Climate Policy

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tcpo20

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CLIMATE POLICY
https://doi.org/10.1080/14693062.2021.1991876

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The urgent case for stronger climate targets for international shipping

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ABSTRACT

International shipping is overwhelmingly reliant on fossil fuels, with annual carbon dioxide emissions equivalent to a country the size of Germany. Actions to reduce its emissions are therefore an important element of global efforts to combat climate change. This article re-assesses the international shipping sector's initial greenhouse gas emissions reduction targets against the Paris Agreement goals. The analysis is based upon the latest data from the Intergovernmental Panel on Climate Change (IPCC) and International Maritime Organization (IMO) and uses the concept of carbon budgets to evaluate proportionate 1.5°C emissions pathways for the sector. The consequences of the resulting Paris-compliant pathways for shipping's existing mitigation targets and strategy are discussed. The article concludes that significantly stronger short- and longer-term targets need to be set for the sector to be compatible with the Paris Agreement's goals: 34% reductions on 2008 emissions levels by 2030, and zero emissions before 2050, compared with the sector's existing target of a 50% cut in CO_2 by 2050. Crucially, strengthening the target by the IMO's strategy revision date of 2023 is imperative. The long asset lifetimes of ships and shipping infrastructure limit the speed of transition such that a delay of even a few years will dictate an untenable rate of decarbonization and increased risk of pushing the already challenging Paris goals out of reach.

Key policy insights:

- There is a gap between targets set out in the IMO's Initial Strategy and what is needed by the shipping sector to be Paris-compliant.
- Paris-compliant targets require a 34% reduction in emissions by 2030, with zero emissions before 2050. Existing targets imply no absolute reduction in emissions to 2030, and only a 50% reduction by 2050.
- The longer the delay in setting new targets, the steeper subsequent decarbonization trajectories become. Delay beyond 2023 would necessitate an untenably rapid transition, given long shipping asset lifetimes and global requirements for new land-side infrastructures, increasing the mitigation burden on other sectors.
- COP26 in November 2021 is an opportunity for the shipping sector to signal its intent to strengthen its targets, and to implement this in its 2023 strategy revision process, at the latest.

ARTICLE HISTORY
Received 21 April 2021
Accepted 6 October 2021

KEYWORDS
Shipping; carbon budgets; Paris; IMO; pathways; climate change; decarbonization

Introduction

The 2015 Paris Agreement sets out goals to prevent dangerous climate change, aiming to limit global temperatures rise to well below 2°C above pre-industrial levels, while pursuing efforts to keep below 1.5°C (United Nations, 2015). Under the Paris Agreement, nations submit 'Nationally Determined Contributions'

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Supplemental data for this article can be accessed https://doi.org/10.1080/14693062.2021.1991876.

with the aim that their summed contributions meet the treaty's goals (United Nations, 2015). However, international shipping is excluded, with responsibility for emissions reductions previously being devolved to the International Maritime Organization (IMO). International shipping has carbon dioxide emissions (CO_2) equivalent to Germany, the seventh highest emitting country globally (Global Carbon Project, 2020). Consequently, assessment of mitigation strategies for international shipping are of great importance for effective global climate governance.

For over a decade, policy makers and academics alike have noted slow progress in developing sufficiently strong policies and plans to mitigate shipping CO_2 (Bows-Larkin, 2015; European Parliament, 2020). It wasn't until 2018, in response to the 2015 Paris Agreement, that the IMO set out an initial draft emissions reduction strategy (IMO, 2018). The strategy states that action should be based upon '*a pathway of CO_2 emissions reduction consistent with the Paris Agreement temperature goals*'. However, as we go on to illustrate, the subsequent targets set by the IMO remain inconsistent with such a pathway.

The IMO strategy sets initial targets to reduce emissions by ***at least*** 50% by 2050 from 2008 levels, and an interim 2030 target to reduce emissions intensity by ***at least*** 40% from 2008 levels (IMO, 2018). With projections of increased shipping demand over the coming decade, the interim intensity target is in practice widely considered to be equivalent to CO_2 emissions staying constant in absolute terms to 2030 (DNV GL, 2018; Faber et al., 2020). Submissions to the IMO in 2017 from member states argued that targets without absolute reductions this decade would be incompatible with the Paris goals (IMO, 2017) and analysis by Bullock et al. (2020) used the concept of carbon budgets to highlight this point.

Future global temperature change is strongly correlated with total cumulative global emissions of CO_2 (Matthews et al., 2018; Millar et al., 2016). A carbon budget is the quantity of cumulative CO_2 emitted over time for a given probability of staying below a prescribed temperature target. This carbon budget metric has been used in national and global mitigation studies (Allen et al., 2009; Anderson et al., 2008; Anderson & Bows, 2011; Rockström et al., 2017) and incorporated as a core concept in IPCC reports (IPCC, 2013; IPCC, 2018). Carbon budgets are also discussed at sectoral level as components of national carbon budgets, for example, for buildings (Habert et al., 2020; Steininger et al., 2020) and road transport (Marsden & Anable, 2021). While shipping is also a sector, most of its emissions are released in international waters. Couple this with its international governance arrangements and it becomes evident that there are practical and political challenges with international shipping emissions apportionment to nations (Gilbert & Bows, 2012). Analysing shipping emissions mitigation using a global carbon budgeting method, as is done here, thus allows for a quantitative interpretation of the Paris Agreement in a way that overcomes these challenges.

Using IPCC carbon budgets, Bullock et al. (2020) concluded that the cumulative international shipping emissions of the existing IMO targets were more than double those of a Paris-compatible carbon budget, and that for a 50% chance of meeting the Paris 1.5°C goal, the shipping sector's fair share of mitigation effort requires a pathway equivalent to a linear reduction to zero CO_2 emissions from international shipping by 2040; similarly, analysis by Smith et al. (2015) concluded that a linear reduction pathway to a 2042 zero emissions date is compatible with 1.5°C.

Such mitigation pathways are considerably more challenging than those laid out in the IMO's initial strategy, however, the complexities of determining proportionate actions for the international shipping sector in meeting the Paris goals is under-researched in the academic literature. This and recently updated IMO emissions data and methodologies necessitate a reassessment of international shipping's contribution to the Paris 1.5°C goal, the focus of this paper.

In particular, the IMO's 4th Greenhouse Gas (GHG) Study in 2020 set out a new methodology for more accurately reflecting the split between international and domestic shipping emissions, the latter being counted within individual nations' emissions inventories. The new approach uses a 'voyage-based' calculation of GHG emissions, and is more accurately aligned with IPCC inventory guidelines (Faber et al., 2020). This change reduces the emissions contribution of international shipping relative to domestic shipping and is reflected in a 16% lower value for GHG emissions from international shipping in 2008, compared with the IMO's 3rd GHG Study.

Here we revisit the analysis in Bullock et al. (2020) and Smith et al. (2015) and use the carbon budget methodology in light of both the newly published IMO 4th GHG Study and the most recent available emissions data, to articulate what a Paris-consistent pathway for shipping is, so as to inform relevant debate at COP26 and at the upcoming IMO Marine Environment Protection Committee (MEPC) Meeting 77, and to promote urgent subsequent revision of the IMO strategy in 2023. The analysis presented provides a robust evaluation of the gap between existing ambition and one that is Paris-compliant, to assist policy makers in setting new and Paris-compliant targets for shipping.

Methods

The analysis sets international shipping GHG budgets and pathways in three steps. First, a global carbon budget is established based upon Chapter 2 of the IPCC 1.5 report (Rogelj et al., 2018), defining the goal as a 50% probability of keeping warming below 1.5°C. All global budgets are set against probability ranges for a given temperature rise. The wording of the Paris Agreement is that nations should 'pursue efforts' to keep temperature rise below 1.5°C. Assigning probabilities to wording such as this cannot be exact, but here we assume that a 50:50 chance is the greatest risk compatible with a 'pursue efforts' aim. It should be noted though, that Article 4's requirement is that actions should represent 'highest possible ambition', and that it would be prudent to improve those odds, given the scale of impacts people are already experiencing at well below 1.5°C. In the results section, for illustrative purposes, we present budgets for 33%, 50% and 66% probabilities of exceeding 1.5°C.

Second, an international shipping share of the global carbon budget is established, based on a grandfathered allocation, using international shipping's share of global CO_2 emissions in a chosen baseline year. This approach is used in Traut et al. (2018) and by the International Chamber of Shipping (2018), and follows the 'fair and proportionate' wording of the IMO (IMO, 2011). A summary of other options by IMO (2017) suggested possible apportionment proportionate to the emissions reduction effort of comparable sectors, or to the effort of all or subsets of countries. However, these approaches are not included here as they explicitly lead to higher temperature outcomes (in the range 1.75–3.1°C) (IMO, 2017). There are also arguments that shipping should receive a larger budget than proportionate to shipping's existing share, due its vital role in global trade (Morimoto, 2018), or that shipping will need to make deeper cuts because of the greater limitations to cutting emissions to zero in other sectors such as agriculture (Bows-Larkin, 2015; Gilbert et al., 2014). The summary paper to the IMO (IMO, 2017) concluded that there remains insufficient data on limitations to sectoral emissions reductions to determine different levels of ambition. Other approaches are possible, for example, a recent study advocated allocating international shipping emissions to nations (Selin et al., 2021), however, others highlight the complex political and technical difficulties in doing so (Gilbert & Bows, 2012); in practice, international shipping emissions remain under the remit of the IMO.

Assessments of contributions to global emissions reduction efforts often focus on the issue of equity or 'differentiated responsibility': where developed ('Annex 1') nations have greater current and historical per capita emissions, and therefore a greater responsibility and requirement to act (Du Pont et al., 2017). For an international sector such as aviation, such arguments suggest greater-than-global-average contributions to mitigation, given flying is highly inequitable between nations. International shipping, on the other hand, underpins global trade, with equity issues far less clear-cut. Nevertheless, global trade is still significantly driven by wealthier countries, so assuming that the sector's share of the remaining budget is proportional to shipping's share in any given baseline year is arguably a generous and inequitable allocation. We also note that negative emissions technologies are likely to be necessary for sectors where CO_2 emissions cannot be reduced to zero, but the evidence indicates that shipping is a sector which can fully decarbonize (Climate Change Committee, 2020; Lloyd's Register, 2019).

The final major issue in allocating an international shipping budget is the choice of baseline year. This parallels discussion in the literature around issues of historical responsibility and fairness (Du Pont et al., 2017). For selecting a baseline year from which to calculate shipping's carbon budget, there are two principal options. The first is a baseline year of 2020, reflecting the most recent date from which to estimate an up-to-date global carbon budget; the second is to use 2008, which is the baseline year used in the IMO's existing strategy. In 2008, international shipping emissions contributed a higher percentage of the global total emissions (2.4%) than in all subsequent years, including 2020, when its global share is estimated to be 2.0%. This reduction occurred because, in the last decade, after cuts in 2009 and 2010, international shipping's emissions have been broadly constant, whereas global emissions have risen. Therefore, the IMO's use of a 2008 baseline allocates a larger share of the remaining global carbon budget to international shipping, compared with using a 2020 baseline. This paper provides analysis for both a 2008 baseline, as it is the year the IMO uses, as well as an analysis for 2020. Using 2008 lowers the required ambition from the international shipping sector, while using 2020 illustrates what a proportional response for the sector would be if Paris-compliant mitigation efforts were shared from the present day.

The analysis then sets out pathways for emissions compatible with these international shipping carbon budgets. To explore the implications for the sector in terms of the timing of policy implementation, the pathway analysis uses a linear function and a logistic function. The linear function presents the simplest mathematical outcome that is bound by the carbon budget, whereas the logistics function presents trajectories articulating mid-term rates of mitigation effort when varying the speed of short-term action. It is assumed that emissions will rebound from the 2020 COVID-19 pandemic during 2021 and 2022. See supplementary material for further methodological detail and sensitivity analysis.

Results

Chapter 2 of the IPCC 1.5 report (Rogelj et al., 2018) sets out a global carbon budget of 580 $MtCO_2$ from 2018 for a 50% chance of keeping warming below 1.5°C. 100 $MtCO_2$ are subtracted to account for earth-system feedbacks (Rogelj et al., 2019). 107 $MtCO_2$ are removed to account for emissions from 2018-2020, assuming a 7% COVID-related reduction in 2020 CO_2 emissions compared with 2019 (Le Quéré et al., 2020). This leaves a remaining global carbon budget of 373 $MtCO_2$ from the start of 2021.

Assuming that international shipping's carbon budget is proportionate to its share of global emissions in a given year, the sector's carbon budgets for different probabilities of achieving the Paris 1.5°C goal are set out in Table 1.

In the following analysis, we take the 2008 and 2020 baselines for 50% probability of limiting warming to 1.5°C as our central pathways.

Cumulative international shipping emissions under the current IMO targets are twice as high as a Paris-compliant carbon budget (Table 2, and see supplementary material). Keeping within a Paris-compliant carbon budget will therefore require the IMO to move beyond the 'at least 50% reduction by 2050' in its initial strategy, to significantly and explicitly strengthen its targets to be over twice as ambitious.

Figure 1 shows pathways compatible with the larger 2008 baseline carbon budget. A linear trajectory is shown alongside two logistic function trajectories for two assumed growth rate factors: one representing a medium delay in action and the other representing a longer delay in action. The figure shows that any delay in action requires a steeper subsequent decarbonization pathway. Table 3 shows the maximum annual carbon reduction rates for each pathway. For the scenario using a 2008 baseline to calculate the sector's carbon budget, if emissions reductions start in 2023 after a COVID bounce-back and then follow a linear downward trajectory, there is a 25-year decarbonization pathway to zero emissions, with an annual reduction rate of 4% on 2023 levels. However, delaying emissions reductions increases the maximum annual reduction rate to as high as 15%. Further detail on annual reduction rates is set out in supplementary material.

It is important to note that using a 2008 baseline allows more leeway for the shipping sector. Using an arguably more appropriate 2020 baseline makes decarbonization trajectories steeper (Figure 2). The implications of this are set out in Table 3. Using a 2020 baseline to calculate the sector's carbon budgets, linear emissions reductions starting in 2023 imply a 16-year transition, with zero emissions by 2039 and an annual reduction

Table 1. International shipping carbon budgets for different probabilities of limiting temperature increase to 1.5°C, and different assumptions around historical responsibility.

Probability of limiting temperature increase to 1.5°C	International shipping carbon budget (2008 baseline) $GtCO_2$	International shipping carbon budget (2020 baseline) $GtCO_2$
33%	17.0	12.5
50%	10.7	7.4
66%	6.8	4.2

Table 2. Paris Agreement 1.5°C carbon budgets compared with existing IMO targets.

	Cumulative emissions from 2021 onwards ($GtCO_2$)
50% 1.5°C carbon budget (2020 baseline)	7.4
50% 1.5°C carbon budget (2008 IMO baseline)	10.7
Emissions implied by current IMO targets to 2050, then assumes linear reduction to zero by 2060	20.2
Emissions implied by current IMO targets to 2050, then assumes linear reduction to zero by 2070	22.2

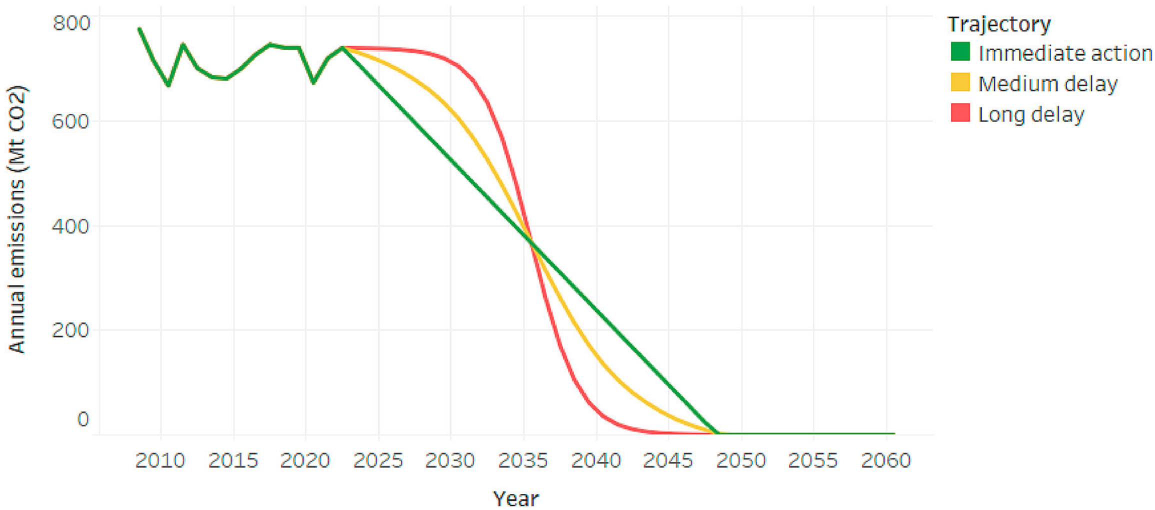

Figure 1. CO_2 pathways to zero emissions, using 2008 IMO baseline for calculating carbon budgets.

rate of 6%. Delay in action requires a steeper transition and the long delay trajectory increases the maximum annual reduction rate to 22%. The graphs are a stark illustration of the degree of urgency. For the 2020 baseline method, even the pathway with the longest transition is just 16 years long – arguably infeasible in any practical sense, particularly given the long asset lifetimes of ships. Because of delays in reducing emissions in the last decade, the only feasible carbon budgets for shipping are the ones which choose generous baselines for the sector.

As shown in Figures 1 and 2, and widely discussed in the literature (Anderson et al., 2008; Peters et al., 2015), cumulative emissions on a linear downward trajectory are dominated by those released in the early years. It follows that if there are delays to implementing appropriate mitigation measures in the near-term, keeping within a given carbon budget requires far deeper reductions in later years. The outcome for shipping, at best, is that the sector would have around a decade to completely decarbonize if the IMO does not strengthen its current 2030 target, assuming ongoing trade growth. The IMO's targets are contrasted with the 2008 baseline 1.5**°C** pathways in Figure 3, which show the deep disconnect between the IMO's current targets and Paris-compatible mitigation efforts.

Table 3. Transition rates and dates for different carbon budget scenarios.

	Carbon budget based on IMO's 2008 baseline year			Carbon budget based on a 2020 baseline		
	Major transition period	Years for transition	Max annual reduction (%)	Major transition period	Years for transition	Max annual reduction (%)
Cuts from 2023	2023–2047	25	4	2023–2038	16	6
Medium delay	2025–2045	21	7	2025–2037	13	12
Longer delay	2030–2040	11	15	2027–2034	8	22

Figure 2. CO_2 pathways to zero emissions, using 2020 baseline for calculating carbon budgets.

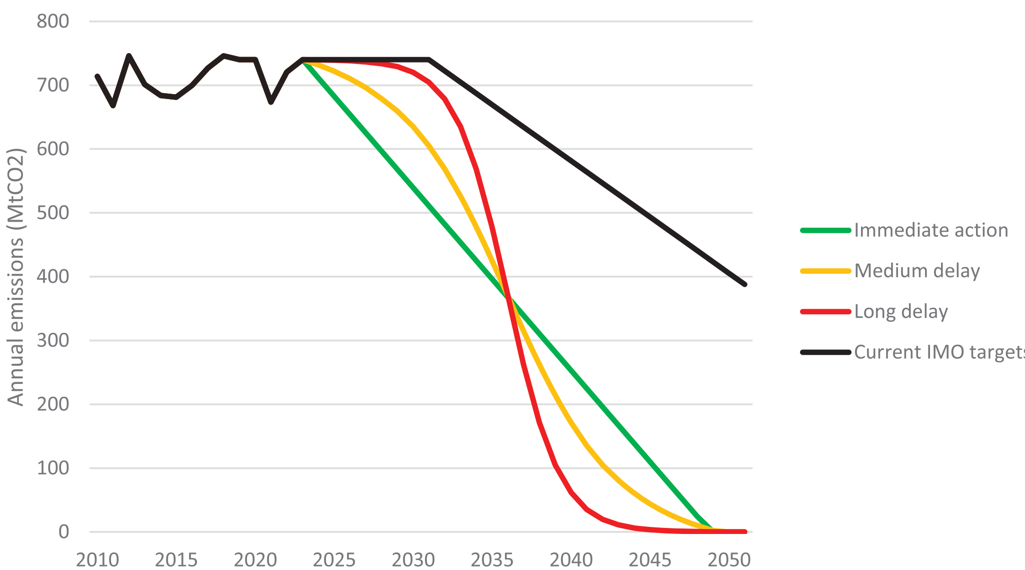

Figure 3. The IMO's targets and Paris-compatible 1.5°C pathways (2008 baseline).

Discussion

Figures 1 and 2 show that the longer the delay in cutting emissions, the greater the required rate of transition. To remain within Paris-compatible carbon budgets, the length of any possible delay depends upon the feasibility of the subsequent increased rate of decarbonization.

Shipping assets have average lifespans of over 25 years (Bullock et al., 2020). In addition, deployment of alternative fuels at scale will require trillions of dollars of investment in land-side infrastructure (Krantz et al., 2020). Consequently, attempting to decarbonize the entire sector across all nations in anything under 25 years would be exceptionally difficult and highly imprudent to be relied upon. We assume here that 90% of the full transition would require a minimum of 25 years.

With the larger 2008 baseline budget, the implied emissions in 2030, under the IMO's current 2030 carbon intensity target, would then require a transition to a completely decarbonized global sector in the following 11 years. This is not feasible, and so requires an urgent revision to the IMO's 2030 target.

All pathways using the 2020 baseline and the 'long delay' pathway using the 2008 baseline require far fewer than 25 years. Even the 'medium delay' pathway using the 2008 baseline requires 21 years, between 2025 and 2045. It would be prudent, therefore, to assume that only the 'immediate action' pathway with a 2008 baseline is both feasible and compatible with the Paris targets. This involves emissions falling from 2023, the same year as the IMO's planned revision of its initial strategy. This pathway, in stark contrast to the IMO's initial strategy, has a 34% cut on 2008 levels by 2030, and zero emissions by 2048. Such targets are slightly less stringent than the earlier assessments (Bullock et al., 2020; Smith et al., 2015), as a consequence of the use of the IMO's baseline and the methodological adjustment used in the 4th GHG Study.

As major international strategies tend not to deliver immediate results, this implies that the IMO should be introducing stronger measures and setting the groundwork for stronger targets well before 2023. The ideal opportunity would be during the UNFCCC COP26 in November 2021, when countries are bringing forward revised Nationally Determined Contributions. This also coincides with the IMO's MEPC77 meeting, which provides a more focused forum for discussion. A delay in implementing new targets would mean that either shipping demand would need to fall, or that shipping could no longer play it fair and proportionate part in meeting Paris goals.

A final issue is whether even 25-year transitions are achievable. The literature is clear that multiple technical and operational options exist for decarbonizing shipping, such as energy efficiency, shore power, wind-propulsion, slower speeds and low-carbon fuels (Balcombe et al., 2019; Bouman et al., 2017; Gilbert et al., 2014; Lloyd's Register, 2019). An analysis of the committed emissions from ships covered by the new EU Monitoring, Reporting and Verification (EUMRV) regulation illustrated how shipping could stay within 1.5°C carbon budgets. It required a dual-track approach. First, targeting the existing fleet in the 2020s with policies focused on speed, energy efficiency and other technical measures. Second, policies to incentivise the widespread deployment of zero-carbon fuels in the 2030s for both new and existing ships (Bullock et al., 2020). This implies that with a similar roll-out of policy and measures in other jurisdictions, international shipping can still make such a transition. It is fortunate also that slow-steaming is an operational change that is not only available now, but one that can deliver immediate and deep emissions reductions (Bouman et al., 2017). A better understanding of the maximum possible deployment rates for all shipping mitigation options is a critical area for future research.

Conclusion

If the shipping sector is to play its fair part in meeting the Paris Agreement goals, and avoid other sectors needing to increase their efforts, then it is imperative and urgent that the IMO strengthens its existing targets. Our results suggest that the IMO should grasp the imminent opportunity to bring a revised set of targets to COP26 and MEPC77, including a 34% cut on 2008 levels by 2030 and a zero emissions target before 2050, and to formalize these in the IMO's 2023 strategy revision. If it does not set such targets quickly, then the required rate of transition will rapidly become untenable, resulting in an increased risk of pushing the already challenging Paris goals out of reach. There is a considerable body of literature that illustrates a wide range of mitigation options that are available to the sector, unlike, for example, to aviation. Nevertheless, setting and meeting such targets requires the IMO and other stakeholders to take immediate action. Implementation requires working across their full range of mitigation levers, from those that influence energy demand and efficiency to others that accelerate the shipping sector's low-carbon technology transition. It is time for the IMO to grasp the nettle of what '***at least***' means in its target setting and face head-on the stark gap between what it is currently proposing and what is needed to be Paris-compliant.

Acknowledgements

Many thanks to three anonymous reviewers whose suggestions and challenges have improved the initial draft.

Authors' contributions

SB, JB and AL designed the study. SB led the writing with input from all authors who edited all drafts. SB, JM and AL contributed jointly on methodology. All authors have read and approved the final manuscript.

Availability of data and materials

Supplementary information contains an excel spreadsheet file with data, and a word document with further detail on methodology and sensitivities.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The authors acknowledge financial support from Engineering and Physical Sciences Research Council (EP/L016141/1) through the Power Networks Centre for Doctoral Training (SB) and the University of Manchester EPSRC Doctoral Training Partnership (JM). These funding bodies did not have a role in the design, analysis or writing of this manuscript, which is the sole responsibility of the authors.

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