Written evidence to the Department for Transport for the consultation of ways to decarbonise the domestic maritime sector including barriers to decarbonisation and suggested intervention measures.

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This response is submitted by the following organisations:

UCL Energy Institute hosts a world-leading research group focused on the decarbonisation of the shipping sector. The shipping research group undertakes research to support the decarbonisation of shipping using models of the shipping system, shipping big data, and social science analysis of the policy and commercial structure of the shipping system. The research group's multi-disciplinary work is underpinned by state-of-the-art data supported by rigorous models and research practices, which makes it have a cutting edge on three key areas; using big data to understand drivers of shipping emissions, using models to explore shipping's transition to a zero emissions future and providing interpretation to key decision makers in the policy and industry stakeholder space.

UCL Energy Institute also leads the Decarbonising UK Freight Transport (DUKFT) which is a network of over forty industry and academic partners funded by the UK Engineering and Physical Sciences Research Council. The Network prioritises research which can enable the energy/propulsion switch across the road, rail, sea and air freight modes by unleashing significant freight-decarbonisation targeted investment and guide enabling policy. Some of the research presented in this response has also been funded by the Centre for Research into Energy Demand Solutions (CREDS).

UMAS is a sector focussed, commercial advisory service that draws upon the world leading expertise of the UCL Energy Institute shipping research group combined with the advisory and management system expertise of UMAS International Ltd. UMAS delivers consultancy services for a wide range of clients in the public and private sectors, including the Department for Transport, UN International Maritime Organisation, Lloyds Register and Global Maritime Forum.

Responses to consultation questions

1. What is your feedback on the overall ambition and feasibility of the Net Zero Strategy pathway for domestic maritime vessel emissions?

1. We suggest the Net Zero Strategy Pathway shown in the consultation document does not showcase a trajectory that enables deep decarbonisation in a non-disruptive and cost-effective manner. From our recent work investigating international transitions, findings have shown that stagnation or inactivity until 2030 will cause a more disruptive transition; it means that a more rapid decarbonisation pathway is required (see red line in Figure 0.1). This is because in a period of stagnation (represented from 2020 to 2030) an accumulation of emissions will cause rapid global temperature rise. To remain within a carbon budget – equivalent to that of a 1.5-degree increase compared to 2008 level – a compressed timeframe of decarbonisation is necessary. Delaying emission reduction would amount to a more costly transition: every year of delay to the start of deep decarbonisation this decade adds approximately $100 bn to the total cost of decarbonisation globally[1]. It is uncertain on the amount specific to UK domestic decarbonisation, however, due to the nature of the domestic shipping sector, which consists of smaller players who are conservative and timely in decision making, this should be a concern, as costs due to inactivity will be reciprocated domestically.

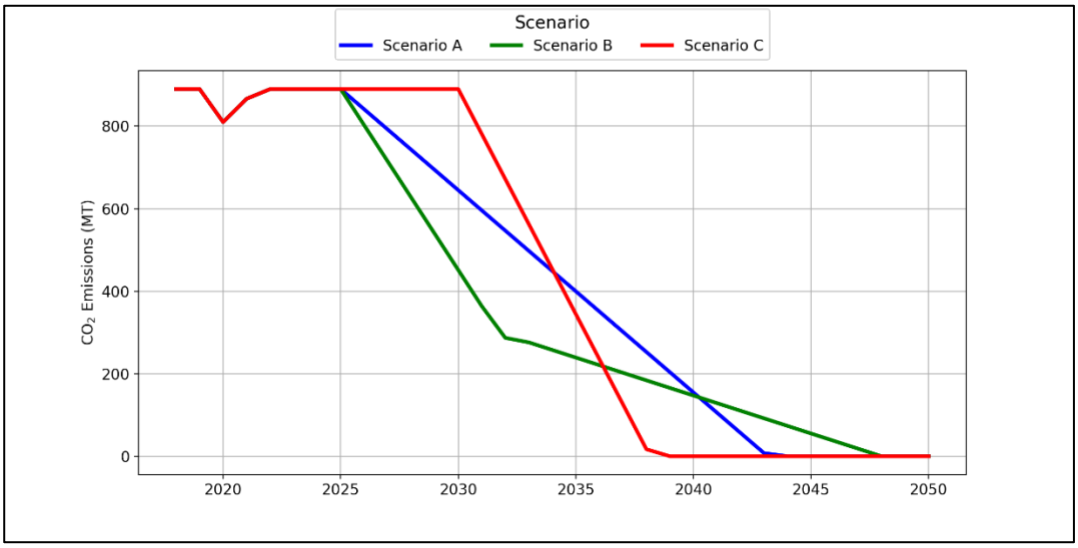

Figure 0.1 – Carbon budget derived pathways in 3 decarbonisation scenarios[2]

2. There is a broad acceptance among the shipping sector that to enable a rapid diffusion of zero carbon fuels across the sector in the 2030s and 2040s, by 2030, 5% of international shipping fuels must be Scalable Zero Emission Fuels (SZEF)[3].

[1] UMAS, E4Tech, "International Maritime Decarbonisation Transitions", 2022 (unpublished)
[2] UMAS, E4Tech, "International Maritime Decarbonisation Transitions", 2022 (unpublished)
[3] P. Osterkamp, T. Smith, and K. Søgaard, "Five percent zero emission fuels by 2030 needed for Paris-aligned shipping decarbonization," UMAS, Getting to Zero Coalition, 2021.

3. Domestic emission reductions are a key driver to facilitate the launch of SZEF this decade. Developed nations, including the UK, must act as ‘early adopters’; it is suggested that together, a group of the 32 developed nations have the ability to account for 2-3% reduction in global shipping emissions by reducing their domestic emissions by 15% by 2030 (ibid). The UN Climate Champions have set a target of 15% of zero emissions fuels by 2030 as the ‘Breakthrough’ amount required for domestic shipping.

4. International pilot projects can facilitate the transition and start reducing emissions by the creation of six green corridors globally by 2025[4]. UK ports could be a part of high-impact transatlantic and Asia-Europe green international corridors[5] whilst launching regional green corridors and clusters within UK-UK shipping and short-sea neighbouring countries. This could unlock UK ports as bunkering hubs of zero emission shipping fuels and help the support the development of clean fuel clusters, in turn, providing security for ship owners/charterers who operate in the surrounding waters to invest in onboard technology.

5. Ports can take the role of decarbonisation hubs for multiple sectors by facilitating cross-sector collaboration, widen investment and thus accelerate the scaling of production of zero emission fuels. The cross-sector projects such as Humber Zero and Shoreham Port shows the importance of ports as decarbonisation hubs. These private and public-private collaborations can enable cross-sector, regional relationships to act as catalyst the hydrogen economy and launch SZEF into multiple sectors.

6. It will be easier for ship owners/charterers that operate their vessels within fixed routes to select an alternative fuel as they obtain more certainty in refuelling locations and infrastructural requirements [6]. Findings from our data indicate that 50% of total domestic emissions come from ferries and Ro-Ros[7] i.e., ships that operate on specific routes and regions. These ship types could be an ideal platform to create regional corridors or clustering hubs to launch zero emission fuels in the domestic market before 2030. Especially since as a business case exists, whereby a lower proportion of ferries and Ro-Ro’s operating costs come from fuel (25-30%), meaning the cost gap of conventional to alternative fuels will result in lower financial weight than ship owners/charterers who operate ships (e.g., global liners) with higher proportion of fuel costs in their operating costs.

7. With characteristic long lifespans, retrofitting from conventional shipping fuels to low/zero alternatives is crucial for shipping decarbonisation and seen as a key driver. Ships built today must be designed to be zero-ready or retrofittable to SZEF. It is predicted that retrofitting activity is significant in the 2030s and will need to encompass ships built today, and potentially ships built prior to 2022. Specifically, findings suggest

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[4] https://www.gov.uk/government/publications/cop-26-clydebank-declaration-for-green-shipping-corridors/cop-26-clydebank-declaration-for-green-shipping-corridors

[5] T. Smith et al., “A Strategy for the Transition to Zero-Emission Shipping,” UMAS, Getting to Zero Coalition, 2021. https://www.u-mas.co.uk/wp-content/uploads/2021/10/Transition-StrategyReport.pdf

[6] Open Innovation Team “DfT Shipping Emissions Workshop”, 2022, unpublished

[7] UMAS, FUSE model

that the number of SZEF retrofits could be equal to the number of newbuilt SZEF ships overt the transition (see Figure 0.2)

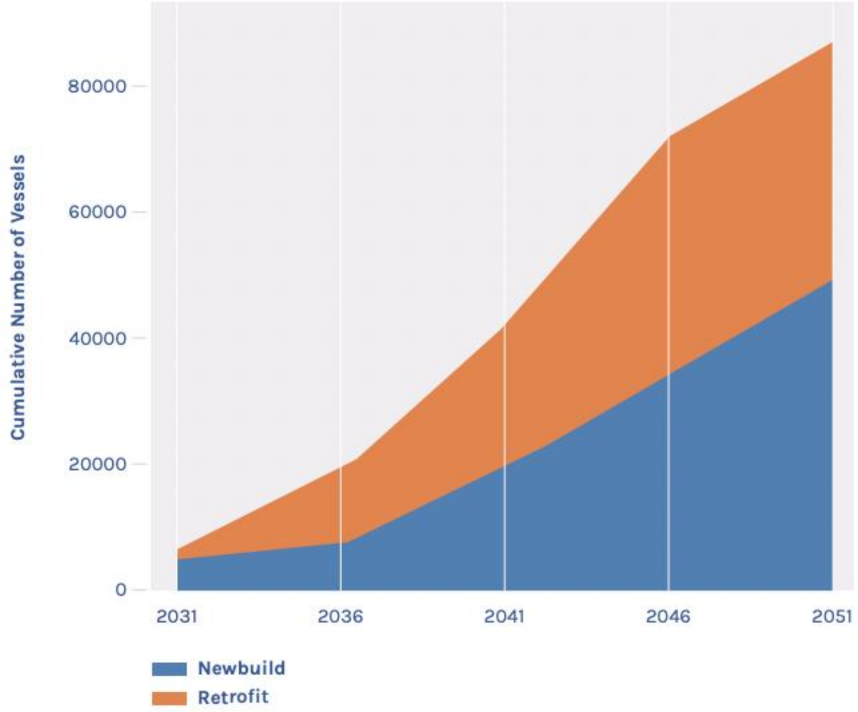

Figure 0.2 – Magnitudes of newbuild SZEF and retrofits to SZEF

2. What role do you think the following alternative fuels and engergies may play in decarbonising domestic maritime sector vessels?

8. Hydrogen-based fuels are essential for domestic and international shipping decarbonisation. Specifically green hydrogen-based fuels or Scalable Zero Emission Fuels (produced from renewable electricity) in addition to battery electrification will have a dominant role in domestic decarbonisation [8]. Hydrogen is the building block of other shipping fuels e.g., ammonia and methanol. It is therefore essential in any pathway to decarbonisation to ramp up production of hydrogen. This was highlighted in our findings for the models in the DfT 2019 Clean Maritime Plan modelling.

9. It is important to distinguish between hydrogen production pathways to ensure reductions are made on a lifecycle basis as there are major concerns with the fugitive methane emissions from natural gas routes (i.e., grey, and blue production pathways) in upstream processes. Methane is 81 times more potent at global warming than carbon over a 20-year period[9] and fugitive emissions are uncertain. It is likely that any progress

[8] Frontier economics and UMAS "REDUCING THE UK MARITIME SECTOR'S CONTRIBUTION TO AIR POLLUTION AND CLIMATE CHANGE", 2019

[9] IPCC, "Summary for Policymakers," in Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 2021. doi: 10.1260/095830507781076194.

made in the reduction of CO_2 from downstream emissions will be counteracted by the fugitive methane emissions from upstream and mid-stream processes.

10. By some, blue hydrogen is seen as a steppingstone for shipping decarbonisation, however the solution is not yet proven as an effective route to decarbonisation. Carbon Capture and Storage (CCS) has not been proven at scale; inefficiencies and current levels of methane emissions, total lifecycle carbon dioxide equivalent emissions for blue hydrogen may only be 9%-12% lower than grey hydrogen[10]. Investment in blue hydrogen could derail investment into green production pathways and, with the current political climate extra demand for large quantities of natural gas could worsen the gas price crisis. Blue hydrogen was seen as a lower cost solution in the near term, but with sustained high gas prices and accelerated investment into renewables and electrolysers this may not turn out to be the case in practice.

11. Ammonia and methanol are superior to hydrogen as an energy carrier. Ship orders would suggest that methanol is becoming the fuel of choice due its technological readiness level today. However, unlike ammonia, carbon must be captured for use in the upstream process to offset downstream emissions, if methanol is to achieve low or zero GHG emissions on a well-to-wake basis. Direct Air Capture (DAC) is required to capture carbon, but this is an energy intensive process and is currently immature/unscaled. Our modelling indicates that green methanol is ~30% more expensive than ammonia and, even with advancement in DAC, the fuel is expected to remain at least 20% more expensive than ammonia[11].

12. First generation (conventional) biofuels do not offer any material reduction in CO2 emissions on a well-to-wake basis. The apparent carbon reductions during the upstream process are negated when highly carbon sequestering forests are replaced with low carbon sequestering croplands[12]. Advanced biofuels offer a significant reduction in overall CO_2 emissions, but the production is far from a scale that can offer any meaningful decarbonisation for shipping. Also, the cost of biofuels can be very different to the prices that will be set by the market and with such high demand from multiple sectors, biofuels will likely be set to exceed the costs of SZEF. Consequently, biofuels will not be used in large volumes in the shipping sector's transition. Findings in our models suggest that biofuels will play a role in the later transition (2040s) as a pilot fuel to enable 100% decarbonisation by replacing the small amount of fossil fuel (typically 5%) required to initiate combustion[13].

13. LNG has been argued as a 'bridge' or 'transition' fuel by some institutions over the last decade but pushing LNG as a solution for clean shipping is misleading. LNG is technologically ready, but it offers only moderate GHG reduction in ideal conditions, which are counteracted through current technology and could be further counteracted

[10] Howarth, Robert W., and Mark Z. Jacobson. "How green is blue hydrogen?." *Energy Science & Engineering* 9.10, 2021,: 1676-1687.
[11] UMAS, E4Tech, "International Maritime Decarbonisation Transitions", 2022 (unpublished)
[12] Zhou, Yuanrong, et al. "The potential of liquid biofuels in reducing ship emissions." *International council of cleaner transporation* (2020): 2020-21.
[13] UMAS, E4Tech, "International Maritime Decarbonisation Transitions", 2022 (unpublished)

from fugitive methane emissions which will occur due to greater uptake. Despite the warnings and risks, the transition from conventional shipping fuels to LNG as a marine fuel is underway – LNG-capable ships represent 30% of the total orderbook in deadweight, while LNG-capable ships only represent 2% of the total existing fleet[14]. The continued growth of investment is creating a large, stranded value risk and in turn creating a technology lock-in risk that could steer investment away from SZEF. Recent findings indicate the current global magnitude of the LNG capable fleet 'value at risk' could be around $850bn by 2030[15].

14. As mentioned in question 1, retrofitting will be a major driver in the transition. Engine manufacturers are developing engines and fuel supply systems that are 'ammonia-ready' for retrofits from LNG and methanol. This makes a future retrofit far less costly with far fewer modifications than a non-ammonia-ready vessel.

15. For some portion of domestic shipping, which consists of smaller and shorter-range ships (e.g., ferries or coastal and inland freight vessels), battery electrification can supply 100% of onboard energy and offers a cost competitive solution to decarbonisation where appropriate. Even for ships that will operate with SZEF and have further distances to travel, batteries can still play a role in a hybrid system by optimising efficiency in powering auxiliary power systems, engage in power-take off and store energy reclaimed from waste heat recovery systems. Near ports and ecological areas, batteries can also eliminate local pollutants.

16. Cold ironing/shore power is essential for the charging of battery electric systems but also connectivity to grid can allow fuel burning ships to turn off engines in ports and run their auxiliary equipment. Shore power is an effective route to decarbonisation and cost-effective solution for ships that spend a lot of time in port; it offers a significant reduction in local port pollution; and is an effective short-medium term solution for cutting a significant proportion of domestic emissions.

17. By using 2018 data of all domestic fleet tracked by the UMAS fuse model we can see 18% of all UK domestic shipping emissions originated within ports (see
18.
19.
20. Table 0.1 i.e., All UK-UK voyages). There is potential to eliminate up to 18% of all UK domestic emissions by conducting a nationwide roll-out of shore power[16].

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[14] Fricaudet, M; Taylor, J; Smith, T and Rehmatulla, N. "Exploring methods for understanding stranded value: case study risk on LNG-capable ships" London, UK, 2022

[15] Fricaudet, M; Taylor, J; Smith, T and Rehmatulla, N. "Exploring methods for understanding stranded value: case study risk on LNG-capable ships" London, UK, 2022

[16] Marine Capital, UMAS and Lloyds Register "UK Domestic Shipping: A Commercial Pathway to Net Zero", 2022, (unpublished)

Table 0.1 – At sea and at port emissions on domestic voyages

CO2e million tonnes	All UK-UK voyages	of which from domestic fleet
Emissions at sea	3.2	2.4
Emissions at UK ports	0.7	0.5
Emissions at short sea ports	-	-
Total	3.9	2.8

21. The detailed implementation of shore power is unique to each port so there can be some variability in costs. Analysis of such parameters revealed that London and Aberdeen have the strongest conditions for investment on both the supply and demand sides. These are followed by six ports which have good electricity supply conditions but more potentially more modest demand (Grimsby & Immingham, Holyhead, Lerwick, Liverpool, Orkney, Tees & Hartlepool). A further two (Clyde and Peterhead) have good demand, but supply conditions are uncertain[17]. Recognising these differences may mean different ports have to have different business cases or prices for electricity. Mandating cold ironing on both ships and ports would be important, both to realise the GHG reduction opportunity, and to ensure that investments are built to the scale needed and demand (from ships) enables the business case.

3. What value do you think different efficiency and energy saving measures could have in helping to achieve domestic maritime vessel decarbonisation (in your sub-sector, if appropriate)?

22. Operational and technical measures (including wind assistance) can reduce fuel consumption by up to 30-50%[18] on new and current operational vessels, relative to a baseline ship. These measures offer a near-term solution to significant emission reductions. A variety of energy efficiency technologies exist and could be combined to offer a significant saving in fuel consumption. By combining these measures with zero emission fuels there is potential of reducing up to 60-88% of emissions when operating on SZEF 50% the time (depending on ship type). This shows how efficiency can work in combination with fuels to achieve large reductions in GHG emissions even in the near term, but that efficiency reductions on their own are not sufficient.

23. By using our data on installation costs of technologies and their potential fuel consumption savings, we have performed a cost-benefit analysis and devised a list of

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[17] A. Chase et al., "Clean Maritime Clusters Research Study," E4tech, UMAS, London, 2020. https://www.u-mas.co.uk/wp-content/uploads/2021/06/E4Tech-UMAS-2021-Clean-MaritimeClusters-Research-Study.pdf
[18] Marine Capital, UMAS and Lloyds Register "UK Domestic Shipping: A Commercial Pathway to Net Zero", 2022 (unpublished)

energy efficient technologies with the greatest potential for various ship types (see Table 0.2).

Table 0.2- – Expected uptake of energy efficiency technologies for various ship types

Vessel Type	Technologies with Greatest Potential
Bulk Carrier	Turbo-compounding in Series|Flettner rotors|Rudder Bulb|Air lubrication Bubbles|Contra Rotating Propeller
Container	Air lubrication Bubbles|Contra Rotating Propeller|Organic Rankine Waste Heat Recovery|Block coefficient reduction
Chemical Tanker	Air lubrication Bubbles|Contra Rotating Propeller|Steam Waste Heat Recovery|Turbo-compounding in Parallel|flettner rotors
General Cargo	Engine derating|Contra Rotating Propeller|Organic Rankine Waste Heat Recovery|Turbo-compounding in Series|Flettner rotors
Ferry-Ropax	Air lubrication Bubbles|Contra Rotating Propeller|Steam waste heat recovery|Turbo-compounding in Series
Service/Offshore	Contra Rotating Propeller|Organic Rankine Waste heat recovery|Turbo-compounding in Series|Rudder Bulb
Tug	Contra Rotating Propeller|Rudder Bulb
Oil Tanker	Air lubrication Bubbles|Contra Rotating Propeller|steam waste heat recovery|Turbo-compounding in Parallel|flettner rotors

4. How should the technological transitions required to decarbonise the domestic maritime sector best be supported? What evidence do you have to help refine our understanding in this area?

24. There can be barriers to technological transitions as much of the domestic shipping sector consists of smaller companies who tend to be very conservative when funding new technologies due to the limited amount of finance accessible[19]. For the example of shore power, the ease and cost of connecting ports/harbours to the grid will be unique to each case. There does not have to be public spending to support the use of shore power or battery electrification, except where there are clear distributional impacts e.g. due to exceptionally high prices for grid connection. But as long as there is a perception that there could be a grant or incentivisation, this also acts as a disincentive to taking action now. Clarity on shore power from a policy/regulatory perspective is therefore critical.

25. Current global green hydrogen supply commitments by 2030 are less than a third of what is required to be on a net-zero path[20]. If global shipping is to reach a 1.5-aligned pathway, by 2030, international shipping would need to warrant nearly ¼ of the current global hydrogen supply. To meet such demands, it is necessary to ramp-up production of green hydrogen and hydrogen-derived fuels such as methanol and ammonia and as part

[19] Marine Capital, UMAS and Lloyds Register "UK Domestic Shipping: A Commercial Pathway to Net Zero", 2022 (unpublished) & Open Innovation Team "DfT Shipping Emissions Workshop", 2022(unpublished)
[20] UMAS "Ascertaining progress Towards 5% Zero Emissions Fuels by 2030"

of a wider decarbonisation effort across multiple sectors. Domestic shipping decarbonisation in countries like UK can help drive the business case for development of UK hydrogen production and supply chain and enable business opportunities and jobs not just in shipping but other sectors reliant on hydrogen for their future competitiveness. This can also help grow the global availability of new energy supply chains that can be used by both domestic and international shipping.

26. Market Based Measures (MBM)/economic instruments such as carbon pricing and Command and Control measures (e.g., technical and operation measures taking the form of fuel mandates, CO2 standard, energy efficiency or others) can be implemented to incentivise the transition and can work in collaboration with each other[21]. Based on previous analysis, a carbon price could play a key role in enabling UK decarbonisation by 2050[22]. Carbon pricing is particularly useful early in a transition to help provide revenues to support early adoption during the emergence phase, and can be partnered with command and control policy used to ensure certainty of CO2 reductions.

27. Albeit an example taken from international shipping, even a low initial carbon price of $11/tonne CO2 allows for an adjustment period for the industry, and the collated revenue could facilitate initial diffusion of zero-emission fuels. Then to incentivise the switch to zero-emission fuels, the carbon price would then need to ramp up to close to US$100/ tonne CO2 in the early 2030s and be around US$230-260/tonne CO2 between 2035-2045. To reach full decarbonisation by 2050, the carbon price in the more ambitious scenario would need to increase even further to around US$360/tonne CO2 (see Figure 0.3) [23]. The scenario illustrates the carbon price levels if carbon pricing was the only policy measure put in place; this also means that if lower carbon prices are implemented, additional measures will be needed to drive the same levels of decarbonisation.

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[21] T. Smith et al., "A Strategy for the Transition to Zero-Emission Shipping," UMAS, Getting to Zero Coalition, 2021. https://www.u-mas.co.uk/wp-content/uploads/2021/10/Transition-StrategyReport.pdf

[22] T. Smith et al., "A Strategy for the Transition to Zero-Emission Shipping," UMAS, Getting to Zero Coalition, 2021. https://www.u-mas.co.uk/wp-content/uploads/2021/10/Transition-StrategyReport.pdf

[23] Baresic, D., Rojon, I., Shaw, A., Rehmatulla, N., Closing the Gap: An Overview of the Policy Options to Close the Competitiveness Gap and Enable an Equitable Zero-Emission Fuel Transition in Shipping. Prepared by UMAS, January 2022, London.

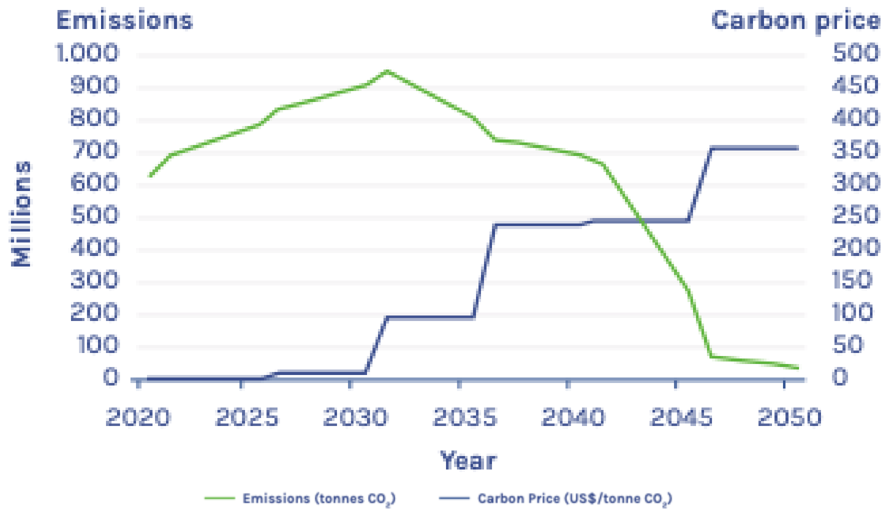

Figure 0.3 – Carbon price trajectory and associated emission projections for net-zero by 2050 pathway.

28. Early clarification of policy measures can help accelerate the transition from Scalable Zero Emissions Fuels and their associated infrastructure and reduce the potential for disruption to the shipping industry[24].

5. Are you able to provide any additional evidence on the costs and benefits associated with decarbonising UK domestic maritime vessels?

29. Independent on the of dimension of shipping decarbonisation (i.e., International and domestic), the proportion of investment on land to onboard will be similar. The biggest share of investments is needed for land-based infrastructure and production facilities – approximately 90% of the total investments[25]. On the land-based production of liquid fuels, most of the cost of production, around 80%, stems from the cost of converting primary energy to electricity i.e., the cost of renewable electricity generated from renewable sources such as wind and solar[26].

30. In the medium-long term, the rapidly falling cost of renewable electricity and renewable energy is expected to make electrolysers the lower cost solution in many geographies. This may even be the case in the shorter term due to the political climate causing natural gas demand to sharply increase and in turn increase the price of blue hydrogen.

6. How should intermediary, indicative decarbonisation targets for UK domestic maritime sector vessel emissions be formulated?

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[24] UMAS, E4Tech, "International Maritime Decarbonisation Transitions", 2022 (unpublished)
[25] https://www.globalmaritimeforum.org/news/the-scale-of-investment-needed-to-decarbonize-international-shipping
[26] LR & UMAS – techno economic assessment

31. Analysis suggests that mandatory, absolute targets set by the government (such as achieving a specified GHG and air pollutant emissions reduction relative to a historic baseline by a specified date) can be the most appropriate and proportionate means for ensuring that environmental goals are realised[27].

32. Medium- to long-term targets should be supported by short- and medium-term checkpoints to help monitor progress and ensure action can be taken to keep actions aligned with the longer-term target.

33. Data and monitoring mechanisms are an essential enabler of achieving the target in a proportionate way. In the context of UK shipping, this implies the need for a credible and verifiable, yet proportionate, way to measure shipping emissions.

7. What are the most significant barriers to domestic maritime decarbonisation at scale (if appropriate, within your subsector)?

Barriers which are not already mentioned in the consultation:

34. Much of the domestic shipping sector comprises of small companies. Access to capital is much more difficult to that of major ports who have access to commercial banks and local/regional funding[28]. Therefore, smaller companies who operate in smaller ports and smaller vessel owners will struggle to raise the funds to commercially roll out alternative fuels bunkering and the installation onboard shipping technologies. It is therefore essential to provide financial support to smaller ports and small vessel owners, other than early-stage grants, to enable smaller companies who operate in non-major ports the necessary help to transition away from fossil fuels.

35. Ships owners that have a higher proportion of their operating costs arising from fuels will find it more costly transitioning to the premium cost of SZEF. Large ocean-going vessels that typically use more fuel such as global liners will be affected with a greater cost. However, this works in reverse – for owners with vessels that have a lower proportion of their costs arising from fuel will find the transition less costly i.e., tugs, ferries & Ro-Ro's and offshore support vessels for which fuels accounts for 10-15%, 25%-30% and 5-10% of their operating costs[29].

10. Are there any additional interventions targeting economic barriers that the government could explore introducing to complement and enhance our current approach, in the short, medium, and long term?

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[27]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/816020/potential-role-targets-economic-instruments.pdf

[28] Marine Capital, UMAS and Lloyds Register "UK Domestic Shipping: A Commercial Pathway to Net Zero", 2022 (unpublished)

[29] DOF Group. *DOF ASA - 2019 Annual Report*.

http://www.dof.no/Files/PDF/DOF%20ASA/IR/2020/DOF%20ASA%20Annual%20Report%202019.pdf (2020).

Economic measures other than Emissions trading scheme[30]

36. **Emissions taxes and levies** are both pricing instruments whereby a pre-defined price is put on either the amount of fossil fuel consumed or the amount of CO2 or GHG emitted, and market actors are required to pay accordingly. Taxes and levies thus make the use of fossil fuels more expensive. For any emissions tax or levy to be effective, it is crucial that the price is set at a level that will drive emissions reductions to the desired environmental output[31]. The expectation of what the carbon price will be in the future is key to establishing the business case for zero-emission investments. Price corridors – i.e. setting a band of minimum and maximum carbon prices – could be implemented to offset some of the business uncertainty with future carbon pricing. Such a measure can help to de-risk investment decisions and thereby facilitate the transition to new fuels and energy sources.

37. A **feebate** is a variant of a tax/levy. In a feebate system, an emissions or carbon intensity benchmark is set. The benchmark can be kept constant or become more stringent over time to increasingly incentivise zero-emission shipping operations. Those participants (i.e. shipowners/operators) emitting above the benchmark are charged fees, whilst those with emissions below the benchmark receive rebates generated from the fees collected (hence the word ‘feebate’, a contraction of ‘fee’ and ‘rebate’).

38. **Fuel subsidies**: Introduced at the fuel consumption/utilisation stage and usually given in the form of a financial support mechanism to an entity[32]. They can be granted as a cash handout or a tax break and can take the form of direct financial support per unit of fuel, or per unit of GHG reduction.

39. **Production subsidies**: Introduced at the production stage to financially support the higher production costs of zero-emission vessels and/or additional costs associated with the production of zero-emission bunkering infrastructure

40. **R&D subsidies**: Introduced to support R&D into alternative fuels and technologies which could lower their prices through new technological developments and support innovation and first movers[33].

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[30] Baresic, D., Rojon, I., Shaw, A., Rehmatulla, N., Closing the Gap: An Overview of the Policy Options to Close the Competitiveness Gap and Enable an Equitable Zero-Emission Fuel Transition in Shipping. Prepared by UMAS, January 2022, London.

[31] High-Level Commission on Carbon Prices (2017) Report of the HighLevel Commission on Carbon Prices. World Bank. Available at: https:// openknowledge.worldbank.org/handle/10986/32419 & WBCSD (World Business Council for Sustainable Development) “Why carbon pricing matters: A guide for implementation”. Geneva, 2018

[32] Tyner, W.E. & Taheripour, “Renewable Energy Policy Alternatives for the Future”. American Journal of Agricultural Economics, 89(5), 1303–1310, 2007

[33] González, X., Jaumandreu, J. & Pazó, C. (2005) Barriers to Innovation and Subsidy Effectiveness. The RAND Journal of Economics, 36(4), 930-950.

14. Which regulatory interventions do you think the government should support in the short, medium, and long term to help accelerate decarbonisation and complement existing plans and proposals?

41. Include shipping in a UK ETS or equivalent MBM. This should cover both domestic shipping (including below the 5000GT level), and be adaptable to include international shipping. This can create revenue streams as well as incentivise the use of more expensive, lower GHG fuels. The concept allows some flexibility as new energy supply chains are developing but also helps to provide for grants, subsidies, guarantees etc. that are used to stimulate both the land-side and onboard technology research, development, and deployment. For revenues generated from international shipping, the revenue use should be associated with the equitable transition of international shipping, which can also help benefit trade relationships. Any component for international shipping needs to be designed to be replaced as soon as effective IMO policy is in place but should not be designed with the assumption that IMO policy would happen in time and at stringency to enable shipping's 1.5-aligned transition.

42. Leverage the IMO's CII regulation to apply UK port maximum carbon intensity requirements and stronger enforcement mechanisms than the existing MARPOL Annex VI provision. This should be for domestic shipping (where applicable) and international ships calling at UK port. It could mandate at least the specification of "A" rating, with penalties applied if a ship has a lower carbon intensity and could be extended to a new A+ category, or incentive for zero emission shipping.

43. Continue to develop green corridors with other countries and use revenues from carbon pricing to enable investment now in long-run scalable zero emission fuel use. Some routes should also be UK-developing country to ensure that there are examples in line with equitable transition.

44. Work at the IMO for adoption of a 1.5-aligned and equitable basket of measures.

45. Use a direct command-and-control measure such as a energy/fuel mandate in the long term to send an unequivocable signal to the market that a fuel transition will take place. This could build on RTFO and extend to include obligation on maritime fuel use as well as the current extension to include maritime use for suppliers of fuels.

46. Mandate shore power use in all UK ports, supported if necessary, by revenues from carbon pricing to manage distributional impacts arising from a mandate.

47. Develop national and regional policy that can ensure the transition of domestic fleets at least at the same rate or sooner than international fleets and that work in synergy with global IMO-driven policy

48. Promote voluntary initiatives and information programmes to stimulate supply-side investments in RD&D and infrastructure, encourage knowledge sharing and support capacity development.