QUANTIFYING THE CLIMATE CHALLENGE FOR SHIPPING: FROM INCREMENTAL TO STEP CHANGE MITIGATION

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ABSTRACT
The language of 'combating climate change' and making a 'transition to low-carbon technologies' is increasingly evoked across all sectors, including shipping. However, seldom is the scale of emissions-reductions quantified in relation to national commitments and international obligations on climate change. Consequently, sectoral emissions are typically guided by vague responses rather than scientifically-informed quantification of the scale and timeframe of emission reductions. With specific focus on shipping, this paper disaggregates global emission profiles to provide an evidence-based suite of quantified emissions pathways for the sector. The UK Government's position that *"average global temperatures must rise no more than 2°C"*, the EU commitment to "adopt the necessary domestic measures… to ensure temperature increases do not exceed 2°C" and the Copenhagen Accord's pledge to *"hold to … below 2 degrees Celsius"* provide a consensual quantification of the climate change challenge. Allying this 2°C obligation with an accompanying range of 'carbon' budgets permits quantified emission-reduction pathways to be developed. Against this backdrop alternative suites of absolute emissions reductions from international shipping can be explored and the implications quantified. If shipping is to make its fair contribution to tackling climate change it must develop carbon reduction technologies and practices in line with Global, EU and UK commitments on 2°C. Such an evidence-based framing of shipping emissions raises fundamental and difficult questions for the sector. Does it continue with a well-meaning but ultimately uninformed characterisation of its emission reductions or does it respond to a scientifically-rigorous framing of the mitigation challenge?
Keywords: shipping, climate change, step-change, mitigation, emissions, targets

1. INTRODUCTION

The world is emerging from an economic downturn to rates of growth in greenhouse gases unprecedented throughout the twentieth century. At the same time there is increasing recognition that the global community is now on a pathway to a 4°C rise in global mean surface temperature during the latter half of this century. Whilst a 2°C rise may be tolerable, evidence suggests 4°C is beyond the capacity of contemporary society to adequately adapt, at least without unacceptable hardships being imposed on large proportions of the global community. Against this backdrop, there is increasing pressure to move beyond the rhetoric and towards the delivery of meaningful mitigation. The shipping sector will not be exempt from such pressure, and this paper endeavours to provide a quantitative framework for understanding the *fair* contribution of international shipping to avoiding dangerous climate change. The paper comprises five sections:

Section 1. *Outlines how scientifically robust mitigation needs to be based on cumulative carbon budgets and not arbitrary long-term targets.*

Section 2. *Describes how global carbon budgets can be disaggregated to provide sectoral emission-reduction pathways.*

Section 3. *Quantifies the global carbon budgets for international, EU and UK commitments on climate change.*

Section 4. *Translates the global budgets into a choice of frameworks for quantifying international shipping emissions.*

Section 5. *Concludes that the scale of mitigation both negates the purpose of differentiating emission-reduction rates between sectors and places radical step-changes and demand management at the heart of any meaningful mitigation strategy.*

2. SETTING THE BACKGROUND FOR A LOW CARBON TRANSITION

In 2009 the Copenhagen Accord enshrined the international community's commitment to *"hold the increase in global temperature below 2 degrees Celsius, and take action to meet this objective consistent with science and on the basis of equity"* (UNFCCC, 2009). The clarity of the agreement and the framing of the Accord around the importance of "*hold[ing] to … below 2 degrees Celsius"* reflects the clear and long-established stances of both the EU Commission and the UK Government. The EU states it "*must adopt the necessary domestic measures… to ensure that global average*

temperature increases do not exceed preindustrial levels by more than 2°C" (European Commission, 2007) [emphasis added]. Similarly, the UK Government's '*UK Low Carbon Transition Plan'*, maintains that "*to avoid the most dangerous impacts of climate change, average global temperatures must rise no more than 2°C* (p.5 DECC, 2009)*"* [emphasis added]. The previous Secretary of State for Energy and Climate Change subsequently reiterated this commitment, stating *"we should limit climate change to a maximum of two degrees"* (Miliband et al., 2009) [emphasis added]; a position broadly supported by the current administration whilst the language of the Accord, EU and the UK is clear in terms of what constitutes a dangerous, or at least an unacceptable, level of climate change, translating this into practical guidance for policy makers and quantitative frameworks for industry requires further refinement. The science underpinning climate change demonstrates a close correlation between temperature increase and the cumulative quantity of greenhouse gases emitted over a given period (e.g. 2°C by 2100 correlates with the total emissions released over the 21st century). Although uncertainties still remain in assigning particular cumulative emissions to particular temperatures by a particular time, the scientific understanding is sufficiently robust to provide meaningful global 'carbon budgets'. These in turn, and with agreement on how global emissions should be divided between nations, regions etc., can provide national carbon budgets which governments can subsequently use to inform policies on mitigation. It is these policies that increasingly specify a quantitative framework within which sectors can understand their respective responsibilities for reducing emissions.

In this regard the UK is probably the most advanced nation in setting explicit carbon budgets for specific timeframes. The latest Committee on Climate Change's proposed fourth carbon budget' was accepted by the Prime minister and Secretary of State for Energy and Climate Change on the 17th May 2011, becoming essentially a binding commitment to which the UK Government is required to adhere. However, although this and previous carbon budgets certainly provide an umbrella under which the UK can transition to a low carbon society, they are not in keeping with the Government's explicit commitments for the UK to make its fair contribution to not exceeding the 2°C threshold between dangerous and acceptable climate change (Anderson et al., 2009). Consequently, when quantifying the mitigation levels necessary from different UK sectors it is important to consider their emissions in relation to both the Committee on Climate Change budgets alongside the Government and the international communities (UNFCCC, 2009) 2°C commitments.[1]

2. FROM CARBON BUDGETSE TO SECTORAL MITIGATION

Having quantified the framework for a low carbon transition, it is necessary to consider the role of the different sectors and whether any particular sector/s should be 'discriminated' against so as to give other sectors a less onerous mitigation challenge. This is certainly a contentious domain, where vested interests thrive and independent analysis is rare and difficult to undertake. Without entering the debate in detail here, there are clearly several relatively uncontentious assertions about the issue that help reveal the merits or otherwise of universal versus prioritised sectoral reduction rates. Firstly, no sector has pronounced that it is amenable and prepared to undertake more rapid and deep reductions than other sectors; by contrast many sectors have voiced exactly the opposite concern. Several have gone so far as to express alarm that they, in particular, have been *'picked on'* whilst others are not making their respective contribution.[2] Second, the protectionist outlook of sectors reflects, at least in part, views commonly espoused by individuals, whereby it is typically suggested others need to burden the shoulder of major reductions, or alternatively an *'I'll do my fair share but only when others do theirs'* position is proffered. Thirdly, similar views repeatedly emerge at international climate change negotiations; where disagreements over the fair level of mitigation from 'industrialising' nations continue to delay stronger international agreements.

Consequently, whether at the individual, sectoral or national level the dominant theme is one of self-interest, and it is important that arguments proposed by such groups are considered in that regard. In relation to 'international' emissions, arguments are given by both the aviation and shipping sectors as to why their inherently international domain makes them unsuitable for inclusion in any other than global mitigation schemes. Moreover, each of the sectors argues that it should be subject to less stringent constraints than the other. Aviation because not

[1] Whilst the focus of this paper is on international shipping within a global context, understanding the UK Committee on Climate Change's choice of *international* budgets relative to 2°C is important as it currently represents the only carbon budget (apportioned to a UK level) framework enshrined in substantive national legislation (to be precise the legislation relates to the budget apportioned to the UK). The Committee is currently considering whether or not to include international shipping in its budgets.

[2] For example, aviation in relation to air passenger duty (and their proposed inclusion in the EUETS from 2012); the power sector for its inclusion in the EUETS (why pick on a few big players when the public and consumers aren't forced to change) and car industry in terms of the forthcoming (2012-15) EU fleet-mean emission standards.

only is it a driver of regional and global economies, but that there are no step-change opportunities for a radical transition to low-carbon aviation and no satisfactory low-carbon alternatives to the services it provides. The shipping sector notes that nothing pivotal to modern society would change if aircraft were grounded, but that a cessation in shipping would have immediate, fundamental and adverse repercussions.[3]

Whilst the process of horse-trading between sectors may be an interesting sociological phenomenon, the scale of mitigation necessary affords little scope for other than a radical and urgent reduction in emissions from all sectors. In 2011, with emissions returning to the unprecedented rates experienced prior to the economic downturn[4], the range of 2000-2100 carbon budgets associated with the 2°C threshold is being eroded rapidly, leaving little meaningful scope for finessing levels of emission reductions between sectors. In this regard shipping and aviation are no different to any other sector. If international commitments on 2°C (and those of the UK Government) are to be more than rhetorical, immediate emission reductions are necessary at a rate well beyond any historical precedents.[5] Within this broader description of urgent and radical reductions, the following section offers a quantitative framing of the mitigation challenge for shipping, demonstrating why mitigation needs to be informed more by a step change than an incremental agenda.

3. QUANTIFYING THE MITIGATION CHALLENGE

As discussed **i**n Section 1, allying the 2°C commitments with an accompanying range of 'carbon' budgets permits quantified emission-reduction pathways to be developed at a global level. Against this backdrop alternative suites of absolute emissions reductions from different sectors can be explored and the implications quantified. For the purpose of this paper, the relevant scope relates to those emissions arising from energy use only and principally to carbon dioxide (CO2). Given scientific uncertainties in quantifying twenty-first century cumulative emissions for 2°C remain, shipping emissions need to be compared with a range of 'carbon' budgets. Amongst other factors, the breadth of this range depends on what probability of not exceeding the 2°C threshold is deemed acceptable, assumptions about emissions arising from deforestation and the role of non-CO_2 greenhouse gases. To this end earlier work by Anderson and Bows (Anderson et al., 2008; Anderson et al., 2011) is used here to provide a range of 2°C-related twenty-first century pathways of 'CO_2 from energy' that takes account of deforestation and non-CO_2 greenhouse gases. This work focussed on at atmospheric concentration of 450ppmvCO_2e as an 'acceptable' approximation for 2°C, and used the full range of respective cumulative values included in the Intergovernmental Panel on Climate Change's (IPCC, 2007) Fourth Assessment Report 4 (AR4).[6] Figure 1 is taken from the Anderson and Bows paper, with the increasing area under the different curves reflective of increasing probabilities of exceeding 2°C, and the two sets of curves representing the different peak-emission years of 2015 and 2020. Whilst the former date was that used in the high-profile low-carbon scenarios of the Stern report (Stern, 2006), Anderson and Bows considered the latter to be more reasonable, though nevertheless still extremely challenging. It is also worth noting that the later the peak year the higher is the probability of exceeding the 2°C threshold.[7]

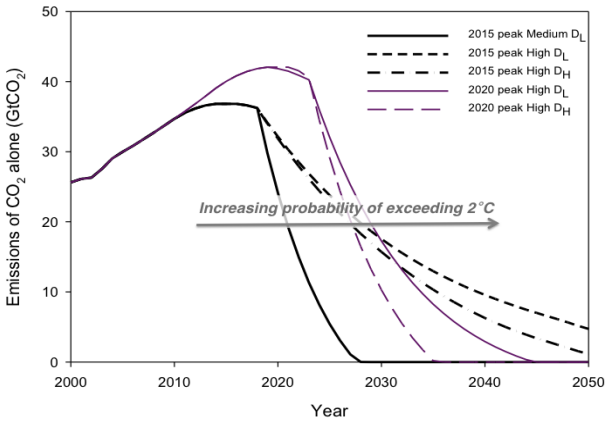


Figure 1: CO_2 emission budgets for energy and process emissions for a range of approximately 33% to 66% chance of exceeding 2°C with emissions peaking around 2015 and 2020. (Derived from Anderson and Bows 2008 and based on cumulative values from IPCC AR4)

Having established quantitative global pathways for emissions from energy and building on the discussion in Section 2 (i.e. the burden of mitigation is distributed evenly amongst sectors), it is possible to make some early comments as to the scale of the mitigation challenge for all sectors. However, before proceeding to give an envelope of emission reduction rates and timeframes it is necessary to weaken the resolve embedded in the

[3] These are views expressed repeatedly at industry stakeholder events and meetings (for aviation and shipping) organised and run as part of Tyndall Manchester's research programme into international emissions (2005 onwards) (Gilbert et al., 2010).
[4] (Friedlingstein et al., 2010)
[5] See for example (Clarke et al., 2009)

[6] The values captured in Fig 1 (taken from Anderson and Bows (2008)) considered initially the full range of IPCC cumulative values, subsequently reducing these in accordance with a suite of 'acceptable' criteria; e.g. growth rates to peak, peaking dates, post-peak reduction rates, amongst others. See their paper for more detail on the assumptions underpinning the curves.
[7] Unless extremely high reduction rates are adopted

Copenhagen Accord and EU and UK commitments on climate change.

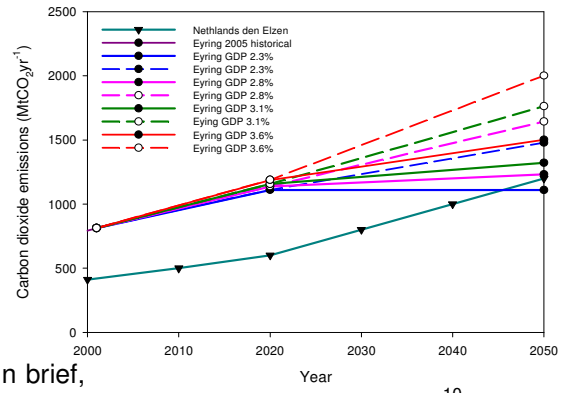
The language of such commitments make it clear that, *"consistent with the science"* the *"necessary domestic measures"* must be adopted to ensure "*global temperatures must rise no more than 2℃"*.[8] In 2011 and with emissions rising at unprecedented rates no such assurance is any longer possible[9] and relatively high probabilities of exceeding 2℃ must now be accepted. The level of 'acceptable' default on the 2℃ commitments has significant implications for the scale of reductions necessary. If a 30-40% chance of exceeding 2℃ is deemed appropriate and if global emissions from energy peak in 2015, then absolute reductions in excess of 20% p.a. are necessary. For the same peak year, but reneging further on the 2℃ commitment to around a 50-60% chance of it being breached, then emission reductions fall to around 6% p.a. Given the proximity of 2015, a later peaking date is worth considering, but this is not without significant penalties. Firstly, a 2020 peak is not compatible with a 30-40% chance of exceeding the 2℃ commitment; and secondly, even for a 50-60% chance of breaching 2℃ the reduction rates of energy-related emissions are in excess of 20% p.a.

Evidently, the implications of even a weakened commitment to 2℃ (i.e. a larger carbon budget) have profound implications for all energy-related sectors and adaptation. It is for this reason that differentiating sectoral responsibilities for meeting the 2℃ commitment risks distracting sectors from the radical reduction in emissions necessary now.

4. FRAMING 'MEANINGFUL' MITIGAITON FROM THE SHIPPING SECTOR

If the shipping sector is to meet the climate challenges of the twenty-first century and if the associated research community are to make full value of their analysis, carbon reduction technologies, practices and polices need to be considered alongside a probabilistic interpretation of Global, EU and UK commitments on 2℃. Specifically, and summarising the earlier analysis, a scientifically robust basis for decisions within the sector requires it to acknowledge explicitly what position on climate change it uses to inform its policies and practices.

Figure 2: Scenarios of future emissions from international shipping from named sources



In brief, Section 3 outlined four broad options[10] from which a responsible shipping sector needs to choose if it is to claim any scientific legitimacy to it position on climate change:

1) A ~30-40% chance of exceeding the 2℃ threshold is the best that now can be achieved. This correlates with total emissions from international shipping peaking in ~2015 and reducing subsequently at over 20% p.a.
2) A ~50-60% chance of exceeding the 2℃ threshold is the best that can now be achieved. This correlates with total emissions from international shipping peaking either in ~2015 with a subsequent reduction of 6-10% p.a. or peaking in ~2020 with a subsequent reductions of >20% p.a.
3) The shipping industry rejects the 2℃ premise of the Copenhagen Accord, along with EU and UK statements on the importance of 2℃. Arguing instead, that the global repercussions of a 2℃ future are less severe than the global impacts of the shipping industry reducing emissions in line with a reasonable probability of avoiding 2℃.
4) The shipping sector has no specific interest in climate change. It will argue for the best outcome for its own industry in the development of any emission-related regulations or pricing mechanisms. The sector will ultimately abide by whatever legislation comes into force, whether regulatory or economic. Moreover, it will make no claims to be a responsible industry with regards to climate change, other than abiding by minimum level standards.

Once a position on climate change is clarified, the accompanying scale of emission reduction (from Fig. 1) can be compared with emission scenarios

[8] The three quotes are taken from the Copenhagen Accord, EU and UK Government respectively.
[9] Arguably, such categorical assurance has not been justifiable for many years if not several decades, at least if it was to be *"consistent with the science"*.

[10] These are not intended to be precise and necessarily definitive, but they do capture broadly the envelope of frameworks dictated by the probabilistic interpretation of 2℃ outlined in this paper. In practice Section 3 was only explicit about the first three options, with option four included for completeness and to provide an opportunity to have minimum engagement in climate change.

for shipping. Based principally on Eyring's analysis (Eyring et al., 2005b) Figure 2 illustrates a range of shipping emissions linked to global economic (GDP) growth, but assuming ongoing reductions in carbon dioxide emissions per mean freight-tonne-km shipped. Figure 3 superimposes the emission enveloped of the shipping scenarios detailed in Figure 2 onto the probabilistic emission pathways for 2°C outlined in Figure 1.

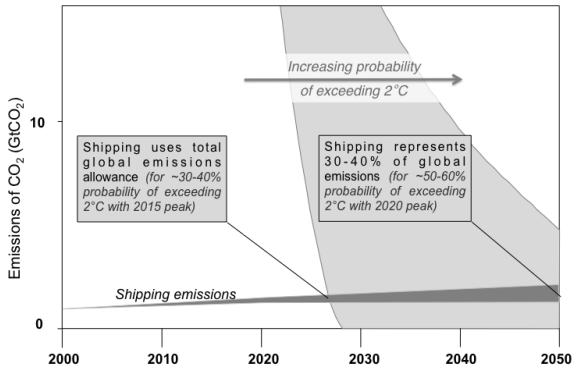


Figure 3: Scenarios of shipping emissions (from Fig. 2) superimposed on global CO_2 budgets for a range of approximately 33% to 66%[11] chance of exceeding 2°C (from Fig. 1).

5. CONCLUSION

The language of *'combating climate change'* and making a *'transition to low-carbon technologies'* is increasingly evoked across all sectors, including shipping. However, seldom is the scale of emissions-reductions quantified in relation to national commitments and international obligations on climate change. Consequently, sectoral emissions are typically guided by vague responses rather than scientifically-informed quantification of the scale and timeframe of emission reductions. Building on international, EU and UK commitments to *"adopt the necessary domestic measures… to ensure temperature increases do not exceed 2°C"*, this paper makes clear the scale of the challenge for the shipping sector. The challenge is such that if commitments on 2°C are to have any meaningful currency all sectors are faced with developing suites of polices to initiate urgent and radical reductions well beyond those typically countenanced. Consequently, whilst mitigation is undoubtedly easier for some sectors than others, in practice even a weakened 2°C commitment demands such stringent cuts that negotiating priorities *between* sectors offers no real benefit and risks further delaying action. Given this and if the shipping sector is to make its fair contribution to not exceeding the 2°C threshold, it needs to develop a strategic vision of its future where relatively orthodox approaches delivering incremental reductions will not be adequate.

[11] The probability range in the Figure captures the majority of estimates derived from Meinshausen's PRIMAP tool; the 66% upper end in the text includes the outlier probabilities.

The quantitative framing of meaningful mitigation for shipping (and other sectors) is stark. If the shipping industry's global emissions can peak by around 2015 and if it adopts a strategic view based on a greater than 50% chance of exceeding 2°C, then it needs to deliver emissions reductions of between 6 and 10% p.a. If, however, the proximity of 2015 as a peaking date is considered untenable, combining a 2020 peak date with the same 50% chance of exceeding 2°C pushes the reduction rates post 2020 well beyond 20% p.a.

Under both of these peaks factoring a growth in freight carried (as embedded in Eyring's scenarios) increases further the *relative* reduction rate. A responsible industry and an appropriate policy regime may push incremental improvements to between 2% and 4% p.a. for two or more decades. However, with a growth in freight-tonne-kms of 2% to 4% p.a. such *efficiency* improvements would likely deliver no *absolute* reduction.

Whichever way the numbers are interpreted, a shipping sector serious about developing a scientifically informed and evidence-based strategy on climate change is unavoidably faced with extremely challenging decisions. The failure of the global community to even curtail the rate growth in emissions over the past two decades allied with current unprecedented emission growth of between 3% and 4% p.a., has put the 2°C threshold at serious jeopardy. Moreover, the relatively high probabilities of exceeding 2°C on which the analysis in this paper is premised, leave a 3°C future a real possibility, even if early peaking and rapid reduction rates can be achieved. If they cannot, previous work suggests there is a serious risk of global mean temperatures reaching 4°C during the later half of the century (* ref Betts, New, Liverman, A&B 1&2 etc). To put this in perspective, climate scientists at the UK's Hadley Centre (Betts et al., 2011) are suggesting that even emission trends lower than present could deliver a global mean surface temperature increase of 4°C as early as around 2060. Such a global rise corresponds with radical regional increases of, for example: a 6°C to 8°C increase in the hottest days in China, 8°C to 10°C in Central Europe and 10°C to12°C in New York. At lower latitudes outputs of staple foods such as maze and rice could reduce by between 30% and 40% (DECC, 2011) at the same time as the world population is on track for around 9 billion by 2050.

Undoubtedly for the shipping and all other sectors the future will be radically different from the past – either in delivering draconian levels of mitigation or in adapting to extreme climatic change – and probably both. However, whilst such an austere future is, to a significant degree, unavoidable, demonstrating leadership and applying ingenuity now could pay medium-to-long term dividends in

making an early transition to a low-carbon and climate resilient society. Delivering incremental improvements in technologies and operational practice needs to be driven hard; at the same time considerable resources need directing towards research, demonstration and delivery of step-change technologies and practices. These will take longer to deliver but the scales of mitigation required in the medium to long-term outlined in this paper cannot be achieved without them. In the meantime and counter to the *raison d'être* of all sectors, demand management is essential if action to to avoid a 2℃ or 3℃ future is be more than empty rhetoric.

It is against this sombre context that the shipping industry and the associated research community must consider its response. To tackle the unparalleled challenges posed by climate change head on, or to shy away from the science and continue business as usual until forced to change by circumstances and legislation – to lead or to be led?

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