Analysis on interaction of CII with GFS

Calibrating IMO energy efficiency and fuels targets

January 2024

Executive Summary

This briefing provides the results of an in-house analysis, which makes the case for implementing stringent energy efficiency requirements along with an ambitious GHG fuel standard (GFS).

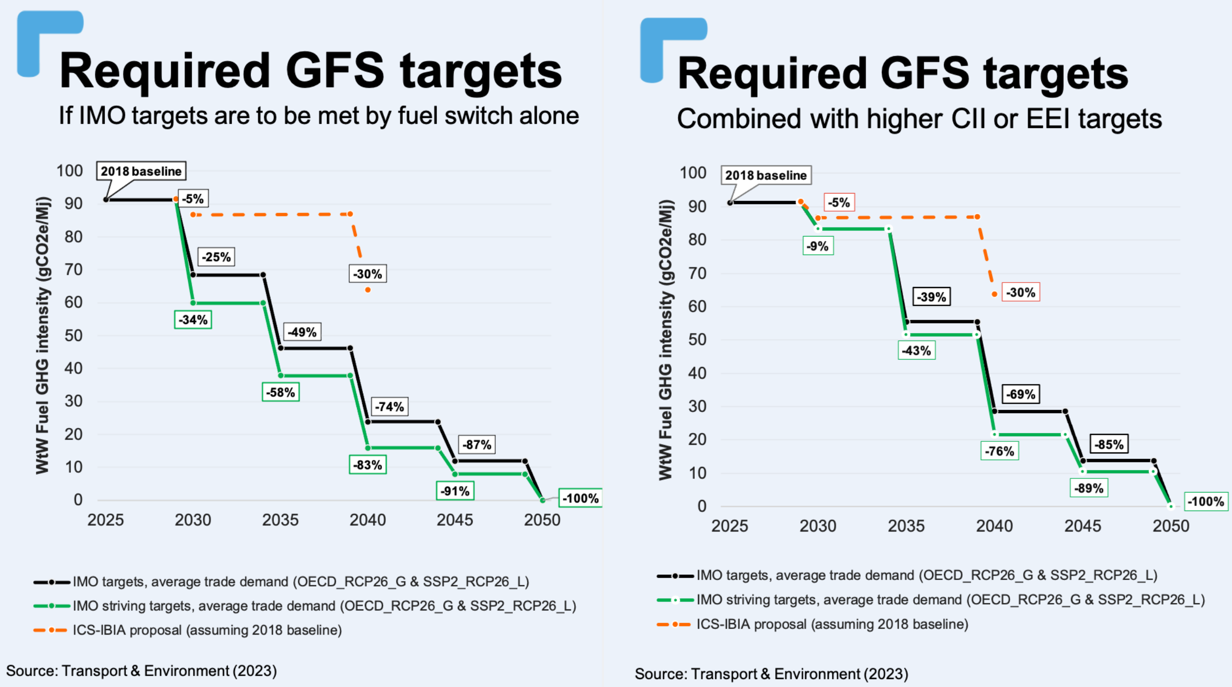

Figure 1: GFS targets combined with no additional energy efficiency requirements (left) and with additional high energy efficiency (right)

The analysis concludes that in order to deliver the absolute emissions targets of the Revised IMO GHG Strategy, more moderate GFS targets could be acceptable if they are combined with stringent energy efficiency standards. The latter could be achieved either by reforming CII to be WtW or transforming it from carbon intensity indicator to energy efficiency indicator (EEI), which ensures needed emissions savings beyond the uptake of 10% fuel zero/near-zero emissions fuels by 2030.

Failing that, GFS targets of between -25% and -34% by 2030 relative to 2018 levels will be required to meet IMO's 2030 absolute emissions reduction target.

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1. Introduction

International Maritime Organisation adopted in July 2023 a Revised Strategy on GHG emissions from international shipping (i.e. Revised IMO GHG Strategy). The Strategy sets the following goals:

- By 2030: 20-30% WtW emissions reduction compared to 2008 levels;
- By 2030: 5-10% zero or near-zero emissions fuels uptake;
- By 2040: 70-80% WtW emissions reduction compared to 2008 levels; and
- By 2050: 100% emissions reduction to reach net-zero.

In achieving these targets, IMO's existing short-term carbon intensity measure (CII) will be revised and additional mid-term measures (GHG fuel standard (GFS) and carbon pricing) will be adopted. In terms of timeline:

- CII revision will need to be finalised by January 1, 2026 covering the period from 2027 onwards;
- GFS and carbon pricing will need to be adopted in time in order to enter into force from March 2027 at the latest.

The key question for the policy-makers and industry alike will be how to calibrate the existing and new IMO measures in order to deliver needed emissions reductions envisaged by the Revised IMO GHG Strategy. This briefing provides a methodology developed and associated analysis carried out by Transport & Environment (T&E), a founding member of the Clean Shipping Coalition (T&E), which can help policy-makers at the IMO in their forthcoming deliberations on revising and adopting new measures to cut shipping GHG pollution. The analysis focuses only on CII and GFS, but recognises the importance of carbon pricing, especially in relation to just and equitable transition that most climate vulnerable countries have called for.

2. Results of the analysis

The analysis is based on 3 step-methodology the details of which can be found in Appendix I:

1. In the first step, we calculate the required GHG emissions reductions needed in order to meet WtW absolute emissions targets (levels of ambition) of the Revised IMO GHG Strategy (section 2.1)
2. In the second step, we calculate what the GFS targets needed to achieve the levels of ambition of the IMO Strategy if all emissions reductions were to be achieved by fuel switching alone. We call this Scenario 1, or "*fuels-only GFS*" (section 2.2)
3. In the third step, we develop more comprehensive sets of targets combining GFS and improved CII whereby IMO targets are achieved by a combination of energy efficiency and fuel switching. We call this Scenario 2 (section 2.3). This scenario further develops two alternative sub-scenarios:
    a. "*Improved CII*", which sees CII targets for 2030 and beyond increased, and the measure being transformed from TtW CO_2 emissions to WtW CO_2e. The goal is ensure coherence and compatibility between CII and GFS and avoid a situation whereby GFS promotes

certain green fuels (e.g. e-methanol that contains carbon), while CII punishes them by treating green e-methanol equivalent to grey methanol because both contain equal amounts of carbon atoms. In this option, a WtW CII becomes an all-encompassing measure that can be attained by fuel consumption reduction (through e.g. speed optimisation, wind-assist technology, etc.) and/or by switching to green fuels. The underlying assumption is that ships will first explore low-hanging fruit, i.e. fuel consumption reduction before switching to expensive green fuels. However, given that IMO Strategy also sets dedicated green fuels targets, GFS working in conjunction with *improved CII* ensures that a minimum of 10% zero or near-zero emission fuels are taken up by 2030. In this sub-scenario GFS functions as a "*nested sub-target*" for CII (section 2.3.1).

b. "*Transformed CII*", which sees CII being transformed from a carbon intensity indicator (expressed in CO_2 or CO_2e per transport work) to an energy efficiency indicator (expressed in MJ per transport work). The goal of this alternative sub-scenario is to separate and clearly delimitate the emissions reduction contributions of energy efficiency and fuel switching and setting separate targets for each of them. In this sub-scenario, "*transformed CII*" (which we call EII - energy efficiency indicator) functions like a pure ***fuel economy*** requirement unaffected by the (WtW) carbon content of the fuel, while GFS drives the switch to ***zero or near-zero GHG emission fuels*** (see section 2.3.2)

2.1. Required absolute emissions reductions

Based on the IMO 4th GHG study, our analysis shows that WtW shipping emissions will grow in a BAU scenario by up to 15% by 2030, 29% by 2040 46% by 2050 compared to 2008 levels in a world where the rest of the economy meets Paris Agreement's temperature targets (table 1).

Table 1: International shipping emissions projections: BAU and IMO targets (WtW)

Scenario name		2008	2018	2020	2025	2030	2035	2040	2045	2050
BAU WtW CO_2e (Mt)	BAU GHG, low trade demand (OECD_RCP26_G)	1095	1089	1051	1076	1076	1089	1102	1126	1156
	BAU GHG, high trade demand (SSP2_RCP26_L)	1095	1089	1118	1193	1258	1318	1411	1500	1597
	BAU average (OECD_RCP26_G & and SSP2_RCP26_L)	1095	1089	1084	1135	1167	1203	1257	1313	1377
Relative change wrt 2008 baseline (%)	OECD_RCP26_G (BAU, low demand growth)					-2%	-1%	1%	3%	6%
	SSP2_RCP26_L (BAU, high demand growth)					15%	20%	29%	37%	46%
	BAU average (OECD_RCP26_G & and SSP2_RCP26_L)					7%	10%	15%	20%	26%
Targeted WtW CO_2e (Mt)	IMO (base) targets, all trade demand scenarios	1095	1089		1076	876	602	328	164	0
	IMO striving targets, all trade demand scenarios	1095	1089		1076	766	493	219	109	0

These are in contrast to 30%, 80% and 100% emissions reduction goals relative to 2008 set by the Revised IMO GHG Strategy (fig. 2). It is important to specifically point out that, IMO targets are relative to the 2008 baseline, while BAU emissions are projected to considerably exceed the 2008 baseline emissions. As a result, emissions reduction relative to BAU projections will need to be much higher, e.g. up to 39% by 2030, and up to 84% by 2040. This suggests that in order to meet the IMO targets, deep emissions cuts need to be achieved, especially in this decade.

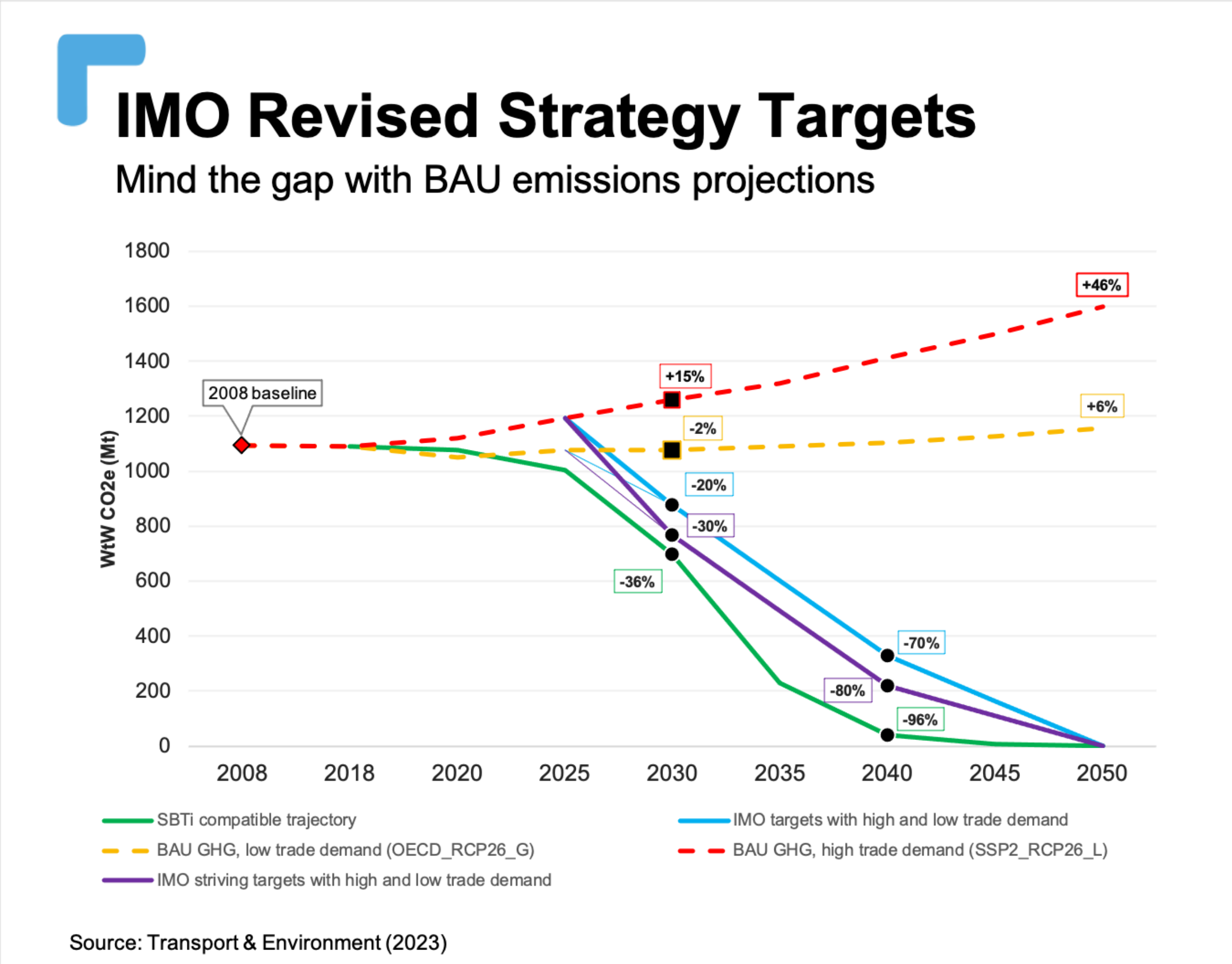


Figure 2: International shipping emissions projections and IMO targets

To deliver these emissions cuts, substantially stringent regulatory measures are required, which can be achieved by improving the existing CII regulation and adopting mit-term measures, including GHG fuel standard (GFS) and ambitious universal carbon levy on international shipping. The below sections will present the results of quantitative analysis for CII and GFS targets. Analysis of carbon levy is beyond the scope of this briefing.

2.2. Scenario 1 - calibrating GFS targets for "fuels-only" approach

Based on the BAU emissions projections and the required emissions reductions envisaged by the IMO target, we can estimate the needed GFS target trajectory all the way to 2050. As explained above, this can be done in a scenario where it is assumed that all of the targeted emissions reductions are entirely achieved by the switch to cleaner marine fuels. We call this "*fuels only*" approach in this briefing.

According to this analysis, "fuels only" approach would require huge improvements in the fuel GHG intensity right from the start of the GFS application; up to 39% GHG intensity reduction by 2030 compared to 2018 baseline in a high trade demand scenario, quickly rising to 62% reduction by 2035 and 84% reduction by 2040 assuming linear improvements required by the forthcoming GFS regulation. For the average trade growth scenario, the required reductions are 34% by 2030, 59% by 2035, 83% by 2040 and 91% by 2045 (see Fig. 3 below and Table A.I.4 in the Appendix I for further detail).

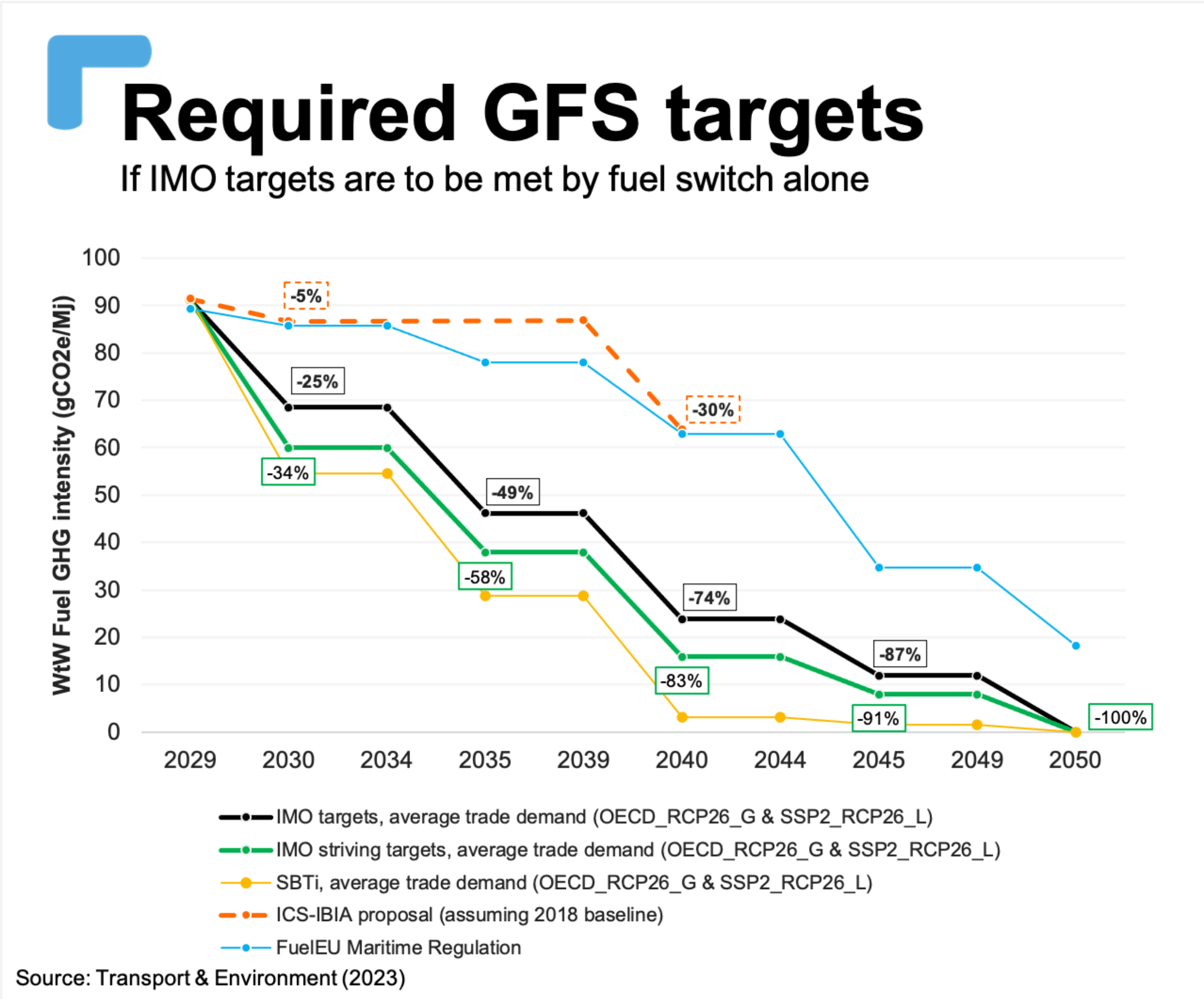


Figure 3: "Fuels-only" approach - calibrating the GFS targets

While achieving these targets via fuel switch is not inconceivable in theory, practically it would be quasi impossible to produce and deliver to the shipping industry this amount of sustainable fuels in this short time horizon, especially before 2035. In a "fuels-only" approach, zero/near-zero emission fuels would need to meet about 38% of the energy demand of international shipping in order to achieve the 2030 striving target of the Revised IMO GHG Strategy under average trade growth scenario modelled by this analysis. For 2035 and 2040, green fuels uptake would need to reach 65% and 87%, respectively (Fig. 4).

Such a rate of renewable fuel/energy uptake is unlikely and to the best of our knowledge has not been achieved in the past by any other mode of transport. There is also a risk of the shipping industry resorting to unsustainable alternative fuels if the sustainable ones are not available in the short term

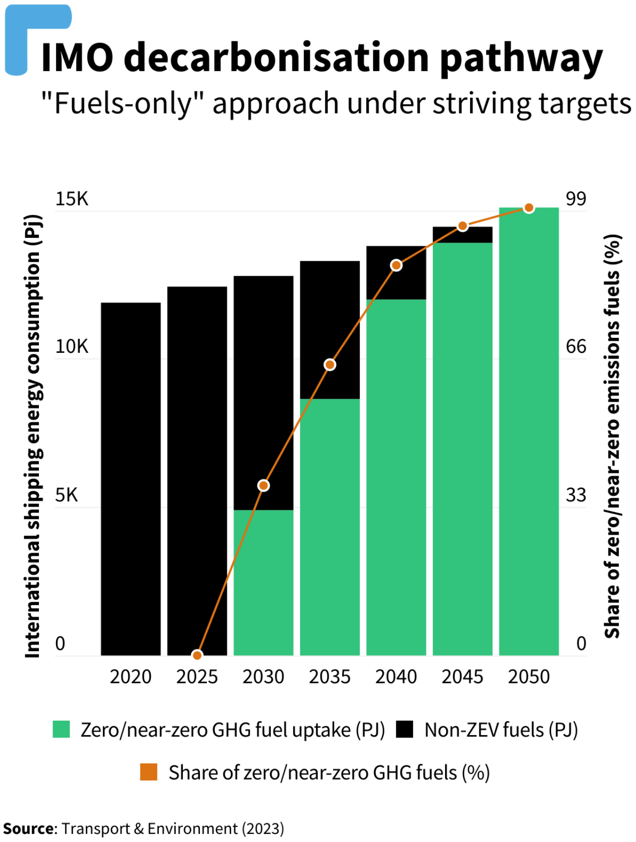


Figure 4: Green fuel uptake under rate under "fuels-only" approach

2.3. Scenario 2 - Combining fuels and ambitious energy efficiency

For this reason, it is highly recommended that IMO and member states (acting nationally and regionally) seek substantial emissions reductions in this decade through energy efficiency. Wide range of literature has concluded that substantial emissions reductions can be achieved in this decade through speed reduction, installation of wind-assist and other energy efficiency technologies (e.g. see Fig. 5).[1]

[1] CE Delft (2023), *Shipping GHG emissions 2030, Analysis of the maximum technical abatement potential;* see also Rehmatulla, N. and Smith, T. (2015), *Barriers to energy efficient and low carbon shipping*, Ocean Engineering, Volume 110, Part B, Pages 102-112, ISSN 0029-8018; CE Delft (2019), *Study on methods and considerations for the determination of greenhouse gas emission reduction for international shipping Final Report* for European Commission, DG CLIMA.

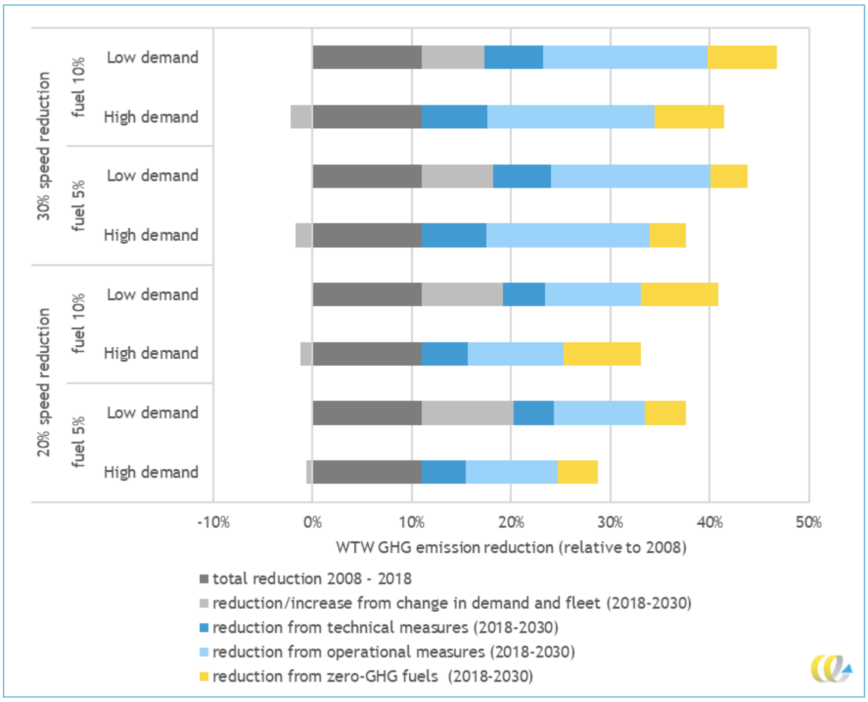


Figure 5: Different options to reduce emissions by 2030 (CE Delft, 2023)[2]

This would not only help immediately reduce emissions, but also cut the amount of renewable energy needed for shipping to decarbonise. In the context of global decarbonisation efforts by all economic sectors, there is a high risk of competition for (initially) scarce and expensive alternative fuels. For this reason, it is important not only to switch to alternative fuels but also cut the overall fuel consumption altogether. The best energy is the one that is not used. This would help speed up the technological transition but also reduce the overall costs thereof.

To deliver substantial energy efficiency improvements, CII would be the most appropriate instrument as it applies to new and existing vessels alike. As explained above, in our opinion CII can be revised in two ways: A) switching from TtW CO_2 to WtW and increasing the reduction targets, B) transforming it from carbon intensity indicator expressed in GHG/t-nm terms to energy efficiency indicator (EEI) expressed in MJ/t-nm terms.

2.3.1. “Improved CII” and moderate GFS targets

This analysis concludes that more moderate GFS targets for this decade can be feasible (Fig. 6) if combined with more stringent reformed CII targets. The key here is to mathematically calibrate CII and GFS in a way that the achievement of the GFS 2030 target delivers the 10% zero/near-zero emissions fuels uptake, while CII fills the remaining emissions gap to reach the IMO 2030 absolute emissions target.

[2] CE Delft (2023), *Shipping GHG emissions 2030, Analysis of the maximum technical abatement potential.*

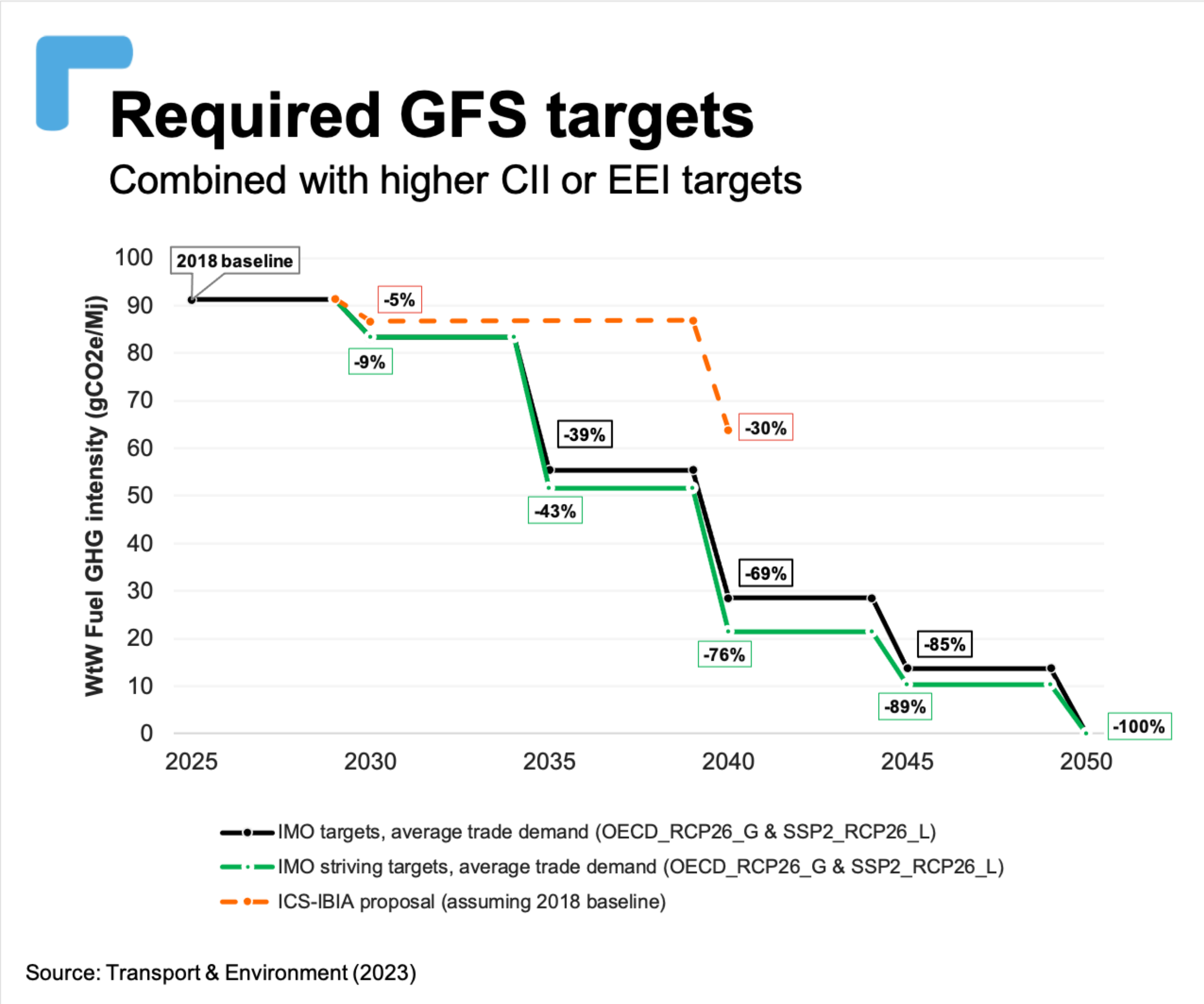


Figure 6: Moderate GFS targets if combined with ambitious reformed CII targets (see Fig. 7)

This analysis concludes that, if the ambition of GFS is to be limited to deliver only 10% zero/near-zero emissions fuels uptake by 2030, which is the upper bound of the said target in the Revised IMO GHG Strategy, then CII needs to deliver between **29.4% and 38.2%** improvement on a WtW basis by 2030 compared to 2018 levels (Fig. 7). In order to reform CII from TtW CO_2 to WtW CO_2e, WtW emissions factors applicable to the future GFS will also need to be applicable to CII reference lines, reduction targets and attained CII levels.

While part of the emissions reduction achieved by WtW CII will overlap with emissions reduction to be delivered by the uptake of zero/near-zero emissions fuels, the majority of these improvements would need to come from the increase in energy efficiency of the existing and new fleet.

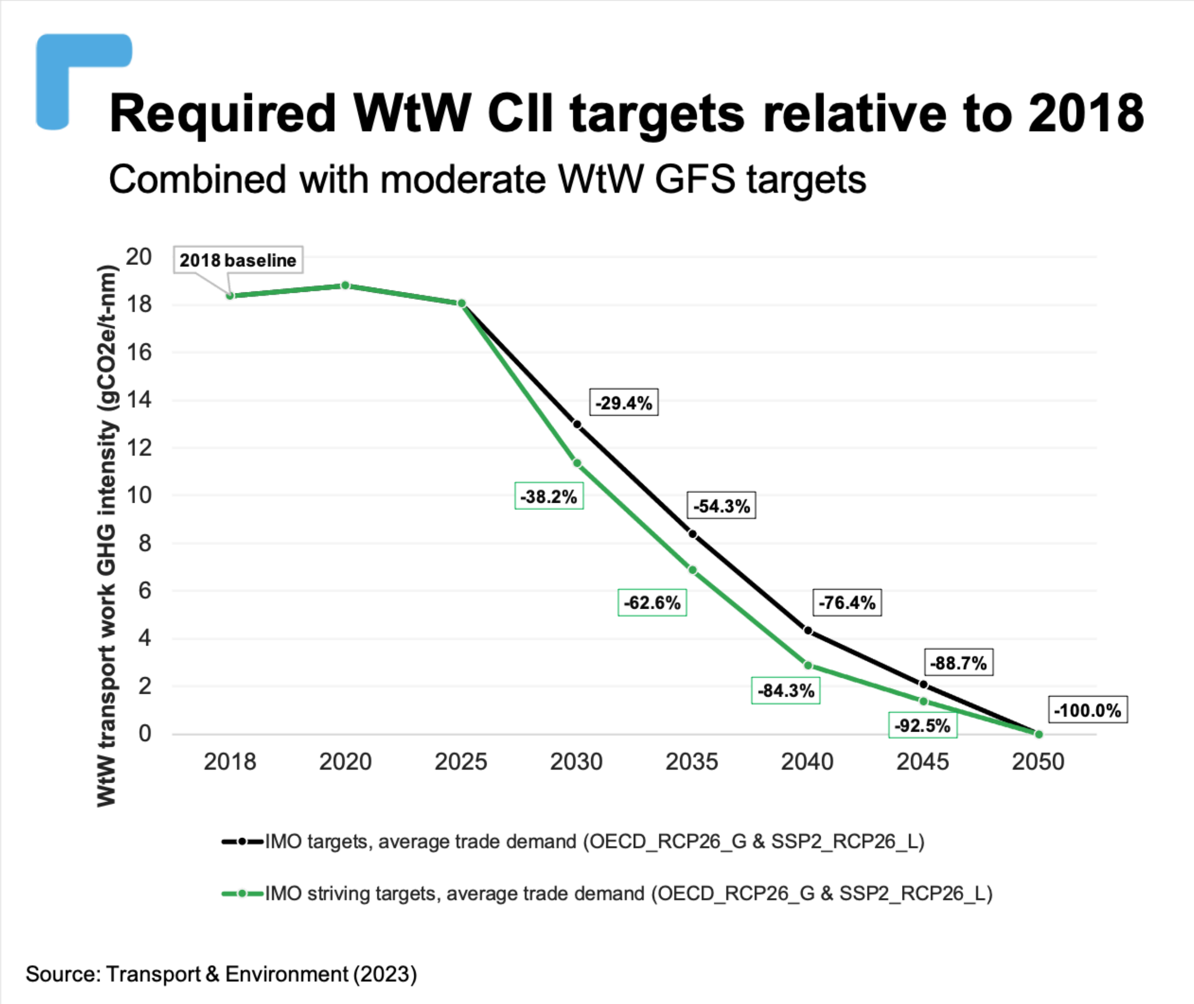
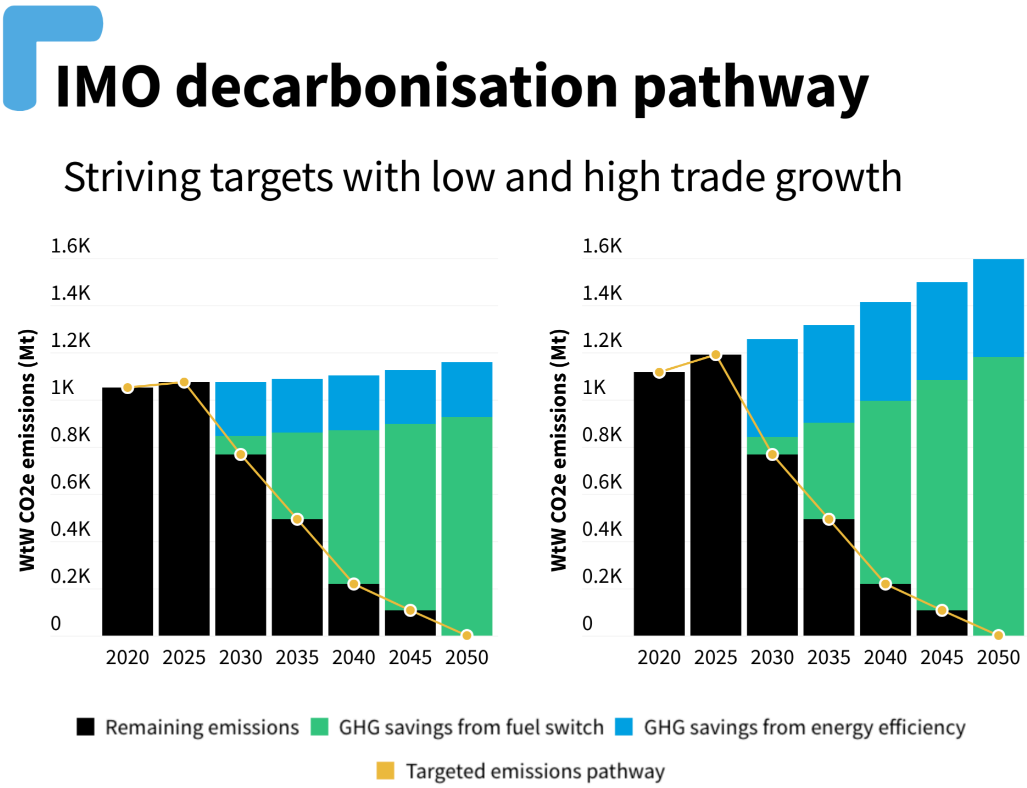


Figure 7: Required CII targets if more moderate GFS targets (see Fig. 6) are chosen

According to our analysis, emissions savings by 2030 through energy efficiency needs to reach between 19% and 30% of the baseline emissions in 2008 in order to offset the average BAU emissions growth and contribute towards further absolute emissions cuts in line with the levels of ambition of the Revised IMO GHG Strategy (Fig. 8). These required improvements in energy efficiency are substantial, but comparable to the maximum technical abatement potential analysed by the CE Delft study[3] published during the Revised strategy negotiations in July 2023 (Fig. 5).

It is important to note that continued improvements in CII for the post-2030 period presented in figure 7 is the result of the continued uptake in zero/near-zero emissions fuels uptake by the sector and not additional CII targets to be set by the IMO. This does not mean discontinuation of CII in a post-2030 period; only the assumption that most of the technical potential of energy efficiency would be achieved in the current decade.

[3] CE Delft (2023), *Shipping GHG emissions 2030, Analysis of the maximum technical abatement potential.*



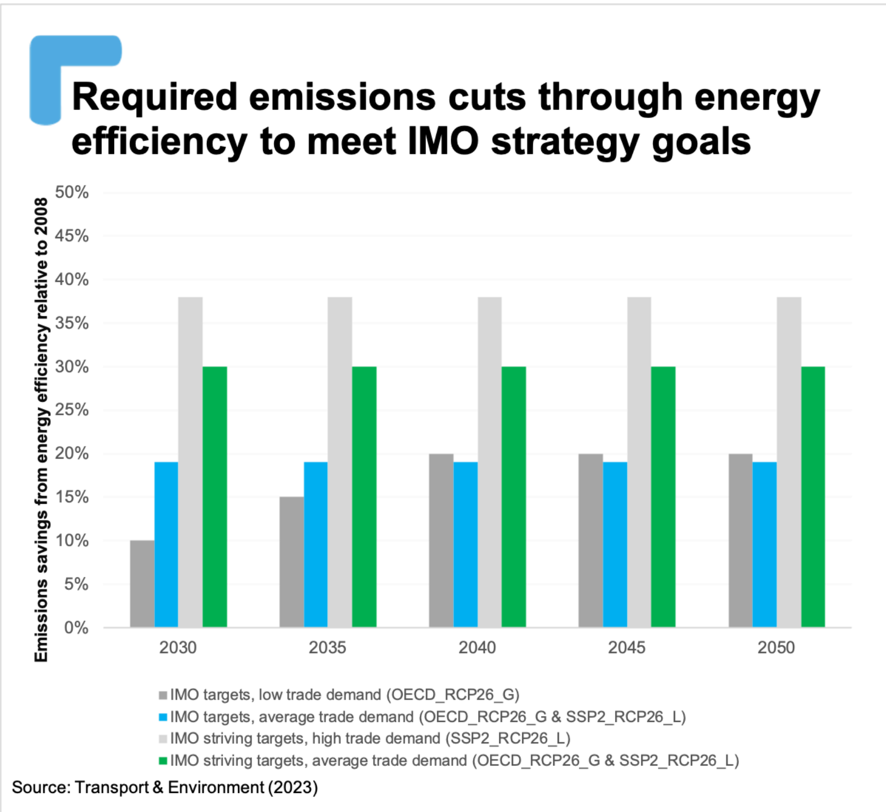


Figure 8: Potential contribution of energy to meeting IMO targets

INFO BOX: Need to limit GFS compliance to zero/near-zero emission fuels

It is important to note that, from the mathematical point of view, for these CII and GFS targets to add up to the IMO levels of ambitions, it is essential to have a stringent definition for the zero and near-zero emission fuels as part of the GFS development. This is rather because our calibration method for CII and GFS assumes *true and substantial* emissions reductions from each unit of zero/near-zero emission fuel promoted by GFS.

To that end, and given that IMO Strategy did not specify a definition for these alternative fuels, we have used the following common sense definitions for zero and near-zero emission fuels:

- **Near-zero: at least 90% WtW emissions reduction below the 2018 baseline by 2030,**
- **Near-zero: at least 95% WtW emissions reduction below the 2018 baseline by 2040,**
- **Zero: 100% WtW emissions reduction below the 2018 baseline by 2050.**

This definition ensures that e.g. 10% uptake of near-zero emission fuels by 2030 delivers at least 9% WtW emissions reduction compared to BAU (after accounting for energy efficiency). In other words, a stringent definition ensures that new volumes of alternative fuels are worthy of the effort from the climate perspective and avoids promoting alternative fuels that do not have the potential to decarbonise the sector at the expense of those that do have.

We strongly recommend IMO to adopt this or comparable definition for zero and near-zero emission fuels and limit the eligibility of compliance under GFS to only these fuels.

Stringent definition is also essential from the perspective of alternative fuels contributing to the IMO's levels of ambition for 2030, 2040 and 2050. Otherwise, even higher stringency in CII would be required in order to make up for reduced emissions savings from alternative fuels if a less stringent definition of zero/near-zero emissions fuels is chosen.

2.3.2. "Transformed CII" and moderate GFS targets

An alternative approach towards a reformed CII would be to transform it from a carbon intensity indicator ($CII = \frac{Fuel\,mass * Cf}{transport\,work}$) to an energy efficiency indicator ($EEI = \frac{Fuel\,mass * LCV}{transport\,work}$), which would explicitly delimitate the contribution of pure energy efficiency options and switching to green fuels towards absolute emissions reductions. The goal would be to guarantee significant reductions in fuel/energy consumption by ships in order to make technological transition less disruptive and more efficient.

The difference between "improved CII" from the previous sub-section and "transformed CII" in this section is visually illustrated in the figure 9. In simple terms, while under the "improved CII" zero/near-zero emission fuels would contribute both to the attainment of GFS and CII at the same time, under the "transformed CII", fuels would not contribute to the improvement of energy efficiency. For the latter, ships would need to perform dedicated operational changes and/or technical improvements to their vessels, e.g. speed and/or route optimisation, hull cleanings, waste-heat recovery systems, hull lubrication, wind-assist technologies, new hull designs, etc. If this approach is preferred over the "improved CII", required energy efficiency improvements can be calibrated to work hand in hand with (moderate) GFS targets presented in the figure 6 above. In our analysis, the energy efficiency index would need to deliver between 23% and 32% improvements by 2030 compared to the 2018 baseline (fig. 10).

Visualising GFS, CII and EEI

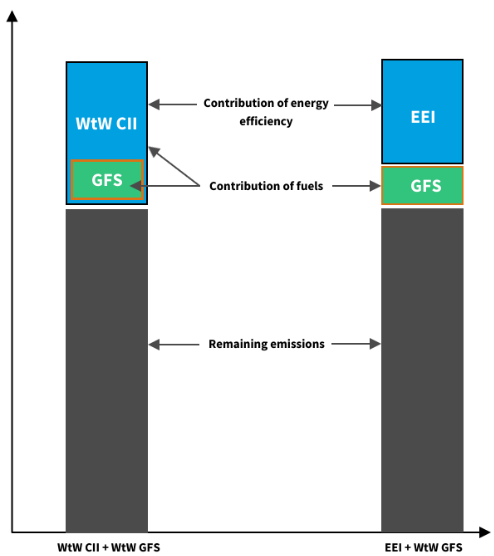


Figure 9: Visualising GFS, CII and EEI

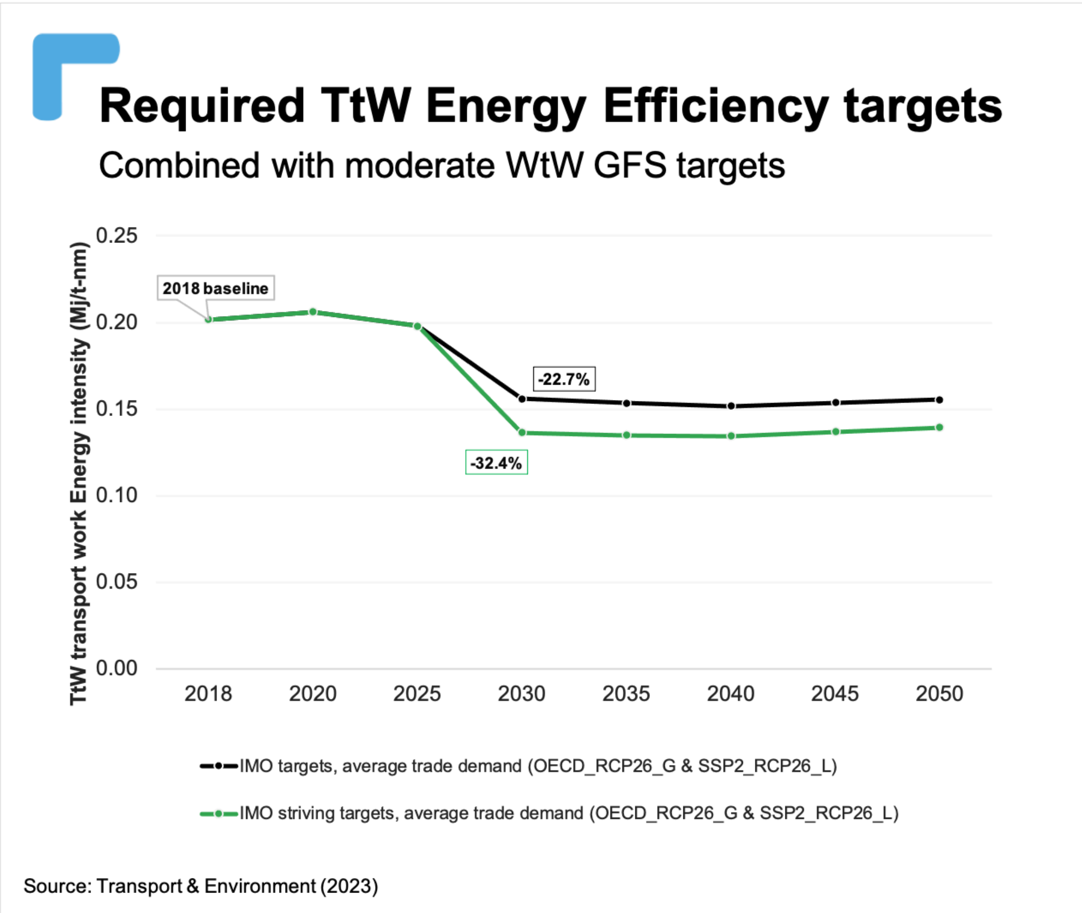


Figure 10: Required energy efficiency targets combined with moderate GFS targets (see Fig. 6)

3. Conclusions

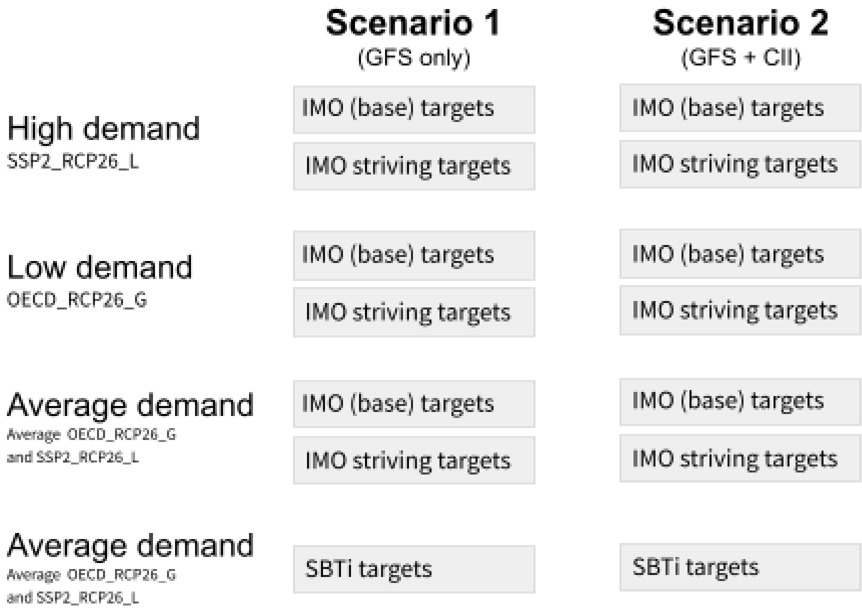
This briefing presented the results of T&E's in-house analysis on GFS and CII targets in order to help the shipping sector to meet IMO's emissions reduction targets. The analysis demonstrated that GFS targets would need to be very stringent right from the start if the levels of the ambitions of the IMO Revised GHG Strategy are to be achieved by the uptake of zero or near-zero emissions fuels. Specifically, about 38% green fuels uptake would be necessary to deliver 30% absolute emissions reductions by 2030 compared to 2008 baseline. For GFS, this would mean improving the fuel GHG intensity by 25-34% by 2030 compared to the 2018 reference line chosen in this analysis.

An alternative, and a more realistic approach would be to calibrate the GFS targets to the improved energy efficiency targets that this briefing recommends the IMO should establish. Energy efficiency improvements can be driven either by a *reformed CII* or *transformed CII*. The former option envisages switching CII from TtW CO_2 to WtW CO_2e and setting between 29.4 and 38.2% carbon intensity reduction targets by 2030 compared to the 2018 baseline. The latter option envisages transforming the CII from carbon intensity indicator to energy efficiency indicator expressed in MJ/t-nm. This means that ships would need to cut their fuel consumption in order to improve their EEI; switching to low-carbon fuels would not be an eligible strategy. If the EEI option is chosen, this analysis concluded that an improvement of between 22.7% and 32.4% would be required by 2030 compared to the 2018 baseline chosen by this analysis.

We believe that EEI would be a more desirable option. This is because this option would clearly delineate between the contribution of pure energy efficiency and green fuels uptake to the reduction of absolute emissions. It would also ensure that ships *max out* the uptake of energy efficiency options before relying on expensive alternative fuels for which the competition from other sectors will be very strong.

Appendix I: Methodology

A.I.1. General outline



A.I.Fig.1: Description of analysed scenarios

The analysis follows a three-step approach to derive the needed regulatory targets to meet the emissions reduction objectives as agreed by the IMO's Revised GHG Strategy (2023):

1. Firstly, we adjusted historical and future projected emissions data from the 3rd and 4th IMO GHG studies to derive two *business as usual* (BAU) emissions/trade demand pathways.
    a. Historical and projected emissions data provided by the IMO studies are only tank-to-wake (TtW), which need to be converted to *well-to-wake* (WtW). To achieve this, we used WtW emissions factors from the EU's recently adopted FuelEU Maritime Regulation as FuelEU provides default emissions values for more fuel types than the current provisional IMO LCA guidelines.
    b. While projected emissions are only provided for global shipping emissions, the IMO only regulates international shipping emissions. Therefore, global projections need to be first scaled down to international emissions.
    c. We analysed two BAU projections: one with high trade demand growth as represented by the SSP2_RCP26_L and one with low trade demand growth as represented by OECD_RCP26_G pathways in the 4th IMO GHG study. See section A.I.2 for further detail.
2. Secondly, using the results from step 1 and the levels of ambition from the Revised IMO Strategy, we derived the absolute WtW emissions levels that need to be achieved by 2030, 2040 and 2050. We assumed linear emissions reductions between those years. In general, given the 2 BAU pathways identified in step 1, and two target levels (i.e. base targets and striving targets) of the Revised IMO Strategy, we ultimately define 4 emissions reductions to be achieved for each target

year relative to the BAU.

3. Lastly, we explored two scenarios as to how those emissions reductions could be translated into regulatory targets for a GFS and revised CII:
   a. *Scenario 1* assumes that all emissions reductions for 2030 and beyond are to be achieved by GFS targets only, which means that no further improvements to energy efficiency (i.e. amount of energy used per transport work) is to be expected. This scenario directly translates the needed emissions reductions into relative GFS improvements expressed in percentage reduction compared to the 2018 baseline and maximum permissible fuel GHG intensity expressed in gCO_2e/MJ. We used 2018 as the baseline year because this is the latest year for which global marine fuel breakdown is available under the 4th IMO GHG study; also because the 2018 absolute emissions were almost identical to 2008 emissions. See section A.I.3 below for further detail.
   b. *Scenario 2* assumes that most of the emissions reduction for 2030 are to be achieved by improved (technical and operational) energy efficiency, while the rest coming from 10% uptake of near zero-emission fuels (as called for by the IMO revised strategy). For the ensuing years we assumed that no further energy efficiency improvements can be achieved and that the remaining emissions reductions required by the fourth IMO GHG study will be achieved by the increased uptake of near-zero and zero emissions marine fuels.[4] This scenario identifies 2 further sub-scenarios:
      - one where the required energy efficiency improvements are based on improved CII expressed in WtW emissions terms. We named this sub-scenario "*improved CII*".
      - another one which assumes that CII is converted from carbon intensity per transport work into energy efficiency per transport (expressed in MJ/t-nm), which is calibrated to deliver the needed emissions reduction beyond the reductions to be delivered by the uptake of 10% near-zero emissions fuels by 2030. We name this sub-scenario "*transformed CII*". See section A.I.4 below for further detail.

A.I.2. Adjusting historical and projected BAU emissions

IMO 3rd and 4th GHG studies provide the breakdown of historical fuel consumption data for domestic, fishing and international shipping sectors. We used the WtW emissions factors and fuel-specific LCVs from the FuelEU Maritime regulation to convert the fuel consumption data into WtW CO_2e emissions, total energy use expressed in petajoules (PJ) and fuel GHG intensity values expressed in gCO_2e/MJ for international shipping (see table A.I.1).

For emissions projections, data was retrieved from the 4th IMO GHG study tables 39 and 43. However, those tables have a small discrepancy with the main vessel-based bottom-up emissions estimates for the

[4] Except for the low trade growth scenario (OECD_RCP26_G), which assumes further energy efficiency improvement potential between 2030 and 2040.

year 2018 in the IMO 4th GHG study's main Table 1. While both tables present emissions for global shipping, the value presented in table 1 is 1056 Mt of CO_2, while the equivalent value in Tables 39 and 43 is 999Mt of CO_2. T&E assumes that the discrepancy could be due to clerical errors in finalising the IMO 4th GHG study. So, we assume the values from table 1 to be accurate and scale up emissions projections in tables 39 and 43 accordingly to correct the discrepancy. This is done by multiplying emissions projections for 2025 and beyond by the ratio of global emissions value in Table 1 and Tables 39 & 43 in the year 2018. We then use the ratio of international and global emissions in Table 1 to calculate emissions projections for international shipping based on Tables 39 and 43. This assumes the ratio of international and global shipping emissions to remain constant beyond 2018. Finally, we translate these values from TtW CO_2 to WtW CO_2e using the default factors presented in table A.I.1 below. The results are presented in Table A.I.2.

Table A.I.1: The breakdown of historical fuel/energy consumption, emissions and fuel GHG intensities

		WtW and LCV values - FuelEU Maritime				Fuel consumption in HFO equivalent (Mt) - IMO 3rd and 4th GHG studies								Fuel consumption (PJ) - T&E calculations based on the IMO 3rd and 4th GHG studies and FEUM default factors							
Fleet sector	**Fuel type**	**WtW emissions (tonne CO2e/tonne fuel)**	**TtW emissions (tonne CO2e/tonne fuel)**	**Fuel GHG intensity gCO2e/MJ**	**LCV (MJ/kg)**	**2008**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2008**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
International shipping	HFO	3.72	3.17	91.74	40.50	257.77	228.69	222.54	220.45	207.02	217.29	225.34	221.78	10440	9262	9013	8928	8384	8800	9126	8982
	LNG	4.08	3.18	83.09	49.10	5.60	8.89	9.11	8.92	8.16	8.47	9.90	11.34	227	360	369	361	330	343	401	459
	MDO	3.88	3.40	90.77	42.70	32.10	34.86	37.02	38.87	59.94	60.43	62.32	61.47	1300	1412	1499	1574	2428	2447	2524	2490
	Methanol	2.00	1.38	100.40	19.90	0.00	0.00	0.00	0.00	0.02	0.13	0.16	0.16	0	0	0	0	1	5	6	6
	Total					**295.47**	**272.43**	**268.70**	**268.34**	**275.95**	**287.04**	**298.32**	**295.16**	**11,966**	**11,034**	**10,881**	**10,864**	**11,143**	**11,596**	**12,058**	**11,937**
	Average fleet GHG intensity (gCO2e/MJ)													**91.47**	**91.34**	**91.32**	**91.31**	**91.28**	**91.29**	**91.26**	**91.21**
	Total fleet WtW CO2e (Mt)													**1095**	**1008**	**994**	**992**	**1017**	**1059**	**1100**	**1089**
Domestic navigation	HFO	3.72	3.17	91.74	40.50	18.43	2.14	1.99	1.93	1.31	1.28	1.25	1.13	747	87	81	78	53	52	51	46
	LNG	4.08	3.18	83.09	49.10	0.00	0.05	0.06	0.09	0.07	0.07	0.06	0.10	0	2	2	4	3	3	2	4

	MDO	3.88	3.40	90.77	42.70	43.29	21.43	23.47	25.57	26.71	26.53	28.34	29.16	1753	868	951	1036	1082	1074	1148	1181
	Methanol	2.00	1.38	100.40	19.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0	0	0
	Total					**61.73**	**24.25**	**26.21**	**28.33**	**28.86**	**28.65**	**30.48**	**31.25**	**2,500**	**957**	**1,034**	**1,117**	**1,138**	**1,129**	**1,201**	**1,231**
	Average fleet GHG intensity (gCO2e/MJ)													**91.06**	**90.84**	**90.83**	**90.81**	**90.79**	**90.79**	**90.79**	**90.78**
	Total fleet WtW CO2e (Mt)													**228**	**87**	**94**	**101**	**103**	**103**	**109**	**112**
Fishing	HFO	3.72	3.17	91.74	40.50	0.48	0.17	0.16	0.19	0.15	0.16	0.15	0.14	20	7	6	8	6	6	6	6
	LNG	4.08	3.18	83.09	49.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0	0	0
	MDO	3.88	3.40	90.77	42.70	5.30	11.61	11.79	12.34	12.86	13.38	12.27	12.35	215	470	477	500	521	542	497	500
	Methanol	2.00	1.38	100.40	19.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0	0	0
	Total					**5.78**	**12.12**	**12.30**	**12.90**	**13.39**	**13.94**	**12.78**	**12.86**	**234**	**477**	**484**	**507**	**527**	**548**	**503**	**506**
	Average fleet GHG intensity (gCO2e/MJ)													**90.85**	**90.78**	**90.78**	**90.78**	**90.78**	**90.78**	**90.78**	**90.78**
	Total fleet WtW CO2e (Mt)													**21**	**43**	**44**	**46**	**48**	**50**	**46**	**46**

Source: all the fuel consumption data (non-highlighted cells) are provided by the IMO 4th GHG study (table 34, page 97). Blue highlighted cells are calculated by T&E using the FUEM WtW default factors. 2008 fuel consumption data is back-calculated from the 3rd IMO GHG study's CO_2 emissions breakdown table 29, page 84 and CO_2 emissions factors from table 34 (i.e. 3.114 for HFO, 3.206 for MGO and 2.75 for LNG - all in gCO2/gfuel terms). For LNG fuel GHG intensity, we assume the average of the 3 available engine technologies, i.e. DF LP - 4stroke, DF LP - 2 stroke, DF HP - 2 stroke.

Table A.I.2: Adjusted WtW emissions projections and relative emissions growth with regard to 2018 levels.

T&E estimated WtW emissions projections based on gravity model - International (Mt CO2e) †								
	2018	2020	2025	2030	2035	2040	2045	2050
SSP1_RCP19_G	1,089	1,115	1,126	1,114	1,115	1,127	1,167	1,195
SSP1_RCP60_G	1,089	1,119	1,180	1,200	1,225	1,258	1,304	1,340
SSP2_RCP19_G	1,089	1,118	1,140	1,134	1,124	1,122	1,128	1,142
SSP2_RCP60_G	1,089	1,118	1,183	1,204	1,233	1,265	1,319	1,363
SSP3_RCP34_G	1,089	1,106	1,132	1,123	1,099	1,079	1,094	1,104
SSP3_RCP60_G	1,089	1,106	1,138	1,134	1,129	1,126	1,146	1,159
SSP4_RCP26_G	1,089	1,114	1,141	1,129	1,125	1,120	1,130	1,134
SSP4_RCP60_G	1,089	1,114	1,165	1,173	1,178	1,186	1,210	1,225
SSP5_RCP19_G	1,089	1,128	1,209	1,255	1,253	1,271	1,284	1,302
SSP5_RCP60_G	1,089	1,128	1,234	1,299	1,361	1,440	1,528	1,604
OECD_RCP26_G	1,089	1,051	1,076	1,076	1,089	1,102	1,126	1,156
OECD_RCP45_G	1,089	1,051	1,090	1,101	1,125	1,148	1,193	1,240

T&E estimated WtW emissions projections based on logistics model - International (Mt CO2e) †								
	2018	2020	2025	2030	2035	2040	2045	2050
SSP1_RCP19_L	1,089	1,075	1,146	1,223	1,320	1,474	1,621	1,782
SSP1_RCP60_L	1,089	1,095	1,199	1,296	1,404	1,567	1,718	1,881
SSP2_RCP26_L	1,089	1,118	1,193	1,258	1,318	1,411	1,500	1,597
SSP2_RCP60_L	1,089	1,120	1,211	1,286	1,360	1,468	1,585	1,707
SSP3_RCP34_L	1,089	1,135	1,203	1,251	1,250	1,272	1,307	1,336
SSP3_RCP60_L	1,089	1,135	1,208	1,260	1,281	1,322	1,362	1,396
SSP4_RCP26_L	1,089	1,126	1,196	1,253	1,307	1,394	1,460	1,531
SSP4_RCP60_L	1,089	1,114	1,165	1,173	1,178	1,186	1,210	1,225
SSP5_RCP34_L	1,089	1,163	1,328	1,495	1,684	1,964	2,207	2,481
SSP5_RCP60_L	1,089	1,163	1,332	1,503	1,705	2,000	2,264	2,558
OECD_RCP26_L	1,089	1,107	1,163	1,193	1,237	1,289	1,346	1,402
OECD_RCP45_L	1,089	1,110	1,177	1,219	1,273	1,338	1,418	1,492

† These tables convert international shipping CO2 to WtW CO2e using the conversion factors from the FuelEU Maritime (FUEM) main tables in the Annex presented in table A.I.1 above.

T&E estimated WtW emissions growth (based on gravity model) relative to 2018 baseline - International (%)								
	2018	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
SSP1_RCP19_G	0%	2%	3%	2%	2%	4%	7%	10%
SSP1_RCP60_G	0%	3%	8%	10%	13%	16%	20%	23%
SSP2_RCP19_G	0%	3%	5%	4%	3%	3%	4%	5%
SSP2_RCP60_G	0%	3%	9%	11%	13%	16%	21%	25%
SSP3_RCP34_G	0%	2%	4%	3%	1%	-1%	1%	1%
SSP3_RCP60_G	0%	2%	5%	4%	4%	3%	5%	6%
SSP4_RCP26_G	0%	2%	5%	4%	3%	3%	4%	4%
SSP4_RCP60_G	0%	2%	7%	8%	8%	9%	11%	13%
SSP5_RCP19_G	0%	4%	11%	15%	15%	17%	18%	20%
SSP5_RCP60_G	0%	4%	13%	19%	25%	32%	40%	47%
OECD_RCP26_G	0%	-4%	-1%	-1%	0%	1%	3%	6%
OECD_RCP45_G	0%	-4%	0%	1%	3%	5%	10%	14%

T&E estimated WtW emissions growth (based on logistics model) relative to 2018 baseline - International (%)								
	2018	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
SSP1_RCP19_L	0%	-1%	5%	12%	21%	35%	49%	64%
SSP1_RCP60_L	0%	1%	10%	19%	29%	44%	58%	73%
SSP2_RCP26_L	0%	3%	10%	16%	21%	30%	38%	47%
SSP2_RCP60_L	0%	3%	11%	18%	25%	35%	46%	57%
SSP3_RCP34_L	0%	4%	11%	15%	15%	17%	20%	23%
SSP3_RCP60_L	0%	4%	11%	16%	18%	21%	25%	28%
SSP4_RCP26_L	0%	3%	10%	15%	20%	28%	34%	41%
SSP4_RCP60_L	0%	2%	7%	8%	8%	9%	11%	13%
SSP5_RCP34_L	0%	7%	22%	37%	55%	80%	103%	128%
SSP5_RCP60_L	0%	7%	22%	38%	57%	84%	108%	135%
OECD_RCP26_L	0%	2%	7%	10%	14%	18%	24%	29%
OECD_RCP45_L	0%	2%	8%	12%	17%	23%	30%	37%

A.I.3. Scenario 1 | deriving potential GFS-only targets

To derive the desired GFS targets, it is important to calculate projected BAU fuel GHG intensities, which in turn requires estimating the breakdown of fuel consumption in the BAU scenario. IMO 4th GHG study does not provide the breakdown of modelled fuel consumption by international shipping, only the total CO_2 emissions. While IMO may decide to carry out a dedicated analysis of BAU fuel mix for the years between 2018 and 2050, T&E considers that the difference with 2018 values is likely to be marginal as far as the total fuel GHG intensity is concerned. This is based on the assumption that ships are unlikely to use expensive renewable fuels without necessary stringent regulatory requirements and the WtW fuel GHG intensities of the current fossil fuels are largely comparable. It is possible that ships may use some grey ammonia and grey methanol, which have considerably higher WtW emissions and WtW GHG intensities than the current fossil fuels. However, one could expect the uptake of these fuels by the new dual-fuel vessels to be relatively small in BAU making their contribution to the fleet-wide absolute WtW emissions and WtW GHG intensities relatively small.

For this reason, in this analysis we assume the BAU fuel mix to be constant beyond 2018 levels, while the total amount of energy consumed growing in proportion to the (corrected) BAU emissions projections presented in table A.I.2 above (see table A.I.3). We also estimate the fuel GHG intensity for 2018 to be 91.21 gCO_2e/MJ as the average of the individual default fuel GHG intensity values (taken from the FuelEU Maritime regulation) and weighted by the fuel mix in that year. This value is fairly similar to the 2020 baseline value of 91.16 gCO_2e/MJ as defined by the FuelEU Maritime Regulation.

In order to derive the GFS targets, in Scenario 1 we assume that IMO targets are met only by fuel switching; therefore, the GFS targets are calibrated to match the targeted absolute WtW emissions to meet the IMO levels of ambitions (i.e. -20%/-30% by 2030, -70%/-80% by 2040 and -100% by 2050 compared to 2008 baseline) as defined by the revised IMO GHG Strategy. For the years 2035 and 2045, for which no specific targets were decided on by the revised IMO GHG Strategy, we carry out linear interpolation (see table A.I.3)

It is important to note that estimation of GFS targets is affected by the definition of zero and near-zero emissions fuels because the GFS target for 2030 will also deliver the 5-10% zero or near-zero fuel uptake goal as defined by the Revised IMO GHG Strategy. Given that the IMO strategy does not provide a concrete definition of zero or near-zero emission fuels/energy, T&E uses the assumption that near-zero emission fuels means delivering at least 90% WtW emissions reductions from 2027 onwards, at least 95% WtW emissions reductions from 2040 onwards and 100% WtW emissions reduction from 2050 onwards (see Table A.I.4). This assumption provides a reasonable transition period for the decarbonisation of the land sectors which will impact the WtT emissions performance of marine fuels.

Table A.I.3: Emissions pathways compatible with the Revised IMO GHG strategy.

		2008	2018	2020	2025	2030	2035	2040	2045	2050
						Target based	*interpolated*	*Target based*	*interpolated*	*Target based*
WtW CO2e (Mt)	IMO targets, low trade demand (OECD_RCP26_G)	1095			1076	876	602	328	164	0
	IMO targets, high trade demand (SSP2_RCP26_L)	1095			1193	876	602	328	164	0
	IMO targets, average trade demand (OECD_RCP26_G & and SSP2_RCP26_L)	1095			1135	876	602	328	164	0
						Target based	*interpolated*	*Target based*	*interpolated*	*Target based*
WtW CO2e (Mt)	IMO striving targets, low trade demand (OECD_RCP26_G)	1095			1076	766	493	219	109	0
	IMO striving targets, high trade demand (SSP2_RCP26_L)	1095			1193	766	493	219	109	0
	IMO targets, average trade demand (OECD_RCP26_G & and SSP2_RCP26_L)	1095			1135	766	493	219	109	0
WtW CO2e (Mt)	*SBTi compatible trajectory*		1089	1075	1005	698	230	42	6	0

Table A.I.4: Estimated GFS targets for scenario 1 (i.e. IMO targets being met by fuel switch only).

		2008	2018	2020	2025	2030	2035	2040	2045	2050
						Target based	*interpolated*	*Target based*	*interpolated*	*Target based*
IMO targets, low trade demand (OECD_RCP26_G)	Total energy consumption (PJ)		11,937	11,519	11,794	11,794	11,937	12,081	12,380	12,678
	GFS targets (gCO2e/MJ)		91.21			74.25	50.72	27.18	13.59	0.00
	GFS targets (% reduction below 2018)		0%			-18.6%	-44.4%	-70.2%	-85.1%	-100.0%
	Zero/near-zero GHG fuel uptake (PJ)					2,437	5,930	8,927	11,098	12,678
	Non-ZEV fuels (PJ)					9,357	6,007	3,154	1,281	0
IMO targets, high trade demand (SSP2_RCP26_L)	Total energy consumption (PJ)		11,937	12,260	13,085	13,790	14,632	15,474	16,490	17,506
	GFS targets (gCO2e/MJ)		91.21			63.50	42.36	21.22	10.61	0.00
	GFS targets (% reduction below 2018)		0%			-30.4%	-53.6%	-76.7%	-88.4%	-100.0%
	Zero/near-zero GHG fuel uptake (PJ)					4,654	8,718	12,499	15,413	17,506
	Non-ZEV fuels (PJ)					9,135	5,914	2,975	1,077	0
IMO targets, average trade demand (OECD_RCP26_G & SSP2_RCP26_L)	Total energy consumption (PJ)		11,937	11,890	12,439	12,792	13,285	13,778	14,435	15,092
	GFS targets (gCO2e/MJ)		91.21			68.46	46.15	23.83	11.92	0.00
	GFS targets (% reduction below 2018)		0%			-24.9%	-49.4%	-73.9%	-86.9%	-100.0%
	Zero/near-zero GHG fuel uptake (PJ)					3,546	7,324	10,713	13,256	15,092
	Non-ZEV fuels (PJ)					9,246	5,961	3,065	1,179	0

		2008	2018	2020	2025	2030	2035	2040	2045	2050
						Target based	*interpolated*	*Target based*	*interpolated*	*Target based*
IMO striving targets, low trade demand (OECD_RCP26_G)	Total energy consumption (PJ)		11,937			11,794	11,937	12,081	12,380	12,678
	GFS targets (gCO2e/MJ)		91.21			64.97	41.54	18.12	9.06	0.00
	GFS targets (% reduction below 2018)		0%			-28.8%	-54.5%	-80.1%	-90.1%	-100.0%
	Zero/near-zero GHG fuel uptake (PJ)					2,437	5,930	8,927	11,098	12,678
	Non-ZEV fuels (PJ)					9,357	6,007	3,154	1,281	0
IMO striving targets, high trade demand (SSP2_RCP26_L)	Total energy consumption (PJ)		11,937			13,790	14,632	15,474	16,490	17,506
	GFS targets (gCO2e/MJ)		91.21			55.57	34.86	14.15	7.07	0.00
	GFS targets (% reduction below 2018)		0%			-39%	-62%	-84%	-92%	-100%
	Zero/near-zero GHG fuel uptake (PJ)					4,654	8,718	12,499	15,413	17,506
	Non-ZEV fuels (PJ)					9,135	5,914	2,975	1,077	0
IMO striving targets, average trade demand (OECD_RCP26_G & SSP2_RCP26_L)	Total energy consumption (PJ)		11,937	11,890	12,439	12,792	13,285	13,778	14,435	15,092
	GFS targets (gCO2e/MJ)		91.21			59.90	37.90	15.89	7.94	0.00
	GFS targets (% reduction below 2018)		0%			-34.3%	-58.5%	-82.6%	-91.3%	-100.0%
	Zero/near-zero GHG fuel uptake (PJ)					4,879	8,657	11,976	13,887	15,092
	Non-ZEV fuels (PJ)					7,913	4,627	1,801	548	0
SBTi, average trade demand (OECD_RCP26_G & SSP2_RCP26_L)	Total energy consumption (PJ)		11,937	11,790	11,016	12,792	13,285	13,778	14,435	15,092
	GFS targets (gCO2e/MJ)		91.21			54.60	28.82	3.04	1.52	0.00
	GFS targets (% reduction below 2018)		0%			-40.1%	-68.4%	-96.7%	-98.3%	-100.0%
	Zero/near-zero GHG fuel uptake (PJ)					5,706	11,859	14,019	15,076	15,092
	Non-ZEV fuels (PJ)					7,086	1,426	-242	-641	0

Table A.I.5: WtW GHG intensities of different marine fuels *(* assumes zero emissions TtW energy source)*

Fuel name (short labels)	Notes	Gravimetric density -LCV (MJ/kg)	WTW (gCO2e/MJ)	WTW (gCO2e/g_fuel)	TTW (gCO2e/MJ)	TTW total (gCO2e/g_fuel)
HFO	HFO ISO 8217 Grades RME to RMK (min)	40.50	91.74	3.72	78.24	3.17
Fuel Oil (VLSFO)	VLSFO	41.00	92.73	3.80	79.53	3.26
MDO/MGO	MDO MGO ISO 8217 Grades DMX to DMB	42.70	90.77	3.88	79.53	3.40
Fossil LNG (DF LP- 4 stroke)	LNG (DF low-pressure 4 stroke)	49.10	89.22	4.38	70.75	3.47
Fossil LNG (DF LP 2 stroke)	LNG (DF low-pressure 2 stroke)	49.10	82.94	4.07	64.47	3.17
Fossil LNG (DF HP 2 stroke)	LNG (DF high-pressure 2 stroke)	49.10	77.11	3.79	58.90	2.89
Grey Methanol	Methanol (natural gas)	19.90	100.40	2.00	69.10	1.38
Biodiesel (waste cooking oil)	Waste cooking oil biodiesel	37.20	16.38	0.61		
Bio-LNG (DFHP 2 stroke)	Bio-LNG	49.10	20.74	1.02		
e-Methanol *	Assuming zero-emissions TtW values	19.90	2.76	0.05		
e-LNG (DF LP- 4 stroke)*	Assuming zero-emissions TtW values	49.10	14.58	0.72		
e-LNG (DF LP 2 stroke) *	Assuming zero-emissions TtW values	49.10	8.30	0.41		
e-LNG (DF HP 2 stroke) *	Assuming zero-emissions TtW values	49.10	1.55	0.08		
e-Ammonia *	Assuming zero-emissions TtW values	18.60	8.28	0.15		
e-Diesel *	Assuming zero-emissions TtW values	42.70	1.29	0.06		
Placeholder near-zero GHG fuel	Delivering "90%" emissions reduction compared to 2018 IMO baseline		9.12			
Placeholder near-zero GHG fuel	Delivering "95%" emissions reduction compared to 2018 IMO baseline		4.56			
Placeholder zero GHG fuel	Delivering "100%" emissions reduction compared to 2018 IMO baseline		0.00			
FuelEU 2020 baseline			**91.16**			
(Suggested) IMO 2018 baseline			**91.21**			

A.I.4. Scenario 2 | combining GFS with "*improved*" and "*transformed*" CII

This scenario assumes that ships meet 10% near-zero emissions fuels targets by 2030 by fuel switching, while the delta between emissions reductions achieved by the fuel switch and targeted emissions (to be in line with the IMO levels of ambitions) are achieved by energy efficiency improvements. To that end, the modelling takes place in 2 steps: we first iteratively identify a *value* for the total amount of emissions savings from energy efficiency that needs to be achieved in combination with the 10% by energy content of green fuels uptake in order to reach the IMO levels of ambition for the year 2030. The said value for energy efficiency is defined as a *percentage of emissions* reductions vis-à-vis 2008 that can be achieved through energy efficiency. It is assumed that energy efficiency options, such as speed optimization and wind-assist uptake are more cost-effective than fuel switching, hence the *delta* mentioned above are delivered by these options.

In a second step, the model calculates the absolute contributions of emissions savings associated with fuel switch and energy efficiency, as well as the required WtW CII improvements and TtW energy efficiency improvements. Once 2030 emissions balance is achieved, the modelling assumes constant energy efficiency for the following years (with regard to 2008 baseline), and automatically derives the amount of zero/near-zero emissions fuels uptake needed to meet the levels of ambitions (i.e. absolute emissions reductions) of the IMO Revised GHG Strategy (see table A.I.6).[5]

WtW CII is calculated as a quotient of the targeted WtW absolute emissions and the projected transport work. Energy efficiency targets are calculated as a quotient of the projected total energy consumption by shipping (after accounting for the reduction in fuel consumption thanks to energy efficiency) and the projected transport work from shipping. The latter is taken from tables 36 and 40 of the 4th IMO GHG Study. This analysis delivers 6 different potential pathways taking into account low, high and average trade demand growth projections and the base and striving IMO targets in the Revised GHG Strategy.

[5] Except for the low trade growth scenario (OECD_RCP26_G), which assumes further energy efficiency improvement potential between 2030 and 2040.

Table A.I.6: Combining GFS with WtW CII or TtW energy efficiency index for low, high and average trade demand projections and different IMO targets

		2008	2018	2020	2025	2030	2035	2040	2045	2050
						Target based	*interpolated*	*Target based*	*interpolated*	*Target based*
IMO (base) targets, low trade demand (OECD_RCP26_G)	BAU emissions (Mt CO2e)	1095	1089	1051	1076	1076	1089	1102	1126	1156
	Targeted emissions (Mt CO2e)	1095	1089	1051	1076	876	602	328	164	0
	Assumed energy efficiency needs/potential (% wrt 2018)					10%	15%	20%	20%	20%
	GHG savings from energy efficiency (CO2e)					109	164	219	219	219
	GHG savings from fuel switch (Mt CO2e)					91	323	555	743	937
	Zero/near-zero fuel GHG intensity (gCO2e/MJ)					9.12	9.12	4.56	4.56	0.00
	Non-ZEV fuel GHG intensity (gCO2e/MJ)		91.21			91.21	91.21	91.21	91.21	91.21
	Total energy consumption (PJ)		11,937	11,519	11,794	10,594	10,137	9,681	9,972	10,278
	Zero/near-zero GHG fuel uptake (PJ)		0			1,104	3,930	6,400	8,572	10,278
	Non-ZEV fuels (PJ)		11,937			9,490	6,207	3,280	1,400	0
	Zero/Near-zero GHG fuel uptake (%)					10%	39%	66%	86%	100%
	Average fuel GHG intensity (gCO2e/Gj)					82.66	59.39	33.92	16.73	0.00
	GFS targets (% reduction below 2018)					-9%	-35%	-63%	-82%	-100%
	Transport work (billion tonne-miles)		59,230	57,679	62,826	67,471	71,613	75,799	79,073	82,464
	CII - EEOI (gCO2e/t-nm)		18.38	18.22	17.12	12.98	8.41	4.33	2.08	0.00
	CII - EEOI improvement wrt 2018 (%)		0.0%	-0.9%	-6.9%	-29.4%	-54.3%	-76.4%	-88.7%	-100.0%
	Energy efficiency index (MJ/t-nm)		0.202	0.200	0.188	0.157	0.142	0.128	0.126	0.125
	Energy efficiency improvement wrt 2018 (%)		0.0%	-0.9%	-6.9%	-22.1%	-29.8%	-36.6%	-37.4%	-38.2%

		2008	2018	2020	2025	2030	2035	2040	2045	2050
						Target based	*interpolated*	*Target based*	*interpolated*	*Target based*
IMO (base) targets, high trade demand (SSP2_RCP26_L)	BAU emissions (Mt CO2e)	1095	1089	1118	1193	1258	1318	1411	1500	1597
	Targeted emissions (Mt CO2e)	1095	1089	1118	1193	876	602	328	164	0
	Assumed energy efficiency needs/potential (% wrt 2018)					27%	27%	27%	27%	27%
	GHG savings from energy efficiency (CO2e)					296	296	296	296	296
	GHG savings from fuel switch (Mt CO2e)					87	420	788	1040	1301
	Zero/near-zero fuel GHG intensity (gCO2e/MJ)					9.12	9.12	4.56	4.56	0.00
	Non-ZEV fuel GHG intensity (gCO2e/MJ)		91.21			91.21	91.21	91.21	91.21	91.21
	Total energy consumption (PJ)		11,937	12,260	13,085	10,549	11,350	12,234	13,240	14,266
	Zero/near-zero GHG fuel uptake (PJ)		0			1,054	5,118	9,088	12,002	14,266
	Non-ZEV fuels (PJ)		11,937			9,495	6,232	3,146	1,238	0
	Zero/Near-zero GHG fuel uptake (%)					10%	45%	74%	91%	100%
	Average fuel GHG intensity (gCO2e/Gj)					83.01	54.20	26.84	12.67	0.00
	GFS targets (% reduction below 2018)					-9%	-41%	-71%	-86%	-100%
	Transport work (billion tonne-miles)		59,230	57,679	62,826	67,471	71,613	75,799	79,073	82,464
	CII - EEOI (gCO2e/t-nm)		18.38	19.39	19.00	12.98	8.41	4.33	2.08	0.00
	CII - EEOI improvement wrt 2018 (%)		0.0%	5.5%	3.3%	-29.4%	-54.3%	-76.4%	-88.7%	-100.0%
	Energy efficiency index (MJ/t-nm)		0.202	0.213	0.208	0.156	0.158	0.161	0.167	0.173
	Energy efficiency improvement wrt 2018 (%)		0.0%	5.5%	3.3%	-22.4%	-21.4%	-19.9%	-16.9%	-14.2%

		2008	2018	2020	2025	2030	2035	2040	2045	2050
						Target based	*interpolated*	*Target based*	*interpolated*	*Target based*
IMO (base) targets, average trade demand (OECD_RCP26_G & SSP2_RCP26_L)	BAU emissions (Mt CO2e)	1095	1089	1084	1135	1167	1203	1257	1313	1377
	Targeted emissions (Mt CO2e)	1095	1089	1084	1135	876	602	328	164	0
	Assumed energy efficiency needs/potential (% wrt 2018)					*19%*	*19%*	*19%*	*19%*	*19%*
	GHG savings from energy efficiency (CO2e)					**208**	**208**	**208**	**208**	**208**
	GHG savings from fuel switch (Mt CO2e)					**83**	**393**	**720**	**941**	**1169**
	Zero/near-zero fuel GHG intensity (gCO2e/MJ)					9.12	9.12	4.56	4.56	0.00
	Non-ZEV fuel GHG intensity (gCO2e/MJ)		91.21			91.21	91.21	91.21	91.21	91.21
	Total energy consumption (PJ)		11,937	11,890	12,439	10,512	10,989	11,497	12,148	12,812
	Zero/near-zero GHG fuel uptake (PJ)		0			1,012	4,791	8,313	10,855	12,812
	Non-ZEV fuels (PJ)		11,937			9,499	6,198	3,185	1,293	0
	Zero/Near-zero GHG fuel uptake (%)					*10%*	*44%*	*72%*	*89%*	*100%*
	Average fuel GHG intensity (gCO2e/Gj)					**83.31**	**55.42**	**28.56**	**13.78**	**0.00**
	GFS targets (% reduction below 2018)					-9%	-39%	-69%	-85%	-100%
	Transport work (billion tonne-miles)		59,230	57,679	62,826	67,471	71,613	75,799	79,073	82,464
	CII - EEOI (gCO2e/t-nm)		**18.38**	**18.80**	**18.06**	**12.98**	**8.41**	**4.33**	**2.08**	**0.00**
	CII - EEOI improvement wrt 2018 (%)		0.0%	2.3%	-1.8%	-29.4%	-54.3%	-76.4%	-88.7%	-100.0%
	Energy efficiency index (MJ/t-nm)		**0.202**	**0.206**	**0.198**	**0.156**	**0.153**	**0.152**	**0.154**	**0.155**
	Energy efficiency improvement wrt 2018 (%)		0.0%	2.3%	-1.8%	-22.7%	-23.9%	-24.7%	-23.8%	-22.9%

		2008	2018	2020	2025	2030	2035	2040	2045	2050
						Target based	*interpolated*	*Target based*	*interpolated*	*Target based*
IMO striving targets, low trade demand (OECD_RCP26_G)	BAU emissions (Mt CO2e)	1095	1089	1051	1076	1076	1089	1102	1126	1156
	Targeted emissions (Mt CO2e)	1095	1089	1051	1076	766	493	219	109	0
	Assumed energy efficiency needs/potential (% wrt 2018)					21%	21%	21%	21%	21%
	GHG savings from energy efficiency (CO2e)					230	230	230	230	230
	GHG savings from fuel switch (Mt CO2e)					80	366	653	787	927
	Zero/near-zero fuel GHG intensity (gCO2e/MJ)					9.12	9.12	4.56	4.56	0.00
	Non-ZEV fuel GHG intensity (gCO2e/MJ)		91.21			91.21	91.21	91.21	91.21	91.21
	Total energy consumption (PJ)		11,937	11,519	11,794	9,274	9,417	9,561	9,852	10,158
	Zero/near-zero GHG fuel uptake (PJ)		0			970	4,463	7,537	9,077	10,158
	Non-ZEV fuels (PJ)		11,937			8,304	4,954	2,023	775	0
	Zero/Near-zero GHG fuel uptake (%)					10%	47%	79%	92%	100%
	Average fuel GHG intensity (gCO2e/GJ)					82.62	52.31	22.90	11.37	0.00
	GFS targets (% reduction below 2018)					-9%	-43%	-75%	-88%	-100%
	Transport work (billion tonne-miles)		59,230	57,679	62,826	67,471	71,613	75,799	79,073	82,464
	CII - EEOI (gCO2e/t-nm)		18.38	18.22	17.12	11.36	6.88	2.89	1.38	0.00
	CII - EEOI improvement wrt 2018 (%)		0.0%	-0.9%	-6.9%	-38.2%	-62.6%	-84.3%	-92.5%	-100.0%
	Energy efficiency index (MJ/t-nm)		0.202	0.200	0.188	0.137	0.132	0.126	0.125	0.123
	Energy efficiency improvement wrt 2018 (%)		0.0%	-0.9%	-6.9%	-31.8%	-34.8%	-37.4%	-38.2%	-38.9%

		2008	2018	2020	2025	2030	2035	2040	2045	2050
						Target based	*interpolated*	*Target based*	*interpolated*	*Target based*
IMO striving targets, high trade demand (SSP2_RCP26_L)	BAU emissions (Mt CO2e)	1095	1089	1118	1193	1258	1318	1411	1500	1597
	Targeted emissions (Mt CO2e)	1095	1089	1118	1193	766	493	219	109	0
	Assumed energy efficiency needs/potential (% wrt 2018)					38%	38%	38%	38%	38%
	GHG savings from energy efficiency (CO2e)					416	416	416	416	416
	GHG savings from fuel switch (Mt CO2e)					76	409	777	974	1181
	Zero/near-zero fuel GHG intensity (gCO2e/MJ)					9.12	9.12	4.56	4.56	0.00
	Non-ZEV fuel GHG intensity (gCO2e/MJ)		91.21			91.21	91.21	91.21	91.21	91.21
	Total energy consumption (PJ)		11,937	12,260	13,085	9,229	10,013	10,914	11,917	12,945
	Zero/near-zero GHG fuel uptake (PJ)		0			921	4,985	8,962	11,244	12,945
	Non-ZEV fuels (PJ)		11,937			8,308	5,029	1,952	672	0
	Zero/Near-zero GHG fuel uptake (%)					10%	50%	82%	94%	100%
	Average fuel GHG intensity (gCO2e/Gj)					83.02	50.35	20.06	9.45	0.00
	GFS targets (% reduction below 2018)					-9%	-45%	-78%	-90%	-100%
	Transport work (billion tonne-miles)		59,230	57,679	62,826	67,471	71,613	75,799	79,073	82,464
	CII - EEOI (gCO2e/t-nm)		18.38	19.39	19.00	11.36	6.88	2.89	1.38	0.00
	CII - EEOI improvement wrt 2018 (%)		0.0%	5.5%	3.3%	-38.2%	-62.6%	-84.3%	-92.5%	-100.0%
	Energy efficiency index (MJ/t-nm)		0.202	0.213	0.208	0.137	0.140	0.144	0.151	0.157
	Energy efficiency improvement wrt 2018 (%)		0.0%	5.5%	3.3%	-32.1%	-30.6%	-28.6%	-25.2%	-22.1%

		2008	2018	2020	2025	2030	2035	2040	2045	2050
						Target based	*interpolated*	*Target based*	*interpolated*	*Target based*
IMO striving targets, average trade demand (OECD_RCP26_G & SSP2_RCP26_L)	BAU emissions (Mt CO2e)	1095	1089	1084	1135	1167	1203	1257	1313	1377
	Targeted emissions (Mt CO2e)	1095	1089	1084	1135	766	493	219	109	0
	Assumed energy efficiency needs/potential (% wrt 2018)					*30%*	*30%*	*30%*	*30%*	*30%*
	GHG savings from energy efficiency (CO2e)					**328**	**328**	**328**	**328**	**328**
	GHG savings from fuel switch (Mt CO2e)					**72**	**382**	**709**	**875**	**1048**
	Zero/near-zero fuel GHG intensity (gCO2e/MJ)					9.12	9.12	4.56	4.56	0.00
	Non-ZEV fuel GHG intensity (gCO2e/MJ)		91.21			91.21	91.21	91.21	91.21	91.21
	Total energy consumption (PJ)		11,937	11,890	12,439	9,192	9,659	10,177	10,824	11,492
	Zero/near-zero GHG fuel uptake (PJ)		0			879	4,657	8,187	10,098	11,492
	Non-ZEV fuels (PJ)		11,937			8,313	5,002	1,991	727	0
	Zero/Near-zero GHG fuel uptake (%)					*10%*	*48%*	*80%*	*93%*	*100%*
	Average fuel GHG intensity (gCO2e/Gj)					**83.36**	**51.63**	**21.51**	**10.38**	**0.00**
	GFS targets (% reduction below 2018)					-9%	-43%	-76%	-89%	-100%
	Transport work (billion tonne-miles)		59,230	57,679	62,826	67,471	71,613	75,799	79,073	82,464
	CII - EEOI (gCO2e/t-nm)		**18.38**	**18.80**	**18.06**	**11.36**	**6.88**	**2.89**	**1.38**	**0.00**
	CII - EEOI improvement wrt 2018 (%)		0.0%	2.3%	-1.8%	-38.2%	-62.6%	-84.3%	-92.5%	-100.0%
	Energy efficiency index (MJ/t-nm)		**0.202**	**0.206**	**0.198**	**0.136**	**0.135**	**0.134**	**0.137**	**0.139**
	Energy efficiency improvement wrt 2018 (%)		0.0%	2.3%	-1.8%	-32.4%	-33.1%	-33.4%	-32.1%	-30.9%

Further information

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