Written evidence submitted by Dr Domagoj Baresic, Dr Nishatabbas Rehmatulla, Dr Santiago de la Fuente and Dr Tristan Smith on behalf of UCL Energy Institute, Centre for Research into Energy Demand Solutions (CREDS), Decarbonising UK Freight Transport (DUKFT) and UMAS

Executive Summary:

- Operational measures in shipping can be implemented at scale in the short to medium term and specific national policies can be used to promote their uptake.
- Mid/long-term adoption of zero carbon marine fuels (i.e. ammonia) is paramount for shipping to decarbonize, policies which provide financial support for pilots, RD&D, support niche shipping segments as test beds and limit long term usage of transitional fuels are favoured.
- Wind assisted technologies (WAT) have a good potential to reduce ship emissions and could benefit from additional financial support.
- The UK has many sites which are favourable for early adoption of zero carbon marine fuels, policies which promote their growth, take local conditions into account and include strategies for multiple industries have the highest potential for success.
- UK should be a proactive player at the IMO supporting development of an ambitious shipping decarbonization plan.
- ICAO's CORSIA has many aspects which could be looked at for inspiration when developing similar measures for shipping.
- Revenue recycling when using carbon pricing for shipping could be considered as a policy option.

Brief introduction:

brief introduction about yourself/your organisation and your reason for submitting evidence

1. The organisations: University Maritime Advisory Services (UMAS) is a sector focussed, commercial advisory service that draws upon the world leading expertise of the UCL Shipping Team combined with the advisory and management system expertise of UMAS International Ltd. Decarbonising UK Freight Transport (DUKFT) is a network of over 40 industry and academic partners funded by the UK Engineering and Physical Sciences Research Council and hosted by University College London. The Centre for Research into Energy Demand Solutions (CREDS) works with researchers, businesses & policy makers, and supports the transition to a net-zero society.

2. The people: Dr Domagoj Baresic is a Research Associate at UCL and specialises in policy and transitions pathways required to decarbonize shipping. Dr Nishatabbas Rehmatulla is a Principal Research Fellow at UCL and leads the social sciences research component on various aspects of shipping decarbonization. Dr Santiago de la Fuente Dr Santiago Suarez de la Fuente is a Lecturer in Energy and Transport at UCL and leads the research group's engineering research component. Dr Tristan Smith is an Associate Professor in Energy and Transport at UCL and PI of the Decarbonising UK Freight Network. He is the lead author of 3rd IMO GHG Study, ISO 19030, co-chair of World Bank's Carbon Pricing Leadership Commission Maritime Thread and member of DfT Clean Maritime Council.

3. The reasons: As a passionate group of organisations and researchers based in the UK working on decarbonization of the UK shipping industry we believe that supporting the UK

Government to develop the best possible strategies to decarbonize is paramount for the future of our society and the environment.

- **What contribution can operational efficiencies make to reduce emissions from aircraft / shipping vessels and over what timescale could these have an effect on emissions?**

4. Shipping energy efficiency can be reduced through operational modifications such as speed reduction, logistical modifications such as just-in-time arrival, structural changes, such as moving to a data-driven operation, as well as improved maintenance, personnel training and running vessels at optimal operational speeds (World Bank, Forthcoming[1]). Such measures can all play an important role in increasing 'energy efficiency' (Table 1) (de la Fuente et al. In Print[2]) but most of these are not being implemented at scale due to market failures and non-market failures (Ibid). Most of these measures require minimal additional capital expenditures, and can be implemented in the short to medium term (i.e., within months and years) (Ibid.).

Table 1 - Potential energy efficiency gains from different operational measures (World Bank, Forthcoming).

Operational energy efficiency measure	**Energy efficiency potential (%)**
Speed Reduction	1.0-60.0
Trim/draft optimization	3.0-10.0
Hull and propeller maintenance	2.0-10.0
Just-in-time arrival	1.0-10.0
Weather routing	0.4-4.0
Autopilot upgrade/adjustment	1.5

5. Speed reduction has significant potential in increasing ship operational efficiency. Speed reduction can decrease the Energy Efficiency Operational indicator (EEOI) of a vessel, but in order to achieve a reduction of 70% or more from the baseline EEOI, operational measures such as speed reduction must be combined with fuel and energy saving technologies (Smith et al, 2016[3]). Just-in-time arrival of ships could avoid some of currently observed energy waste. Current standard voyage charterparty clauses stipulates that vessel proceed at utmost despatch towards a port, regardless of the port conditions thus leading to inefficient operations (Ibid.).
6. Other areas of potential improvement exist in trim/draft optimisation by securing an optimal trim at which the vessel's fuel consumption is lowest for each loading position. Hull and propeller maintenance through hull surface and propeller surface maintenance. Weather routing services can optimize the route a ship takes, whilst ship's autopilot can be used to maintain a steady heading, thus reducing rudder movement and corresponding drag (Ibid.).

7. Recommendations:

[1] World Bank. Forthcoming. Energy Efficiency in Shipping. Report by CE Delft and UMAS

[2] Suarez de la Fuente, S., Baresic, D. & Smith, T. (In Print). Greenhouse Gases and a Low-Carbon Future. In: Marine Engineering. Society of Naval Architects and Marine Engineers (SNAME), 4th Edition.

[3] Smith, T., Raucci, C., Haji Hosseinloo S., Rojon I., Calleya J., Suárez de la Fuente S., Wu P., Palmer K. CO2 emissions from international shipping. Possible reduction targets and their associated pathways. Prepared by UMAS, October 2016, London.

- Create policies which facilitate uptake of operational efficiency measures, such as: reduced port levies/dues, grants and support for inclusion of optimisation measures (i.e., pilotage upgrades, and support for ship maintenance) and standards that mandate operational efficiency thereby overcoming market failures.
- Offer training and education to ship operators on ship operations such as weather routing, hull and propeller maintenance and trim/draft optimisation to secure better operations.
- Work with charterers to improve voyage charter agreements thus facilitating just-in-time arrival to reduce energy consumption.

❖ **How close are zero carbon fuels to commercialisation for aviation / shipping? How effective will the Jet Zero Council be in catalysing zero emissions technologies? What role should transitional fuels such as alternative hydrocarbon fuels play?**

8. Zero carbon fuels usually discussed in shipping are ammonia, hydrogen, various biofuels, and e-hydrocarbons (Englert et al., 2021[4]). All of these are currently at different levels of readiness, but in order to be available at scale for production and utilisation, further technological, policy and industry modifications are necessary. Even though energy and operational efficiency measures in shipping are very important, in order for shipping to be in line with the Initial GHG Strategy, the shipping industry will have to zero-carbon fuels (Baresic et al., Forthcoming[5], Smith et al, 2016). Figure 1 shows that even at the lowest IMO 'level of ambition' (Scenario E), that is a 50% GHG reduction by 2050, low-/zero-carbon fuels such as ammonia would have to become the dominant fuel in order for shipping to be aligned with the IMO strategy.

Scenario E: Target of 50% absolute reduction in operational shipping GHG emissions globally by 2050 (compared to 2008); zero operational shipping GHG emissions globally by 2070.

Scenario D: Target of zero operational shipping GHG emissions globally by 2050

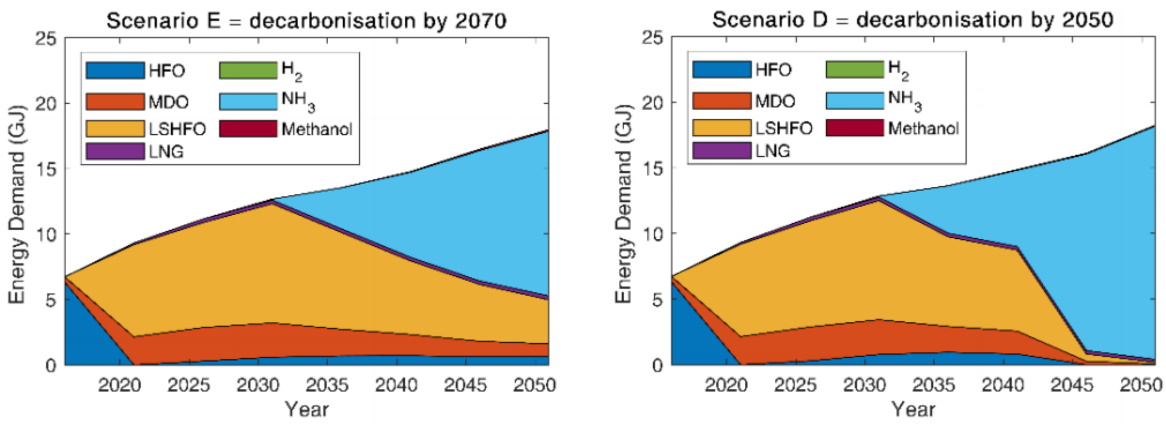

Figure 1 Projected future marine fuel demand for two decarbonisation scenarios (Raucci et al. 2020[6])

9. Ammonia[7] as a ship fuel addresses many technological and environmental obstacles posed by regularly discussed alternatives. However, for ammonia to become price

[4] Englert, D., Losos, A.,Raucci, C., Tristan, S. 2021. The Role of LNG in the Transition Toward Low- and Zero-Carbon Shipping. World Bank.
[5] Baresic, D., Rojon, I., Shaw, A., Rehmatulla, N., Smith, T. Forthcoming. Closing the gap - An overview of the policy options for a zero-carbon fuel transition in shipping. Prepared for Global Maritime Forum by UMAS. Forthcoming. London.
[6] Raucci, C., Bonello, J.M., Suarez de la Fuente, S., Smith, T. & Søgaard, K. 2020. Aggregate investment for the decarbonisation of the shipping industry. UMAS. London.
[7] Produced through electrolysis of hydrogen with renewable electricity or via steam reformation of natural gas with carbon capture and storage (CCS)

competitive, by 2030, renewable electricity would need to be available at a price of approximately 19 $/megawatt hour (LR & UMAS 2019[8]). A combination of targeted public and private sector investment, domestic shipping adoption and international zero carbon routes or corridors could lead to viable transition pathways for a global 5% adoption of zero carbon fuels such as ammonia by 2030 (Osterkamp et al.,2021[9]).

10. Biofuels, such as bio-methanol and bioLNG could play a limited role in shipping's road decarbonisaiton. Any such discussion will be dependent on future bioenergy's availability for shipping use and wider impacts (e.g., issues associated with land-use and life cycle emissions) (Smith et al, 2016). It seems unlikely that shipping could predominantly depend on bioenergy as a dominant feedstock for its energy requirements, as in such a scenario, bio-energy capacity would need to grow significantly, reaching approximately 60, 150, above 300 EJ respectively in 2030, 2040, 2050 (LR & UMAS 2019). Such growth would require wide-scale changes in global land use, with an estimated 2.5 billion hectares having to be repurposed for bio-energy production (Ibid.).

11. Methanol, liquefied natural gas (LNG) and diesel produced as electro fuels have a significantly higher technology and production readiness than biofuels and especially ammonia and the on-board technology is almost the same as that for fossil fuels (LR & UMAS 2019). In addition, these fuels can utilize existing bunkering technology and require minimal additional investment in fuelling, which is a significant cost component for fuels such as ammonia (Raucci et al. 2020). These fuels are still in the concept stage and their total cost of operation (TCO) will depend on the evolution of key carbon capture technologies such as direct air capture (DAC) (LR & UMAS 2020).

12. Liquified natural gas (LNG) has been used as an alternative fuel for shipping for over 2 decades (Baresic, 2020[10]). It is usually touted for its environmental benefits with significantly lower SOx, NOx, and PM emissions compared to HFO (Ibid). However, there is no significant CO2eq. reduction achieved through the use of LNG (Baresic et al. 2018). There are growing number of dissenting voices within the shipping industry around LNG (Baresic 2020, Baresic et al. 2018[11]). In the short term, LNG can play a transient role in addressing air pollutant concerns, but in the mid to long term it cannot play a dominant role as an alternative marine fuel if shipping is to decarbonize and as such could lead to shipping and infrastructure assets being stranded (Ibid.).

13. Recommendations:
    - Provide financial support, through research grants, and subsidies for the establishment of a true domestic industry and value chain for alternative fuels that have the least cost and potential to have the lowest emissions from a lifecycle perspective, such as ammonia.
    - Work on measures which can lead to creation of viable niche markets for low carbon shipping fuels (Baresic, 2020).
    - Limit usage of LNG and biofuels to short term specific niche industry segments.

❖ **What new technologies are there to reduce emissions from aircraft / shipping vessels and how close to commercialisation are they?**

[8] LR and UMAS 2019. Zero-emission vessels: Transition Pathways. UMAS. London.
[9] Osterkamp, P., Smith, T., Søgaard, K., 2021. Five percent zero emission fuels by 2030 needed for Paris-aligned shipping decarbonization. Getting to Zero Coalition.
[10] Baresic, D. 2020. Sustainability transitions in the maritime transport industry: the case of LNG in northern Europe. Doctoral thesis (Ph.D), UCL (University College London).
[11] Baresic, D., Smith T., Raucci, K., Rehmatulla, C., Narula, N. & Rojon, I. 2018, 'LNG as a marine fuel in the EU: Market, bunkering infrastructure investments and risks in the context of GHG reductions', UMAS, London.

14. Wind assisted technologies (WAT) have a significant potential to reduce ship energy efficiency. When considering investing in WAT, wind resource availability, speed and direction need to be considered (World Bank, Forthcoming), as well as chartering contracts, ship operator's profit objectives and trade patterns (Rehmatulla et al., 2017[12]). Current uptake of WAT has been limited but growing (World Bank, Forthcoming).

Table 2 - Recorded WAT installations until 2021 (International Windship Association, 2021[13]).

Technology Name	Current Deployment	Ship types
Rigid Sails	Four large vessels and several small	Wetbulk, RoPax, General cargo
Flettner Rotor	10 vessels (21 rotors)	Wetbulk, Drybulk, RoPax, General cargo
Kite	10 commercial installations (few still operational)	Drybulk, RoPax, General cargo

15. WAT could be an important technology in the medium and long term, with some estimating between 3,700 and 10,700 WAT by the 2030s (Nelissen et al., 2016[14]). These could reduce shipping CO_2 emissions between 3.5 and 7.5 million tonnes by 2030 (World Bank, Forthcoming). WAT challenges include the relatively high initial cost, cost efficiency and the certainty of such cost efficiency (Ibid.), as well as the cost of capital, split incentives and information barriers (Rehmatulla & Smith, 2015[15]).

16. Recommendations:
- Create a domestic grant mechanism which can support shipowners willing to invest in WAT technologies.
- Work with shipping stakeholders to reduce and eliminate information barriers related to investment in WAT.

❖ **How should the Government's net zero aviation strategy support UK industry in the development and uptake of technologies, fuels and infrastructure to deliver net zero shipping and aviation?**

[12] Rehmatulla, N., Parker, S., Smith, T. & Stulgis, V., 2017. Wind technologies: Opportunities and barriers to a low carbon shipping industry. Marine Policy, Volume 75, p. 217–226.
[13] International Windship Association. 2021. Recorded WAT installations until 2021. IWSA. London.
[14] Nelissen, D., Traut, M., Kohler, J., Mao, W., Faber, J., and Ahdour, S., 2016. Study on the analysis of market potentials and market barriers for wind propulsion technologies for ships. DOI 10.2834/68747
[15] Rehmatulla, N. & Smith, T., 2015. Barriers to energy efficiency in shipping: A triangulated approach to investigate the principal agent problem in shipping. Energy Policy, Volume 84, pp. 44-57.

17. Regarding shipping, the Government should ensure that all net zero strategies, for air, land sea transport and other industries are aligned so that they reinforce each other and lead to a cascading effect of accelerated decarbonization. When policies are aligned between shipping and land-based industries, a rapid adoption of an alternative fuel can take place, where these sectors can share the investment risk (Baresic, 2020). Ongoing work at UCL, funded by CREDS has shown that multiple sites in the UK have high suitability for early adoption of zero carbon marine fuels (i.e., a score of over 50) (Figure 2), with many other sites following closely behind (Baresic & Rehmatulla, Forthcoming[16]). Factors such as local and national policies over multiple sectors play a crucial role in reinforcing existing geographic endowments with other benefits (i.e., pilot projects, R&D clusters, intermodal projects, supply chain development, etc.).

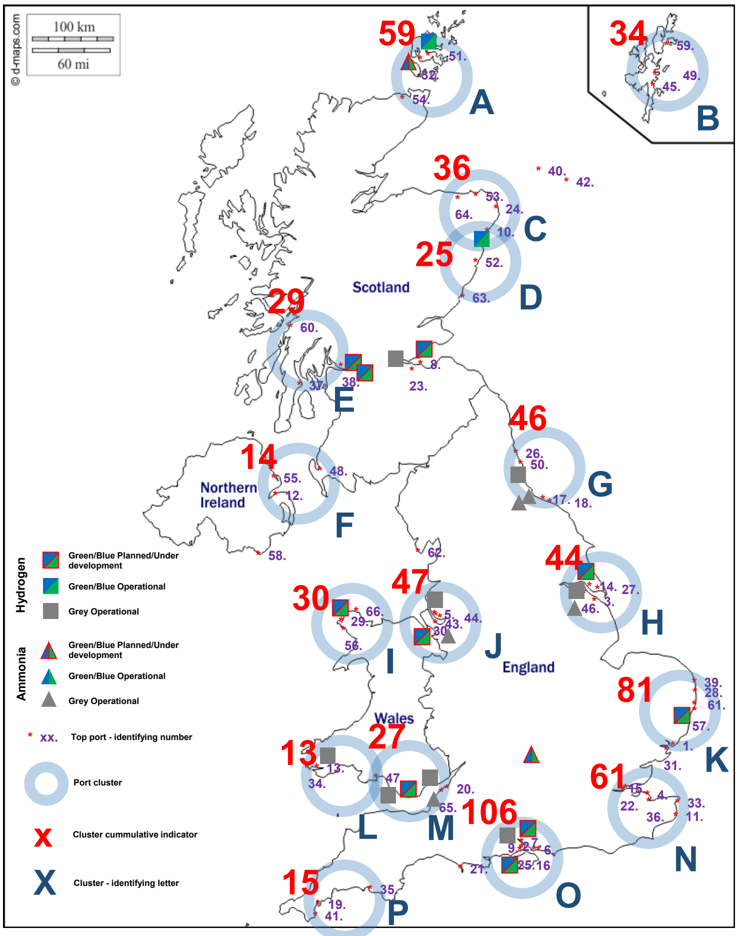

Figure 2 Map of all clusters (lettered) for hydrogen/ammonia adoption in UK with associated accumulated indicator values in red (Baresic & Rehmatulla, Forthcoming)

18. Recommendations:
- Net zero strategies for different industries should be aligned to promote intramodality, creation of robust zero carbon fuel supply chains, and facilitate creation of innovation clusters.
- Geographic factors such as local endowments, population, transport links should be considered when creating policies.

❖ **Are there any policy mechanisms that could reduce our reliance on shipping?**

[16] Baresic, D, Rehmatulla, N. Forthcoming. Zero carbon marine fuel transition indicators for Hydrogen and Ammonia: United Kingdom as a Case Study. UCL.

19. Because the technologies and fuel alternatives for fully decarbonising shipping exist, unlike aviation, there isn't a need to reduce demand for shipping, (this is different to reducing the demand for fuel for shipping). However in the process of reducing emissions from shipping certain policies may create disproportionate negative impacts in certain regions and small and developing economies, where maritime transport costs account for a significant share of overall costs (Halim et al. 2019[17]). Therefore mechanisms to overcome the negative impacts should be further investigated rather than mechanism to reduce demand/reliance on shipping.

❖ **What further action is needed by the International Civil Aviation Organization and International Maritime Organization to drive emissions reductions? What can the UK Government do to drive international action on emissions?**

20. Further ambitious global action is necessary in order for shipping to decarbonize (Smith et al., 2019[18]). Policy at the IMO must provide sufficient incentive for action through an ambitious (Paris-aligned) and enforceable standard. A uniform market-based mechanism (MBM) for international shipping could also be part of the policy solution (Ibid.). The level of the carbon price which would have to be applied would depend on many factors, including the potential for revenue 'recycling' (i.e., investing the collected carbon pricing revenue back into the shipping industry), other measures and technological maturity (Baresic et al., Forthcoming). The UK, as other countries with large economies and a significant shipping industry (e.g., USA, Japan, South Korea, etc.) can play a significant role in moving the IMO decarbonization agenda forward (Osterkamp et al, 2021[19]).

21. Recommendations:
    - UK can lead by example, by setting ambitious domestic shipping decarbonization goals.
    - UK can lead the way in setting the agenda for future IMO meetings in order to continue discussions on mid- and long-term measures for shipping decarbonization (Ibid.).
    - UK can work closely with partners at IMO to increase ambition and enforcement of IMO short term measures.

❖ **How effective will the global offsetting scheme for international airlines (ICAO's CORSIA) and the UK and EU ETS be at stimulating technology improvement and/ or behaviour change to reduce emissions from aviation / shipping?**

22. ICAO CORSIA - Previous analysis has shown that certain aspects of the ICAO Sustainable Aviation Fuels framework provide a good blueprint which could also be followed by the IMO (Rehmatulla et al. 2020[20]). The CORSIA includes GHG emissions beyond just CO2, except the non-CO2 emissions from the aircraft tailpipe. This approach avoids incentivising a switch to alternative fuels that may have lower operational CO2

[17] Halim, R., Smith, T. & Englert, D., (2019) Understanding the Economic Impacts of Greenhouse Gas Mitigation Policies on Shipping: What Is the State of the Art of Current Modeling Approaches? DOI:10.1596/1813-9450-8695
[18] Smith, T., O'Keeffe, E., Hauerhof, E., Raucci, C., Bell, M., Deyes, K., Faber, J. & 't Hoen, M. 2019. Reducing the Maritime Sector's Contribution to Climate Change and Air Pollution: Scenario Analysis: Take-up of Emissions Reduction Options and their Impacts on Emissions and Costs. A report for the Department for Transport. UK Department for Transport, London.
[19] Osterkamp, P., Smith, T., Baresic, D. 2021. US steps up to fill leadership vacuum in International Maritime Organization, sets and pushes for Paris aligned targets and regulation. CLEEN Project.
[20] Rehmatulla, N., Piris-Cabezas, P., Baresic, D., Fricaudet, M., Raucci, C., Cabbia Hubatova, M., O'Leary, A., Stamatiou, N., and Stratton, A. 2020, Exploring the relevance of ICAO's Sustainable Aviation Fuels framework for the IMO, London, UK.

emissions, but overall higher lifecycle GHG emissions. The IMO could follow this example for shipping, with emphasis put on methane, a potent greenhouse gas. In addition, as is the case in ICAO, a full lifecycle emissions perspective could benefit the IMO approach as well. Similarly, the ICAO SAF framework does not automatically allow all biofuels to claim zero CO2 emissions and estimates emissions from Induced Land Use Change (ILUC) (Ibid.). In shipping such measures could support innovation in addressing methane leakage from LNG and promote fuels which have lower upstream emissions, such as ‘green’ and ‘blue’ ammonia.

23. OFFSETTING- offsetting in shipping should not be encouraged. Whilst it would allow emissions reductions to begin with sectors which are easier to decarbonise than shipping (Smith et al, 2016) it could disincentivize in-sector decarbonization (Smith et al, 2016) and divert resources from a sector which already has a significant GHG reduction potential.

24. EU ETS and carbon pricing schemes can play an important role in closing the price gap between alternatives and current fuels (Baresic et a., Forthcoming). Furthermore, in the future potentially revenue collected from carbon pricing schemes, could be ‘recycled’ (i.e. reinvested) into the shipping industry, thus accelerating the closing of the price gap between fossil fuels and zero carbon alternatives, whilst lowering the necessary carbon price for this to be achieved (Ibid.). If a 100% of the revenue generated by a carbon pricing mechanism was reinvested into the industry through subsidising low-/zero-carbon fuels and associated infrastructure, the carbon price necessary to close the price gap between fossil fuels and low-/zero-carbon fuels could be significantly reduced (Figure 3).

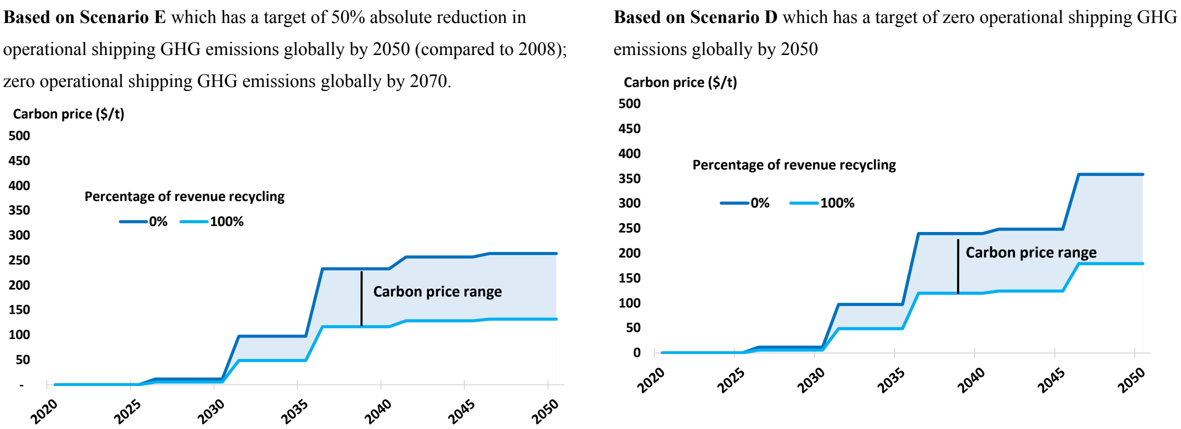

Figure 3 Carbon price trajectories based on % of revenue recycling for two decarbonisation scenarios

25. Recommendations:
    - Promote the adoption of similar mechanisms to the ICAO CORSIA by the IMO, in particular accounting for GHG emissions, not just CO2, taking into consideration full lifecycle emissions, and in terms of biofuels take into consideration their overall sustainability and ILUC.
    - Offsetting in shipping should be limited and discouraged wherever possible.
    - Revenue recycling when using carbon pricing could be considered as a policy option.

❖ **How should the UK define its ownership of international aviation and shipping emissions (i.e. arrivals, departures or both) in order to include them in legislative targets?**

26. Previous analysis, has used the following definition of international and domestic shipping emissions (Smith et al., 2019):
    - Domestic shipping was defined in terms of shipping activity that starts and ends at a UK port.
    - UK's international shipping emissions were defined using a trade-weighted basis, with the emissions estimated based on the amount of shipping activity undertaken for the purposes of UK trade. This approach takes into account that ships often call at multiple international ports and that the entirety of the ship route might not be determined solely by UK trade. Such an approach provides a rationale for linking international shipping emissions with an individual country (Ibid.)

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