1 Denmark: Green Ship of the Future

Danish maritime sector

The Danish maritime sector is home to several large shipowners such as Maersk, DFDS, Norden and Svitzer that operate either across Europe or globally. Collectively, Danish firms own and operate the fifth largest fleet in the world and shipping is Denmark's largest single export industry, accounting for roughly 20% of total exports[115]. As such, the industry's focus is on reducing emissions from its international fleet rather than the far smaller domestic fleet.

Green Ship of the Future

Founded in 2008, the Green Ship of the Future is an independent non-profit technical forum financed by its members. These include international shipowners and operators, industry associations, marine engineering and equipment manufacturers, classification societies, naval and technical academic institutions, and the Danish Maritime Authority[116]. The organisation operates with minimal headcount, flexing to scale with projects by accessing the time and skills of its members via secondments.

The programme facilitates collaborative studies into innovative technologies undertaken by groups of its members (Table 7.4). Academic institutions and government participate in some studies but play a limited advisory role. By sharing project costs and findings among members, the programme aims to overcome barriers such as high R&D costs and lack of clarity on viable low and zero emission technologies/fuels[117].

Table 7.4: Major projects coordinated by Green Ship of the Future

Project Name	Summary
Retrofit project	- Analysis of emissions savings gained through retrofits of proven technical solutions on different vessel types
Shipping in a Circular Economy	- Development of circular economy concepts in the shipping industry, and the role of shipping as an enabler of a global circular transition
RegionalECOfeeder	- Assessment of emissions reductions achievable for small coastal feeder fleet through operational and technological (energy efficiency) solutions
Digitisation for decarbonisation	- Evaluation of the potential value of data sharing across suppliers in a specific ships system
3D print in the maritime industry	- Exploration of commercial feasibility for 3D printing on board vessels and at large scale within supply chain

Source: GSF[116]

Overcoming stakeholder competition

Many of the programme's members operate in direct competition, which initially inhibited collaboration. Two factors have helped overcome this hurdle. First, as most Danish shipping companies are based in Copenhagen, the community is close-knit. Over time, members came to realise that the advancement of the entire Danish shipping industry benefitted them all against global competitors. Second, commercial conflict was reduced by a focus on exploratory rather than exploitative research. Studies undertaken were either practical in nature or investigated higher level issues such as systemic barriers to zero emission shipping and future development of energy and fuel markets[117].

Without a similar group of cooperative industry stakeholders overcoming competitive habits, elements of this approach would be difficult to replicate in the UK. However, collaboration could be fostered by, for example, common ambition to grow market share in clean maritime technology exports. Collaboration on common issues can help form a cohesive narrative that encourages investment decision making.

Summary

The programme operates in a similar environment to Norway, where long-standing relationships between professionals have helped overcome corporate competition and reach agreement that working collectively on developing practical solutions is cheaper and faster, and (ultimately) to the benefit of all.

7.3.2 Netherlands: Maritime Masterplan

Dutch maritime sector

The Netherlands has a substantial maritime sector. Its ports are major hubs for transhipment (transferring cargo and containers to smaller vessels for onward regional transport) and marine bunker fuel provision. Its shipyards and marine equipment suppliers specialise in niche markets such as dredging, offshore, renewable energy, short sea shipping and superyachts, constructing complex vessels with high added value. The country also has a large domestic fleet, and the largest fleet of inland vessels in Europe[118].

Developing the Maritime Masterplan

The Dutch government established an integrated strategy for its maritime cluster in 2015, largely in response to developments in the global market which posed competitive pressures but also presented opportunities. Government policy focused on enhancing competitive advantage through research, development and innovation programmes conducted jointly between public and private partners[119].

In 2019, the Ministries of Economic Affairs and Climate Policy, Infrastructure and Water Management, and Defence, launched a joint initiative (the Green Deal on Maritime, Inland Shipping and Ports) to move towards a more sustainable shipping sector. This laid out government ambition on emissions reduction by inland and maritime shipping as a set of near (2024), mid (2030/2035) and long-term (2050) goals[120].

Recognising that funding research and innovation alone was not enough to compel adoption of low and zero emission fuels and technologies, the Dutch government launched the Maritime Masterplan in 2021 as a channel through which direct subsidies could be offered to shipowners to encourage early uptake. As well as supporting Dutch shipowners and lowering domestic shipping emissions, it is hoped that this plan will build competence in the design and construction of zero emission technologies and vessels, lower the ongoing cost of construction by enabling advanced solutions to be developed and thereby increase the competitiveness of Dutch shipyards and secure market share in the maritime energy transition[121].

Demonstration projects and R&D funding

The demonstration programme will procure 20 zero emission navy vessels and subsidise 30 zero emission merchant vessels, for which the Dutch government has budgeted up to €190 million. For the commercial vessels, the programme will subsidise up to 50% of the additional cost of the zero emission technology for a newbuild vessel or retrofit. Vessels from a range of sectors will be chosen to develop a broad knowledge base and while it is hoped that direct benefit will flow to national shipyards and maritime supply chain, it cannot be mandated[122].

In addition, at the end of 2021, the Dutch government awarded €53 million in R&D funding. However, this funding went to only three projects. An LNG project to reduce methane slip received €4 million; projects researching the use of methanol and hydrogen as marine fuels received €24 million each. These projects will deliver pilots indicating that the Dutch government is seeking to accelerate the commercialisation of either of these fuels/technologies.

Summary

The Dutch government has adopted the role of first mover by subsidising commercial vessels to create a demand base for new fuels. This is further supported by the R&D grant funding it has awarded targeting zero emission fuel solutions.

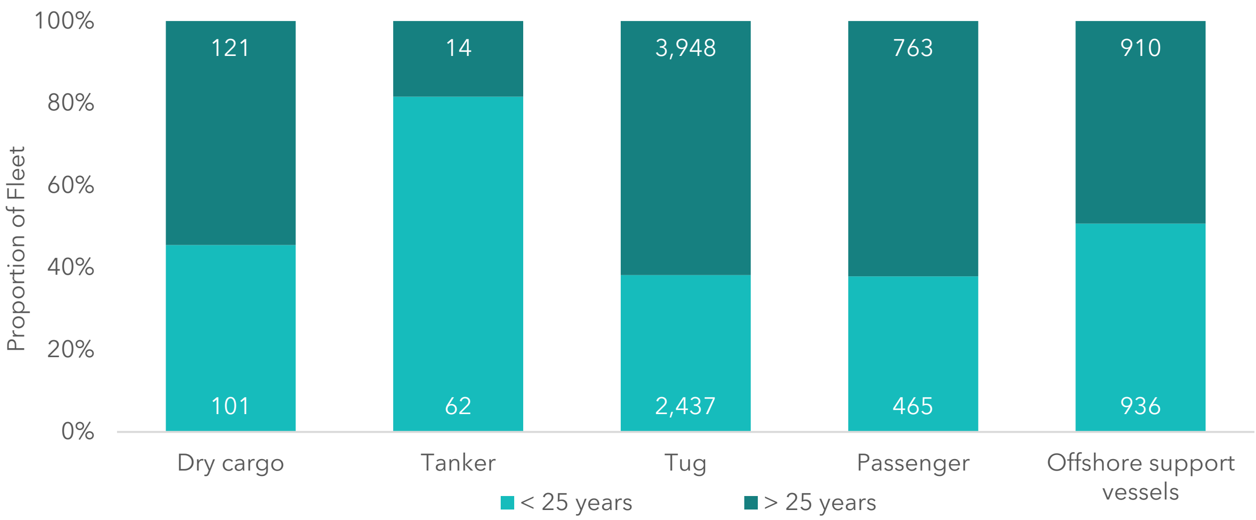
7.3.3 United States and Canada: Blue Sky Coalition

US maritime sector

The US maritime sector differs to that of most other regimes. Domestic shipping covers a very large geographical area: along both coastlines, to and from the non-contiguous states (Hawaii and Alaska) and territories, on inland lakes and waterways, and also across the offshore oil and gas fields in the Gulf of Mexico. The majority of US-flagged vessels operate domestically and approximately 70% of emissions result from domestic voyages[55].

The present domestic maritime landscape in the US has been shaped by the Merchant Marine Act of 1920 (also known as the Jones Act). This protectionist legislation requires that all shipping activity between US ports takes place on vessels that are built at US shipyards, crewed by US citizens, owned by a US citizen or company, and registered under the US flag. This has created an environment where US ships are four to five times more expensive to build and twice as costly to operate as equivalent vessels in other jurisdictions[123].

Figure 7.4: Proportion and number of vessels above and below 25 years age in US-flagged fleet



Source: National Transportation Statistics from the Bureau of Transportation Statistics[124]

The high cost of replacement means that ships tend to be operated for far longer than they would be elsewhere, particularly in bulker, tug and fishing segments where vessels more than 50 years old still operate[55]. However, it also means that US shipowners typically have long-standing relationships with financial institutions meaning that access to funding may not be as large a hurdle as found elsewhere.

The advanced age of so many vessels means that there is an urgent need for replacement, preferably with low or zero emission equivalents. However, there is tension between the urgency for fleet renewal and the lack of certainty on the appropriate choice of zero emission fuel and technology, particularly as the high capital cost and resultant long economic life of the vessels increases exposure to future obsolescence risk. Even when resolved, US shipbuilding capacity and capability is likely to be an ongoing constraint. While the US domestic maritime sector and some of the challenges it faces are rather unique, the approaches taken still provide insight into creating system-wide change.

Blue Sky Maritime Coalition

Launched in June 2021, the Blue Sky Maritime Coalition is an industry group focused on accelerating the decarbonisation of domestic shipping in the US and (latterly) in Canada. Coalition members come from almost every element of the maritime value chain and include shipowners, operators, charterers, ports, marine fuel providers, Classification Societies, finance and legal service providers, and NGOs, academia and other knowledge centres. The coalition aims to identify and instigate demonstration projects covering areas such as technological and operational solutions, commercial arrangements, and policy.

So far, the coalition has initiated 11 projects, five of which address the technical and commercial issues of producing green fuels and establishing associated infrastructure[125]. The coalition is focused on industry-led actions, but it also hopes that involvement of the entire value chain can produce strategies that go beyond marginal gains, beyond incremental change, to deliver a system-wide transition in the domestic maritime sector. This would require federal and/or state support (for instance, through incentives for hydrogen production and infrastructure investment, support for green initiatives at ports and funding of zero emission vessel pilots[126]).

As with other industry groups, it has been challenging to overcome competitive inclinations across, and siloed viewpoints up and down, the value chain to enable collaboration on these issues. Membership fees prevent membership being used for greenwashing purposes and every member is required to contribute manhours (some doing so through secondment). The diversity of membership has compelled open discussions and promoted buy-in to the opportunities attainable through a coordinated approach. Members themselves now act as spokespersons to the wider maritime community, articulating the benefits of the coalition and its aims[127].

Summary

The US maritime sector operates in a unique environment and so faces distinct challenges. However, many commercial issues are universal. The Blue Sky Maritime Coalition is seeking to involve all parts of the value chain to provide a wide overview of the changes that are needed. Industry participants have become de facto spokespersons for the coalition, drawing in more members. Building a critical mass increases the probability of success of individual projects and accelerates the speed of change.

7.3.4 Singapore: Maritime Singapore Decarbonisation Blueprint

Singapore's role as a bunkering hub

Singapore is one of the world's busiest transhipment and bunkering ports. In 2021, Singapore sold almost 50 million tonnes of marine fuel, roughly 20%-25% of the total consumed by the international fleet. It also marked the start of ship-to-ship LNG bunkering operations[128]. Singapore's Maritime and Port Authority (MPA) considers LNG to be a transitional fuel and is positioning itself to be a key LNG bunker hub. Longer term, the MPA recognises that lower and zero emission fuels such as biofuels, methanol, ammonia and, eventually, hydrogen will be added to the mix, and so is currently assessing how Singapore can transition to a multi-fuel bunker hub.

The MPA began to invest in green maritime initiatives in 2011, funding three green programmes: the Green Ship Programme, the Green Port Programme and the Green Technology Programme. The first two offered reductions in tonnage tax and port fees that favoured LNG vessels (i.e. incentives that coincided with the MPA's strategy to establish an LNG bunkering hub). These programmes were enhanced in 2019 and a maritime tech start-up co-invest platform launched[129]. In 2021, the Global Centre for Maritime Decarbonisation (GCMD) was formed by the MPA and industry partners to test and validate new fuels and technologies (with a focus thus far on developing a trial for ammonia bunkering)[130].

In March 2022, the Maritime Singapore Decarbonisation Blueprint: Working Towards 2050 was published, detailing targets and strategies to reduce emissions from port operations and domestic harbour vessels, develop standards and infrastructure for future marine fuels and support efforts to decarbonise international shipping through its registry and the IMO[131].

Table 7.5: Green maritime initiatives established in Singapore by the MPA

Initiative	Launched	Action
Green Ship programme	2011	Certifies green credentials of the ship and offers reduction of 75% on initial registration fee and rebate of up to 50% on annual tonnage tax
Green Port Programme	2011	Port due concessions (25% – 35%)
Green Energy and Technology Programme	2011	Co-funds up to 50% of development costs and pilots for green maritime technologies
Green Awareness Programme	2019	Training for carbon accounting and internal carbon pricing
SEEDS Capital	2019	Co-investment platform for maritime tech start-ups in shipping, port logistics, port operations and maritime services
Global Centre for Maritime Decarbonisation (GCMD)	2021	Not for profit organisation part funded by MPA to fund studies and pilots that support the decarbonisation of international shipping
Maritime Singapore Decarbonisation Blueprint	2022	Decarbonisation targets and strategies for emissions reductions at port and by domestic vessels, the development of new fuels and bunkering facilities, and supporting decarbonisation of the wider fleet

Source: MPA [129, 131]; GCMD[130]

As a major port and bunker hub, Singapore benefits from access to many shipowners and operators, energy companies and marine bunker suppliers, and storage providers. This has enabled the MPA to remain fuel and technology agnostic, assessing each in partnership with industry stakeholders and sharing the costs. Carbon capture, storage and utilisation technologies are also being investigated as a solution for the maritime industry, but also to opportunely position Singapore in the development of a CO_2 maritime transport chain (e.g. as a hub for aggregation before onward shipping for sequestration)[132].

Decarbonisation of domestic fleet

Although the MPA's primary focus is aligned with the decarbonisation of international shipping, it has also committed to reducing emissions from port operations and domestic harbour vessels. The domestic fleet consists of 250 large vessels (mainly bunker tankers) and 1,350 smaller vessels (comprised of launches, ferries, tugboats). In the near term, biofuels will be used, and then the group of larger vessels is expected to transition to ammonia, methanol or hydrogen, while the group of smaller will switch to fuel cells or full electric battery systems. Pilot projects for electrification and biofuels are also planned, and a subsidy scheme is being considered to stimulate uptake. Emissions reduction regulation will be progressively tightened to facilitate an orderly transition[131].

Summary

Singapore's maritime strategy is shaped around its role as a major bunker supplier and R&D funding and other incentives are aligned accordingly. Singapore's access to large industry players also enables it to participate in a wide range of fuel-based projects that will have ramifications for the global shipping industry. Closer to home, the government has given clarity on how (and over what timeframe) regulation and supportive policies will be employed to decarbonise the domestic fleet.

7.3.5 New Zealand: Ports of Auckland Hydrogen Demonstration Project

Ports of Auckland

New Zealand's ports are mostly publicly owned, and all are controlled by local councils. The Ports of Auckland (a group of two seaports and four inland freight ports) is owned by Auckland Council and together constitute the second largest port in New Zealand. In 2020, these ports were reported to have handled 63% of all container traffic and 33% of the country's total import volumes[133].

The Ports of Auckland has a 2040 zero emission target and is a signatory of the Climate Leaders Coalition, which aims to enable the transition to a lower emissions economy. Over the short to medium term, the group intends to decarbonise its port equipment (reach stackers, forklifts, etc.) using biofuels. However, as a long-term solution, the group began exploring the use of hydrogen to fuel this equipment[134].

Hydrogen Demonstration Project

Launched at the end of 2018, the Ports of Auckland Hydrogen Demonstration Project was a joint venture between Auckland Council, Auckland Transport and KiwiRail. The aim of the project was to build an onsite hydrogen production plant and refuelling facility at Auckland's Waitematā port that would then be used to power vehicles (buses and cars) and port equipment fitted with hydrogen fuel cells[135].

Initially, the project intended to start producing hydrogen within one year, but safety considerations and regulatory standards (which were not designed for the use of hydrogen) delayed consent for the electrolyser until the end of 2020 when the port was able to obtain a hazardous substance compliance certificate for a ring-fenced area of the port[136]. In the interim, a small-scale refuelling system was installed to allow a hydrogen fuel cell bus to be trialled[134].

In 2021, Japanese construction company, Obayashi Corporation, which has invested in pilot hydrogen plants elsewhere. became an equity partner in the project and took on responsibility of delivering the main refuelling facility[134]. However, by the end of 2021, the Ports of Auckland decided to exit the joint venture leaving existing partners to continue the project and Obayashi Corporation to take over operation of the refuelling facility[137].

Summary

The Hydrogen Demonstration Project was an ambitious pilot project aiming to leverage aggregate demand for hydrogen from multiple modes of transport (road, rail, and sea). Safety and consent issues delayed the project, despite Auckland Council being a stakeholder. Although the Ports of Auckland decided to step back from the project based on commercial grounds, industry partners were able to step in, leaving open the possibility of a hydrogen production facility eventually being constructed.

7.3.6 Key insights from national programmes and projects

The national programmes and projects launched to by governments and industry coalitions around the world offer interesting insights into how the local environment shapes the challenges and opportunities seen in different domestic maritime sectors, and they offer valuable lessons on how stakeholders tackled and embraced them. These are summarised in Figure 7.5.

Figure 7.5: Summary of key insights from green domestic shipping programmes and projects

Opportunities	Challenges	Approaches
- Government can support decarbonisation through a **range of initiatives** - Involvement of stakeholders reaching a **critical mass** can accelerate change	- Encouraging competitive stakeholders to **collaborate** is a universal challenge - **Safety issues** related to new fuels can have serious impact on project timescales	- Programmes are shaped by **existing advantages** (e.g. strength of local maritime community or current focus of industry) - Early projects benefit from **public and private** partners

Source: Marine Capital

8

Bridging the Commercial Gap

There are a number of measures that government can use to start to bridge the gap in cost between conventional fuels and zero emission alternatives, to offer support for certain stakeholders and segments, and to mitigate risks for investors, thereby facilitating the inward flow of private capital into the industry.

8.1 Key challenges and opportunities

The domestic maritime sector faces multiple and varied challenges to decarbonisation. Policy makers will need to use a range of measures to support (and/or dictate) the transition to net zero and to mobilise the inward flow of private capital into the sector. The key characteristics, challenges, opportunities. and lessons learned are summarised in Figure 8.1.

Figure 8.1: Key characteristics, challenges, opportunities. and lessons learned

Source: Marine Capital

8.2 Policy tools to support decarbonisation

8.2.1 Use of direct regulation

As summarised in Chapter 6, there is a range of policy tools available to government that can oblige and support the maritime sector to decarbonise. These measures work either by imposing direct regulation that the industry is obliged to meet, or by applying economic instruments that encourage behaviour to change. No decarbonisation-related direct regulation has been implemented as yet, but the government has suggested a number of possible measures (Table 8.1).

Table 8.1: Forms of direct regulation that have been suggested by government

Proposed measure	Considerations
Setting emission target	- Heterogeneity of vessels (even within the same segment) makes setting uniform targets difficult - Will need to set up reporting system to measure/track
Introducing phase-out date for sale of new non-zero emission domestic vessels Mandating (or incentivising) zero emission capability standard for new vessels	- Could be linked with subsidies for replacement vessels (i.e. scrap and replace) - Would primarily affect segments with bespoke vessels where it is common practice to build and own/operate for life (ferries, Ro-Ros, etc.) - There is far less pressure to replace older vessels with new vessels in the generic sectors (cargo and some service vessels) and the global market for zero emission vessels is likely to develop very slowly
Mandating uptake of shore power	- Provision of shore power can be difficult or impractical for a number of reasons; can assess on a case-by-case basis (e.g. ports can apply for exemption) - Can prioritise ports where the types of domestic vessels visiting can be electrified - Will need funding
Mandating (or incentivising) uptake of energy efficiency technologies on board domestic vessels	- Vessels exposed to range of technical and operating constraints that make blanket adoption difficult - Large degree of shipping activity not related to cargo or passenger transport; limits benefit of energy efficiency technologies
Mandating carbon intensity measure for fuels (i.e. akin to FuelEU Maritime)	- Verification and leakage issues (similar to FuelEU Maritime) - Heterogeneity of vessels could lead to suitability issues for low carbon drop-in fuels

Source: DfT[87, 10]

Direct regulation is a powerful but typically inflexible policy tool. In the domestic maritime sector, the heterogeneity of the vessels, variation in activity and the range of technical, operational and commercial constraints makes setting blanket policies difficult. Lack of detailed knowledge can result in unintended consequences. For example, mandates on standards for new vessels may delay emissions reduction in segments that use generic vessels, where an active second-hand market can lead to avoidance. Direct regulation can be set by vessel type/size, but the profile of vessels, common technical and/or operational constraints, and the typical model of asset ownership needs to be considered when doing so.

8.2.2 Use of economic instruments

The UK will need to complement any direct regulatory measures with economic instruments. These create fiscal incentives and/or disincentives that can bridge the commercial gap between conventional and alternative fuels/technologies, and they can provide targeted support where needed (Table 8.2).

Table 8.2: Characteristics of different economic instruments

Characteristics	Carbon taxes and levies	ETS	Subsidies
Mechanism	- Price set by government; market determines emissions reduction - Feebate system is a variant wherein emissions over benchmark pay fees and those below are rebated	- Emissions cap set by government; price determined by market	- Fund R&D; subsidise gap in fuel and/or capital costs (demand or supply side) - Government procurement/ provision of public services
Effect on market	- Carbon price is stable and changes can be signalled to market in advance	- Carbon price can be volatile which increases uncertainty and risk for investors	- Volume, level and recipient of subsidy determined by government
Effect on emissions	- Level of emissions reduction unknown in advance	- Emissions reduction trajectory can be controlled	- Complements other policy tools with targeted support in hard-to-abate segments

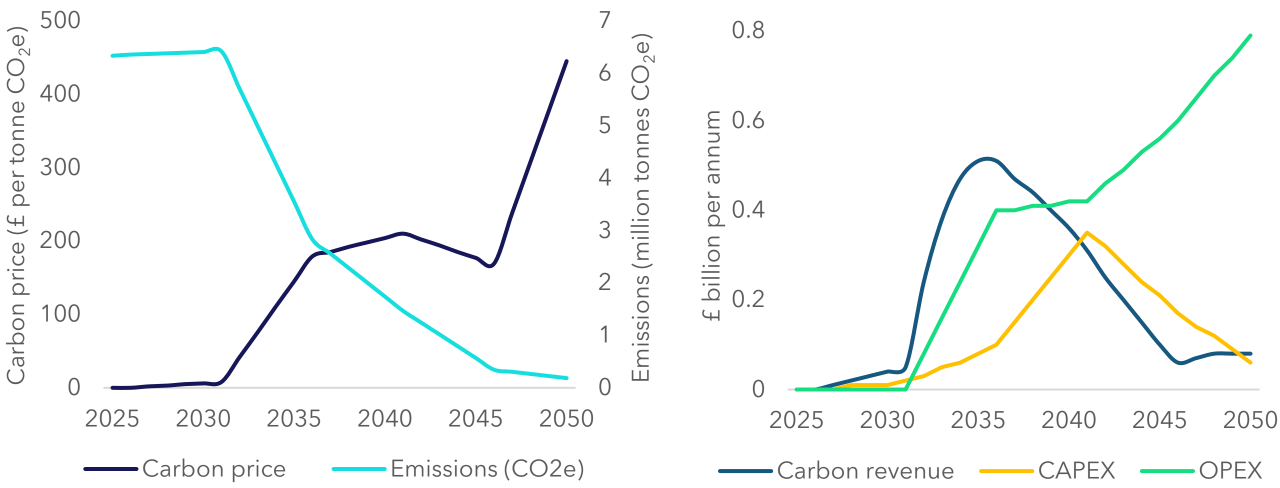
Source: Getting to Zero Coalition[44]

Economic instruments are critical policy tools to effect change in hard-to-abate industries. They can cut or close the gap in fuel costs, but they do so in different ways. Those that apply a carbon price (taxes, levies, ETS) raise the cost of conventional fuels while fuel subsidies (and the balancing half of the feebate system) reduce the cost of zero emission fuels. Carbon pricing and subsidies can be used in tandem, but it is implausible that subsidies can be used alone given the scale of funding needed. A key benefit of carbon pricing is that it generates revenue which could then be recycled into subsidies and/or directed into other efforts to support an equitable transition. In other words, carbon pricing is considered to be essential to reach net zero, whereas subsidies are a choice.

Based on modelling undertaken for the Clean Maritime Plan of the scenario to reach net zero by 2050, Figure 8.2 shows an indicative carbon price and the resulting emissions trajectory (shown for domestic shipping emissions, not domestic fleet emissions), alongside the resulting revenues, and the incremental fuel and capital costs associated with retrofitting existing vessels and building new zero emission vessels.

This modelling shows that rising carbon prices increase revenue generation until the mid-2030s, at which point falling emissions cause revenues to decrease. During the transition (2030 to 2040), revenues are comparable to the incremental capital cost. In this period, subsidies may help to accelerate the uptake of zero emission fuels and clean maritime technologies. This approach has been adopted by the EU where the decision has been taken to recycle 75% of revenues generated by shipping in the EU ETS to help decarbonise the sector.

Figure 8.2: Scenario modelling to indicate carbon price required to reach net zero by 2050 and resulting emissions saving (left); revenues, incremental fuel and capital costs (right); all costs shown basis 2015



Source: UMAS[56]

Thus far, the UK government has employed or proposed three different economic instruments for use in the domestic maritime sector:

1) R&D grants have been offered through the Clean Maritime Demonstration Competition (CMDC)
2) Renewable fuels of non-biological origin (RFNBO) for maritime use have been included under the Renewable Transport Fuel Obligation (RTFO), although without a corresponding mandate obliging either supply by the fuel industry or use by the maritime industry
3) Inclusion of larger domestic merchant vessels in the UK ETS

The first two economic instruments act as subsidies (although, as seen in its application across wider transport fuels, the RTFO functions as a carbon price when matched by a corresponding obligation on the fuel supplier). The UK ETS is a revenue-generating carbon price, but in its current proposed form, it applies to a very limited subset of the domestic fleet and therefore more measures and mechanisms will need to be employed to disseminate carbon pricing throughout the domestic fleet. These may entail the removal of fuel rebates (i.e. 'red diesel') for vessels on inland waterways and/or imposing fuel duties on coastal and seagoing commercial vessels.

8.2.3 Types of economic support schemes

Economic support schemes, such as grants and subsidies, are generally flexible policy tools. They can be specifically targeted (e.g. project or location basis) or can be made available to the wider sector (e.g. the CMDC scheme). In this way, economic support schemes can act as a channel through which funding can pass to areas where investment is needed but the business case does not initially work (e.g. investment in onshore fuel or power infrastructure that would not be commercial on a standalone basis). Such schemes can also help to overcome the split incentives issue (e.g. with grants to cover part of the incremental cost of retrofitting energy efficient technology, similar to the Norwegian NOx Fund approach). Economic support schemes could, in principle, help ensure that the whole sector transitions to net zero in the timescales necessary.

Table 8.3 outlines some examples and applications of economic support schemes and their potential recipients. The UK government may consider using fuel and capital support schemes as incentives, but the suitability of such measures will depend on the specific situation.

Table 8.3: Examples of economic support schemes

Form of support	Function/considerations	Types	Target recipients
Innovation or R&D funding	- Support for fuel and technology trials - Can accelerate time to commercialisation - Trade-off between breadth and level of support	- Grants - Tax (accelerated allowances)	- Manufacturers - Fuel producers/ suppliers
Fuel subsidy	- Rebates all/part of cost difference between zero emission fuel and benchmark conventional fuel - Support over long term can disincentivise cost reduction in zero emission fuels	- Contracts for difference (CfD) - Tax (fuel rebate)	- Shipowners - Charterers
Capital subsidy	- Covers all/part of capital expenditure related to decarbonisation (e.g. incremental cost of zero emission versus like-for-like conventional vessel, cost of shore power or fuel infrastructure provision) - Covers all/part of capital cost of energy efficiency technology retrofit	- Grants - Soft loans - Guarantees - Tax (accelerated allowances)	- Shipowners - Ports - Fuel producers/ suppliers - Shipyards
Government procurement	- Where government has direct control/ownership of vessels, can dictate timing of investment in zero emission solutions (where feasible) - Where government indirectly procures shipping services (e.g. offshore wind), can encourage local content as part of tender process	- Subsidised lifeline services - Local content requirement	- Public - Shipowners - Charterers - Manufacturers - Shipyards

Source: Getting to Zero Coalition[44]

Innovation funding

Innovation grants are useful to stimulate investment in nascent technologies, are often targeted at small companies, and are typically awarded through competitions. An innovation funding programme built around specific goals would need to target support toward likely winners rather than provide broad support for many ideas. The viability of technology would need to be assessed at each stage (feasibility, pilot, commercialisation) as an increasing level of funding will be needed to progress through each stage. This is the approach that has been adopted by the CMDC.

In some schemes (again like the CMDC), access to innovation funding may be dependent on matched funding from industry partners. This can be useful in building collaborative partnerships between stakeholders, and the proportion between public and private funding can be adjusted over time, encouraging increasing levels of private investment.

Enhanced capital allowances

Capital allowances are claimed by businesses which have spent money on R&D activity or have purchased long-lived assets. Via capital allowances, the cost of this investment is offset against taxable profits over a period of time that is typically in line with the life of the asset. Enhanced capital allowances allow for a greater deduction of the capital cost early on in the asset's life (typically in the first year) and are available for certain assets (including R&D activity, qualifying energy efficient and low/zero carbon technologies, and plant and machinery equipment in freeports) to encourage investment[138].

Enhanced capital allowances could be extended to cover investment in low or zero emission vessels used in the domestic maritime sector (this will only apply to qualifying domestic shipowners that do not operate in the Tonnage Tax scheme). France currently allows domestic shipowners to claim 125% of the incremental capital cost (relative to a like-for-like conventional fuelled vessel) if the propulsion system is fully decarbonised, or 105% if the vessel uses LNG[139].

Contracts for Difference

A recent proposal suggested using a 'Contracts for Difference' (CfD) scheme to subsidise zero emission fuel use by international shipping[140]. This is a mechanism that has been used, with great success, by the UK government since 2014 to support investment in renewable electricity generation projects, including offshore and onshore wind, solar, and energy from waste/biomass.

The CfD scheme allows project developers to bid for a fixed (strike) price for electricity generation which the government guarantees to pay over a 15-year period[141]. The project capacity and strike price are agreed upfront, and over the duration of the contract, the government pays/receives the difference between the strike price and a reference (wholesale electricity) price depending on whether the reference price is lower/higher than the strike price.

The costs in renewable electricity generation projects are generally front-loaded: the construction period requires a lot of capital, but ongoing operational costs are low (compared with, say, a gas power plant where the input gas would be a significant and variable ongoing cost). Therefore, access to private capital is critical for renewable electricity generation projects. The CfD provides the developers of these projects with guaranteed, stable revenues over the duration of the contract, enabling them to access project finance to fund construction.

The CfD scheme has been hugely successful in bringing large-scale private investment into renewable electricity generation projects and market-led innovation has reduced prices significantly over time, particularly in offshore wind. Through the use of competitive auctions, the strike price for offshore wind has fallen by more than two thirds from £120 per MWh in Round 1 to £37 per MWh in Round 4[142].

However, transposing the CfD scheme to the shipping and maritime fuel industry would be challenging for a number of reasons. Firstly, it would need to cope with a much more complex structure, involving pass-throughs between multiple stakeholders such as fuel suppliers, shipowners and/or operators. The agreements reached between the stakeholders would need to ensure that the incremental capital cost of constructing a zero emission vessel was covered and that the split incentives issue was resolved if the shipowner and operator were not the same entity. Secondly, while the stakeholders might agree on the contractual period, they might not necessarily be able to stipulate a discrete quantity of fuel (as this would depend on the activity of the underlying vessel).

Thirdly, the CfD mechanism works well when the renewable energy project has high upfront capital costs (which are reasonably certain) and low operational costs. The structure allows potential risks/return to be assessed beforehand, which is attractive to the more conservative institutional investors that are able to offer low-cost funding. However, suppliers of zero emission fuels will need to use renewable electricity to produce these fuels and so will be exposed to a variable (and potentially high) operational cost element which means the income profile of the project is much more uncertain (even with a CfD in place). This would make the project less attractive to inward investment by institutional investors.

Lastly, CfD auctioning has reduced the strike price considerably for renewable energy projects over time. To see a similar level of innovation and competition by suppliers of zero emission fuels through CfD schemes, an equivalent auction process would be needed. This may be difficult to achieve given there will likely be a range of low and zero emission fuels that can be made in different ways and associated uses, and that project volumes are unlikely to be at the same scale as seen in renewable electricity generation.

The falling strike price is a key benefit of the CfD mechanism as it reduces the cost of renewable electricity generation from successive projects. However, the level of economic support provided by government is variable as it is determined by the difference between the strike and reference prices. The latter is based on the wholesale price of electricity, itself determined by the marginal source of generation (i.e. wholesale gas price). In a low gas-price environment, renewable projects receive income from the government; in a high gas-price environment, they deliver revenue to the government.

If a CfD were to be introduced in the domestic maritime sector, the role of government would be to meet any shortfall between the strike price agreed on the output from a zero emission fuel project and the reference price (most likely a conventional marine bunker fuel). As seen in renewable electricity generation projects, the government could see a shift from cash outflows to inflows, although this would depend on future fossil fuel and carbon prices.

Given the issues surrounding their application, the use of CfDs to support zero emission fuel production is likely to be limited to specific projects (e.g. linked to the formation of green corridors or for offshore wind maintenance vessels where the fuel generation is localised). However, depending on the circumstances, other forms of support may be more appropriate (e.g. underwriting a fuel purchase agreement with a fuel supplier).

Capital subsidies

Grants and soft loans (debt with favourable terms such as low interest rates and/or long amortisation profiles) can support:

1) Fuel suppliers investing in production facilities to make zero emission fuels
2) Ports investing in infrastructure needed to deliver zero emission fuels and shore power
3) Expansion of production capacity/capability at shipyards and equipment manufacturers
4) Incremental cost of low/zero emission vessels

Parts of the zero emission fuel supply chain currently do not have a viable business case for investment, but are needed to decarbonise the wider maritime sector (e.g. shore power at ports or zero emission fuel infrastructure). These are strong candidates for capital subsidies, and potentially even direction regulation to mandate provision and/or use.

Grants that contribute to vessel retrofits and/or cover a proportion of the incremental cost of a lower/zero emission vessel (compared with a like-for-like vessel) are a way of overcoming the split incentives issue and lowering the hurdle for investment decision faced by shipowners. Such grants have been offered to shipowners in Norway and the Netherlands.

This may not be enough for many domestic owners facing fleet renewal, particularly those with a business model formed around the purchase of second-hand rather than new vessels. Additional support may therefore be required. For example, in Norway, grants have been augmented by soft loans for some newbuild projects and a scrap and replace scheme for short sea and fishing vessels has also been offered[112].

However, alternative solutions that enable funding can obviate the need for grants. Examples of such mechanisms are illustrated in Chapter 10.

Government procurement/local content

Local content requirements are a useful tool for supporting domestic maritime industries. In many areas, the developers of offshore wind projects are encouraged to demonstrate their support for local content as part of their bids in auctions. In turn, the developers similarly request shipowners tendering for long-term charters of offshore wind maintenance vessels to specify how much local content can be included in their proposals.

The proposed guarantee scheme for domestic shipbuilding applying to domestic shipowners could also support increased use of local content. This could be bolstered in future, by linking grants and/or loans offered for vessel retrofitting of energy efficiency technologies to UK shipyards and/or equipment manufacturers.

8.3 Policy tools to mobilise private capital

8.3.1 Why investments need to be de-risked

Economic instruments that bridge the commercial gap between zero emission and conventional fuels support the business case for investment in the production and distribution of the former. However, this will not necessarily mobilise private capital into the industry to fund that investment. A favourable risk assessment is the key determinant that unlocks inward investment.

The private sector is often unwilling to take on early-stage, developmental risk, particularly where this involves new technologies or industries where government policy is likely to play a significant role in the trajectory of development and political risk is deemed to be high. Mitigating this risk is therefore a crucial element in encouraging private sector investment and this can be achieved in a number of different ways (Table 8.4).

Table 8.4: Summary of forms of government support that can unlock private capital investment

Form of support	Function/considerations	Target beneficiaries
Grants and subsidies	- Many types/uses of grant funding and subsidies - Innovation stage funding de-risks nascent technologies - Capital grants and/or fuel subsidies can de-risk investment depending on which risks are covered and which still remain	- Equipment manufacturers - Shipyards - Ports - Shipowners
Matched funding	- Joint funding from public and private sources shares risk - Allows government to participate in upside	- Equipment manufacturers - Fuel suppliers
Public-private partnerships	- Infrastructure or project-based funding by private capital de-risked by long-term contracts	- Ports - Shipowners
Government guarantees	- Government underwrites element of debt facility - Type and timing of guarantee depends on key risk exposure (e.g. credit quality, asset risk, construction risk)	- Shipyards - Shipowners

Source: Marine Capital

8.3.2 Policy tools available

Grants and subsidies

Carbon pricing and fuel subsidies are policies which, respectively, raise the cost of conventional fuels and lower the cost of zero emission fuels. Although both close the commercial gap, they send out different market signals and may be used at different stages of development. Fuel subsidies are useful at an early stage of the transition where, along with R&D funding, they can create a 'technology-push' effect on the production of new zero emission fuels by de-risking investment in demonstration and initial projects. This de-risking function is attractive to private capital providers so long as the projects are of sufficient scale (as seen in offshore wind projects).

Carbon pricing typically acts as a later stage 'market-pull' measure which can help to level the cost of different fuel types, depending on the size of the gap and the price set[143]. When it is introduced after the market has been formed, investment in fuel production and/or the vessels that use these fuels will be less exposed to technology and stranded asset risk, but will still be exposed to a level of market risk. The barriers that currently inhibit fleet renewal (i.e. those caused by the state of the underlying market) will still be in place and will be further compounded by the incremental cost of zero emission replacements. For this reason, capital grants for shipowners could be required over a longer period than fuel subsidies.

Matched funding

Matched funding involves joint contributions from private investors and the public sector. This is a typical approach seen in innovation funding (as used by the CDMC) and is being used to stimulate investment in clean maritime technologies by some nations. For example, in the Maritime Singapore Green Initiative, the Singapore government provides capital to investment vehicles which are focused on decarbonisation initiatives and managed by asset/fund managers in the private sector.

The participation of the public sector mitigates risk to the private investor either by taking on a higher level of risk (e.g. by acting as 'first loss' capital, the first to be exposed to any losses incurred by the investment) or by accepting a lower return. However, issues can also arise if the risk/return requirements and other investment criteria differ between the public sector and private market investors; trying to achieve alignment between the two can be problematic.

The UK has two main institutions through which such investment could most obviously be channelled: the British Business Bank and the UK Infrastructure Bank. Either or both of these could potentially provide matched funding to support the marine decarbonisation transition, and more specifically, the clean maritime manufacturing sector.

Public-private funding models

Public-private funding models (commonly known as Public-Private Partnerships, PPPs) are arrangements between the private sector and a public body where the former finances the construction of infrastructure (or a long-term asset) on behalf of the latter. In such projects, it is common for the private investor to also operate and/or maintain the infrastructure or asset (e.g. a concession to provide a ferry service). The type of contractual arrangement between the public and the private body varies, but for institutional investors to enter a project, there typically needs to be clear risk mitigation.

The role of the public body is to offer support that mitigates the risk. This may be in the form of direct public funding (which occurs upfront, over the life of a project, or at its end), or in the form of a guarantee (in which case public funding may or may not eventually be required). In either case, the role of the public body is to modify the risk profile of the project so that it is acceptable to the providers of private capital. This will depend on the return expectations and risk tolerance of private investors and, as is often seen on large projects involving significant construction periods, different investors will enter and exit over different stages of the project.

In the UK, PPP models have been used since the 1990s to finance large infrastructure projects such as roads and hospitals. The structure of the contractual arrangements has shifted over time to ensure that less obligation rests on the public sector, but variations of the model are still used by the UK and regional governments[144]. Given the level of support that will be needed to overcome the commercial hurdles to develop, produce and supply zero emission fuels and domestic vessels, some form of PPP model may well have a role to play in the decarbonisation of the domestic maritime sector.

There will be opportunities throughout the zero emission fuel supply chain for different forms of public-private models. These include the construction of renewable electricity generation capacity (likely through the CfD scheme) to generate these fuels, the production facilities, and infrastructure at ports to store the fuels. The provision of shore power at ports is also likely to require some form of government support.

Where government currently owns or otherwise subsidises the provision of lifeline ferry/Ro-Ro services, private finance could be introduced via a PPP model, particularly where fleet renewal is necessary (an example of this is given in Chapter 10). But the government may need to step in to play a role in the wider domestic maritime sector (particularly in the harder-to-abate segments with old vessels) to enable fleet renewal and decarbonisation. This could be through the use of guarantee or insurance mechanisms that enable private capital to flow into those segments.

Government guarantees/insurance

To unlock private capital that will fund the cycle of fleet renewal *and* decarbonisation, steps to de-risk investment will need to be taken (over and above those that initiate the production of zero emission fuels and technologies). Although this could be delivered through capital grants and other subsidies, not all policy options are monetary.

Under a guarantee mechanism, the public sector guarantees the revenue received by private capital providers. The arrangement can exist between the government and the private investor (e.g. in the CfD mechanism used for renewable energy generation) or the government can step in as an intermediary to underwrite a debt obligation between a company and the private capital provider, e.g. if the company has insufficient track record/credit quality. The proposed Home Shipbuilding Credit Guarantee is an example of this as it would give UK shipyards access to finance to underwrite the shipowners' payment obligations in domestic contracts.

This mechanism is used by Export Credit Agencies (ECAs) to guarantee loans provided by commercial banks to support the export of a domestic good or service (this is a common tool used by shipbuilding nations to support the construction of ships in their shipyards). Although the UK has an ECA (UK Export Finance, UKEF), in its current guise, its role is likely to be confined to supporting domestic shipyards and manufacturers of clean maritime technologies for export. The UKEF has limited ability to assist in securing loan facilities to owners of the domestic fleet.

As well as concerns over credit quality, commercial debt providers are very hesitant to take on residual value exposure on long-lived assets, particularly when involving new technologies. Insurance products that cover any capital loses in a private investment at a given (or range) of points in the life of the project or asset, where available, can help overcome this by providing a safety net midway through the economic life of an asset that mitigates obsolescence and stranded asset risk.

This is a potential tool that could be used to facilitate debt finance for the construction of new vessels in the domestic market by underwriting the value of the vessel at the end of the loan term. Such products are available from time to time on the commercial insurance market and have been used in transport and other types of assets (particularly aviation). Known as Residual Value Insurance (RVI), these products protect against capital loss at an agreed future date.

In shipping, RVI normally covers a period of 3-5 years and guarantees that if a properly maintained asset cannot be sold for more than a specified value at a future point in time, the underwriters either pay the policy limit and take over the asset or pay the difference between the best sale price that can be achieved during a re-marketing process and the RVI agreed value. However, the product is targeted at generic vessels in international shipping where valuations are robust and transparent, and large parts of the domestic fleet would struggle to qualify.

Government could play a similar role to underwrite the residual value of vessels at a future point and thus enable smaller shipowners who will struggle to fund fleet renewal with new zero emission vessels to access finance. An example of this mechanism is outlined in Chapter 10.

9

Identifying the Priorities

The government's strategy for decarbonising the domestic maritime industry should align with the UK's energy strategy and should also be grounded in a wider transportation strategy.

Measures that oblige and/or support this goal should focus on the high-emission segments of the domestic fleet first and should be informed by the underlying commercial characteristics of those segments.

Key target segments of the fleet identified include ferries and Ro-Ros (particularly in connection to green corridors) and offshore service vessels (supporting the oil and gas and offshore wind industries).

9.1 Identifying the levers of change

Across all parts of the world, maritime sectors face similar challenges to decarbonisation. A key factor is the cost gap between conventional fuels and low or zero emission alternatives, which is currently too great to be bridged by any willingness to pay for greener shipping. Universal issues also include the uncertainty over which future fuel(s) will be widely available, the 'chicken and egg' problem that hinders the provision of onshore fuel and power infrastructure, and the lack of clarity about what obligations (and possibly support) regulatory and economic instruments will provide. Many of these challenges are interlinked, and progress with one will help propel another towards resolution.

Distinct challenges emerge within each regional or domestic maritime sector, but so do opportunities to advance towards net zero. These can relate to the types of shipping activity that are undertaken, the profile of the current fleet, the existence of legacy infrastructure, the level of shipbuilding and maritime manufacturing capabilities, the involvement (or lack thereof) of government, the business models adopted by stakeholders, or the relationships between them.

These factors will shape how the transition can be navigated, and by understanding the challenges and opportunities they represent, the path to net zero can be more effectively piloted. A strategic approach is needed to deliver change in an effective and timely manner, and the policies applied must be coherent and consistent.

Policy tools that oblige and/or support decarbonisation can be targeted at specific areas to create greater momentum for change within the whole sector. There will be priority areas for decarbonisation, whether due to the level or concentration of emissions, the age of the fleet, or the stakeholders involved. There will also be segments where more support will be needed to reach net zero. These have been identified in this chapter, along with potential funding mechanisms that could assist in mobilising the inward flow of private capital.

9.2 Critical elements to support the transition

9.2.1 Viewing energy and transport as interlinked systems

The decarbonisation of the domestic maritime sector is embedded within the transition of wider energy and transport systems. Coherent, joined-up strategies are needed to deliver change effectively across all components of these systems.

Energy strategy

Decarbonisation will shift the energy landscape, both nationally and globally. New supply chains for zero emission fuels will emerge and the UK's energy strategy will need to evolve to cover the production, consumption, and the import and export of these fuels, along with the associated ramifications for energy security. However, this also presents an opportunity to reconceive the sectors which are intrinsically linked to the production, transportation, and use of energy. The scale of investment required to transition to net zero provides a singular opportunity to coordinate discrete elements of the supply chains and rebuild legacy infrastructure.

The international shipping industry awaits the development, production, and supply of low and zero emission fuels. The industry is just one source of demand for such fuels and will not dictate the direction or rate of change; rather, it will adapt to whichever fuels and technologies emerge as the overall winners in the global energy transition. At the domestic level, however, there will be opportunities for the UK government to support strategic tie-ins between renewable energy and clean maritime projects, but each will need to be assessed carefully to ensure the benefits (e.g. an opportunity to eventually supply fuels to a wider fleet or other industries) outweigh those offered by other approaches.

Lastly, the provision of shore power at ports will also need to be coordinated with the national energy strategy, particularly where the electrification of domestic vessels is a feasible solution for eliminating greenhouse gas emissions. This is a thorny issue which individual ports will struggle to overcome in isolation and where coordinated action by government will be needed.

Transport strategy

The decarbonisation of domestic shipping should also be viewed in the context of a wider transportation strategy, both at national and regional level. This strategy should assess the relative decarbonisation trajectories and costs between different modes of transport, how shipping can be used to reduce transport emissions on an end-to-end basis across the logistics chain, and what demands shipping will need to meet in the future.

Goods and passengers can be moved from one location to another using one, or often multiple, modes of transport: road, rail, sea and air. Each mode has different advantages (flexibility, efficiency, speed), but shipping is the most emissions-efficient form of transport. These modes often complement one another (forming an intermodal transportation network), but they can also compete with one another.

All forms of transport will need to decarbonise, but the trajectories taken by each will differ, as will the costs borne. An overarching transportation strategy is needed to ensure that regulatory and/or policy interventions do not inadvertently shift demand away from shipping. This could lead to an overall increase in emissions (as well as road traffic) and would have serious consequences for the industry, ultimately making decarbonisation even harder to achieve. To ensure that unintended consequences do not result from future policy decisions, careful consideration is needed to assess how changes that are targeted at specific links in the logistics chain can impact all others.

Intermodal substitution, however, also represents an opportunity for the shipping industry, particularly when emissions are assessed on an end-to-end basis. Companies that report on the greenhouse gas emissions from their supply chain (Scope 3 emissions), may take greater steps to substitute coastal and short sea shipping for road and rail. For example, the emissions associated with transporting goods from Felixstowe to Newcastle upon Tyne by truck are six times higher than would result from shipping those goods[145].

Decarbonisation will affect the purpose and change the shape of domestic transportation and its supporting infrastructure. The cars, trucks and trains of the future may look very different to their current counterparts and may be used in different ways. The services required of shipping may also evolve (e.g. the needs of the lifeline ferry services in Scotland may change), but given the long life of vessels, it is important that such trends are recognised early and that transportation policy is delivered in a coordinated manner.

Domestic maritime strategy

Not only does the decarbonisation of the domestic maritime sector needs to be linked to wider energy and transport strategies, but the sector itself would benefit from a coordinated approach by government. This could be achieved through a single unit (such as UK SHORE) that could be tasked with developing and monitoring a suite of complementary policy tools and ensuring greater communication and coordination across government departments such as BEIS, HM Treasury, DIT, etc. The unit could help bridge the parts of the industry that are currently disjointed and siloed and encourage key stakeholders to align their strategies with the government's net zero vision.

Such a unit could also, together with stakeholders from the maritime sector, develop a clear and cohesive net zero strategy delivered through a package of complementing regulatory and policy tools, against defined targets and timelines. This would eliminate one source of uncertainty for the industry, help unlock investment decisions, and remove one barrier dissuading private capital from entering the sector. Undoubtedly the strategy will need to evolve over the course of the transition, and again, this is easier to manage if a single department bears overall long-term responsibility for execution and oversight.

As well as addressing the commercial barriers to decarbonisation, this strategy might also consider other challenges where government could play a crucial role in them being overcome. This could include, for example, ensuring that the safety issues related to new fuels are addressed/regulated as quickly as is reasonably possible, and that training is made available for those working with these fuels. Lastly, such a unit could also play a valuable role through active engagement with the industry, and by creating a forum through which major stakeholders in traditionally siloed parts of the industry can build more collaborative relationships.

9.2.2 Supporting innovation and building skills

There are multiple reasons for supporting innovation in clean maritime technologies. Such technologies can directly support the decarbonisation of domestic shipping, but they can also be sold more widely into the global maritime industry. Innovation can also lead to greater manufacturing capacity and capability, enhancing domestic supply chains, increasing competitive advantage, and building the skills needed to work with new low and zero emission fuels (which will become imperative in domestic shipping).

Innovation needs support, which is typically delivered through grants at the initial stage. As with other capital-intensive industries, it can take significant levels of funding for a technology to move from conception through to commercialisation and the timescales between each stage may be long. To fund through to the latter stages of development, grant schemes must assess which technologies are the most viable and which offer the greatest value. This value could be linked to adjacent industries (e.g. support for technologies that provide demand for a zero emission fuels that are also being developed), or it may be based on wider benefits to building manufacturing hubs certain locations, or because there is a focus on developing certain skills or competitive advantage.

The scaling up of CMDC funding indicates an intention to deliver increasingly focused support of clean maritime technology innovation. This should make it easier for those projects to access external capital and finance, but government entities such as UKEF and the UK Infrastructure Bank could also be called upon to offer structures supportive of external investment capital.

9.2.3 Regulation and the use of economic instruments

The proposed inclusion of domestic shipping emissions into the UK ETS needs to be carefully assessed and the reach of the scheme needs to be fully understood. Within the domestic fleet, the vessels primarily affected will be ferries and Ro-Ros that that sail between the UK mainland and Northern Ireland, and from the UK mainland to islands, including those that provide subsidised lifeline services in Scotland.

Where domestic emissions result from vessels that are not in the domestic fleet (i.e. from vessels that only occasionally sail between UK ports), then an assessment of how that traffic may be altered by the UK ETS is needed. This could have an impact on road congestion if the trading pattern of these vessels shifts from multiple stops at UK ports to just one.

In addition, areas of potential friction between the UK and EU ETS regimes must be identified and methods by which avoidance can be deterred need to be determined. Once the EU finalises the package of policies that will apply to all shipping activity in Europe, an assessment of the benefits and disadvantages of mirroring (or not) European regulation and policy should be undertaken. Given the potential scope for leakage (e.g. vessels altering trading patterns or refuelling in certain jurisdictions to avoid paying levies), domestic maritime regulation cannot be formed in isolation.

Regulation and the use of economic instruments will play a vital role in decarbonising domestic and short sea shipping. Such tools will be necessary to reduce the commercial gap between conventional fuels and zero emission alternatives. They can be used to compel emissions reduction in existing and new vessels and can offer specific support where needed.

However, these tools are more effective if introduced as a package that allows different components to address distinct challenges in a coherent and complementary manner. This requires a careful assessment of the domestic maritime sector, its stakeholders and the unique challenges and opportunities presented. By doing so, the areas of priority for early intervention or support can also be identified.

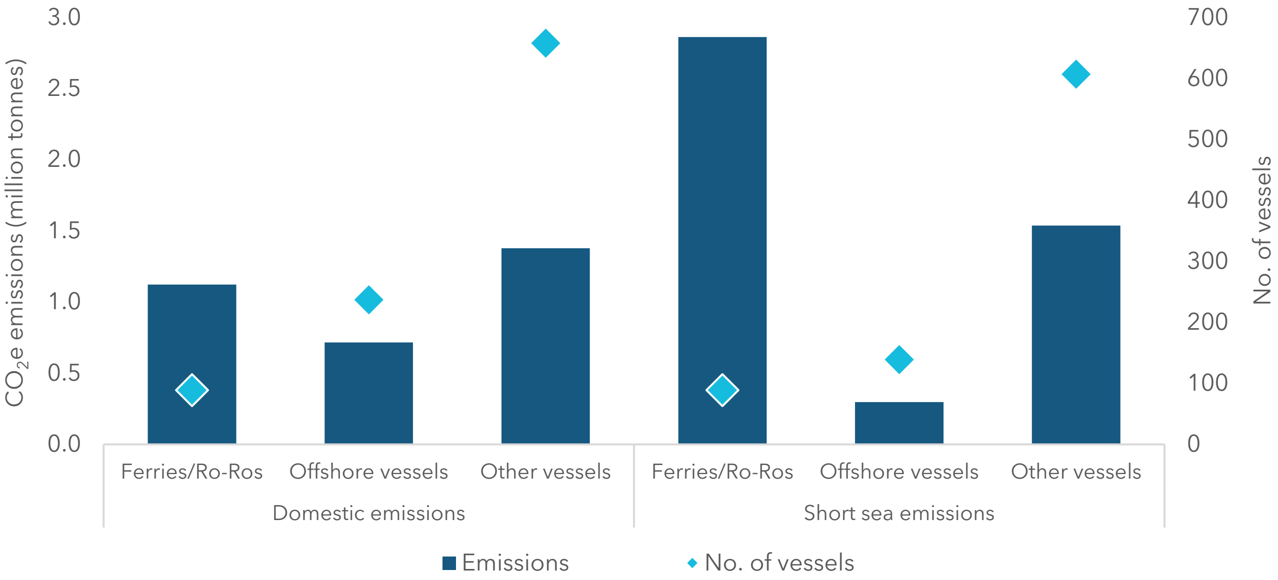
9.3 Determining the areas of priority

9.3.1 Identifying the early wins

The evaluation of greenhouse gas emissions in the domestic and short sea fleets shows how important decarbonising ferries (Figure 9.1), Ro-Ros and offshore vessels will be. Ferries/Ro-Ros form the largest source of emissions. This segment is highly concentrated with a small number of vessels accounting for a high proportion of overall emissions. Offshore vessels work in the oil and gas and offshore wind industries (although currently a far greater number work in the former) and are collectively the second largest source of emissions. These vessels are therefore an obvious target for early decarbonisation.

The offshore wind sector is also well suited to early decarbonisation for a number of reasons and doing so would align with the objectives of the industry coalition set up as part of Operative Zero at COP26. It is a discrete sector, where specific targets and support can be more easily directed. The long-term charters between wind farm developers and shipowners for key vessel types makes the split incentives issue easier to resolve. Focus on this sector could also provide an opportunity to build local supply chains and greater manufacturing capacity.

Figure 9.1: Emissions (million tonnes CO_2e) from domestic and short sea fleets (left); number of vessels in domestic and short sea fleets (right)

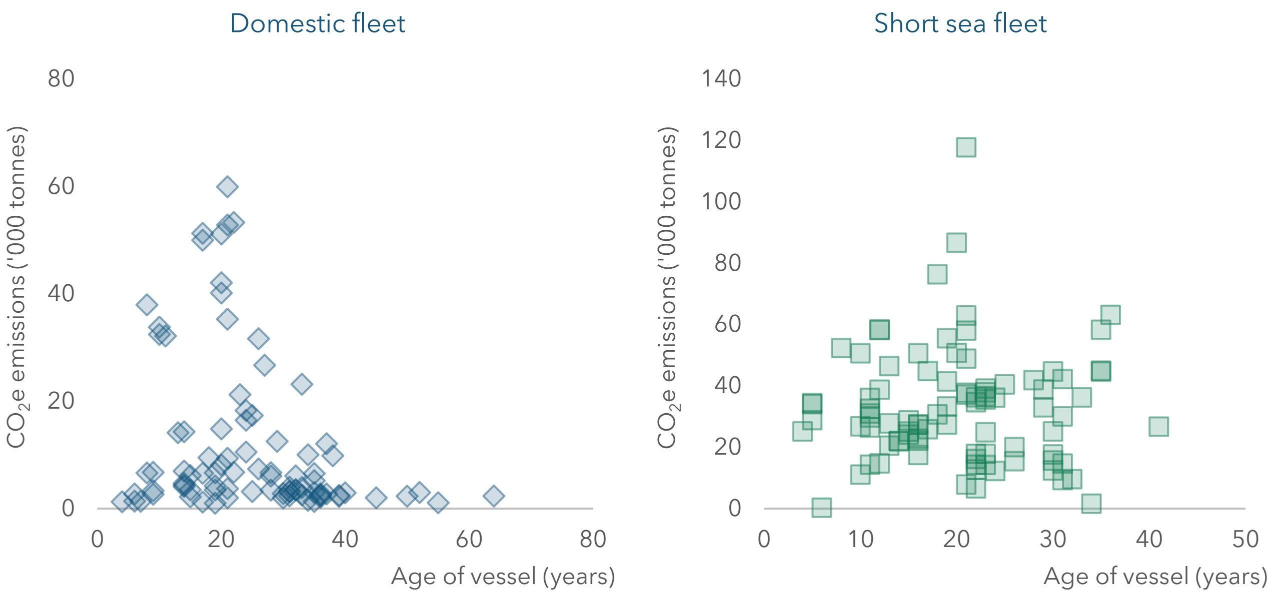


Source: Based on UMAS FUSE[16] data

9.3.2 Green corridors: domestic and regional opportunities

The scale of emissions in the ferry and Ro-Ro segments of the domestic and short sea fleets, and the level of concentration in a low number of vessels shows how important it is to decarbonise the segment. The current age profiles of the fleets in Figure 9.2 indicates an opportunity to lock-in significant emissions reduction when the cohort of vessels currently aged 20-25 years is renewed.

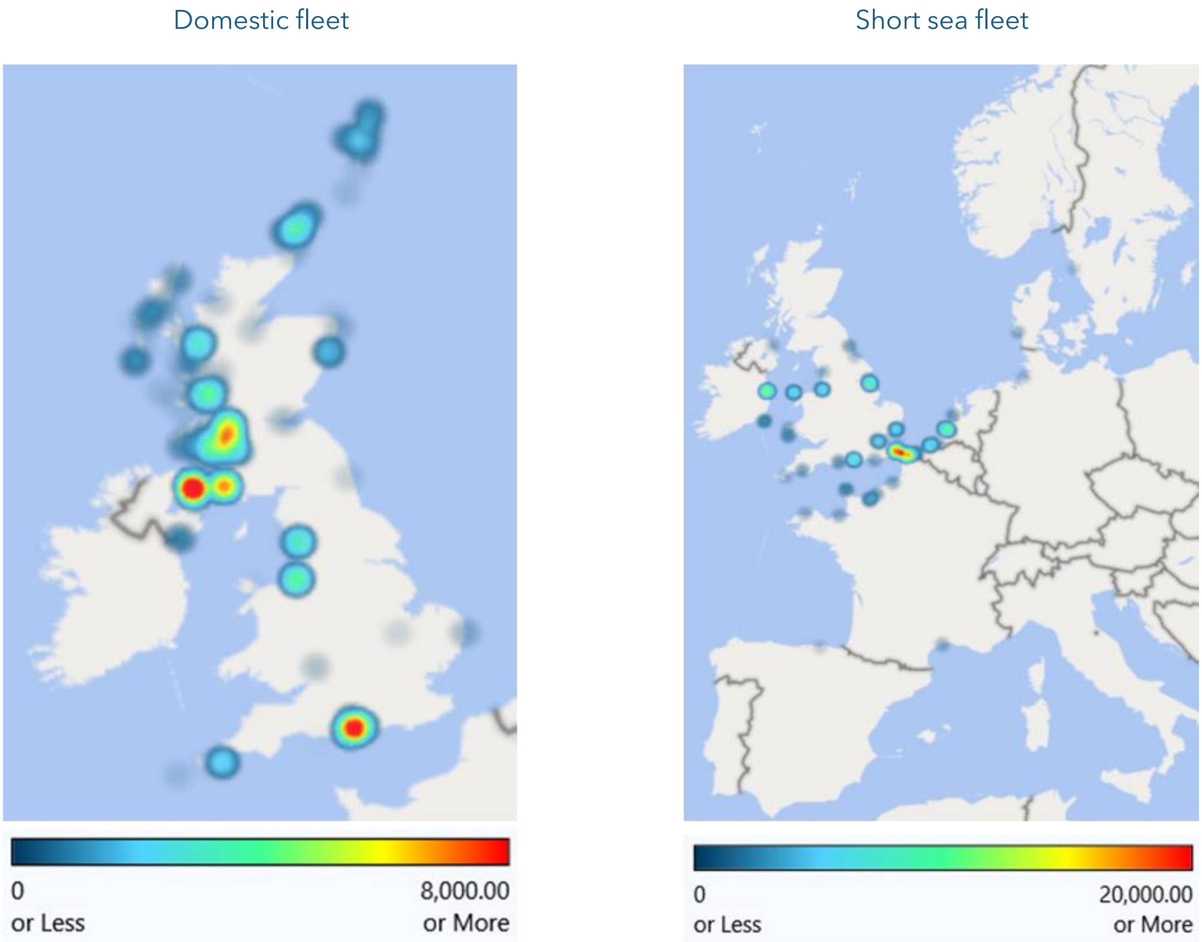
Figure 9.2: Vessel age and emissions from ferries and Ro-Ros in the domestic and short sea fleet



Source: Based on UMAS FUSE[16] data

Ferries and Ro-Ros are well suited to participation in establishing green corridors as these vessels trade consistently from the same ports, the relationships between ports and shipowners are typically long-standing and zero emission fuels need only be provided in a limited number of ports (Figure 9.3). However, green corridor projects also need collaboration between multiple stakeholders, support from policy makers and a willingness from cargo owners and customers to pay for green shipping.

Figure 9.3: Heat map of emissions (tonnes CO_2e) at UK ports from ferries and Ro-Ros in domestic fleet and at UK and short sea ports from ferries and Ro-Ros in short sea fleet



Source: Based on UMAS FUSE[16] data

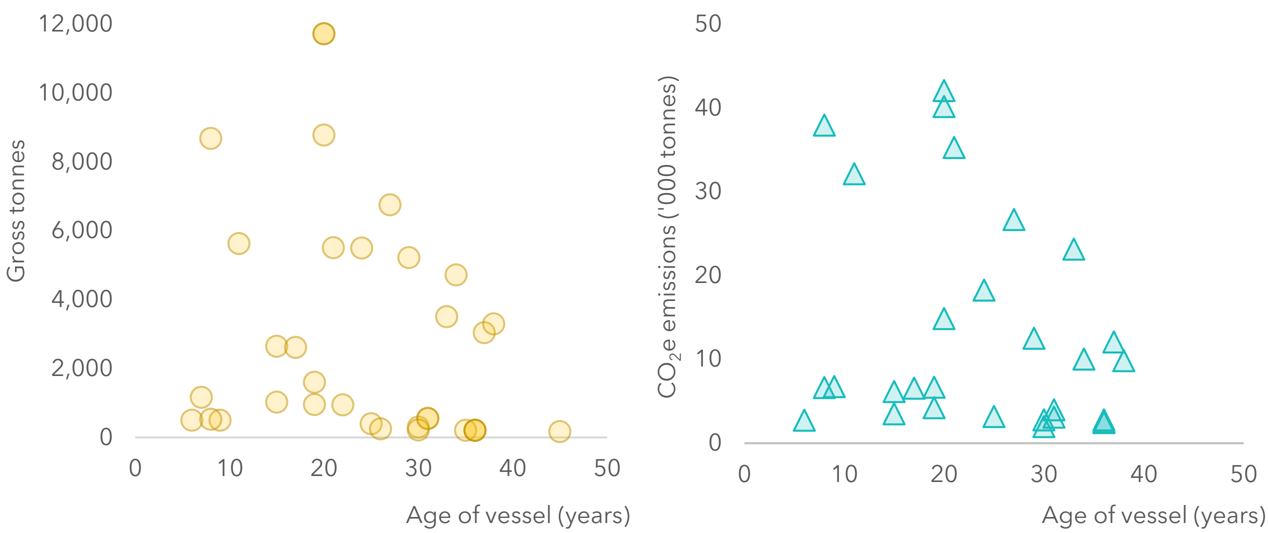
9.3.3 Scottish ferries: a significant source of greenhouse gas emissions

The manner in which subsidised lifeline ferry services are provided for island communities in Scotland is unique and not reflective of ferry ownership/operation models found elsewhere in the UK. The fleet of ferries is owned by the Scottish Government (through Transport Scotland) via an asset-owning company (CMAL) and are currently operated by CalMac Ferries Ltd (which is also owned by Transport Scotland) and the Serco Group. In addition, CMAL owns 16 ports and harbours in western Scotland (which are operated on a day-to-day basis by CalMac Ferries), and leases properties and port infrastructure at 10 other sites[146]. The Scottish Government directly funds investment in vessels and shore side infrastructure as part of its national infrastructure investment plan[147].

This arrangement has evolved over decades, and although the division between asset ownership and operation was intended to generate best value from tenders for subsidised services, it has also led to operational inefficiencies. Vessels have been built to very varied specifications, which typically leads to higher construction costs and makes ongoing operation and maintenance more complex and costly than otherwise. As the fleet has aged, the cost of maintenance has increased significantly[148].

The fleet is comprised of 36 ferries and one landing craft. This fleet is responsible for 40% of emissions from the domestic ferry/Ro-Ro segment and 15% of emissions from the entire domestic fleet. The median age of the vessels in the fleet is 25 years, and more than a third are 30 years or older (Figure 9.4).

Figure 9.4: CMAL fleet by age and size (left) and by age and emissions (right)



Source: Based on UMAS FUSE[16] and Clarksons Research Services[53] data
Note: Four of the ferries currently owned by CMAL were not tracked by the UMAS FUSE model and so emissions for these vessels are not shown

There is a pressing need for fleet renewal, however, only four new vessels are currently on order. These are two dual-fuel LNG-capable ferries being built at Scottish shipyard Ferguson Marine Engineering Ltd (expected to be delivered in 2023)[61] and two under construction at a Turkish shipyard (expected to be delivered in 2024/2025)[149]. Additional investment in vessels and port infrastructure is planned over the coming decade and the Scottish Government has set a target for 30% of the fleet to be 'low emission' by 2032, although this ambition will be primarily met through the replacement of smaller vessels which account for less than 5% of total emissions from CMAL's fleet[150]. Significant levels of funding will be required to deliver large-scale fleet renewal and overall emissions reduction.

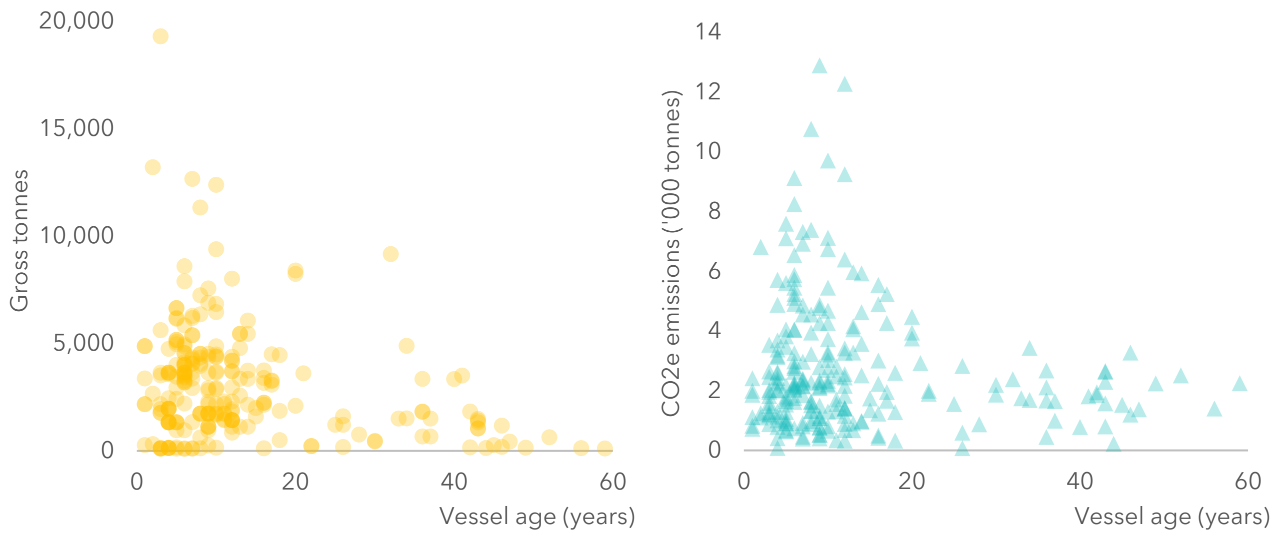
In many ways, CMAL's network of vessels and ports offers an ideal opportunity for early decarbonisation through a programme that coordinates investment in replacement vessels with a plan for funding shore-side infrastructure. Investment by external providers of long-term capital could enable a such programme to be developed. This could be tied to an overarching strategy that takes into consideration the future requirements for lifeline services to island communities and how local energy production could accelerate decarbonisation. An example of how this partnership and funding model for this unique business structure could work is outlined in Chapter 10.

9.3.4 Offshore oil and gas vessels: capital grants funded by the industry

This is a highly diverse segment and vessels range from the very simple (e.g. crew transfer vessels) to the highly complex (e.g. specialised support vessels). Collectively, offshore oil and gas service vessels are the second largest group of greenhouse gas emitters. As can be seen in Figure 9.5, the level of emissions varies by vessel, but the fleet profile is far younger than seen in most other segments, indicating that opportunities to retrofit existing vessels may be more economically viable than in older vessels.

These vessels can be chartered directly by energy companies but are more commonly subcontracted through companies that service the oil and gas sector. In this sector, split incentives may present a challenge to emissions reduction as long-term contracts are not typical. Grants that cover a portion of the cost of retrofitting existing vessels, or a portion of the incremental capital cost associated with building new low or zero emission vessels, is one potential form of such support. This approach was shown to be an effective solution for reducing NOx emissions in Norway.

Figure 9.5: Offshore fleet by age and size (left) and by age and emissions (right)



Source: Based on UMAS FUSE[16] data

Vessels working in the oil and gas industry could be encouraged to reduce emissions by government setting specific targets for the sector, and a grant for the incremental capital costs could potentially be funded by the oil and gas companies which own the platforms. Again, a similar arrangement was set up in Norway as part of the strategy to reduce NOx emissions. This approach gave shipowners and charterers the flexibility to decide what fuels and technologies would best deliver the emissions reduction required and accelerated innovation in vessel and engine design.

As most of the offshore oil and gas fleet is comprised of generic vessels, one solution shipowners may possibly adopt would be to substitute existing tonnage with more efficient alternatives. This means that zero emissions could be achieved much earlier in this sector than would be seen in a sector where bespoke assets operate (i.e. ferries/Ro-Ros) and where emissions reductions are determined by the age of existing vessels and the timeline for replacement.

9.3.5 *Offshore wind sectors: enabling domestic stakeholder participation*

The offshore wind sector offers an attractive opportunity to decarbonise the whole supply chain, including operation and maintenance vessels. This could have more wide-reaching benefits by providing support for domestic shipbuilding and manufacturing, increasing economic activity in regional areas that have been identified as part of the government's 'levelling up' strategy, and growing the participation of domestic shipowners and asset management within the sector, thereby strengthening the maritime cluster all-round.

Offshore wind is one sector of the shipping market which generates significant interest from institutional investors and financial institutions given their increasing focus on renewable energy projects and the expected significant growth in the market. It should therefore be a sector for which institutional capital could be attracted with relative ease.

Although this is an area in which more domestic shipowners could in theory participate, the relatively 'closed' nature of the market (e.g. the tendency to limit contract awards to existing participants), the low rates of return that may be on offer in long-term contracts, and the nature of individual transactions (too small for institutional investor equity and too large for individual shipowners) all make it difficult for domestic shipowners to break into the market. Stipulating the desire for UK local content in the contract award process does not necessarily favour a wider group of UK shipowners due to the lack of equity funding. A potential solution to this issue is outlined in Chapter 10.

9.4 Enabling investment in complex segments

Several segments of the maritime sector will need assistance in decarbonising assets and operations. Where this facilitates wider decarbonisation efforts (e.g. support for fuel infrastructure and provision of shore power at ports), then careful consideration of the support required is warranted. This is likely to be on a case-by-case basis. For example, a competition similar to the CMDC could give ports the opportunity to apply for funding for a shore power project (whether through grid connection or through onsite/local energy generations). Funding could be granted based on criteria such as improvements to air quality near densely populated areas or power supply for local electric vessels.

For domestic shipping, while the scale of emissions by ferries, Ro-Ros and offshore vessels marks these segments as priority areas, the rest of the fleet must also be encouraged to reduce emissions. Given the diversity of vessel types in the service segment, different challenges will be faced by each. Some of these challenges will be technical (e.g. limiting the types of fuels or technologies that could be applied); some will be operational (e.g. vessels which do not operate from fixed locations will find a fuel-based transition difficult until supply is widely available); while others will be commercial (e.g. split incentives, lack of willingness to pay by customers, current business/asset-ownership models).

Some of these issues will be resolved through the passage of time: the selection of fuels and technologies that are feasible and available will become apparent. However, commercial hurdles are likely to remain. From a funding perspective, there are a number of policy tools that could be employed, such as scrap and replace schemes, grants, soft loans, and guarantees (potentially in combination). There will not be a one-size fits all policy to these challenges so it is important to recognise where and why additional support might be needed, and how best it may be applied.

There are many medium and small-sized shipowners in the domestic maritime sector, and they are most likely to own second-hand vessels. These owners will find meeting an obligation to shift to zero emission shipping difficult as it will entail a significant shift in business/asset-ownership model. They will need much greater levels of funding to replace existing vessels but are likely to struggle to access it given that credit quality is also likely to be an issue. A potential solution/funding mechanism has been suggested in Chapter 10.

Potential Funding Models

Access to capital is a key constraint to investment in low and zero emission vessels. With appropriate risk mitigation the inward flow of capital into the domestic shipping industry could be facilitated.

A set of potential funding solutions have been developed with the assistance of a working group formed of members from various (primarily) financial institutions.

These funding models can be employed immediately to assist early adopters of zero emission fuels and technologies and to help tackle the acute need for vessel replacement.

10.1 Developing targeted funding models

Given the heterogeneity of the domestic maritime sector, a variety of mechanisms will be required to address different challenges. The issues faced by shipowners vary depending on size, activity, asset base, and operating and business model, but many find accessing funding difficult. This, in turn, affects their ability to fund the decarbonisation of their fleet and their operations. Government support can help overcome these hurdles and mobilise the flow of private capital into the domestic maritime sector.

The potential funding models described below address the priorities outlined in the preceding chapter. In the first two case studies, the suggested funding model is a variation of a tool or mechanism which has been, or currently is, used to stimulate private sector capital investment in other industries. In the last case study, the suggested funding model draws on financial products which are not currently available from the commercial sector, but which could be offered by government.

These are mechanisms which can be rolled out immediately. The funding models do not rely on other decarbonisation-related policies being in place, nor do they need to wait for a functioning market in zero emission maritime fuels and technologies to develop. By developing structures through which private investors are able to participate in the domestic maritime sector, the inward flow of investment would 1) assist early adopters of zero emission fuels and technologies and 2) help tackle the acute need for vessel replacement (which will also deliver emissions reduction through more efficient new vessels).

Another important characteristic of these funding models is that while government support is required to assuage certain risk concerns for the investor, they do not take the form of upfront funding or subsidy. Rather, investor exposure to technology/asset risk can be mitigated by support from the government which enables long-term funding to be put in place.

To determine how these funding models could be applied in practice, a working group of financial institutions, institutional investors, and professional service providers was formed to provide suggestions and give feedback. These members discussed how the concerns and issues that might well be raised by private sector investors could be addressed. The group consisted of representatives from Abrdn, Citi, Equitix, EY, Green Finance Institute, NatWest (Lombard), Shawbrook Bank and Watson Farley & Williams.

10.2 Asset leasing case study: Scottish ferries

As described in the previous chapter, the split asset ownership and operation model in place for Scottish ferries is unique in the UK's domestic maritime sector. A considerable level of funding will be needed to replace this fleet and given the long working life of these vessels and the fact that they account for a meaningful portion of domestic shipping emissions, a fleet renewal programme that does not deliver a move towards low/zero emission vessels will be a lost opportunity. Therefore, although the Scottish ferries business structure is atypical, it is well-deserving of specific attention as a case study.

The key tenet of the funding model proposed in this case study, asset leasing, is a well-known concept that has been used successfully to fund the construction of new assets in a variety of markets such as aviation, the rail industry (rolling stock) and international shipping. While this funding mechanism could also be employed across the wider domestic fleet, a large-scale Scottish ferries replacement programme could provide an investment opportunity of sufficient size to attract institutional investor interest.

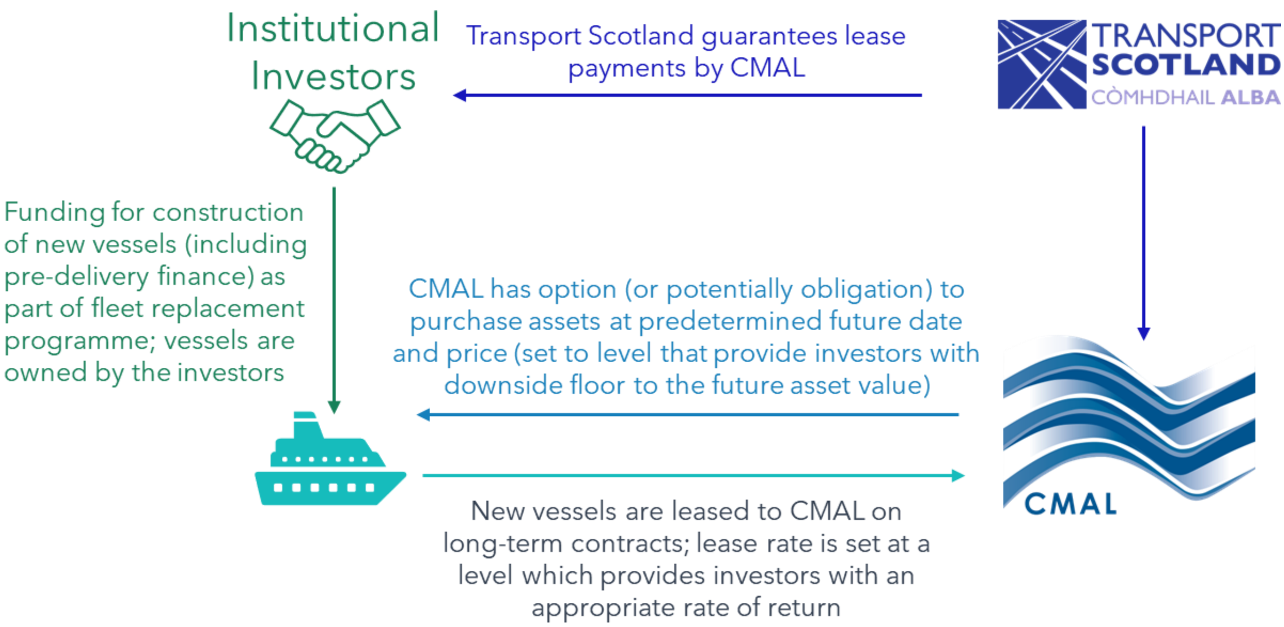
The Scottish Government faces a very large funding requirement for fleet replacement. The cost of replacement for the 18 vessels that are over 25 years old is likely to be in the region of £750 million on a like-for-like basis. Zero-emission vessels could add 15% to 20% to the newbuild cost (assuming use hydrogen or ammonia fuel cells). In addition, funding will also be needed to build the required onshore energy infrastructure.

Transport Scotland has announced an investment programme of £280 million over a 5-year period to address the issue of fleet replacement. This includes the construction of the two new vessels ordered in March 2022, along with the small vessels replacement programme. A further £306m has been allocated to CMAL to fund improvements to piers and harbours that support ferry services[147].

Significantly greater investment in vessels is required and a viable long-term funding solution is needed to deliver decarbonisation as well as vessel replacement. The high cost of new vessels means that they must operate for many years and given current decarbonisation targets, they will either need to operate with zero-emission fuels upon delivery or be delivered with the capability to be converted in future.

All existing vessels are financed through unsecured loans from the Scottish Government which has stated that any future capital expenditure will be funded in the same way. Given the scale of the impending outlay, this may prove undesirable for the Scottish Government and private sector capital may be required. A public-private partnership structure could be developed whereby the private sector provides the capital, in the form of debt and/or equity, to finance a large-scale fleet replacement programme (Figure 10.1).

Figure 10.1: Illustrative structure of public-private partnership asset leasing mechanism



Source: Marine Capital

Using this mechanism, the private sector capital finances the construction of new vessels as part of the fleet replacement programme in the context of a strategic transportation and energy policy. The key features of this mechanism are:

- The provision of pre-delivery finance included as part of the funding provision
- The vessels would be leased to either CMAL (as the vessel owning entity) or CalMac (as the vessel operating entity)
- Long-term/lifetime contracts for the vessels would offer security for investors
- Contract structures and government guarantees would be needed to mitigate asset/technology and residual value risks
- Standard industry shipyard guarantees and a close supervision process (which could be delegated wholly or in part to CMAL) would protect against construction risk.

There are of course, several issues that would have to be addressed in order to ensure the appropriate level of interest from institutional investors and that the lowest possible cost of funding is achieved. The key risks/concerns include:

Asset/technology risk

The large CMAL ferries that need to be replaced in the coming decade may not have zero emission solutions available and, unless the vessels are built with the capability for future conversion/retrofit, any potential risk of obsolescence prior to the end of their economic life will need to be mitigated through the support underpinning the lease contracts.

One option would be to match the lease tenor with the full economic life of the asset. This would transfer asset risk fully to CMAL or CalMac. Alternatively, a long-term (but not lifetime) lease with a purchase obligation at a predetermined future date and price could be used to remove residual value risk for the investors. Additionally, rather than a large-scale newbuilding programme, smaller packages of vessels over a 10-year period could also help investors to achieve familiarity and comfort with the sector and assist in mitigating some aspects of concern.

However, should private capital be available, the Scottish Government may then be in a position to pursue a more ambitious plan for fleet decarbonisation given its control of the onshore fuel infrastructure and its ability to subsidise the cost of this fuel directly for the ferry operator CalMac. This could mean that more innovative technologies and vessel designs could be employed, potentially delivering a quicker transition to net zero for the fleet. Again, to offset any technology risk, investors will want to see leasing arrangements be supported appropriately.

Credit risk

Any such transaction would require guarantees from the Scottish Government, and the cost of capital would reflect the perceived credit risk associated with this guarantee (rather than UK sovereign risk).

Operational inefficiencies

The current organisational structure headed by Transport Scotland splits asset ownership (CMAL) and asset operation (CalMac). This can introduce inefficiencies. A lack of standardisation in vessel design could result in higher maintenance costs, and it may prove more difficult to match the specification of new vessels to the requirements of the particular routes they will service. These issues would be concerning to investors, who would likely desire evidence of effective coordination between asset ownership and operation.

Reputational risk

As these ferries provide lifeline services, any interruption in operation can have a material impact on the quality of life for those living on islands. Such exposure would be viewed as reputational risk. Similarly, any delays and budget overruns for the vessels being constructed would be politically sensitive issues. Investors will be wary of reputational risk that can arise from being implicated in any such controversies.

Despite these concerns, the project would likely attract institutional investor interest and a public-private partnership could be developed on the basis of an appropriate contract, structured with suitable protections. Transport Scotland has a number of public-private partnership arrangements in place which have been implemented for improvements to motorways over the last 25 years[151].

10.3 Consortium case study: offshore wind vessels

Offshore wind is one sector of the shipping market which generates significant interest from institutional investors and financial institutions given their increasing focus on renewable energy projects and the expected significant growth in the market. It should therefore be a sector for which it could be relatively easy to attract institutional capital.

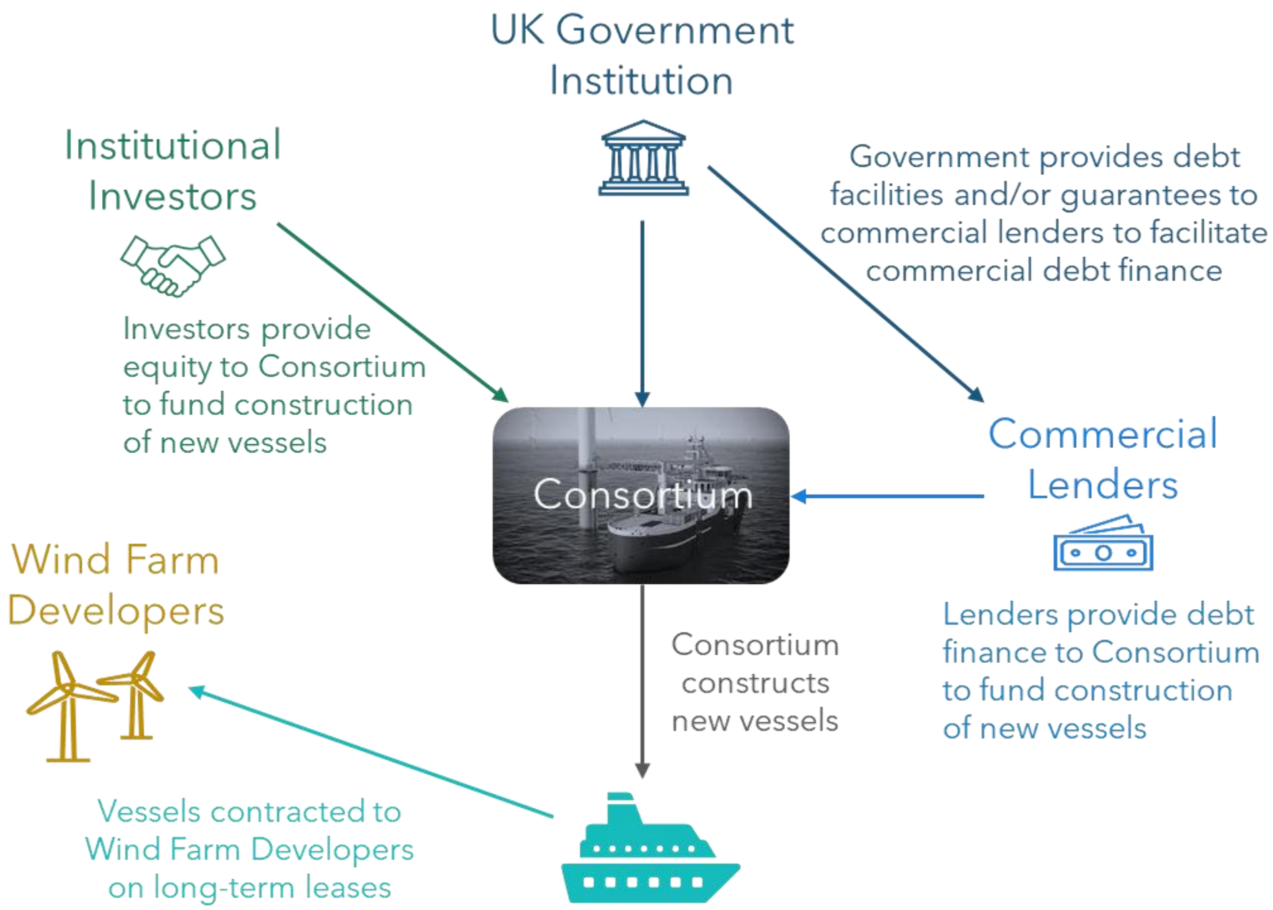
In the lead up to the launch of Operation Zero at COP26, the UK government commissioned a report that outlines a roadmap to decarbonise offshore wind operations and maintenance vessels in the North Sea. This report concluded that, in total, up to 140 service operation vessels (SOVs) and 315 crew transfer vessels (CTVs) could be needed by 2030 to operate and maintain offshore wind farms in the North Sea[152]. Approximately 40% of this capacity could be needed for offshore wind farms in the UK.

The UK has a potential pipeline of 80 GW of offshore wind capacity. There is currently 12 GW of offshore wind capacity fully commissioned, another 55 GW under development, in pre-planning or under construction, and a further 12 GW of potential future capacity[153]. The UK government recently increased its 2030 target from 40 GW to 50 GW in offshore wind capacity[154].

This presents a huge opportunity for the domestic offshore wind industry and associated manufacturing supply chain, along with associated port developments. As well as supporting the production of offshore wind turbines and components, there will also be increased demand for operation and maintenance vessels to service the turbines. A portion of these may be built in the UK, supporting domestic shipbuilders and maritime equipment manufacturers. There is also an opportunity for domestic shipowners to participate in the tender process for owning and operating these vessels.

However, individual UK shipowners may lack the size, equity and credit quality required to access low-cost debt and offer competitive bids for tenders by wind farm developers for long-term vessel charters. A solution to these challenges could be a consortium approach involving a group of UK shipowners coming together to offer a package of vessels to a group of wind farm developers. This consortium would be funded by equity capital from institutional investors, as illustrated in Figure 10.2.

Figure 10.2: Illustrative structure of consortium approach to offshore wind vessel provision



Source: Marine Capital

The key features of this approach are:

- It would allow a wider group of domestic shipowners to participate in the growing demand for offshore wind operation and maintenance vessels over this coming decade
- It could give small (but eligible) UK shipowners the opportunity to compete with larger non-domestic shipowners as part of the consortium group
- Government could facilitate commercial debt financing through facilities and guarantees provided through UKEF or UKIB at a lower cost than shipowners could individually secure
- Combined newbuild orders could allow the consortium to access lower pricing at shipyards through a single packaged bid
- Some vessels could be constructed at UK shipyards, and/or utilise domestic maritime equipment thus increasing the domestic skills base (particularly if clean maritime technologies are stipulated)
- Provides an opportunity for domestic shipowners to grow in capacity and capability allowing them to meet demand for future projects without similar reliance on a similar structure

Once again, there are a number of issues that will need to be addressed if this approach is employed.

Provision of commercial debt

In shipping finance, commercial banks typically provide debt finance on specific assets which are chartered to named entities by individual shipowners. A consortium approach poses a number of challenges for commercial debt providers as the shipowners, charterers (wind farm developers) and assets are 'pooled' at the outset. The question of who has security over what must be resolved at the outset. In addition, banks generally require relatively short (in relation to the asset life) loan tenors and prefer little or no residual value exposure at the end of the debt finance facility.

To overcome these issues, government support would likely be required, at least in the initial years. The most obvious route for the government to provide this support would be via an appropriate government institution with lending capability in the form of preferential debt facilities and/or guarantees (e.g. UKIB).

Provision of equity

Equity providers would face similar issues to debt providers on the identification and isolation of the credit risk on the chartering counterparty if they are funding a group of assets which would be chartered to a range of counterparties. In principle, the risk would be assessed on the quality of the weakest owner and chartering counterparty, but careful drafting could allay investor concerns. Wind farm developers are large, creditworthy energy companies, which should provide further comfort. The eventual capability to build scale and diversification beyond an initial project would also help mitigate these risks.

Decarbonisation requirement

To ensure that, where technologically possible, zero emission vessels in the UK offshore wind supply chain become a reality in the coming decade, decarbonisation criteria can be stipulated more strongly in upcoming wind farm tenders, thereby requiring bidders to factor this element and its associated cost into their bids.

Residual value risk

Vessels such as SOVs in the offshore wind market are typically constructed to meet the requirements of specific wind farms. These vessels are usually chartered long term by the wind farm developers and the tenor is sufficient to reduce residual value risk to a satisfactory level for commercial lenders.

10.4 Asset leasing case study: platform for multiple owners/assets

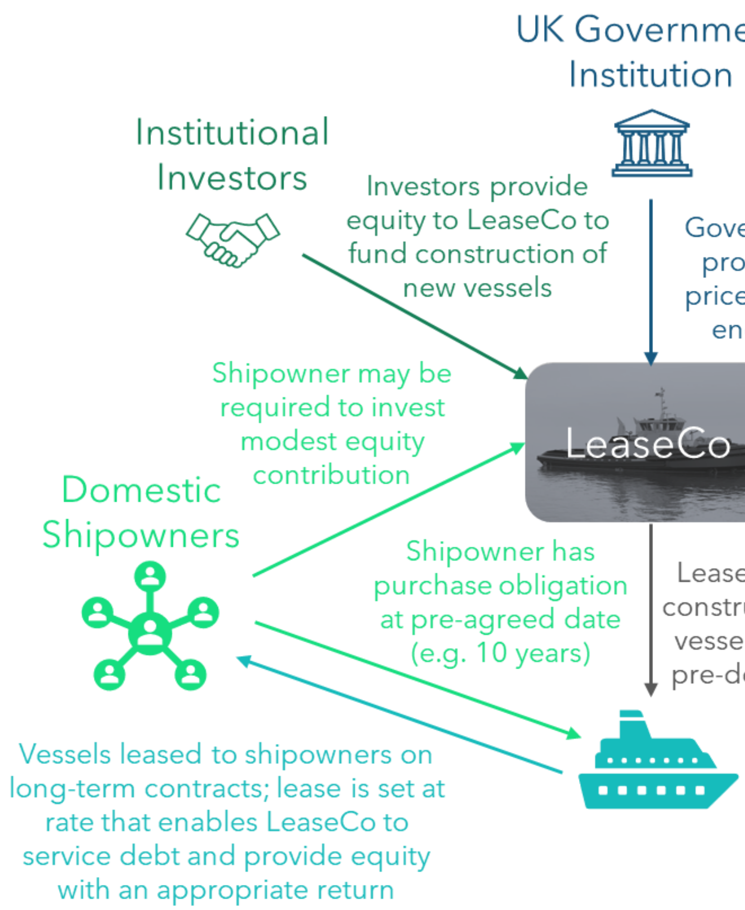
The domestic maritime sector is primarily comprised of small and medium-sized shipowners, many of which will struggle to fund the construction of new vessels (particularly those that typically acquire second-hand rather than build new) due to insufficient equity and/or credit quality. An asset leasing platform could be used to address the issues of access to finance and credit quality for shipowners that qualify (under precise criteria as to what qualifies as a 'domestic owner' and a 'domestic vessel').

This leasing platform (LeaseCo) could be established with the participation of private sector capital (both debt and equity) to fund the construction of new vessels to meet fleet replacement requirements across multiple shipowners and types of vessels. The vessels could then be offered on a long-term lease to those owners. Given that some owners are facing imminent pressure to replace existing end-of-life vessels, it is unlikely that initial new vessels constructed will be zero-emission, but stricter decarbonisation criteria would be implemented over time as further progress is made along the transition pathway.

There is, however, a 'chicken and egg' challenge facing commercial lenders and institutional equity investors in such a leasing entity. While many lenders and equity providers would consider participating in such an entity when it is already up and running, neither would be prepared to take the first-mover initiative by, for example, funding an initial bloc of transactions that would grow the platform to a minimum 'investible' scale.

Before this scale is reached, commercial lenders and equity investors would assess their risk exposure (i.e. the size, credit quality, asset risk, etc.) based on each individual transaction within the bloc. However, as the platform grows, the diversification of risks (particularly credit quality) and the portfolio of staggered, long-term cash flows created from the leases would be a vehicle that is of much greater interest to lenders and equity providers. To overcome the challenges associated with the initial start-up period, government could offer residual value insurance (RVI) to provide the lessors with a guarantee for the residual value of the assets (at a pre-agree floor price) at the end of the lease period as illustrated in Figure 10.3.

Figure 10.3: Illustrative structure of asset leasing platform for multiple owners/assets with government RVI



Source: Marine Capital

Under this mechanism, the residual value insurance would unlock commercial debt and equity investment; institutional investors provide equity capital and commercial lenders provide debt finance to the platform and this enables the platform to fund the construction of new vessels for a large-scale fleet replacement programme.

The key features of the mechanism are:

- The platform aggregates the funding requirements from the domestic shipping industry and so creates the level of scale sought by institutional investors and financial institutions
- New vessels would be constructed in line with the decarbonisation pathway: in practice this could mean alignment with technical efficiency design standards, or vessels that are built to be capable of future retrofitting (potentially with follow-on funding available to finance this as part of the debt package).
- A range of qualifying criteria could be set for both vessels and owners which could be employed in green corridor projects to enable participation at an early stage
- Government RVI guarantees a floor for the residual value of the assets based on a pre-agreed amortisation schedule (e.g. 50% of newbuild value at year ten)
- Underwriting by government enables LeaseCo to provide high leverage (up to 95%) lease finance to domestic owners, limiting the level of shipowner equity required
- There is no upfront cost to the government and the mechanism could be structured to provide an element of profit participation to the government in return for the underwriting (e.g. if a vessel is sold during the life of the lease and a profit is realised over and above the benchmark or strike price, the government could receive a pre-set percentage of this profit)

There are a number of concerns/risks in the early stages of the platform's operation that would need to be addressed to ensure interest from investors and commercial debt providers.

Credit risk

Even once the platform achieves scale, a significant portion of the underlying lessees will be of low credit quality. The workboat market would be a good example of this, with shipowners likely counted in the hundreds, vessels in the thousands, and with individual asset values ranging from a few hundred thousand pounds up to £2 million, depending on size and specification.

The credit risk issue could be addressed by focusing initial transactions on larger domestic shipowners with upcoming fleet replacement requirements (and possibly linked to green corridors or clean maritime hubs). This would facilitate the provision of private sector capital (both debt and equity). As the platform developed its own balance sheet and expanded its activities, it could include a greater number of transactions with smaller owners.

The platform could then develop securitisation structures where cash flows of similar tenor, effective interest rate, and credit quality are bundled. The risk-return profile of each tranche would attract different institutional capital depending on the investors' individual target criteria. This would allow equity investors to choose their level of exposure to credit quality risk, in return for an appropriate level of return.

Operational risk

In any lease arrangement, there is the risk of default by the lessee. In such instances, the lessor may need to take physical control of the asset and then can either seek to 1) sell the asset, 2) find an alternative lessee, or 3) find employment for the asset directly in the market. However, even where the vessels are generic, and so could potentially be sold or employed more easily, lenders are extremely hesitant to get involved in either process. This reluctance will be even greater for vessels built bespoke to operate on specific routes and trades.

One solution would be for the leasing platform to establish a level of operational capability at the outset. In this way, it could manage alternative arrangements for the asset (if not directly operate) in the event of a default. This could be achieved by developing an in-house operational capability, or by liaising (by appropriate tender) with a small group of operators/managers whose role it would be to provide all necessary support to the platform in the event of default by any individual underlying domestic shipowner.

Management complexity

Establishing and operating an asset leasing platform requires a variety of skills: commercial, operational, technical and financial. There is also an administrative function that must be covered to oversee day-to-day operations. The platform should be managed by a commercial entity(-ies) rather than the public sector, with government having the appropriate oversight capability.

Conclusion

Despite the challenges, the energy transition also offers opportunities: to renew the domestic fleet with low and zero emission vessels; to reconceive legacy infrastructure; to build maritime manufacturing supply chains and skills in clean energy.

To achieve its goals, in the timeframe required, government will need to develop a coherent strategy, introduce cohesive policies, and facilitate inward investment through appropriate measures.

In 2019, the UK government committed to reaching net zero by 2050 and published the Clean Maritime Plan, outlining its vision of how this could be realised in the domestic maritime sector. There has been visible progress towards this goal with the launch of the Clean Maritime Demonstration Competition and UK SHORE. It is vital that attention remains on the sector, and that a coordinated and cohesive strategy continues to be built, in conjunction with industry, to support the decarbonisation of domestic maritime.

The UK's maritime sector is a complex jigsaw of stakeholders, infrastructure, and vessels, and there is no easy division between the international and domestic sections. It is important to clearly define what constitutes the 'domestic fleet' and to understand the key characteristics of that fleet. Questions such as, "what function do the vessels serve, where do they operate between, what level of emissions do they generate, how old are they and who owns them?", can help determine what factors will shape the trajectory of the transition and what measures may be needed to support this.

Carbon pricing is a key policy tool, but although it can help bridge the gap between conventional and alternative fuels, it is not the panacea. The underlying commercial structure of the domestic market will still present challenges to decarbonisation, and government must understand what these are and where they lie.

It is vital that measures are targeted appropriately to ensure that the transition is accelerated rather than impeded. Here again, a thorough understanding of the sector is needed, but so too is acknowledgment of its part in the wider picture. The government's maritime strategy must be an integral component of a broader plan to decarbonise transportation which should assess how the impact of measures in one area can shift cargo and passengers away from vessels (and possibly onto a mode of transport with higher emissions). Encouraging firms to report on emissions from their supply chain (Scope 3) will support progress towards net zero goals across the logistics industry. Policies must also reflect the interactions with different regulatory frameworks, particularly that of the EU.

Where support is offered to the maritime sector, it must be on the basis of greatest benefit. This may be to enable the commercialisation of promising technologies with proven markets, to build skills in clean energy that the maritime and other sectors will require in future, or to ensure that vital infrastructure is put in place. Individual sectors and stakeholders may also require assistance, but support does not always require direct funding by government.

Much of the focus thus far has been on encouraging innovation in zero emission fuels and technologies. However, the energy transition will require a whole-system transformation and to achieve this in the timescales required, solutions to multiple hurdles must be considered simultaneously. As fuels and technologies are developed, safety issues related to their use must be resolved, commercial barriers must be overcome to encourage uptake, supply chains and skills must be developed, and new infrastructure and vessels must be built. This study has suggested how funding for this last element can be facilitated now, without waiting for the introduction of carbon pricing or the selection of a 'winning' zero emission fuel solution.

Access to capital is a critical barrier across the shipping industry, for both large and small shipowners. The level of investment required to replace the existing fleet, in addition to decarbonising it, presents a huge challenge. Current sources (and structures) of financing will not be sufficient to deliver this, and new channels of funding will be needed. Institutional investors (such as pension funds and insurance companies) represent over $80 trillion in assets and could be a viable source of funding. However, government support will be needed to overcome some of the hurdles facing their participation.

To enable the inward flow of this private capital, there are a number of steps that government can take. Insight from the approaches in other countries in this study highlighted the benefit of drawing the investment community in at an early stage. Knowledge can be shared in both directions and channels of funding are more easily established. This is particularly important for transition-stage funding, where the investors are keen to participate, but wary of the risks involved.

This study has considered how and where government can mitigate those risks, and in conjunction with a working group of financial institutions, institutional investors, and professional service providers, funding models have been proposed that address these issues. While the first two case studies illustrate solutions for specific cases, the third represents a broader generic solution which could be rolled out fleet-wide. This mechanism can be applied immediately and offers an opportunity to effect transformational change across a much larger part of the domestic fleet by unlocking currently untapped investment capital.

Appendices & Bibliography

I. Shipping emissions model

In recent years, the improved quality of ship tracking data (Automatic Identification System, AIS) has enabled greenhouse gas emissions to be more accurately evaluated on a discrete voyage basis. Domestic shipping emissions and the domestic and short sea fleet profiles in this study have been generated by the UMAS FUSE model, which combines AIS (to quantify factors such as speed and draught), vessel technical specification (such as engine power), and port databases to estimate fuel consumption and greenhouse gas emissions of vessels on a port-to-port voyage basis[16]. This model was used in the Fourth IMO Greenhouse Gas Study[59].

The UMAS FUSE model uses data from 2018, but as it has undergone extensive processing to attribute technical specifications to vessels as small as 100 gross tonnes, gives comprehensive coverage of the smaller vessels typically seen operating domestically. However, vessels less than 100 gross tonnes and those without AIS transponders (which are not legally required on domestic cargo ships of up to 500 gross tonnes[155]) are not captured.

The UK has been using AIS data to estimate domestic shipping emissions since 2017[156]. The NAEI calculates domestic shipping emissions for the DfT each year, and these figures are submitted to the United Nations Framework Convention on Climate Change (UNFCCC). This calculation is based, in part, on modelling of AIS data, but is also supplemented by top-down estimates for fuel consumption on inland waterways from commercial and leisure vessels and for voyages between the UK and Gibraltar, the Overseas Territories and Bermuda[157].

In 2018, the DfT reported total emissions of 6.0 million tonnes of CO_2e from domestic shipping. Although the AIS-based portion of that figure is not broken out, the NAEI's modelling of 2014 AIS data estimated domestic shipping emissions to be 5.0 million tonnes of CO_2e, including fishing vessels. This suggests that there is a difference of approximately 1 million tonnes of CO_2e between NAEI and the UMAS FUSE model which is attributed to the different ways in which missing data on vessel details was infilled and/or excluded and how out-of-range voyages were treated.

II. Fleet valuation model

To understand the level of investment required to decarbonise the domestic and short sea fleets, each vessel has been individually identified. Domestic shipping fulfils a wider range of activities than is seen in international shipping, and thus the fleet is very diverse. Even within the same sector, vessels fulfilling similar roles may be dissimilar (this heterogeneity is particularly marked in the offshore sector). Therefore, a granular assessment of the fleet was conducted to determine the specification and function of each vessel.

Once identified, the replacement cost (as of January 2022) for the vessel on a like-for-like basis and was determined from the current global orderbook as tracked by Clarksons Research Services[53]. The orderbook contains all live orders for newbuild vessels and, where the information is public, the contractual price agreed between the shipowner and shipyard. As these orders reach back several years, Clarksons newbuild price index has been used to account for changes in newbuild price between when the order was placed and January 2022.

The global orderbook covers the larger shipyards across the world, which typically build international vessels. There is direct overlap with some vessel types found in the domestic fleet including all generic cargo vessels (tankers, gas carriers, container ships, bulk carriers, general cargo), and larger ferries, Ro-Ros, car carriers, cruise ships and offshore support vessels such as accommodation units, anchor handling tug supply vessels, platform supply vessels and research vessels. Newbuild prices for vessels that are not captured by the global orderbook (e.g. workboats, dredgers, small offshore vessels, and fishing vessels) have been estimated from the five-year average of the $ per gross tonne cost for newbuild vessels.

Each vessel type in the orderbook was grouped, and the newbuild price interpolated against the most suitable size metric (Table Appendix II-1).

Table Appendix II-1: Size metric used to estimate individual vessel values

Size metric	Vessel types
Deadweight tonnes (DWT)	Tankers, bulk carriers, container ships, general cargo ships, diving support vessels, multipurpose supply vessels, platform supply vessels
Cubic metres (CBM)	Gas carriers
Gross tonnage (GT)	Dredgers, fishing vessels, landing craft, tugs, workboats, research/survey vessels, offshore supply vessels, anchor handling tug supply vessels, tenders, cable and pipe layers, crewboats, emergency response and rescue vessels, high speed craft, jack-ups, offshore supply vessel
Lanes (m)	Ro-Ro
Safe working load (SWL)	Heavy lift crane vessels
No. of passengers	Cruise ships, ferries, RoPax, accommodation units
No. of cars	Car carriers

Source: Clarksons Research Services[53]

The specific newbuild price for each vessel in the domestic fleet was then estimated based on its size. This approximation works better for simple, generic vessels. In more bespoke and complex vessels the newbuild price will be less dependent on the size of the vessel. For example, the cost of a cruise ship will largely depend on its interior design, and an offshore vessel on its technical equipment. Also, the average global newbuild price may not be representative of what would be available from the region a replacement would be ordered from. For example, most offshore vessels in the orderbook are with Asian shipyards, and the price of an equivalent vessel ordered in Europe would likely be higher.

Vessel ownership was identified from the IHS Markit maritime database[21]. This database is not exhaustive, but it did return results for 99.3% of the domestic and short sea fleet. As the IHS Markit database reflects current ownership of the vessels, it will not perfectly represent the 2018 fleet. However, it is still deemed to be a reasonable proxy for the proportion of vessels owned by UK-based companies.

III. Relative cost of vessel retrofits/upgrades

Table Appendix III-1: Key for relative cost of upgrade and retrofit technologies

Symbol	£	££	£££	££££	£££££	N/A	-
Percentage of newbuild cost	< 1%	< 2.5%	< 5%	< 10%	> 10%	Technology not applicable	No data available

Table Appendix III-2: Energy efficient technology cost relative to newbuild cost by type and size of vessel

Vessel type	Vessel size	Engine derating	Organic Rankine Waste Heat Recovery	Trim optimisation	Air lubrication bubbles	Contra rotating propeller	Rudder bulb	Turbo-compounding in series	Twisted rudders	Block coefficient reduction	Flettner rotors	Steam waste heat recovery
Ferry pax	1	££££	£	-	N/A	££££	£	£	N/A	£££	N/A	££££
	2	£££	££	-	££££	£££	££	£	N/A	££££	N/A	£££££
Offshore	1	££	££	-	N/A	££	££	£	N/A	££££	N/A	££££
Cruise	1	£	£	-	N/A	££	£	£	N/A	£££	N/A	£££
	2	££	££	-	N/A	££	££	£	N/A	££££	N/A	££££
	3	£££	££	-	N/A	££££	££££	££	N/A	£££££	N/A	£££££
	4	££££	£££	-	££££	££££	££££	£££	N/A	£££££	N/A	£££££
	5	££££	£££	-	£££££	£££££	££££	££££	N/A	£££££	N/A	£££££
Dry bulk	1	££	£	£	N/A	££	£	£	£	£££	N/A	£££
	2	£££	£	£	N/A	£££	££	£	££	£££	££££	£££££
	3	£££	££	£	N/A	££££	£££	£	££	££££	££££	£££££
	4	££££	£	£	££££	££££	££	£	££	££££	£££££	£££££
	5	££££	££	£	£££££	£££££	££££	££	££	£££££	£££££	£££££
	6	££££	££	£	£££££	£££££	££££	££	££	£££££	£££££	£££££
RoPax	1	£	£	-	N/A	££	£	£	£	£££	N/A	£££
	2	££££	££	-	££££	££££	£££	££	££	££££	N/A	£££££
Offshore vessel	1	£	£	-	N/A	££	££	£	N/A	££££	N/A	££££
Tug	1	£	£	-	N/A	££	£	£	N/A	£££	N/A	££££
Container	1	£££	£	-	N/A	£££	££	£	£	£££	N/A	£££££
	2	££££	££	-	N/A	£££££	£££	££	££	££££	N/A	£££££
	3	££££	££	-	N/A	£££££	££££	££	££	££££	N/A	£££££
	4	££££	£££	-	££££	£££££	££££	£££	££	£££££	N/A	£££££
	5	££££	£££	-	£££££	£££££	££££	£££	££	£££££	N/A	£££££
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	8	£££££	£££	-	£££££	£££££	££££	££££	£££	£££££	N/A	£££££
Ro-Ro	1	££	£	-	N/A	££	£	£	£	£££	N/A	£££
	2	££££	££	-	££££	££££	£	£	££	£££	N/A	£££
Tankers	1	££	£	£	N/A	££	£	£	£	£££	N/A	£££
	2	££	£	£	N/A	££	£	£	£	£££	N/A	££££
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Source: UMAS and various[158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174]

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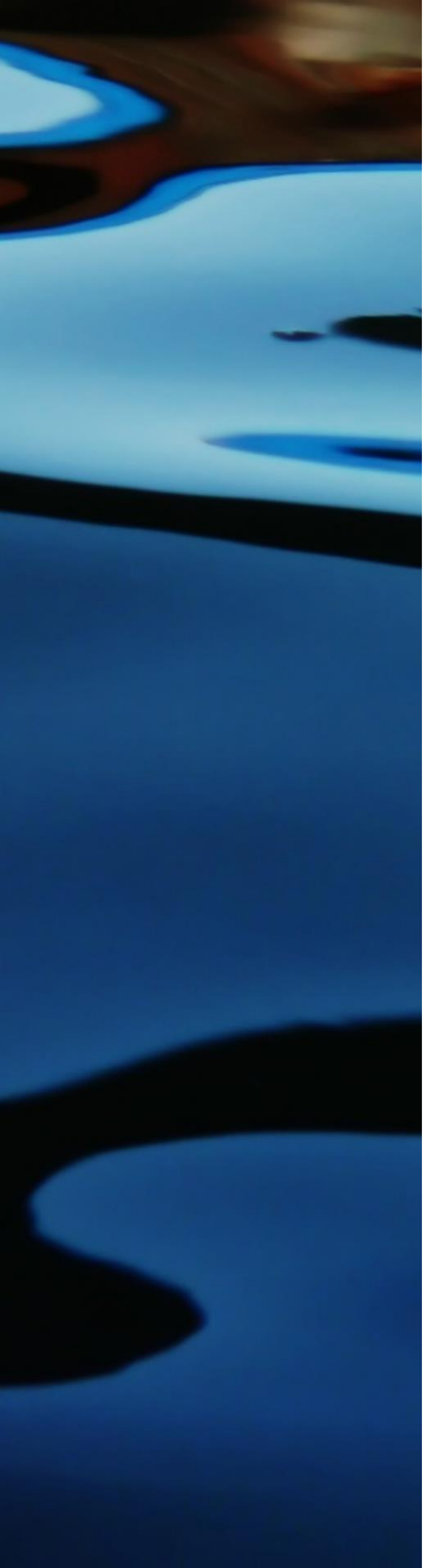

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