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FURTHER CONSIDERATION OF HOW TO PROGRESS THE MATTER OF REDUCTION OF GHG EMISSIONS FROM SHIPS

The costs of GHG reduction in international shipping

Submitted by IMarEST

SUMMARY

Executive summary:	In order to contribute to the temperature goals of the Paris Agreement, a global emissions pathway is needed for international shipping in which emissions start declining as soon as possible. This document discusses the methods for estimating the costs associated with GHG reduction generally, recent evidence on the costs for GHG reduction in the global economy, and emerging evidence on the costs of GHG reduction in international shipping. This document also discusses the potential for cost reduction and evidence of how costs are already reducing for low carbon technologies.
Strategic direction:	7.3
High-level action:	7.3.2
Output:	7.3.2.1
Action to be taken:	Paragraph 31
Related documents:	MEPC 71/WP.5 and MEPC 65/5/1

Introduction

1 ISWG-GHG 1 and MEPC 71 undertook initial discussions on the IMO Roadmap. Document MEPC 71/WP.5 describes the discussion on among other topics "costs and benefits". On this topic, the group agreed (paragraph 37.1) that:

> "…there is a need for information and updates on the MACC to have an understanding of the cost and development of technology and low-carbon fuels…"

2 This document summarizes some of the current literature on the costs of GHG reduction and introduces some ongoing work to provide greater information and updates on the topic of costs to the IMO Roadmap process.

Methods for estimating costs of GHG reduction

3 There are several different approaches for estimating the costs of GHG reduction. One commonly used method is techno-economic analysis or modelling, in which information on the GHG reduction potential and costs of different modifications are assembled. Although control of all GHGs is relevant to the achievement of specific temperature goals (e.g. increase in temperature relative to pre-industrial temperatures), analysis and models often focuses on CO_2 since it is a long-lasting GHG and for many sectors including shipping it is the most significant GHG contributor. Analyses by sector focus on the operational emissions of that sector, although the upstream emissions impacts and lifecycle impact of a sector's technology pathway also need consideration.

4 In addition to estimating costs and GHG reduction potential, a number of assumptions are required for describing the sector and estimating its macroeconomic drivers. These include, for example, the underlying oil price or cost of conventional fuels, the growth in trade and the development of other impinging regulations (e.g. on air pollution). These are often referred to as "exogenous" or "external" factors and due to their uncertainty can justify the use of scenario analysis – in which a number of foreseeable and coherent combinations of these external factors are formed into scenario definitions.

5 The information on individual modifications (e.g. propeller modifications, hull coatings, machinery choices, fuel choices, operational modifications as described in document ISWG-GHG 1/2/10) costs and GHG reductions can be used in:

.1 cost-benefit analysis looking at one modification or group of modifications;

.2 the production of Marginal Abatement Cost Curves (MACCs) by prioritizing the order of implementation of different modifications, and combining these modifications linearly and without interaction effects; and

.3 the production of a MACCs using simulation models sometimes referred to as "whole system" models that estimate the future technological and operational development of a sector (e.g. shipping) by estimating the combination of modifications selected over time, and the evolution of the global fleet, in response to both regulatory and market conditions.

6 MACCs quantify the cost of abating a marginal tonne (e.g. one additional tonne) of CO_2 at a discrete point in time and are primarily a way of presenting and visualizing results.

7 Analysis can sometimes indicate that modifications are available that reduce GHG emissions at net negative costs (i.e. if they result in cost savings). The explanation for this is that market barriers and failures can prevent the adoption of modifications that would otherwise be profitable, but these barriers and failures have not been included in the modelling/analysis. The observation of negative costs in a MACC or similar analysis implies that GHG reductions can potentially reduce transport costs through the use of policy that reduces or removes those market barriers or failures.

8 The Second IMO GHG Study 2009 included an inventory of modifications, listing CO_2 reductions and costs, and used this information to produce estimated MACCs using method ".2" described in paragraph 5. An example is given in figure 1. The Third IMO GHG Study 2014

used similar data on modifications (modified where assumptions had been refined) but did not display MACCs in the report, although these were an implicit part of the analysis of future scenarios. Neither of these analyses included zero GHG technologies, such as hydrogen fuel or batteries/electrification.

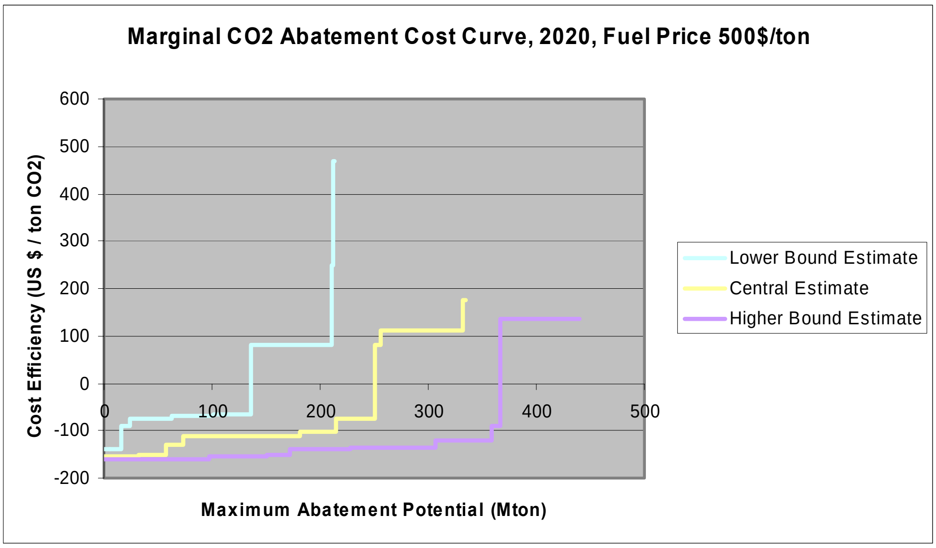

Figure 1: Example of a MACC produced in the Second IMO GHG Study 2009, Figure A4.1 MACC for 2020, a fuel price of $500/tonne and an interest rate of 4%

9 MACCs are necessarily a simplified presentation of the combinations of technologies that can abate increasing quantities of GHG emissions. They produce an intuitive and easily understandable curve, which makes information accessible to policy makers. When produced using method ".2" in paragraph 5, they have shortcomings because of the simplicity of the underlying model. This method often does not represent the interaction between modifications accurately – for example where technological modifications (e.g. a propeller modification) may have a performance that interacts with operational modifications (e.g. slow steaming). This risk of inaccuracy was first pointed out in the IMarEST's submission document MEPC 65/5/1. It is the reason why simulation models are often a preferred means of identifying technology pathways. It is also the reason why simulation models are more accurate for quantifying the costs of CO_2 abatement in shipping because they can take account of these important interactions when selecting the design and operating specification of a ship.

10 For a diverse sector such as international shipping, it is hard to generalize the costs and abatement benefits of modifications at an aggregate "global fleet" level, since different ship types, sizes and routes may have very specific differences. For example, a ship equipped with wind-assistance technology may have a significantly greater CO_2 reduction potential on a route with favourable wind strength and direction, than the equivalent ship (with the same basic cost), operating on a less favourable route. For this reason, it is commonly the case the modification assumptions need to be assembled for the detailed specification of a given ship type and size (e.g. panamax bulk carrier). For this reasons, MACCs are often formulated for a specific ship type and size category.

11 Results for costs of decarbonization are often described using a carbon price (which can be defined from the marginal cost of carbon). This uses the carbon price as a proxy for quantifying the costs experienced in a sector and does not necessarily imply an endorsement of Market Based Measures (MBMs) as the most appropriate policy solution. For example, a carbon price of $100/t at today's HFO price of approximately $300/t, would imply an increase to approximately $600/t for bunker fuel. The carbon price is inclusive of both the capital and

operating cost components of any modification, and includes assumptions about the cost of capital (e.g. the interest rate and amortization associated with capital).

The cost and benefit of decarbonizing the economy: carbon pricing corridors as indicative costs

12 The current state-of-the art work on the subject of carbon prices and climate policy can be used to obtain indicative information for shipping's carbon prices. In May 2017, a High-level Commission on Carbon Prices[1], chaired by Joseph Stiglitz and Nicolas Stern, produced an analysis of the carbon price needed to keep global average temperature increase below 2 degrees. Recognizing the uncertainty of the cost and rate of development of technology, they estimated corridors (ranges) and that a price of $40 to $80 per tonne is needed in 2020, rising to $50 to $100 per tonne by 2030. These findings reinforce other research that indicates that costs of decarbonization are likely to need to increase over time, both as the lower cost "low hanging fruit" are taken up and the absolute emissions reductions relative to a "no policy" pathway increase.

13 Costs of GHG reduction in international shipping may be higher or lower than these ranges identified for the global economy, however these can provide some indication of the possible scales of cost associated with GHG reduction.

14 Including consideration of the benefits and impacts, the panel of economists also investigated the consequences of climate policy on the Sustainable Development Goals, finding "…climate policies, if well designed and implemented, are consistent with growth, development and poverty reduction…". That is to say, that in combination to understanding the capital and operating cost changes associated with GHG reduction, it is also important to understand and analyse the benefits.

The shape of the cost-curve for shipping

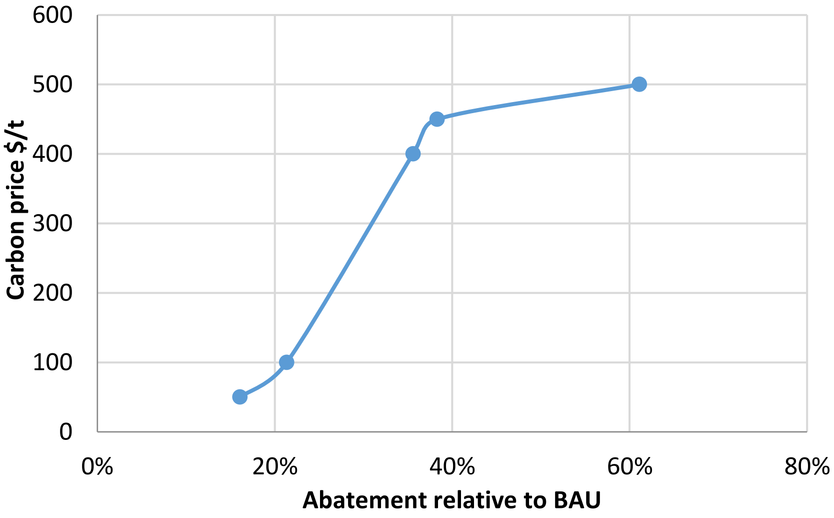

Figure 2: Simulation model (GloTraM) derived estimate of a MACC in 2030, displayed as % abatement relative to a Business As Usual, BAU (no further policy) emissions pathway. Please note, this is ongoing work and the quantification of carbon price on the y-axis should be treated as indicative.

1 https://www.carbonpricingleadership.org/highlevel-economic-commission-1/

15 Further ongoing work has built on the simulation modelling of decarbonization pathways for international shipping developed in the Shipping in Changing Climates research project, included documents MEPC 71/7/7 (Belgium et al.) and ISWG-GHG 1/2/10 (IMarEST and RINA). This research is now being used to derive relationships between cost and abatement. Some preliminary results are shown here in figure 2.

16 Unlike the MACCs produced for the Second IMO GHG Study 2009, the work addresses the issue of interaction between different technological and operational modifications (refer to document MEPC 65/5/1), and is inclusive of a number of low and zero emission alternative fuels and machinery options – specifically biofuels, synthetic fuels (e.g. hydrogen), and electrification (batteries).

17 One key finding from the preliminary analysis, which can be seen in figure 2 and the turning point in the curve that occurs at approximately 40% abatement, is associated with the shape of the sector's MACC. This shows that once very low and zero emission fuels and machinery are included in this type of analysis, the shape of the curve changes from one of monotonically, incrementally increasing cost (costs steadily rising as emissions abatement increases) as seen in the Second IMO GHG Study 2009 (figure 1), to a shape where a "plateau" or limit on the carbon price can be seen. The plateau's shape and position is determined by the costs of those zero emission fuel/machinery combinations.

18 This finding is important because at different points in the curve, the same increase in level of ambition can either be associated with a high increase in cost (carbon price), or a low increase in cost. For example, in figure 2, the cost increase in 2030 associated with increasing ambition from 40% to 60% emission reduction smaller than the cost increase associated with increasing ambition from 20% to 40% emission reduction.

19 Figure 2 is an early output of the work and an estimate of the aggregate (whole fleet) relationship between carbon price and emissions abated. It is inclusive of limited biofuel and hydrogen but not electrification technologies. Given the nature of the work as ongoing, the quantification of carbon price on the y-axis should be treated as indicative, a more detailed and refined analysis will be produced for ISWG-GHG 3. As more up-to-date data and additional technologies are added to the model, it is expected that the costs will reduce in magnitude. The estimates for GHG reduction costs and carbon prices should therefore be considered to be a conservative, upper-bound estimate.

The impact of research, development, innovation and cumulative production on the cost of GHG emission reduction

20 Figure 2 is produced using currently available information on the costs of technology, and included as 2010 costs/prices. It also limits the model to select from technologies that are known and available today, so cannot incorporate the impacts of new technologies or innovations that arise over the coming years.

21 The simulation model used, GloTraM, does not currently incorporate any cost reductions resulting from R&D spend, innovation or from the increased production of technologies. In this respect, the model is highly conservative as the evidence of cost reductions achieved for other low carbon technologies suggest that substantial cost reductions are to be expected. Figure 3, an analysis of renewable power generation costs, shows the cost reductions achieved for solar PV was a factor of 10 (1 order of magnitude) in a 15-year period (1998-2013). The costs reduced as cumulative production scaled from 100 MW to 100,000 MW. It is not necessarily directly comparable in terms of units of production, but for indicative purposes using units of power, this is equivalent to the cumulative production of a

technology from installation in one large container ship (at ~100 MW installed power), to installation in 1,000 large container ships.

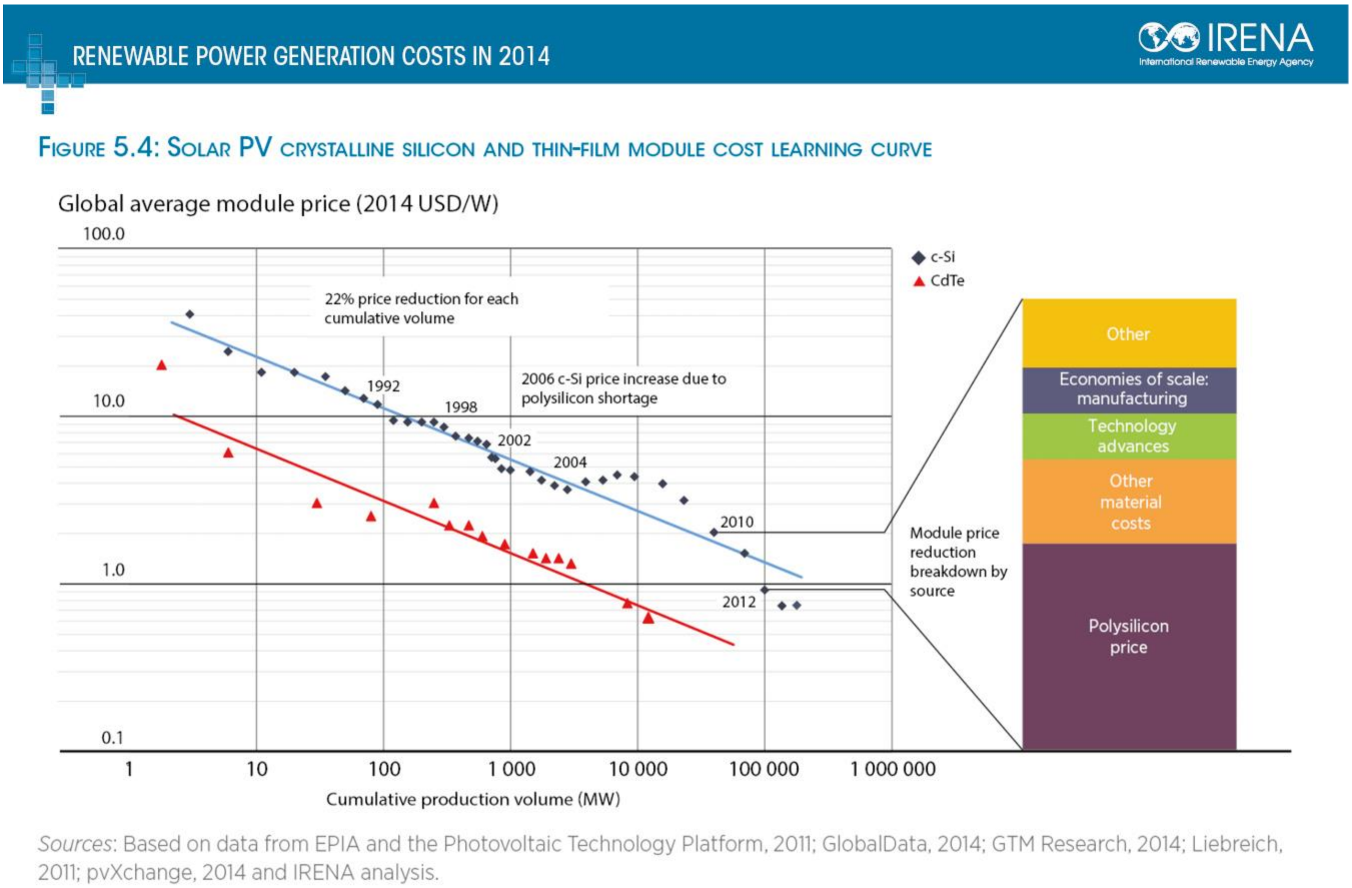

Figure 3: Cost reductions achieved for solar PV technology to 2014

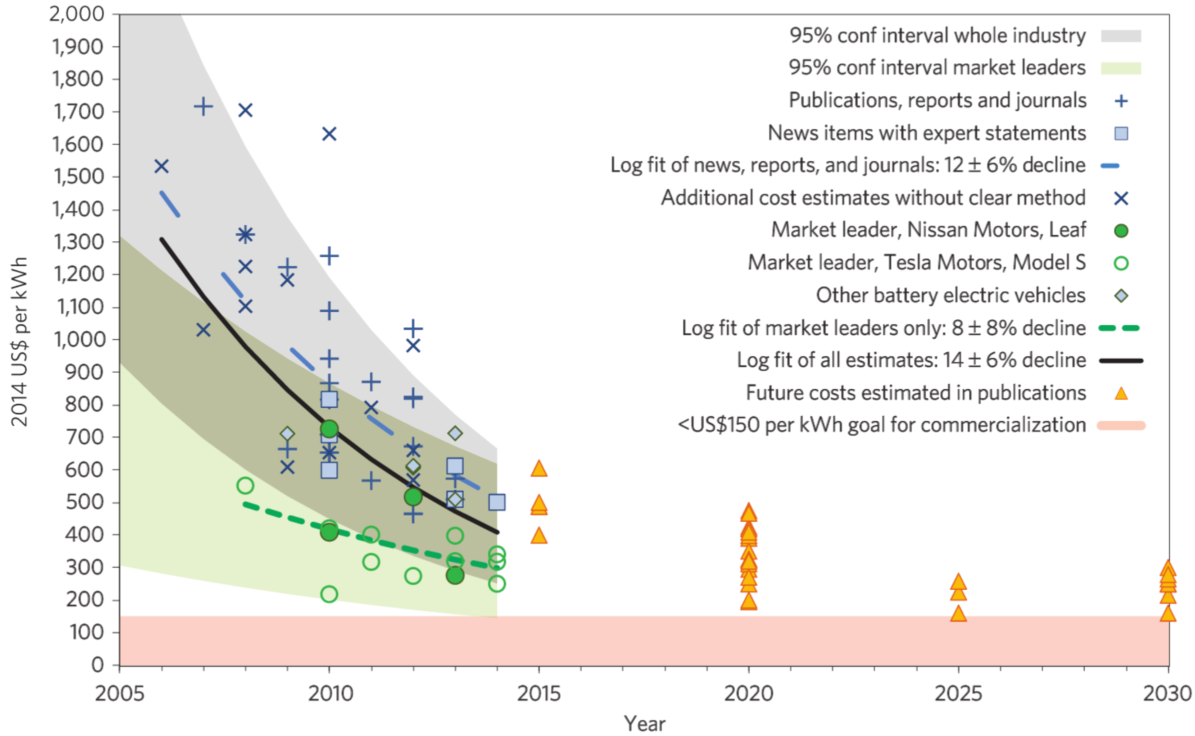

Figure 4: Estimates of cost reductions achieved for battery technologies, source: Nykvist B. and Nilsson, M. (2015) Nature Climate Change 5:329-332

22 Figure 4 shows the dramatic reduction in costs during a nine-year period (2005 to 2014) of another important low carbon technology, batteries. The technology cost is reducing approximately 8% to 14% per annum, and the achieved cost reductions in 2014 already exceed all the cost estimates in the "future costs" literature for 2015 and most of the cost estimates in literature for 2020.

23 Cost reductions for shipping can occur either because of R&D, innovation and cumulative production experience gained in the shipping industry, or from the same activities in other sectors which are developing equivalent or similar technology.

Concluding remarks

24 There are different methods for estimating the costs of GHG reduction in a sector. Most rely on the assembly of information on the costs of individual modifications and their respective GHG reductions (e.g. technologies, operations, fuels, machinery), and then the deployment of that information in a model that looks at cumulative GHG reductions resulting from combinations of modifications.

25 MACCs are useful for displaying information, but if compiled from simple linear addition of modifications, may misrepresent important interaction effects (e.g. between technological modifications and operational modifications). Simulation models or "whole system" models can provide a more accurate estimate of a sector's GHG reduction costs and are a more appropriate way to produce MACCs.

26 Many previous analyses for shipping GHG reduction (including the Second IMO GHG Study 2009), have focused on energy efficiency modifications only, and not included zero emission fuel/machinery options (such as hydrogen, battery electrification, etc.). These may

have given the impression that costs increase monotonically and incrementally as GHG reductions increase.

27 Credible estimates are increasingly available for the costs of GHG reduction in the wider economy. These quantify carbon price "corridors" or ranges for the global economy, and estimate that $40 to $80 per tonne is needed in 2020, rising to $50 to $100 per tonne by 2030, in order to achieve a goal of limiting temperature rise to below 2 degrees.

28 Ongoing work using the simulation model GloTraM, is attempting to update information on the cost of GHG reduction for international shipping. Further work will be presented at ISWG 3, but an initial finding is shown in this document illustrating that contrary to energy-efficiency centric MACCs, the inclusion in analyses of low/zero GHG fuel and machinery modifications produces a plateau in the cost-curve in which large levels of GHG abatement can be achieved for smaller increases in cost.

29 The quantification of the cost of GHG reduction in figure 2 is based on currently available cost information which is not inclusive of innovation, R&D and production cost learning. The estimates for GHG reduction costs and carbon prices should be considered to be a conservative, upper-bound estimate.

30 Evidence is increasingly available of how R&D, innovation, and experience gained from cumulative production is reducing the cost of low carbon technologies. Ideally, models for quantifying future GHG reduction costs should include such effects when appropriate and it is expected that this would significantly reduce the current estimates of the cost of GHG reduction. If quantitatively including this effect is not possible, it is important that this evidence is taken into account qualitatively.

Action requested of the Working Group

31 The Working Group is invited to note the information in this document and take action as appropriate.

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