Residuals bunker fuel ban in the IMO Arctic waters

An assessment of costs and benefits

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Content

Summary

There are two major concerns with regard to heavy grade oil carriage and use in polar regions: First, an oil spill could have severe impacts on marine and coastal ecosystems and could endanger Arctic indigenous food security and livelihoods. Second, the global warming and health effects of black carbon emissions, with black carbon emissions expected to be higher for heavy grade oil fuels than for other oil-based fuels.

In Arctic waters just as in the Antarctic area, the Polar Code applies, but an additional ban on the use and carriage of heavy grade oils comparable to the ban applying in the Antarctic area has not been implemented in the Arctic waters yet.

The IMO has agreed to start working on the development of a ban on the use and carriage of heavy fuel oil (HFO) as fuel by ships in Arctic waters. Such a ban would not prohibit the carriage of heavy grade oil in bulk as cargo, but would require ships sailing in the Arctic waters to use and carry non-HFO bunker fuels only. This would, on the one hand, lead to a reduction of black carbon emissions and reduce costs and damages in case of an oil spill, and on the other hand impose additional costs on those ship owners/operators that otherwise would have used and/or carried HFO bunkers or blends thereof for on-board combustion purposes.

Due to the stricter 2020 global sulphur cap, the use of distillate fuels and LNG is expected to rise independently of a potential HFO ban, but most ships are expected to switch to low sulphur heavy fuel oil (LSHFO) and some ships will comply with the sulphur standard using HFO in combination with scrubbers and would therefore have higher transport costs due to the ban.

Concerns have been raised regarding the potential impact of the ban on maritime trade, in particular on Arctic communities and economies. In this context, the objective of the study is to assess costs and benefits of a ban on the use and carriage of HFO as fuel by ships in Arctic waters. The study does however not constitute a comprehensive cost-benefit analysis.

More specifically, the study assesses (1) the ban-related additional costs for ship owners/operators on the IMO Arctic fleet level and (2) at individual ship level, differentiated by ship type, (3) the potential impact on consumer prices by means of two case studies, and (4) assesses the clean-up costs that could be saved in case of an oil spill.

The main findings of the study are as follows:

1. We have estimated the ban-related costs for the year 2021 on the Arctic fleet level for ships' activities within the IMO Arctic waters, assuming that all ships choose to comply with the ban by using distillate fuels. Depending on the 2021 bunker fuel prices, these costs are assessed to amount to between 4 and 21 million USD in Low and High cases; and 13 million USD in the Base Case Price Scenario. The latter assumes a medium price spread between distillate fuel and residual fuels. This means that the Arctic fleet's fuel expenditure for its activities within the IMO Arctic waters would, depending on the bunker fuel prices, increase by 3 to 18% in 2021 due to the HFO ban; in the Base Case Price Scenario by 9%.

2. We have estimated the ban-related additional average per ship costs differentiated by ship type. Again, this was done for ships' activities within IMO Arctic waters and under a scenario in which all ships comply with the ban on use and carriage of HFO fuels by ships by switching to distillate fuels. For the Base Case Price Scenario, we found the additional average costs for individual ships to increase by 2% for ships choosing LSHFO to comply with the global 2020 sulphur cap and, depending on the scrubber costs, to increase by 4 to 15% for ships choosing for HFO in combination with a scrubber to comply with the global sulphur cap; the majority of the ships is expected to sail on LSHFO to comply with the global sulphur cap.

3. The potential impact of the HFO ban on consumer prices has been analysed by means of two case studies. One case study estimates the potential ban-related additional costs for consumers in Greenland, finding a 0.2 to 0.5% increase of the average import and export price due to the HFO ban. A second case study looks into the potential ban-related additional costs of food shipped to Iqaluit in North Canada, finding a 0.2% increase in household expenditures due to the HFO ban. Both case studies show that the impact of the ban on consumer prices can be expected to be relatively low, even if the ban-related additional transport costs would be fully passed on to the consumer.

4. Clean-up costs that accrue in case of an oil spill are lower if ban-compliant fuel was spilled instead of residual fuel. The benefit of the HFO ban in terms of the clean-up costs saved is estimated to amount to between 3.4 and 45 million USD (LSHFO spill) and between 5.3 and 70 million USD (HFO spill) for one bunker fuel spill, depending on the ship type and size involved and assuming that all bunker fuel carried by a ship would be spilled. Next to the clean-up cost savings, the HFO ban also reduces the socio-economic and environmental damage costs in case of an oil spill. To actually asses at which frequency of occurrence of an oil spill the benefits of the HFO ban still outweigh its additional costs thus requires a comprehensive assessment of the benefits of the ban.

1 Introduction

1.1 Context of study

Since August 2011, the carriage in bulk as cargo as well as the carriage and use as fuel of heavy grade oils has been banned in the Antarctic area (MARPOL Annex I, Chapter 9, Regulation 43).

There are two major concerns with regard to heavy grade oil carriage and use in polar regions: First, an oil spill could have severe impacts on marine and coastal ecosystems and could endanger Arctic indigenous food security and livelihoods. Due to harsh conditions, seasonal darkness and a lack of infrastructure an oil spill in the Arctic is difficult to clean up and heavy grade oils have a slow rate of degradation, especially in colder regions (EP, 2017). Second, the global warming and health effects of black carbon (BC) emissions, with BC emissions expected to be higher for heavy grade oil fuels than for other fuels (e.g. PPR 5/INF.10 and PPR 5/INF.16).

The Polar Code, which has been in force since January of 2017 and applies to both the Arctic waters and the Antarctic area, prohibits the discharge of oil or oily mixtures from any ship into the sea and sets structural requirements to category A and B ships constructed on or after 1 January 2017. However, a ban on the use and carriage of heavy grade oils, which includes heavy fuel oil and which already applies in the Antarctic area, has not yet been implemented in the Arctic waters (EP, 2017).

The IMO has agreed to start working on the development of a ban on the use and carriage of heavy fuel oil (HFO) as fuel by ships in Arctic waters. MEPC 73 is expected to task PPR 6 to develop a definition of HFO, prepare a set of guidelines on mitigation measures to reduce risks of use and carriage of heavy fuel oil as fuel by ships in Arctic waters, and on the basis of an assessment of the impacts, develop a ban on HFO for use and carriage as fuel by ships in Arctic waters, on an appropriate timescale (IBIA, 2018).

The focus of this study is this potential ban on the use and carriage of HFO as fuel by ships in IMO Arctic waters. A ban on the carriage of heavy grade oils in bulk as cargo in the IMO Arctic waters is not considered.

1.2 Aim of the study

A ban on the use and carriage of HFO as fuel by ships in Arctic waters would require ships sailing in the Arctic waters to use and carry non-HFO bunkers only, imposing additional costs on those ship owners/operators that otherwise would have used and/or carried HFO bunkers and blends thereof for on-board combustion purposes.

Due to the stricter 2020 global sulphur cap, the use of distillate fuels and LNG is expected to rise independently of a potential HFO ban, but most ships are expected to switch to low-sulphur heavy fuel oil and some ships will comply with the 0.5% sulphur standard using HFO in combination with scrubbers and would therefore have higher transport costs due to the ban.

Concerns have been raised regarding the potential impact of the ban on maritime trade, in particular on Arctic communities and economies (IBIA, 2018).

In this context, the objective of the study is to assess costs and benefits of a ban on the use and carriage of HFO as fuel by ships in Arctic waters.

1.3 Scope of the study

The analysis focuses on the year 2021 – the year in which the ban is proposed to become effective.

The specific geographic scope for the analysis of the ban is the Arctic waters as defined by the IMO (A 26/Res.1024) which is the region north of 60°N latitude, but limited by a line from Greenland - south at 58° - north of Iceland, southern shore of Jan Mayen, Bjørnøya and Cap Kanin Nos (DNV GL, 2016) (see Figure 1). This means that coastlines of the US (Alaska), Canada, Greenland, the Russian Federation, Norway (Svalbard archipelago, including Spitzbergen) fall within the scope of the IMO Arctic waters and that there is no geographic overlap with the existing Emission Control Areas.

Figure 1 – IMO Polar Code Arctic

Source: Polar code (MEPC 68/21/Add.1, Annex 10).

The scope of the analysis covers the ban of the use and carriage of residual bunker fuels (like HFO) and blends thereof (like low sulphur (0.5%) heavy fuel oil (LSHFO)[1].
The ban analysed would not prohibit the carriage of heavy grade oil in bulk as cargo.

Specific costs and benefits associated with the ban are assessed in this study.
The study however does not constitute a comprehensive cost-benefit analysis.

[1] LSHFO is a blend of HFO and distillate fuel.

2 Costs of the ban

2.1 Introduction

If a ban on the use and carriage of HFO as fuel by ships in IMO Arctic waters was implemented, ships sailing in these waters would be obliged to use and carry ban-compliant fuels only. This means that ships would have to use and carry distillate fuels (like marine gas oil (MGO)), LNG or non-fossil fuel when sailing in the IMO Arctic waters.

This also means that if ships sailed on residual bunker fuels on voyages heading towards the Arctic waters, the volume carried thereof should be negligible if not zero when entering the IMO Arctic waters. Whereas for voyages coming from the Arctic this would mean that when ships leave the IMO Arctic waters they would not be able to switch immediately to residual bunker fuels since they would not be allowed to carry residual bunker fuels.

Ships that would have used residual bunker fuels and blends thereof in the IMO Arctic waters in the absence of a ban, would have higher transport costs under the ban.
If a ship chose to comply with the ban by using distillate fuels, these extra costs would consist of additional fuel costs associated with the use of the more expensive distillate fuel. And if a ship chose to comply with the ban by using LNG, it would, on the one hand, have to incur additional capital costs, but, on the other hand, would be able to reduce its fuel expenditures by using the less expensive LNG. Additional capital costs would accrue for either retrofitting an existing ship to be able to run on LNG or would, if a new ship was purchased, be associated with the higher purchase price of an LNG-fuelled newbuild.

In the following section, these ban-related costs for the ship owners/operators will be assessed in a first step on the IMO Arctic fleet level (see Section 2.2). In a second step (see Section 2.3), the potential impact of the ban on the average per ship costs, differentiated by ship type, will be discussed and Section 2.4 analyses the potential impact on consumer prices by means of two case studies.

2.2 Change of costs of ship owners/operators on fleet level

2.2.1 Results

Should a ban on use and carriage of HFO fuels by ships in the IMO Arctic waters be implemented, additional costs would accrue to those ships that otherwise had used residual bunker fuels and blends thereof when sailing in the IMO Arctic waters (see Section 2.1 for a description of the cost items).

We have estimated these ban-related costs for the year 2021, on the Arctic fleet level, for ships' activities within the IMO Arctic waters assuming that all ships choose to comply with the ban by using distillate fuels.

Depending on the 2021 bunker fuel prices, these costs are assessed to amount to between 4 and 21 million USD, with in the Base Case Price Scenario in which a medium price spread between residual fuels and distillate is assumed to around 13 million USD (see Table 1).

Table 1 - Ban-related additional 2021 costs of the Arctic fleet, depending on the fuel price scenario [million USD]

	Low Case Scenario	Base Case Scenario	High Case Scenario
Relevant ban scenario costs	154	146	137
Relevant baseline costs	150	133	117
Ban-related additional costs	4	13	21
Cost increase in percentage terms	3%	9%	18%

This means that the Arctic fleet's fuel expenditure for its activities within the IMO Arctic waters would, depending on the bunker fuel price, rise by 3 to 18% in 2021 due to the HFO ban.

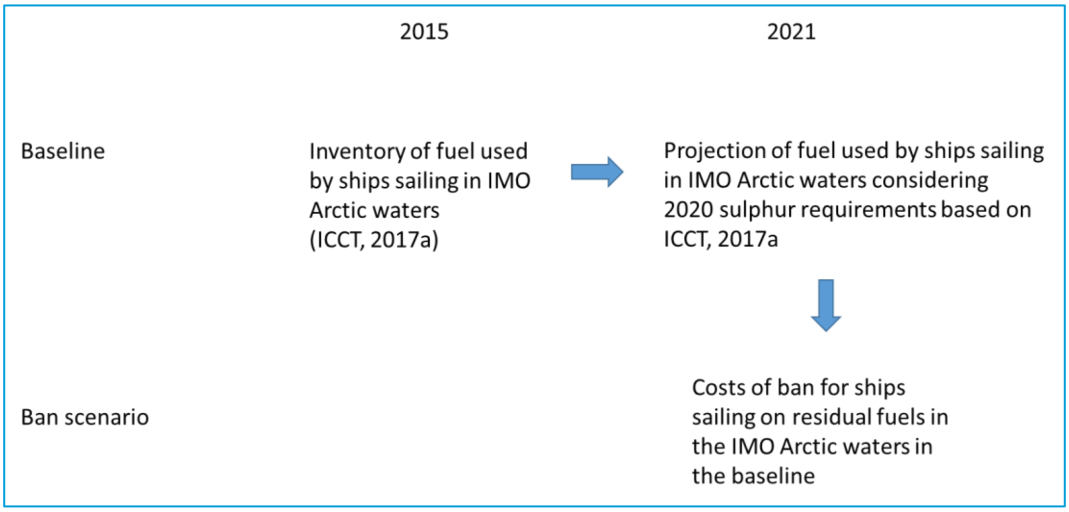
Section 2.2.2 will describe in detail how these costs have been derived and Section 2.2.3 will discuss the results.

2.2.2 Method

Figure 2 illustrates the approach of the analysis.

In order to estimate the ban-related additional costs for ship owners/operators, the baseline scenario has to be determined in the first place. This means that for the situation that no ban was implemented the ships that are expected to sail in IMO Arctic waters in 2021 and their fuel consumption have to be determined. To this end, the results of a 2015 inventory are used to feed into a projection for 2021. Based on this projection, the costs of the ban for ships sailing on residual fuel in the IMO Arctic waters in the baseline are determined for the ban scenario.

Figure 2 - Illustration of approach



Baseline

Several studies have characterized the ships that have been sailing in the Arctic, some of which also estimated the fuel consumption and/or the emissions of these ships (e.g. Winther et al., 2017; Eguíluz et al., 2016; Winther et al., 2014; Corbett et al., 2010, DNV, 2013; ICCT, 2017a), with – to our knowledge – only the latter two studies analysing the IMO Arctic waters as such. The following analysis builds on the more recent of these two studies, which is ICCT (2017a).

2015 inventory

ICCT (2017a) have, amongst other things, estimated the fuel used by ships in the IMO Arctic waters in 2015, differentiated by ship type and fuel type based on satellite and terrestrial Automatic Identification System (AIS) data.

Table 2, Figure 3 and Figure 4 summarise the results of this inventory.

Table 2 - Number of ships active and fuel consumption (t) in IMO Arctic waters in 2015

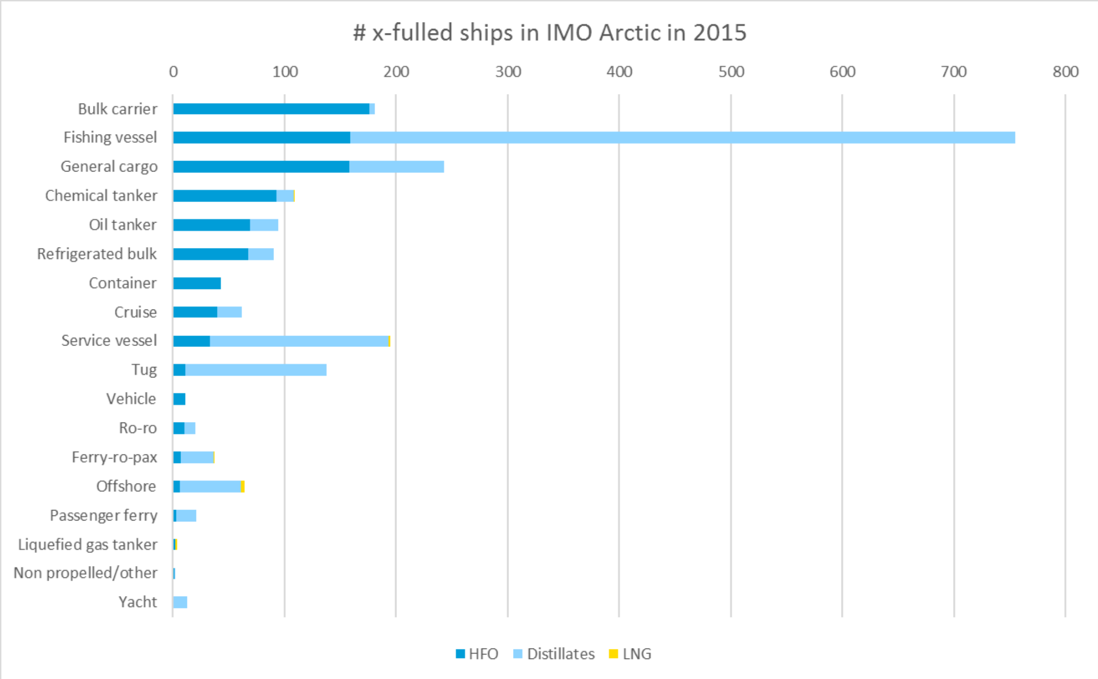
	HFO		Distillates		LNG	
	# ships	Fuel consumed	# ships	Fuel consumed	# ships	Fuel consumed
Bulk carrier	176	23,450	5	455		
Chemical tanker	93	17,170	15	1931	1	24
Container	43	12,749				
Cruise	40	24,528	22	10,239		
Passenger ferry	3	1,370	18	3,588		
Ferry-ro-pax	7	1,486	29	14	1	2
General cargo	158	65,990	85	6,620		
Liquefied gas tanker	2	4			2	25
Fishing vessel	159	23,381	596	90,560		
Non propelled/other	1	140	1	0		
Offshore	6	656	55	6,363	3	100
Oil tanker	69	43,124	25	1,898		
Refrigerated bulk	67	17,578	23	11,429		
Ro-ro	10	1,453	10	1,988		
Service vessel	33	15,441	160	41,221	2	244
Tug	11	1,227	127	9,271		
Yacht			13	679		
Vehicle	11	29				
Total	**889**	**249,777**	**1,184**	**186,256**	**9**	**394**

Source: ICCT (2017a).

According to ICCT (2017a), about 2,100 ships have been active in the IMO Arctic waters in 2015 of which around 57% have been distillate-fuelled and 43% HFO-fuelled. Only a very small number of ships have been LNG-fuelled.

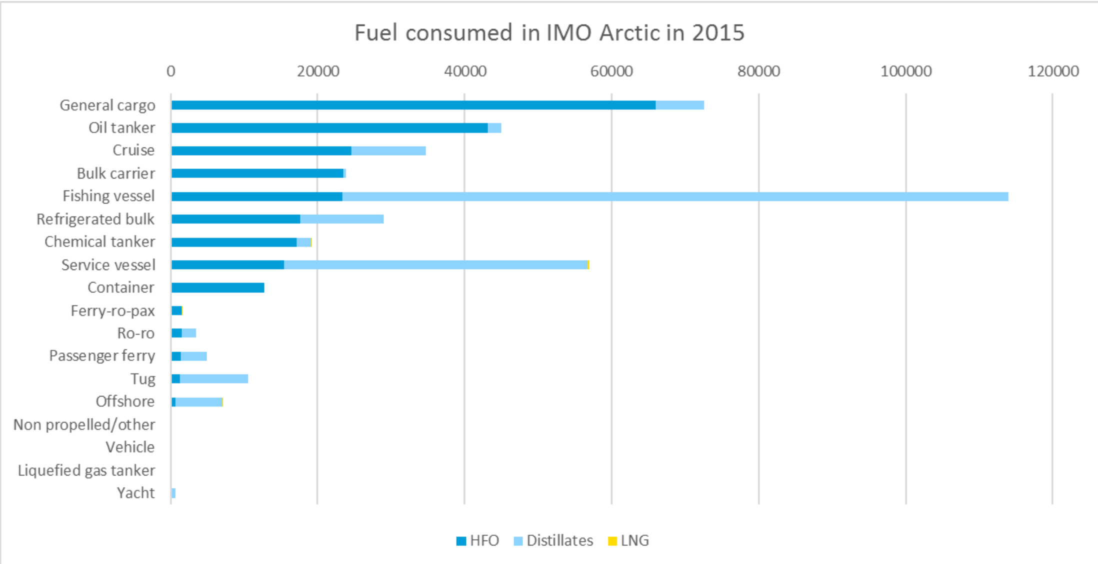
In total, these ships have consumed around 436,000 tonnes of bunker fuel in the IMO Arctic waters, of which approximately 43% distillates and 57% HFO.

Figure 3 - Number of ships active in the IMO Arctic waters in 2015



Source: Illustration based on ICCT (2017a).

Figure 4 - Fuel consumed (t) in IMO Arctic waters in 2015



Source: Illustration based on ICCT (2017a).

In terms of numbers of ships (see Figure 3), fishing, general cargo and service vessels, bulk carries and tugs have been the most prevalent ships in the IMO Arctic waters, with the number of HFO-fuelled ships being highest for bulk carriers, fishing vessels, general cargo vessels, chemical tankers and oil tankers.

Fishing, general cargo, and service vessels, oil tankers, and cruise vessels had the highest fuel consumption in the IMO Arctic waters in 2015 (see Figure 4), with general cargo ships, oil tankers, cruise ships, bulk carriers and fishing vessels being the top-5 HFO consumers.

2021 baseline projection

In 2021, the 2020 sulphur requirement will be in place and ship activity in the IMO Arctic waters will have changed compared to 2015.

Applying the same approach as ICCT (2017a), we expect (Table 3) ships to consume around 452,000 tonnes of fuel in the IMO Arctic waters in 2021, which is around 4.5% more than in 2015. Around 60% of the fuel (262,400 tonnes) is expected to be residual fuel, with around 90% being LSHFO and around 10% HFO. Around 40% of the fuel consumed is expected to be distillate fuel and LNG is expected to have a negligible share.

Table 3 - 2021 projection of the fuel consumed in the IMO Arctic waters (t)

	2015	2021	Share in 2015 and 2021
Residuals	249,800	262,400	58%
thereof LSHFO	0	230,900	(88% of residuals)
thereof HFO (3.5%)	249,800	31,500	(12% of residuals)
Distillates	186,300	189,300	42%
LNG	390	430	< 0.1%
Total	**432,200**	**452,100**	

Source: ICCT (2017a) and own calculation based on ICCT (2017a).

To project the fuel consumption of the ships sailing in the Arctic waters, we have applied 2021 growth factors ,which we derived from the 2020 and 2025 growth factors as presented in ICCT (2017a).[2]

To determine the 2021 fuel mix, we applied the same approach as ICCT (2017a).
The distribution of the fuel over residuals, distillates and LNG is thereby assumed to be just as in 2015. And the 2021 share of LSHFO and HFO - 88 and 12% of residual fuel respectively – is as specified in CE Delft et al. (2016).[3]

Ban scenario

The ban-related additional costs of the Arctic fleet can be derived by comparing the fleet’s costs under the ban (ban scenario) with the fleet’s costs for the case that no ban was implemented (baseline scenario). Table 4 gives an overview of the cost items that have to be considered to this end.

2 See Table 9 in ICCT (2017a); ICCT (2017a) derived the growth factors from Winther et al. (2014).

3 See Base case in Table 24.

Table 4 - Relevant cost items to determine the ban-related costs of the Arctic fleet

Relevant 2021 baseline costs	Relevant 2021 ban scenario costs
A. LSHFO fuel expenditure + B. HFO fuel expenditures + operational scrubber costs*	C. Distillate fuel expenditures for ships that switch from residual fuel to distillates due to the ban + D. LNG fuel expenditures and LNG related capital costs for ships that switch from residual fuel to LNG due to the ban

* The capital costs of a scrubber accrue in both scenarios in equal measure, at least for an existing ship.

As Table 4 shows, the relevant 2021 baseline costs consist of the fuel expenditures for LSHFO (A.) as well as of the fuel expenditures for HFO together with the operational scrubber costs of the HFO-fuelled ships (B.). And the relevant 2021 ban scenario costs consist of the fuel expenditures of the ships that switch from residual fuel to distillates due to the ban (C.) and of the fuel expenditure costs for LNG for the ships that opt for LNG due to the ban together with the according capital costs (D.).[4]

The ban-related additional costs then amount to the difference between the relevant ban scenario costs and the relevant baseline scenario costs:

Ban-related additional costs = (C.+D.) – (A.+ B.)

The estimation of the relevant 2021 baseline costs is based on the baseline bunker fuel mix as specified in Table 3. They are equal to the expenditures for LSHFO (230,900 tonnes) and HFO (31,500 tonnes), as well as the operational scrubber costs of the HFO-fuelled ships.

To determine the relevant 2021 ban scenario costs, for those ships that use residual fuel in the baseline, the actual 2021 fuel mix under the HFO ban would need to be determined as well as the number of ships per ship type that would switch to LNG.[5] Data availability however does not allow to make these distinctions. Given this lack of data and given that the LNG uptake due to the ban can be expected to be rather low in 2021[6], the ban-related additional costs will be presented for the case in which all ships that are HFO- and LSHFO-fuelled in the baseline will opt for distillate fuel under the HFO ban only.

The relevant 2021 ban scenario costs then are equal to the expenditures for distillate fuels of those ships that have to switch from residuals to distillate fuels. From the 2021 projection (see Table 3) we know that the according fuel volume is 262,400 tonnes (in terms of residuals).

To calculate the relevant baseline and ban scenario costs, the following assumptions have been made with respect to the bunker fuel prices, the energy content of the fuels and the operational scrubber costs.

4 If ship owners decide to switch to LNG, the costs associated with either the retrofitting of the ships or the additional purchase cost of a newbuild LNG vessel have to be accounted for.

5 Capital costs associated with a switch to LNG depend on ship type and size.

6 Since LNG retrofitting is rather costly (for the Arctic fleet probably at least 1.5 and at most more than 10 million USD per ship, depending on the ship type and size), it can be expected that only a minority of ships would find LNG to become a profitable option due to the ban. Ships that opt for LNG retrofitting would probably be rather new ships that consume a relatively high amount of fuel in IMO Arctic waters (like cruise and service vessels or passenger ferries), Emission Control Areas, or both.

Due to the uncertainty with regards to the future bunker fuel prices, especially due to the upcoming stricter sulphur requirements, we considered three different fuel price scenarios, called Low Case, Base Case and High Case Scenario, depending on the spread between the price of residual fuels and distillates (see Table 5); the High Case Scenario for example is the scenario with the highest price spread between residual fuels and distillates and thus potentially highest ban-related costs.

Table 5 - 2021 fuel price scenarios considered (USD_{2021}/metric ton)

	Low Case Scenario		Base Case Scenario		High Case Scenario	
	Price	Price spread wrt distillate	Price	Price spread wrt distillate	Price	Price spread wrt distillate
Distillate	616		583		550	
LSHFO	595	-21	535	-48	475	-75
HFO	466	-150	368	-215	270	-280

The low scenario stems from (CE Delft et al., 2016) and the high scenario from (SEB, 2018). The base scenario has been chosen as an ‘in between’- scenario with respect to both the distillate price and the price spread with respect to distillates.

Note that the prices for distillate bunker fuel used in this analysis are for distillates with a maximum sulphur content of 0.1% - this is the distillate fuel that is currently mainly traded and which is used to comply with strict sulphur requirements, like in Emission Control Areas or in EU ports. Since there is, at least on IMO and EU level, currently no regulatory requirement to use 0.5% distillates, there is, to our knowledge, currently no market for 0.5% distillates. A combination of the 2020 low sulphur requirement and a ban on residual fuels in the Antarctic area and the Arctic waters however would lead to a demand for distillates with a maximum sulphur content of 0.5%. If supplied, a distillate fuel with a maximum sulphur content of 0.5% m/m would probably be cheaper than a 0.1% distillate, but more expensive than 0.5% LSHFO.

The following energy densities of the different fuels have been applied in the analysis.

Table 6 - Energy densities of the fuels considered (MJ/kg)

	Energy density
Distillate	42
LSHFO	41
HFO	40

Source: MEPC.1/Circ.866; LSHFO density assumed to be equal to LFO density.

Ships using HFO in the baseline will have to use a scrubber to comply with the stricter 2020 sulphur requirement. The according operational scrubber costs have been roughly estimated by applying the average power of the ships (differentiated by ship type) that have been sailing in the IMO Arctic waters to the operational cost formulas for scrubbers as presented in CE Delft et al. (2016), thereby accounting for the hours ships are operating in the IMO Arctic waters as presented in ICCT (2018) and assuming that 12% of the residual fuel consumed per ship type in 2021 in the Arctic waters is HFO.[7]

[7] For the baseline fuel mix (see Table 3) it has been estimated that 12% of the residual fuel consumed on fleet level is HFO.

As already presented in Section 2.2.1, the ban-related additional costs for the Arctic fleet are estimated to amount to between 4 and 21 million USD, depending on the 2021 bunker fuel prices, with in the base case price scenario in which a medium price spread between residual fuels and distillate is assumed to around 13 million USD (see Table 7).

Table 7 – Ban-related additional costs for the Arctic fleet depending on fuel price scenario [million USD]

	Low Case Scenario	Base Case Scenario	High Case Scenario
Relevant ban scenario costs	154	146	137
Relevant baseline costs	150	133	117
Ban-related additional costs	4	13	21
Cost increase in percentage terms	3%	9%	18%

This means that the Arctic fleet's fuel expenditure for its activities within the IMO Arctic waters would, depending on the bunker fuel price, rise by 3 to 18% in 2021 due to the HFO ban.

2.2.3 Discussion of results

There are different arguments why the ban-related additional costs for ship owners/operators as derived might be an over- or an underestimation of the actual ban-related costs.

For four reasons, the costs derived might be an overestimation of the actual costs:

1. As discussed above, a combination of the 2020 low sulphur requirement and a ban on residual fuels in the Antarctic and the Arctic waters would lead to a demand for a distillate fuel with a maximum sulphur content of 0.5% m/m. If supplied, this 0.5% distillate fuel would probably be cheaper than the MGO 0.1%, reducing the ban-related costs for ships switching to distillates.
2. The growth factors applied in the analysis to derive the 2021 fuel consumption of the fleet active in the IMO Arctic waters stem from Winther et al. (2014). Scope of this study is the geographic Arctic (~59°N and above) rather than the IMO Arctic waters. From (ICCT, 2017a) it becomes clear that there are significant differences between the ship activities in these two regions, with the ship activity in the IMO Arctic waters being significantly lower. This might also apply to the future growth of the ship activities in these two different regions – at least if the growth in traffic in the IMO Arctic would not mainly be driven by traffic diverted from the Suez and Panama Canals through the Arctic, affecting both the growth in traffic in the IMO Arctic waters and the geographic Arctic.
3. In the baseline, the LNG uptake due to the 2020 sulphur requirement might be higher leading to less ships having to switch fuels. The assumed 2021 LNG share is in accordance with (ICCT, 2017a) assumed to be less than 0.1% in terms of tonnes of fuels used, whereas in the base case of in the Assessment of Fuel Oil Availability (CE Delft et al., 2016), LNG has a share of 5% if taken Russia & CIS, Europe and North America taken together.
4. The International Convention on Civil Liability for Bunker Oil Pollution Damage requires ships over 1,000 GT to maintain insurance or other financial security to cover the liability of the registered owner for pollution damage. Since insurance costs are probably related to the potential damage costs, which can be expected to be lower for ban-compliant fuel than for residual bunker fuels, the ban might lead to lower insurance costs for ships having to switch fuel under the ban.

On the other hand, the costs derived might constitute an underestimation of the actual costs: As explained under Section 2.1., ships on voyages coming from the IMO Arctic waters will, under the ban, not be able to switch to residual bunker fuels the moment they leave the IMO Arctic waters, since they would not be allowed to carry residual bunker fuels during their voyage in the IMO Arctic waters. This means that ships that comply with the ban by switching to distillates would need to sail the entire voyage coming from IMO Arctic waters on distillates. Since we do not dispose of activity data of ships leaving the IMO Arctic waters, the fuel switching costs on these voyages could not be considered.

2.3 Ban-related average per ship costs

2.3.1 Results

In Section 2.2 an estimation of the ban-related additional costs on the Arctic fleet level has been presented. In addition, we have also determined the ban-related additional average per ship costs differentiated by ship type. Again, this has been done for ships' activities within the IMO Arctic waters and for the case that all ships choose to comply with the ban on use and carriage of HFO fuels by ships by switching to distillate fuels.

For the Base Case Price Scenario (see Table 5), in which a medium spread between distillate and residual fuel prices is assumed, we find that the average per ship costs for ships' activities within the Arctic waters would, due to the ban, increase by 2% if ships sailed on LSHFO in the baseline and would, depending on the baseline scrubber costs, increase by 4 to 15% if ships sailed on HFO in the baseline. Considering that some ships also sail outside the IMO Arctic waters and that for part of these voyages they would not have to switch fuels, the ban-related annual increase of the average per ship costs would be lower in both cases.

In general, if ships use HFO and a scrubber in the baseline, the ban-related additional costs are higher than if they sail on LSHFO. This is due to the higher bunker price differential between MGO and HFO. And the additional costs are naturally higher for those ship types that annually sail relatively many hours in the IMO Artic waters (like service vessels) and/or consume a relatively high amount of fuel per hour (like cruise ships and oil tankers) – the volume of the fuel that needs to be switched is higher in these cases.

2.3.2 Method

From the 2015 inventory (ICCT, 2017a), we know for the ships that sailed on residual fuels in the IMO Arctic waters, the average per ship residual fuel consumption, differentiated by ship type. We have used this per ship fuel consumption data to determine the ban-related additional average per ship costs in 2021[8], thus assuming that the average ship's fuel consumption in 2021 will be similar to 2015.

The costs have been calculated for two cases, i.e. the case in which a ship uses either LSHFO or HFO in combination with a scrubber if no ban was implemented.

In the first case (LSHFO used in baseline), the ban-related additional costs are equal to the additional bunker fuel expenditures, associated with the use of the more expensive

[8] Assuming that the 2021 per ship fuel consumption is equal to the 2015 per ship fuel consumption, means that we have implicitly assumed that the growth of the fuel consumption between 2015 and 2021 can be explained by more ships being active in the Arctic waters and not by an increase of the ships' activity in the Arctic waters.

distillate bunker fuel. In the second case (HFO used in baseline), the ban-related additional costs are equal to the difference between the fuel expenditures for the distillate fuel in the ban scenario and the fuel expenditure for HFO together with the operational scrubber costs in the baseline scenario.

Table 8 presents for both cases the ban-related average additional per ship costs differentiated by ship type and for the Base Case Price Scenario (see Table 5). Note thereby that the majority of the ships sailing on residual fuels in the baseline are expected to sail on LSHFO.

The costs have been calculated under the same assumptions with respect to the bunker fuel prices, the energy content of the fuels and the operational scrubber costs as presented under Section 2.2.2.

Table 8 - Ban-related average additional per ship costs (USD) in the Arctic waters if ships switched to distillate fuel (2021); Base Case Price Scenario.

	Ban scenario distillate per ship fuel expenditure	Case A: Ship sails on LSHFO in baseline			Case B: Ship sails on HFO in baseline and uses scrubber in addition		
		Per ship expenditure for LSHFO in baseline	Ban-related average additional per ship costs	Ban-related average increase of per ship fuel costs in Arctic waters	Per ship expenditures for HFO and operational scrubber costs in baseline	Ban-related average additional per ship costs	Ban-related average increase of fuel costs* in Arctic waters
Bulk carrier	74,000	69,500	**4,400**	6%	52,800	**21,100**	40%
Chemical tanker	102,500	96,400	**6,100**		74,300	**28,200**	40%
Container	164,600	154,800	**9,900**		116,700	**47,900**	40%
Cruise	340,500	320,100	**20,400**		233,700	**106,700**	45%
Passenger ferry	253,600	238,400	**15,200**		193,500	**60,100**	30%
Ferry-ro-pax	117,900	110,800	**7,100**		82,600	**35,300**	45%
General cargo	231,900	218,000	**13,900**		166,100	**65,800**	40%
Fishing vessel	81,600	76,800	**4,900**		71,900	**9,700**	15%
Offshore	60,700	57,100	**3,600**		51,200	**9,500**	20%
Oil tanker	347,000	326,200	**20,800**		232,600	**114,400**	50%
Refrigerated bulk	145,700	136,900	**8,700**		103,700	**42,000**	40%
Ro-ro	80,700	75,800	**4,800**		57,300	**23,300**	40%
Service vessel	259,800	244,200	**15,600**		189,900	**69,900**	35%
Tug	61,900	58,200	**3,700**		52,700	**9,200**	20%

*HFO fuel costs including operational scrubber costs.

Table 8 shows that the ban-related average additional costs per ship differ significantly between the cases and differ highly between ship types: for case A in which the ships are assumed to sail on LSHFO in the baseline, the additional average costs range from 3,600 to 21,000 USD and for case B in which the ships are assumed to sail on HFO in the baseline from 9,200 to 114,000 USD.

If ships use HFO and a scrubber in the baseline, the ban-related additional costs are in general higher than if they sail on LSHFO in the baseline. This can be explained by the larger price difference between HFO and distillates and LSHFO and distillates, even if the operational costs of scrubbers are accounted for.

The additional costs are also higher for those ship types that annually sail relatively many hours in the IMO Artic waters (like service vessels) and/or consume a relatively high amount of fuel per hour (like cruise ships and oil tankers) – the volume of the fuel that needs to be switched is higher in these cases.

If these ships are active in the Arctic waters only, their annual average per ship fuel expenditures would, in the base case price scenario, rise by around 6% if LSHFO was the baseline fuel. This is equal to the price differential of the two different fuels, considering the energy content differential between LSHFO and MGO. And if HFO was the baseline fuel, the fuel costs for the average ship would rise between 15 and 50%, depending on the ship type and the according operational scrubber costs. For ships sailing a relatively high number of hours in the IMO Arctic waters (like e.g. fishing vessels) the operational costs of scrubbers would be relatively high leading to relatively lower additional ban-related costs.

Assuming that ships' fuel costs account in the Base Case Price Scenario (see Table 5) for 30% of ships' total costs[9], the average per ship costs for ships' activities within the Arctic waters would, due to the ban, increase by 2% if ships sailed on LSHFO in the baseline and would, depending on the baseline scrubber costs, increase by 4 to 15% if ships sailed on HFO in the baseline.

Considering that some ships also sail outside the IMO Arctic waters and that for part of these voyages they would not have to switch fuels, the ban-related annual increase of the average per ship costs would be lower in both cases.

2.4 Change of consumer prices

2.4.1 Maritime transport cost incidence

Ships that due to the ban on the use and carriage of HFO as fuel by ships in IMO Arctic waters would need to switch fuels, would have ban-related additional costs.

These additional transport costs might be borne by different parties in the value chain. This might be the ship operator/owner or also:
- in the cargo transport segment the shipper or the consumer/consignee;
- in the fishing segment the processing industry;
- in the service segment the recipient of the service;
- in the passenger transport segment the passenger.

The more the ship operator/owner can bring the additional costs into account by raising the shipping price/freight rates, the less he will bear the additional costs himself. Whether he can raise the freight rates depends on different factors. The higher the ship capacity that is

[9] According to S&P Global Platts (2017), bunker costs may take up to 70-80% of total voyage expenses in 2020. For the Base Case Price Scenario we assumed that 75% of voyage costs are bunker costs. We further assume that ships' voyage costs account for 40% of the ships' total annual costs. This share can differ between ship types and sizes and also depends on their age. The 40% is based on the 10-year-old Capesize bulk carrier as presented in Stopford (2009); this share has been adjusted for the higher fuel oil share.

available for the according trade and time and the more affordable alternatives the demand side has (e.g. by using air transport instead), the lower the probability that the freight rates will rise in accordance with the additional transport costs.

The ship operator/owner will of course seek to operate to at least cover all of his costs. In some segments, like the container segment freight rates therefore have a variable component (bunker adjustment factor) to be able to account for changes in bunker fuel costs. But high overcapacity, as has been the case following the global financial crisis, can lead to ship operator/owner operating not being able to cover all of their costs.

If the ship operator/owner is able to raise the freight rates in accordance with the additional transport costs, another party or different parties in the chain will bear the additional costs. The flexibility of the user of the transport service is thereby vital. The more alternatives to the transported product/service he has (cruise passenger might choose a different holiday, a fish processor might be able to buy fish caught in other areas), the less the user of the transport service will have to bear the costs.

An econometric analysis of a specific trade in the Arctic, considering the different determinants of the consumer prices, amongst which freight rates for shipping, would be required to determine whether an increase in freight rates has had an impact on consumer prices in the past. This is however beyond the scope of this study. In the following two case studies, the maximum impact of a maritime transport cost increase, considering a full cost pass-through onto consumers, is therefore considered.

2.4.2 Case study 1: Ban-related additional costs for consumers in Greenland

Results

The Government of Greenland has given Royal Arctic Line A/S (RAL) an exclusive concession for the transportation of all sea cargo to and from Greenland and between the Greenlandic towns and settlements. The ban-related additional costs for consumers in Greenland depend on three main factors: first, how RAL decides to comply with the 2020 sulphur requirements, second, on the future bunker fuel prices and, third, on the degree to which RAL will be able to pass the additional transport costs onto the consumers.

Assuming that RAL chooses to comply with the ban by switching from residual fuels to distillates and depending on the 2021 bunker fuel prices (see Table 5 for the scenarios considered) as well as RAL's low sulphur requirement compliance strategy, the 2021 ban-related additional maritime transport costs are estimated to amount to between 0.75 and 2.0 million USD (mix of LNG, HFO & scrubber and LSHFO in baseline) and to between 0.8 and 2.6 million USD (mainly LSHFO and one HFO & scrubber ship in baseline).

For the Base Case Price Scenario (see Table 5), with a medium price spread between distillate and residual bunker fuel, the 2021 ban-related additional maritime transport costs amount to between 1.4 and 1.7 million USD, depending on the baseline scenario. If these costs were fully passed on, the average import and export price would increase by 0.2 to 0.5%, depending on the share of shipped products (75 to 25%) in the total value of Greenland's imports and exports (around 1.3 billion USD in 2017).

Analysis

To determine the ban-related additional costs for consumers in Greenland we have estimated the ban-related change of the maritime transport costs and related these costs to the value of the imports and exports of Greenland. This gives an indication for the maximum average increase of the consumer prices, given that the entire maritime transport costs are passed onto the consumers.

To give the reader a better understanding of the potential impact of the ban on Greenland, the analysis is embedded into a sketch of the relevant aspects, like the Greenland's transport infrastructure and its patterns of trade.

Introduction

Greenland is the world's largest island, situated on the North American continent between the Arctic Ocean and the North Atlantic Ocean, northeast of Canada (Government of Greenland, 2018).

Greenland has around 56,000 inhabitants living in 22 towns and 120 villages/settlements, with more than one third (17,800) living in the capital Nuuk (Government of Greenland, 2018; Statistics Greenland, 2018a). Most of the towns and villages are located on the west coast (RAL, 2018a).

Greenland, like the Faroe Islands, is an autonomous constituent part of the Kingdom of Denmark and is not an EU member (EU, 2018). This means that EU specific regulations like the strict sulphur requirement for the fuel that ships are allowed to use when at berth in EU ports do not apply to Greenland's ports. It is however associated to the EU under the Overseas Association Decision (EC, 2018).

Trade

Apart from fishing and hunting, Greenland has a very limited domestic production of commodities. Therefore, more or less all goods necessary in households, businesses and institutions have to be imported (Statistics Greenland, 2018a) and Greenland highly depends on support from the Danish State. The annual block grant from the Danish State amounted to around 20% of Greenland's GDP in 2016.

In 2017, the value of Greenland's imports amounted in total to around 706 million USD. Roughly, one third of the import value is related to fuel/oil products and machinery (see Table 9 categories 27, 84, 85).

Table 9 – Ten product categories with the largest share in Greenland's 2017 total import value

Product category	Share import value of product category in total import value
27 Mineral fuels, mineral oils and products of their distillation - bituminous substances - mineral waxes	16.03%
84 Nuclear reactors, boilers, machinery and mechanical appliances - parts thereof	9.78%
85 Electrical machinery and equipment and parts thereof - sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles	5.49%
73 Articles of iron or steel	3.87%
87 Vehicles other than railway or tramway rolling-stock, and parts and accessories thereof	3.76%
94 Furniture - bedding, mattresses, mattress supports, cushions and similar stuffed furnishings - lamps and lighting fittings, not elsewhere specified or included - illuminated signs, illuminated name-plates and the like - prefabricated buildings	3.24%
02 Meat and edible meat offal	3.21%
88 Aircraft, spacecraft, and parts thereof	3.10%
89 Ships, boats and floating structures	2.95%
19 Preparations of cereals, flour, starch or milk - pastry cooks products	2.61%

Source: Statistics Greenland (2018b).

The value of Greenland's exports amounted in total to around 571 million USD in 2017. The fishing industry (see Table 10 categories 03 and 16) thereby constitutes the lion's share (95% in 2017).

Table 10 - Ten product categories with the largest share in Greenland's 2017 total export value

Product category	Share export value of product category in total export value
03 Fish and crustaceans, molluscs and other aquatic invertebrates	78.78%
16 Preparations of meat, of fish or of crustaceans, molluscs or other aquatic invertebrates	16.43%
99 Unspecified goods	3.29%
84 Nuclear reactors, boilers, machinery and mechanical appliances - parts thereof	0.50%
90 Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus - parts and accessories thereof	0.30%
97 Works of art, collectors pieces and antiques	0.17%
23 Residues and waste from the food industries - prepared animal fodder	0.10%
71 Natural or cultured pearls, precious or semi-precious stones, precious metals, metals clad with precious metal, and articles thereof - imitation jewellery - coin	0.09%
72 Iron and steel	0,08%
43 Furskins and artificial fur - manufactures thereof	0,05%

Source: Statistics Greenland (2018b).

Transport and transport infrastructure

Due to the climate and geography, Greenland has no railroads or roads to connect towns and settlements. Passengers and goods are transported by sea or air only. Most towns have paved roads. Here, cars are the typical means of transportation (Statistics Greenland, 2018).

From Disko Bay (on west coast) to North Greenland and on the east coast, the waters are usually filled with ice in the winter and supplies must be delivered by air for three to six months of the year (RAL, 2018a).

As of 2018, Greenland has 17 ports in towns and 58 harbours in settlements and 14 airports and 43 helipads (Statistics Greenland, 2018; Mittarfeqarfiit, 2018). Six of the airports are international airports, with international connections limited to Denmark and Iceland. These international routes are served by Air Greenland and by Air Iceland, with limited cargo capacity.

Regarding sea transport, the Government of Greenland has given Royal Arctic Line A/S (RAL) an exclusive concession for the transportation of all sea cargo to and from Greenland and between the Greenlandic towns and settlements. RAL is wholly owned by the Government of Greenland (RAL, 2018b).

Regarding international transport, RAL offers transport to/from Denmark (Port of Aalborg) and Iceland (Port of Reykjavík) (RAL, 2018c).

RAL cooperates with the Eimskip transportation company in the following way: the approaches to Iceland have connections to Eimskip's routes, which includes the Faroe Islands, England, Canada (Port of Halifax, Port of Argentia, Port of St Anthony) and the USA (Port of Portland) (RAL, 2018d). Cargo from Iceland and from Eimskip's other destinations to Greenland are thereby consolidated in Reykjavik, shipped with RAL's vessels (RAL, 2018d).

RAL's fleet (see Table 11) consists of five larger vessels mainly used for international voyages as well as seven smaller ships used for domestic shipping to/from settlements. In terms of age, the fleet is mix of fairly new and fairly old ships.

Table 11 - Royal Arctic Line fleet in June 2018

		Built	Dwt	Trade lanes 2018
Larger vessels which can all carry at least some containers	Malik Arctica	2017	8,438	Denmark - Greenland
	Mary Arctica	2005	6,365	
	Naja Arctica	1994	9,556	Denmark - Iceland - Greenland
	Nuka Arctica	1994	9,556	
	Irena Arctica	1994	5,817	Coastal trade between Greenland ports
Settlement ships	Ivalo Arctica	2016	650	Between Greenland ports
	Minik Arctica	2016	650	
	Angaju Ittuk	1984	255	
	Aqqaluk Ittuk	1983	200	
	Vestlandia (chartered)	1983	1,525	
	Pajuttaat	1979	1,300	
	Johanna Kristina	1960	225	?

Source: RAL (2018e).

RAL has three vessels on order:

- two settlement vessels that will replace the Pajuttaat and the Vestlandia (Zamakona Yards, 2018);
- one 2,150 TEU container vessel which will be equipped with a scrubber systems and a system for exhaust gas recirculation, expected to be delivered in 2019 (RAL, 2017 and Langh Tech, 2017).

Seaborne trade

Unfortunately, the publicly available data, does not allow to differentiate between the value of Greenland's seaborne and airborne trade:

Statistics Greenland provides trade data for 97 product categories in terms of both, weight (kg) and value. It does however not differentiate between air and seaborne trade. And RAL reports its cargo in terms of volume (cbm), differentiating between northbound, southbound, domestic and project cargo.(RAL, 2018a) It describes its cargo in qualitative terms as follows: 'Cargo to Greenland mainly consists of food, consumer goods and other ordinary goods as well as material for the construction industry. Northbound cargo accounts for the greater part of the company's revenue and volume is, to a high degree, dependent on the general development in Greenland' (RAL, 2018a). This means that the datasets cannot be combined.

Also neither Air Greenland nor Air Iceland provide data on the cargo they transport to/from Greenland. As a consquence, we worked with three scenarios in which 75, 50 and 25% of the value of all imports and exports are seaborne.

Estimation of change of maritime transport costs

Greenland is entirely located in the Arctic waters as defined by the IMO. This means that under a ban of residual bunker fuel oils, all ships sailing from a port in Greenland would – the entire voyage - have to carry and sail on ban-compliant fuel only. And vessels sailing from outside the IMO Arctic waters to Greenland would either have to restrict the volume of residual fuels carried and used to be negligible if not zero when entering the IMO Arctic waters or would have to use and carry ban-compliant fuel the entire voyage.

As a consequence, the transport costs would rise by the additional fuel expenditures associated with the necessary fuel switch.

According to RAL, its smaller ships sail currently on diesel, whereas its larger ships are operated on HFO (Sermitsiaq, 2017). The fuel consumption of these larger ships is specified in RAL's CSR reports as given in Table 4.

Table 12 - RAL's container ships' fuel consumption (tonne)

	2013	2014	2015	2016	2017
MGO	3,407	3,112	3,183	4,797	5,393
Ultra-LSHFO*	6,448	6,045	4,636	4,383	5,103
HFO (3.5%)	18,969	18,221	18,447	17,894	18,414
	28,824	**27,378**	**26,266**	**27,074**	**28,910**

Source: RAL (2016 and 2018f); *We find it plausible to assume that the low sulphur HFO presented in CSR report is ultra-low sulphur HFO used in the ECA.

In 2017, the fleet has consumed around 18,000 tonnes of HFO and around 5,400 tonnes and 5,100 tonnes of MGO and low sulphur HFO respectively; MGO and ultra LSHFO have probably been used in the North Sea Emission Control Area (ECA).

Once the stricter sulphur requirement for bunker fuels is in place in 2020, RAL might decide:
1. To use LSHFO (0.5%) instead of HFO (3.5%) on all existing ships, with the ordered container ship using HFO (3.5%) in combination with the scrubber; or
2. To retrofit all existing ships with scrubbers and use HFO (3.5%) on all ships in and outside the ECA; or
3. To retrofit all existing ships for the use of LNG; or
4. To choose a combination thereof, i.e. to retrofit some of the existing ships whilst others use LSHFO (0.5%).

Given that RAL is well aware of the potential ban of the residual fuels in the Arctic waters we do not expect RAL to retrofit its existing ships with scrubbers and given the age of the ships we expect, if at all, RAL to maximally retrofit two of its existing ships to be retrofitted for LNG use. Which leaves us with the two potential baseline scenarios presented in Table 13.

Table 13 - 2021 baseline scenarios for the fuel used by RAL's non-settlement ships

# of ships	Baseline Fleet Scenario with LNG	Baseline Fleet Scenario without LNG
LNG-fuelled ships	2	0
HFO-fuelled ships equipped with scrubber	1	1
LSHFO-fuelled ships	3	5

Assuming that RAL chooses to comply with the ban by switching from residual fuels to distillates and depending on the 2021 bunker fuel prices (see Table 5 for the scenarios considered), the ban-related additional maritime transport costs then amounted to between 0.75 and 2.0 million USD (Baseline Fleet Scenario with LNG) and to between 0.8 and 2.6 million USD (Baseline Fleet Scenario without LNG), with for the base case price scenario 1.4 and 1.7 million USD for Scenario 1 and 2 respectively.

Since we cannot differentiate the bunker fuels consumed on routes to and from Greenland, the analysis assumes that ships would have to switch entirely from residuals to ban-compliant fuels. Should RAL decide to under the ban sail on residuals on voyages heading towards the IMO Arctic waters then the estimation constitutes an overestimation of the ban-related change of the maritime transport costs.

As an alternative, RAL might also choose to comply with the ban by retrofitting its/some of its ships to be LNG-fuelled. Due to the costly retrofit, this option can, if at all, only be expected to be profitable for the (relative) new ships, but this highly depends on the operational pattern of a ship.

Estimation of ban-related impact on consumer prices

Related to the value of Greenland's 2017 imports and exports (around 1,3 billion USD), an increase of the transport costs of 1.4 and 1.7 million USD in 2021 would - if costs were fully passed on – lead in the Base Case Price Scenario to an increase of the average import and export price by 0.2 to 0.5%, depending on the share of shipped products (75 to 25%) in the total value of Greenland's imports and exports (around 1.3 billion USD in 2017).

Given that RAL has the exclusive concession for the transportation of all sea cargo to and from Greenland one would expect RAL to be in a good position to actually pass on the ban-related additional costs. And RAL works with bunker fuel adjustment factors to account for bunker fuel price volatility (RAL, 2018g), It is not clear however whether bunker fuel price changes have been fully compensated by these adjustments in the past.

2.4.3 Case study 2: Food shipped to North Canada

Results

In the North of Canada, food prices are relatively high compared to other regions in Canada, which is why there are concerns that a ban on the use and carriage of HFO as fuel by ships in the IMO Arctic waters would lead to even higher food prices in this region.

We expect that the ban would lead to an increase of the costs for shipping non-perishable food items to the North of Canada, but that the impact of this cost increase on the prices of these items would be relatively small: In the case study which looks into the sealift re-supply of Iqaluit, the capital of Nunavut, we estimated that an average household in Iqaluit spends around 20,000 USD per year for goods purchased in supermarkets and other grocery stores and that the additional ban-related shipping costs amount to maximally around 30 USD per household per year. There are two main reasons for this relatively low potential impact: First, the annual sealift services provided per year are limited due to the short summer season and the remoteness of the region, and second, other supply chain costs are already rather high in the region.

Analysis

The coastline of four territories of Canada are directly located at the IMO Arctic waters:
- Northern Canada territories' (Yukon, Northwest Territories, Nunavut) coastlines;
- Nord-du-Québec (administrative region of Quebec territory).

The coastlines of Manitoba and Ontario are located at the Hudson Bay, with the access to the Hudson Bay lying within the IMO Arctic waters.
These coastlines and their hinterlands are sparsely populated.[10] The majority of the communities have no connection to the electricity grid and no year-round surface transportation, i.e. have no rail access, no permanent road or marine access. In most cases, the communities can be supplied by air during the entire year whereas supply by maritime ships and by barges is only possible during summer season and supply by trucks (via ice roads) only possible during winter season.

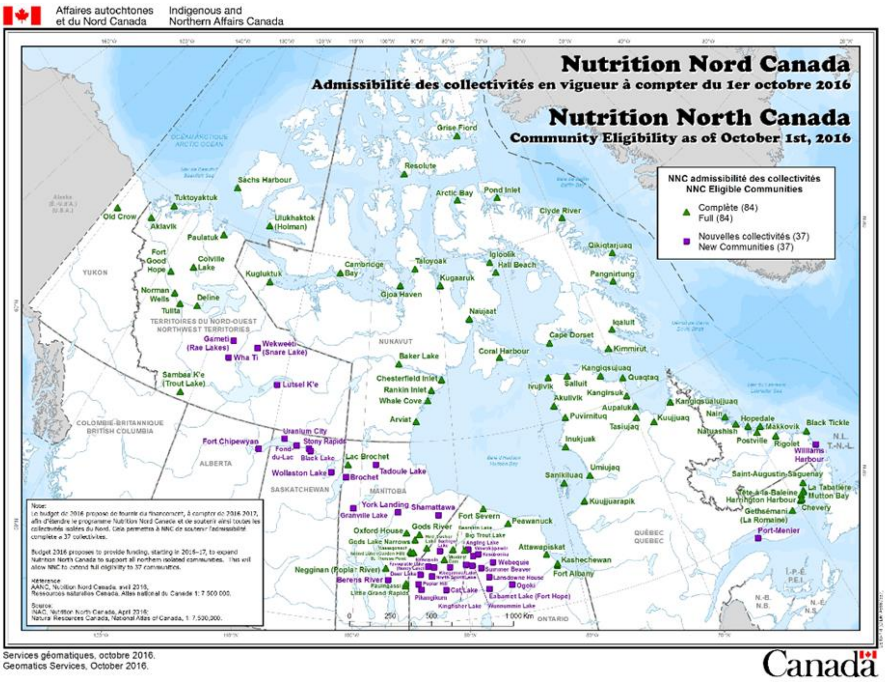
Sealifts are significantly cheaper than airlifts, which is why communities are supplied as much as possible by sealift. However, the number of the annual sealift services provided per year can be very limited due to the short summer season (July-September) and due to

[10] Yukon: 38,630 inhabitants as by December 2017 (Yukon Bureau of Statistics, 2018); Northwest Territories: 44,736 inhabitants as by April 2018 (NWT Bureau of Statistics, 2018); Nunavut: 38,500 inhabitants as by April 2018 (Nunavut Bureau of Statistics, 2018); Nord-du-Québec: 45,367 inhabitants in 2017 (Institut de la statistique Québec, 2018).

the remoteness of the regions. Retailers then purchase a large inventory of non-perishable items (NRG Research Group, 2014).

Airlifts are relatively expensive, but inevitable when it comes to supplying communities with perishable food items. To make perishable and nutritious food more affordable and more accessible in the North, the Canadian government provides registered retailers and suppliers with subsidies (‘Nutrition North Canada’) to reduce the prices for specific perishable and nutritious food items (Government of Canada, 2017). Communities that lack year-round surface transportation (121 communities; see Figure 5) and airlifted products are eligible for this subsidy[11] (Government of Canada, 2018; Government of Canada, 2017).

Figure 5 - Communities eligible for ‘Nutrition North’ subsidies



Source: Government of Canada, 2016.

Since, in particular, non-perishable items are transported by ship, an increase in transport costs by the ban will most likely have an effect mainly on the prices of non-perishable food items.

We expect that the increase in transport costs will probably have little effect on the prices of these non-perishable food items, since the share of the ship’s bunker fuel costs in the prices of products seems to be relatively low for the following reasons.

[11] The programme has had a subsidy budget of 80.6 million CAD for 2016-2017. The subsidy rate in each community is determined through four criteria: geographical distance from the supply centre to the isolated community, distance flown, population, and minimum wage. (Government of Canada, 2017)

Certain other transport cost factors are relatively high in this region (NRG Research Group, 2014):

1. Due to a lack of natural ports and limited harbour infrastructure, transhipping using lightering tugs and barges can be required.
2. Icebreaking operations can be required.
3. Operations are small-scale operations with no economies of scale.

In addition, competition is restricted not only amongst ship operators but also between retailers, allowing for relatively high margins.

And the retailers have to incur relatively high costs not only due to the large inventories they have to hold, but also due to the high operational costs for e.g. energy, maintenance, recruitment, salaries, and spoilage in these remote communities (Nrg Research Group, 2014).

The following example illustrates to what extent the additional ban-related transport costs can be expected to maximally impact food prices.

Iqaluit is the capital of Nunavut and re-supplied by ship only a couple of times per year. According to the 2018 sealift schedule, Iqaluit will be re-supplied five times in 2018 with goods respectively being loaded in Valleyfield near Montreal (NEAS, 2018).

The sea distance between Valleyfield and Iqaluit amounts to roughly 3,000 km (SeaRates, 2018), with approximately 2,500 km/1,350 nm within the North American Emission Control Area (ECA) and 500 km/270 nm within the IMO Arctic waters. Ships transiting the North American ECA to re-supply communities in North Canada are exempted from the ECA requirement (Vard, 2016) and would, without the HFO ban switch from distillates or LNG to LSHFO or HFO when leaving the IMO Arctic waters. Under the ban this would not be possible since ships would not be allowed to carry residual bunker fuels whilst sailing in the Arctic waters.

Four different ships[12] are used for re-supplying Iqaluit in 2018 (NEAS, 2018), three of which are multi-purpose carriers and one which is a general cargo vessel, all in the range of 10,000 to 13,000 dwt. According to Clarksons (Clarkson Research Services Limited, 2018), the multi-purpose carriers sail at a speed of 14 or 15 knots and consume 16.5 to 22 tonnes of bunker fuel per day at this speed. No data is available for the general cargo vessel. We therefore make the assumption that it - given the similar size (13,000 dwt) – also sails at 15 knots and also consumes 22 tonnes of bunker fuel per day.

In the baseline scenario, in which the 2020 sulphur requirement applies, but no ban is introduced, we see three different scenarios, given the age of the four ships:

1. All four ships sail on LSHFO (0.5%) in the IMO Arctic waters.
2. The newest ship is retrofitted with a scrubber and uses HFO whereas the three relatively older ships sail on LSHFO in the IMO Arctic waters.
3. The newest ship is retrofitted to be LNG-fuelled whereas the relative old three ships sail on LSHFO in the IMO Arctic waters.

[12] M/V Mitiq (year of build: 1995), M/V Nunalik (year of build: 2009), M/V Qamutik (year of build 1994), M/V Avataq (year of build: 1989). (Clarkson Research Services Limited, 2018)

Assuming that the ships all switch to distillates to comply with the ban, the ban-related additional costs would amount to

- between 9,000 and 38,000 (Baseline scenario 1);
- between 28,000 to 76,000 USD (Baseline scenario 2); and
- between 8,000 and 25,000 (Baseline scenario 3);

depending on the future bunker prices.

The fuel switching costs from either LSHFO or conventional HFO (& scrubber) to MGO on return trips in the ECA have thereby been considered. This explains why the ban-related additional costs are relatively high in the second baseline scenario in which the ship that is equipped with a scrubber has to switch to MGO in the ECA as well.

Per household in Iqaluit – currently around 2,500 – the ban-related additional shipping costs would amount to:

- between 4 to 15 USD (Baseline scenario 1);
- between 11 to 31 USD (Baseline scenario 2); and
- between 3 to 16 USD (Baseline scenario 3).

Retail sales of supermarkets & other Grocery (except Convenience) stores in Nunavut as a whole amounted to around 246 million USD in 2017 (Nunavut Bureau of Statistics, 2018) and, based on the share of Nunavut's households in Iqaluit and the relative size of the average household in Iqaluit, we estimated that around 50 million USD of these sales can be attributed to households in Iqaluit. This entails of course both air and sealifted goods, but if the retail sales per household amount to on average 20,000 USD per year in Iqaluit and the additional ban-related transport costs to maximally around 30 USD per household per year (i.e. 0.2% cost increase), the impact on the food retail prices can expected to be low.

For those communities that are re-supplied by ship more often, the additional costs per year would naturally be higher, but the price pressure due to airlifted products can also be expected to be lower in these communities.

And for those communities that are re-supplied by ships sailing longer distances, the ban-related additional shipping transport costs would also be naturally higher, but for these communities the number of re-supplies can be expected to be lower per year.

3 Benefits of the ban

There are two major concerns with regard to heavy grade oil carriage and use in polar regions: First, an oil spill could have severe impacts on marine and coastal ecosystems and could endanger Arctic indigenous food security and livelihoods. Due to harsh conditions, darkness, and a lack of according infrastructure an oil spill in the Arctic is difficult to clean up and heavy grade oils have a slow rate of degradation, especially in colder regions. Second, the global warming and health effects of black carbon (BC) emissions, with BC emissions being expected to be higher for heavy grade oils than for other fuels (EP, 2017; e.g. PPR 5/INF.10 and PPR 5/INF.16).

A ban on the use and carriage of HFO as fuel by ships in IMO Arctic waters would thus have two positive effects. It would reduce the black carbon emissions from ships sailing in Arctic waters and the impacts thereof. And it would also reduce the costs and damages associated with a bunker fuel spill. If a bunker fuel spill occurred with a ban in place, no residual bunker fuel or blends thereof, but ban-compliant bunker fuel would be spilled, which would result in less severe impacts and costs. In the following section, we will focus on the latter impact, i.e. the ban-related cost savings in case of a bunker fuel spill.

3.1 Ban-related fuel spill cost savings

Costs associated with an oil spill not only include costs for oil spill response measures (e.g. clean-up costs) and transaction costs (e.g. litigation costs), but also the costs associated with socio-economic and environmental damages. This analysis focuses on the clean-up costs of oil spills.[13]

Costs for oil spill response measures and transactions costs are incurred by the ship owners/operators and their insurers as well as the affected governments. The socio-economic costs (e.g. revenues lost in fishing sector) and environmental damage costs (e.g. harm to marine life) are external costs and are in many cases not (fully) internalized, i.e. not (fully) born by the ship owners/operators and their insurers (e.g. Exxon Valdez). Therefore, either governments and/or the affected parties have to incur the according damage costs.

The costs and damages that accrue in case of an oil spill are highly dependent on the actual circumstances. Relevant factors include the oil type spilled, the amount of oil spilled, the geographic location of the spill (proximity to the shoreline and sensitive resources), the local response capacity and the clean-up technologies used, as well as weather and sea conditions (Etkin, 2000; Etkin, 1998).

Estimating the potential fuel oil spill costs in the IMO Arctic waters is thus difficult since the actual circumstances are ex ante not known. In addition, we are not aware of cost data on fuel oil spills having taken place in the IMO Arctic waters. The clean-up costs per tonne of oil spilled in case of the 2004 Selendang Ayu oil spill close to an Alaskan Island (see Table 14) however suggest that rough weather and sea conditions can lead to a significant higher clean-up costs.

[13] See Cohen (2010) for a taxonomy of oil spill costs.

To nevertheless be able to give an indication of the ban-related fuel spill costs saved, we apply the clean-up spill cost differential between spilled residual fuel and spilled distillate fuel. Trang (2006, p. 1-2) explains the cost difference as follows: ‘In general, light oil and light crude oils do not persist on the surface of the sea for long, as a result of the fast evaporation of the volatile components and the easy dispersion, especially when the sea is rough. Clean-up cost in these cases are low as a rule. But, other types of oil such as heavy crude, emulsified crude and heavy fuel oils are persistent in the environment, because they contain a high ratio of non-volatile components and they have a high viscosity. Clean-up of these oils in the environment is difficult and the cost may be very high.’

Table 14 - Clean-up costs for different oil types

Reference	Location of oil spill	Fuel	Spilled oil (t)	Total cleanup costs (million USD)	Cleanup costs per tonne spilled (USD/t)	Cleanup costs per tonne spilled (USD_{2017}/t)	Distillate/ residual
ICCT (2017b); based on Etkin (2000)	Worldwide	No2 fuel (similar to marine distillate fuel)	-	-	3,100 USD_{2015}/ton	3,300	Distillate
		No6 fuel (similar to HFO)	-	-	22,400 USD_{2015}/ton	23,600	Residual
		< 0.5% S residual fuel[14]	-	-	16,800 USD_{2015}/ton	17,700	Residual
Etkin (2000)	Worldwide; 1999 USD	No2 diesel fuel	-	-	2,300 USD_{1999}/ton	4,700	Distillate
		Light crude	-	-	4,300 USD_{1999}/ton	8,900	Crude
		No4 fuel	-	-	23,900 USD_{1999}/ton	49,200	Blend
		No5 fuel	-	-	23,200 USD_{1999}/ton	47,800	Residual
		Crude oil	-	-	7,300 USD_{1999}/ton	15,000	Crude
		Heavy crude oil	-	-	8,500 USD_{1999}/ton	17,500	Crude
		No6 fuel	-	-	17,000 USD_{1999}/ton	35,000	Residual
Deere-Jones (2016)	Spain/Portugal (Prestige, 2002)	HFO	63,000 of which 43,000 cleaned up	1,163 (shore cleaning costs)[15]	27,000 USD_{2009}	34,600	Residual
	Bay of Biscay (Erika, 1999)	HFO	20,000	244 (material damage)[16]	12,200 USD_{2008}	16,000	Residual

[14] Clean-up costs for LSHFO (which ICCT called “<0.5% S residual fuel”) is assumed to be 25% less than for HFO because some proportion of the fuel is assumed to be lighter distillates that evaporate off.

[15] 1.3948 USD/Euro.

[16] 1.4708 USD/Euro.

Reference	Location of oil spill	Fuel	Spilled oil (t)	Total cleanup costs (million USD)	Cleanup costs per tonne spilled (USD/t)	Cleanup costs per tonne spilled (USD_{2017}/t)	Distillate/ residual
	Sea of Japan (Nakhodka 1997)	MFO	17,400	186-203	11,000-12,000 USD_{2013}	13,200-21,100	Residual
	Ulanaska Island (Selendang Ayu, 2004)	Mainly MFO	1,200	103 (incl. compensation for lost taxes)	86,000 USD_{2007}	122,100	Mainly residual
Department of Environmental Conservation (2018); Desroches (2018)	Port William, Southern end of Shuyak Island	Fuel Oil No. 6 (Bunker C)	11.5	9	783,000 USD_{2018}		Residual

Etkin (2000) determined the average clean-up costs for different fuel oil types of worldwide oil spills (see Table 14). Her analysis shows a clean-up cost differential between HFO and distillate fuel of around 15,000 in 1999 USD. Like ICCT (2017b), we take this estimation as basis for our analysis.

Whether the clean-up costs for LSHFO correspond to the clean-up costs of one of the other fuel oil types analysed by Etkin et al. (2000) is unclear. ICCT (2017b) have assumed that the clean-up costs for LSHFO are 25% less than for HFO, because some proportion of LSHFO is assumed to be lighter distillates that evaporate off and do not have to be cleaned up - an assumption that we will also apply in the following.

Converted into 2017 USD[17] the clean-up costs that would be saved if MGO was spilled instead of LSHFO amount to 19,500 USD/tonne and if MGO was spilled instead HFO 30,300 USD/tonne.[18]

The amount of bunker fuel that would potentially be spilled if a fuel spill occurred in the IMO Arctic waters can be determined based on (ICCT, 2017a) who have, per ship type, estimated for 2015, 2020, and 2025 the residual fuel carried by ships that have been and are expected to be active in the IMO Arctic waters. From the average volume of residual fuel carried per ship and ship type, the minimum and maximum amount of fuel spilled can be determined, should a single ship spill fuel. This volume lies within a range of around 180 tons to 2,300 tons, at least if the entire volume of the fuel carried would be spilled.

The benefit of the HFO ban in terms of the clean-up costs that can be saved if ban-compliant fuel was spilled instead of residual bunker fuels is estimated to amount to between 3.4 and 45 million USD (LSHFO spilled) and between 5.3 and 70 million USD (HFO spilled) for one bunker fuel spill, depending on the ship type and size involved and assuming that all bunker fuel carried by a ship would be spilled.

[17] The World GDP deflator has been applied to this end: https://data.worldbank.org/indicator/NY.GDP.DEFL.KD.ZG?view=chart

[18] The difference with the clean-up costs differential applied by ICCT (2017b) can be explained by the different deflators used to convert the clean-up costs as published by Etkin (2000).

We have estimated the ban-related additional costs on fleet level (see Section 2.2) to amount to around 13 million USD annually in the Base Case Price Scenario, a price scenario with medium price spread between distillate fuel and residual fuel. This means that the ban-related additional costs just equal the clean-up costs saved due to the ban if a major LSHFO spill (2,300 ton) occurred every 3.5 year, a major HFO spill occurred every 5.5 year or a relatively small (LS)HFO occurred several times a year.[19] This however does not mean that the benefits of the HFO ban in the Arctic waters only outweigh its additional costs if an oil spill occurred at theses frequencies or more frequently. If the other costs associated with an oil spill, such as the socio-economic and environmental damage costs were to be taken into account, the implementation of an HFO ban would be desirable even if a bunker fuel spill occurred less frequently. To assess at which frequency of occurrence of an oil spill the benefits of an HFO ban in the Arctic waters still outweigh its additional costs thus requires a comprehensive social cost-benefit analysis.

To put the results into perspective: Allianz Global Corporate & Speciality (2018) reports the causes of casualties in the Arctic Circle waters per year (see following table). And although it is not clear whether these shipping incidents have occurred in- or outside the IMO Arctic waters and although it is not clear whether these incidents have led to oil spills it shows that the number of incidents that could potentially lead to an oil spill per year is rather high.

Table 15 - Shipping incidents in Arctic Circle waters with casualties, including 18 total losses

Causes of casualties	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Machinery damage/failure	5	13	14	16	12	13	20	27	46	32	**198**
Wrecked/stranded	10	11	14	9	9	8	10	14	6	11	**102**
Miscellaneous	5	1	4	4	2	6	5	5	6	4	**42**
Collision		1	4	10	4	4	2		3	2	**30**
Fire/explosion	3	1	2	6	6	1	4	2	4	1	**30**
Contact (e.g. harbour wall)	1	1	1	3	1	3	6	4	5	1	**26**
Hull damage	3	1	6	2	2	1	2	1	1	2	**21**
Foundered	1	1	2		3	1	1	2		1	**12**
Labour dispute										1	**1**
Total	**28**	**30**	**47**	**50**	**39**	**37**	**50**	**55**	**71**	**55**	**462**

Source: Allianz Global Corporate & Specialty (2018).

[19] Assuming that the clean-up cost differential is only half this high, then the ban-related additional costs would just equal the ban-related clean-up cost savings, if a major oil spill occurred every 1.8 year (LSHFO spill) or every 2.8 year (HFO spill).

4 Conclusions

The IMO has agreed to start working on the development of a ban on the use and carriage of heavy fuel oil (HFO) as fuel by ships in Arctic waters. Such a ban would not prohibit the carriage of heavy grade oil in bulk, but would instead require ships sailing in the Arctic waters to use and carry non-HFO bunker fuels only.

The study assesses benefits and costs of such a ban. More specifically, the study assesses (1) the ban-related additional costs for ship owners/operators on the IMO Arctic fleet level and (2) at individual ship level, differentiated by ship type, (3) the potential impact on consumer prices by means of two case studies, and (4) assesses the clean-up costs that could be saved in case of an oil spill. The study does not constitute a comprehensive cost-benefit analysis.

The main findings of the study are as follows

1. We have estimated the ban-related costs for the year 2021 on the Arctic fleet level for ships' activities within the IMO Arctic waters, assuming that all ships choose to comply with the ban by using distillate fuels. Depending on the 2021 bunker fuel prices, these costs are assessed to amount to between 4 and 21 million USD in Low and High cases; and 13 million USD in the Base Case Price Scenario. The latter assumes a medium price spread between distillate fuel and residual fuels. This means that the Arctic fleet's fuel expenditure for its activities within the IMO Arctic waters would, depending on the bunker fuel prices, increase by 3 to 18% in 2021 due to the HFO ban; in the Base Case Price Scenario by 9%.

   This estimation might be an overestimation for the following reasons: a distillate bunker fuel with a maximum sulphur content of 0.5% might become available that can be expected to be cheaper than MGO 0.1%, the growth of the fleet activity in the IMO Arctic waters might be lower than assumed, the LNG uptake in the baseline might be higher than assumed. And in addition, other costs of the ships, like oil spill insurance costs, may decline. On the other hand, this estimation might also constitute an underestimation, as only those parts of the voyages that fall within the IMO Arctic waters could be considered.

2. We have estimated the ban-related additional average per ship costs differentiated by ship type. Again, this was done for ships' activities within IMO Arctic waters and under a scenario in which all ships comply with the ban on use and carriage of HFO fuels by ships by switching to distillate fuels. For the Base Case Price Scenario, we found the additional average costs for individual ships to increase by 2% for ships choosing LSHFO to comply with the global 2020 sulphur cap and, depending on the scrubber costs, to increase by 4 to 15% for ships choosing for HFO in combination with a scrubber to comply with the global sulphur cap; the majority of the ships is expected to sail on LSHFO to comply with the global sulphur cap.

   Considering that some ships also sail outside the IMO Arctic waters and that for part of these voyages they would not have to switch fuels, the ban-related annual increase of the average per ship costs would be lower in both cases.

In general, if ships use HFO and a scrubber in the baseline, the ban-related additional costs are higher than if they sail on LSHFO. This is due to the higher bunker price differential between MGO and HFO. And the additional costs are naturally higher for those ship types that annually sail relatively many hours in the IMO Artic waters (like service vessels) and/or consume a relatively high amount of fuel per hour (like cruise ships and oil tankers) – the volume of the fuel that needs to be switched is higher in these cases.

3. The potential impact of the HFO ban on consumer prices has been analysed by means of two case studies. One case study estimates the potential ban-related additional costs for consumers in Greenland and a second case study looks into the potential ban-related additional costs of food shipped to Iqaluit in North Canada. Both case studies show that the impact of the ban on consumer prices can be expected to be relatively low, even if the ban-related additional transport costs would be fully passed on to the consumer.

   The Government of Greenland has given Royal Arctic Line A/S (RAL) an exclusive concession for the transportation of all sea cargo to and from Greenland and between the Greenlandic towns and settlements. We have assessed the 2021 ban-related additional maritime transport costs for RAL, assuming that RAL chooses to comply with the ban by switching from residual fuels to distillate fuels. For the Base Case Price Scenario, with a medium price spread between distillate and residual bunker fuel, these costs are estimated to amount to between 1.4 and 1.7 million USD, depending on RAL's low sulphur requirement compliance strategy. If these costs were fully passed on, the average import and export price would increase by 0.2 to 0.5%, depending on the share of shipped products (75 to 25%) in the total value of Greenland's imports and exports (around 1.3 billion USD in 2017).

   We expect that the ban would lead to an increase of the costs for shipping non-perishable food items to the North of Canada, but that the impact of this cost increase on the prices of these items would be relatively small: In the case study which looks into the sealift re-supply of Iqaluit, the capital of Nunavut, we estimated that an average household in Iqaluit spends around 20,000 USD per year for goods purchased in supermarkets and other grocery stores and that the additional ban-related shipping costs amount to maximally around 30 USD per household per year. There are two main reasons for this relatively low potential impact: First, the annual sealift services provided per year are limited due to the short summer season and the remoteness of the region, and second, other supply chain costs are already rather high in the region.

4. Clean-up costs that accrue in case of an oil spill are lower if ban-compliant fuel was spilled instead of residual fuel. The benefit of the HFO ban in terms of the clean-up costs saved is estimated to amount to between 3.4 and 45 million USD (LSHFO spill) and between 5.3 and 70 million USD (HFO spill) for one bunker fuel spill, depending on the ship type and size involved and assuming that all bunker fuel carried by a ship would be spilled. Next to the clean-up cost savings, the HFO ban also reduces the socio-economic and environmental damage costs in case of an oil spill. To actually asses at which frequency of occurrence of an oil spill the benefits of the HFO ban still outweigh its additional costs, thus requires a comprehensive assessment of the benefits of the ban.

5 References

Allianz Global Corporate & Speciality, 2018. *Safety and Shipping Review 2017, An annual review of trends and developments in shipping losses and safety,* s.l.: s.n.

CE Delft, Stratas Advisors, UMAS, NMRI, Petromarket Research Group, Hanayama, S., 2016. *Assessment of Fuel Oil Availability,* Delft: CE Delft.

Clarkson Research Services Limited, 2018. *World Fleet Register Listing,* s.l.: s.n.

Cohen, M., 2010. A Taxonomy of Oil Spill Costs, What are the Likely Costs of the Deepwater Horizon Spill?. *Resources for the Future, Backgrounder*, May; revised in June.

Corbett, J. J. et al., 2010. Arctic shipping emissions inventories and future scenarios. *Atmospheric Chemistry and Physics,* Volume 10, p. 9689–9704.

Deere-Jones, T., 2016. *Ecological, economic and social costs of marine/coastal spills of fuel oil* , s.l.: (A report to) the European Climate Foundation.

Department of Environmental Conservation, 2018. *Port William Shuyak Island Bunker C Spill.* [Online]
Available at: https://dec.alaska.gov/spar/ppr/spill-information/response/2018/04-shuyak/
[Accessed August 2018].

Desroches, K., 2018. Response wraps up on Shuyak Island oil spill. *KMXT Kodiak*, 18 April.

DNV GL, 2016. *The IMO Polar Code in force, beginning 1 January 2017 : How to comply.* [Online]
Available at: https://www.dnvgl.com/news/the-imo-polar-code-in-force-beginning-1-january-2017-how-to-comply-83230
[Accessed 26 July 2018].

DNV, 2013. *Heavy fuel in the Arctic (Phase 2),* Høvik (No): Det Norske Veritas (DNV).

EC, 2018. *International Cooperation and Development, Countries : Greenland.* [Online]
Available at: https://ec.europa.eu/europeaid/countries/greenland_en
[Accessed 13 July 2018].

Eguíluz, V. M., Fernández-Gracia, Juan, Irigoien, Xabier & Duarte, Carlos M., 2016. A quantitative assessment of Arctic shipping in 2010–2014. *Scientific Reports,* Issue 6.

EP, 2017. *Key Issues at Stake at the 71st Session of the IMO Marine Environment Protection Committee (MEPC 71).* [Online]
Available at:
http://www.europarl.europa.eu/thinktank/en/document.html?reference=IPOL_BRI(2017)602062
[Accessed 21 July 2018].

Etkin, D. S., 1998. *Financial Costs of Oil Spills in the United States : Oil Spill Intelligence Report,* Arlington (MA USA): Cutter Information Corp..

Etkin, D. S., 2000. *Worldwide Analysis of Marine Oil Spill Cleanup Costs Factor., Presented at: Arctic and Marine Oilspill Program Technical Seminar (June 2000).* Winchester (MA, USA), s.n.

EU, 2018. *Denmark : overview.* [Online]
Available at: https://europa.eu/european-union/about-eu/countries/member-countries/denmark_en
[Accessed 13 July 2018].

Government of Canada, 2016. *Map of eligible communities as of October 1, 2016.* [Online]
Available at:
http://www.nutritionnorthcanada.gc.ca/eng/1415540731169/1415540791407#map
[Accessed 31 July 2018].

Government of Canada, 2017. *How Nutrition North Canada works.* [Online]
Available at: http://www.nutritionnorthcanada.gc.ca/eng/1415538638170/1415538670874
[Accessed July 2018].

Government of Canada, 2018. *Eligible communities.* [Online]
Available at: http://www.nutritionnorthcanada.gc.ca/eng/1415540731169/1415540791407
[Accessed 31 July 2018].

Government of Greenland, 2018. *Facts on Greenland.* [Online]
Available at: https://naalakkersuisut.gl//en/About-government-of-greenland/About-Greenland/Facts-on-Greenland
[Accessed 13 juli 2018].

IBIA, 2018. *IMO takes first step toward Arctic HFO ban, but first needs to define 'HFO'.* [Online]
Available at: http://ibia.net/imo-takes-first-step-toward-arctic-hfo-ban-but-first-needs-to-define-hfo/
[Accessed 2018].

ICCT, 2017a. *Prevalence of heavy fuel oil and black carbon in Arctic shipping, 2015 to 2025,* Washington D.C.: International Council on Clean Transportation (ICCT).

ICCT, 2017b. *Alternatives to heavy fuel oil use in the Arctic: : Economic and environmental tradeoffs,* s.l.: The International Council on Clean Transportation (ICCT).

ICCT, 2018. *Heavy Fuel Oil use in the IMO Polar Code Arctic : Summarized by Ship Type, 2015, Briefing 2,* s.l.: The International Council on Clean Transportation (ICCT).

Institut de la statistique Québec, 2018. *Le Nord-du-Québec ainsi que ses municipalités régionales de comté (MRC), Fiche synthèse par MRC.* [Online]
Available at: http://www.stat.gouv.qc.ca/statistiques/profils/region_10/region_10_00.htm
[Accessed July 2018].

Langh Tech, 2017. *Langh Tech delivers hybrid scrubbers and EGR water treatment systems to container vessels.* [Online]
Available at: https://www.langhtech.com/single-post/2017/11/21/Langh-Tech-delivers-hybrid-scrubbers-and-EGR-water-treatment-systems-to-container-vessels
[Accessed 18 July 2018].

Mittarfeqarfiit, Greenland Airports, 2018. *Today's Flights, Airports.* [Online]
Available at: http://www.mit.gl/en/todays-flights/
[Accessed 13 July 2018].

NEAS, 2018. *Schedule Nunavut : Sealift Schedule for 2018, Subject to weather and ice conditions, August 06 as of 12:00.* [Online]
Available at: https://neas.ca/wp-content/uploads/sailing_schedule.pdf
[Accessed 6 August 2018].

NRG Research Group, 2014. *Northern Food Retail Data Collection & Analysis,* s.l.: s.n.

Nunavut Bureau of Statistics, 2017. *Retail Trade Report.* [Online]
Available at: https://gov.nu.ca/sites/default/files/retail_trade_report_december_2017.pdf
[Accessed 6 August 2018].

Nunavut Bureau of Statistics, 2018. *Nunavut Quick Facts.* [Online]
Available at: http://stats.gov.nu.ca/en/home.aspx
[Accessed July 2018].

NWT Bureau of Statistics, 2018. *Current Indicators.* [Online]
Available at: https://www.statsnwt.ca/
[Accessed July 2018].

PPR 5/INF.10, 2017. *Consideration of the Impact on the Artic of Emissions of Black Carbon form International Shipping: New findings of a multi-instrument Black Carbon measurement campaign, Submitted by Canada and Germany,* London: IMO, Sub-committee on Pollution Prevention and Responce (PPR).

PPR 5/INF.16, 2017. *Consideration of the Impact on the Artic of Emissions of Black Carbon form International Shipping: Black Carbon emissions and fuel use in global shipping 2015, Submitted by FOEI, Greenpeace International, WWF, Pacific Environment and CSC,* London: IMO, Sub-committee on Pollution Prevention and Responce (PPR).

Royal Arcitc Line (RAL), 2018b. *Royal Arctic Line A/S, About us.* [Online]
Available at: http://www.royalarcticline.com/about-us/
[Accessed July 2018].

Royal Arcitc Line (RAL), 2018c. *Rute oversigt.* [Online]
Available at: http://www.royalarcticline.com/media/640847/ruter.pdf
[Accessed July 2018].

Royal Arctic Line (RAL), 2016. *FN global compact CSR report 2015, Corporate Social Responsibility at Royal Arctic Line,* s.l.: s.n.

Royal Arctic Line (RAL), 2017. *Press release: Royal Arcitc Line orders new vessel in China and show progress on the potential capacity sharing with Eimskip.* [Online]
Available at: http://www.royalarcticline.com/news/2017/january/press-release/
[Accessed July 2018].

Royal Arctic Line (RAL), 2018a. *Annual Report 2017,* Nuuk: Royal Arctic Line A/S (RAL).

Royal Arctic Line (RAL), 2018d. *Cargo from Iceland, US and Canada.* [Online]
Available at: http://www.royalarcticline.com/customerservice/icland-usa-and-canada/
[Accessed 16 July 2018].

Royal Arctic Line (RAL), 2018e. *Our fleet, Specially designed and flexible solutions.* [Online]
Available at: http://www.royalarcticline.com/about-us/ships-fleet/
[Accessed July 2018].

Royal Arctic Line (RAL), 2018f. *UN Global Compact CSR report 2017, Social Responsibility at Royal Arctic Line,* s.l.: s.n.

Royal Arctic Line (RAL), 2018g. *Oil and currency surcharge.* [Online]
Available at: http://www.royalarcticline.com/cargo/oil-and-currency-surcharges/
[Accessed July 2018].

S&P Global Platts, 2017. *Tackling 2020 : the impact of the IMO and how shipowners can deal with tighter sulfur limits,* s.l.: S&P Global Platts.

SeaRates, 2018. *Distance & Time.* [Online]
Available at: https://www.searates.com/services/distances-time/
[Accessed July 2018].

SEB, 2018. *IMO2020 Report : New 2020 sulphur regulations for global shipping,* Oslo: SEB Commodity Research.

Sermitsiaq.AG , 2017. *Brændstof : Grønlandske skibe sejler på tung olie.* [Online]
Available at: http://sermitsiaq.ag/node/194317
[Accessed 16 July 2018].

Statistics Greenland, 2018a. *Greenland in Figures 2018 : 15th revised edition,* Nuuk: Statistics Greenland.

Statistics Greenland, 2018b. *Detailed imports and exports by transaction, prodruct, time, unit and month.* [Online]
Available at:
http://bank.stat.gl/pxweb/en/Greenland/Greenland__IE/IEXDET.px?rxid=IEXDET13-08-2018%2009:43:38

Stopford, M., 2009. *Maritime Economics.* Third Edition ed. London; New York: Routledge.

Trang, C. T. T., 2006. *Oil spills and clean-up costs.* [Online]
Available at:
https://www.researchgate.net/publication/259272466_OIL_SPILLS_AND_CLEAN-

UP_COSTS?enrichId=rgreq-79f92462a85d86e55dcc549f8ce742d9-XXX&enrichSource=Y292ZXJQYWdlOzI1OTI3MjQ2NjtBUzoxMDE2MzA4MDg2OTA2OTVAMTQwMTI0MjA4MTQ5MA%3D%3D&el=1_x_2&_esc=publicationCoverPd
[Accessed August 2018].

Vard, 2016. *Arctic Fuel Switching Impact Study,* s.l.: WWF Canada.

Winther, M., Christensen, J.H., Angelidis, I. & Ravn, E.S., 2017. *Emissions from shipping in the Arctic from 2012-2016 and emission projections for 2020, 2030 and 2050,* Aarhus: Aarhus University ; DCE – Danish Centre for Environment and Energy.

Winther, M. et al., 2014. Emission inventories for ships in the arctic based on satellite sampled AIS data. *Atmospheric Environment,* 91(July), pp. 1-14.

Yukon Bureau of Statistics, 2018. *Population Report, Fourth Quarter, 2017,* s.l.: s.n.

Zamakona Yards, 2018. *Zamakona Yards signs a construction contract with Royal Arctic Line to build two ships.* [Online]
Available at: http://www.zamakonayards.com/en/tag/royal-arctic-line/
[Accessed July 2018].