Shipping GHG emissions 2030

Analysis of the maximum technical abatement potential

CE Delft

Committed to the Environment

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Summary

As an input for the negotiations on the revision of the Initial IMO Strategy on the Reduction of GHG Emissions from Ships, CE Delft has analysed the maximum technical abatement potential for international shipping by 2030.

The maximum technical abatement potential is defined as the emission reduction that could be realised if all ships in the world fleet would use all technical and operational abatement options from the CE-Ship model, including:
- the wind-assisted propulsion option with the largest efficiency improvement (which may vary per ship);
- 20 or 30% speed reduction relative to 2018 (for those ship types where such a speed reduction results in a reduction of GHG emissions, after taking into account that the fleet will need to increase to provide the same amount of transport work as in BAU); and
- 5-10% of the energy is derived from zero-GHG fuels.

The report concludes that it is technically possible to reduce shipping emissions by 28-47% by 2030, relative to 2008, under the assumptions listed above. This amounts to approximately 175–350 Mt CO_2e on a WtW basis per annum, depending on the BAU emissions in 2030. When introduced gradually from 2025, the measures could avoid cumulative emissions of 500–1,000 Mt CO_2e.

About half of the emission reductions result from lower speeds and other operational measures, a quarter from wind-assisted propulsion and other technical measures and another quarter from using zero and near-zero-GHG fuels.

Implementing these measures would increase shipping costs by 6-14% on average, relative to BAU.

1 Introduction

In 2018, the IMO adopted its Initial IMO Strategy on the Reduction of GHG Emissions from Ships (IMO, 2018). The Initial Strategy contains, amongst others, a vision to phase our GHG emissions from ships; levels of ambition for the carbon intensity of shipping as well as for emissions reductions; a list of candidate measures; and a section on impacts on States.

The initial Strategy contains the ambition to reduce GHG emissions of shipping by at least 50% by 2050, relative to 2008, ‘as a point on a pathway of CO_2 emissions reduction consistent with the Paris Agreement temperature goals’.

In July 2023, a Revised Strategy is planned to be adopted. One of the main issues left to agree upon are the levels of ambition on absolute GHG emissions from shipping, not only for 2050 but also for 2030 and 2040. Many delegations have proposed to include the ambition to decarbonise shipping by 2050. For 2030, delegations have proposed emission reductions ranging between 29 and 50% relative to 2008, and for 2040 50 to 96%.

As input for the negotiations, Transport & Environment, Seas at Risk, Ocean Conservancy and Pacific Environment have asked CE Delft to estimate the maximum technical abatement potential in 2030 and the minimal remaining GHG emissions from shipping.

The aim of this project is to quantitatively analyse shipping GHG emission trajectories towards 2030 which yield the lowest technically possible emissions of 2030.

This report analyses GHG emissions of *international* shipping and focusses on emissions from fuel combustion on a WtW basis.

2 Methodology

We have modelled the shipping emissions with CE-Ship, CE Delft's proprietary GHG emissions model of the global shipping sector (Textbox 1). Based on the 2018 fleet baseline and transport work projections, both derived from the Fourth IMO Greenhouse Gas Study (Faber et al., 2020), this model projects fleet developments, emissions, capex, non-fuel opex and fuel costs out to 2050.

Textbox 1 - The CE-Ship model

CE-Ship has been designed to project and analyse shipping GHG emissions and fleet developments under a wide range of BAU and abatement scenarios.

The model contains information on 70 ship type/size combinations, and the techno-economic information on 8 operational efficiency measures; 21 technical efficiency measures; 10 types of low- and zero-GHG fuels used in either internal combustion engines and in fuel cells.

The model takes into account global and regional regulation which is in force (e.g. the EEDI, EEXI and CII) and can evaluate the impacts of economic and technical policy measures on emissions, costs and on the fleet.

CE-Ship has been used, amongst others, to support work of the UK Climate Change Committee (2011), the European Commission DG CLIMA (2009); the IMO (2014 and 2020); and the UK Department for Transport (2019).

For this study, 10 model runs have been made, namely 2 BAU model runs and for each BAU scenario 4 abatement scenarios.

The BAU scenarios and abatement scenarios have the following specifications:

1. Two BAU runs from Faber et al., (2020) representing maritime transport demand compatible with a 1.5 degrees pathway. We have selected the highest (SSP2-RCP2.6-L) and lowest (OECD-RCP2.6-G) transport demand of the BAU runs.
2. For each of these BAU runs, additional runs with the following specifications:
   a All operational and technical efficiency options in the model switched on; combined with:
      - Speed reduction:
         - a 20% reduction of 2018 average speed values (taking into account the emissions from additional ships that may be needed to provide the same level of transport work);
         - a 30% reduction of 2018 average speed values (taking into account the emissions from additional ships that may be needed to provide the same level of transport work).

   b And additional uptake of zero-emission fuels:
      - 5% zero-GHG fuel with the lowest TCO increase (100% green ammonia in an ICE engine);
      - 10% zero-GHG fuel with the lowest TCO increase (100% green ammonia in an ICE engine).

Thus, we arrive at 8 abatement scenario runs as shown in Table 1.

Table 1 - Overview of abatement scenario runs

	Low demand		**High demand**	
	20% speed reduction	30% speed reduction	20% speed reduction	30% speed reduction
5% zero-GHG fuels	I	II	V	VI
10% zero-GHG fuels	III	IV	VII	VIII

Apart from CE-Ship, we have deployed the TCO model that has also been used in ABS et al., (2022). Using the costs results per scenario as calculated in CE-Ship (CAPEX, OPEX, energy costs, energy use), we calculate the total costs of ownership in this model.

We have assumed that the zero-GHG used fuel is ammonia, which is used for dual fuel engines on all ships. In other words, we assume that the CAPEX costs of installing a dual fuel engine applies to all ships. The energy costs are calculated according to the relative share of HFO and zero-GHG fuels.

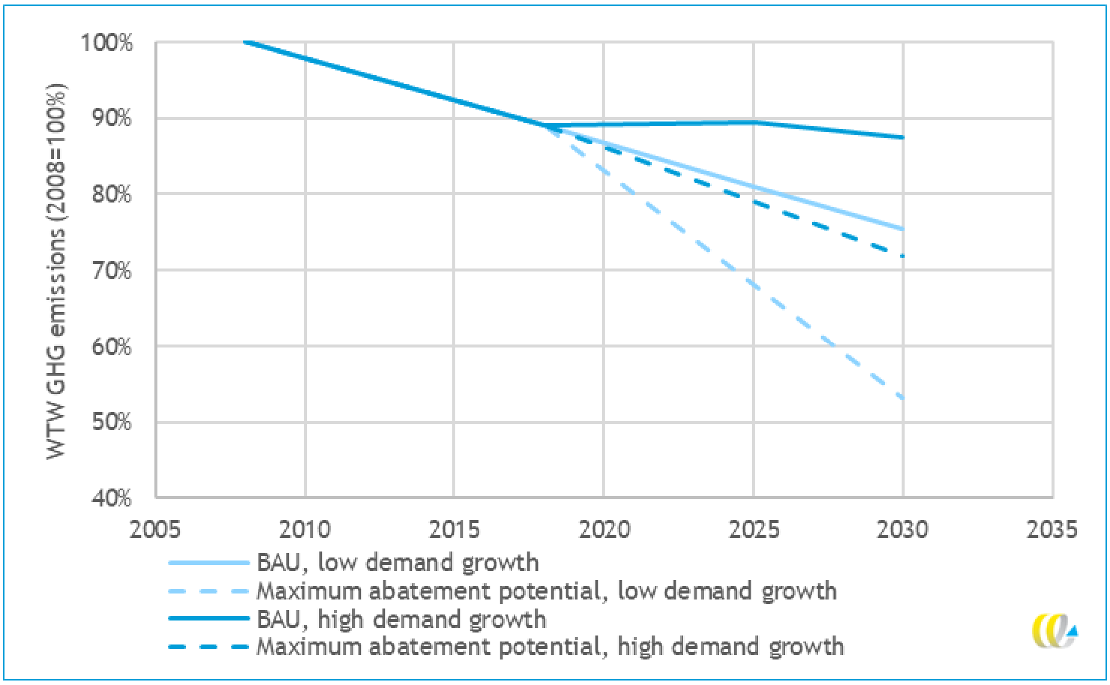
In the TCO analysis, we take into account the increased CAPEX and OPEX costs due to extra ships needed for the same amount of transport, when 20 or 30% speed reduction is implemented. Furthermore, the energy savings that result from the speed reduction are taken into account. Lastly, the costs for all other measures such as wind propulsion systems are included.

3 Maximum technical abatement potential in 2030

Main results

For each of the abatement scenarios as described above, the resulting total maritime shipping GHG emissions in 2030 have been calculated. Figure 1 presents the GHG reduction as a consequence of these policies, relative to the emissions in 2008 and to the BAU scenarios. The maximum technical abatement potential ranges from 28 to 47% of the 2008 emissions, which is equivalent 17 to 30% reduction relative to 2030 emissions in the BAU scenarios.

Figure 1 – 4 projections of the total GHG emissions of the global maritime shipping sector to 2030: For high demand and low demand growth scenarios, both the BAU scenario and the maximum abatement potential is plotted



Abatement potential per scenario

Table 2 and Table 3 give the individual results of each abatement scenario as a reduction relative to 2008 GHG emissions (Table 2), and as a reduction relative to the BAU scenario relevant to the specific abatement scenario (Table 3). Concretely, this means abatement scenarios I to IV are calculated relative to the low demand scenarios, and abatement scenarios V to VIII are calculated relative to the high demand scenarios.

The highest reduction percentages result from the abatement scenarios with most drastic measures: consistently, 10% zero-GHG fuel leads to more reduction than 5% zero-GHG fuel. Likewise, 30% speed reduction always leads to more GHG abatement than 20% speed reduction. Furthermore, more GHG reduction is achieved in a low demand growth scenario, as less shipping and hence less GHG emissions are present, compared to a high demand growth scenario.

Table 2 - GHG reduction of the abatement scenario's, compared to 2008 GHG emissions

	Low demand growth OECD-RCP2.6-G		High demand growth SSP2-RCP2.6-L	
Share zero-GHG fuels (GJ/GJ)	**5%**	**10%**	**5%**	**10%**
20% speed reduction relative to 2018	38%	41%	28%	32%
30% speed reduction relative to 2018	44%	47%	36%	39%

Table 3 - GHG reduction of the abatement scenario's, compared to the GHG emissions according to the BAU scenarios in 2030. I.e. the four lefter values are relative to the low demand growth, while the four righter values are relative to the high demand growth

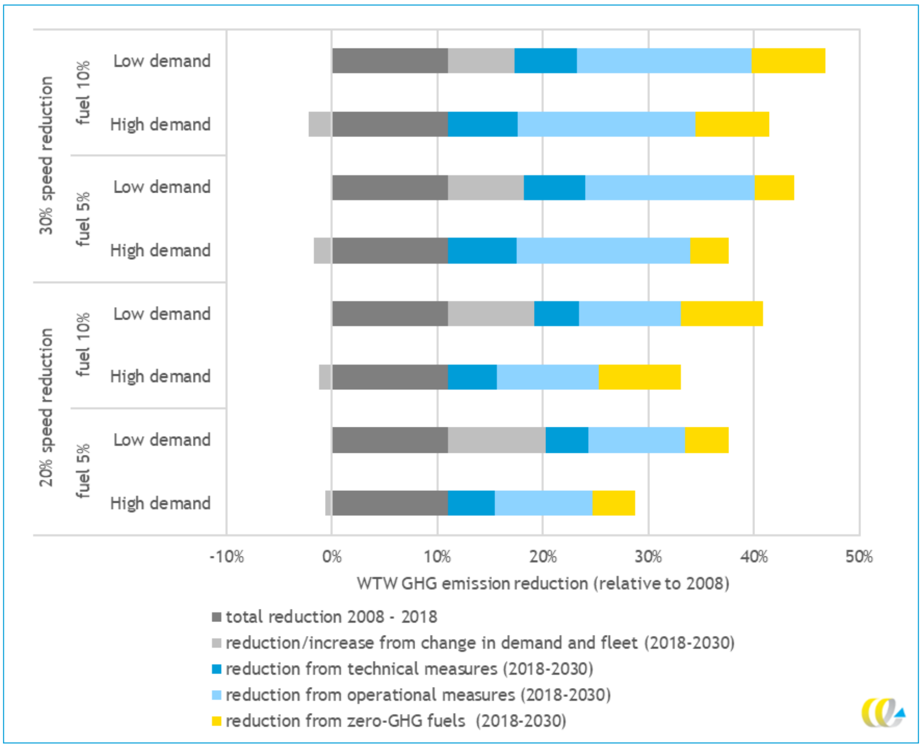
	Low demand growth OECD-RCP2.6-G		High demand growth SSP2-RCP2.6-L	
Share zero-GHG fuels (GJ/GJ)	**5%**	**10%**	**5%**	**10%**
20% speed reduction relative to 2018	17%	22%	18%	22%
30% speed reduction relative to 2018	26%	30%	27%	30%

Abatement potential per measure group

The reduction potential in 2030 can be divided into five different contributors. First, a part of the reduction is due to technical measures. In the abatement scenarios as presented here, these effects are mainly a consequence of the installations of wind-assisted propulsion systems on ships. Second, GHG is reduced by operational measures, for which the 20 and 30% speed reduction in the abatement scenario's is the main contributor. Third, the implementation of zero-GHG fuels is another source of GHG reduction. Fourth, the change in demand and fleet size can cause an increase or decrease in GHG emissions.

In our model, the contributions of these four sources of GHG reduction can be distinguished in the projection years 2018 to 2030. Considering the abatement potential in 2030 relative to 2008 however, a significant part of the total reduction is already an effect of measures in the years 2008 to 2018. Because this reduction cannot in the current model be analysed in terms of the previous three contributions, it forms a fifth independent contribution.

Figure 2 - The abatement potential in 2030 relative to 2008 for each scenario, split up into contributions of technical measures, operational measures, the implementation of zero-GHG fuel, the reduction in the period 2008-2018 and the reduction or increase due the change in demand and fleet growth



The resulting distribution of the abatement potential per abatement scenario is given in Figure 2. For the net reduction numbers, see Table 2. The GHG reduction in the years 2008 to 2018 is 11% in all scenarios. For 2018 to 2030, the demand and growth in fleet causes either a positive or negative reduction, depending on the scenario. Of the reduction through measures, operational measures account on average for 53%, while technical measures account for 23% and zero-GHG fuels for 24%.

Unsurprisingly, the highest GHG reduction is achieved in the scenario with most radical measures: 30% speed reduction and 10% zero-GHG fuels. Since the shipping sector will grow the least in the low demand BAU scenario, in this scenario these measures lead to the highest abatement potential.

While overall, the total GHG reduction is lower in high demand scenarios, the GHG reduction of technical measures is always higher in these scenarios. This is due to the implementation of wind propulsion systems: for higher growth, there will be more ships, which will be equipped with wind propulsion systems (according to the scenarios policy). Hence, the GHG reduction due to technical measures increases.

The reduction of operational measures is mainly due to speed reduction. This shows in the results, as all abatement scenarios with 30% speed reduction have significantly more GHG reduction from operational measures than the scenarios with 20% speed reduction.

Obviously, the reduction from zero-GHG fuels increases when more zero-GHG fuel is implemented. However, 5% zero-GHG fuel leads to less than 5% GHG reduction compared to BAU, because less fuel is needed in total due to the speed reduction of either 20 or 30%.

Table 4 - The abatement potential for each abatement scenario in 2030 relative to 2008, split up into contributions of technical measures, operational measures, the implementation of zero-GHG fuel, and the reduction in the period 2008-2018

		High demand growth		Low demand growth	
	Share zero-GHG fuels (GJ/GJ)	**5%**	**10%**	**5%**	**10%**
20% speed reduction	**Total reduction relative to 2008**	**28%**	**32%**	**38%**	**41%**
2018-2030	Reduction from technical measures	4%	5%	4%	4%
2018-2030	Reduction from operational measures	9%	10%	9%	10%
2018-2030	Reduction from zero-GHG fuels	4%	8%	4%	8%
2018-2030	Reduction from change in demand and fleet	-1%	-1%	9%	8%
2008-2018	Overall reduction 2008-2018	11%	11%	11%	11%
30% speed reduction	**Total reduction relative to 2008**	**36%**	**39%**	**44%**	**47%**
2018-2030	Reduction from technical measures	6%	7%	6%	6%
2018-2030	Reduction from operational measures	16%	17%	16%	16%
2018-2030	Reduction from zero-GHG fuels	4%	7%	4%	7%
2018-2030	Reduction from change in demand and fleet	-2%	-2%	7%	6%
2008-2018	Overall reduction 2008-2018	11%	11%	11%	11%

4 Costs of achieving emission reductions

Main results

For each abatement scenario, the change in yearly TCO in 2030 is calculated, relative to the TCO of the BAU scenario in 2030. The results are given in Figure 3 and Table 5, and range from an increase of 6 to 14%.

In general, abatement scenarios with a 20% speed reductions cause a higher increase in total costs compared to 30%, and likewise for abatement scenarios with a 10% zero-GHG fuel implementation compared to 5%. As a consequence, the abatement scenario with 20% speed reduction and 10% zero-GHG fuel presents the largest costs (14% increase relative to BAU), while the scenario with 30% speed reduction and 5% zero-GHG fuels present the smallest costs (6% increase relative to BAU).

Figure 3 - Change in yearly TCO in 2030, relative to the yearly TCO 2030 of the corresponding BAU scenario

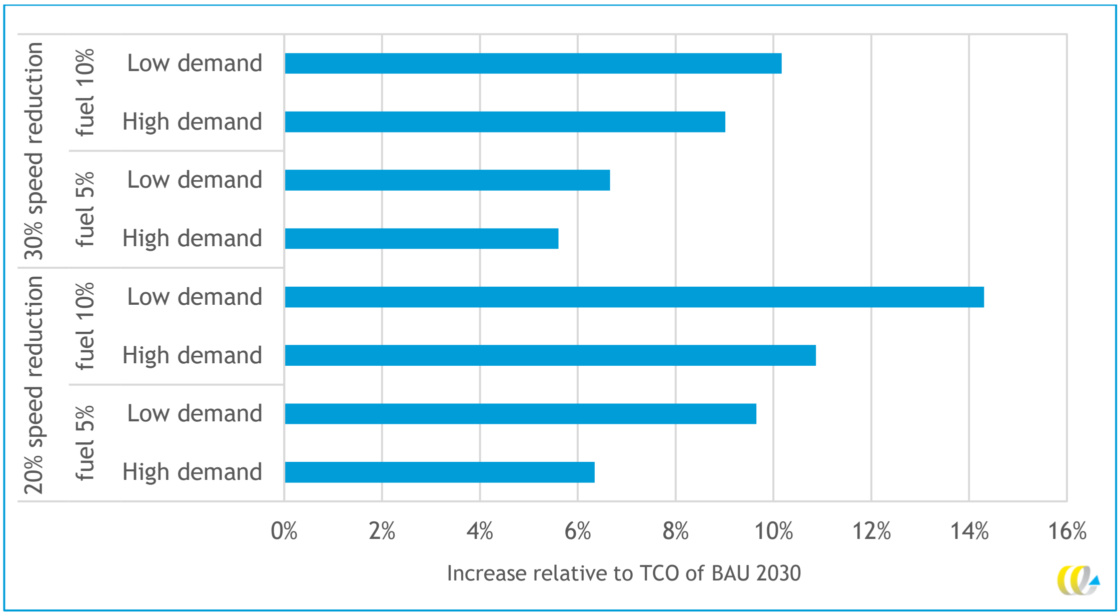


Table 5 - Change in yearly TCO in 2030, relative to the yearly TCO 2030 of the corresponding BAU scenario

	Low demand growth OECD-RCP2.6-G		High demand growth SSP2-RCP2.6-L	
Share zero-GHG fuels (GJ/GJ)	5%	10%	5%	10%
20% speed reduction relative to 2018	+10%	+14%	+6%	+11%
30% speed reduction relative to 2018	+7%	+10%	+6%	+9%

Change in costs per component

The change in yearly TCO by the abatement scenario's is due to three components that contribute to the TCO. First, policy measures cause a change in CAPEX costs, by the installation of new engines and wind propulsion systems, and by the need for more ships due to speed reduction. Second, the OPEX increases due to the recurring costs of these same installations and measures. Third, the energy costs change. On the one hand, costs increase due to the use of ammonia, which is more expensive than HFO. On the other hand a counterbalance is found by the decreased use for fuel, due to wind propulsion systems and the increased fuel use efficiency by slow steaming.

In Figure 4, the change in yearly TCO is presented for each of the abatement scenarios, broken down to the three changing main components that constitute the TCO. From this figure, we find that the increase in CAPEX and OPEX is counterbalanced by the decrease in energy costs in all scenarios.

The energy cost savings are significantly higher for scenarios with 30% speed reduction than similar scenarios with 20% speed reduction. This result derives from the fact that a higher speed reduction leads to lower demand for fuel, even when considering the additional ships necessary for the same amount of transport. Although the CAPEX and OPEX costs are also higher for 30% speed reduction, this increase is relatively lower. As a result, the net TCO change is lower for 30% speed reduction scenarios.

Additionally, scenarios with 5% zero-GHG fuel implementation typically lead to more energy cost savings than their equivalent counterparts with 10% zero-GHG fuel. The reason for this result is the higher fuel price of zero-GHG fuels, compared to HFO.

Figure 4 - Breakdown of the change in yearly TCO per abatement scenario, compared to the BAU scenarios in 2030

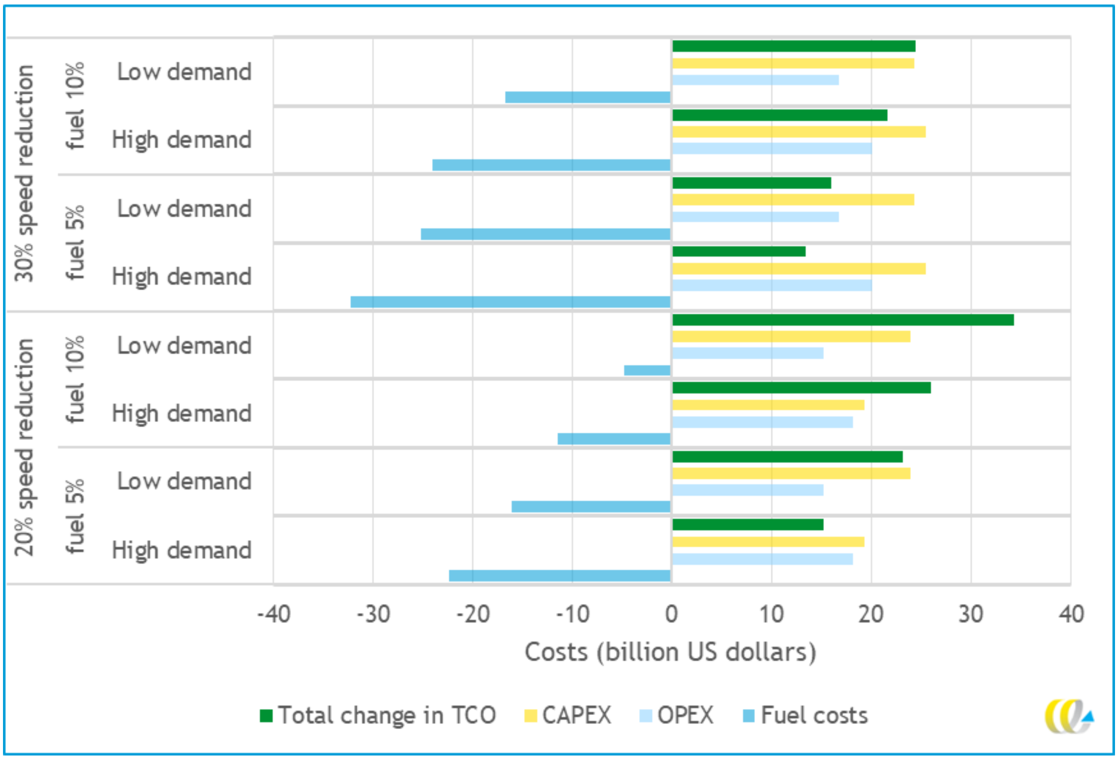


Table 6 - Change in yearly TCO in 2030 per abatement scenario, relative to BAU in 2030

	Share zero-GHG fuels (GJ/GJ)	Low demand growth				High demand growth			
		Fuel Costs	OPEX	CAPEX	Total costs	Fuel Costs	OPEX	CAPEX	Total costs
20% speed reduction relative to 2018	5%	-8%	+113%	+78%	+10%	-12%	+130%	+52%	+6%
	10%	-2%	+113%	+78%	+14%	-6%	+130%	+52%	+11%
30% speed reduction relative to 2018	5%	-13%	+125%	+79%	+7%	-17%	+144%	+69%	+6%
	10%	-8%	+125%	+79%	+10%	-13%	+144%	+69%	+9%

Table 7 - Change in yearly TCO in 2030 per abatement scenario, compared to BAU in 2030. All values are in billion US dollars

	Share zero-GHG fuels (GJ/GJ)	Low demand growth				High demand growth			
		Fuel Costs	OPEX	CAPEX	Total costs	Fuel Costs	OPEX	CAPEX	Total costs
20% speed reduction relative to 2018	5%	-16	+15	+24	+23	-22	+18	+19	+15
	10%	-5	+15	+24	+34	-11	+18	+19	+26
30% speed reduction relative to 2018	5%	-25	+17	+24	+16	-32	+20	+25	+13
	10%	-17	+17	+24	+24	-24	+20	+25	+22

5 Discussion of plausibility of transport demand scenarios

The BAU projections of the Fourth IMO GHG Study were made in 2020, using data from before 2019.

Since then, several studies have pointed to a possible change in globalisation trends, for example:

- trade openness, defined as the sum of global imports and exports as a share of global GDP, has stagnated since 2008 (Peterson Institute for International Economics, 2022);
- the number of trade restrictions has increased, foreign direct investments are increasingly being restricted, and policies have been implemented fostering domestic production and consumption in major economic blocks, resulting in what the IMF calls ‘geoeconomic fragmentation’ (Aiyar et al., 2023).

Although this hasn’t yet resulted in a decline in maritime trade (measured either as tonnes loaded or in cargo tonne-miles, (UNCTAD, 2022)), it is possible that the trend will reverse as a result of geoeconomic fragmentation. This could make the lower transport work projections more plausible than the higher projections.

6 Conclusions

It is technically achievable to reduce shipping emissions by 28-47% by 2030, relative to 2008. These emission reductions would require:

- a speed reduction of 20-30% relative to 2018;
- widespread adoption of wind-assisted propulsion on ships for which it is technically feasible to do so; and
- 5-10% of the energy from zero-GHG fuels.

Implementing these measures would increase shipping costs by 6-14% on average, relative to BAU.

The maximum technical abatement potential amounts to approximately 175–350 Mt CO_2e on a WtW basis per annum, depending on the BAU emissions in 2030. When introduced gradually from 2025, the measures could avoid cumulative emissions of 500–1,000 Mt CO_2e.

About half of the emission reductions result from lower speeds and other operational measures, a quarter from wind-assisted propulsion and other technical measures and another quarter from using zero and near-zero-GHG fuels.

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