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Charting a low carbon future for shipping: A UK perspective

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ABSTRACT

Projected growth in the international shipping industry is set to outstrip CO_2 reductions arising from incremental improvements to technology and operations currently being planned and implemented. Using original scenarios, this paper demonstrates for the first time that it is possible for a nation's shipping to make a fair contribution to meeting global climate change commitments, but that this requires transformation of the sector. The scale and nature of technology change varies depending on the level of demand and how this is satisfied. The scenarios show that to develop successful marine mitigation policy, it is essential to consider the interdependencies between ship speed, level and pattern of demand for services, and the extent and rate of innovation in propulsion technology. Across the scenarios, it is difficult to foresee how deep decarbonisation can be achieved without an immediate, fleet-wide speed reduction; and a land-based energy-system transition strongly influences shipping demand, which in turn, influences the extent of required low-carbon propulsion technology change. Setting the industry on a 2 °C heading requires multifaceted and near-term changes in the shipping sector, but these are unlikely to materialise without a major shift by stakeholders to realise new and innovative deep decarbonisation policies in the coming decade.

1. Introduction

The globalised character of modern societies links economic growth to shipping activity. Between 1950 and 2005, the productivity of the shipping industry in terms of seaborne imports increased by 4.7% per annum [36]. The past half a century has seen the emergence of key trading nations such as Japan and more recently China [40]. Over the same period, growth in demand for shipping has resulted in an eight-fold increase in the total capacity of the global fleet, with more and bigger vessels, the latter for the benefit of economies of scale. These developments have impacted on the character of supply chains. For example, rising demand for oil and the location of refineries closer to end markets has led to the shipping of large quantities of crude oil [9]. Over the past decades these and other changes such as containerisation, have increased the distances over which goods are shipped.

Shipping has been instrumental in facilitating trade between developed and developing countries. In the 1970s, developing countries predominately supplied raw materials; by 2012 the quantity of goods unloaded and loaded by developing countries was approximately 60% of global trade [37], reflecting the expansion of trade of intermediate goods amongst developing nations. Taken together, these changes have significant implications for the growth of shipping greenhouse gas emissions. Eyring et al. [13] estimate that between 1950 and 2001 the CO_2 emissions attributable to shipping increased over four-fold.

Looking ahead, the International Maritime Organisation (IMO), has implemented two energy efficiency regulations, the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP). Analysis suggests, however, that these policies will not reduce shipping's absolute CO_2 emissions, due to growth in transport demand and the slow pace of technology innovation [33]. This is despite the IMO's aim for the shipping sector to make its fair and proportionate contribution to keeping global mean temperatures below 2 °C (see Morooka [24] for example). Within this global context, the High Seas research project focused on understanding how 'UK shipping' may cut CO_2 in line with a 2 °C goal. The insights from this work have relevance beyond the UK and related policy frameworks, given the international nature of shipping.

Within this paper 'UK shipping' is defined as the freight work (i.e. tonne kilometres) associated with transporting goods from the country of loading to the UK (imports), as well as trade around the UK. Imports are chosen as the UK is a net importer of materials and imports arguably represent a closer reflection of the resource demands within a region

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and UK domestic trade is included to reflect the movement of goods around the UK.

A set of qualitative and quantitative scenarios were developed to explore ways in which shipping's CO_2 can remain within a carbon budget commensurate with 2 °C. The scenarios aim to inform policy and decision making by expressly focusing on energy consumption and CO_2 emissions change, without detailed economic estimates. While economic assessments can complement this work, this study avoids introducing the very large uncertainties related to costing technologies, operational and demand-side change up to forty-years hence. This paper initially provides an overview of other shipping CO_2 scenarios before moving on to describe the challenges faced by the sector contributing to the global 2 °C goal. The method section outlines the scenario process and the results section presents scenario narratives, and quantification including cumulative CO_2 emissions. The discussion compares the outcomes of the scenarios, concluding by drawing out key lessons for CO_2 mitigation options available to the shipping system.

1.1. Future shipping emissions

A few notable studies have considered implications of climate change mitigation for shipping, [13,14,34,6,8]. In the IMO's Third Greenhouse Gas study, global shipping emissions are projected to 2050 [34], framed by the Intergovernmental Panel on Climate Change (IPCC)'s 'Representative Concentration Pathways' (RCPs) and 'Shared Socioeconomic Pathways (SSPs) [39]. Future demand for shipping is projected and emissions estimated taking into account mitigation measures. The results suggest CO_2 emissions in 2050 will lie between 810 and 2,800, Mt CO_2, compared with 810 Mt CO_2 in 2012. The lower value is achieved within the context of RCP 4.5, with its high uptake of liquid natural gas and significant efficiency (60%) improvements in the fleet relative to 2012.

Drawing on the Special Report on Emission Ecenarios (SRES) [14,25] project shipping emissions based on assumptions on demand for shipping, linked to global GDP, and technology. While the range of absolute emissions projected in Eyring et al. [14] is not as broad as in Smith et al. [34], the projected growth in emissions (relative to 2012) is comparable to three of the four business as usual emission pathways described in Smith et al. [34]. Crucially neither demonstrates an absolute decrease in CO_2 from their respective base year by 2050.

Paxian et al. [27] project global shipping emissions using a bottom-up ship movement inventory, supplemented with a route finding algorithm and ship characteristic data. Shipping emissions are projected to range between 859 and 1525 Mt CO_2 in 2050 for both a 'clean technology' and 'business as usual' projection respectively.

Focusing on economics, Eide et al. [11] project shipping emissions to 2030 in conjunction with different mitigation measures, to identify potential costs associated with sectoral decarbonisation. They estimate that by 2030 global shipping emissions can be reduced by 33% (from a 2010 baseline) without incurring an additional marginal cost. The authors also suggest an upper limit on the cost effectiveness of carbon reduction, beyond which additional costs result in a marginal increase in emission savings. The importance of fiscal and regulatory measures that pressurise the industry over and above any anticipated fuel price increases are highlighted.

The studies outlined focus on emissions in 2050 and principally on a 2050 end-point, as opposed to considering cumulative emissions. However, it is the cumulative emissions of CO_2 over time that have a much closer relationship to the climate outcome in terms of temperature [35].

1.2. Cumulative emissions and emission pathways

As emissions of CO_2 are long-lived, the climatic response to CO_2 depends on its accumulation in the atmosphere over time. Estimates of the temperature response to cumulative emissions vary but there is a general consensus that the temperature response to cumulative emissions is relatively constant over time [1]. The benefit of a 'cumulative emissions' framing is it connects limits on CO_2 across a particular time frame with the likelihood of avoiding a given average global temperature increase.

Table 1
Shipping CO_2 cuts, taken from [2].

Year	Reduction relative to 2010
2010	0
2020	15%
2030	40%
2040	70%
2050	85%

With the ratification of the Paris Agreement, nations are committed to keeping global mean temperatures to well below 2 °C [38]. Prior to the Paris Agreement, a statement from a senior IMO representative said that the shipping industry should "make its fair and proportionate contribution" to the levels of mitigation deemed necessary to reduce the likelihood of a global mean temperature rise commensurate with averting dangerous climate change [19]. Taking emission reduction pathways commensurate with 2 °C, Anderson and Bows [2], derived proportional CO_2 pathways for the shipping sector for a 50% likelihood of maintaining global temperature increase to within 2 °C above pre-industrial levels (Table 1). The scenarios presented in this paper build on that analysis to show how UK shipping CO_2 could be reduced to be consistent with the CO_2 cuts in Table 1.

The method of assuming global emission reductions for the aggregate of all sectors allows the assigning of appropriate targets for international shipping at both global and a national scale. This is in the absence of an agreed definition on how to apportion the global emissions burden differentially to nations [15].

2. Method

Each scenario is described by a qualitative narrative, with quantitative indicators to capture freight work, energy consumption and cumulative CO_2 emissions. The method takes a backcasting approach [29,30] applied in five steps with iteration to ensure that the cumulative emissions pathway remains within the boundary set by Table 1. This builds on related work focusing on the whole energy system [23] as well as specific sectors [5].

The first step in the process is to define the cumulative CO_2 budget. The second is to understand the present day shipping system, in particular demand for shipping, freight work, energy demand, fuel consumption and CO_2 emissions produced; this is achieved using a bespoke model, ASK C [41]. The third step is to identify driving forces that could influence CO_2 reduction in the shipping sector. The driving forces are articulated in a set of narratives in step four, quantified using the ASK C model in the final step. The scenarios were informed by stakeholders and model assumptions about the deployment of new technology within the shipping sector were based on technology roadmaps, which were co-produced with stakeholders [16]. More detail on the full scenarios can be found in Bows-Larkin et al. [4].

2.1. Identification of decarbonisation themes

Carbon emissions from shipping, like all other sectors, will change depending on three principal factors: demand for shipping services (e.g. higher demand for transported goods can result in more journeys and/or larger ships), new technology (e.g. alternative fuels, energy efficiency measures) and operational change (e.g. logistics and ship speed). Following a literature review and preliminary scenario development considering these three principal factors, a panel of academics and