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Global energy scenarios and their implications for future shipped trade

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ABSTRACT

About half of the world's oil supply, a fifth of coal supply and a tenth of natural gas supply are traded by ship. Accordingly, any significant shift in the size and shape of the global energy system has important consequences for shipping, which underpins international trade and supports economic development. The Paris Agreement requires an acceleration of the drive towards energy system decarbonisation. Yet, the International Maritime Organisation's understanding of the future is more in line with the high-carbon scenarios analysed here. This paper is a first comprehensive and global assessment of implications of fundamental changes to global and regional energy systems for international shipping, under-researched in energy scenarios consistent with deep decarbonisation. It concludes that, despite uncertainties (particularly with negative emission technologies), fossil fuel trade by the middle of the century will almost certainly be significantly lower under low-carbon than under high-carbon scenarios, and (for oil and coal) lower than in 2012. As to bioenergy and captured carbon dioxide, while their supply is expected to increase during a low-carbon transition, worldwide shipped trade in these commodities will not necessarily grow, based on the analysis in this paper. In other words, if the low-carbon futures envisioned in the Paris Agreement materialise, energy-related shipping will likely decline (by a quarter for oil and by 50% for coal in the median < 2 °C scenarios by 2050), with significant ramifications for policies and regulation in the shipping sector and international trade.

1. Introduction

The Paris Conference of the Parties to the UN Framework Convention on Climate Change has confirmed an international commitment to keeping the rise in global mean temperature “well below 2 °C and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels” [1]. However, the current emission trajectory is more closely aligned with a 4 °C increase by 2100 [2], and even if the pre-Paris Agreement's pledges, the Intended Nationally Determined Contributions, are realised, they fall well short of the Agreement's goal to stay under 2 °C with at least a 66% probability [3].

In its Assessment Reports over the years, the Intergovernmental Panel on Climate Change [4,5] has considered how to mitigate and adapt in line with a range of future temperatures compared to pre-industrial levels. Concurrently, a significant body of scenario literature has evolved analysing how these temperatures changes might influence the global energy system through mitigation policies [6–11]. Depending on the stringency of a temperature target, emission reductions are anticipated to transform all sectors and all economic activities across the globe. For example, shipping will be affected by a 2 °C scenario not only through the need to directly decarbonise ships, but also as a result of knock-on effects from lower or even eliminated fossil fuel use [12]. Given that fossil fuels are among the top commodities both by weight, at 44% of international seaborne trade in tonnes [13], and by value, at 16% of the US$18.8 trillion global trade [14], even partial decarbonisation will affect shipping. In addition, the lower-carbon agenda enhances the prospects for increased trade in some commodities such as bioenergy, liquefied natural gas and, potentially, liquefied carbon dioxide.

Despite the impending impacts of energy system decarbonisation on shipping, thus far, climate change has been a low priority, in deed if not in word, with the International Maritime Organisation (IMO) [15], the UN's agency responsible for shipping safety and maritime pollution. Since being tasked to reduce bunker fuel emissions in 1997, the IMO has adopted two standards related to reducing carbon: the Energy Efficiency Design Index for new ships and the Ship Energy Efficiency Management Plan for all ships [16]. Both standards have been criticised for being inconsistent with the scale of change required for a 2 °C target [17,18]. Moreover, the IMO has prioritised issues of local and short-term sulphur pollution over global and longer-term carbon ‘pollution’, potentially locking out low-carbon measures [19]. In addition, a widespread view is that shipping is a derived demand merely serving

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world trade, with absolute CO_2 reductions outside its direct control [20,21]. Short-term priorities, the fragmented nature of the sector, and the long lifecycle of both ships and related land-based infrastructures intensify the challenge of the sector's low-carbon transition.

The shipping sector's lack of decarbonisation effort is further complicated by the limited attention of whole-energy-systems research to shipping. Within global energy scenario studies [e.g. [6,7]], assumptions and outputs related to shipping are rarely mentioned. These are framed as international trade and/or partly disaggregated as international bunkers or hidden within the transport sector. Trade is mentioned in the context of international climate governance and development, i.e., helping poorer countries to adapt and mitigate [22], or in the context of worsening terms of trade for hydrocarbon exporters [23]. As a caveat, even in the studies that do not discuss shipping, both the sector and fuel trade might still be part of the underlying model, as is the case with the TIMER and IMAGE models [8]. Some studies, for example Deng et al. [24], do disaggregate shipping in their models and even explicitly report some of the underlying assumptions, but the indirect impacts of wider decarbonisation on the sector are generally ignored.

Recognising the shipping sector's limited progress on decarbonisation, nationally-focused research has started to explore both technology and operational change within the sector [25,26], as well as demand-side change outside the sector [12,27,28]. Furthermore, Matzenberger et al. [29] analyse how mitigation of the energy systems through bioenergy could affect shipping and trade in the longer term. These studies should be distinguished from research that considers shipping decarbonisation scenarios [30,31]. This paper adds to the literature by, for the first time, systematically analysing indirect and systemic impacts on the shipping system of land-based decarbonisation of varying stringency, to articulate a plausible scenario space for future shipped trade. To this end, global decarbonisation scenarios are interrogated to identify shifts in demand for energy commodities, shedding new light on how the low-carbon agenda may affect global trade in the coming decades. Firstly, absolute and relative changes are analysed in the fossil fuel supply, bioenergy supply and carbon captured and stored (CCS) over time between 2010 and 2050. Secondly, it is estimated how these supply and CCS changes can affect future shipped trade. Finally, policy recommendations are developed based on the analysis in this paper.

2. Method

Energy and emissions pathways from scenario databases [e.g. [32]] including both high- and low-mitigation cases are analysed to capture a range of temperature rises compared with pre-industrial levels, from below 2 °C (denoted here as < 2 °C) to above 3 °C (denoted here as > 3 °C). For the < 2 °C temperature threshold, this paper focuses on keeping under 2 °C with at least a 66% probability, as this probability is consistent with the Paris Agreement's goal and has been the focus of most scenario analysis to date.

Six publicly available databases are identified: IPCC AR4 [33], IPCC AR5 [32], Representative Concentration Pathways [34], Global Energy Assessment [35], LIMITS [36], Roadmaps towards Sustainable Energy futures [37] and AMPERE [38]. The IPCC AR5 database contains information from LIMITS, GEA, RoSE and AMPERE. For consistency, the IPCC AR5 database is used for global data. However, as necessary data *by region* is not available in the IPCC AR5 database, GEA and LIMITS are used instead. An important limitation of the databases is their extensive reliance on speculative negative emissions [39–41] that guarantee a continued large-scale use, and hence shipping, of fossil fuels out to 2050 and beyond.

These databases are used for identifying the quantitative scale of changes to the energy system globally and region-wise that might have repercussions for shipping. Specifically, the databases provide the following variables for the analysis in this paper: fossil fuel mix of total primary energy supply; amount of bioenergy in the primary energy fuel mix; and captured CO_2 emissions. Pathways for these variables between 2010 and 2050 are extracted from the databases and derive quartiles building on a range of maximum, median and minimum values. In addition to absolute changes, relative changes in the short (2020) and long (2050) terms are calculated. The year 2020 is chosen due to the immediacy of this timeframe and 2050 as an important milestone for strategic planning, given the long life-span of ships and shipping infrastructure.

After the scenario data is processed, it is analysed in three stages. First, each variable (e.g. supply of a particular fuel or CCS emissions) is analysed within each region across the different temperature thresholds; for example, how oil supply in Asia compares in the < 2 °C and > 3 °C scenarios. Second, each variable and each temperature thresholds are analysed across different regions and years; for example, how gas supply in Latin America for < 2 °C compares to gas supply in other regions for < 2 °C. Finally, to identify how the changes in a decarbonised energy system might affect shipping activity, data and assumptions are considered on future fossil fuel trade, on future regional bioenergy availability and trade, and on geological storage of CO_2 by region. For example, historical trade-to-supply ratios [42–44] are applied to the IPCC AR5 scenarios' supply numbers to determine future fossil fuel trade in exajoules. In the case of bioenergy, this paper uses regional technical potentials in 2020–2030 and 2050 [45] to estimate bioenergy surpluses and deficits by region. Similarly, for CCS, data on potential storage space in geological formations [46,47] is compared to the CO_2 capture numbers from the IPCC AR5 scenario database. A limitation of this study is in linking data from different sources whose regional groupings might differ, even if the regions bear the same name.

3. Results

3.1. Uncertainty and scenario spread in absolute terms

Future energy trade will significantly affect the demand for shipped freight. As it is impossible to predict the future accurately, there is much uncertainty about future changes faced by the sector. One way of dealing with this uncertainty is to consider a range of potential non-probabilistic futures, such as the scenarios analysed here. Assuming that each scenario is as likely as another, this analysis does not exclude outliers. If planning strategically, the shipping sector should prepare for, or at least consider, a full range of outcomes. For example, while there might be several scenarios towards the top of the range that lead to high oil supply and trade in future, on balance such scenarios are rare. This highlights the usefulness of considering a range of futures rather than one or two discrete outcomes.

Fig. 1 provides regional trends in oil supply between 2010 and 2050 for the two temperature thresholds. The > 3 °C spread of the regional oil pathways is generally narrower than the < 2 °C spread (with the Reforming Economies region in panel (e) of Fig. 1 being the exception). This difference between the spreads for the two temperature thresholds is especially stark in the Latin America pathways (see panel (b) of Fig. 1). One possible explanation for this difference is that a < 2 °C future can be achieved in many more different ways/pathways than a > 3 °C future that essentially continues current trends. Another potential explanation is that, as these pathways are generated through optimisation, there is generally agreement that a continuation of current trends is the ‘cheapest’ solution.

A caveat to keep in mind, when interpreting the graphs in Fig. 1, is that the respective quartiles do not necessarily correspond to the same scenarios. For example, the top edge of the 4th quartile, i.e., maximum values, in oil is not one single pathway corresponding to the same model. Instead, it is a composite of maximum values across a range of oil supply pathways over time. The 4th quartile includes the highest 25% of pathway in 2010, then the highest 25% in 2020 and so on. In other words, it is not possible to tell, from the quartiles, whether the