UCL ENERGY INSTITUTE

CO_2 emission targets for shipping

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Full Report - Prepared for Sustainable Shipping Initiative

September 2015

CONTENTS

1 Background

The IMO is currently following a three-step plan towards the implementation of further GHG emission regulation:

1. Develop a system for data collection on individual ship's fuel consumption, emissions and efficiency (e.g. MRV)
2. Agree and pilot a regulation containing further technical and operational measures for emission reduction
3. Roll out the refined regulation across all ships.

These three steps are being pursued with no attention to the 'goal' or 'target' that the industry is hoping to achieve as an outcome (e.g. relative or absolute emission reductions or the level or stringency that might be required). The consequence is both a lack of urgency and a lack of focus to the discussions – it is hard to develop a data collection system if the purpose and ambition of the measures is not clear.

This IMO activity can be contrasted with the UNFCCC process, which has agreed on numerous occasions to limit global mean temperature rise to no greater than 2°C. This sets a clear expectation that globally there will be a complete transition away from fossil fuel by sometime between 2050-2100, and that all sectors will be expected to undertake a 'fair share' of decarbonisation consistent with a series of sectoral carbon budgets.

At IMO MEPC 68 the Marshall Islands (the third largest registry) made a call for the MEPC to debate a timeline for the development of a target. Whilst many member states gave support in principle, this call was rejected by a plenary apparently obsessed by procedure and the aforementioned three-step plan. The call for a target will be revisited at an "appropriate time", which could be as soon as MEPC 69 or 70, depending on the outcome of the Paris UNFCCC talks.

International shipping needs global regulatory solutions and IMO is the only body with this mandate. However climate change mitigation is a zero-sum game. There is a finite amount of CO_2 that can be emitted and every sector is expected to contribute. Therefore, the continued procrastination at IMO on the subject of GHG is the biggest risk to the future of the shipping industry and world trade – delaying implementation of regulation only increases the rate at which the industry will need to change. An industry experiencing a high rate of change will see more disruption, more bankruptcy and larger negative impacts on the demand that it services, than an industry undertaking a more gradual transition. Its therefore crucial that progressive voices in the industry produce both a ground-swell of support for a target, and also the evidence base that the industry is prepared for the challenge that an ambitious target implies.

This paper follows on from Smith et al. (2015), a paper presented at IMO MEPC 68 as a first framing of the concept of a target for shipping. This paper uses that paper's findings to set a series of interview questions that are put to a number of SSI members. The answers to those questions are then used to produce a number of further scenarios for the future of international shipping. The interviews and the model results are then used to discuss the challenge ahead for shipping.

1.1 Objectives of this study

- Understanding what a target means for SSI members
- Understanding the implications of a target for SSI members
- Explore modelling parameters with SSI members
- Supporting the establishment of a target for SSI members

2 Deriving CO_2 budgets and a target for shipping

The Third IMO GHG Study 2014 provides both an estimate of present GHG emissions from shipping (during the period 2007-12) and a range of projections for future emissions from shipping (2012-2050). Of all the GHG emissions produced by shipping, CO_2 was found to be by far the most significant GHG and for this reason is the focus of this paper.

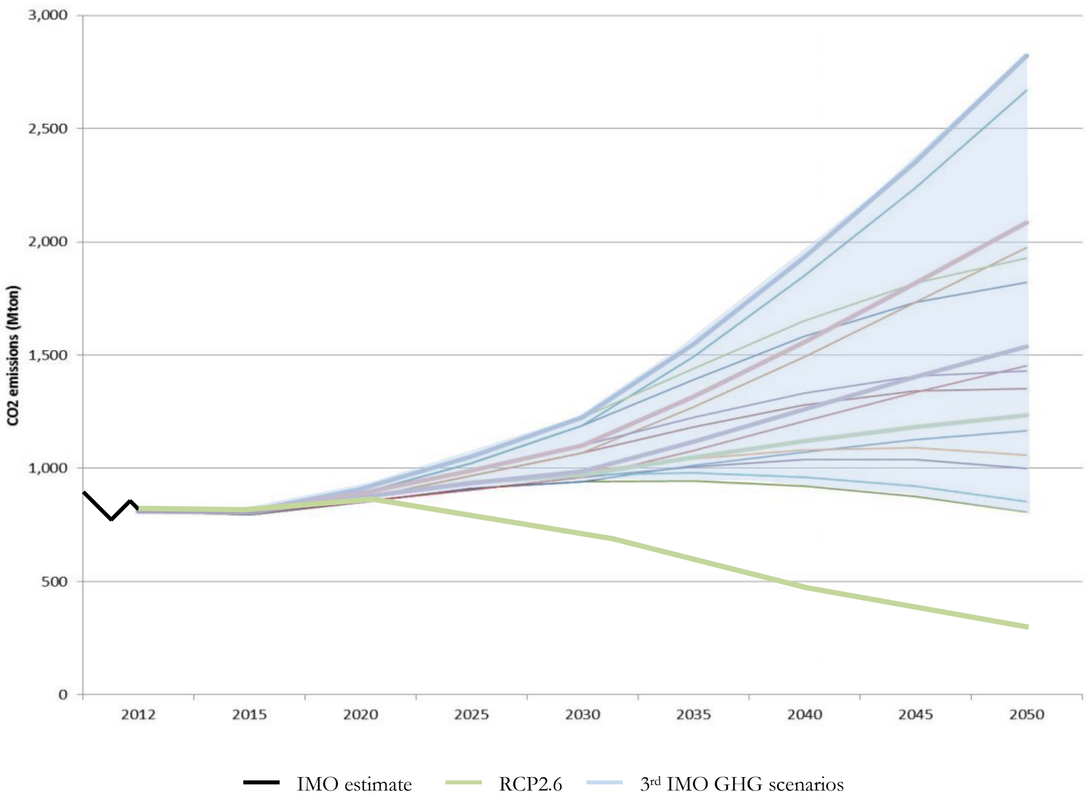

Figure 1: Scenarios for CO_2 emissions trajectories.

Figure 1 contains three pieces of information:

1. The estimate from the Third IMO GHG study 2014 of CO_2 emissions from international shipping during the period 2007-12
2. The future scenarios of international shipping CO_2 emissions, calculated in the Third IMO GHG Study 2014
3. The central CO_2 emissions pathway consistent with a 2°C stabilisation, as calculated in the IPCC AR5 (RCP 2.6), indexed to the CO_2 emissions of the shipping industry in 2012.

The key message from Figure 1 is the contrast between point 2. and 3. All the future scenarios estimated for shipping under current IMO policy anticipate rising emissions, with at best stabilisation of emissions by 2012. Conversely the RCP 2.6 pathway describes a peak of emissions in 2020, followed by a 50% reduction of 2012 emissions by 2050. This specific contrast was first highlighted in Bows-Larkin (2015) and sets the main justification for why both further policy and a clear target CO_2 trajectory are needed for shipping to transition and assist all other sectors in mitigating the risk of dangerous climate change.

To consider what a target or budget might look like for shipping, first a target for all anthropogenic CO_2 emissions must be defined. From this, some 'fair share' of the budget for shipping can then be allocated. Similar to the derivation in Smith et al. (2015), this paper uses the climate model MAGICC (Meinshausen et al. 2011 a&b) to calculate the climate's temperature response to emissions scenarios over the 21st century. In the 2°C reference scenario, which has a 50% chance of staying below 2°C of global warming, cumulative CO_2 emissions over the period 2011 to 2100 are estimated to be 1428GtCO_2.

The Third IMO GHG Study 2014 estimates CO_2 emissions from 2007 to 2012, amounting to 2.33% of global CO_2 emissions over that period. Extending this percentage into a future 2°C scenario, this results in an initial estimate of a shipping CO_2 budget of 33Gt over the time period from 2011-2100.

2.1 CO2 and EEOI trajectories

Consistent with a shipping CO_2 budget of 33Gt, Figure 2 highlights three interacting trajectories for the three ship types focused on in Smith et al. (2015): the demand trajectories, the fleet's CO_2 trajectories and the required operational CO_2 intensity (EEOI) trajectories that satisfy the combination of the demand trajectory and the CO_2 trajectory. The EEOI is presented as the required aggregate average EEOI inclusive of all sizes of ship within the ship type at a given point in time (including both the newbuild ships and the existing fleet). This allows for there to be a range of efficiencies of individual ships, varying according to the ship's age, size and specific design and operational specifications.

The EEOI and CO_2 trajectories are calculated through an accountancy process by assuming that:

- Demand is exogenous, that is to say there is no feedback between the level of decarbonisation, or change in operational CO_2 intensity, and demand
- From 2020, each ship type undertakes similar percentage improvements in operational CO_2 intensity over the period out to 2050.
- The aggregate CO_2 trajectory of all three ship types is set to meet the their share of the total budget for international shipping.
- That the share of international shipping's emissions associated with containerized, dry bulk and wet bulk (tanker) shipping remains constant between 2012 and 2050 at 62% of international shipping's CO_2 emissions.

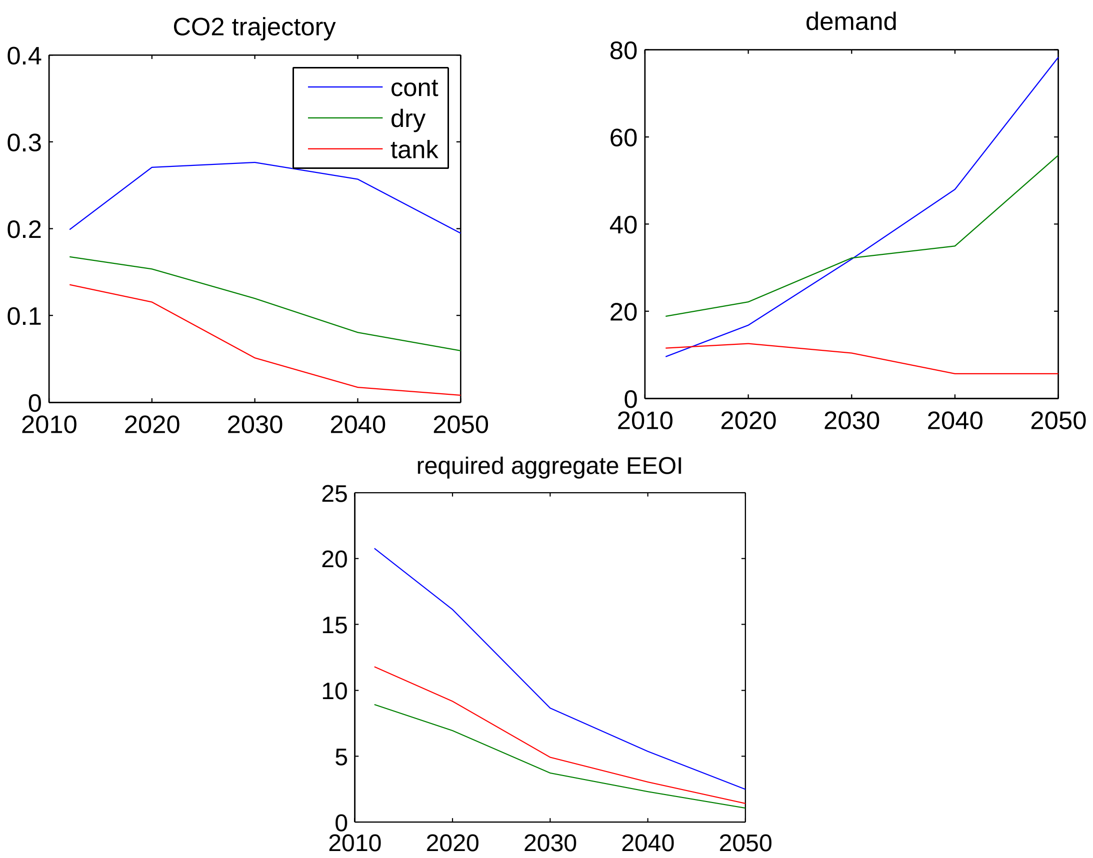

Figure 2: CO_2 trajectory, demand and required aggregate EEOI consistent with a 2.33% share of total CO_2 and a 2 degree stabilisation pathway

3 Exploring sensitivities to the trajectories for shipping

3.1 Interviews with members of the SSI

Interviews with seven SSI members (five shipowner/operators and two technology providers) were undertaken in order to explore the subject in greater detail and to reflect their views/opinion on various modelling parameters discussed above.

3.1.1 Members understanding of the subject

Most of the members interviewed had a good understanding of the subject after reading the MEPC 68 report (Smith et al. 2015). They understood the difference between targets based on cumulative budgets under a 2°C scenario compared to targets based on achieving a reduction at a set point in time. All of the respondents highlighted that this was a new way of looking at the GHG issue and two respondents suggested that this approach was the more realistic and correct way of approaching the subject. One member did not agree that CO_2 targets should be based on cumulative budgets.

3.1.2 Proportionate emission reductions for shipping

One of the key assumptions of the modelling based on cumulative CO_2 budgets is that regarding the future share of emissions from shipping. Given that all other sectors will continue to decarbonise (under national inventories) as a result of 1.5°C or 2°C commitments, shipping and aviation as two international sectors will see an increase in their relative share of global CO_2 emissions if emissions continue to rise under the business as usual scenario.

The consequence of maintaining 2-3% share of global CO_2 emissions and with increasing demand outlook, is that steep supply side reductions in CO_2 intensity are required as shown in Figure 2. The members unanimously agreed that this was an extremely ambitious target. The SSI members had mixed suggestions on the share of CO_2 emissions from shipping, one questioned whether 2-3% current share is the correct level, not in terms of accountancy but in terms of benefit to society. Most respondents believed that shipping should continue to maintain its share of 2-3% but couldn't figure out how that would be achieved and therefore expected the share to increase in the future. Only one member suggested that within their company they would like to and are planning for reductions that are similar to that required under the 1.5°C scenario.

3.1.3 Design or technical measures that can lead to reductions required under the 2°C target

The members were asked what design and technological measures they thought would enable the transition towards the lower CO_2 intensity by 2050.

Most members suggested that switching from HFO would be required to meet the stringent target. Three members suggested switching to LNG would be part of the mix, as the technology is relatively mature and can lead to around 25% reduction in CO_2 emissions. All members suggested that switching to other energy sources e.g. bio derived fuels, renewable sources e.g. wind and solar, and hydrogen were not possible in the near future due to several challenges e.g. supply (volumes), infrastructure, safety, reliability etc.

All members also suggested that around 5-25% reduction can be achieved from other technological measures such as energy saving devices (ESD's), change in hull forms, low friction paints, engine modifications etc. One member suggested that in the first few years there is higher potential to reduce CO_2 intensity with known technologies i.e. at a faster rate. In the future it may be more difficult to decarbonise or reduce the CO_2 intensity at the same rate.

The key point raised by most members was that their view of the technical measures is on the basis of commercial and economic viability i.e. cost-effectiveness of the measures as well as the risk involved. One member suggested that the gap between commercially viable technologies and lower TRL (Technology Readiness Level) emerging technologies e.g. renewable energy sources (including wind technologies), or alternative fuels such as hydrogen, which may be required to achieve the high reduction target is significant and a quantum leap is necessary. The member also pointed out the lack of reliability in testing measures or 'trialability' of measures. A solution suggested by the same member to overcome this barrier or risk was to collectively test technologies but the disadvantage will be that competitive advantage may no longer be there. Given the above views of the members a maximum achievable potential from design and technical measures would be around 50% reduction in the CO_2 intensity of ships.

3.1.4 Operational measures can lead to reductions required under the 2°C target

All members suggested that speed reduction or slow steaming is the key operational measure for reducing emissions during operations but were concerned regarding it's future potential due to changing market conditions, and increasing transport supply. The members thought that mandating slow steaming would be difficult. One member suggested mandating operations through indices and evaluating their stringency. Other measures mentioned were route/network optimisation, cargo efficiency (requiring a rethink in the transportation of high volume products e.g. cars), tackling port congestion and virtual arrival.

3.1.5 Purchasing of CO_2 offsets from other sectors

By this stage of the interview it was clear that there was a disconnect between the 2°C scenario and what was felt to be technically and operationally feasible. Members presented mixed opinions on the issue of being able to offset the shipping industry's emissions from other sectors. Five members agreed as this is the only way to reduce emissions and two members disagreed, for different reasons. Those who recognised the need for purchasing of CO_2 offsets were of the opinion that it would be too costly for shipping to reduce its emissions compared to other sectors in light of the challenge, one member suggested land based sectors have better options for CO_2 abatement, and that there was a need to price carbon externalities for which the final consumer should pay. The members who were of the opinion that shipping should not buy offsets from other sectors suggested that this was in order to maintain the credibility of the sector (i.e. achieve target using shipping's own resources) and to avoid shipping being treated as a 'cash cow'.

3.1.6 Differentiated targets for the shipping sectors

Given the different demand growth forecasts for drybulk, wetbulk and containers coupled with difference in CO_2 intensities of the different ship types, the respondents were asked whether they thought that this should merit a disaggregated approach for CO_2 reductions i.e. individual targets for individual ship types/sectors. There were mixed responses, three members suggested all ship types should have similar reduction targets and two suggested differentiated targets for each ship type.

Those who suggested a differentiated or independent approach recognised that there were more opportunities in container than wetbulk/drybulk due to supply side efficiencies e.g. speed reductions and demand side pressure e.g. container demand growth. Some members suggested that this should be according to the share of emissions of the sectors (driven by demand scenario), using the same methodology applied to the whole sector e.g. 2-3% assumption.

The reason for keeping the reduction targets similar was because of the difficulty in justifying targets based on future projections. The members who favoured a collective target also gave example of the Energy Efficiency Design Index (EEDI), which is a semi-differentiated approach i.e. similar relative targets but different absolute reductions.

3.1.7 Consequences of the target on demand for shipping

The members identified various future trends that will impact the demand for shipping, some as a direct result of the target. The 3D printing technology was mentioned by several members and the changing landscape of production/manufacturing and consumption patterns, local production and consumption. One member questioned the rebound effect of a neutral/low CO_2 shipping on international trade. One member suggested that their sector will see 80% increase in demand by 2020 on 2007 levels but was trying to decouple this with emissions growth.

3.1.8 Tackling contentions of a target at the IMO

All members acknowledged the slow progress of IMO on the matter of CO_2 emissions due to the political nature of the organisation. The members suggested different ways of overcoming the contentions that could arise when the targets are raised again at a future date in MEPC. One member suggested that to get an agreement initially one would have to lower the target to make it practical or technically feasible and review this at a later date, following the precedent of EEDI regulations. On the subject of precedent of EEDI regulations, two members also suggested including impacts/cost burden on developing nations and technology transfer. One member suggested that EU has been effective at applying pressure on the IMO to react to the subject of GHG emissions and perhaps this work needs to be presented to EU DG Clima. Similarly, to apply more pressure at the IMO another member suggested more scientific routes (e.g. IMarEST & RINA) should be used to publicise and educate the shipping and wider stakeholders. The science behind the modelling should also be looked into in greater detail and presented more openly e.g. the MAGICC model used in the MEPC 68 report should be validated with other climate models perhaps developed at foreign institutions.

3.1.9 Consequence of starting later than 2020

Given the impasse at the IMO it is likely that discussion on targets will be delayed. This will have a direct consequence on the CO_2 trajectory for shipping and will require steeper and even more stringent reduction targets. Four members suggested that the discussion at the IMO should start as soon as possible although acknowledged that this is not realistic. One member suggested that the IMO could pursue a similar approach to NOx regulations i.e. pre-empt tougher regulations.

3.1.10 Support for a 2°C target under the SSI

Five members were supportive for the SSI to advocate a 2°C target (in principle) and two members did not have management approval to support the target (due to short time frame from initial contact and interview).

3.1.11 Remaining on course for a 2°C target

The members who were supportive of the target were asked what they would do or are currently doing within their organisations to remain on course for a 2°C target. All members except one suggested that much of their efforts are based around incremental changes not step changes. The measures being looked at are new design concepts (e.g. minimum ballast), LNG as a fuel, economies of scale, energy saving devices, slow steaming. One member suggested if they were inclined to commit to a 2°C target they would increase testing of more innovative technologies and take the risk of trialing these technologies. Only one member suggested that their organisation was seeking to achieve 50% EEOI reductions by 2020 and had an aspirational target of net zero environmental impact in the future.

3.1.12 Conclusions for modelling

- CO_2 emissions share – all members believed shipping should continue to maintain its share of 2-3% but couldn't figure out how that would be achieved and therefore expected the share to increase. Modelling: Model 2-3%, & 4-5%
- CO_2 offsets – mixed responses. 5 agreed as this is the only way to reduce emissions. 2 disagreed.
- Start date – Four members agreed this needs to start as soon as possible although realistically will be post 2020. Three members abstained from commenting. Modelling: 2020, 2030.

3.2 Further modelling

Using the findings from the interviews (summarised in Section 3.1.12), a number of scenarios further to those shown in Section 2.1 were then modelled. In total, six scenarios were modelled, and all scenarios were aligned to a global carbon budget consistent with a 2°C stabilisation by 2100.

3.3 Defining the demand and CO_2 trajectories

Following the suggestion by SSI members that demand might not grow as fast as it was estimated in the Third IMO GHG Study, two sets of demand scenarios were considered:

- A baseline scenario D1, as defined in the Third IMO GHG study BAU consistent with a 2°C stabilisation
- A low scenario D2, defined by applying a 50% reduction in D1 by 2050 (applied linearly from 2015), to represent a shift to local production and local consumption.

The justification to apply a 50% reduction by 2050 is not rigorously derived (unlike the logic behind the D1 scenario, which is consistent with IPCC AR5 SSP4 economic growth, wider economy decarbonisation and commodity trade scenarios). However, it can help by providing an understanding of the sensitivity to the required EEOI targets in response to large variations in demand. The two sets of demand scenarios, both indexed to 2012 demand (t.nm) are shown in Figure 3.

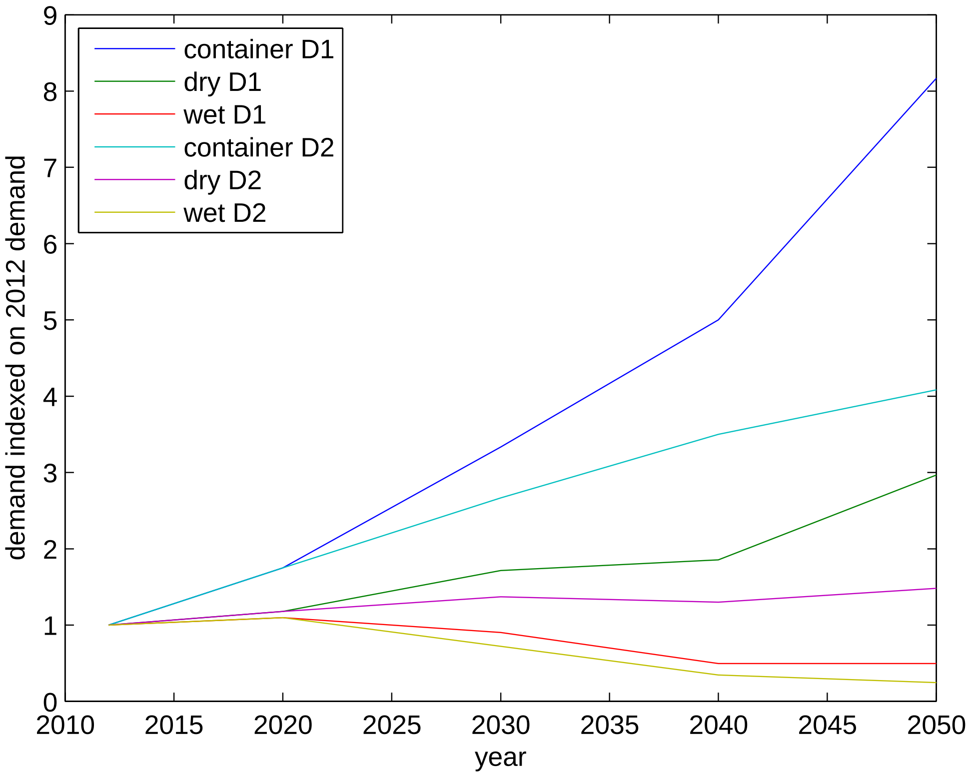

Figure 3: Demand scenarios D1 and D2 for container shipping, wet bulk and dry bulk

Taking the input from the SSI members, and as a share of the 2°C stabilisation global carbon budget, shipping's carbon budget was defined by two scenarios:

- Remain constant at approximately 2.3% of total CO_2 emissions
- Double its share to approximately 4.6% of total CO_2 emissions

Shipping's emissions trajectory was calculated, according to the input from SSI members, to peak either in 2020 or 2030. These two years for peak emissions approximating the year that IMO regulation enters into force in order to reduce emissions.

In accordance with the majority view, the overall reduction target was shared equally between ship types.

Although a majority did think that offsetting could be a useful way to bridge the gap between a target and current technologies, no carbon offsetting was applied to any of the scenarios - the assumption was that all CO_2 reductions were achieved 'in sector'.

Figure 4 presents the results from these assumptions as a family of CO_2 emissions trajectories.

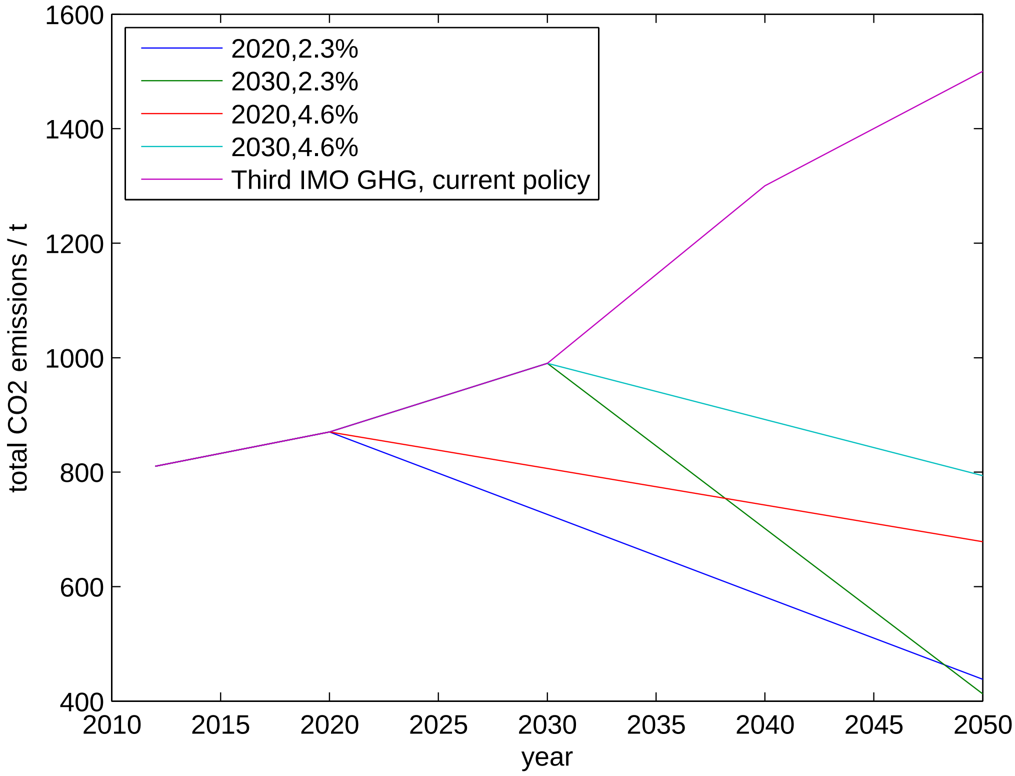

Figure 4: CO_2 emissions trajectories for the 4 scenarios used and contrasted against the Third IMO GHG Study current policy scenario consistent with RCP 2.6 and SSP4

3.4 Required EEOI trajectories

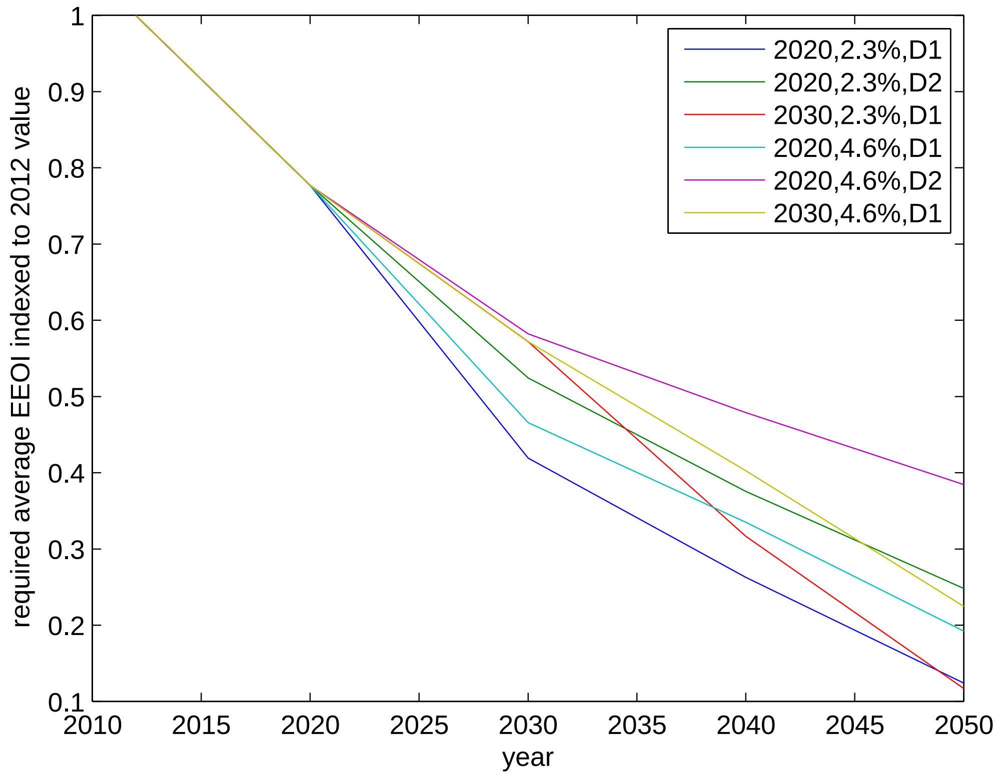

Figure 5: Indexed EEOI trajectories for each of the six scenarios considered

The calculated required EEOI trajectories are presented in Figure 5 for each of the six combinations of demand and CO_2 trajectory defined in Figure 3 and Figure 4. The results show the required EEOI trajectories that are consistent with those scenarios, in this case averaged across all ship types and indexed to the 2012 EEOI. These results, in combination with the CO_2 trajectories in Figure 4 show that:

- In both demand cases D1 and D2, delaying the peak of shipping's emissions causes a steeper gradient in the eventual, post-peak, rate of decarbonisation required
- If shipping's emissions are retained at their current 2.3% share of total emissions, regardless of the peak-year, shipping's emissions will need to approximately halve (on 2012 levels) by 2050
- If shipping's share of emissions is allowed to increase (e.g. to 4.6%) then shipping requires approximately carbon-neutral growth (e.g. no increase in emissions relative to 2012 levels) over the next 40 years, followed by reductions in emissions.
- In the most unambitious scenario (low demand, increase in shipping's share of emissions), shipping's average EEOI will need to reduce by 60% by 2050, or in the most ambitious scenario (BAU demand and shipping's share of emissions held constant), shipping's average EEOI will need to reduce by 85% by 2050.
- In all scenarios, substantial improvements in EEOI are required by 2030 – between 40% and 60% reduction depending on the specifics of the scenario (failure to achieve such rates will make the decarbonisation target for 2030-2050 only more onerous).

Under the assumption that all sectors take a similar EEOI reduction pathway (e.g. no ship type is expected to undergo more stringent CO_2 intensity reduction than any other ship type), the trajectories for each ship type's required EEOI trajectory, presented in Figure 6, are similar but varying in magnitude.

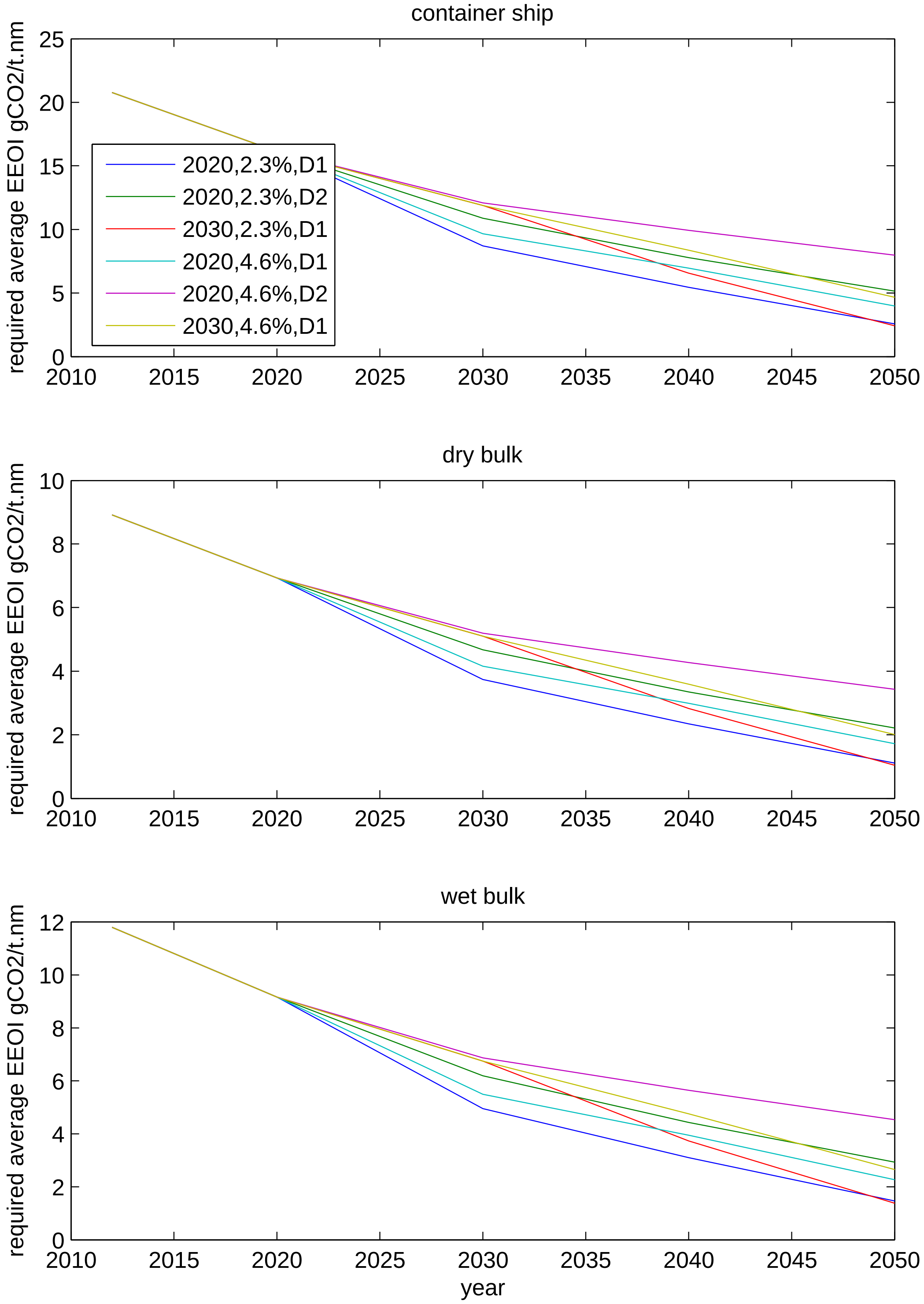

Figure 6: Ship type specific EEOI scenarios

Another way of visualising the EEOI reduction target is relative to the range of EEOI's achieved by the existing fleet. In practice EEOI varies between ship size categories (economies of scale mean that on average larger ships achieve lower EEOIs), and also within ship size categories (varying as a function of the technical and operational specifics of each ship). Figure 7 presents the 2.3% share, demand scenario D1 2050 required average EEOI in contrast to the range of EEOI's achieved by the dry bulk fleet in

2012. The 2050 required average EEOI is a line at EEOI = 1.25 gCO_2/t.nm, and is significantly below the best EEOI's achieved across the size range. This indicates that the reduction target cannot be achieved by increase in ship size alone, it will require further technical and operational measures.

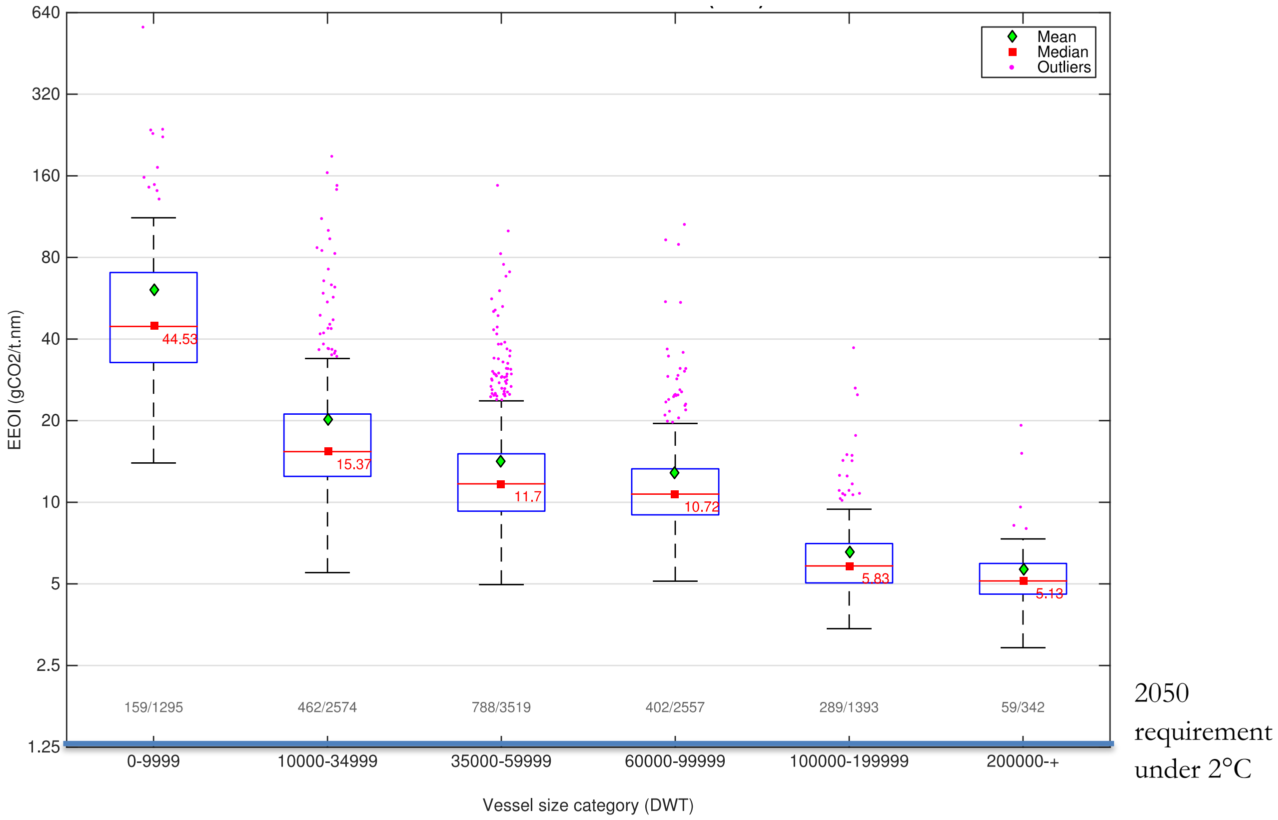

Figure 7: EEOI for dry bulk carriers, data from Third IMO GHG Study and follow-up MEPC 68 Inf. 24 (Smith et al. 2015b)

3.5 Carbon offsetting

In all of this work, the assumption has been made that the CO_2 emission reduction is achieved 'in sector'. That is to say that there is no purchasing of offsets from other sectors. If offsetting were enabled, then the emissions from ships would require a less stringent rate of decarbonisation than those described in Figure 4, with a consequent lower stringency in the required EEOI trajectory.

For offsetting to work, two conditions are required:

- There must be another sector with better CO_2 mitigation cost-benefit than shipping (e.g. the cost of mitigating 1 tonne of CO_2 in another sector must be less than the cost of mitigating 1 tonne of CO_2 from shipping).
- There must be mechanisms that allow for multi-sector carbon trading and offsetting.

Furthermore, the shipping industry must be comfortable with the concept of capital flowing from shipping decarbonisation and into another sector's decarbonisation. At present, there is significant resistance to the perception of shipping being used as a 'cash cow' and this was referred to by SSI members. There is also no substantial evidence that CO_2 emissions mitigation would not, at least initially, be more cost-effective for shipping than any other sector, nor are there presently any mechanisms to enable offsetting. For all these reasons, offsetting was not included for now, although it deserves further consideration and remains the subject of ongoing work in the Shipping in Changing Climates research project.

4 Concluding remarks

- A major challenge lies ahead for the global shipping industry: historical trends of rising GHG emissions need to be halted imminently and then reversed. Postponing this action makes matters worse for the industry in the long-run, and increases the potential for catastrophic impacts on world trade.
- This study demonstrates the disconnect that exists between the present day stakeholder attitudes, and that challenge. Even in the most moderate scenario, carbon intensity reduction of shipping far exceeding magnitudes envisioned 'commercially viable' by the members are shown in the modelling to be required.
- Some relief from the magnitude of the challenge can be found from arguing to increase shipping's share of total GHG or purchasing GHG offsets from other sectors, but neither change the need for a fundamental change and transition in the industry away from its current fossil-fuel dependency.
- The industry can minimise the risk of any damage that this inevitable transition will cause by:
    - Pooling knowledge and sharing expertise and data on the size of the challenge and the range of foreseeable transitions
    - Setting and committing to a clear, credible and 2°C compatible target for the future trajectory of shipping GHG, and gaining widespread industry and regulatory buy-in to that target
    - Identifying the combination of public regulation and private standards that can create a level-playing field and stable commercial environment to enable the development of technology and operational practice that will be needed for the transition.

4.1 Further work

This paper has provided a simple and transparent analysis of a number of different future scenarios for shipping. The carbon budgets and the required EEOI trajectories demonstrate the scale of the challenge ahead but they do not reveal the roadmap of technologies and operational change that will be required for shipping to transition. Concerns expressed by SSI members about the magnitude of emission reductions that can be achieved using known and 'commercially viable' technologies highlight that there is still a fear that a target might lock the shipping industry into additional cost or even a technologically impossible goal.

To elaborate further on the next steps identified above, both further analysis and further dialogue are needed, a description of some of these steps is given in Figure 8. Some of this can be conducted within the shipping industry e.g.:

- Understand the range of technologies and operational steps that could achieve the different foreseeable EEOI trajectories,
- Understand the consequences of adoption of those technology and operational steps on the industry (e.g. how might they affect transport cost, how changes in transport cost might in due course affect transport demand)
- Understand the consequences of change on the market dynamics of the industry (e.g. the consequences for small and large companies, the risks of volatility and stranded assets or asset lock-in)

- Understand the policies that might be technically and politically feasible (e.g. both the type of measure (tax, levy, efficiency standard, and the features of that measure such as in-sector vs. out of sector emission reduction)

Other further work might be necessary to be undertaken in combination with other sectors:

- Understand how both policy and mitigation costs and benefits relate to other sectors, and therefore the appropriateness of shipping's CO_2 target

This long list of further work should not be seen as an excuse to delay the definition of a target – this study's illustration of the negative consequences to the industry created by procrastination on starting CO_2 mitigation suggest that an initial target should be defined in parallel to further work on shipping's GHG emission reduction challenges. A mechanism is then needed for ongoing review of the target and if necessary, revision.

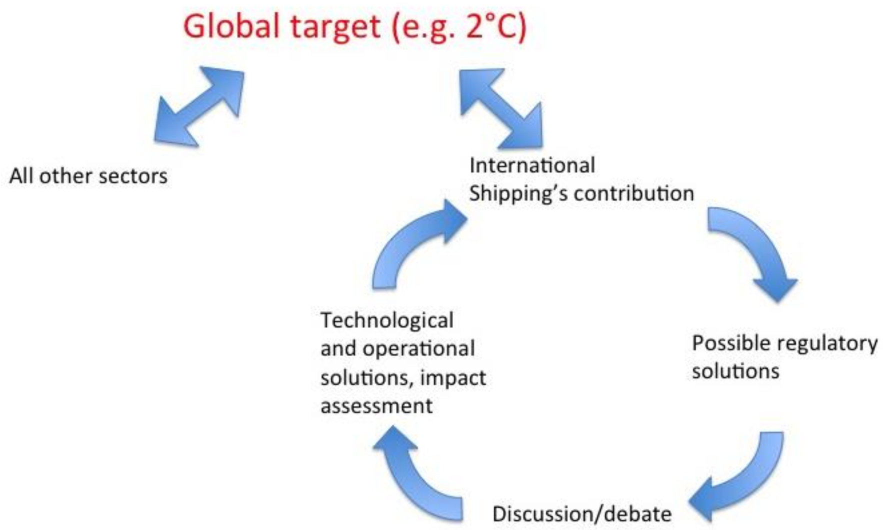

Figure 8: Iterative process to identify a target for international shipping

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