Maritime shipping and EU ETS

An assessment of the possibilities to evade ETS costs

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Content

Summary

The European Commission has proposed to include the emissions from maritime transport in the European Emissions Trading Scheme (EU ETS) as part of the Fit for 55 package. The aim of the inclusion of maritime transport in the EU ETS is to address greenhouse gas emissions from this sector and to ensure that shipping contributes to meeting the economy-wide emission reduction targets of the European Union. Ships could, in principle, avoid the system by changing their routes or changing the routes of their cargo. Such evasive behaviour could impact the competitive position of European seaports as well as undermine the aims to reduce the emissions from shipping.

The Port of Rotterdam has requested CE Delft to conduct case studies for different sailing schedules of container lines in order to get a better understanding whether and if so, under which circumstances, avoidance of EU ports would be a profitable strategy.

There are four ways in which could plausibly avoid the EU ETS, which are:
1. Adding an extra port call just outside of the EU.
2. Changing the order of the ports in the existing schedule such that a port close to the EU is the first port of call in the EU region.
3. Removing EU ports from the schedule and feedering to these ports from a non-EU port.
4. Removing some EU ports from the schedule and feedering from an EU port.

For each of the five case studies we calculated the costs and benefits of the evasive options which apply to the specific case study. The case studies show that avoidance of the EU ETS by changing the order of ports or adding an additional port call is sometimes profitable and can therefore not be ruled out. The likelihood of avoidance having a net benefit for the shipping company is larger when:
- the price of emission allowances is higher;
- the costs of evasion (port costs, operational costs, charter costs, container handling costs, opportunity costs) are lower;
- the emissions on the last voyage to an EU port or the first voyage from an EU port are higher; or
- the costs of transhipment are lower.

However, we also conclude that the impact of this evasive behaviour on European seaports is likely to be limited. First of all, this is because all cargo destined for the EU will still need to be unloaded in European seaports. The evasive behaviour will therefore mostly affect the transhipment activities in European seaports. Operational constraints or capacity limits in non-EU ports could further reduce the risk in the short term.

There are several options to mitigate the risk of evasion. The best way to reduce the risks is to ensure that similar market-based measures are implemented at the IMO level or in countries close to the EU. Changes to the legislative proposal to limit evasion either result in an increase in administrative tasks, reduce the effectiveness of the EU ETS or have legal implications. Therefore, such options should only be implemented if the evasive behaviour turns out to be higher than acceptable.

1 Introduction

The European Commission has proposed to include the emissions from ships in the European Emissions Trading Scheme (EU ETS) as part of the Fit for 55 package (EC, 2021).

In the current version of the policy proposal, the emissions of cargo and passenger ships of 5000 GT and above would be included in the EU ETS system with the following geographical scope:

- all emissions between EU ports count for 100%;
- all emissions from non-EU ports to EU ports count for 50%;
- all emissions from EU ports to non-EU ports count for 50%;
- all emissions between ports outside of the EU are outside the scope of EU ETS.

The aim of the inclusion of maritime transport in the EU ETS is to address greenhouse gas emissions of this sector and to ensure that shipping contributes to meeting the economy-wide emission reduction targets of the European Union. These aims would be undermined when ships avoid the system by changing their routes or changing the routes of their cargo.

The impact assessment of the revision of the EU ETS contains an analysis of the possibility that ships have for avoidance. The general conclusion is that the risk of evasion is limited, unless the allowance prices are high or when all emissions on voyages between EU and non-EU ports would be included, both of which are not actually proposed by the Commission.

The Port of Rotterdam has requested CE Delft to conduct case studies in order to get a better understanding whether and if so, under which circumstances, inclusion of shipping in the EU ETS can give rise to avoidance of EU ports.

1.1 Scope and aim

The aim of this study is to get a better understanding of the situations in which EU ETS avoidance might occur and the expected impact of such avoidance on the activity in European seaports. The general analysis of the evasion options which is included in this study applies to all shipping types. However, the cost-benefit analysis for the three case studies focusses on container shipping.

1.2 Outline

Chapter 2 contains a general analysis of the possibilities to evade EU ETS costs. The results of the cost-benefit analysis for three different container shipping lines are presented in Chapter 3. The conclusions of this study are presented in Chapter 4.The detailed assumptions in the cost-benefit analysis can be found in Annex A.

2 Possibilities to evade EU ETS

2.1 How can shipping companies avoid EU ETS?

The inclusion of maritime shipping in EU ETS would imply that the costs for shipping increases on voyages from non-EU ports to EU ports or shipping between EU ports. This cost increase is caused by the requirement to submit emission allowances for CO_2 emissions on these routes. The EU ETS costs are a function of the amount of fossil fuel used on those voyages, which in turn is a function of the fuel-efficiency of the ship, the length of the voyage and the type of fuel.

The cost increase of the EU ETS can be avoided in multiple ways. In the literature (European Commission et al., 2021, KIM, 2021, T&E, 2021) and based on our own reasoning, we distinguish seven different ways in which EU ETS can be avoided:

1. Adding an extra port call just outside of the EU.
2. Changing the order of the ports in the existing schedule such that a port close to the EU is the first port of call in the EU region.
3. Removing EU ports from the schedule and feedering to these ports from a non-EU port.
4. Removing some EU ports from the schedule and feedering from an EU port.
5. A modal shift to modes of transport that are not within the EU ETS scope (currently, this could be road, inland traffic or rail).
6. Using vessels under the EU ETS threshold (5,000 T gross tonnage).
7. Using the most fuel-efficient ships for intra-EU trips, while using more polluting ships outside of the EU.

For some of these options evasion of EU ETS on a significant scale is unrealistic. For other options, on the other hand, the risk of evasion is more likely. The next section contains a general analysis of each option.

2.2 Analysis of the different evasion options

1. **Adding an extra port just outside of the EU**
   When a vessel sails between the EU and distant destinations such as East Asia or the Americas, emission allowances need to be surrendered for 50% of the emissions on those voyages. Adding a port call just outside of the EU, for example in the UK or Morocco, can reduce the emissions in the scope of the EU ETS and thus lower the costs of compliance. Because a port call is only recognised as the start of a new voyage when cargo is loaded or discharged, adding a port call is more costly for ships carrying cargo in bulk than for ships carrying unitized cargo such as container ships. For this reason, the analysis focusses on container ships.

2. **Changing the order of the ports in the existing schedule such that a port close to the EU is the first port of call in the EU region**
   In the current situation, for some liners it is the case that (after approaching from a distant port) they first call an EU port and afterwards a nearby non-EU port. In such situations, it could be beneficial to change the order of the schedule: if the nearby non-EU port is called first, no EU ETS costs are paid for the long leg between the distant destination and the EU.

3. **Removing some EU ports from the schedule and feedering from an EU port**
   Since all emissions on voyages between EU ports are included in the EU ETS, the compliance costs can be lowered by using vessels that have the optimal capacity. Consider a situation where a 20,000 TEU container ship travels between three different EU ports versus a situation where the 20,000 TEU container ship only visits one port, from which the other two ports are serviced with the use of feeders. In the latter scenario, the EU ETS costs are lower due to the lower fuel use per kilometre of the feeders. Of course, other costs will be higher because containers have to be transhipped and new vessels need to be added to the fleet; the avoidance is only rational when the savings from compliance with the EU ETS exceed the costs.

4. **Removing EU ports from the schedule and feedering to these ports from a non-EU port**
   Since all emissions on voyages between EU ports are included in the EU ETS, the compliance costs can be lowered by feedering to the EU. Consider a situation where a 20,000 TEU container ship travels between two different EU ports and a UK port versus a situation where the 20,000 TEU container ship only visits the UK port, from which the other two ports are serviced with the use of feeders. In the latter scenario, the EU ETS costs are lower, since the fuel use of these feeders per kilometre is lower.

5. **A modal shift to modes of transport that are not within the EU ETS scope (currently, this could be road, inland shipping or rail)**
   - Transporting goods using modes outside of the EU ETS scope is a way to evade the EU ETS costs. However, this is not a realistic option in almost all situations since other modes of transport are either:
     - already included in the EU ETS (this is the case for electric rail transport because all electricity generation is included in the EU ETS);
     - subject to climate regulation that increases their costs, such as the Renewable Energy Directive and the Fuel Quality Directive, both of which currently increase the costs of road transport and diesel rail transport but not the costs of maritime transport; and
       - the Commission also proposes to include fuels for land transport modes in a separate EU ETS.
   - Combined with the fact that maritime transport is much less carbon intensive than other transport modes, other modes face cost increases that are larger than maritime transport.

6. **Using vessels under the EU ETS threshold (5,000 T gross tonnage)**
   When goods are transported in vessels outside of the EU ETS scope, costs are avoided. However, the avoided costs are not nearly enough to compensate for the added inefficiency of using these small vessels.

7. **Using the most fuel-efficient ships for intra-EU trips, while using more polluting ships outside of the EU**
   When shipping companies use the cleanest ships for transport to and from Europe, they can lower the EU ETS costs. However, this does not directly affect the activity in European ports.

2.3 Conclusions

Since Options 1 up to 4 could, based on a first analysis, realistically be used by shipping companies to evade EU ETS, these are analysed in more detail in Chapter 3. Options 5 and 6 cannot realistically lead to evasion on a significant scale: therefore they are not analysed further in this study. Option 7 does not affect the activity in EU ports: therefore this option is not discussed further either.

3 Cost-benefit analysis for five case studies

It is not always possible to intuitively tell whether an evasion option is cost-effective or not. For this reason, we present five case studies in which different evasions are analysed in detail. Five existing container lines form the basis of this case study. For each of these lines, one or multiple evasions are candidate options. The case studies are chosen such that together they give a good impression of the costs and benefits of the different evasive options.

Methodology of the cost-benefit analysis

In the cost-benefit analysis, scenarios in which EU ETS costs are evaded are compared to the current situation. If the benefits of evasion exceed the costs of evasion, it can be concluded that there are financial incentives to evade EU ETS.

We have quantified the following costs and benefits:
- fuel costs (VLSFO);
- operational costs;
- charter costs;
- port costs;
- opportunity costs;
- EU ETS costs;
- container handling costs[1].

Specific cost estimates were used for the different ship types. Also, for fuel costs, charter costs, EU ETS costs and opportunity costs three different values (low, middle, high) were used to account for the large volatility in the costs over time. For the UK, Algeciras and Tanger Med port costs, we used assumed cost values which may deviate from port costs as published by the respective ports.

The detailed assumptions of the cost-benefit analysis are included in Annex A.

Disclaimer
In this study, we only included the seven cost-parameters as described above. In reality, there might be other financial or non-financial reasons which influence the decisions of shipping companies which this study does not account for. Some examples of factors which we did not quantify are: network effects for the shipping companies, congestion levels at different ports and the costs of delivering containers later and administrative burden of changing the schedule to include a port which is normally not visited by the shipping company.

Also, the assumptions for the cost-parameters that we did quantify might in some cases deviate from the actual values. The cost assumptions (as presented in Annex A) were chosen such that they are representative for liners similar to the actual case studies.

[1] These costs are only quantified in cases where feeder operations are added or removed compared to the original schedule.

3.1 Case 1: Maastricht Maersk

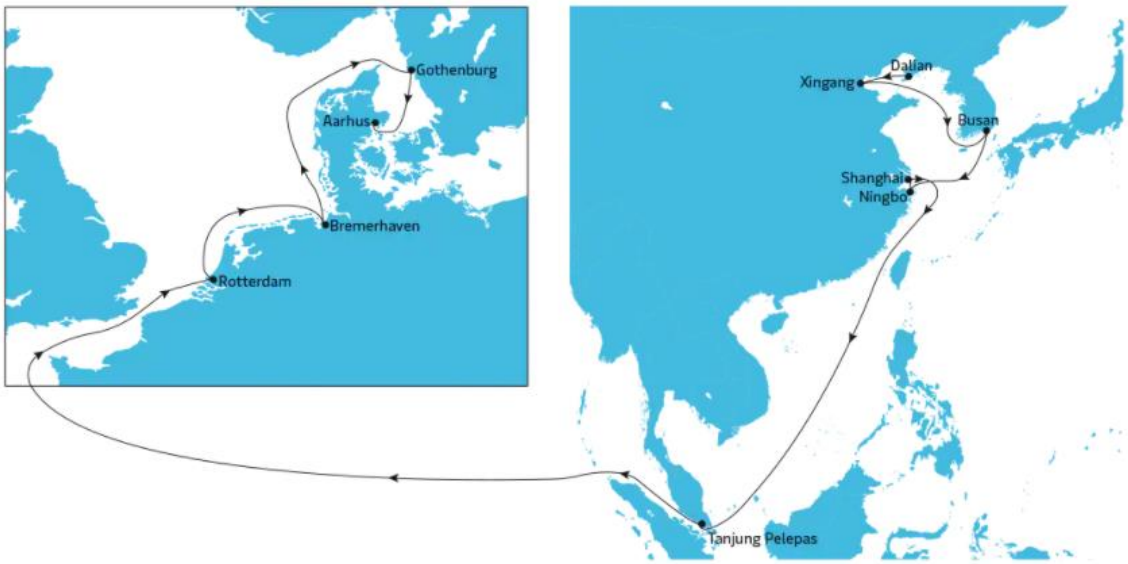
Maastricht Maersk is a 20,568 TEU container vessel which sails between East Asia and North-West Europe on service AE5. The westbound part of the schedule is summarised in Figure 1 and the whole round trip is summarised in Table 1.

Because of this specific route, the following evasion options have been analysed:
1. Adding Felixstowe as an extra port of call in between Tanjung Pelepas and Rotterdam.
2. Removing Aarhus and Gothenburg from the schedule and feedering to these ports using smaller vessels.

Table 1 - Maastricht Maersk Schedule

Ports	Time to next port (days)	Distance to next port (nautical miles)	EU ETS charge (% CO_2-emissions)
Gothenburg - Aarhus	2	169	100%
Aarhus - Bremerhaven	3	471	100%
Bremerhaven - Wilhelmshaven	2	61	100%
Wilhelmshaven - Port Tangier Mediterranee	5	1,849	50%
Port Tangier Mediterranee - Singapore	17	7,720	0%
Singapore - Shanghai	6	2,692	0%
Shanghai - Dalian	4	585	0%
Dalian - Xingang	2	229	0%
Xingang - Busan	3	906	0%
Busan - Ningbo	4	607	0%
Ningbo - Shanghai	4	12,489	0%
Shanghai - Tanjung Pelepas	7	2,713	0%
Tanjung Pelepas - Rotterdam	19	9,286	50%
Rotterdam - Bremerhaven	3	309	100%
Bremerhaven - Gothenburg	7	384	100%
Total round trip	**88**	**40,470**	**-**

Figure 1 - Maastricht Maersk schedule - westbound



Source: MAERSK : AE5 Westbound

Round trip costs of the regular schedule

The first analysis which we present for this case study is a cost breakdown for one round trip[2]. It can be seen that the EU ETS costs for a round trip range between 0.2-1.0 million euro's, depending on the EU ETS price assumption. Of these costs 67% are from the long journey between Tanjung Pelepas and Rotterdam, even though only 50% of the emissions on this voyage are included in the EU ETS. Avoiding such costs therefore could be a significant cost saving.

Table 2 - Cost breakdown for a round trip - Maastricht Maersk

Cost type	Cost estimate	Costs (€/round trip)
EU ETS costs	Low	201,000
	Middle	447,000
	High	1,005,000
Fuel costs	Low	1,660,000
	Middle	6,141,000
	High	7,192,000
Operational costs	-	674,000
Charter costs	Low	5,559,000
	Middle	13,030,000
	High	24,271,000
Port costs	-	1,878,000

[2] For the EU ETS price, the fuel price and the charter price three cost estimates were used in this study: 'low', 'middle' and 'high'. The precise assumptions are documented in Annex A.1.

3.1.1 Adding Felixstowe

When an additional port call would be made in Felixstowe, the EU ETS costs of Maastricht Maersk are lowered by 132-660k euros for one round trip, depending on the EU ETS price. However, the operational costs, fuel costs, charter costs, port costs and opportunity costs are higher compared to the reference scenario.

Table 3 shows the cost changes for Maastricht Maersk when Felixstowe is added to the schedule. When the EU ETS costs are low, the additional costs exceed the benefits. However, when the EU ETS costs are high, it is likely that the evasive port call might be profitable. Note that the outcomes are highly dependent on the assumptions for the evasive port call costs (see Annex A for a detailed explanation).

Table 3 - Change in round trip costs compared to the regular schedule

Cost type	Cost estimate	Change in costs (€/round trip)
EU ETS costs	Low	-132,000
	Middle	-294,000
	High	-660,000
Fuel costs	Low	2,000
	Middle	6,000
	High	7,000
Operational costs	-	8,000
Charter costs	Low	63,000
	Middle	148,000
	High	276,000
Port costs	-	98,000
Opportunity costs	Low	112,000
	Middle	228,000
	High	372,000

However, some containers on board of Maastricht Maersk might be destined for the UK. In this case, we also need to account for the feeder operation which delivers these containers in the UK. For three different cases (500 TEU destined for the UK, 1,000 TEU destined for the UK and 2,000 TEU destined for the UK), the extra costs of the feeder operation are summarised in Table 4[3].

Table 4 - Costs of transporting 500, 1,000 or 2,000 containers from Rotterdam to the UK (€)

Cost estimate (for all parameters)	500 TEU	1,000 TEU	2,000 TEU
Low	107,000	214,000	427,000
Middle	115,000	230,000	459,000
High	140,000	280,000	559,000

[3] In all three cases it was assumed that the containers are transported on a 1,000 TEU ship. For the 500 TEU scenario, half of the costs which this ship makes were used in the calculation. For the 2,000 TEU ship, double the costs were used in the calculation.

Table 5 shows the total cost-benefit, including the saved costs of feedering 0, 500, 1,000 or 2,000 TEU to the UK, in nine different scenarios. It can be concluded that EU ETS evasion may or may not be cost-effective, depending on the following factors:

- if the EU ETS price is high, adding an evasive port call becomes more attractive;
- if there are many containers destined for the UK on board, adding an evasive port call becomes more attractive;
- if the cost parameters other than EU ETS are low, adding an evasive port call becomes more attractive.

In some of the scenarios in Table 5, evasion would have been cost-efficient even without EU ETS costs. The cases in which the added EU ETS costs are decisive are shown in **bold face**. Since the EU ETS costs are decisive in eighteen scenarios, we can conclude that the risk of evasion is substantial.

Table 5 - Total cost-benefit in four different scenarios (€)

Cost estimate	0 TEU	500 TEU	1,000 TEU	2,000 TEU
Low EU ETS costs				
Low other costs	151,000	44,000	**-63,000**	-277,000
Middle other costs	356,000	241,000	126,000	**-103,000**
High other costs	629,000	489,000	350,000	70,000
Middle EU ETS costs				
Low other costs	**-11,000**	**-118,000**	**-225,000**	-438,000
Middle other costs	194,000	80,000	**-35,000**	**-265,000**
High other costs	468,000	328,000	188,000	**-92,000**
High EU ETS costs				
Low other costs	**-378,000**	**-485,000**	**-591,000**	-805,000
Middle other costs	**-172,000**	**-287,000**	**-402,000**	**-632,000**
High other costs	101,000	**-39,000**	**-179,000**	**-458,000**

3.1.2 Feedering from Bremerhaven to Aarhus and Gothenburg

Another evasive option is to limit the amount of ports which are visited in the EU.
For Maastricht Maersk, the most obvious ports that could be removed from the schedule are Gothenburg and Aarhus. Doing so would save Maastricht Maersk 30-148k of EU ETS costs, depending on the EU ETS price.

The costs of the replacing feeder operations to Aarhus and Gothenburg are summarised in Table 6. It can be concluded from this table that the EU ETS savings are largest when only a small number of containers is destined for these ports. The total cost savings per container which follow from this evasive option are in the range of 2-65 euros per container which is delivered in Aarhus or Gothenburg, depending on the number of containers and the EU ETS price[4].

[4] The EU ETS costs per container for all containers present on Maastricht Maersk are lower, since these are the costs per container destined for Aarhus or Gothenburg.

Table 6 - EU ETS costs of feeder operations to Gothenburg and Aarhus

Costs	2,000 TEU	4,000 TEU	8,000 TEU
Low EU ETS price	4,000	8,000	16,000
Middle EU ETS price	9,000	17,000	35,000
High EU ETS price	20,000	39,000	78,000

When setting up such a feeder operation, there are other costs and benefits which should be accounted for:

- the costs of container handling;
- the extra operational, fuel, charter and port costs of the feeder;
- the saved operational, fuel, charter and port costs by Maastricht Maersk;
- the negative opportunity costs due to the time saved by Maastricht Maersk.

For this case, we have chosen not to include a quantitative analysis similar to the other cases. The reason for this is that the EU ETS costs are low compared to the other costs and benefits which are stated above[5]. It is therefore, due to the uncertainties in our cost parameter assumptions, difficult to indicate in what situations the EU ETS costs would be the deciding factor.

However, it can be concluded that in some situations the added EU ETS costs could make the removal of certain EU ports from the schedule, and feedering to these ports, cost-efficient.

3.2 Case 2: HMM Algericas

HMM Algeciras is a 23,964 TEU container vessel which sails between East Asia and North-West Europe on service FE4. The schedule is summarised in Figure 2 and in Table 7.

Because of this specific route, the following evasion options have been analysed:

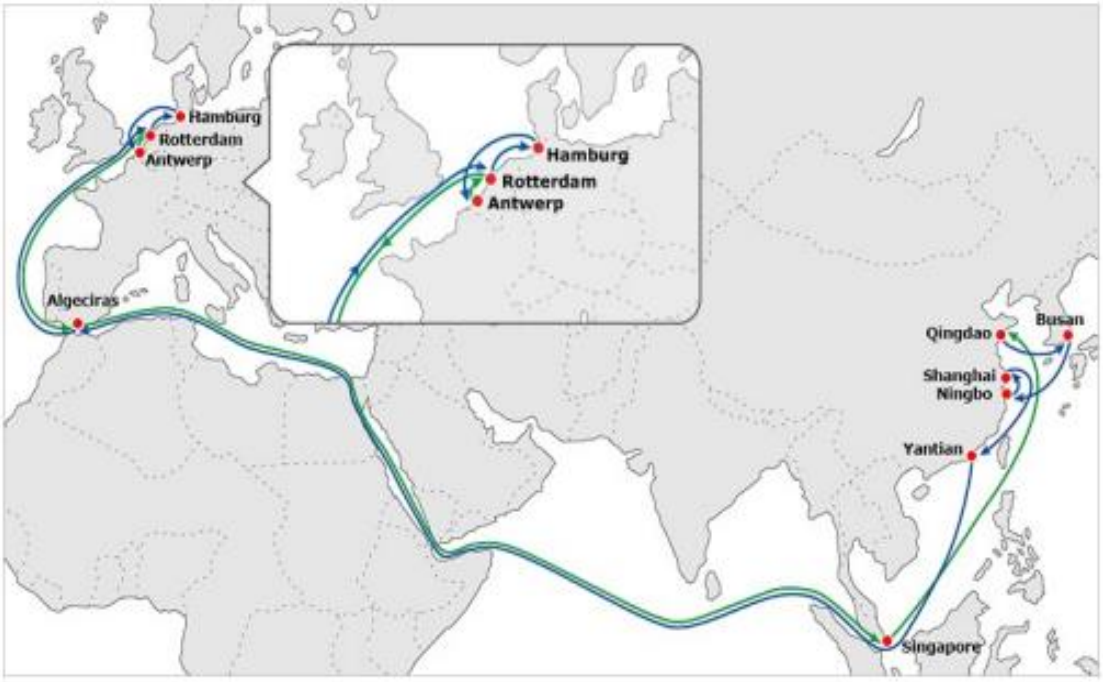
1. Adding London Gateway as an extra port of call in between Algeciras and Rotterdam.
2. Replacing Algeciras by Tangier.

[5] In this particular case, relative to the other case studies, the EU ETS costs are low due the small distances between EU ports. Also, the effect on the operations are much larger compared to the other case studies (for example, removing Aarhus and Gothenburg from the service would shorten the round trip of Maastricht Maersk with about nine days). Because of the uncertainties in quantifying the effects of such large deviations, we chose to adopt the less quantitative approach in this case study.

Table 7 - HMM Algeciras schedule

Ports	Time to next port (days)	Distance to next port (nautical miles)	EU ETS charge (% CO_2-emissions)
Qingdao - Busan	3	607	0%
Busan - Ningbo	3	87	0%
Ningbo - Shanghai	4	968	0%
Shanghai - Yantian	23	9,506	0%
Yantian - Algeciras	4	1,538	50%
Algeciras - Rotterdam	1	272	100%
Rotterdam - Hamburg	4	341	100%
Hamburg - Antwerp	3	426	100%
Antwerp - Rotterdam	2	144	100%
Rotterdam - Algeciras	4	1,652	100%
Algeciras - Singapore	19	7,691	50%
Singapore - Qingdao	8	3,041	0%
Total round trip	**81**	**26,892**	**-**

Figure 2 - HMM Algeciras schedule



Source: [HMM Container Services : Service Network]

Round trip costs of the regular schedule

The first analysis which we present for this case study, is a cost breakdown for one round trip[6]. It can be seen that the EU ETS costs for a round trip range between 0.4-1.8 million euros, depending on the EU ETS price assumption. Of these costs, 37% are from the long journey between Yantian and Algeciras and 13% are from the journey between Algeciras and Rotterdam. Especially for the Yantian-Algeciras leg, avoiding EU ETS could mean a significant cost saving.

Table 8 - Cost breakdown for a round trip - HMM Algeciras

Cost type	Cost estimate	Costs (€/round trip)
EU ETS costs	Low	370,000
	Middle	822,000
	High	1,849,000
Fuel costs	Low	1,096,000
	Middle	4,057,000
	High	4,751,000
Operational costs	-	613,000
Charter costs	Low	5,054,000
	Middle	11,845,000
	High	22,065,000
Port costs	-	1,306,000

3.2.1 Adding London Gateway to the schedule

When adding London Gateway to the schedule in between Algeciras and Rotterdam, the EU ETS costs are lowered by 26-132k euros for one round trip, depending on the EU ETS price. However, the operational costs, fuel costs, charter costs, port costs and opportunity costs are higher compared to the reference scenario. Table 9 shows the cost changes for HMM Algeciras when a port call at London Gateway is added. In all scenarios, the costs of adding London Gateway to the schedule are higher than the benefits.

Table 9 - Change in round trip costs for HMM Algeciras compared to the regular schedule

Cost type	Cost estimate	Change in costs (€/round trip)
EU ETS costs	Low	-26,000
	Middle	-59,000
	High	-132,000
Fuel costs	Low	6,000
	Middle	24,000
	High	28,000
Operational costs	-	8,000
Charter costs	Low	63,000
	Middle	148,000
	High	276,000
Port costs	-	98,000
Opportunity costs	Low	208,000
	Middle	460,000
	High	755,000

[6] For the EU ETS price, the fuel price and the charter price three cost estimates were used in this study: 'low', 'middle' and 'high'. The precise assumptions are documented in Annex A.

However, it could be the case that there are containers destined for the UK on board of HMM Algeciras. If this is the case, there would have been additional transport costs for the feeder operations from Rotterdam to the UK. The extra costs of the feeder operation are summarised in Table 10[7].

Table 10 - Costs of transporting 500, 1,000 or 2,000 containers from Rotterdam to London Gateway (€)

Cost estimate (for all parameters)	500 TEU	1,000 TEU	2,000 TEU
Low	108,000	216,000	431,000
Middle	118,000	236,000	472,000
High	144,000	288,000	576,000

Table 11 shows the total cost-benefit, including the saved costs of feedering 0, 500, 1,000 or 2,000 TEU to the UK, in nine different scenarios. It can be concluded that EU ETS evasion may or may not be cost-effective, depending on the following factors:

- if the EU ETS price is high, adding an evasive port call becomes more attractive;
- if there are many containers destined for the UK on board, adding an evasive port call becomes more attractive;
- if the cost parameters other than EU ETS are low, adding an evasive port call becomes more attractive.

In some of the scenarios in Table 11, evasion would have been cost-efficient even without EU ETS costs. The cases in which the added EU ETS costs are decisive are shown in **bold face**. Since the EU ETS costs are decisive in three of the total 36 scenarios, we can conclude that the risk of evasion in this scenario is small.

Table 11 - Total cost-benefit in four different scenarios (€)

Cost estimate	0 TEU	500 TEU	1,000 TEU	2,000 TEU
Low EU ETS costs				
Low other costs	253,000	145,000	37,000	-178,000
Middle other costs	481,000	363,000	245,000	9,000
High other costs	761,000	617,000	472,000	184,000
Middle EU ETS costs				
Low other costs	221,000	113,000	5,000	-211,000
Middle other costs	449,000	331,000	213,000	**-23,000**
High other costs	728,000	584,000	440,000	152,000
High EU ETS costs				
Low other costs	147,000	39,000	**-69,000**	-284,000
Middle other costs	375,000	257,000	140,000	**-96,000**
High other costs	655,000	511,000	366,000	78,000

[7] In all three cases it was assumed that the containers are transported on a 1,000 TEU ship. For the 500 TEU scenario, half of the costs which this ship makes were used in the calculation. For the 2,000 TEU ship, double the costs were used in the calculation.

3.2.2 Replacing Algeciras by Tanger Med

Another way to evade EU ETS in this case study would be to replace the port call at Algeciras by one at Tanger Med. By doing so, the long distance from Yantian to Europe is outside of the scope of EU ETS. However, if this is done, the containers destined for Algeciras need to be feedered the short distance across the Mediterranean.

Table 12 shows the change in costs compared to the reference scenario for HMM Algeciras. Since calling at Tanger Med instead of Algeciras is not a real detour, and the port costs in these two ports were assumed equal in the two ports, the EU ETS benefits clearly outweigh the extra costs made by HMM Algeciras.

Table 12 - Change in round trip costs for HMM Algeciras compared to the regular schedule

Cost type	Cost estimate	Change in costs (€/round trip)
EU ETS costs	Low	-161,000
	Middle	-358,000
	High	-805,000
Fuel costs	Low	1,000
	Middle	4,000
	High	5,000
Operational costs	-	0
Charter costs	Low	0
	Middle	0
	High	0
Port costs	-	0
Opportunity costs	Low	0
	Middle	0
	High	0

However, one needs to account for the extra costs made for the feeder operation to transport containers from Tanger Med to Algeciras. Table 10 shows the costs estimates of transporting 500, 1,000 or 2,000 containers from Tanger Med to Algeciras. In reality, there might also be containers destined for Tanger Med on board, which would have to be feedered when the port of call is Algeciras. If containers are present for both destinations, only the 'difference' in the amount of containers on board is what influences the outcomes of the cost-benefit analysis[8]. Table 13 can therefore also be interpreted as 'the added costs of transporting 500/1,000/2,000 TEU *more* to Algeciras than to Tanger Med'.

It is important to note that 92% of total traffic in Algeciras is associated with transhipment (European Commission et al., 2021). Therefore, in most cases there will probably not be substantial amounts of containers which need to be delivered in Algeciras on board.

[8] As an example, consider that there are 1,000 TEU with destination Algeciras on board, whereas there are 500 TEU with destination Tanger Med on board. Without the evasive port call, 500 TEU need to be feedered to Tanger Med. With the evasive port call, 1,000 TEU need to be feedered to Algeciras. If the costs of feedering both ways are equal, the extra costs of feedering from Tanger Med to Algeciras equal the feedering of 500 TEU.

Table 13 - Costs of transporting 500, 1,000 or 2,000 containers from Tanger Med to Algeciras (€)

Cost estimate (for all parameters)	500 TEU	1,000 TEU	2,000 TEU
Low	100,000	199,000	398,000
Middle	96,000	191,000	382,000
High	114,000	228,000	456,000

Table 14 shows the total costs in three different scenarios. When only a small amount of containers is destined for Algeciras, it is favourable to evade EU ETS by making a port call in Tanger Med instead. However, if more than 1,000 containers need to be delivered in Algeciras, it is in most market circumstances not cost-efficient to do this.

The cases in which the added EU ETS costs are decisive are shown in **bold face**. Since the EU ETS costs are decisive in 27 scenarios of the 36, we can conclude that the risk of evasion in this scenario is substantial.

Table 14 - Total cost-benefit in four different scenarios (€)

Cost estimate	0 TEU	500 TEU	1,000 TEU	2,000 TEU
Low EU ETS costs				
Low other costs	**-155,000**	**-61,000**	39,000	238,000
Middle other costs	**-152,000**	**-56,000**	45,000	246,000
High other costs	**-151,000**	**-42,000**	72,000	300,000
Middle EU ETS costs				
Low other costs	**-352,000**	**-253,000**	**-153,000**	46,000
Middle other costs	**-349,000**	**-248,000**	**-147,000**	54,000
High other costs	**-348,000**	**-234,000**	**-120,000**	108,000
High EU ETS costs				
Low other costs	**-799,000**	**-670,000**	**-600,000**	**-402,000**
Middle other costs	**-796,000**	**-695,000**	**-594,000**	**-393,000**
High other costs	**-795,000**	**-681,000**	**-567,000**	**-339,000**

3.3 Case 3: MSC Santa Rosa

MSC Santa Rosa is a 7,114 TEU container vessel which sails between North America and North-West Europe on service NEUATL2. The schedule is summarised in Figure 3 and in Table 15. Because of this specific route, the following evasion option has been analysed:

- Changing the order of the port calls such that Felixstowe is the first port of call in Europe, after which the vessel continues sailing to Bremerhaven, Antwerp, etc.

Table 15 - HMM Algeciras schedule

Ports	Time to next port (days)	Distance to next port (nautical miles)	EU ETS charge (% CO_2-emissions)
Bremerhaven - Felixstowe	2	379	50%
Felixstowe - Antwerp	1	163	50%
Antwerp - Le Havre	3	244	100%
Le Havre - New York	7	3,662	50%
New York - Baltimore	3	507	0%
Baltimore - Norfolk	1	197	0%
Norfolk - Savannah	4	570	0%
Savannah - New York	3	871	0%
New York - Bremerhaven	9	4,163	50%
Total round trip	33	10,756	-

Figure 3 - MSC Santa Rosa schedule

Source: MSC, (2017).

Round trip costs of the regular schedule

The first analysis which we present for this case study is a cost breakdown for one round trip[9]. It can be seen that the EU ETS costs for a round trip range between 98k-219k euros, depending on the EU ETS price assumption. Of these costs, 47% are from the long journey between New York and Bremerhaven. Avoiding EU ETS therefore could be a significant cost saving.

[9] For the EU ETS price, the fuel price and the charter price three cost estimates were used in this study: 'low', 'middle' and 'high'. The precise assumptions are documented in Annex A.

Table 16 - Cost breakdown for a round trip - MSC Santa Rosa (€)

Cost type	Cost estimate	Costs (€/round trip)
EU ETS costs	Low	98,000
	Middle	219,000
	High	492,000
Fuel costs	Low	340,000
	Middle	1,257,000
	High	1,472,000
Operational costs	-	175,000
Charter costs	Low	287,000
	Middle	1,017,000
	High	2,055,000
Port costs	-	453,000

Felixstowe before Bremerhaven

Table 17 shows the change in costs in the different scenarios. According to our analysis, changing the order of the port calls such that Felixstowe is visited before Bremerhaven is a cost-efficient change of the itinerary. Interestingly, the change would have been marginally cost-efficient even without the added EU ETS costs. However, it must be noted that our calculations only give an indication of the cost-effectiveness. In reality it could very well be that visiting Bremerhaven first is more cost-efficient due to factors which our calculations did not account for.

For this same reason, it cannot directly be concluded that the (even more) cost-effective outcome of the analysis due to the evasion of EU ETS would actually be enough motivation for HMM to change the itinerary. However, in general, if the financial incentives are large enough it is likely that some liners in similar situations will change the order of their port calls. Therefore, we conclude that there is a risk of evasion in this example.

Table 17 - Change in round trip costs compared to the regular schedule (€)

Cost type	Cost estimate	Change in costs (€/round trip)
EU ETS costs	Low	-39,000
	Middle	-87,000
	High	-197,000
Fuel costs	Low	-3,000
	Middle	-13,000
	High	-15,000
Operational costs	-	0
Charter costs	Low	0
	Middle	0
	High	0
Port costs	-	0
Opportunity costs	Low	0
	Middle	0
	High	0

3.4 Case 4: MOL Tribute

MOL Tribute is a 20,170 TEU container vessel which sails between East Asia and North-West Europe on service FE2. The schedule is summarised in Figure 4 and in Table 18.

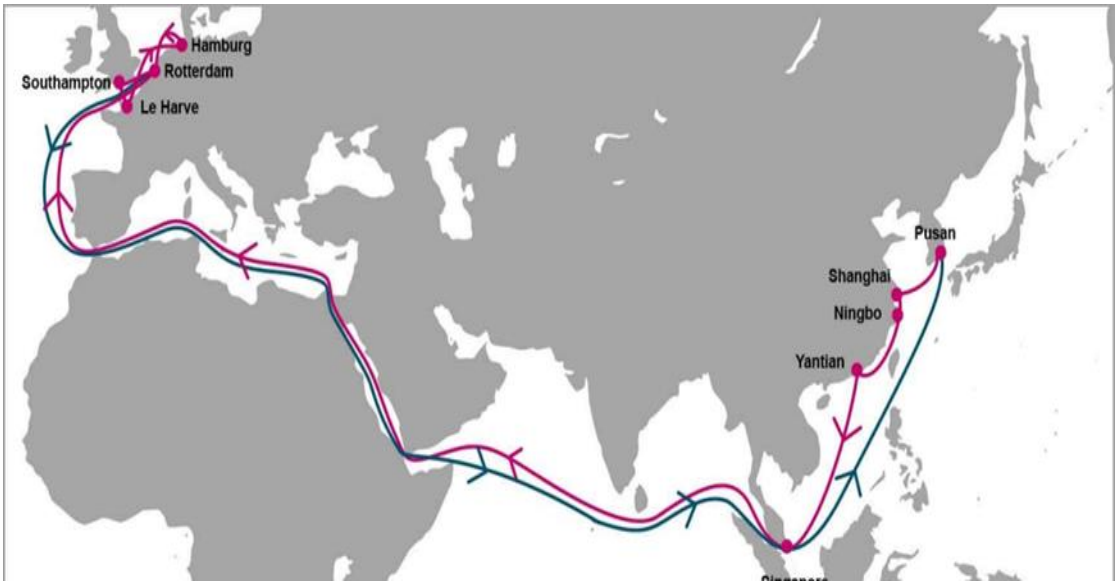
For this specific route, the following evasion options have been analysed:

1. Changing the order of port calls such that Southampton is the first port call in Europe.
2. Changing the order of port calls such that Southampton is the last port call in Europe.
3. Changing the order of port calls such that Southampton is both the first and the last port call in Europe.

Table 18 - MOL Tribute schedule

Ports	Time to next port (days)	Distance to next port (nautical miles)	EU ETS charge (% CO_2-emissions)
Busan - Shanghai	4	535	0%
Shanghai - Ningbo	3	87	0%
Ningbo - Yantian	4	917	0%
Yantian - Singapore	5	1,851	0%
Singapore - Rotterdam	22	9,343	50%
Rotterdam - Southampton	6	293	50%
Southampton - Le Havre	4	126	50%
Le Havre - Hamburg	2	613	100%
Hamburg - Totaal round trip	26	9,620	50%
Singapore - Busan	9	3,208	0%
Total round trip	**85**	**26,593**	-

Figure 4 - MOL Tribute schedule



Source: One-line Container Services : Service Network

Round trip costs of the regular schedule

The first analysis which we present for this case study is a cost breakdown for one round trip[10]. It can be seen that the EU ETS costs for a round trip range between 297k-1,487k euros, depending on the EU ETS price assumption. Of these costs, 45% are from the journey between Singapore and Rotterdam and 47% are from the journey between Hamburg and Singapore. Avoiding EU ETS on one or both of these legs therefore could be a significant cost saving.

Table 19 - Cost breakdown for a round trip - MSC Santa Rosa (€)

Cost type	Cost estimate	Costs (€/round trip)
EU ETS costs	Low	297,000
	Middle	661,000
	High	1,487,000
Fuel costs	Low	1,091,000
	Middle	4,035,000
	High	4,726,000
Operational costs	-	651,000
Charter costs	Low	5,370,000
	Middle	12,586,000
	High	23,444,000
Port costs	-	1,421,000

3.4.1 Southampton before Rotterdam

Table 20 shows the change in costs in the different scenarios. According to our analysis, changing the order of the port calls such that Southampton is visited before Rotterdam is a cost-efficient change of the itinerary.

Similar to the Santa Rosa case, our calculations show that changing the order of port calls could be cost-effective even without EU ETS costs. However, it must be noted that our calculations only give an indication of the cost-effectiveness. In reality it could very well be that visiting Bremerhaven first is more cost-efficient due to factors which our calculations did not account for.

For this same reason, it cannot directly be concluded that the (even more) cost-effective outcome of the analysis due to the evasion of EU ETS would actually be enough motivation for MOL Tribute to change the itinerary. However, in general, if the financial incentives are large enough it is likely that some liners in similar situations will change the order of their port calls. Therefore, we conclude that there is a risk of evasion in this example.

[10] For the EU ETS price, the fuel price and the charter price three cost estimates were used in this study: 'low', 'middle' and 'high'. The precise assumptions are documented in Annex A.

Table 20 - Change in round trip costs compared to the regular schedule (€)

Cost type	Cost estimate	Change in costs (€/round trip)
EU ETS costs	Low	-133,000
	Middle	-296,000
	High	-665,000
Fuel costs	Low	-8,000
	Middle	-29,000
	High	-34,000
Operational costs	-	0
Charter costs	Low	0
	Middle	0
	High	0
Port costs	-	0
Opportunity costs	Low	0
	Middle	0
	High	0

3.4.2 Southampton after Hamburg

Table 21 shows the change in costs in the different scenarios. According to our analysis, changing the order of the port calls such that Southampton is visited before Rotterdam is a cost-efficient change of the itinerary.

Table 21 - Change in round trip costs compared to the regular schedule (€)

Cost type	Cost estimate	Change in costs (€/round trip)
EU ETS costs	Low	-127,000
	Middle	-282,000
	High	-635,000
Fuel costs	Low	700
	Middle	3,000
	High	3,000
Operational costs	-	0
Charter costs	Low	0
	Middle	0
	High	0
Port costs	-	0
Opportunity costs	Low	0
	Middle	0
	High	0

3.4.3 Southampton before Rotterdam and after Hamburg

It is interesting to consider what happens if two port calls in Southampton are made – one as the first port in Europe and one as the last port in Europe. In order to do so, MOL Tribute would need to purposefully leave some cargo destined for Southampton on board during the first port call. We assume that adding this second port call to the schedule takes one day. Therefore, more port costs, operational costs, fuel costs, charter costs and opportunity costs are made. However, the EU ETS benefits are approximately twice as large (since both the leg to Singapore and from Singapore are now not within the scope of EU ETS).

Table 22 shows the change in the different cost components in the different scenarios. Table 23 summarises the outcome of the cost-benefit analysis for different EU ETS prices and market conditions for the other cost components. The cases in which the added EU ETS costs are decisive are shown in **bold face**. Only when the EU ETS costs are low and/or the other market conditions are unfavourable are the costs higher compared to the benefits.

It is interesting to compare these outcomes to the two other evasion options for MOL Tribute which we analysed. This comparison shows that, for low EU ETS costs and/or unfavourable other market conditions, it is more cost-effective to change the order of the port calls than to visit Southampton twice. However, when the EU ETS prices are high and/or the other market conditions are favourable, it is the most cost-effective option to visit Southampton twice.

Table 22 - Change in round trip costs compared to the regular schedule (€)

Cost type	Cost estimate	Change in costs (€/round trip)
EU ETS costs	Low	-264,000
	Middle	-586,000
	High	-1,318,000
Fuel costs	Low	-4,000
	Middle	-14,000
	High	-16,000
Operational costs	-	8,000
Charter costs	Low	63,000
	Middle	148,000
	High	276,000
Port costs	-	98,000
Opportunity costs	Low	101,000
	Middle	222,000
	High	362,000

Table 23 - Total cost-benefit for different EU ETS prices and other market conditions.

Cost estimate	Low EU ETS	Middle EU ETS	HIGH EU ETS
Low other costs	3,000	**-320,000**	**-1,052,000**
Middle other costs	198,000	**-125,000**	**-856,000**
High other costs	463,000	141,000	**-591,000**

3.5 Case 5: NYK Nebula

NYK Nebula is a 4,888 TEU container vessel which sails between East Asia and North-West Europe on service AL5. The schedule is summarised in Figure 5 and in Table 24.

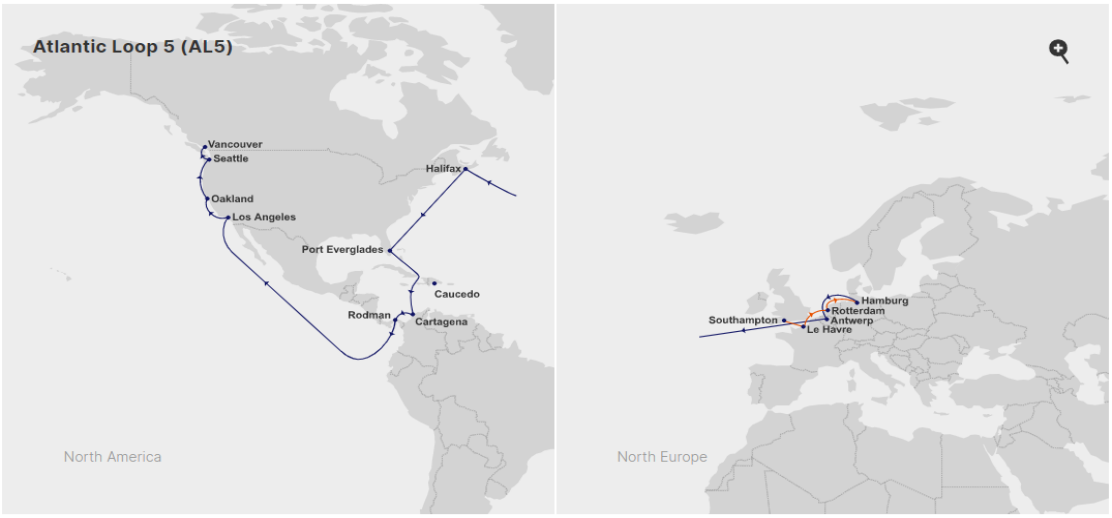
For this specific route, the following evasion option has been analysed:

— Adding Southampton as a last port of call in Europe.

Table 24 - NYK Nebula schedule

Ports	Time to next port (days)	Distance to next port (nautical miles)	EU ETS charge (% CO_2-emissions)
Vancouver - Oakland	3	968	0%
Oakland - Los Angeles	2	467	0%
Los Angeles - Rodman	10	3,427	0%
Rodman - Cartagena	3	329	0%
Cartagena - Caucedo	2	828	0%
Caucedo - Halifax	6	1,811	0%
Halifax - Southampton	8	2,969	0%
Southampton - Le Havre	2	126	50%
Le Havre - Rotterdam	1	335	100%
Rotterdam - Hamburg	2	341	100%
Hamburg - Antwerp	3	426	100%
Antwerp - Halifax	7	3,163	50%
Halifax - Port Everglades	5	1,730	0%
Port Everglades - Cartagena	3	1,382	0%
Cartagena - Los Angeles	2	329	0%
Rodman - Oakland	9	3,423	0%
Los Angeles - Oakland	3	467	0%
Oakland - Seattle	4	923	0%
Seattle - Vancouver	1	123	0%
Total round trip	**76**	**23,567**	**-**

Figure 5 - NYK Nebula schedule



Source: Hapag Lloyd Route finder

Round trip costs of the regular schedule

The first analysis which we present for this case study is a cost breakdown for one round trip[11]. It can be seen that the EU ETS costs for a round trip range between 46k-229k euros, depending on the EU ETS price assumption. Of these costs, 58% are from the journey between Antwerp and Halifax. Avoiding EU ETS on this voyage therefore could be a significant cost saving.

Table 25 - Cost breakdown for a round trip - MSC Santa Rosa (€)

Cost type	Cost estimate	Costs (€/round trip)
EU ETS costs	Low	46,000
	Middle	102,000
	High	229,000
Fuel costs	Low	558,000
	Middle	2,065,000
	High	2,418,000
Operational costs	-	356,000
Charter costs	Low	925,000
	Middle	3,402,000
	High	6,263,000
Port costs	-	499,000

3.5.1 Adding a port call in Southampton after Antwerp

It is interesting to consider what happens if two port calls in Southampton are made – one as the first port in Europe and one as the last port in Europe. In order to do so, NYK Nebula would need to purposefully leave some cargo destined for Southampton on board during the first port call. We assume that adding this second port call to the schedule takes one day. Therefore, more port costs, operational costs, fuel costs, charter costs and opportunity costs are made.

Table 26 shows the change in the different cost components in the different scenarios. Table 27 summarises the outcome of the cost-benefit analysis for different EU ETS prices and market conditions for the other cost components. The case in which the added EU ETS costs are decisive is shown in **bold face**. Adding the evasive port call only makes economic sense when the EU ETS costs are low and the other costs are all high. Therefore we can conclude that the risk of evasion is relatively low.

[11] For the EU ETS price, the fuel price and the charter price three cost estimates were used in this study: 'low', 'middle' and 'high'. The precise assumptions are documented in Annex A.

Table 26 - Change in round trip costs compared to the regular schedule (€)

Cost type	Cost estimate	Change in costs (€/round trip)
EU ETS costs	Low	-25,000
	Middle	-55,000
	High	-123,000
Fuel costs	Low	200
	Middle	700
	High	800
Operational costs	-	5,000
Charter costs	Low	12,000
	Middle	45,000
	High	82,000
Port costs	-	28,000
Opportunity costs	Low	31,000
	Middle	83,000
	High	127,000

Table 27 - Total cost-benefit for different EU ETS prices and other market conditions.

Cost estimate	Low EU ETS	Middle EU ETS	HIGH EU ETS
Low other costs	52,000	21,000	**-47,000**
Middle other costs	137,000	107,000	39,000
High other costs	218,000	188,000	120,000

3.6 Conclusions

This study shows that avoidance of the EU ETS by changing the order of ports or adding an additional port call cannot be ruled out. This finding confirms the Commission's impact assessment which concludes that these types of avoidance are increasingly likely with higher carbon prices. By taking into account the costs and benefits of container terminal operations, the present report shows that avoidance may also occur at lower carbon prices.

The case studies show that it is possible that partially avoiding the EU ETS could be profitable. The likelihood of avoidance having a net benefit for the shipping company is larger when:

- the price of emission allowances is higher;
- the costs of evasion (port costs, operational costs, charter costs, container handling costs, opportunity costs) are lower;
- the emissions on the last voyage to an EU port or the first voyage from an EU port are higher; or
- the costs of transhipment are lower.

The case studies also show that similar types of avoidance, such as changing a non-EU port for an EU port in a schedule, yield a benefit for some lines but not for all lines.

In reality, other considerations than presented in this report will also matter. For example, ports and terminals may have operational constraints; the capacity of non-EU ports for expansion may be limited; or shipping companies may want to operate their entire fleet as efficiently as possible (and not optimise a single line as in this study).

If avoidance were to occur on some lines, ships sailing those lines would be less incentivised to reduce emissions. This would make the inclusion of maritime shipping in the EU ETS less effective.

Moreover, if avoidance were to occur, it would reduce the demand from the shipping sector for allowances, thus lowering the price of allowances and reducing the incentive for emission abatement on other sectors. However, in view of the total number of allowances, this impact would probably be small.

Finally, the impact of avoidance on the competitiveness of EU ports is constrained by the fact that a large share of the containers on board of ships sailing to and from the EU are destined for the EU. Even when in some cases a detour would be made, the containers would still need to be delivered to EU ports. If there is an impact, it will be on the number of containers being transhipped.

Note that when the UK would introduce a similar measure, the scope for avoidance would be significantly reduced. The benefits in the Mediterranean, Black Sea and Baltic Sea are smaller because of longer distances to avoidance ports and lower demand for containers in those ports, so the risks of avoidance are smaller in those sea areas.

4 Mitigating the risks of evasion

Based on the case studies presented in Chapter 3, we concluded that evasion of EU ETS cannot be ruled out. The main effect of these evasive behaviours would be that EU ports, which are currently first port of call in Europe, would no longer be the first port of call. This could first of all negatively affect transhipment activities in these EU ports. Second of all, the evasion would reduce the demand for allowances from the shipping sector. This would reduce the incentive for abatement in the maritime sector in the EU ETS as a whole.

However, we also concluded that the evasive effects are limited, because all cargo destined for European seaports will still need to be delivered in European seaports and other modes of transport . Also, there are operational constraints in the evasive ports which would, at least in the short term, limit the possibilities to evade EU ETS.

Because of the reasons stated before, any measures which would reduce the risk of evasion without negative consequences should be taken. If these measures are not enough, it can be considered to implement other safeguards against evasion. However, these additional measures should only be taken if the benefits outweigh the negative consequences.

No regret measures

If other countries would implement a similar market based measure which is seamlessly connected with the EU ETS, evasive port calls are no longer an option. Therefore, the EU should strongly advocate other countries to participate in the efforts to reduce emissions in shipping. The ideal scenario would be that an emission trading system or another type of market-based measure is implemented at the IMO level. If this is not feasible on the short term, the second best option would be when near-EU countries such as the UK and North African countries would implement similar systems.[12] If this effort succeeds, the risks of evasion are significantly reduced.

Our second recommendation would be to closely monitor the activity in European seaports in the period before and after the EU ETS is extended to maritime shipping. The aim of this monitoring should be to get a good understanding of the evasive behaviour that is observed in practice. This knowledge can be used to evaluate whether there is more EU ETS evasion than is acceptable.

[12] There have been press reports about plans of the UK Government to include shipping in the UK ETS (Osler, 2021).

Other options to reduce the risk of evasion

It is possible to discourage evasive port calls by means of specific measures. Below, some options for how this can be done are listed:

- **Increase the threshold to qualify as a port call.** The current EU MRV regulation requires ships to load or unload passengers or cargo in order for a stop to count as a port call. This already is a barrier for evasive port calls, since anchoring in a port without any activity does not count. If this barrier turns out not to be strict enough, additional requirements could be added such as:
  - a certain minimum amount of cargo or passengers that should be loaded or unloaded;
  - a minimum duration of the port call.
- **Implement a minimum charge per cargo or passenger handled.** Another option would be to implement a minimum charge for cargo or passengers, depending on their origin. By doing so it could be ensured that, even if an evasive port call is added, a certain level of carbon pricing is achieved. This would reduce the incentive to add evasive port calls. If neighbouring countries have an emission trading scheme or another form of carbon pricing of their own, this minimum charge should not apply.

Both of the options mentioned above have some difficulties in the implementation. In case that the threshold to qualify as a port call is increased, issues could arise when vessels make port calls that happen to be under the threshold, without the intention to evade EU ETS. Also, in order for such a system to work, the monitoring of CO_2-emissions should extend to ports outside of the current scope of EU MRV[13].

The other option, to implement a minimum charge per cargo or passenger handled, is simpler in the sense that no monitoring of the emissions outside of the scope of EU MRV is necessary. However, this option could be difficult to implement since a taxation per amount of cargo or containers is no longer a EU ETS charge. Therefore, it is possible that such a mechanism is not in line with WTO agreements.

For these reasons, we advise to only implement such measures when it proves to be necessary to protect EU ports from excessive evasive behaviour. Whether this is the case will depend on different factors such as the willingness of other countries to participate in the emission trading scheme, the EU ETS price and other market conditions and practical constraints for shipping companies to introduce evasive port calls.

[13] Currently, all voyages to and from EU ports are in the scope of EU MRV. If you want to bring voyages to evasive port calls within the scope as well, it is necessary to monitor the emissions of these port calls. It could be difficult to implement this.

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A Underlying assumptions of the cost-benefit analysis

In this Annex, we present the assumptions made in the cost-benefit analysis. The following costs were quantified in the calculation:

1. Fuel costs.
2. Operational costs.
3. Charter costs.
4. Port costs.
5. Opportunity costs.
6. EU ETS costs.
7. Container handling costs.

All costs were calculated in euros. Whenever necessary, an exchange rate was used of 1.13 USD/EURO (Valuta.nl, 2022). The fuel use for different container ship sizes was calculated from the nautical distance between ports based on (Ports.com, 2022) and the fuel use based on (IMO, 2020). From the fuel use, the fuel costs were calculated.

EU ETS costs were calculated from the fuel use with an emission factor of 3,114 tonne CO_2/tonne VLSFO (EC, 2016).

A.1 Fuel costs

Fuel costs were calculated using three different values for the VLSFO price, as shown in Table 28. The low cost corresponds to the lowest price point since 2019. The middle value corresponds to the average price over the last six months. The high price corresponds to the highest price since 2019. All values were obtained from Ship & Bunker, (2022) and correspond to the bunker prices in Rotterdam.

Table 28 - Fuel cost assumptions

Cost assumption	Costs (€/mt VLSFO)
Low	133
Middle	491
High	575

A.2 Operational costs

The operational cost assumptions are based on Drewry, (2019). The quantified costs include: manning, insurance, stores, spares, lubricants, Repair & Maintenance, Dry Docking, management and admin.

Table 29 lists the assumed operational costs for the different ship types.

Table 29 - Operational cost assumptions

Ship type	Costs (€/day)
20,000 TEU container ship	7,664
7,000 TEU container ship	5,292
1,000 TEU container ship	3,814

A.3 Charter costs

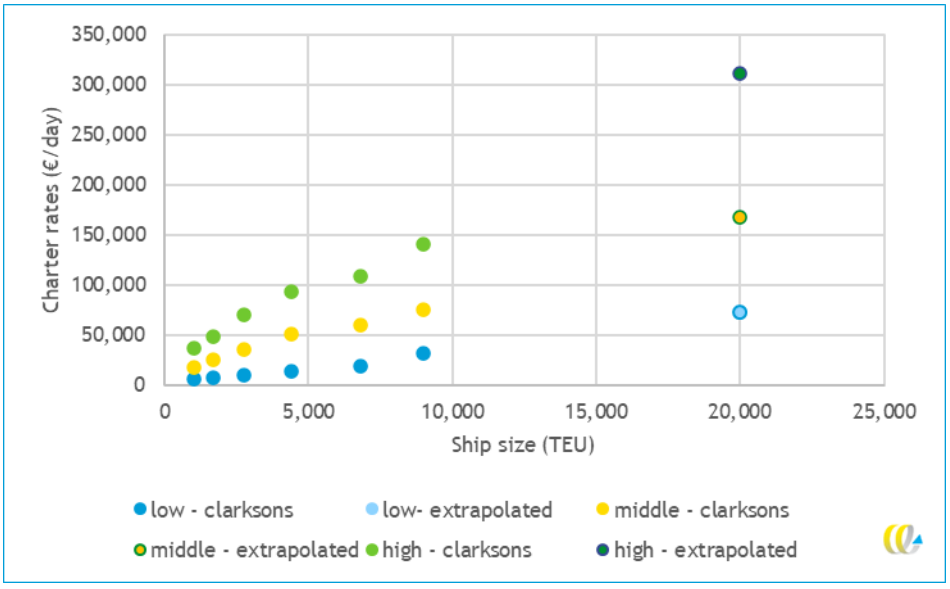
The charter rates are based on data from the Clarksons Shipping Intelligence Network (Clarksons Research, 2022). In this dataset, the largest container ship size is 9,000 TEU. Therefore, the assumed charter rate for 20,000 TEU ships was linearly interpolated (Figure 6 shows that there is an approximately linear relationship between the ship size and charter rates).

For all ship types, three different charter rates were used to account for the volatility in the prices. The lowest price cost assumption corresponds to August 2020, when the charter prices were relatively low. The middle value corresponds to the average value in 2021. The high value corresponds to August 2021, when due to various reasons the charter rates were extremely high.

Table 30 - Charter rate assumptions

Ship type	Low (€/day)	Middle (€/day)	High (€/day)
20,000 TEU container ship	63,176	148,069	275,811
7,000 TEU container ship	16,593	52,832	95,575
1,000 TEU container ship	5,000	15,846	32,522

Figure 6 - Charter rates based on Clarksons data and extrapolated values for 20,000 TEU containerships



A.4 Port costs

For the port costs, we based ourselves on data which was provided to us by Port of Rotterdam. This dataset contains the port costs for Rotterdam, Hamburg, Antwerp, Bremen and Wilhelmshaven. Since these are not all relevant ports in our dataset, assumptions needed to be made about other ports. We decided to assume that the UK port costs are 20% higher than the port costs in Rotterdam and that the ports Algeciras and Tanger Med are 20% lower compared to Rotterdam[14]. All other port costs were assumed to be equal to the costs in Rotterdam.

Especially for the UK ports, these assumptions are significantly different from the cost assumptions which are published by the UK ports. For example in Felixstowe, the published ship dues are £1.19 per GT (Port of Felixstowe, 2021). Compared to the ship dues for deep sea containers vessels in Rotterdam, which are 0.255 € per GT, these are very high (Port of Rotterdam, 2022). In other UK ports, such as Southampton, the published tariffs are even higher.

Since the Port of Rotterdam and CE Delft considered such large differences in port dues between competing ports unlikely, we have contacted the port of Southampton. They indicated that for the cases considered in this report, pre-agreed rates would be applied rather than the public tariffs. For this reason, we have chosen to use the assumptions for the port costs as reported in Table 31[15].

Table 31 - Port cost assumptions

Ship type	Rotterdam (€/day)	Algeciras/ Tanger Med (€/day)	UK ports (€/day)
20,000 TEU container ship	81,649	65,319	97,979
7,000 TEU container ship	41,196	32,957	49,435
1,000 TEU container ship	5,885	4,708	7,062

A.5 Opportunity costs

When the schedule of a liner is adjusted in such a way that a round trip takes longer, we quantified opportunity costs to account for the fact that less revenue can be made.

For example, assume that a vessel which normally makes one round trip in 60 days takes six days longer. If this is the case, the vessel can make 365/66 instead of 365/60 round trips per year (which is about half a round trip per year less). In the calculations, we assumed that the shipping company compensates for this by using (a fraction of) another vessel to make sure that the revenues are constant. In this example the costs of 6/60'th of a vessel needs to be added as opportunity costs.

[14] This choice was made to account for the information provided by Port of Rotterdam that UK port costs are usually more expensive compared to Rotterdam, whereas the Algeciras and Tanger Med port costs are lower.

[15] The assumed port costs for the different ports were suggested by the Port of Rotterdam.

A.6 Container handling costs

The costs of transporting a container from a ship to the dock, or from one ship to another ships, were quantified as 180 €/TEU.

A.7 EU ETS costs

For the EU ETS costs, we used three different assumptions as listed in Table 32 The middle value corresponds to the EU ETS value on January 24th 2022 (Ember.climate.org, 2022).

Table 32 - EU ETS cost assumptions

Cost assumption	Costs (€/tonne CO_2)
Low	30
Middle	67
High	150