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Impact of including maritime transport in the EU ETS

Julia Hansson, Lars Zetterberg, Johan Rootzén, Rasmus Parsmo, Erik Fridell, Jonas Flodén, Johan Woxenius, Zeeshan Raza, Anastasia Christodoulou, Dimitrios Dalaklis, Aykut I. Ölcer

Author: Julia Hansson, Lars Zetterberg, Johan Rootzén, Rasmus Parsmo, Erik Fridell, Jonas Flodén, Johan Woxenius, Zeeshan Raza, Anastasia Christodoulou, Dimitrios Dalaklis, Aykut I. Ölcer
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IVL Swedish Environmental Research Institute Ltd.
P.O Box 210 60, S-100 31 Stockholm, Sweden
Phone +46-(0)10-7886500 // www.ivl.se

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Preface

This report summarizes the outcomes of the project "EU Emission Trading System - impacts of including maritime transports" financed by The Swedish Transport Administration under grant TRV 2020/25878. The project was a joint effort of IVL Swedish Environmental Research Institute, the School of Business, Economics and Law at Gothenburg University and the World Maritime University. We thank The Swedish Transport Administration for the funding and the reference group for valuable contributions.

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Summary

The European Green Deal from the European Commission in 2019 set a high aim: that EU will become climate neutral by 2050. As a part of this, the European Commission proposed that the EU Emission Trading System (ETS), is extended to include the maritime sector. This report assesses different design features of shipping in ETS, analyse the impact on the shipping industry and the environment.

The report investigates what impacts the inclusion of shipping may have on incentives for abatement, what types of emission reductions may follow, if the policy will lead to modal shifts or carbon leakage (meaning that vessels avoid EU ports in order to evade the policy) and what attitudes and expectations can be found among Swedish shipping lines and transport customers.

Including shipping in EU ETS is an important decarbonization policy. We find that inclusion of shipping in the EU ETS would be instrumental in creating incentives that stimulate investments in carbon abatement technologies. However, the large variation of the carbon prices over years creates additional risks in this respect. Besides the internal factors (such as setting the level of the emissions cap) that has an impact on price, there are external factors (such as reduced emissions in other sectors) that could result in reduced carbon prices and, consequently lower incentives for investments in green technologies and fuels.

Interviews and workshops have been conducted with Swedish shipping lines and transport customers in the RoRo and RoPax sectors to determine the potential modal shift in a Swedish setting. Overall, the shipping industry's perception of the EU ETS is positive. The shipping industry expects a significant cost increase from the EU ETS. In the short term, a modal shift away from RoRo/RoPax shipping is expected by the interviewed firms as EU ETS is introduced and freight rates subsequently increase. The competitive situation is different for different routes, where some compete mainly against other shipping lines on price, some against road on price and some on a superior logistics service.

The potential impact on carbon dioxide (CO_2) emissions and emissions of other greenhouse gases (GHGs) (including methane CH_4 and nitrous oxides N_2O) is addressed both for the European and Swedish case. The total CO_2 emissions from European shipping in 2019 included in the MRV system amounts to approximately 144 Mton. The estimated GHG emissions amount to 147 Mton of CO_2-equivalents(eq.) (with 0.67 Mton CO_2-eq for CH_4 and 2.42 for N_2O). The total CO_2 emissions from Swedish related shipping in 2018, amounts to approximately 4.6 Mton. The GHG emissions corresponds to 4.7 Mton of CO_2-eq (0.01 Mton CO_2-eq for CH_4 and 0.08 Mton N_2O).

The potential impact on emissions is assessed using an approach based on the cost effectiveness of implementing measures for specific ships included in MRV i.e., considering carbon abatement costs for selected measures. The developed modelling approach is tested for selected abatement measures, exemplified in this report with results for the retrofit of ships to use alternative fuels in the form of biomass-based methanol, and electro-methanol (produced from water and CO_2 using electricity), as well as the implementation of energy efficiency measures for existing ships in the form of propeller upgrade and waste heat recovery. For the shift to biofuel or other measures to be profitable for the ship owner the ETS allowances price must be higher than the abatement cost. We do not expect many ships to convert to bio-methanol with costs for ETS allowances below €100. Propeller upgrade, on the other hand, would be beneficial for a large number of ships while waste heat recovery is found too costly.

Thus, if shipping is included in EU ETS, least-cost measures mainly related to increased energy efficiency of ships and operation (e.g., propeller polishing and engine improvements) are likely to be implemented first, while shipping measures with higher carbon abatement costs but also higher emission reduction potential, such as fuel switch to renewable fuels, will not be introduced in large-scale as long as the price for the allowances are lower than the carbon abatement cost linked to these fuels. Due to the expected cost of emissions allowances in the short to mid-term, including shipping in EU ETS is not expected to be enough to promote large-scale fuel shift in the shipping sector in the short term. Other policy initiatives for the promotion of renewable marine fuels are thus needed. However, the inclusion of shipping in the ETS may lead to increased reduction of emissions in other sectors included in the ETS (via out-of-sector abatements) and will thus contribute to emission reduction. In addition, given that the inclusion of shipping in the EU ETS leads to significant in-sector emission reductions a significant benefit on air quality can also be expected.

Sammanfattning

I den europeiska Gröna given från EU-kommissionen 2019 är målet högt: att EU ska bli klimatneutralt senast 2050 och det föreslås en översyn av EU:s utsläppshandelssystem (EU ETS) för att inkludera en utvidgning till sjöfartssektorn. Denna rapport studerar olika designmöjligheter för sjöfartens inkludering i ETS, samt analyserar påverkan på sjöfartsindustrin och miljön.

Att inkludera sjöfarten i EU ETS är ett viktigt styrmedel för att minska koldioxidutsläppen. I rapporten konstateras att höga priser på utsläppsrätter är avgörande för att stimulera investeringar i åtgärder som minskar koldioxid (CO_2)-utsläppen, och den stora variationen i prisincitament mellan åren skapar risker i detta avseende. Förutom de interna faktorer som inbegriper fastställande av utsläppstaket, vilket skulle leda till höga prisincitament genom ett begränsat antal utsläppsrätter, finns det externa faktorer (som minskad efterfrågan på utsläppsrätter i andra sektorer) som skulle kunna leda till sänkta koldioxidpriser och därmed lägre incitament för investeringar i grön teknik och förnybara bränslen.

Som en del av detta projekt har intervjuer och workshops genomförts med svenska rederier och transportkunder inom RoRo- och RoPax-segmenten för att analysera potentiell överflyttning mellan trafikslag i en svensk kontext. På det hela taget är sjöfartsindustrins uppfattning om EU:s utsläppshandelssystem positiv. Sjöfartsindustrin förväntar sig en betydande kostnadsökning på grund av EU:s utsläppshandelssystem. På kort sikt förväntar de intervjuade företagen en trafikomställning bort från RoRo/RoPax-sjöfarten, i takt med att EU:s utsläppshandelssystem införs och fraktpriserna därefter ökar. Konkurrenssituationen är olika för olika rutter, där vissa främst konkurrerar med andra rederier om pris, vissa mot väg och vissa med en bra logistiktjänst.

Potentiell påverkan på CO_2-utsläpp och utsläpp av andra växthusgaser (inklusive metan (CH_4) och lustgas (N_2O)) undersöks både för europeisk och svensk sjöfart. De totala koldioxidutsläppen från europeisk sjöfart 2019 som ingår i MRV uppgår till cirka 144 Mton. Växthusgasutsläppen för denna sjöfart uppskattas uppgå till 147 Mton CO_2-ekvivalenter (0,67 Mton CO_2-ekv CH_4 och 2,42 Mton N_2O). De totala CO_2-utsläppen från svensk sjöfart 2018 uppgår till cirka 4,6 Mton. Utsläppen av växthusgaser för denna sjöfart uppskattas motsvara 4,7 Mton CO2-ekv (0,01 Mton CH_4 och 0,08 Mton N_2O).

Den potentiella påverkan på utsläppen beräknas med hjälp av en metod som bygger på kostnadseffektiviteten i genomförandet av åtgärder för specifika fartyg som ingår i MRV, dvs. med beaktande av kostnaderna för koldioxidminskning för utvalda åtgärder. Den utvecklade modelleringsmetoden testas för utvalda minskningssåtgärder, exemplifierat i denna rapport med resultat för att använda alternativa bränslen i form av bio-metanol och elektrometanol (producerad från vatten och CO_2 med el) i befintliga fartyg (retrofit), samt energieffektivitetsåtgärder för befintliga fartyg i form av propelleruppgradering och återvinning av spillvärme. För att övergången till biobränsle (liksom andra åtgärder) ska vara lönsam för fartygsägaren måste priset på utsläppsrätter inom utsläppshandelssystemet vara höga. Vi förväntar oss därför inte att många fartyg kommer att ställa om till biometanol med kostnader för utsläppsrätter som understiger 100 euro per ton CO_2. Propelleruppgradering, å andra sidan, skulle vara fördelaktigt för ett stort antal fartyg medan återvinning av spillvärme anses vara för kostsam.

Om sjöfarten inkluderas i EU ETS kommer åtgärder med relativt låg kostnad som främst är relaterade till ökad energieffektivitet hos fartyg och drift (t.ex. propellerpolering och motorförbättringar) sannolikt att genomföras först, medan åtgärder med högre kostnader för koldioxidminskning men också högre potential för utsläppsminskning, såsom bränslebyte till förnybara bränslen, inte kommer att införas i stor skala så länge priset för utsläppsrätterna är lägre än kostnaden för koldioxidminskning kopplad till dessa bränslen. På grund av den förväntade kostnaden för utsläppsrätter på kort till medellång sikt förväntas inte en inkludering av sjöfarten i EU:s utsläppshandelssystem vara tillräcklig för att främja en storskalig bränsleomställning inom sjöfartssektorn på kort sikt. Det behövs därför andra styrmedel för att främja förnybara marina bränslen. Införandet av sjöfarten i utsläppshandelssystemet kan dock leda till ökade utsläppsminskningar inom andra sektorer inom handelssystemet och därmed bidra till utsläppsminskningar. Med tanke på att införandet av sjöfart i EU:s utsläppshandelssystem leder till utsläppsminskningar inom sektorn kan man dessutom förvänta sig en betydande fördel för luftkvaliteten.

Background

Shipping contributes with 2.9% of global anthropogenic emissions of green-house gases in 2018 (IMO 2020) and may increase significantly in the future if no measures are taken. In view of this the International Maritime Organisation (IMO 2022) has decided on objectives on how to reduce the emissions and on instruments to achieve this. IMO´s objectives include a 50% decrease in greenhouse gases (GHG) emissions from all shipping by 2050 (with 2008 as base-year) and elimination of fossil fuels by the end of the century. Further, there are objectives on reduced carbon intensity (the emissions related to produced transport work) by 2030. To reach these goals the IMO has decided on several instruments to improve ships´ fuel efficiency (Energy Efficiency Design Index (EEDI), Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII)) and are discussing market-based instruments to be implemented in the coming years (IMO 2022).

However, the progress in IMO is unsatisfactory to many groups and therefore regional approaches have been suggested in the EU. In the European Green Deal from the European Commission in 2019 (COM(2019) 640 final) the aim is set high: that EU will become climate neutral by 2050, and proposed, amongst other measures, is a review of the EU Emission Trading System (ETS), to include, among, other things, an extension to the maritime sector. These objectives are in line with the Swedish climate goals of no-net emissions of GHG by 2045 and the ambition of reaching a fossil free transport sector, where shipping (together with aviation) is the transport mode lagging, from a GHG reduction perspective.

In the European Green Deal from the European Commission in 2019 (COM(2019) 640 final) the aim is set high: that EU will become climate neutral by 2050, and proposed, amongst other measures, is a review of the EU Emission Trading System (ETS), to include, among, other things, an extension to the maritime sector. The subject of study has during the project been a moving target. In November 2020, the European Commission (2020b) indicated that the revision of the EU ETS Directive will involve an assessment of the impact of "Including at least internal EU emissions of the maritime sector to ensure the sector contributes to the emission reductions needed". In July 2021, the European Commission presented its legislative proposal for the inclusion of shipping in the EU ETS. In June 2022, the European Parliament presented their position and during the Autumn of 2022 the EU institutions (Council, Parliament, and Commission) are negotiation and are expected to iron out the final details. The final legislation is expected to come into force 2023 or 2024. An overview of the legislative process involved in including shipping in the EU ETS is presented in Figure 1.

The process in the EU around the inclusion of shipping in EU ETS has involved different designs of the system like the lower size-limit of ships to be included (400 or 5000 gross tonnage, GT), the geographical scope and if only carbon dioxide (CO_2) or also other GHGs are to be included. We have in our analyses tried to cover the different options discussed.

This report contains an overview of the project activities, summaries of the results from the different work-packages and an outlook. For more detailed results we refer to the papers and other deliverables produced during the project.

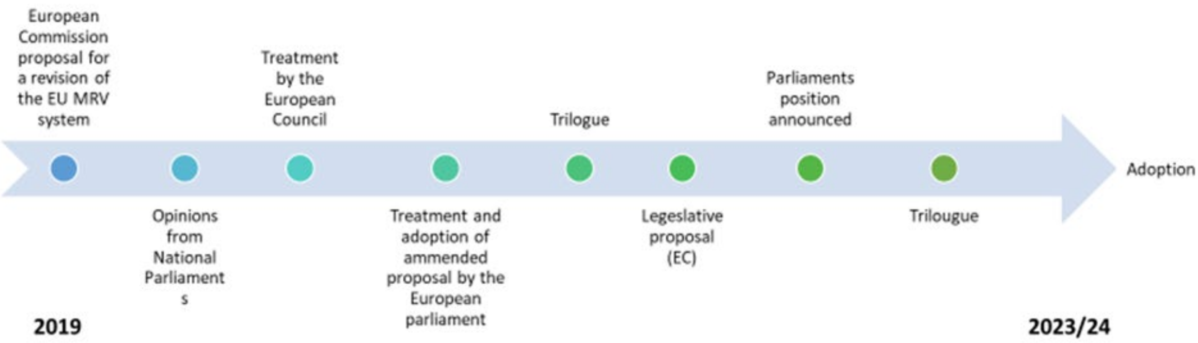

Figure 1. Overview of the legislative process involved in including shipping in the EU ETS.

Project activities and output

The development of the proposal for the inclusion of shipping in the EU ETS, the views of different actors and the assessments performed in the project have been discussed with the reference group of the project including representatives from the Swedish Shipowners' Association, Transport and Environment, Swedish Environmental Protection Agency, Swedish Transport Agency, Swedish Transport Administration, Port of Gothenburg, Air Pollution & Climate Secretariat, and International Windship Association. There have been four meetings with the reference group whose members have actively contributed to the project (December 2020, April 2021, October 2021, and April 2022). The deliverables and main communication activities from the project are listed below.

Papers and other contributions in scientific journals

Christodoulou, A., Dalaklis, D., Ölcer, A. and Masodzadeh, P.G., 2021. Inclusion of Shipping in the EU-ETS: Assessing the Direct Costs for the Maritime Sector Using the MRV Data. Energies 14(13), 3915. https://doi.org/10.3390/en14133915

Hansson, J., 2021. Cap and trade for decarbonizing ocean transport. A net-zero future for freight – Voices. One Earth 4, November 19, 2021. https://www.cell.com/one-earth/issue?pii=S2590-3322(20)X0012-1

Flodén, J., Raza, Z., Woxenius, J., Christodoulou, A., forthcoming. The impact of EU-ETS on RoRo and RoPax shipping (preliminary title). Manuscript to be submitted to scientific journal.

Parsmo, R., Hansson, J., Fridell, E., forthcoming. Inclusion of shipping in the EU ETS: assessment of the potential impact on GHG emission and other air pollutants (preliminary title). Manuscript to be submitted to scientific journal.

Zetterberg, L., Christodoulou, A., Flodén, J., Hansson, J., Fridell, E., Parsmo, R., Rootzén, J., forthcoming. Inclusion of Shipping in the EU ETS (preliminary title). Manuscript to be submitted to scientific journal.

Policy brief

Zetterberg, L., Rootzén, J., Mellin, A., Hansson, J., Fridell, E., Christodoulou, A., Flodén, J., Elkerbout, M., 2021. Policy Brief – Shipping in the EU ETS. www.ivl.se/download/18.1ee76657178f8586dfcd5c2/1621949838330/Shipping_in_EU_ETS_final.pdf

Extended abstracts, conference proceedings and posters

Christodoulou, A., Dalaklis, D., Ölcer, A., Masodzadeh, P.G., 2022. Analysis of the MRV database and the evolution of the EU carbon price over the years: how do external factors affect the inclusion of shipping in the EU ETS? Extended abstract presented (online) at the IAME (International Association of Maritime Economists) Conference 2022, 14-16 September, Busan, Korea.

Flodén, J., Raza, Z., Woxenius, J., Christodoulou, A., 2022. The impact of EU-ETS on RoRo and RoPax shipping, Extended abstract presented (online) at IAME 2022, International Association of Maritime Economists Conference 2022, September 14-16, Bexco Busan, South Korea.

Hansson, J., Parsmo, R., Fridell, E., Brynolf, S., 2022. Potential Impact on Biofuels, Hydrogen and Electrofuels for shipping of GHG Emission Reduction Policies. Poster and poster presentation at the European Biomass Conference & Exhibition (EUBCE) 2022, 9-12 May, 2022.

Parsmo, R., Hansson, J., Fridell, E., 2022. On the potential environmental impact of including maritime shipping in the EU ETS, Extended abstract presented (online) at the International Association of Maritime Economics (IAME), 14-16 September, 2022, Bexco Busan, South Korea.

Zetterberg, L. and Rootzén, J., 2022. Early assessment of the effects of including shipping in the EU Emission Trading System. Extended abstract presented (online) at the International Association of Maritime Economists Conference, 14-16 September, Bexco Busan, South Korea.

Christodoulou, A., Dalaklis, D., Ölcer, A., Masodzadeh, P.G., 2021. An analysis and interpretation of the MRV database: useful outcomes in relation to the energy efficiency of vessels operating in the European Economic Area. Presentation at the IAME (International Association of Maritime Economists) Conference 2022, 25-27 November, Rotterdam, Netherlands.

Presentations

”Möjliga utformningar och konsekvenser av att införliva sjöfarten i EU ETS”, Presentation at Transportforum, 13 January, 2021 (Anna Mellin)

“Sjöfarten i EU:s utsläppshandelssystem”, Presentation at Lighthouse Webinar 26 May 2021 (Johan Rootzén)

“The impact of EU-ETS on RoRo and RoPax shipping” by Flodén, Raza, Woxenius, Christodoulou, Presentation at National Conference on Transport Research, Lund, 18-19 October 2022 (Jonas Flodén)

”Styrmedel för att minska växthusgasutsläppen från sjöfart och påverkan på bränsleval”, Presentation at Transportforum, 13 January 2021 (Julia Hansson)

“Potential Impact on Biofuels, Hydrogen and Electrofuels for shipping of GHG Emission Reduction Policies”, Poster presentation at the European Biomass Conference & Exhibition (EUBCE) 2022, 10 May 2022 (Julia Hansson)

Policy design of EU ETS

Assessment of key design features

The ambition in the project has been to provide an overview and an early assessment of the design options that are part of the discussion pending the final legislative proposal (compiled in Table 1) and discuss possible implications on function and effectiveness of the policy. The assessment is based on lessons learned from previous emission trading systems, inclusion of aviation in the EU ETS in 2012, proposals from the EU institution (Parliament, Council and Commission), and input from the shipping industry, NGOs, and academia.

Covered ship categories. If shipping is included in the EU ETS the system it will most likely at least cover the same ship categories as the shipping MRV (monitoring, reporting and verification) regulation, i.e., ships >5000 gross tonnage with certain exemptions (Transport & Environment, 2022), which is also proposed by the Commission. This would mean that 55% of all ships calling into EEA (European Economic Area) ports that are covered by the MRV regulation (together responsible for more than 90% of the CO_2 emission from shipping) would be covered by the scheme. The Parliament has proposed a lower gross tonnage threshold (>400 gross tonnage) as to avoid market distortion and further increase the coverage.

Geographical coverage. We have identified three main options: 1) EU internal routes; 2) all incoming and outgoing routes to/from EU/EEA ports; and 3) semi-full coverage meaning EU internal routes plus 50% of the routes to/from EU/EEA ports (which is proposed by the Commission while the Parliament in addition suggest to cover 100% from 2027). Only targeting internal-EU shipping would significantly reduce the overall shipping emissions covered but could be an easier political sell. The shipping industry has raised concerns that a 'global' scope may lead to perverse incentives, e.g., ships from international ports calling at a port just outside the EU before sailing to an EU port. Recent estimates (Transport & Environment, 2020b) suggest that the added cost associated with port stops for the purpose of evading CO_2 prizing rarely makes economic sense, while another assessment indicate that there is a risk for carbon leakage by such activities also for relatively low allowance prices (Wang et al., 2021; Lagouvardou and Psaraftis, 2022).

Included Greenhouse gases. The EU ETS legislation covers all six greenhouse gases, however, in the EU ETS Handbook CO_2, N_2O and PFCs are covered for selected industry sectors, but methane (CH_4) is left out for all included activities. In the European Commission proposal only, CO_2 would be covered (at least initially) but in the Parliament proposal also CH_4 and N_2O are included.

Regulated entity. The ship owner is an obvious choice since they have the power to reduce emissions, by technical choices such as vessel form, power trains etc. However, for some categories of shipping it is common that an operators lease the ships. In these cases, operators may be a better choice as the regulated entity since they have power to reduce emissions by efficient routing, efficient loading, and logistics. Choosing the fuel supplier will come with a high risk that fuelling will occur outside the EU. Transport buyers could be the regulated entity since they are responsible for transporting the cargo and can choose other transport modes (substitution). However, it would be more administratively complicated since there would be a need to link emissions from each vessel to several (sometimes thousands of) buyers of transport services. In the European Commission's (2021) original proposal 'the person or organisation responsible for the compliance with the EU ETS should be the shipping company, defined as the shipowner or any other organisation or person, such as the manager or the bareboat charterer, that has assumed the responsibility for the operation of the ship from the shipowner […]'. To account for the fact that the shipping company is not always responsible for purchasing the fuel or taking operational decisions that affect the greenhouse gas emissions of the ship the European Parliament (2022) suggests that 'a binding clause should be included in such arrangements for the purpose of passing on the costs so that the entity that is ultimately responsible for the decisions affecting the greenhouse gas emissions of the ship is held accountable for covering the compliance costs paid by the shipping company'. This amendment would make sure that e.g., an operator leasing a ship which is responsible for the choice and purchase of the fuel used by the ship and for strategic decisions related to the operation of the ship, as regards, for example, the choice of the cargo carried by, or the route and speed of, the ship, also carries the carbon costs.

Allocation of allowances. Auctioning is the main method for allocating allowances in the EU ETS (and is proposed by both the Commission and the Parliament). Auctioning is consistent with the polluter pays principle, transparent and creates high incentives for reducing emissions. Auctioning will result in a higher compliance cost per ton of fuel than in case allowances are allocated for free.

Table 1. Overview of the European Commission proposal (July 2021) and the EU Parliament position (June 2022).

EC proposal	EU Parliament proposal
Introduction: Gradual extension of the ETS to maritime starting in 2023, with a 3-year phase in period; 20 % of verified emissions reported for 2023, 45% 2024, 70% 2025, 100% 2026	*Full inclusion of the shipping industry from 2024*
Included GHGs: start with CO2, others to be included later	*Both CO2 and CH4, as well as nitrious oxide (N2O)*
Covered ship categories (>5000 gross tonnage)	*Ships of 400 gross tonnage and above*
Geographical coverage: All Intra-EU traffic and 50% of the emissions from incoming outgoing traffic	*After 2027, the scope should be extended to 100% of ships entering and leaving European port*
Allocation of allowances: Auctioning	*Auctioning*
Ear marking: Auction revenues tunneled to MS:s state budgets (partly earmarked for funding of climate and energy-related measures but no dedicated "Ocean/Shipping fund")	*An ocean fund should be established by earmarking 75% of the revenues generated by the shipping allowances to the energy transition of the sector.*

Impact on ship-owners

Short summary of initial assessment of direct economic impacts

If shipping is included in the EU ETS with semi-full geographical coverage, allowance auctioning and an allowance price of 50 EUR per ton CO_2, we estimate the compliance cost to be approximately 100 EUR per ton fuel used (Zetterberg et al., 2021; Christodoulou et al., 2021). This can be compared to the price of fuel which is currently at 480 EUR/ton and has varied between 200 and 500 the last 12 months. If we assume that fuel costs account for one third of total transport costs, the compliance cost for shipping in the EU ETS will be less than 7% of the total transport related costs. If instead 85% of allowances are allocated for free by benchmarking under a semi-full geographical scope, assuming an allowance price of 50 EUR per ton CO_2, we estimate the compliance cost to be 15 EUR per ton fuel used (on average for the whole sector) or approximately 1% the total transport related costs (Zetterberg et al., 2021).

Transport & Environment (2020b) has also investigated compliance costs, applying auctioning under a semi-full scope ETS design. They conclude that CO_2 costs would add only a very small amount to the overall transport costs. For transporting a standard container (TEU) from Spain to Singapore, the CO_2 costs would represent less than 1% of the overall transport costs.

In case the emission allowances are fully auctioned or partially free allocated on the basis of a uniform benchmark, the increased costs would be disproportional among the maritime segments. Such a scheme would penalise Roll-on/Roll-off (RoRo) and Roll-On/Roll-Off/Passenger (RoPax) segments due their high fuel consumption per transport work in relation to oil tankers and bulkers (Christodoulou et al., 2021). The establishment of differentiated benchmarks per segment seems to be a prerequisite for the effective inclusion of shipping in the EU-ETS that will reward energy efficient vessels in each segment and avoid competition distortion within the maritime industry (Christodoulou et al., 2021).

Analysis of the MRV database over the years

In order to analyse the potential impact that the inclusion of shipping in the EU ETS could have on ship owners over the years and following our initial assessment of the direct costs for different maritime segments (presented in Christodoulou et al., 2021), we analysed and compared the MRV data over the years through a descriptive statistical analysis (Christodoulou et al., 2021). We also explored how unexpected events (e.g., COVID-19) that affect maritime operations are reflected in this database and, by relating this data to the evolution of the EU carbon price over the respective period, we attempted to reveal how and to what extent external to shipping factors can affect the inclusion of shipping in the EU ETS.

The MRV database, established by the EU MRV Regulation 2015/757, can be considered as the initial and essential step for the adoption of recent EU Directives that target the reduction of GHG emissions from shipping within the EEA. The extension of the EU ETS to include maritime emissions or the FuelEU Maritime Directive that aims to accelerate the energy transition of the maritime sector through the adoption of green fuels and the use of electrification from vessels while at berth both presuppose the annual monitoring and verification of shipping CO_2 emissions for the allocation of allowances and the setting of marine fuel carbon intensity limits respectively.

The R software package is used for conducting a descriptive statistical analysis of the MRV data that enables the identification of total CO_2 emissions per maritime segment, the average CO_2 emissions per transport work, the CO_2 emissions from intra-European or international voyages. Since its entry into force in 2018, the MRV database provides valuable data on vessels' CO_2 emissions per ship type, per transport work, distance travelled and an analysis of this data over the years will allow the exploration of the impact of unexpected events (e.g., COVID-19) on maritime operations and associated CO_2 emissions. Our analysis includes the MRV data since the year 2019 that was the first year this data was published by the European Maritime Safety Agency (EMSA) in relation to total shipping CO_2 emissions, CO_2 emissions per ship type and CO_2 emissions from intra-European or international voyages. Our analysis is restricted to nine maritime segments, whose CO_2 emissions account for 82% of the total emissions reported in the MRV system, namely container ships, oil tankers, bulkers, RoPax vessels, chemical tankers, general cargo carriers, LNG carriers, RoRo vessels and passenger ships. The MRV data are further used in our analysis as the main data source for the identification of potential differentiated impact of unexpected events on different ship types that could also affect the allocation of allowances among the maritime segments.

Along with the MRV data analysis, the evolution of the EU carbon price over the years is analyzed in relation to the MRV data in order to reveal how and to what extent external to shipping factors can affect the inclusion of shipping in the EU ETS. This analysis is scenario-based and includes different price incentives over the years highlighting the importance of this parameter for the effective inclusion of shipping in the EU ETS.

Results/Findings

The results of this research verify the importance of high price incentives for the effective inclusion of shipping in the EU ETS and underline the differentiated impact of unexpected events on different ship types that could also affect the allocation of allowances among the maritime segments (Figure 2). Our findings verify the fact that passenger vessels were by far the ship type most affected by COVID-19 for the respective period with their operations and associated CO_2 emissions reduced up to 80% (Figure 3).

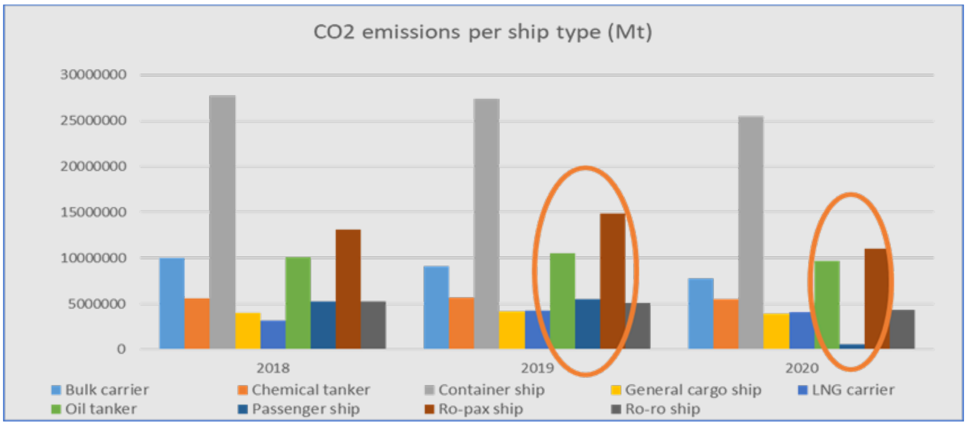

Figure 2. CO_2 emissions per ship type (Mton)

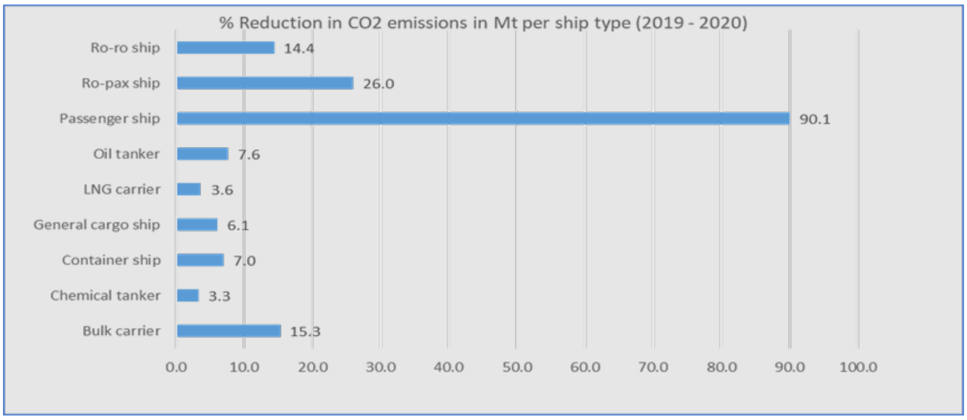

Figure 3. % reduction in CO_2 emissions (Mton) per ship type (2019 - 2020)

In addition to the reduced traffic over this period, the price incentive (EU carbon price) was also low compared to the current level with the relevant direct costs for the maritime sector from its potential inclusion in the EU ETS varying largely over the years (Figure 4). It is worthwhile to mention here that the geographical scope analysed here includes semi-full coverage meaning EU internal routes plus 50% of the routes to/from EU/EEA ports. If we assume that maritime traffic remains at the levels of 2020 (impact of COVID-19), the direct costs from the inclusion of CO_2 emissions of different segments in the EU ETS for the period 2018 – 2022 (in case no technical or operational measures are adopted) can be seen in Figure 5. These costs are directly relevant to the emissions per ship type, but also the price incentive that varies significantly over the years. Figure 6 presents these directs costs in the case where the maritime traffic returns to the levels of 2019 (before the pandemic).

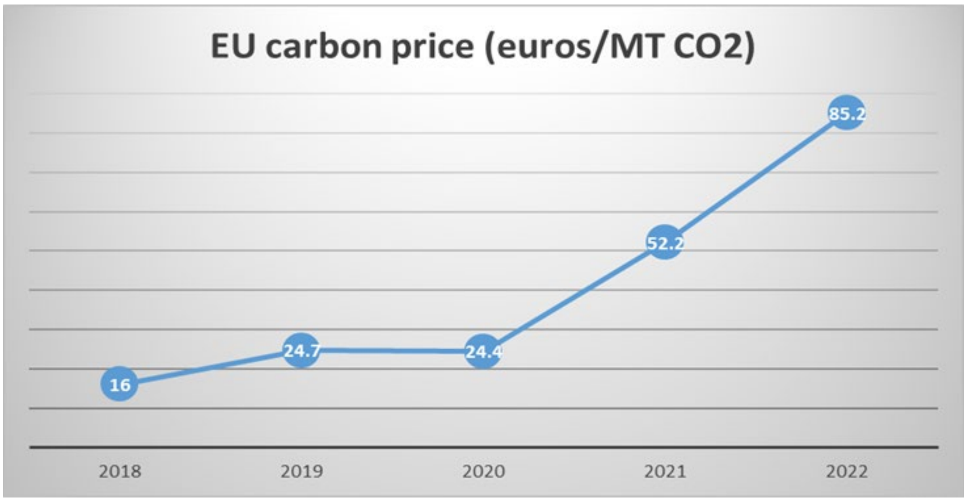

Figure 4. EU carbon price (euros/Mton CO_2)

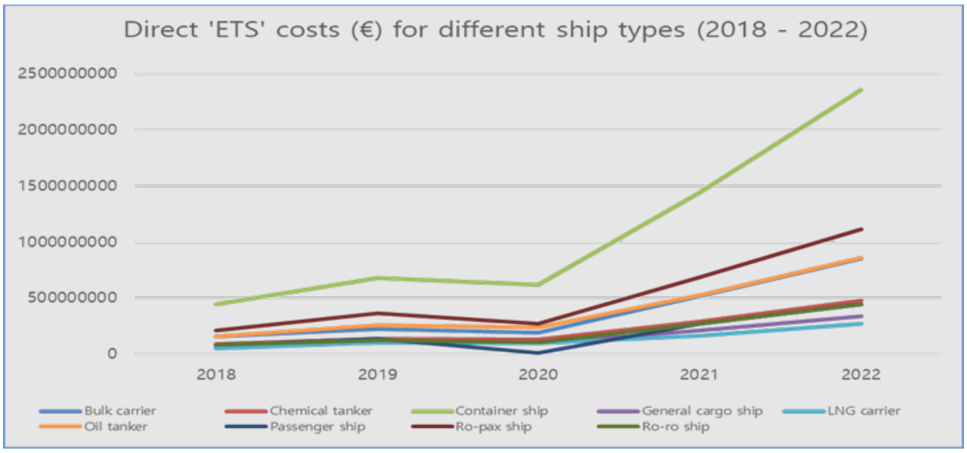

Figure 5. Direct ‘ETS’ costs (euros) for different ship types in case maritime traffic goes back to pre-pandemic levels (2018-2020).

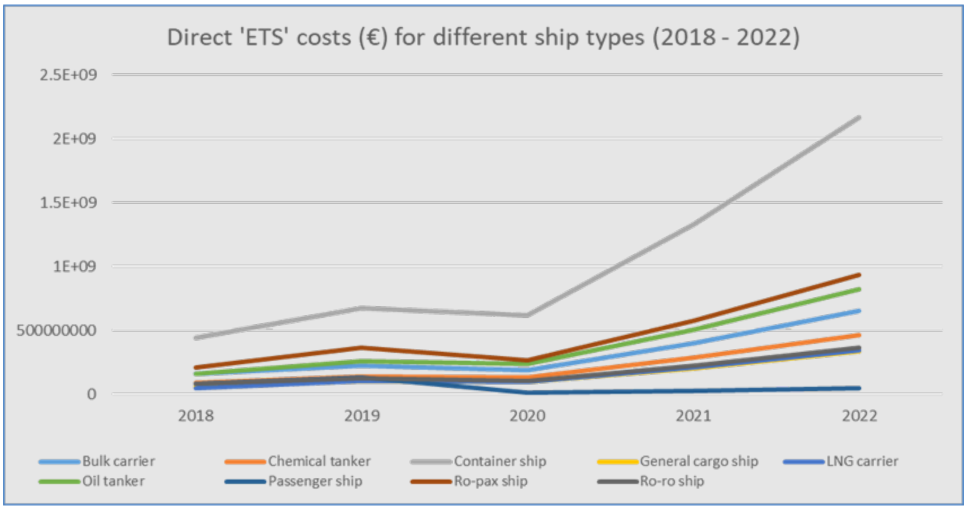

Figure 6. Direct ‘ETS’ costs (euros) for different ship types in case maritime traffic remains at pandemic levels (2018-2020).

That there are significant differences in the price incentives among the years can create increased uncertainty to shipping companies that will constantly need to follow and adjust to the new prices. In this way, there will be an additional risk to the already volatile shipping market conditions for proceeding with radical changes and improvements of the fleet’s energy efficiency. Periods of low carbon prices can also jeopardize the energy transition of the sector as the provision of incentives for investments to innovative energy technologies and green fuels will be minimized and the shipping companies will probably seek to comply with the Directive by buying adequate emission allowances in the market. Moreover, the energy transition of specific ship types might be postponed due to unexpected events that cause significant reduction of their operations and emissions that is accompanied with a decrease of emission allowances that need to be surrendered in order to cover their emissions.

Policy implications

This analysis provides an overview of the MRV data over the years through a descriptive statistical analysis and relates this data to the evolution of the EU carbon price over the respective period in order to reveal how and to what extent external to shipping factors can affect the inclusion of shipping in the EU ETS. The results of this research verify the importance of high price incentives for the effective inclusion of shipping in the EU ETS and underline the differentiated impact of unexpected events on different ship types that could also affect the allocation of allowances among the segments.

Numerous parameters need to be considered for the development of an effective carbon pricing mechanism for shipping. In relation to the extension of the EU ETS to include shipping emissions, the provision of high price incentives is crucial in order to stimulate investments in energy technologies and green fuels and the large variation of the price incentives among the years creates additional risks in this respect. Besides the internal factors that include the correct setting of the emissions cap that would result in high price incentives through limited amount of emission allowances, there are external factors that could result in reduced carbon prices and, consequently lower incentives for investments in green technologies and fuels.

Potential modal shift

Adding shipping to EU ETS will add costs and thereby reduce the competitiveness for shipping. This potentially leads to a modal shift away from shipping to other traffic modes. The potential modal shift is most imminent in shipping sectors with a direct competition with other traffic modes, particularly short sea RoRo and RoPax shipping. RoRo/RoPax typically traffic trucks, semi-trailers, cassettes and other rolling cargo, which are often integrated in a transport chain involving land transport.

Figure 7. Trucks leaving a RoPax ferry (Picture: Stena Line)

A typical example would be a truck picking up goods from a consignor, driving to a port and onto a ferry for a sea voyage for a few hours, or perhaps overnight. After the ferry voyage, the truck continues by land to its destination (illustrated in Figure 7). The transport is thereby already adapted to the road transport system as the goods is loaded into a vehicle that could be transported by land, fixed bridge connection or another ferry route. From a business perspective, the shipping line is often a subcontractor where the transport is typically managed by a road haulier or forwarder. There is a certain demand elasticity as it is not particularly complicated to shift to another traffic mode. In a Scandinavian setting, most RoRo and RoPax routes face head-to-head competition with road and rail, at least for parts of the route, as is visible from Figure 8. The impact of EU ETS is therefore also much dependent on the technical and regulatory development in the road- and rail sector.

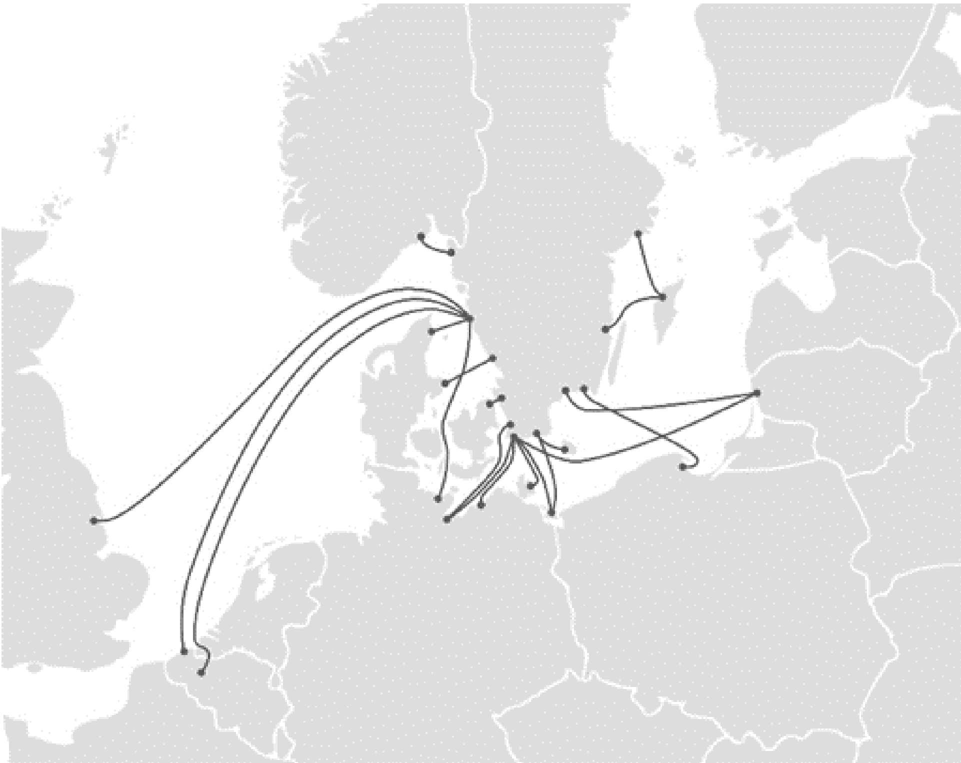

Figure 8. Map of RoRo and RoPax routes from southern Sweden (Flodén and Woxenius, 2022)

Short sea container shipping can also to some extent be affected, although these services are often feeder traffic connecting to the intercontinental container routes and are regularly planned to use maritime transport from the closest container port. Container shipping is thereby less susceptible to a modal shift. Further, the physical characteristics of the ISO container as a load unit is not well adapted to road transport as it does not fully utilise the allowed length and weight. A shift to rail has more potential as it can link to the port infrastructure through a dry port setup where a full train load is picked up at a port and deliver to an inland dry port terminal, although this requires access to suitable infrastructure and large enough volumes. Like for road, the container does not fully utilise the capacity but rather the maximum width and height for rail.

Intercontinental shipping is less exposed to a modal shift as the alternative transport options are few. Air transport is significantly more expensive, even after the EU ETS. Rail has started to emerge as a competitor between China and Europe, although volumes are still small, and prices are high compared to shipping. The rail link has also suffered from sanctions against Russia following the war in Ukraine. Similarly, bulk shipping has limited alternative transport options. Although possible to transport, for example petrol or wheat, by road and rail, the large volumes involved in bulk shipping gives shipping a significant cost advantage.

As part of this project, interviews and workshops have been conducted with Swedish shipping lines and transport customers in the RoRo and RoPax sectors to further determine the potential modal shift in a Swedish setting. Eight interviews and one workshop were held during spring 2022. Overall, the shipping industry's perception of the EU ETS is positive. A greater focus on sustainability issues is perceived as something necessary and important. A clear shift can be seen in the attitude in the industry, as sustainability related proposals would have been received much more negatively just a few years ago. Specifically for the EU ETS, the respondents perceive that there are still a lot of uncertainties but acknowledge that the EU ETS is just something that they have to accept and deal with as a part of doing business in the future. However, it is underlined that the implementation must be fair, both between competing shipping lines and against other traffic modes. As long as everyone is treated equal, the general sentiment is that the EU ETS will be accepted. Overall, respondents perceive that there is so much happening in the freight industry today (e.g., the pandemic with the following container crisis, Ukraine war, energy crisis and inflation) that the EU ETS is just one of many things to deal with right now.

From the interviews it appears that transport customers have very little knowledge about the EU ETS. As a matter of fact, many customers witnessed that they had not even heard about the EU ETS. Their focus is on transport price and the service offered, and they have little knowledge of, or interest in, how the shipping industry operates internally. The interest in paying extra for more sustainable transport is low, as the customers perceive that their customers in turn are not willing to pay extra. However, noteworthy is that shipping lines perceive that the customers have a small increased willingness to pay extra for sustainability.

The shipping industry expects a significant cost increase from the EU ETS. The interviewed shipping lines all state that the cost will be transferred to the customers as a surcharge. This is an attempt to make it clear that it is an externa cost outside the control of the shipping lines and to push that cost to the customer. However, transport costumers perceive surcharges very negatively, as an unfair way to increases prices. It is argued that everyone has taxes and fees to pay and that these should be included in the price. Shipping lines, in turn, argue that very few transport customers understand the shipping industry and how it operates. In the short term, the shipping lines plan no changes to fuels, ships, routes etc. stating that the time frame until implementation is too short and that their only option is to push the cost on to the customer.

In the short term, a modal shift away from RoRo/RoPax shipping is expected by the interviewed firms as EU ETS is introduced and freight rates subsequently increase. The competitive situation is different for different routes, where some compete mainly against other shipping lines on price, some against road on price and some on a superior logistics service. The modal shift will therefore impact routes differently. In general, longer RoRo/RoPax routes are more exposed than shorter as the fuel part of the total cost is higher. Longer RoRo/RoPax routes are also in general more challenging to operate as they have a lower frequency. RoPax and cruise ferries have the added complication of allocating the EU ETS cost between the passenger and freight segments. Cruise ferry services, in particular, have a significant part of their income from onboard sales (restaurants, shopping etc.) which also needs to be considered. A cruise ferry is a ferry service with a large focus of passenger entertainment, catering to leisure travellers who travel to enjoy themselves onboard and often just return on the same ferry (and can be exemplified by the ferries between Stockholm and Helsinki).

A concern in the industry is that shipping prices is perceived to have been increasing faster than road transport prices over time, largely due to the use of low-cost road hauliers from eastern European countries. Routes with a direct competition with road is particularly exposed to this price development. However, both transport customers and shipping lines highlight that it is not only about price, but that shipping also must match the logistics requirements. For example, the departure time of a ferry must match pick-up and delivery times set by customers. Truck drivers are required to follow driving time regulations and it is beneficial if a ferry crossing can match with required resting times. The potential modal shift is thus very contextual. Not only a price increase, but also changes in routes, timetables, and ship types to mitigate the effects of the EU ETS can impact the modal split.

In a longer-term impact, shipping lines expect the EU ETS to aid the transition to more sustainable transport as previously unprofitable measures might become profitable. Alternative fuels that are currently unprofitable to use might become profitable due to the EU ETS. Similarly, when investing in new ships, the higher fuel price will be included in the calculations and make alternative designs financially more attractive. This push is perceived positively by the shipping industry as they state that they need help to decarbonise, and that the EU ETS will provide a necessary push for investments. In the long run, the shipping industry perceives that the EU shipping industry will gain from the EU ETS as it will force them to develop and gain a competitive advantage against other nations. However, the EU ETS is also expected to affect international competition as transport becomes more expensive. Sweden is geographically located in the outskirts of Europe and Swedish manufacturers express concerns that high transport prices will make their products more expensive compared to manufacturers located in central Europe. Similarly, there are concerns that customers outside the EU might decide to also source from non-EU countries as the transport costs are lower.

Environmental consequences

In this section we summarize our findings linked to the assessments of the potential environmental impacts of including shipping in EU ETS and the influence of different design options. The potential impact on CO_2 emissions and emissions of other GHGs (including CH_4 and N_2O) is addressed both for the European and Swedish case. Initially by assessing the amount of CO_2 and GHG that will be affected for different cases.

Then, the potential impact on emissions is assessed using an approach based on the cost effectiveness of implementing measures for specific ships included in MRV i.e., considering carbon abatement costs for selected measures. Linked to this also the potential impact on other air pollution is assessed, in this report exemplified by the impact on nitrogen oxides (NO_X) of a fuel switch but also particulate matter and sulphur oxides (SO_X) are addressed in the project. Finally, the potential impact on cost-effective marine fuel choices of including shipping in EU ETS is assessed based on the relative cost of different fuel options using an energy system model. For more details the reader is referred to Parsmo et al. (2022) and Parsmo et al. (forthcoming).

Potential impact on GHG emissions on a European level

Geographical and ship coverage

The total CO_2 emissions from shipping covered by the EU ETS will depend on the chosen geographical scope and ships covered (size and types). Figure 9 presents CO_2 emissions covered per shipping segment in case (i) all EU/EEA internal routes and incoming and outgoing routes to and from EU/EEA ports are included (from the last or first port of call outside EU/EEA) and in case (ii) EU/EEA internal routes plus 50% of the routes to/from EU/EEA ports are included based on the MRV data for the year 2019 i.e., including ships above 5000 GT. The division of the CO_2 emissions between internal shipping, in port and from ingoing and outgoing voyages is also shown in Figure 9.

The total CO_2 emissions from EU shipping in 2019 included in the MRV system amounts to approximately 144 Mton. For the 50% of ingoing/outgoing case the emissions amounts to 99 Mton.

According to Transport & Environment (2022) the CO_2 emissions from ship types covered by the MRV system but with a size below 5000 GT in the EU for the case including intra-EU-shipping and 50% of ingoing and outgoing voyages amount to about 9.6 Mton of CO_2 in 2019. Thus, if all these smaller ships were also covered by the EU ETS about 7% more emissions would be covered. However, there are also ship types that are not covered by MRV, such as offshore and service vessels, fishing vessels, yachts, and military vessels. The emissions from these correspond to approximately 6 Mton CO_2 for vessels above 5000 GT and 10.1 Mton CO_2 for vessels below 5000 GT (Transport & Environment, 2022). For the EU case the year 2019 is chosen in this report to avoid the impact of the Covid-19 pandemic (which is explored in another section).

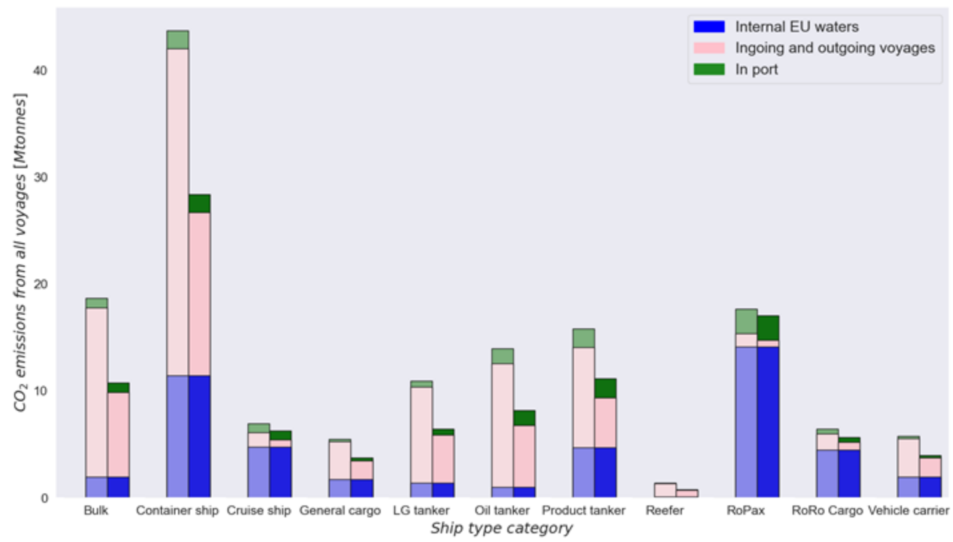

Figure 9. CO_2 emissions in Mton per maritime shipping segment in 2019, total emissions (left bar) and internal EU/EEA ship emissions and 50% of incoming and outcoming voyages (from the last or first port of call outside EU/EEA) based on MRV data.

Included GHGs

The GHG emissions per shipping segment in the EU in 2019 including besides CO_2 also direct CH_4 and N_2O emissions i.e., in a tank to wake (TtW) perspective are estimated in Figure 10 in a GWP100 perspective for the two cases of geographical coverage proposed. In the 100% case for EU shipping, the emissions amount to 147 Mton of CO_2-equivalents(eq.) (with 0.67 Mton CO_2-eq. for CH_4 and 2.42 Mton CO_2-eq for N_2O using the GWP100 values from the IPCC Fourth Assessment Report (IPCC, 2007) used for reporting to the EU Commission and in the EU ETS). For the 50% of ingoing/outgoing case the GHG emission amounts to 101 Mton CO_2-eq. Fuel dependent emissions factors from Faber et al., (2020) are used.

Even if the current contribution of non- CO_2 GHG emissions is limited, the inclusion of shipping in EU ETS should cover also non- CO_2 GHGs to limit the potential GHG emissions from alternative fuels, e.g., CH_4 emissions for LNG and N_2O emissions for ammonia. However, marine fuels are also associated with so-called upstream GHG emissions from fuel production and distribution (well to tank, WtT). There seem to be no suggestion among the EU institutions to specifically include WtT GHG emissions linked to shipping in the EU ETS. CH_4 emissions are exempted for other activities and are thus not in practice regulated by the EU ETS.

For comparison, the GHG emissions from a WtT perspective linked to the shipping fuels used in the EU in 2019 is estimated to approximately 26.7 Mton CO_2-eq. (i.e., about 15% of the well to wake, WtW, emissions) using the default values proposed in the Fuel EU Maritime (EP&C, 2021).

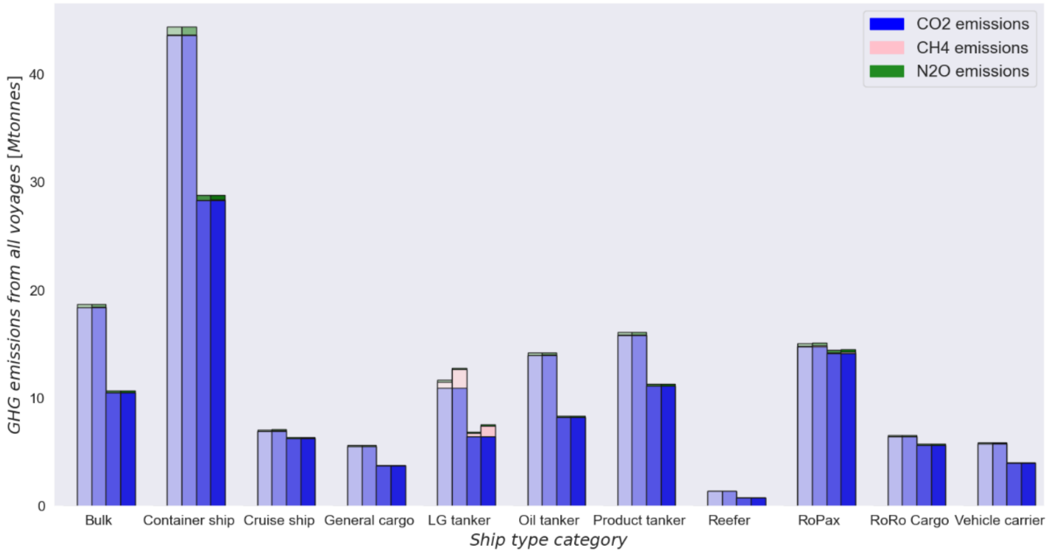

Figure 10. Estimated total GHG emissions in Mton CO_2-equivalents (including also CH_4 and N_2O emissions) per maritime shipping segment in 2019 in EU for ships above 5000 GT (left bar for 100% geographical coverage case in a GWP100 perspective, second bar for 100% geographical coverage case in a GWP20 perspective, third and fourth bar for the case with internal plus 50% of the voyages to/from EU/EEA ports in a GWP100 and GWP20 perspective respectively).

Potential impact on GHG emissions for the case of Sweden

Geographical and ship coverage

For the case of Sweden, CO_2 emissions for ships above 5000 GT travelling to and from Swedish ports are estimated for 2018 for the two cases of geographical coverage as in the EU case above, i.e., domestic shipping and 100% or 50% of incoming and outgoing routes to and from Swedish ports, respectively (see Figure 11). This estimation is based on multiplying the emission factor for each individual ship (MRV statistics CO_2/NM), with the distances between ports (Searoutes, 2022). The data on individual ships and arrivals departure ports (also called port call statistics) are from Marine Traffic (for ships>5000GT) and Swedish Maritime Administration (SMA) (<5000GT) (SMA, 2018; MarineTraffic, 2022).

The total CO_2 emissions from Swedish related shipping in 2018, for ships above 5000 GT, amounts to approximately 4.6 Mton and to 2.5 Mton for the 50% of ingoing/outgoing case. The estimated number of port calls for ships below 5000 GT for the Swedish case per maritime shipping segment in 2018 is presented in Figure 12. The estimated emissions from about two thirds of all the vessels between 300-5000 GT making port calls at Swedish ports in 2018 (for which an estimate is possible based on existing information in SMA, 2018) is about 0.65 Mton CO_2, for the case when 100% of domestic and 50% of the ingoing and outgoing international voyages are included.

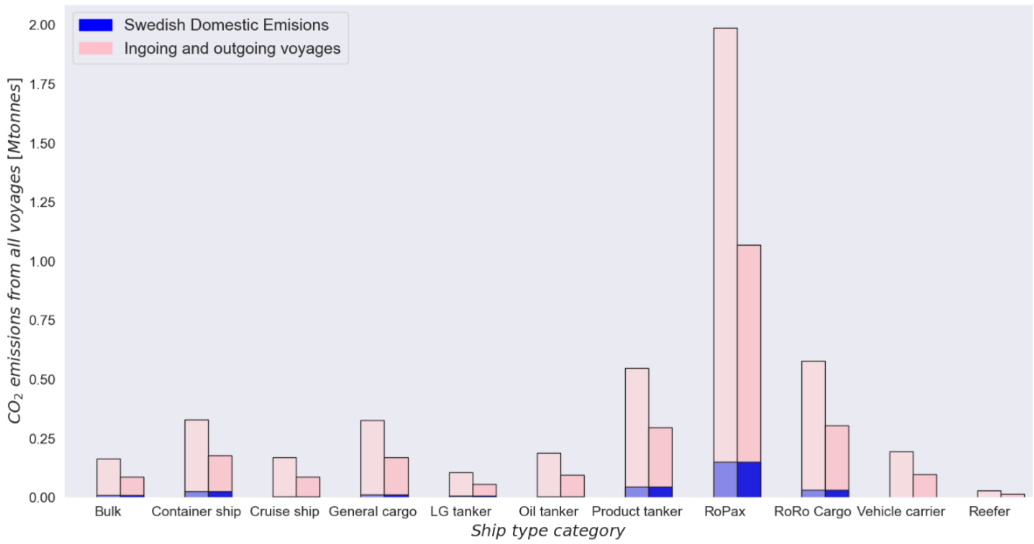

Figure 11. CO_2 emissions in Mton per maritime shipping segment in 2018 for the Swedish case, total emissions (left bar) and domestic ship emissions plus 50% of incoming and outcoming voyages (from the last or first port of call outside Sweden).

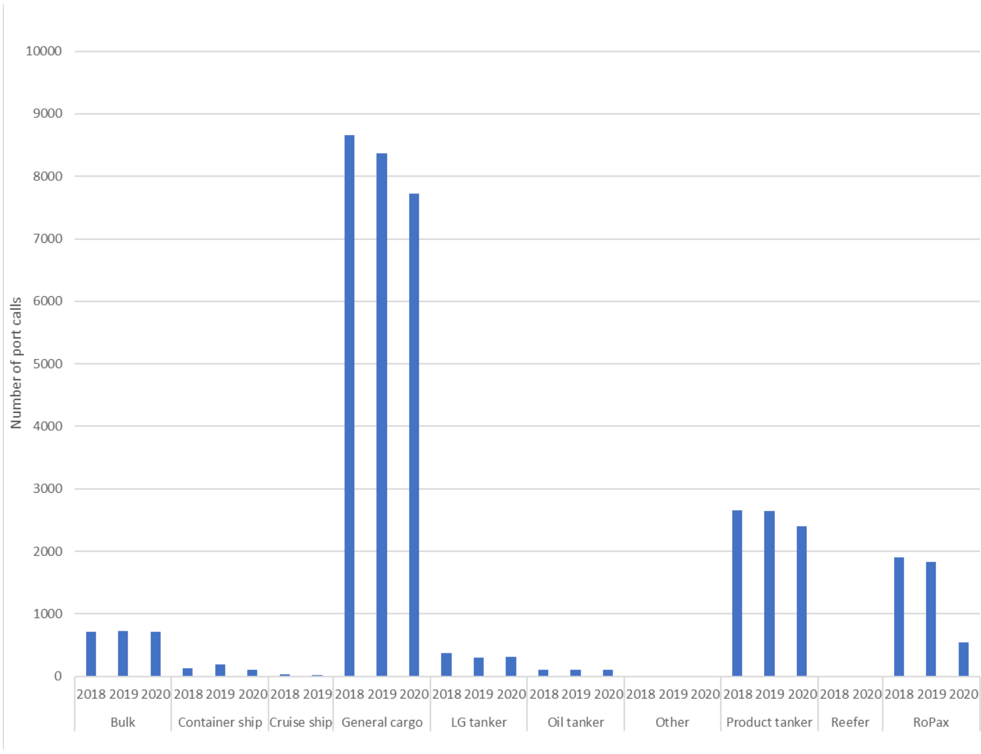

Figure 12. Number of port calls registered in SMA statistics for ships below 5000 GT for the Swedish case.

Included GHGs

The GHG emissions per shipping segment for the Swedish case in 2018 in a tank to wake (TtW) perspective are estimated in Figure 13 in a GWP100 perspective for the two cases of geographical coverage proposed. In the 100% case for EU shipping, these emissions correspond to 4.7 Mton of CO_2-eq (0.01 Mton CO_2-eq. for CH_4 and 0.08 Mton CO_2-eq for N_2O using the same GWP100 values as above). For the 50% of ingoing/outgoing case the GHG emission amounts to 2.5 Mton CO_2-eq.

For comparison, the GHG emissions from a WtT perspective linked to the shipping fuels used in the Swedish case in 2018 is estimated to approximately 0.9 Mton CO_2-eq. (i.e., about 16% of the well to wake, WtW, emissions) using the default values proposed in EP&C (2021).

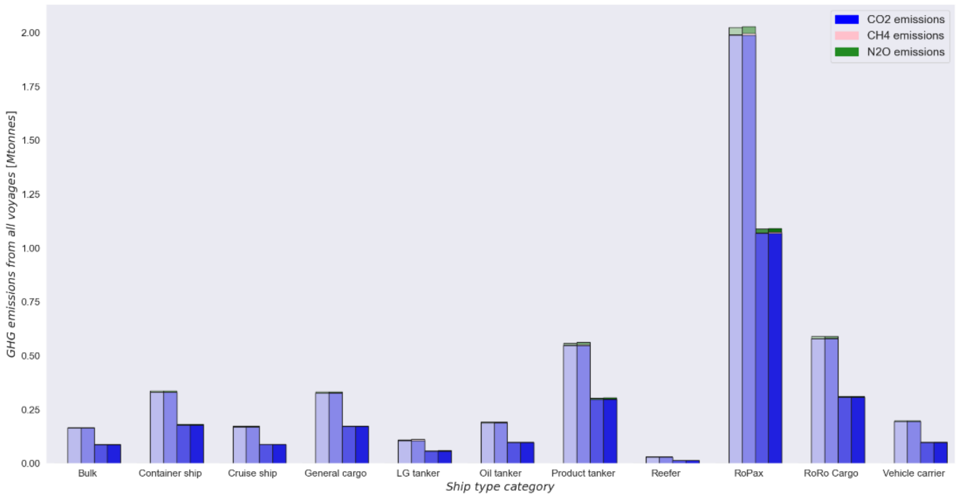

Figure 13. Estimated total GHG emissions in Mton CO_2-equivalent (including also CH_4 and N_2O emissions) per maritime shipping segment in 2018 for the Swedish case in a GWP100 perspective for ships above 5000 GT.

Potential impact on the fleet and associated impact on emissions of GHG and other air pollutants

The actual GHG emissions reduction from including shipping in the EU ETS will come from (i) mitigation measures implemented in the maritime sector itself, or from (ii) mitigation measures implemented in other sectors in the EU ETS i.e., out-of-sector abatement. The division will depend on the cost for ETS allowances versus the abatement cost and potential for different measures for the shipping sector in relation to the abatement costs and potential in other included sectors.

From a general point of view, it is less costly to reduce CO_2 emissions in the stationary sectors included in the EU ETS than from transportation (OECD, 2016). However, abatement measures with negative or low CO_2 abatement costs seem to be available for shipping, including mainly operational ones, e.g., slow steaming, propeller polishing and weather routing (Wan et al., 2018;

Eide et al., 2011). In case shipping is included in the EU ETS, some of these measures might be implemented. A very rough estimate of the potential reduction of GHG in the EU by 2030 for low or negative cost abatement measures, when assuming the same reduction for all parts of the global shipping sector potential (based on Eide et al., 2011) is about 50 Mton of CO_2. However, even if the abatement cost for certain abatement measures for shipping is lower than the ETS allowance price it is not certain the ship owner will implement the measure.

The abatement cost for technical measures varies from about 50-100 euro per ton (e.g., fuel cells as auxiliary engines and fixed sails or wings) to higher costs (e.g., solar panels and waste heat recovery) with alternative marine fuels in the upper range (150-230 euro per ton CO_2 for biofuels and 150-1250 for liquefied hydrogen and various electrofuels (Chryssakis et al., 2017; Lloyd's Register and UMAS, 2017; Brynolf et al., 2022).

In this study we analyse the possible effects of the inclusion of shipping in ETS on emissions of GHGs and air pollutants using an approach based on the cost effectiveness of implementing measures for specific ships included in MRV. The developed modelling approach is tested for selected abatement measures, exemplified in this report with preliminary results for the retrofit of ships to use alternative fuels in the form of biomass-based methanol, and electro-methanol (produced from water and CO_2 using electricity), as well as the implementation of energy efficiency measures for existing ships in the form of propeller upgrade and waste heat recovery.

Based on ship specific MRV data (plus ship details from Seaweb) and assumptions for costs and potential emission reduction linked to the selected measures, the annual cost of abatement (in Euro per ton CO_2) and the potential total emission reduction (in ton of CO_2) for each included ship are estimated for each studied measure (THETIS-MRV, 2022; IHS, 2021). The costs include capital cost for the investment and operational costs e.g., fuel cost (based on literature mainly Brynolf et al., 2022; Winnes, 2020; Faber et al., 2020; Grahn et al., 2022; Kanchiralla et al., 2022; Korberg, et al., 2021; Lindstad et al., 2015). For the methanol case, associated NO_X abatement potential is assessed using emission factors from the literature (Faber et al., 2020; Winnes et al., 2020).

CO_2 emissions

The estimated annual abatement cost for bio-methanol for each ship included in the MRV system as a function of the potential total emission reduction on a European level is presented in Figure 14. For the shift to biofuel to be profitable for the ship owner the ETS allowances price has to be higher than the abatement cost. Thus, we do not expect many ships to convert to bio-methanol with costs for ETS allowances below €100. The availability and supply potential for bio-methanol is not considered here.

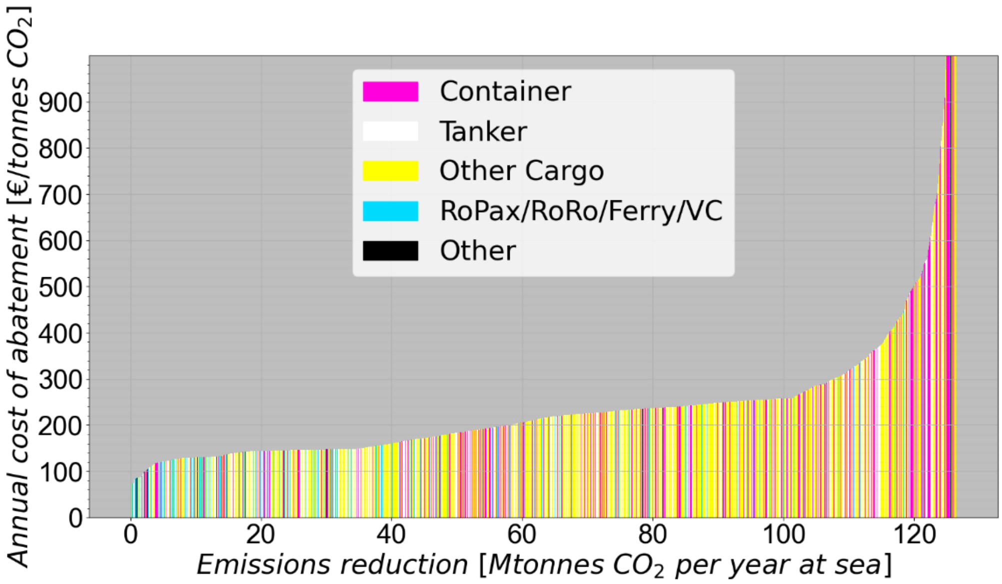

Figure 14. Annual abatement cost and CO_2 emission reduction potential per ship at sea in the case of retrofit to bio-methanol, for all ships included in the MRV system where each coloured column represents one specific ship.

Likely, there must be a clear and relatively long-term situation of profit for such investments to really be implemented. Further, the potential for shifting to bio-methanol is (like for other biofuels) restricted by the supply and potential for bio-methanol production. The annual abatement cost and CO_2 emission reduction potential per ship for retrofit to electro-methanol is therefore illustrated in Figure 15 where the abatement costs are even higher.

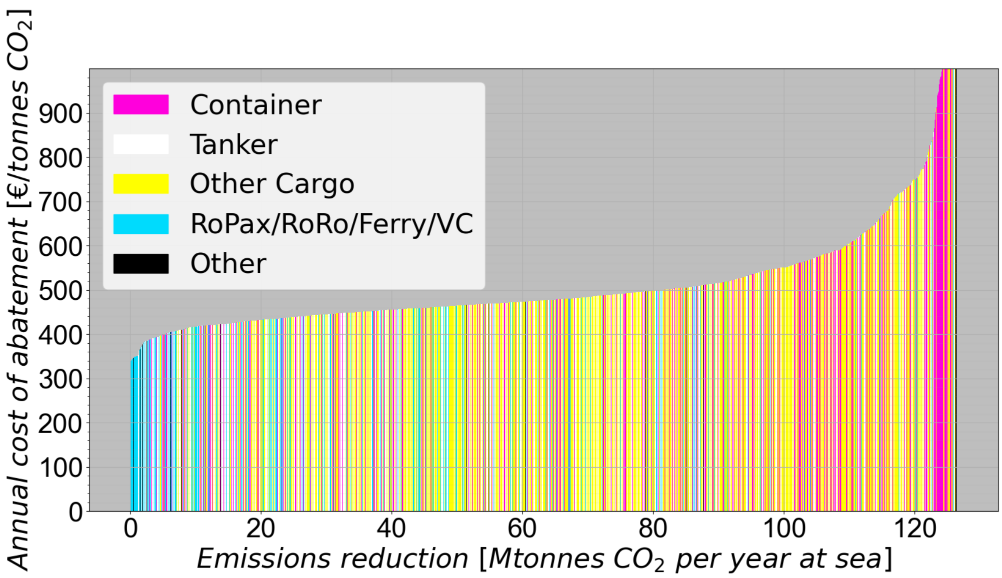

Figure 15. Annual abatement cost and CO_2 emission reduction potential per ship at sea in the case of retrofit to electro-methanol, for the ships included in the MRV system where each coloured column represents one specific ship.

For comparison, the price of ETS allowances was around 25 Euro per ton CO_2 during 2019 but increased substantially during end of 2021 (at occasions reaching levels above 90 Euro in 2022 but varied between 60-95 during the last year) (Trading Economics, 2022). The future allowance price is highly uncertain but also with the current higher levels the shift to renewable methanol is more costly than the allowance with current assumptions.

The estimated annual abatement cost for propeller upgrade and implementation of waste heat recovery for relevant ships included in the MRV system as a function of the potential total emission reduction on a European level is presented in Figures 16 and 17, respectively. Only ships that according to MRV spend more than 25% of the hours per year at sea in Europe are included. These ships are assumed to mainly cruise to to/from/in EU. Abatement costs would be lower if also emissions outside EU would be included. This both since emissions would be lower but also since fuel consumption outside the EU also would be lowered. The abatement costs for these measures are estimated based on Lindstad et al. (2015) but are uncertain. Thus, the results in Figures 16 and 17 should be seen as example of potential abatement cost for these measures and need to be assessed further.

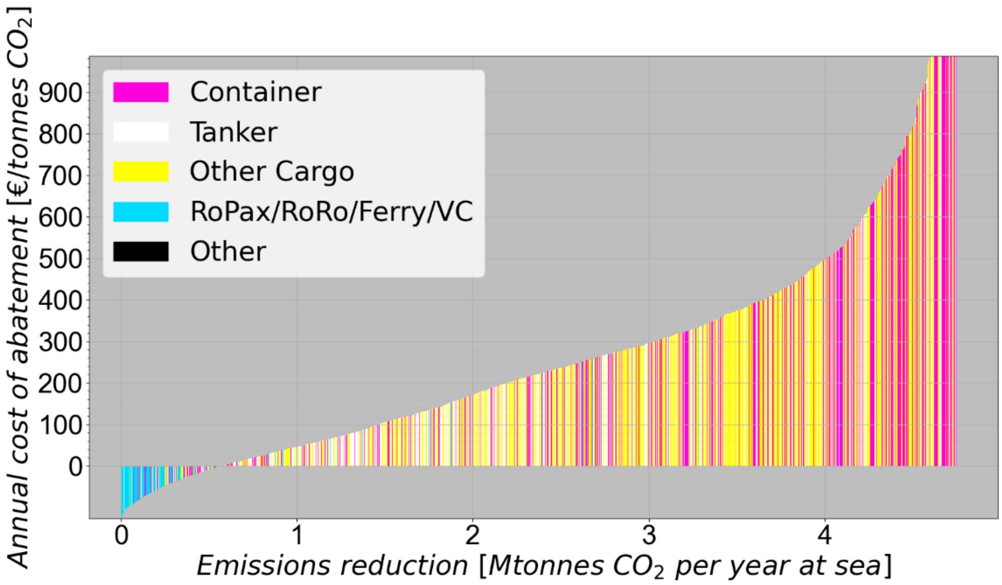

Figure 16. Annual abatement cost and CO_2 emission reduction potential per ship at sea in the case propeller upgrade is implemented, for the relevant ships included in the MRV system where each coloured column represents one specific ship.

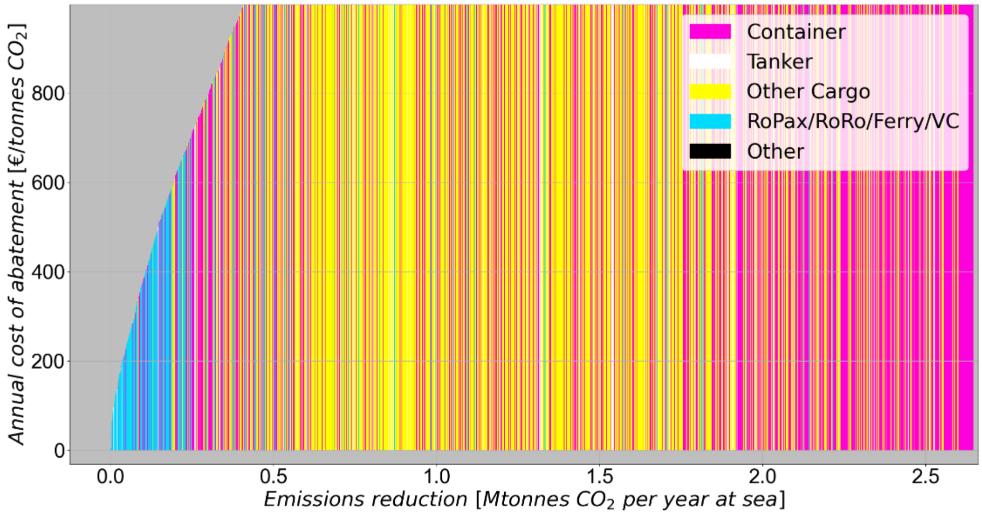

Figure 17. Annual abatement cost and CO_2 emission reduction potential per ship at sea in the case waste heat recovery is implemented, for the relevant ships included in the MRV system where each coloured column represents one specific ship.

Other air pollution

The implementation of mitigation measures will besides GHG emissions also influence other emissions such as NO_X, SO_X, and particulate matter (PM). The extent will depend on which mitigation measures that are implemented, and many alternative fuels also reduce these emissions. In EC (2021) it is estimated that in 2030 in case shipping is included in EU ETS the emissions of NO_X, PM10, and SO_X may be reduced by 7%, 7% and 8%, respectively, compared to a reference case.

A shift to methanol as marine fuel influences emissions such as NO_X, SO_X, and PM. The NO_X abatement potential for the investigated shift to bio-methanol in Europe is illustrated in Figure 18. Since the use of methanol as fuel results in lower NO_X emissions per amount of fuel used there will be an added environmental benefit from the shift to methanol. Similar effects, but even more pronounced, can be seen for PM and SO_X. Thus, there is a significant potential added benefit on air quality from implementing CO_2 reduction measures.

Different scenarios for the implementation of measures are further explored in Parsmo et al. (forthcoming).

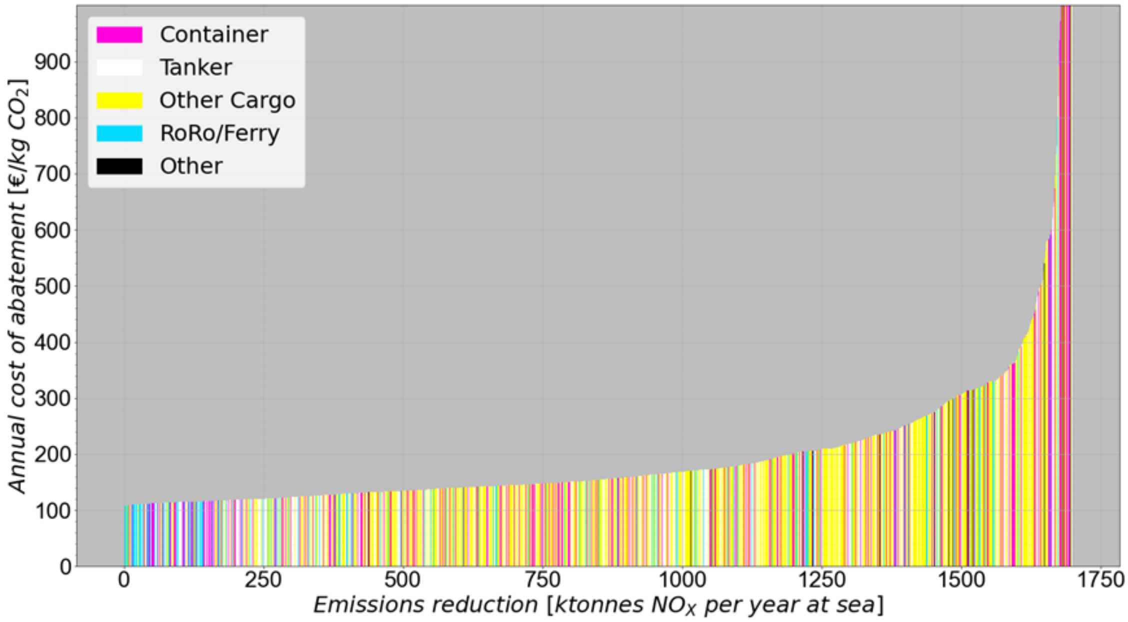

Figure 18. Estimated impact on NO_X emissions linked to the shift to methanol as marine fuel in Europe.

Potential impact on cost-effective fuel choices of including shipping in the EU ETS

The potential impact on cost-effective marine fuel choices when including shipping in EU ETS are assessed using the Global Energy Transition (GET) Model (described for example in Lehtveer et al. (2019) and Taljegård et al. (2014)). The GET model is a cost minimizing "bottom-up" model of the global energy system constructed as a linear programming problem and divided into 10 world regions where Europe is one.

The objective is to minimize the total energy system cost for the studied period (in this case 2070) while meeting an externally defined energy demand and a carbon constraint (expressed as a cap or a bound). In this study an emission cap is placed either on the shipping sector in Europe, on the total European emissions and/or on the total global emissions (the latter via a carbon dioxide emission budget) and the impact on fuel choices is studied. The focus is on CO_2 emissions in the assessments presented in this report. The emission cap is set following the proposed emission reduction targets for the revision of the EU ETS (corresponding to minus 61% compared to 2005, in the model compared to 2010). The total global target is represented by a CO_2 budget for the period 2011-2100 and set to 905 GT CO_2 which represents a climate target of an expected temperature rise of 2ºC by 2100.

Compared to the base case with no emission targets and where LNG is introduced to replace part of the use of oil, the application of an overall CO_2 budget of 905 GT CO_2 besides the introduction of LNG, from 2040 leads to an introduction of hydrogen-based energy carriers in the form of hydrogen or ammonia in the shipping sector, both globally and in the EU, see Figure 19.

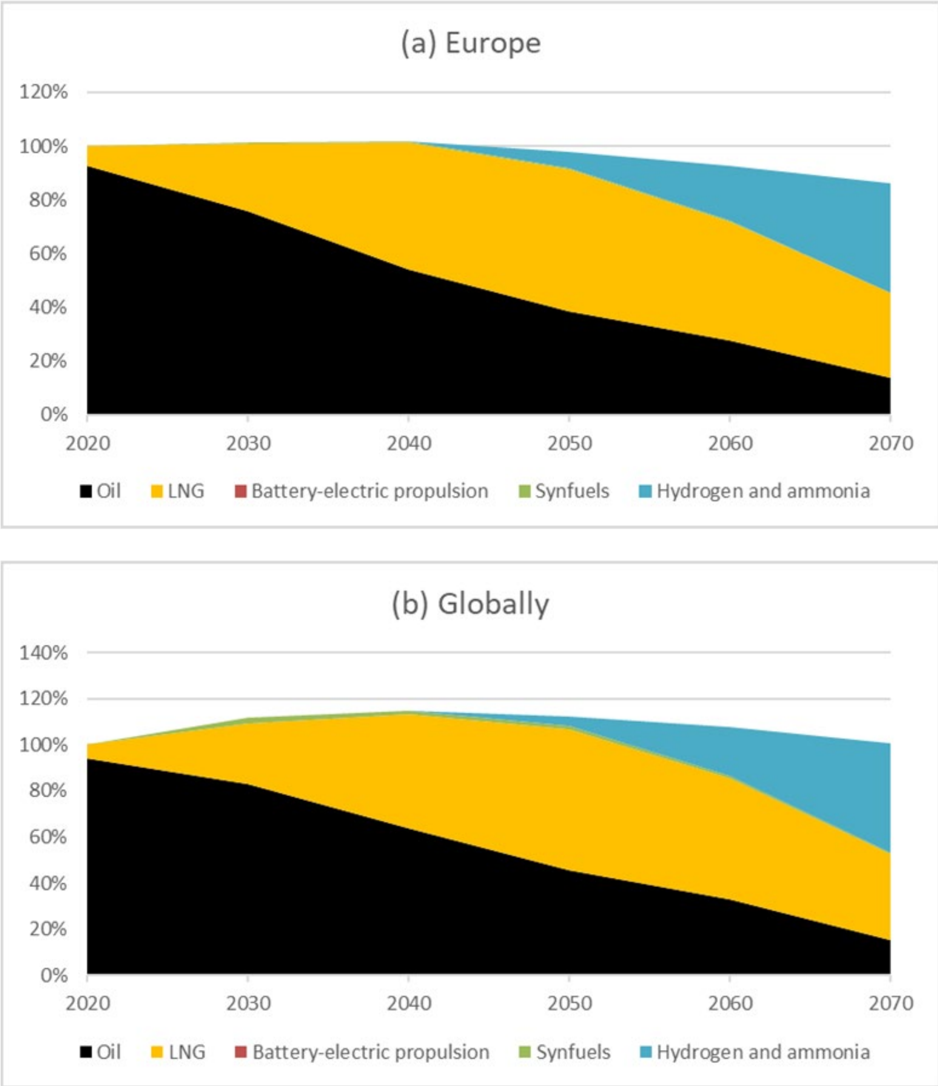

Figure 19. Cost-effective marine fuel choices in (a) Europe and (b) globally in the case of an overall global emission/temperature target but also in the case shipping is included in the EU ETS.

The inclusion of shipping in EU ETS which in the model is represented by a cap on the total European CO_2 emissions i.e., also including the shipping sector, in case there are also an overall global emission target does not influence the marine fuel choices compared to the case with only an overall global emission target, Figure 19. This indicate that the emission cap in the EU is not strict enough to require an additional introduction of alternative marine fuels on its own.

In case a separate ETS for the shipping sector is introduced or a closed bubble for the shipping emissions in the EU ETS (without the possibility to buy allowances from other sectors) in combination both with and without a global emission target, the modelling indicates that there is a considerable impact on marine fuel choices. Battery electric propulsion and in particular ammonia and hydrogen are introduced from the start in Europe, Figure 20.

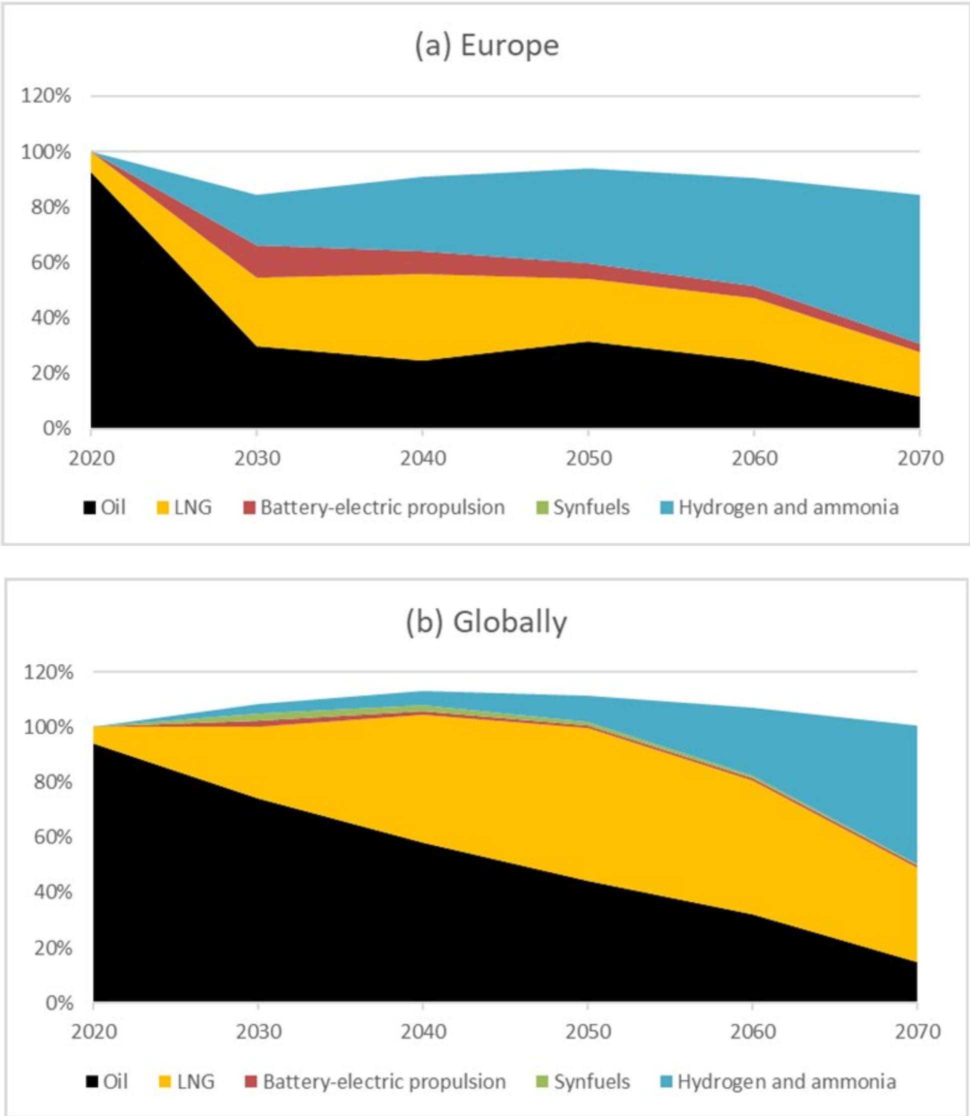

Figure 20. Cost-effective marine fuel choices in (a) Europe and (b) globally in the case of a separate ETS for the shipping sector is introduced or a closed bubble for the shipping emissions in the EU ETS (without the possibility to buy allowances from other sectors) in combination with an overall global emission target.

Policy implications

Including shipping in EU ETS is an important decarbonization policy. If realized, however, least-cost measures mainly related to increased energy efficiency of ships and operation (e.g., propeller polishing and engine improvements) are likely implemented first, while shipping measures with higher carbon abatement costs but also higher emission reduction potential, such as fuel switch to renewable fuels, will not be introduced in large-scale as long as the price for the allowances are lower than the carbon abatement cost linked to these fuels. Due to the expected cost of emissions allowances in the short to mid-term, including shipping in EU ETS is not expected to be enough to promote large-scale fuel shift in the shipping sector in the short term. Other policy initiatives for the promotion of renewable marine fuels are thus needed. However, the inclusion of shipping in the ETS may lead to increased reduction of emissions in other sectors and will thus contribute to emission reduction. In addition, given that the inclusion of shipping in the EU ETS leads to significant in-sector emission reductions a significant benefit on air quality can also be expected.

Outlook

The urgent need to decarbonize shipping presupposes the introduction of a market-based measure that would incentivize and stimulate investments for the energy transition of the maritime sector. The effectiveness of such a measure, though, largely depends on designing a rather stable regulatory framework with reduced uncertainty for the maritime actors that already operate in volatile market conditions.

Whereas the trilogue, that is negotiations between the EU Parliament, Council and Commission, has yet to be settled before the final legislation can be implemented the maritime transport sector will most likely be included in the EU ETS within a few years. This is a major breakthrough in international climate mitigation and is also clearly intended to put pressure on other international actors to make progress on the development of a global market-based measure at the IMO level as well as on other regions to act in similar way. Likewise, this may put pressure on international aviation to increase efforts through an international mitigation regime.

The impacts of the inclusion of shipping in EU ETS will depend on several design features. The size limit will have implications on ships in the future; with the 5000 GT limit there is a risk that a large number of ships will be excluded from the trading scheme, and even that ships just below 5000 GT will become frequent in the future in order to avoid having to purchase emission allowances. Thus, it is important to also monitor the emissions from ships below 5000 GT. Further, the expected inclusion of emissions of methane in MRV and ETS will be important for the development of LNG as a fuel in Europe. It may lead to the introduction of LNG engines with low methane slip or the use of abatement equipment. However, how the methane emissions from individual ships will be estimated/reported are important for the impact. The likely inclusion of nitrous oxides might also in a similar manner influence the development of ammonia and associated propulsion systems.

It is unclear if and to what extent the inclusion of shipping will lead to carbon leakage, that is, that ships would increasingly call on ports outside EU in order to avoid purchase emissions allowances in the EU ETS. This will need further investigation and also depends on to what extent the regulation manages to reduce this risk and the actual future price of emission allowances.

However, the impacts will also depend on the development of other policies. For example, although the currently estimated cost of EU ETS in itself is not likely to cause any major modal shift, it can possibly influence certain segments such as RoRo and RoPax, but the extent will depend on the development of policies and cost for transport in competing transport sectors, mainly road transport. There are also other policy instruments being developed in the EU which will significantly influence the emissions of GHG from shipping, such as EU Fuel Maritime.

In parallel with the development in the EU, the IMO is discussing market-based instruments with the aim of introducing them within the next few years. The IMO aims at its goal of reducing GHG emissions from shipping by 50% by 2050, compared with 2008, even if also the level if this goal is being discussed. A cap-and-trade system is one possibility for IMO, as is a levy on CO_2 and regulating the fuel intensity of marine fuels. Most likely EU policies will be modified if effective global instruments are introduced by the IMO.

It seems important that the research community continues to study these policy instruments in order to assure that negative effects on trade is not inherent in the systems and to assure that the expected reductions in emissions of GHG (and air pollutants) will materialize. How the combination of different policies for the shipping sector (but also in other sectors) influences the decarbonization of the shipping sector need to be further explored.

References

Brynolf, S., Hansson, J., Anderson, J.E., Ridjan Skov, I., Wallington, T.J., Grahn, M., Korberg, A.D., Malmgren E., Taljegård, M., (2022). Review of electrofuel feasibility - Prospects for road, ocean, and air transport. Progress in Energy, 4, 042007; https://doi.org/10.1088/2516-1083/ac8097.

Christodoulou, A., Dalaklis, D., Ölcer, A., Masodzadeh, P.,G., 2021. Inclusion of Shipping in the EU-ETS: Assessing the Direct Costs for the Maritime Sector Using the MRV Data. Energies 14, 3915.

Chryssakis C, Brinks HW, Brunelli AC, Fuglseth TP, Lande M, Laugen L, Longva T, Raeissi B, Tvete HA, 2017. Low carbon shipping towards 2050. Technical Report. DNVGL; 2017. Available at: https://www.dnvgl.com/publications/low-carbonshipping-towards-2050-93579, Accessed 2022-02-15.

Eide, M.S., Longva, T., Hoffmann, P., Endresen, Ø., Dalsøren, S.B., 2011. Future cost scenarios for reduction of ship CO_2 emissions. Maritime Policy Management. 38, 11–37.

European Commission (EC), 2021. Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757. COM(2021) 551 final. Brussels, 14.7.2021.

European Commission (EP), 2022. Amendments adopted by the European Parliament on 22 June 2022 on the proposal for a directive of the European Parliament and of the Council amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757 (COM(2021)0551 – C9-0318/2021 – 2021/0211(COD))

Faber, J., Hanayama, S., Zhang, S., Pereda, P., Comer, B., Hauerhof, E., et al., 2020. Reduction of GHG Emissions from Ships—Fourth IMO GHG Study 2020—Final Report. Retrieved from https://www.imo.org/en/OurWork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx

Flodén, J., Woxenius, J., 2022. Risk in transporting dangerous goods via RoRo and RoPax shipping, In: Basu Bal, A., Rajput, T. Argüello, G., Langlet, D. (Eds.) Contemporary Issues in Regulation of Risk: Transport, Trade and Environment in Perspective - Liber Amicorum Lars-Göran Malmberg, Brill, Leiden. Forthcoming.

Grahn, M., Malmgren, E., Korberg, A.D., Taljegard, M., Anderson, J., Brynolf, S., et al., 2022. Review of electrofuel feasibility—cost and environmental impact. Progress in Energy, 4(3), 032010.

HIS, 2021. Seaweb - Maritime Portal: Ship database. Retrieved from: maritime.ihs.com/

IMO, 2020, Fourth IMO Greenhouse Gas Study

IMO, 2022. https://www.imo.org/en/OurWork/Environment/Pages/AirPollution-Default.aspx

IPCC, 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

Kanchiralla, F.M., Brynolf, S., Malmgren, E., Hansson, J. Grahn, M., 2022. Life-Cycle Assessment and Costing of Fuels and Propulsion Systems in Future Fossil-Free Shipping. Environmental science & technology, 56 (17) p. 12517–1253.

Korberg, A.D., Brynolf, S., Grahn, M., Skov, I. R. (2021). Techno-economic assessment of advanced fuels and propulsion systems in future fossil-free ships. Renewable and Sustainable Energy Reviews 142.

Lagouvardou, S., Psaraftis, H., 2022. Implications of the EU Emissions Trading System (ETS) on European container routes: A carbon leakage case study. Maritime Transport Research 3, 100059.

Lehtveer, M., Brynolf, S., Grahn, M., 2019. What Future for Electrofuels in Transport? Analysis of Cost Competitiveness in Global Climate Mitigation. Environmental Science & Technology, 2019. 53: p. 1690-1697.

Lindstad, H., Verbeek, R., Blok, M., Van Zyl, S., Hübscher, A., Kramer, H., et al., 2015. GHG emission reduction potential of EU-related maritime transport and on its impacts, (Ref: CLIMA. B. 3/ETU/2013/0015), TNO report.

Lloyd’s Register and UMAS, 2017. Zero emissions vessels 2030 – How do we get there? Available at: https://www.lr.org/en/insights/global-marine-trends-2030/zero-emission-vessels-2030/, Accessed 2020-02-18.

MarineTraffic. (2022). MarineTraffic - historical data port calls. Nordic Port Calls 2018 ships larger than 5000 GT. Retrieved from https://www.marinetraffic.com/en/p/ais-historical-data. https://www.marinetraffic.com/en/p/ais-historical-data

OECD, 2016. Effective Carbon Rates. Pricing CO_2 through Taxes and emissions trading systems. Paris: OECD Publishing; 2016.

Searoutes, 2022. Sea Distances/Port distances - online tool for calculation distances between sea ports. Retrieved from https://developer.searoutes.com/reference/introduction-2.

SMA, 2017. Swedish port call statistics 2017. The data is not public.

Taljegård, M., Brynolf, S., Grahn, M., et al., 2014. Cost-Effective Choices of Marine Fuels in a Carbon-Constrained World: Results from a Global Energy Model. Environmental Science & Technology, 2014. 48(21): p. 12986-12993.

THETIS-MRV, 2022. CO_2 Emission Report. Retrieved from https://mrv.emsa.europa.eu/#public/emission-report

Trading Economics, 2022, EU Carbon Permits. Date of access: 29/11/2022. https://tradingeconomics.com/commodity/carbon

Transport & Environment, 2022. Climate Impacts of Exemptions to EU's Shipping Proposals. Report. Available at: www.transportenvironment.org/wp-content/uploads/2022/01/Climate_Impacts_of_Shipping_Exemptions_Report-1.pdf

Wan, Z., el Makhloufi, A., Chen, Y., Tang, J., 2018. Decarbonizing the international shipping industry: Solutions and policy recommendations. Marine Pollution Bulletin 126, pp. 428-435.

Wang, S., Zhen, L., Psaraftis, H. N., & Yan, R. (2021). Implications of the EU's Inclusion of Maritime Transport in the Emissions Trading System for Shipping Companies. Engineering , 7(5), 554-557. https://doi.org/10.1016/j.eng.2021.01.007

Winnes, H., Fridell, E., Ntziachristos, L., Grigoriadis, A., & Jalkanen, J.-P., 2020. Evaluation, control and Mitigation of the EnviRonmental impacts of shippinG Emissions (EMERGE) - Summary and analysis of available abatement methods for SO_X, NO_X and PM, together with data on emissions, waste streams, costs and applicability.