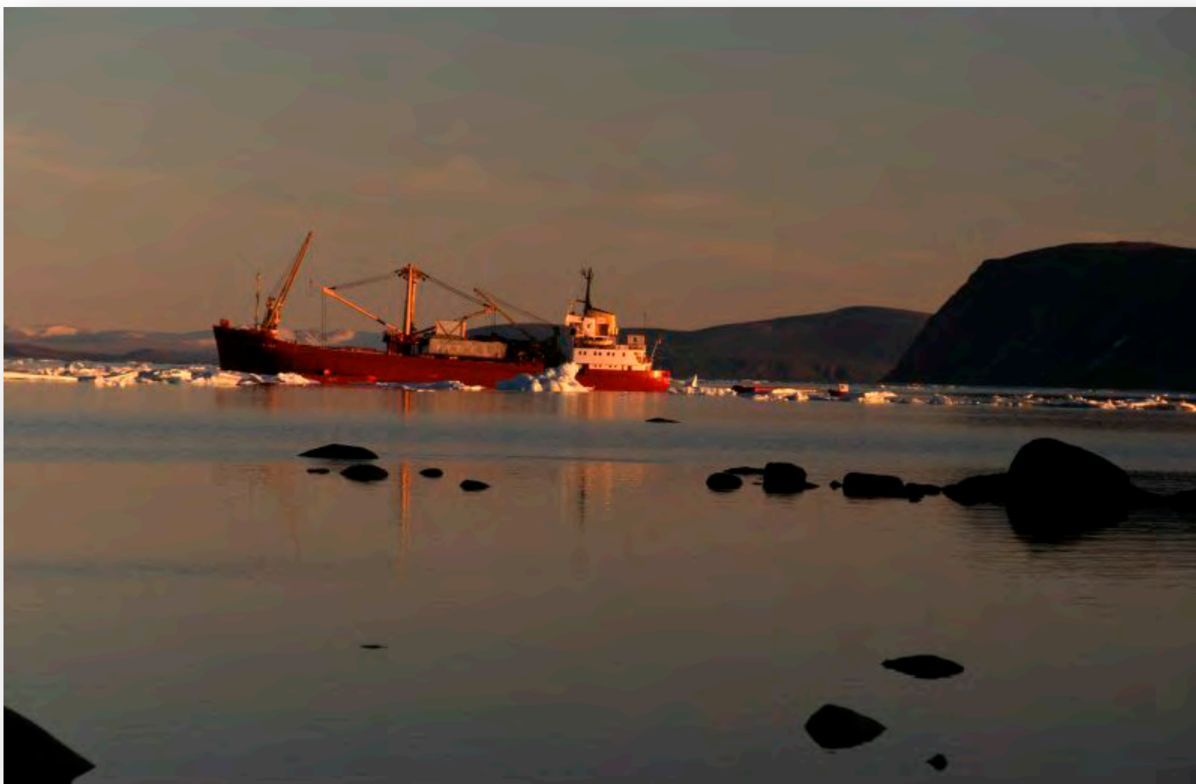
Phasing Out the Use and Carriage for Use of Heavy Fuel Oil in the Canadian Arctic: Impacts to Northern Communities

Report to WWF-Canada



Supply ship, Clyde River, Nunavut, Canada. © Peter Ewins, WWF-Canada

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Table of Contents

Executive Summary

This report examines possible impacts to communities associated with a ban on the use and carriage for use of HFO by vessels operating in the Canadian Arctic. The analysis focuses on three types of impacts associated with an HFO ban: (1) potential increased shipping costs to transport commodities to Canadian Arctic communities; (2) potential impacts from a heavy fuel oil spill in the Canadian Arctic; and (3) potential costs incurred by Canadians as a result of a heavy fuel oil spill in the Arctic. Qualitative and quantitative methods are applied to evaluate each type of impact, based on the authors' respective areas of expertise as economic and oil spill analysts.

Key findings include:

- The price of IFO 380 (a type of HFO commonly used as marine fuel) has varied significantly in recent years, yet community resupply vessels continued to deliver goods to northern communities during times (i.e. the late 2013s) when IFO 380 prices were higher than 2017 average marine gas oil (MGO) prices.
- A review of historical IFO 380 fuel cost data and historic food prices in Nunavut does not indicate a correlation between fuel costs and food prices. In fact, while IFO 380 prices fell nearly 65% from 2014 to 2017, the average cost of select shelf-stable food items in communities increased by about 15%.
- A modeled analysis of vessel using MGO rather than IFO 380 along a Nunavut resupply route in 2017, when MGO prices were more than double those of IFO, showed that the incremental costs of using more expensive fuel is about $11 (2018 Canadian dollars) per cargo tonne, or about one cent per kilogram of cargo transported. These estimates decrease if the price differential between IFO and MGO decreases as predicted.
- An Arctic HFO spill would be more challenging to clean up, more persistent, and likely more damaging than a distillate spill; this factor should be incorporated into any community impact analysis.
- HFO spills are more costly than distillate fuel spills, but existing oil spill cost models are not readily applied to Arctic spills. Improved cost modeling is needed to estimate the potential cost impacts of oil spills in the Canadian Arctic.
- The current Canadian liability regime does not require adequate ship owners' insurance to cover the potential costs of an Arctic fuel oil spill.
- If an HFO ban were to result in an increased cost of goods to Canadian Arctic communities, policy options should be explored to mitigate these short-term impacts in order to realize long-term benefits of removing HFO from Arctic waters.

Impact of Fuel Prices on Cost of Goods in Nunavut

The fuel cost analysis focused on two types of marine fuel: IFO 380, a heavy residual fuel oil; and marine gas oil (MGO), a distillate fuel that is compliant with both the 2020 sulphur emission cap and the proposed Arctic HFO ban. Historical price data for both fuels from late 2013 through 2017 shows significant variability, with a trend toward overall price reduction of both fuel types. The price difference between IFO 380 and MGO ranged from a low of $268/tonne in September 2016 to a high of $522/tonne in February 2014. Prices remained relatively stable through out 2017, with MGO costing about 1.5 times as much as IFO 380.

Over the roughly four years of monthly fuel price data, the highest price for IFO 380 ($654 in November 2013) was higher than the lowest price for MGO ($526 in January 2016), suggesting that the shipping industry has adapted to extreme price fluctuations in the past, since historic IFO 380 prices have been higher than the current MGO prices. Average monthly MGO prices in Montreal were lower than the average November 2013 price for IFO 380 every month from August 2015 through December 2017.

Predicting future marine fuel prices is challenging because of the complexities and interdependencies in the global refining and marine fuel markets. Most analysts agree that there will be a period of volatility in the years leading up to the 2020 global sulphur cap, but that eventually the markets will settle out and global refining capacity will adjust to higher demand for distillate fuels. This will narrow the price gap between HFO and distillate fuels.

Since distillate fuels are currently more expensive than HFO, a ban on the use and carriage for use of HFO could result in increased fuel costs for community resupply (sealift) vessels. Before projecting potential future impacts of fuel switching, the past relationship between fuel prices and cost of goods in Canadian Arctic communities were explored. Past IFO 380 prices (averaged by year) were compared to food basket costs as compiled by the Nunavut Statistics Board. The data do not correlate fuel prices with food basket costs. For example, the cost of IFO 380 went down by nearly 50% from 2014 to 2015, while the food basket survey showed that food prices in all three Nunavut regions increased during the same time period.

While this analysis shows no clear correlation between marine fuel costs and food item costs, additional analysis was performed to explore the potential for increased fuel costs to carry through to individual food items that are typically delivered by sealift. A simple cost model was used to estimate the incremental cost associated with using distillate fuel rather than HFO, on a per-kilometer and per-kilogram cargo basis.

Based on 2017 average Montreal fuel prices, the modeled analysis predicted that it would cost about $11/tonne for a sealift vessel to burn MGO rather than IFO 380 along a community resupply route (2018 Canadian dollars). Spread further, the per-kg cost increase from the use of MGO is just over one cent, and it decreases if the future cost spread between IFO and MGO decreases as predicted.

Considering the incremental cost impacts of fuel switching on a per-kilometer or per-kilogram cargo basis provides additional context for considering the trade-offs associated with replacing HFO with less polluting fuels. For example, a modeled analysis showed that the net effect of doubling fuel costs breaks down to pennies or less in increased transportation costs by weight, which is how most freight costs are established. In order to accurately estimate the potential impacts of an Arctic HFO ban on the cost of goods in Canadian Arctic communities, more information is needed about the relationship between fuel costs and sealift prices. Refined estimates of future price differences between IFO 380 and MGO or other less polluting fuels will also inform estimates of cost-of-good impacts from the pending HFO ban.

Impact of a Heavy Fuel Oil Spill in Canadian Arctic Waters

Oil spills from vessels operating in Arctic waters – whether community resupply vessels, cruise ships, or large freight vessels transiting the northern sea route – can have significant and long-lasting impacts on Arctic coastal communities. The risks associated with an Arctic HFO spill are one of the main drivers of the HFO ban; therefore, the impact of eliminating this risk is an important consideration in assessing overall community impacts.

All oil spills have the potential to devastate wildlife and habitat and to impact the people and communities that rely on an intact ecosystem for food and socio-cultural activities. Arctic conditions complicate the oil spill response process, potentially adding to the severity of oil spill impacts. Arctic conditions may also exacerbate the consequences of an oil spill for a number of reasons, including: slower biodegradation; encapsulation of oil in sea ice; slower reproductive cycles of Arctic species; smaller food webs; aggregate stressors due to climate change; and heavy reliance on subsistence foods in the north.

While any Arctic spill could have significant adverse impacts, an HFO spill would likely be more challenging to clean up and more harmful to the environment than a distillate spill. Residual oil spills are slow to naturally degrade and difficult to clean up, because they are denser and more viscous than distillates, and are usually harder for oil spill response systems to skim, pump, and store. The typical response to a residual oil spill involves cleaning the tarry residue off whatever it contacts. Any HFO that is not removed would persist in the environment much longer than distillate fuels, with more widespread geographic and temporal impacts.

The potential impacts from spilling new and emerging hybrid fuels and residual fuel blends are poorly understood, especially in the Arctic. Because these fuels are blended specifically to reduce sulphur air emissions, they retain many of the characteristics of HFO that make it particularly persistent and challenging to clean up. Information is sparse about how these low sulphur residual fuel blends and hybrids behave when spilled, but based on published research, they appear to have similar characteristics to diluted bitumen. An Arctic HFO ban should include these hybrid fuels, which have a similar risk profile to HFO.

Cost Impact of an Arctic Heavy Fuel Oil Spill

HFO spills are typically much more persistent and therefore more expensive to clean up than distillate fuel spills, with more extensive damages to wildlife, habitat, subsistence foods, and socio-economic values. Canada's "polluter pays" system, which establishes the financial responsibility of vessel owners and operators to pay for the cleanup costs and damages associated with fuel oil spills, may not provide adequate assurance that all costs will be paid by the polluter's insurance. Additional funds are available through Canadian and international trust funds, but disbursements from these sources are also limited. Any costs above these financial responsibility limits would fall to the governments, communities, individuals, and private companies that incur expenses to clean up oil spills or suffer damages from the spill impacts.

The costs associated with oil spill response are generally grouped into the following three categories: (1) cleanup costs; (2) environmental costs; and (3) socioeconomic costs. In addition to these three broad cost categories, there are a number of oil spill costs that are not always taken into consideration. For an Arctic ship-source fuel oil spill, these may include: private costs incurred by the spiller; death or harm to individuals involved in the ship accident; response costs incurred by government agencies; cost of repairing damaged infrastructure; losses by affected businesses; loss of consumer value from shifting purchases; natural resource damages and restoration costs; cost of litigation to all injured parties; societal costs associated with focusing government and public resources away from day-to-day functions; and social costs that cannot be compensated through a transfer of funds.

The most commonly cited oil spill cost model – which is not Arctic-specific – estimates the cost per volume of spill cleanup for HFO compared to distillate spills. The cost per tonne of an HFO spill is estimated at between U.S.$106,000 and U.S.$512,000 per tonne spilled, including shoreline clean up costs, socio-economic costs, and environmental costs. By comparison, the per-ton costs estimated for a distillate spill range from U.S.$32,000 to $193,000 per tonne. Anecdotal data from other (non-Arctic) HFO spills show that HFO cleanup costs may be as much as $300,000 to $800,000 per tonne spilled.

Shipowner liability for fuel oil spills in Canada is based on the ship's tonnage; for example, for a 6,000 GT cargo vessel (typical of a community resupply/sealift ship serving communities) has a liability limit of approximately $7.2M for a bunker fuel spill. Assuming the fuel capacity for a 6,000 GT cargo vessel is 570 tonnes, the liability limit on the vessel owner would calculate to about $13,000/tonne. This is significantly lower than the per-tonne cleanup costs derived from models or anecdotal data. Even for a relatively small spill (10% of fuel capacity on a small cargo ship, or 57 tonnes), the liability limit of the vessel owner under Canadian law would be $6.8M lower than the estimated response costs derived from the model, which is not Arctic-specific. This gap grows to over $167M in the event of a total loss of bunkers. If the anecdotal cost data from past spills were applied, the gap would increase by nearly threefold.

The Canada's Ship-source Oil Pollution Fund (SOPF) provides supplemental funding in the event that spill costs exceed the funds available through the ship's insurance. The maximum liability per incident is adjusted annually; the 2017 limit is approximately $172M. Theoretically, this would be sufficient to cover the conservatively estimated gap for the 100% fuel loss scenario. However, such a claim would be an order of magnitude greater than any claims paid out of the fund to date (total expenditures for all claims combined since 1972 have been about $19M). The criteria for evaluating SOPF claims excludes any damage that might be related to lost use, such as lack of opportunity to gather subsistence foods, loss of recreational opportunities, or socio-cultural impacts that cannot be monetized.

Paying a significant portion of oil spill response costs for an Arctic heavy fuel oil spill out of the Canadian fund would transfer the cost burden from the polluter to the government and taxpayers of Canada.

Mitigating Community Impacts

Banning HFO use and carriage for use through Canada's delicate marine ecosystem offers a number of benefits to ecological and human health. However, there are also economic costs associated with switching Arctic ships over to cleaner burning fuels. While the per-tonne costs associated with switching from IFO 380 to MGO will likely decline over time as global marine fuels market adjusts to new regulatory requirements, it is also likely that shipping companies will pass along some or all of their initial cost increase to communities. A higher cost of goods may seem like a reasonable trade-off for slowing ice melt and protecting ecological and human health, yet high north communities are understandably concerned that any increases will threaten their economic well-being.

Policy options that mitigate the impacts to community members from higher sealift fuel costs should be explored alongside the implementation planning for an HFO ban. Several options are identified for consideration including:

- Using government subsidies to protect communities from increased cost of goods during initial price inflation, if one occurs.
- Adopting a phased or adaptive implementation process that incentivizes fuel switching.
- Continuing to explore and analyze the relationship between fuel costs and cost of goods in northern communities.

Banning HFO use and carriage for use in Arctic waters will significantly diminish the risk of HFO spills. However, an HFO ban does not remove the potential for other types of marine fuel oils or bulk oil shipments to spill and impact Arctic waters. Many of the issues raised in this study bear consideration even after an HFO ban takes effect, including:

- Creating a more robust Arctic oil spill response capacity;
- Enhancing oil spill prevention measures; and
- Exploring new funding sources to build spill response capacity.

An Arctic HFO spill would not only be catastrophic, but would be extremely cost-intensive to clean up. The current liability system for fuel oil spills caps a ship owner's liability at a level that removes any incentive for switching away from HFO. The fact that so many of the costs of an oil spill are borne by government and society makes the cost/benefit equation more complex, and worth considering through a different lens. Incentives that reward risk-reduction and spill prevention measures could be created to offset additional fuel costs associated with the HFO ban.

1 Introduction

Nuka Research and Planning Group, LLC (Nuka Research) and Northern Economics, Inc. (NEI) developed this report for WWF-Canada to support their ongoing evaluation of the impacts associated with phasing out the use of Heavy Fuel Oil (HFO) by ships operating in the Canadian Arctic.

1.1 Purpose

The purpose of this report is to estimate impacts to communities resulting from a ban on the use and carriage for use of HFO by vessels operating in the Canadian Arctic.

This report was developed to support ongoing discussions within the International Maritime Organization (IMO) Marine Environment Protection Committee (MEPC), and to inform the development of an impact assessment methodology, which is scheduled for discussion at the 73rd session in October, 2018.

1.2 Scope

The report considers certain impacts – both positive and negative – associated with the switch from HFO to less polluting fuels for community resupply vessels and other commercial shipping vessels that may transit northern shipping routes. The analysis focuses on three types of impacts associated with an HFO ban: (1) potential increased shipping costs to transport commodities to Canadian Arctic communities; (2) potential impacts from a residual fuel spill in the Canadian Arctic; and (3) potential costs incurred by Canadians as a result of a heavy fuel oil spill in the Arctic. Qualitative and quantitative methods are applied to evaluate each type of impact, based on the authors' respective areas of expertise as economic and oil spill analysts.

Figure 1-1 shows the study region and identifies communities in the north that rely on shipping for the transport of some goods. The map shows both the Arctic Circle and the 60° North latitude line, which represents the boundary of the Polar Arctic. This report is inclusive of Hudson Bay communities south of 60° North, because they also rely on sea lifted cargo for community resupply.

Figure 1-1. Map of Canadian northern communities

1.3 Contents and Organization of this Report

This report is organized into six sections, including this introduction. Section 2 provides background information about marine fuel use by vessels operating in the IMO Arctic, and in the Canadian Arctic. Section 3 presents a cost analysis that considers the relationship between marine fuel costs and the cost of goods in northern communities. Section 4 identifies key considerations for understanding the potential ecological impacts and response challenges associated with Arctic HFO spills. Section 5 considers the potential impacts of paying for oil spill cleanup costs and damages in the event of a major HFO spill in the Canadian Arctic. Section 6 considers options to mitigate the impacts described in Sections 3 through 5.

2 Marine Fuel Use and Carriage in the Canadian Arctic

WWF-Canada has worked within Canada and internationally on a range of efforts to study and understand the tradeoffs associated with the shipping industry's shift from the use of HFO to lower-emitting and less persistent fuels such as diesel and marine gas oil (MGO). This section provides context for evaluating the impacts of an HFO ban to Canadian Arctic communities.

2.1 Marine Fuel Oils

Marine vessels may opt to use different types of fuel for propulsion, depending upon their size, configuration, operating routes, and other operational, logistical, and financial considerations (Ocean Conservancy, 2017). All marine fuel oils begin with crude oil in some form; from there, different levels of processing and blending result in a range of fuel oil types.

Marine fuel oils are broadly characterized as either residual oils or distillates (Bomin Group, 2015b). Distillates are the petroleum products created by refining crude oil. They are called distillates because distillation is a key step in upgrading these products; however, depending upon the refinery, there may be additional steps involved (such as vacuum distillation, catalytic cracking, and breaking). Distillate fuels include gas, naptha, kerosene, and diesel (in this case, diesel refers to the specific distillation cut of petroleum, not the type of engine used to burn oil).

Residuals are all of the leftover components of crude oil that are separated from the upgraded, distilled products. Residual marine fuels typically do not undergo any type of upgrading, although they may be mixed with distillates to achieve certain desired chemical or physical properties.

Table 2-1 summarizes the terminology used in this report to describe marine fuels, and indicates whether each is considered residual or distillate.

Table 2-1. Marine Fuel Oil Terminology

TERMINOLOGY U.S.ED TO DESCRIBE MARINE FUEL OILS		
Marine Fuel Oil Name	**Composition**	**Type**
Bunker C/Fuel oil No. 6	Residual oil	HFO
Intermediate Fuel Oil (IFO) 380	Residual oil (~ 98%) blended with distillate	HFO
Intermediate Fuel Oil (IFO) 180	Residual oil (~88%) blended with distillate	HFO
Low sulphur marine fuel oils	Residual oil blended with distillate (higher ratio of distillate to residual)	HFO derivative
Marine diesel oil (MDO)/ Fuel oil No. 2	Distillate fuel that may have traces of residual oil	Distillate
Marine gas oil (MGO)	100% distillate	Distillate

2.1.1 Residual Oils and HFO

The term HFO is used to describe both a category of marine fuels and certain marine fuel oil blends. Heavy fuel oils (as a category of marine fuels) are created from residuum, the tar-like sludge that is the end product of upgrading crude oil (Ramberg and Van Vactor, 2014). The quality and chemical makeup of HFO is highly variable, depending on its components and the way they are blended to achieve the desired viscosity and flow characteristics (McKee et al., 2014).

The MARPOL Convention defines HFO as a general category of marine fuels that have a density above 900 kg/m^3 at 15°C, or a viscosity of more than 180 mm^2/s at 50°C (Bomin Group, 2015). Residual fuel blends such as Number 6 oil and Bunker C oil are common in the marine industry and are often referred to as HFO. Heavy fuel oils typically have higher sulphur content than distillate fuels and create more particulates when burned, resulting in higher air emissions of sulphur, black carbon, greenhouse gasses, and other pollutants (Bomin Group, 2015).

HFOs are the cheapest fuel oils that refineries can produce. Since most developed economies prohibit burning HFOs, the marine fuel market is the primary consumer for HFO (Ramberg and Van Vactor, 2014). The low cost of HFO compared to other fuels has contributed to its widespread use for marine propulsion (O'Malley, et al., 2015).

In addition to their use as marine fuels, residual oils are used for power generation in some developing countries. Residuum is also used to produce asphalt. As air emissions standards have become stricter, the global demand for residual oils has steadily declined since the mid-1980s, with future predictions supporting continued reductions in demand (O'Malley et al., 2015).

Refineries do have the ability to upgrade residuum into petroleum coke (used to produce synthetic crude oils) or into middle distillates and gasoline. For some refineries, upgrading residuum would require additional capital investments, while other refineries have existing capability to upgrade residuum. The decision to upgrade is typically driven by market forces; if distillate fuel prices are sufficient to cover the additional refinery costs associated with upgrading residuum, then refineries may choose to upgrade and sell distillate products rather than residual fuels (Ramberg and Van Vactor, 2014).

2.1.2 Distillate Fuels

The International Standards Organization (ISO) has established fuel standards for marine distillate fuels. Common types of distillate marine fuels are marine diesel oil (MDO), distillate marine diesel (LDO or DMA, DMB, or DMX) and marine gas oil (also called MDC or MGO). Marine distillate fuels have a density at or below 900 kg/m^3 at 15°C, and a viscosity range between 1.4 and 11.0 mm^2/s at 40°C. The sulphur content of marine distillate fuels is below 1.5% (ISO 8217, 2017). These fuels require additional processing by refineries, and are therefore more expensive than residual fuels.

Distillate fuels are used for propulsion on a range of vessel types, from fishing boats to cruise ships and cargo vessels. Some ships that use HFO as a primary propulsion fuel may carry a smaller supply of distillate fuel for secondary engines.

2.1.3 Residual Blends

Newly emerging low sulphur marine fuel oil (LSMFO) blends are become more popular as an HFO alternative that complies with newly emerging air emission standards. These blends – also called hybrid fuels – are made when residual oils are combined with lighter products such that when the fuel burns, the plume that is emitted does not exceed prescribed thresholds. Larger vessels (container ships, ro-ro ships, and general cargo ships) operating in emission control areas, primarily in Europe, are using these hybrid oils as an alternative to distillate fuels (HelstrØm, 2017).

Ultra and very low sulphur residual fuel oils available on the market fall well below the HFO viscosity limit, but some still exceed the 900 kg/m^3 density threshold.[1] One European refinery is developing a low sulphur blend with a higher viscosity (around 300 mm^2/s at 50°C) to solve the engine lubrication problems that sometimes result when ships switch from high viscosity HFO to low viscosity distillates or blends (James, 2017). From an oil spill fate and behavior perspective (discussed in Section 4.3), these oils would still behave more like a heavy fuel oil than like a lower density distillate fuel.[2]

A representative of Finland refiner Neste pointed out in a news article that low sulphur marine fuel blends are similar to distillates, but still retain some characteristics of residual oils. "If you look at the low-sulphur [sic] fuel oil available in the market, it is not fuel oil, it is distillates…just a little bit dirtier that's all." (James, 2017)

A recent analysis of residual fuel blends found that there is some variability in product properties depending upon the refinery batch, which may reflect differences in the composition and properties of the fuels blended to make the hybrid (HelstrØm, 2017).

2.1.4 Other Marine Propulsion Options

In addition to residual oils, distillates and residual blends, ships may opt for other propulsion systems. Liquefied natural gas (LNG) is becoming more prevalent, particularly on newer ships. LNG-powered vessels require specific infrastructure and fuel availability (DNV-GL, 2017). Some ships use alternative fuels such as biofuels or methanol. Battery and hydrogen power are other alternatives to burning marine fuel oils.

These other options are not explored in this study, but are acknowledged as less-polluting alternatives to HFO.

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[1] For example, the specification sheet for Shell's ULSFO cites typical density between 700-910 kg/m^3; ExxonMobil's Premium HDME 50 blend, designed specifically for ECA compliance, is also well below the viscosity threshold but has a density of 900-915 kg/m^3.

[2] Typical density for a marine gas or marine diesel oil is around 860 kg/m^3.

2.2 Marine Fuel Use in Arctic Shipping

2.2.1 HFO Use in Polar Code Arctic

Less than half of the vessels that transit the Polar Code Arctic burn HFO, but because heavy fuels are primarily used on larger vessels with bigger fuel tanks, more than 75% (by mass) of the fuel oil used in the Arctic is HFO (Comer et al., 2017; DNV, 2013a; DNV, 2013b). Bulk carriers, container ships, oil tankers, general cargo vessels, and – in some areas – fishing vessels all burn HFO along Arctic routes. While 75% of the fuel carried through the Arctic is HFO, it accounts for about 57% of the fuel burned by ships operating in the Arctic (Comer and Olmer, 2016; Comer et al.; 2017).

Recent trends show an increase in HFO carriage in the Arctic – from 400,000 tonnes in 2012 to 830,000 tonnes in 2015 (Comer et al., 2017; DNV, 2013a; DNV 2013b). The exposure from these transits, based on the number of transits and volume carried onboard, combined with projected increases in Arctic vessel traffic due to diminishing sea ice, increases the potential for HFO spillage in Arctic waters (Comer et al., 2017; Azzara et al., 2015).

Figure 2-1 shows HFO use by ships in the IMO Arctic based on 2015 data (Comer et al., 2017).

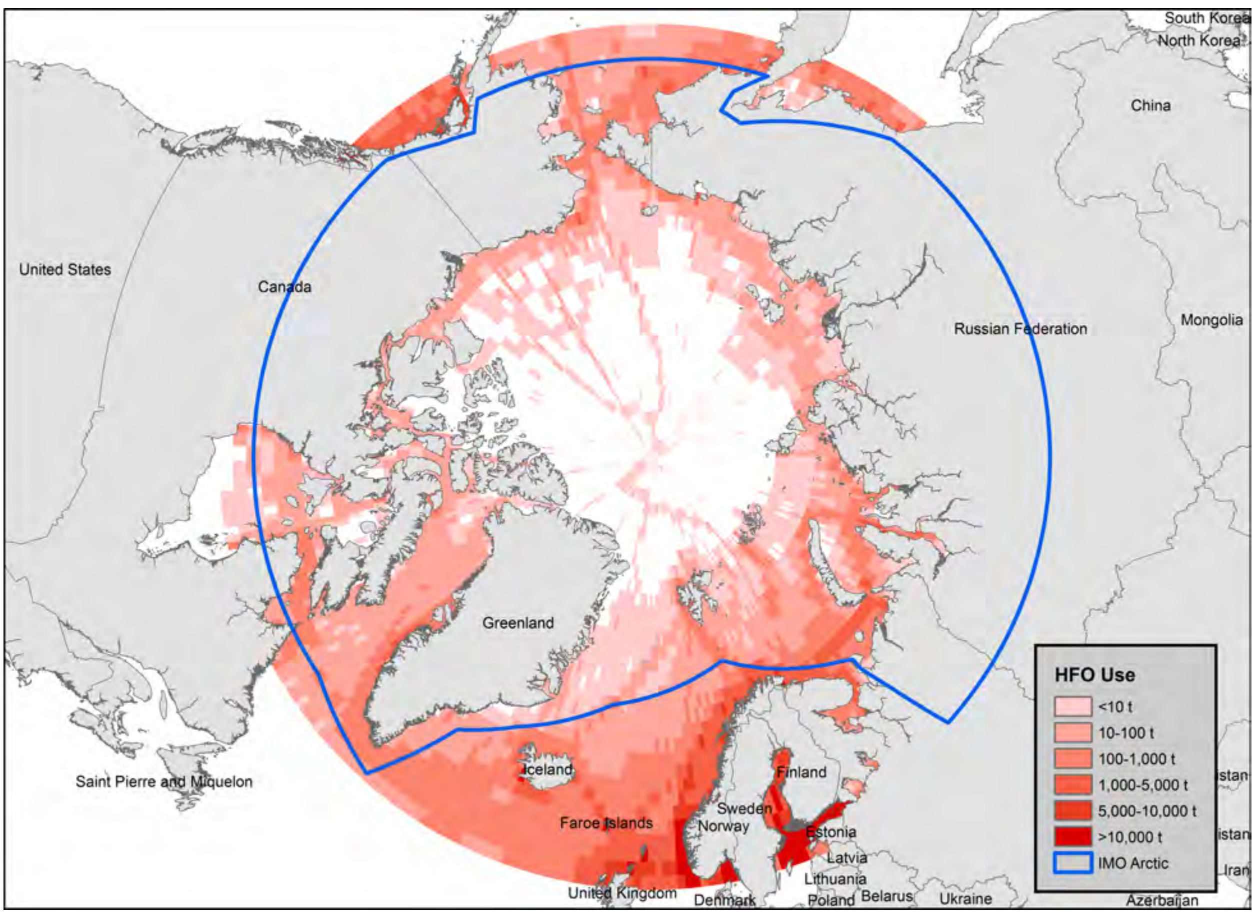

Figure 2-1. HFO Use in Arctic during 2015 (Comer et al., 2017)

2.2.2 Canadian Arctic Shipping Traffic

Vessel traffic patterns in Canada's Arctic waterways are changing as sea ice conditions open new travel routes. Cruise ships and personal recreational boats are visiting previously inaccessible Arctic regions, alongside military ships, cargo traffic, and fishing boats. Most of the cargo ships operating in the Canadian Arctic call on one or more ports in the region; however, large cargo ships operating between Asian and European ports are also transiting northern sea routes.

The distance traveled by ships through the Canadian Arctic has increased significantly over time. During the 26-year period from 1990 through 2015, the distance traveled by ships through the Canadian Arctic nearly tripled from 364,179km to 918,266 km. The largest proportion of ship traffic in the region is from general cargo vessels and government ships (icebreakers and research vessels). Recreational vessels (private yachts and pleasure craft) represent the fastest growing vessel activity in the Canadian Arctic. Shipping routes include vessels serving mining operations as well as international transits along the northern and southern Northwest Passage routes (Dawson et al., 2018).

WWF-Canada analyzed Automated Information System (AIS) data to estimate the use of HFO by ships transiting the Canadian Arctic (Figure 2-2).

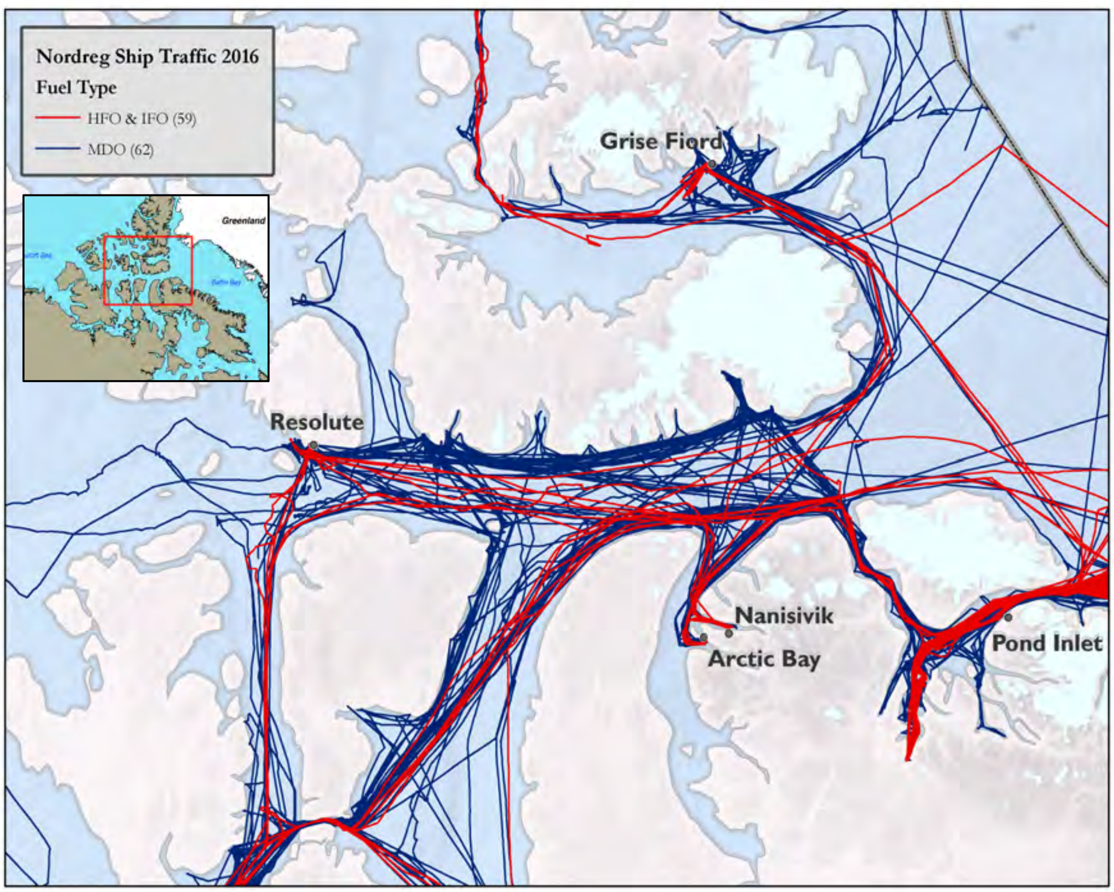

Figure 2-2. Fuel use by vessels operating in region of Canadian Arctic in 2016

Figure 2-2 shows the fuel use by vessels operating along the northern Northwest Passage route as well as local traffic among several Nunavut communities. Of the 123 transits mapped, approximately half of the vessels were burning a residual fuel (HFO or IFO), and the other half used distillate fuels (MDO).

2.2.3 Community Resupply Vessels

Canada's far northern communities lack rail or road infrastructure to support the movement of goods, so most cargo is delivered either by community resupply vessels (sealift) or airplanes. Sealift deliveries are typically an annual event, and one that is critical to supporting communities in Nunavut, Northern Quebec, and coastal areas of the Northwest Territories. Cargo rates for community resupply are already very high, and any factor that increases the operating costs for sealift operators could potentially increase shipping costs to communities that are already dealing with a high cost of living (Vard, 2016).

Due to the nature of the shipping route (ice conditions, short operating season), only a few shipping companies operate along northern resupply routes, and their vessels run on HFO (Vard, 2016). Figure 2-3 shows traffic routes for vessels burning residual fuel oils in Nunavut, based on 2016 AIS data. Bulk carriers, general cargo ships, and tankers all used HFO, with nearly 70% of the traffic made up of general cargo ships. All three types of vessels appear to have been traveling between communities, likely for resupply.

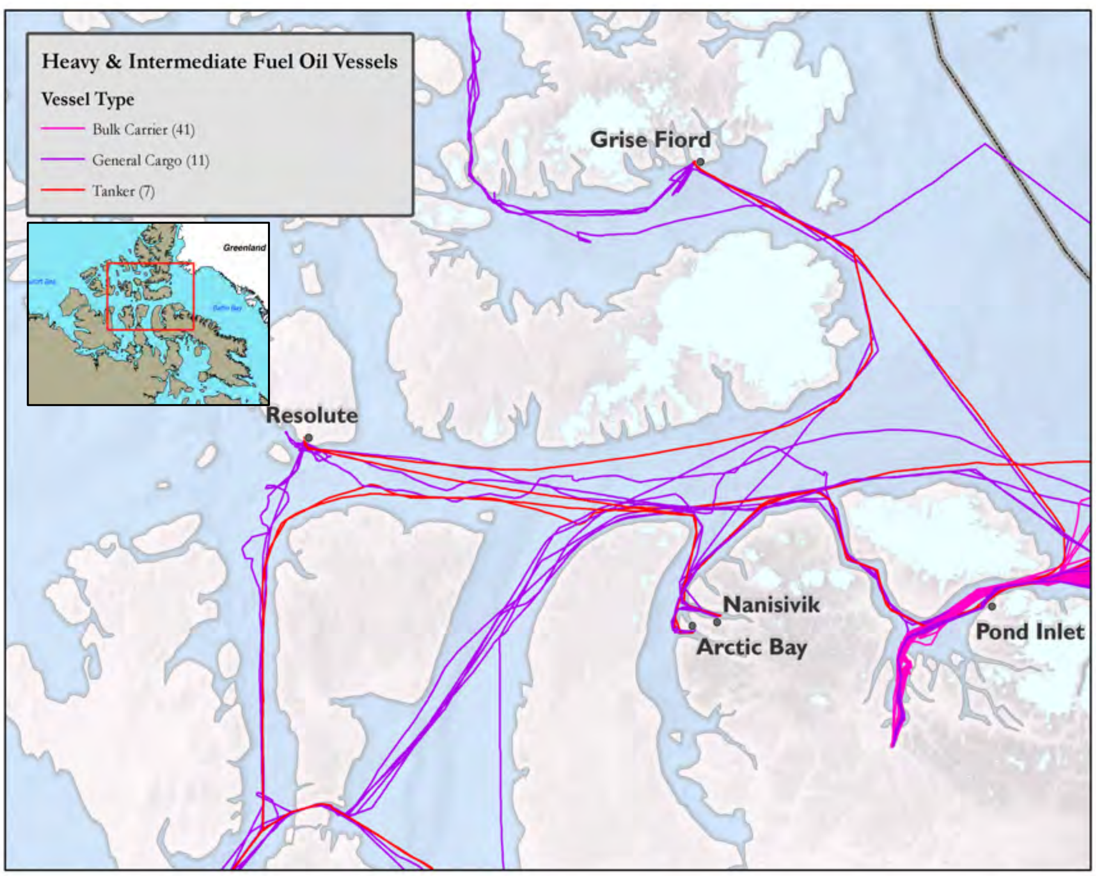

Figure 2-3. Vessels using heavy fuel oils in region of Canadian Arctic in 2016

2.3 Phasing out HFO Use and Carriage for Use by Ships Operating in the Arctic

The use of HFO as a marine fuel has diminished in many regions of the globe due to stricter international, national and port-level regulations and standards.

2.3.1 Existing Emission Standards Limit HFO Use in Many Regions

While the proposed phase out of HFO use and carriage for use is tied primarily to the potential impacts of an HFO spill in Arctic waters, there is a relatively long history of HFO regulations that are tied to air emissions. Air emissions from ships burning HFO contain more pollutants than emissions from burning distillate fuels. Of particular concern are sulphur, nitrogen oxide, and black carbon; all cause adverse impacts to human and environmental health.

International policies limiting the amount of sulphur emissions from marine fuels have been in place for over 20 years. In 1997, MARPOL Annex VI established a 4.5% sulphur cap. In 2008, the MEPC lowered the cap to 3.5% (effective 2012), and set a limit for 2020 of 0.5% sulphur. (FOEI et al., 2016). Beginning in 2015, the IMO designated certain areas in North America and Europe as Emission Control Areas (ECA), subject to a sulphur emissions cap of 0.1% (or equivalent control measures).[3] The North American ECA, which extends to 200nm offshore, incorporates the entire Pacific Coast and the Atlantic Coast as far north as the southern opening to Hudson Strait. Arctic regions are excluded from the existing ECAs.

In addition to the IMO designated ECAs, local and national authorities have established additional emission control areas in China, California, and the EU (CARB, 2017; Gard, 2014).

Compliance strategies for vessels facing sulphur emission control standards have been unfolding as new standards take effect. Available options for complying with emissions caps generally fall into one of three categories: (1) transitioning from high sulphur residual fuel oils to either distillate fuels (such as MGO) or low sulphur hybrid fuels; (2) retrofitting vessels to utilize alternative fuels like LNG; or (3) installing scrubber systems that reduce the level of sulphur in vessel air emissions to below 0.5%, allowing vessels to continue to burn residual oils. Other technologies, such as biofuels and water injection, are described in the literature but have not been widely adopted. (O'Malley et al., 2015)

A fourth option is not to comply at all, and based on a 2017 estimate of 8% non-compliance with ECA emission standards, industry experts estimate that non-compliance with the 2020 global sulphur standard could be as high as 15% (Gallagher, 2018; Leavens, 2018).

2.3.2 Existing and Proposed HFO Bans

Currently, there are only a few regions of the world's oceans where HFO use and carriage is prohibited; HFO bans exist in the AntArctic Ocean and in the Svalbard region of Norway (EPPR, 2017; IMO, 2011).

[3] Prior to this, ECAs had been in place in the Baltic and North Seas with a 1% sulphur limit (MARPOL Annex VI Regulation 14).

Banning HFO use and carriage for use in the Arctic has been advocated for by European Parliament and some Arctic nations (European Parliament, 2017) for many years. In April 2018, an eight-nation coalition proposed to the IMO's MEPC an HFO ban for vessels operating in the Polar Code Arctic. The ban would take effect in 2021, with provision for delayed implementation (five years) for HFO-burning vessels that have fuel tank protections in place (IMO, 2018).

Eliminating the use of heavy fuel oils would not only achieve the global emissions standards, but would also eliminate the potential for a heavy oil spill. An Arctic HFO ban may influence how some vessels opt to comply with global sulphur standards, creating a disincentive for scrubber use on vessels that operate in the Arctic, which will likely lead to a more widespread use of low sulphur fuel oil or distillates.

For community resupply shipping in the Canadian Arctic, an HFO ban would require these vessels to switch to distillate fuels, as this is the only option that satisfies both the global sulphur emission standard and the Arctic HFO ban. Since the proposed HFO ban extends to both use and carriage for use of heavy fuel oils, sealift vessels would presumably not be allowed to have any HFO onboard, even if they had other measures in place to comply with the sulphur emissions cap for the portions of their journey south of 60°N. These scenarios presume that Arctic resupply vessels will be required to comply with both the global sulphur cap and the Arctic HFO ban, despite the fact that community resupply vessels that service northern communities are currently exempted from emission standards by the federal government when they transit through the North American ECA.

3 Estimating the Impacts of HFO Ban to Shipping Costs and Cost of Goods in Canadian Arctic

Any significant increases to the cost of goods would adversely impact the Arctic communities that already face a high cost of goods against limited economic opportunities. Several studies have estimated the cost to communities of an HFO ban based on the increases to shipping costs (Vard, 2016; Kalli et al., 2009; Martino et al., 2009; UNCTAD, 2010). The results have generally supported the concept that rising fuel prices lead to higher consumer costs, but the relationship between cost of goods and fuel costs is complex and calculated estimates for future price scenarios vary based on the assumptions and coefficients applied.

This section considers the relationship between fuel prices and the cost of specific consumer goods in Canadian Arctic communities by exploring the relationship between actual fuel costs and price of goods over recent years, and modeling the potential impacts of an HFO ban to the cost of goods along a specific Arctic resupply route.

3.1 Fuel Costs for Northern Community Resupply

3.1.1 Fuel Cost Variability and Ship Operating Costs

The price of fuel is one of many operating costs that affect the cost of transporting goods over northern sea routes. Other costs include labor, port costs, materials and repair, overhead and other indirect costs, and insurance. Determining the contribution of fuel costs to journey costs depends upon the price of fuel, but is also influenced by market trends in the price of consumer goods and commodities, fuel consumption rates, and cargo capacities of individual vessels (Martino et al., 2009).

Marine fuel prices are set daily at ports around the world and are influenced by a complex web of economic factors and market forces. Figure 3-1 shows a daily fuel cost summary from May 8, 2018, reflecting the daily variations across individual ports and global averages from major ports for two marine fuels (IFO 380 and MGO) for this particular day (Ship and Bunker, 2018).

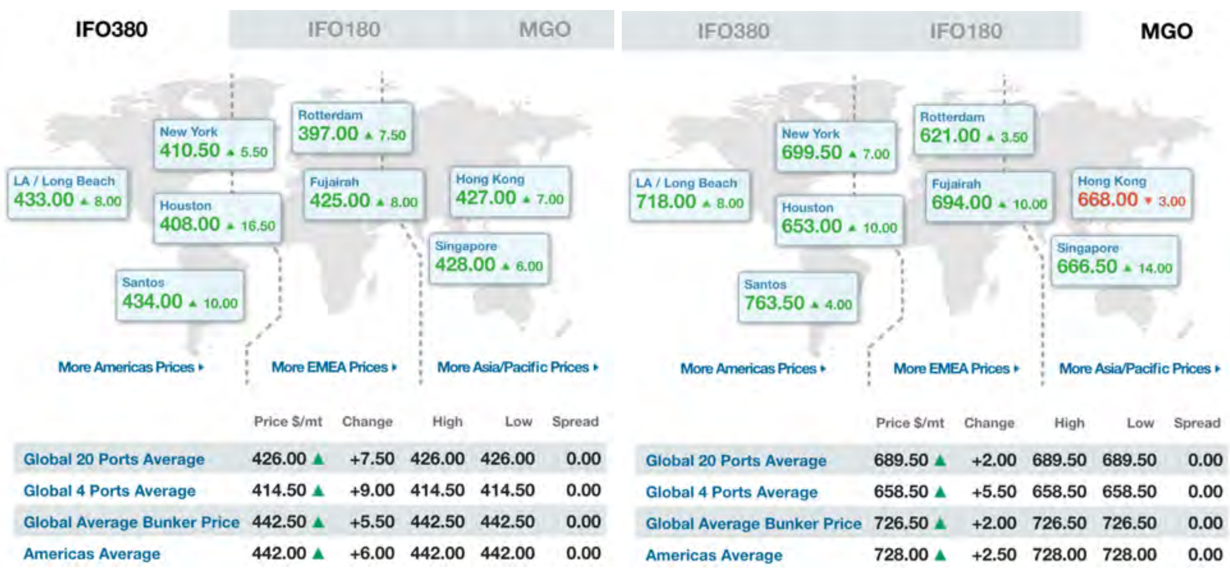

Figure 3-1 Example of daily marine fuel price for IFO 380 (left) and MGO (right) at select ports worldwide in U.S. dollars (Source: shipandbunker.com)

3.1.2 Montreal Fuel Price Variability

To characterize the variability in marine fuel pricing that would impact Arctic resupply vessels, fuel price data for Montreal was compiled for a 50-month time period from November 2013 through December 2017. Daily price data for two types of marine fuels – a residual oil (IFO 380) and a distillate (MGO) were compiled and then averaged across each calendar month. The data were then analyzed to evaluate overall price trends as well as the cost spread between the two fuel types. Figure 3-2 summarizes this information, showing an overall price reduction trend for both the higher-priced MGO and lower-priced IFO 380 since November 2013. The figure highlights the spread between prices at several points in time.

The price spread in Figure 3-2 was calculated both as the U.S. dollar amount difference per metric ton (tonne) of fuel oil and as the percentage difference between the price of IFO 380 and the price of MGO. The cost spread ranged from a high of $522/tonne in February 2014 to a low of $268/tonne in September 2016. The highest percentage spread occurred in January 2016, when the price of MGO ($526/tonne) cost 3.47 times more than IFO 380 ($152/tonne). The lowest percent spread occurred in November 2013, when the price of MGO ($1,058/tonne) cost 1.62 times more than the cost of IFO 380 ($654/tonne). Because of the way the spread percentage was calculated, it was highest during months when IFO 380 was at its least expensive.

Throughout 2017, the spread between MGO and IFO 380 was relatively stable by both measures, with a price spread of around $350 between MGO (which stayed in the $600/tonne range) and IFO 380 (which stayed in the $250 range). Based on Montreal prices, MGO cost about 1.5 times as much as IFO 380 throughout 2017.

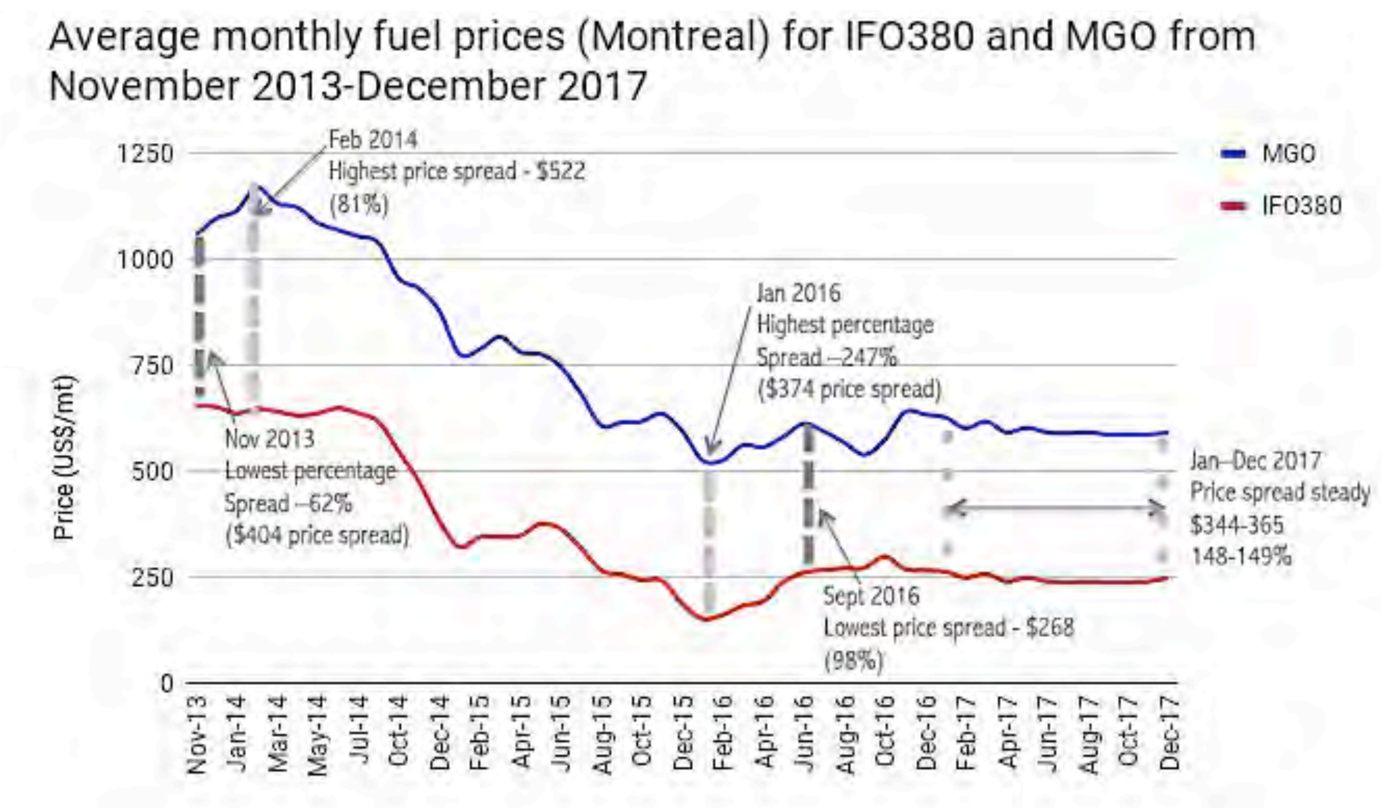

Figure 3-2. Average monthly prices for IFO-380 and MGO in Montreal from November 2013 through December 2017 (Sources: Bunkerworld and Ship and Bunker)

Over the roughly four years of monthly fuel price data, the highest price for IFO 380 ($654 in November 2013) was actually higher than the lowest cost for MGO ($526 in January 2016).

Essentially,[4] the fuel cost for a vessel burning MGO in January 2016 would have been lower than the fuel costs for a vessel burning IFO 380 in November 2013. In fact, the average monthly MGO prices in Montreal were lower than the average November 2013 price for IFO 380 every month from August 2015 through December 2017.

The fuel price data used to generate Figure 3-2 is included in Appendix A.

3.1.3 Predicting Future Marine Fuel Prices

Distillate fuels cost more than residual fuels, and while the fluctuations in both prices and price differentials have varied significantly from 2013-2016, data from 2017 show that both fuel prices and the spread between IFO 380 and MGO have held relatively steady. Data from the first four months of 2018 (not shown) indicate that IFO 380 prices have fluctuated from U.S.$382 to $440/tonne and MGO prices have varied from $645 to $722/tonne. The prices of both IFO and MGO appear to be slowly rising over 2017 prices, with slightly more variability in the price spread, but nothing approaching the $512 difference between IFO 380 and MGO prices in February 2014.

In addition to the changes over time to both fuel prices and the IFO/MGO spread, there are significant interdependencies among international shipping policies, ship operations, and refinery operations that also influence pricing. Impending policy initiatives like the global sulphur cap and potential Arctic HFO ban will eventually influence how refineries allocate their feed stocks to create and maintain inventories. Most analysts agree that there will be a period of volatility ahead of the 2020 sulphur cap, but that eventually the markets will settle out (Gallagher, 2018; Leavens, 2018). One study suggested that global refinery capacity is sufficient to meet the increased demand for distillate and low-emitting fuels in 2020 (CE Delft, 2016).

Nonetheless, the long-term price differentials between HFO, low sulphur residual blends and distillate fuels are a source of uncertainty. Present differentials between residual oils, residual hybrid blends, and distillates are still high, but there have been some suggestions that changing demands in the coming years will change this dynamic. Figure 3-3 shows one estimate from a 2017 working paper published by the International Council on Clean Transportation (ICCT). The ICCT study shows that while distillate oils are expected to remain as the most expensive fuels, the price difference between HFO and distillate fuels will be lower in the future than in 2015, and that the price difference between low sulphur residual blends and distillate fuels is expected to narrow considerably. Other analysts have pointed to reduced demand for HFO as a factor that will drive residual fuel prices down and increase the difference between distillate and residual fuels (Healing, 2018).

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[4] This example does not consider inflation or fuel efficiency/consumption for the two different fuel types; it is presented to emphasize that the potential price of using MGO is within the range of past fuel prices for IFO 380.

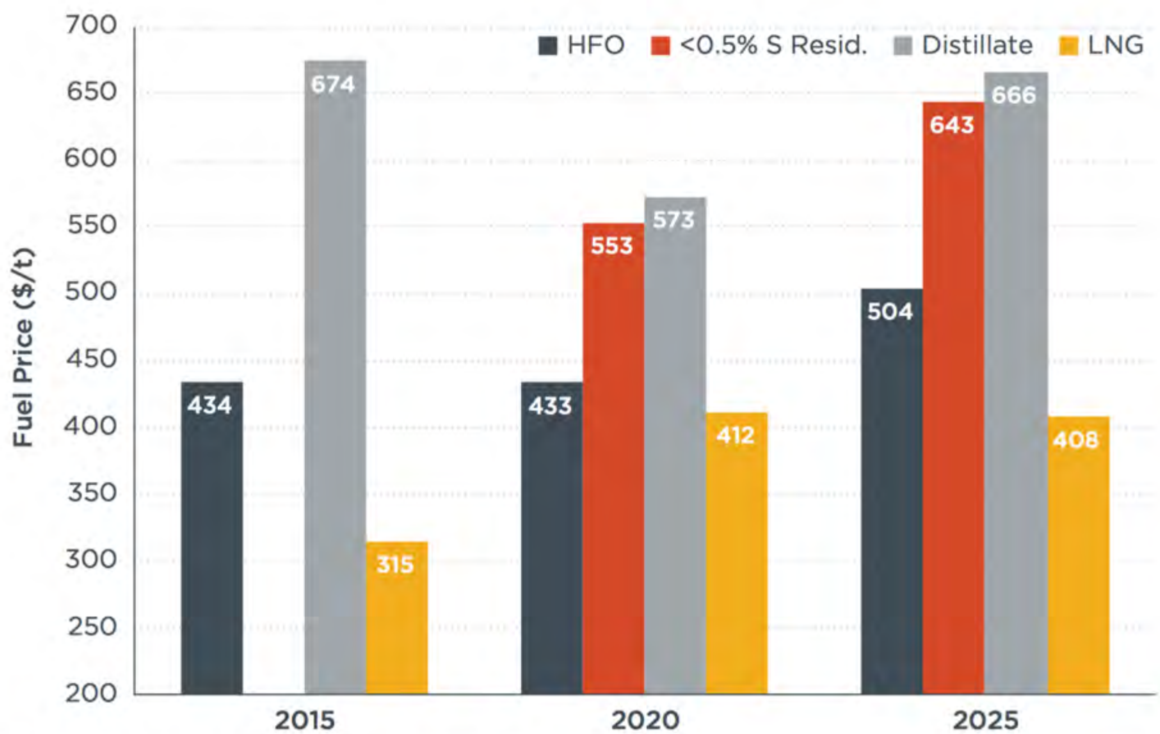

Figure 3-3. Estimated price of marine fuels in 2020 and 2025 (Roy and Comer, 2017)

3.2 Relationship between Fuel Prices and Cost of Goods in Nunavut Communities

3.2.1 Fuel Prices

Community resupply ships operating in the Canadian Arctic burn residual oils, which may include IFO 180, IFO 380, or bunker C oil. While marine fuel prices fluctuate daily, the shipping season for community resupply is condensed to the ice-free summer months. Montreal marine fuel price data from July of each calendar year from 2014-2017 were used as an index for fuel prices, as summarized in Table 3-1. Change in price from previous years is shown as a percentage of cost change from one year to the next. In this case, IFO 380 prices fell each year, with the most significant drop from 2014 to 2015.

Table 3-1. Average July Prices for IFO 380 in Montreal, 2014-2017

Average July Prices for IFO 380 (Montreal) by Year		
Year	**IFO Price**	**Change from previous year**
2014	$637/tonne	n/a
2015	$319/tonne	-49%
2016	$267/tonne	-16%
2017	$238/tonne	-11%

3.2.2 Food Prices

To explore the relationship between fuel prices and the price of goods in Nunavut communities, price data from the Nunavut Bureau of Statistics[5] were compiled from 2014 through 2017. Price survey data for food and non-food items is compiled annually through community surveys to evaluate changes over time and across communities. The Bureau of Statistics also compares the price of goods in Nunavut communities to those in the rest of Canada. Compiled data from March 2016 shows that on average, consumers pay about twice as much for goods in Nunavut communities as they do in the rest of Canada (NBS, 2018).

Data is available for individual food and non-food items, food baskets (consisting of a standard assortment of commonly purchased items), and per-kg or liter costs for specific food items. To compare changes in fuel prices to changes in cost of goods year-over-year, food basket cost[6] averages for three regions of Nunavut – Baffin, Kivalliq, and Kitikmeot – were compiled for 2014 through 2017, as summarized in Table 3-2 (NBS, 2018).

From 2014 to 2015, fuel basket prices increased across all regions, ranging from 3.4% to 3.8%. From 2015 to 2016, prices increased in the Baffin and Kivalliq regions by roughly 5-7%, but decreased in Kitikmeot by 1%. In 2017, only Kivalliq saw a price increase over 2016 food basket prices; prices in Baffin and Kitikmeot both fell by about 2%. By comparison, the consumer price index rose by 1.1-1.4% from 2014 to 2015 and 2015 to 2016 respectively.

Table 3-1. Average Food Basket Prices by Nunavut Regions by Year, Compared to Consumer Price Index Annual Changes

Average Food Basket Prices for Nunavut Regions by Year							Canada CPI Annual Change
Year	Baffin Region		Kivalliq Region		Kitikmeot Region		
	Cost (CAD)	Change from Prior Year	Cost (CAD)	Change from Prior Year	Cost (CAD)	Change from Prior Year	
2014	$160.86	n/a	$144.80	n/a	$165.81	n/a	n/a
2015	$167.03	3.8%	$149.66	3.4%	$182.75	10.2%	1.1%
2016	$178.30	6.7%	$157.15	5%	$180.90	-1%	1.4%
2017	$174.61	-2.1%	$160.38	2.1%	$177.30	-2%	n/a[7]

3.2.3 Comparison

Figure 3-4 plots the changes to average annual IFO 380 prices against the changes to average regional food basket prices in Nunavut. It is not a rigorous analysis of the relationship between food costs and fuel prices; it is presented to illustrate a general lack of correlation based on the data examined. This does not mean that fuel prices and food costs are unrelated; however, it

[5] http://www.stats.gov.nu.ca/en/Economic%20prices.aspx
[6] Food basket items include milk, margarine, eggs, frozen corn, frozen French fried potatoes, frozen pizza, soda crackers, canned salmon, canned baked beans, canned cream of mushroom soup, instant rice, spaghetti noodles, macaroni and cheese dinner, oatmeal, white flour, baby food in jars, white bread, apples, bananas, carrots, potatoes, ground beef, pork chops, and wieners.
[7] Data available through 2016 on Nunavut Bureau of Statistics website.

shows clearly that the significant variability in fuel prices year-to-year, particularly the nearly 50% reduction in the cost of IFO 380 from 2014 to 2015, does not correspond to a significant reduction in the cost of food items. In fact, the food basket survey shows that food prices in all three Nunavut regions increased from 2014 to 2015, against significant declines in fuel prices.

The data available through Nunavut Statistics does not equivocally state whether all items in the food basket are transported by sealift. However, the reality that marine fuel prices do not impact goods that are transported to communities through other means than sealift is an important point that sometimes gets lost in the assessment of the potential impact of marine fuel costs to consumer goods in the north. If the result of an HFO ban was, in fact, an increase in the cost of goods – which is open to further exploration – these impacts would be limited to those consumer goods transported by sealift.

The comparison of fuel prices and food costs does not factor in other considerations that might influence pricing, such as retailer markups.

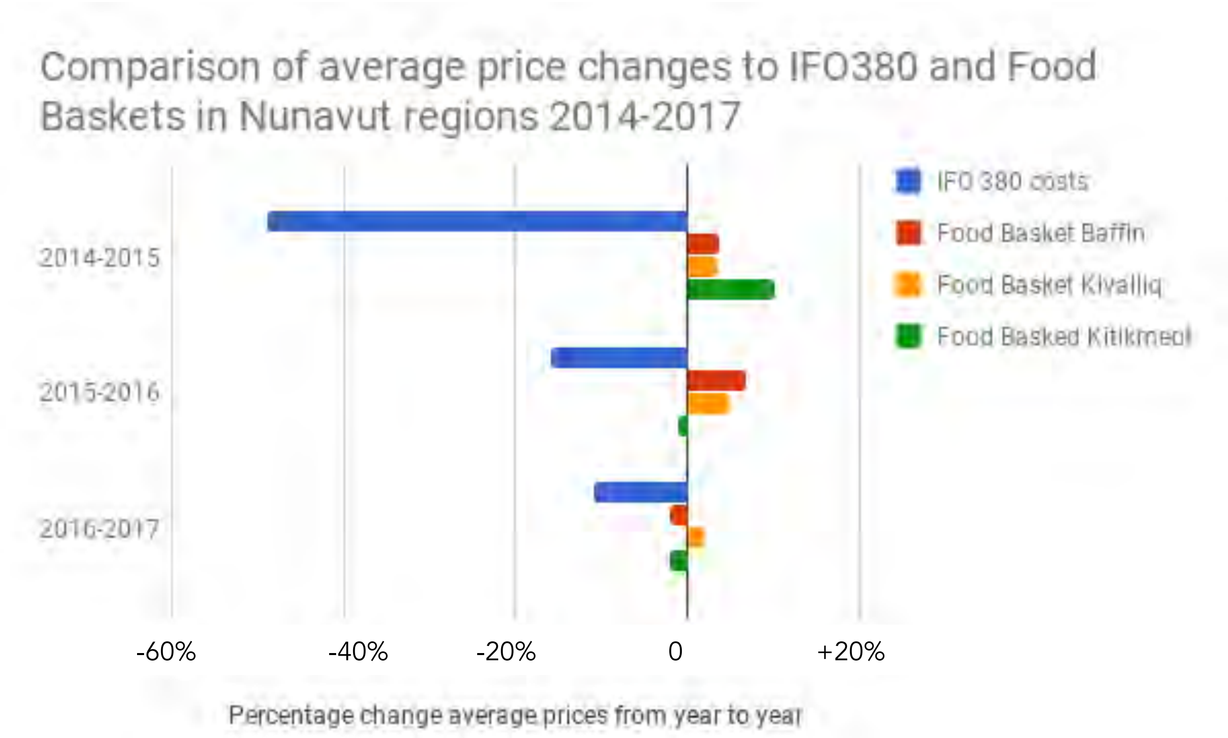

Figure 3-4. Comparison of average annual changes to fuel prices and food basket costs in Nunavut, 2014-2017

3.3 Estimating Potential Impacts of HFO Ban to Cost of Goods

While historical data does not show a clear correlation between marine fuel costs and the cost of food items in Nunavut, it is still possible that a ban on the use and carriage for use of HFO in the Arctic would increase fuel costs to shipping companies, and that these costs would be passed along to consumers. Even with current MGO prices lower than historic IFO 380 prices and projections suggesting the cost differential will decline over time (Figure 3-3), MGO prices in 2018 are still about one-and-a-half times more expensive than IFO 380 (see Figure 3-1).

A cost model[8] was developed to evaluate how increased fuel costs to ships operating along Canadian Arctic community resupply routes might influence the costs of goods transported by sealift, based on the fuel cost per tonne incurred by a vessel along a specific route, as well as past and predicted future marine fuel prices.

3.3.1 Relationship between Past Fuel Cost and Food Prices in Nunavut

To estimate the fuel cost per tonne of cargo transported, several community resupply vessel routes were evaluated, along with vessel-specific factors to estimate fuel usage and cargo capacity. Table 3-2 summarizes the input factors for three of the vessel routes evaluated. A different shipping company operates each vessel. Vessel A was selected as the basis for further analysis.

Table 3-2. Community resupply routes, vessel characteristics, and fuel use assumptions

Vessel	Maine Engine power[9]	DWT[10]	Max speed[11]	Fuel use per kWh[12]	Route	Total distance[13]
Vessel A	5,430 kW	12,760	14.5 kts (13.7 kts service)	205 g/kWh	Valleyfield – Pangnirtung – Iqaluit - Coral Harbour - Chesterfield Inlet - Rankin Inlet – Arviat - Whale Cove - Deception Bay - Valleyfield	11,010 km (433 hours at sea)
Vessel B	5,400 kW	12,776	14 kts (13.3 kts service)	195 g/kWh	Ste. Catherine – Matane – Kuujjuaq – Salluit - Repulse Bay - Rankin Inlet – Churchill – Arviat - Whale Cove - Chesterfield Inlet - Rankin Inlet - Coral Harbour – Kangiqsujuaq – Becancour – Ste. Catherine	11,013 km (448 hours at sea)
Vessel C	6,600 kW	17,034	14.5 kts (13.7 kts service)	205 g/kWh	Lewisport-Iqaluit-Cape Dorset-Coral Harbour-Arviat-Whale Cove-Rankin Inlet-Baker Lake-Resolute-Bathurst Inlet-Kugluktuk-Lewisport	13,902 km (547 hours at sea)

To estimate the fuel cost per tonne of cargo incurred by the ship operator, average monthly fuel costs from July of 2014 through 2017 were used, adjusted to 2015 U.S. dollars.[14] The fuel

[8] Northern Economics, Inc. developed a spreadsheet model with input from Nuka Research and Planning Group, LLC. Data sources are cited in text, and shipping experts and operators, on condition of anonymity, validated certain assumptions and inputs.
[9] Source: Seaweb.
[10] Dead Weight Tonnage, which is a measure of the ship's carrying capacity by weight (inclusive of cargo, fuel, and ship's stores).
[11] Source: Seaweb.
[12] From MEIT for a 4-stroke engine, built before 2000.
[13] Calculated using Google Earth.
[14] The inflation calculator at https://www.officialdata.org/ was used for all adjustments.

costs for Vessel A on the route shown in Table 3-2 was estimated for each year based on July IFO 380 prices and the estimated fuel usage derived from route distance, travel time, and estimated fuel usage. The resulting total fuel cost was then divided by the tonnage of the vessel to estimate the cost of fuel per tonne of mass in a fully loaded ship. Table 3-3 shows the inputs and formula for fuel consumption estimation for Vessel A in this scenario.

Table 3-3. Estimating fuel consumption for Vessel A over specified route

Vessel A Fuel Consumption Estimate over Specified Route									
Maine Engine power[15]	DWT	Service speed[16]	Engine Load	Power demand per hour	Fuel use per kWh[17]	Hourly fuel consump-tion	Total distance for Route[18]	Operating hours[19]	Fuel used along route[20]
5,430 kW	12,760	13.7 kts	0.85	4,616 kW/h	205 g/kWh	0.95 t/h	11,010 km	433 h	410 t

Formula to estimate fuel use:
*(Main Engine Power) * (Engine Load) * (Fuel use per kWh)/ (10^6 g fuel/tonne fuel) * (operating hours) = fuel use*

Fuel Cost Estimates Based on July IFO 380 prices from 2014 to 2017 (in 2015 USD)								
	Fuel Prices[21]		Total Fuel Costs per Trip		Fuel Costs per km[22]		Fuel Costs per tonne[23]	
	IFO 380	MGO	IFO 380	MGO	IFO 380	MGO	IFO 380	MGO
2014	$648	$1056	$265,680	n/a	$24	n/a	$21	n/a
2015	$319	$683	$130,790	n/a	$12	n/a	$10	n/a
2016	$264	$586	$108,240	n/a	$10	n/a	$8	n/a
2017	$230	$571	$94,300	$234,110	$9	$21	$7	$18

The total fuel costs associated with Vessel A's Nunavut community resupply run steadily declined from roughly $266,000 in 2014 to $94,000 in 2017; this is approximately a 65% reduction in fuel costs over the three-year time span. Spreading fuel costs across the journey, either by distance or by cargo weight, provides perspective on the incremental cost increases over the course of a trip. Because of the decline in IFO 380 prices during this time, the fuel cost per tonne fell from $24 (2015 U.S.D) in 2014 to $9 in 2017; the per-km fuel costs dropped

15 Source: Seaweb.
16 Estimated for vessel based on 85% maximum engine load and max speed of 14.5 kts.
17 From MEIT for a 4-stroke engine, built before 2000.
18 Calculated using Google Earth.
19 Derived from route distance and service speed.
20 Calculated based on fuel consumption and hours at sea, assuming that a vessel traveling at service speed uses about 85% of the ship's main engine power.
21 Average July price (Montreal) converted to 2015 US dollars.
22 (Total fuel costs)/(Total distance for route) = cost per km (rounded to nearest dollar)
23 (Total fuel costs)/(Deadweight tonnage) = cost per tonne (rounded to nearest dollar)

from $21 in 2014 to $7 in 2017. Because both calculations are tied to total fuel costs, the total cost reduction is still approximately 65%.

To explore whether there was a correlation between fuel cost per tonne and the cost by weight of shelf-stable food items that may have been included in community resupply, past food prices were analyzed, based on published price data from the NBS.[24] Price per kilogram for four food items (skim milk powder, spaghetti noodles, canned pink salmon, and peanut butter) were compiled for 2015-2017[25] for three communities along the Vessel A resupply route: Pangnirtung, Chesterfield Inlet, and Coral Harbour, as shown in Table 3-4.

Table 3-4. Price of Food Items per kg in Three Nunavut Communities

Food Item	Nunavut Community	Price of food items per kg		
		2015	2016	2017
Skim milk powder (500g)	Pangnirtung	$22.70	$22.75	$22.78
	Chesterfield	$18.99	$18.35	$18.75
	Coral Harbour	$15.99	$24.58	$21.98
Spaghetti noodles (900g)	Pangnirtung	$8.11	$8.25	$7.52
	Chesterfield	$10.15	$10.17	$10.17
	Coral Harbour	$6.24	$7.82	$8.51
Canned pink salmon (213g)	Pangnirtung	$21.24	$29.06	$26.90
	Chesterfield	$16.84	$13.10	$19.44
	Coral Harbour	$19.18	$24.93	$32.19
Peanut butter (1kg)	Pangnirtung	$12.72	$11.33	$10.89
	Chesterfield	$10.99	$9.12	$10.99
	Coral Harbour	$9.94	$12.49	$14.85
Average across community and food item		**$14.42**	**$16.00**	**$17.08**

Food prices were averaged by community, and then by year, and plotted against fuel costs per vessel tonnage. Figure 3-5 shows no apparent correlation between fuel cost reduction and per-kg food prices, which is consistent with the lack of correlation between food basket costs and fuel prices (Figure 3-4). In other words, while IFO 380 prices fell nearly 65% from 2014 to 2017, the average cost of select food items in communities increased by about 15%.

The apparent lack of correlation between past IFO 380 costs and past food prices does not necessarily mean that these costs are unrelated, as there are many complexities involved in food pricing beyond the scope of this report. Shipping companies have access to internal data and analysis that would better describe the influence of fuel costs on the price of goods transported by sealift. This is an issue for further exploration as Canada attempts to understand the impact of an HFO ban to sealift transport costs.

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24 http://www.stats.gov.nu.ca/en/Economic%20prices.aspx

25 Price per kg data was not available for 2014.

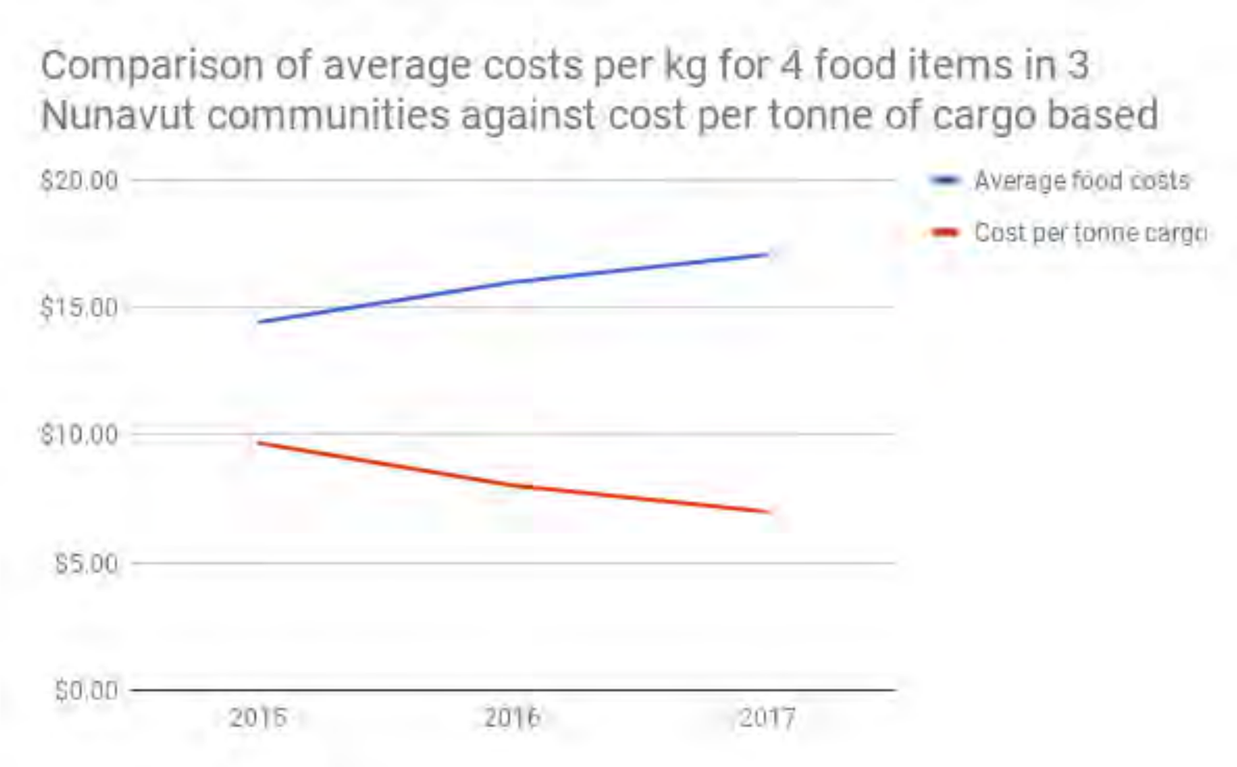


Figure 3-5. Comparison of cost per kg of four shelf-stable food items in three Nunavut communities served by Vessel A, compared with fuel cost per tonne of cargo transported on that vessel along a route serving the three communities

3.3.2 Estimating Costs of Fuel Switching Based on Increases to Per-tonne Cargo Costs

To estimate the per-tonne impact for cargo transport based on increased fuel costs associated with switching from IFO 380 to MGO, actual fuel price data from 2017 was compared to projections for 2020 and 2025 (based on Roy and Comer, 2017). All costs were adjusted to 2015 U.S. dollars. Table 3-5 shows the average Montreal fuel costs for MGO and IFO 380 for 2017 (entire year average), and the 2020 and 2025 estimates, applied to the Vessel A route (Table 3-2) to estimate the cost difference per kilometer and per tonne of cargo transported in this scenario.

Table 3-5. Fuel cost per trip, kilometer, and tonne cargo for Vessel A operating along Nunavut resupply route

Fuel Price Scenarios	Fuel price per tonne		Fuel cost per trip (Vessel A)		Fuel cost per kilometer traveled		Fuel cost per tonne cargo		Cost difference between IFO and MGO	
	MGO	IFO 380	MGO	IFO 380	MGO	IFO 380	MGO	IFO 380	Per tonne	Per kg
2017	$578	$237	$236,980	$97,170	$21.52	$8.83	$18.57	$7.62	**$10.96**	**$0.011**
2020	$573	$443	$234,930	$177,530	$21.34	$16.12	$18.41	$13.91	**$4.50**	**$0.004**
2025	$666	$504	$273,060	$206,640	$24.80	$18.77	$21.40	$16.19	**$5.21**	**$0.005**

The cost per tonne difference between MGO and IFO 380 declines significantly, based on the predicted future prices, which reflect changing global marine fuel supply as sulphur emission standards come into force in 2020. This transfers to reduced fuel costs per vessel trip, which can be broken down for this particular vessel route based on both distance traveled and cargo weight. Figure 3-6 shows how the fuel price changes and predicted decrease in future price spreads impact the cost per kilometer for Vessel A traveling 11,010 km on the community resupply route shown in Table 3-2.

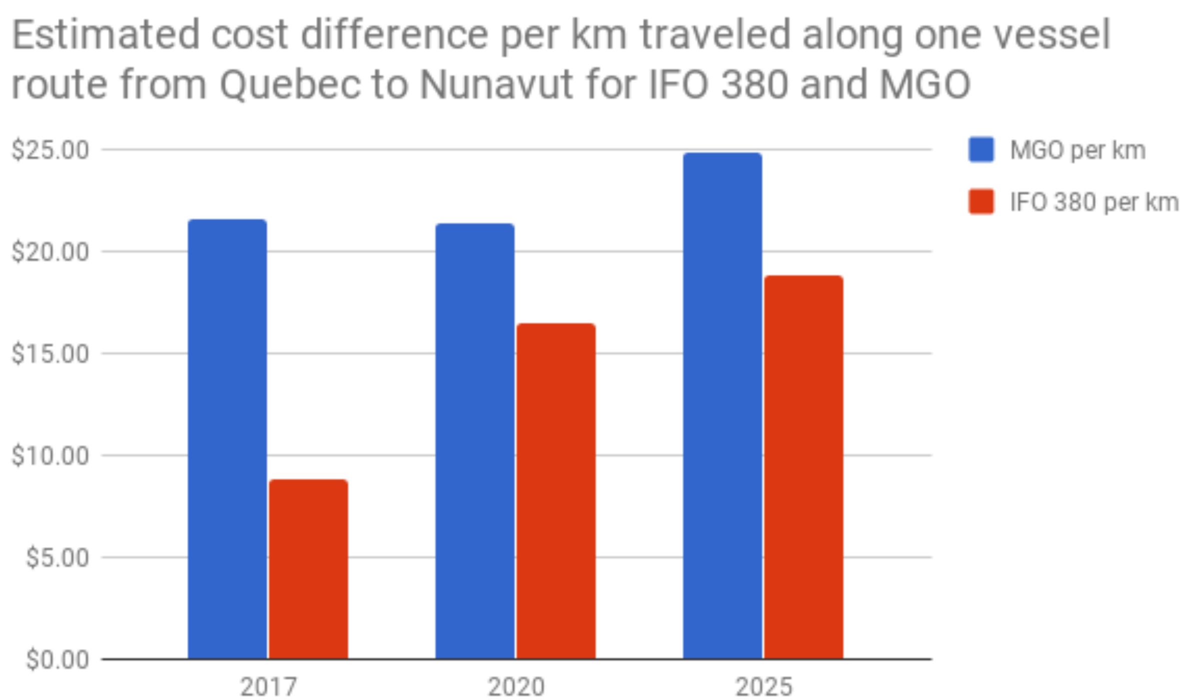


Figure 3-6. Cost per km traveled based on fuel switching at 2017, 2020, and 2025 fuel prices (2015 U.S. dollars)

Figure 3-7 shows the estimated cost per tonne increases along the same resupply route based on actual 2017 fuel prices and estimated future prices (all expressed in U.S. 2015 dollars), assuming the vessel is loaded to capacity (12,760 deadweight tonnes). Based on 2017 prices, the increased cost of using MGO rather than IFO 380 along this particular resupply route would be more than double (Table 3-5), but when this cost is spread across the full vessel load, it increases the cost of transporting one tonne of cargo by about $11. If the price difference between IFO 380 and MGO declines as predicted (Roy and Comer, 2017), by 2020, the increased per-tonne cost of using MGO is about $4.50. Converted to 2018 Canadian dollars, [26] the difference is still less than $12/tonne based on 2017 prices, and less than $5/tonne for predicted 2020 prices.

[26] The following calculator was used to convert 2015 US dollars to 2018 US dollars. https://www.officialdata.org/2015-dollars-in-2018 An exchange rate of 1.3 Canadian to US dollars was applied based on online rates from May 26, 2018.

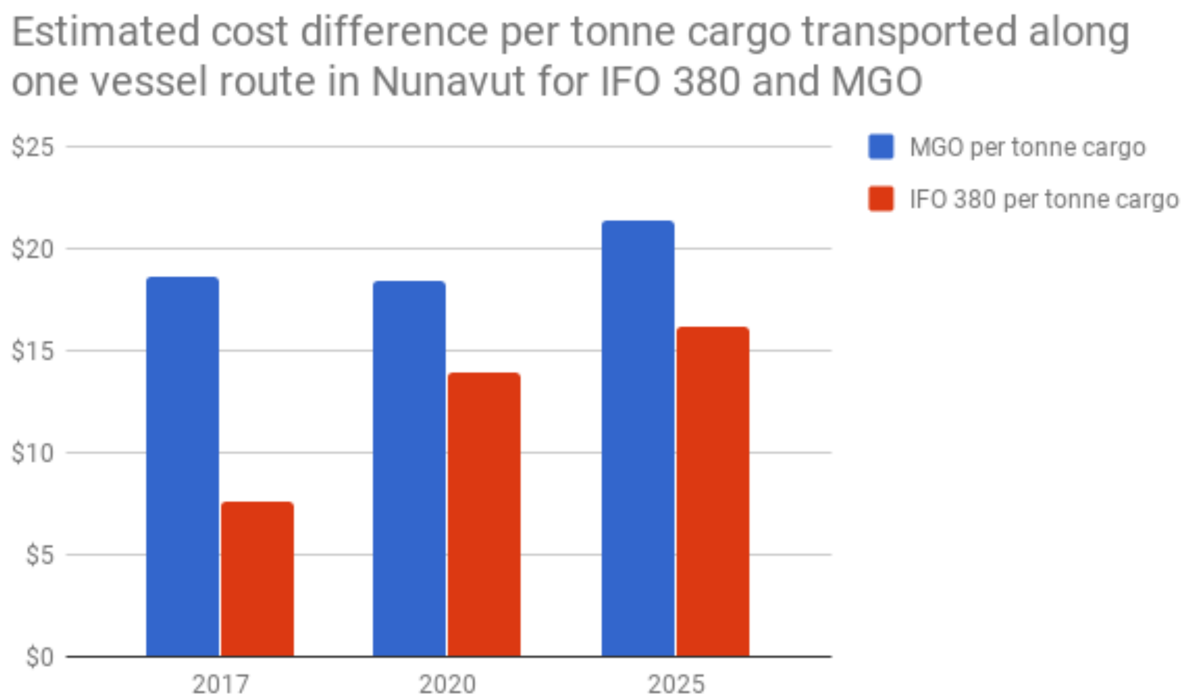


Figure 3-7. Cost per tonne cargo transported based on fuel switching at 2017, 2020, and 2025 fuel prices (2015 U.S. dollars)

If these costs were spread further, the per-kg price difference resulting from an HFO ban (presuming vessels switch from IFO 380 to MGO) would be just over $0.01/kg based on 2017 actual fuel costs. If the price difference decreases as predicted, the per-kg increase to cargo transportation costs for fuel switching is about a half a cent in 2020 and beyond.[27]

Considering the incremental cost impacts of fuel switching on a per-kilometer or per-kilogram cargo basis provides additional context for considering the trade-offs associated with replacing HFO with less polluting fuels. Looking at 2017 as an example, the price of MGO was more than double the price of IFO 380. But in the context of a community resupply trip along an existing route in Nunavut, based on the maximum cargo capacity of an existing resupply ship, the net effect of doubling fuel costs to the per-kg cost of transporting goods is about a one-cent increase. This estimate could be refined or adjusted if additional information was available about cargo loads and pricing structure, but at face value it supports the observation that the cost of goods are minimally effected by fuel price changes.

Table 3-4 carries the food item costs shown in Table 3-3 forward, but also shows what 2017 prices might have been if community resupply Vessel A had been burning MGO rather than IFO 380 ($0.01/kg as calculated above). Even if fuel prices had doubled due to a switch from IFO 380 to MGO, a family purchasing one kilogram of skim milk powder in Pangnirtung might

[27] These are converted from 2015 US dollars to 2018 Canadian dollars using the same method as above.

have paid $22.79 rather than $22.78 if the fuel cost difference were spread to a per-kg cargo cost based on one sealift vessel route.

In order to accurately estimate the potential impacts of an Arctic HFO ban on the cost of goods in Canadian Arctic communities, more information is needed about the relationship between fuel costs and sealift prices. Refined estimates of future price differences between IFO 380 and MGO will also inform estimates of cost-of-good impacts from fuel switching.

Table 3-4. Price of Food Items per kg in Three Nunavut Communities for 2015-2017, with projected costs based on increase from IFO 380 to MGO (2017 actual fuel cost data)

Food Item	Nunavut Community	Price of food items per kg (actual as reported by NBS)			MGO price
		2015	2016	2017	2017
Skim milk powder (500g)	Pangnirtung	$22.70	$22.75	$22.78	$22.79
	Chesterfield	$18.99	$18.35	$18.75	$18.76
	Coral Harbour	$15.99	$24.58	$21.98	$21.99
Spaghetti noodles (900g)	Pangnirtung	$8.11	$8.25	$7.52	$7.53
	Chesterfield	$10.15	$10.17	$10.17	$10.18
	Coral Harbour	$6.24	$7.82	$8.51	$8.52
Canned pink salmon (213g)	Pangnirtung	$21.24	$29.06	$26.90	$26.91
	Chesterfield	$16.84	$13.10	$19.44	$19.45
	Coral Harbour	$19.18	$24.93	$32.19	$32.20
Peanut butter (1kg)	Pangnirtung	$12.72	$11.33	$10.89	$10.90
	Chesterfield	$10.99	$9.12	$10.99	$11.00
	Coral Harbour	$9.94	$12.49	$14.85	$14.86
Average across community and food item		**$14.42**	**$16.00**	**$17.08**	**$17.09**

4 Estimating the Impacts of an Arctic HFO Spill

The commodity costs associated with the increased price of distillate fuels over residual oils is one aspect of community impacts, but the price of goods is not the only consideration. Oil spills from vessels operating in Arctic waterways – whether community resupply vessels, cruise ships, or large freight vessels transiting the northern sea route – can have significant and long-lasting impacts to Arctic coastal communities. The risks associated with an Arctic HFO spill are one of the main drivers of the HFO ban; therefore, the positive impacts of removing the risks of a residual fuel oil spill is an important consideration in assessing overall impacts.

A 2009 Arctic Marine Shipping Assessment highlighted oil spills as the most significant threat to the marine environment from Arctic shipping (Arctic Council, 2009). The risk of oil spills from Arctic shipping is difficult to quantify, but it is generally acknowledged that increased transits of northern shipping routes create an increased risks of vessel accidents and oil spills (Baskh et al., 2018). As traffic levels increase over the coming years, so does the threat of an oil spill.

All oil spills have the potential to devastate wildlife and habitat, and to impact the people and communities that rely on an intact ecosystem for food and socio-cultural activities. There are a number of factors that will influence the severity of oil spill impacts, such as: size of the spill; type of oil spilled; location of the spill; seasonality/timing of spill; and the effectiveness of mitigation measures to contain and recover the spill. This section considers several factors that contribute to the adverse impacts from oil spills in Arctic waters, with a focus on the comparative impacts of residual and distillate fuel spills.

4.1 Arctic Oil Spill Response Considerations

4.1.1 Window of Opportunity

The first line of defense for a ship-source oil spill, whether in Arctic or temperate waters, is to stop the flow of oil and contain the spilled volume of oil as close to the source (the ship) as possible. Therefore, this is a race against time, and the general rule of thumb is that the best opportunity for successful containment and recovery is within 72 hours of the release.

From the moment it is released into the environment, spilled oil experiences a range of physical and chemical changes that drive the window-of-opportunity for containing and recovering the oil. Figure 4-1 illustrates how oil spilled to Arctic waters will spread, change, and partition into various components of the air, water, and sediment.

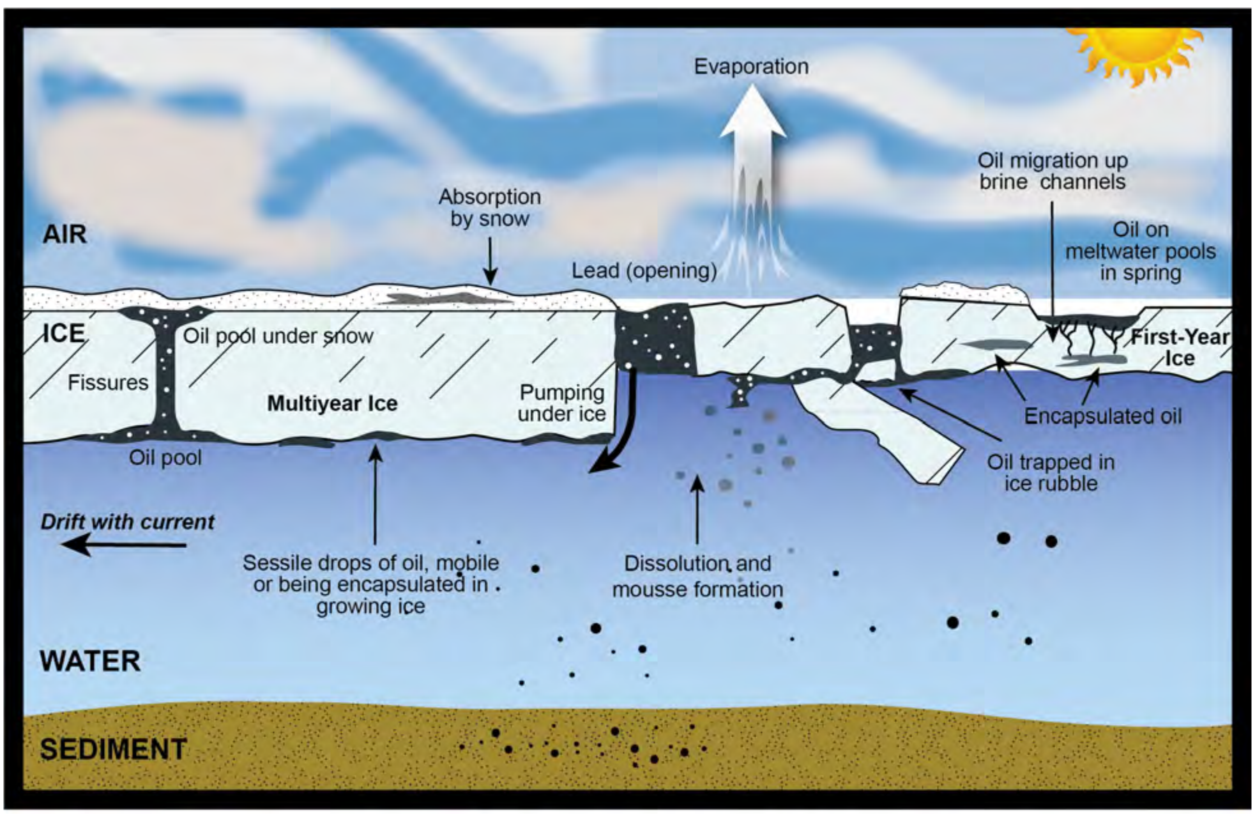


Figure 4-1. Physical and chemical processes that impact oil fate and behavior in the presence of sea ice

The presence of sea ice adds a layer of complexity, as the oil will interact with the ice both at the air-ice and the water-ice interfaces. As time passes, containment and recovery becomes more difficult, and any oil that has not been recovered within about 72 hours of the spill will typically either wash ashore, where it can be cleaned post-impact, or disperse/evaporate/sink depending upon the type of oil and the environment into which it has been spilled. When sea ice is present, the oil may also be encapsulated within or trapped under the ice, where it may travel great distances along with the ice, or refloat in open water leads some distance from the spill site.

4.1.2 Response Viability Limits

Oil spill response system performance is influenced by a number of factors. In addition to the short window-of-opportunity for encountering floating oil slicks, there are also limits associated with the impact of environmental conditions on oil spill response systems, equipment, and personnel.

Oil spill response even in the most favorable conditions is challenging, with the often-cited statistic that only 10-20% of most major marine oil spills are actually recovered. The percentage of oil mechanically recovered in the Gulf of Mexico during the Macondo blowout in 2010 is estimated at about 5%, and that spill occurred in a temperate ocean during the spring and summer, with a continuous release making the oil more accessible for skimming operations than if it had been a single point release (as is more typical for vessel spills).

There have been several prominent studies about the oil spill response viability limit in the Arctic Ocean – the most recent published by the Arctic Council. In a 2017 analysis of how Arctic meteorological and oceanographic conditions impact spill response, researchers concluded that Arctic conditions would preclude the use of vessels, booms and skimmers to contain and recover oil spills between 65% and 92% of the time year-round (circumpolar Arctic average). Response viability was lowest during November through March, with the best opportunity for mechanical spill response during June through August (DNV GL and Nuka Research, 2017). A previous study that focused on the Canadian Beaufort Sea and Davis Strait found that during periods of open water in central Davis Strait, conditions would be favorable for oil containment and recovery operations between 9% and 36% of the time (SL Ross, 2011).

4.1.3 Ecological Impacts

Figure 4-1 shows how oil can spread, move and change once it enters the environment. The dynamic nature of oil spills can complicate efforts to estimate which proportion of the oil will end up where, and how it will move or change over time. There has been some work done to try to enhance oil spill trajectory models to anticipate where oil would go and how it would change when spilled in Arctic waters, but these models are still being developed and refined.

While the potential ecological impacts of a major oil spill to the Arctic ecosystem are difficult to predict or quantify, it is well accepted that Arctic conditions have the potential to exacerbate the consequences of an oil spill for a number of reasons, including:

- Biodegradation of oil is slower in cold climates;

- Ice trapping oil and creating a cycle of re-oiling every summer, followed by oil being trapped in ice and potentially transported to a new place that would be re-impacted in subsequent years;
- Slower reproductive cycles of many Arctic species;
- Smaller food webs make species more vulnerable to trophic impacts;
- Aggregate stressors from climate change and sea ice loss make species more vulnerable; and
- Heavy reliance of many Arctic communities on subsistence foods.

4.2 Heavy Fuel Oil Spill Impacts

Residual fuels (HFO and others) have many characteristics that make them more challenging to clean up and more harmful to the environment than distillate fuel spills (Brown et al., 2016). Table 4-1 summarizes some of the key considerations, which are discussed in subsequent sub-sections.

Table 4-1. Oil Spill Characteristics and Properties of Different Fuel Types

FUEL TYPE		CHARACTERISTICS AND PROPERTIES		
Marine Fuel	**Composition**	**Behavior when spilled**	**Spill Cleanup**	**Ecological Impacts**
Bunker C/ Fuel oil No. 6	Residual oil	May sink or become neutrally buoyant. Forms tar balls and patties. Emulsifies (incorporates water).	Limited technologies for on-water recovery. Most of the cleanup will likely involve remediating shorelines and oiled substrate.	Coats feathers and fur. Persistent and sticky, can have long-term impacts to shoreline, intertidal, and benthic communities.
Intermediate Fuel Oil (IFO) 380	Residual oil (~ 98%) blended with distillate	May sink or become neutrally buoyant. Emulsifies (incorporates water) and may increase 2-3 times original spill volume.	Fresh product may be recoverable within hours of initial spill, but as oil emulsifies it becomes more difficult to recover with skimmers. Weathered oil will coat surfaces and may be difficult to remove from coarse sediments and substrate.	
Intermediate Fuel Oil (IFO) 180	Residual oil (~88%) blended with distillate			
Low sulphur marine fuel oils	Residual oil blended with distill$ate (higher ratio of distillate to residual)	Initial laboratory and mesoscale testing suggests that it will behave similar to other residual oils, emulsifying and generally acting as a persistent fuel.	Poorly studied. Information from recent pipeline spill in Hawaii suggests that residual blends will pose similar response challenges to other residual fuels.	Poorly studied, likely to be similar to IFO. May have higher initial toxicity than residual fuels because of higher percentage of distillate, which will initially disperse or evaporate.
Marine diesel oil (MDO)/Fuel oil No. 2	Distillate fuel that may have traces of residual oil	High percentage will evaporate or disperse into water column within first few hours of release. Will remain floating but slick will spread in open water.	Can be skimmed from surface if contained to sufficient thickness. As oil spreads and weathers, more difficult to recover.	High initial toxicity to wildlife, particularly in water column, but oil is less persistent in environment. Will still harm fur and feathers when it comes into contact.
Marine gas oil (MGO)	100% distillate			

4.2.1 HFO Response Challenges

Residual oils are denser and more viscous than distillates, and are usually harder for oil spill response systems to skim, pump, and store. In the event that environmental conditions did not allow for any spill response, which is a strong possibility in the Canadian Arctic, an untreated oil slick would be left to weather, spread, dissolve, or strand. Under such a scenario, distillate fuels would break up and change phases much more quickly than residual oils, due to their respective physical and chemical properties. A heavy fuel oil slick would be slower to degrade and change, and would therefore persist in the environment for a much longer period of time, spreading impacts more broadly across both time and space.

The type of oil spilled will influence the selection of equipment and tactics used to remediate the spill. Most of the response methods in use today were originally developed for crude oil spills. Neither residual fuels nor distillates behave exactly like crude oil; the closest similarity is probably between marine diesel oil (Fuel Oil No. 2) and light, sweet crude oils. Otherwise, distillate fuels tend to evaporate and disperse fairly quickly, making booming and skimming challenging. The high volatility of certain distilled fuels (like jet fuel or gasoline for cars) may actually create safety issues for booming it (due to vapor plumes).

Residual fuel oils, on the other hand, are so viscous and high in wax content that they typically resemble peanut butter rather than oil. This makes them difficult to remove with skimmers, and the fact that they quickly emulsify (incorporate water to form a mousse-like substance) makes on-water skimming even more challenging. Residual oil slicks will typically break up into tar mats, tar balls, and tar patties. Depending on the salinity of the water and the availability of suspended sediments or particulate matter in the water, residual oil may eventually become neutrally or negatively buoyant. Once the oil drops below the sea surface, even if it is only by a matter of millimeters, it is essentially unavailable to booming and skimming operations.

Most of the "response" to a residual oil spill will involve cleaning the tarry residue off whatever it contacts. Cleaning beaches can be very labor-intensive, and there is usually some fraction of the spill – possibly rather high- that is left behind on rocks and beach substrate as coating or stain. Freshly spilled residual oil or mousse that comes into contact with fur-bearing mammals and feathered birds will stick to their fur or feathers and can harm or kill the animal. Residual spills are typically viewed as less acutely toxic because they do not contain as much volatile material, which is the most biologically available. But residual oil spills still kill a range of marine life, particularly birds and mammals. Benthic or shoreline communities can also be smothered by oil that sinks or comes ashore.

4.2.2 Ecological Impacts of HFO Spills

HFO is also highly toxic to fish species, and particularly to embryonic fish. Because of its high density, HFO may sink under certain circumstances (low salinity, high sediment interaction), or become stranded in shoreline sediment, posing a risk to fish larvae (Martin et al., 2014). Since HFO contents are variable based upon the refining process, their ecotoxicity also varies (Comber et al., 2011).

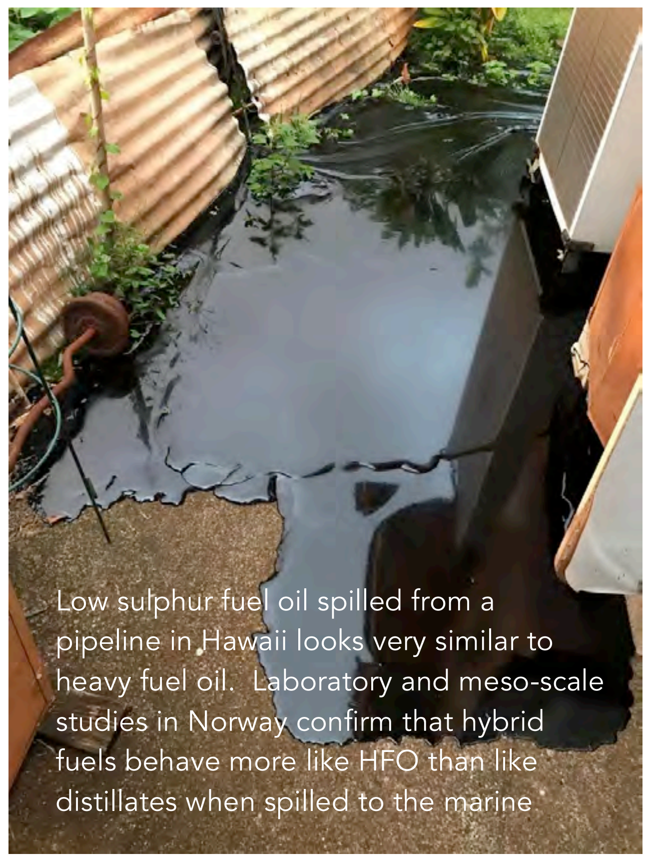
While there has not been a major Arctic HFO spill, experience from heavy oil spills in other parts of the globe confirm that the toxic effects can be both acute and long-lasting. For example, the 2002 *Prestige* spill off the coast of Spain caused significant damage to seabird populations, including not only immediate deaths but also long-term effects on reproduction and population dynamics (Alonso-Alvarez et al., 2007).

An Arctic heavy fuel oil spill would also harm communities along the Arctic coastline. Most people living adjacent to Arctic waters rely on the ocean for food and transportation. Indigenous peoples also have close cultural and spiritual ties to the marine environment and wildlife. An oil spill has the potential to devastate Arctic communities by contaminating their food sources, imperiling their culture, and disrupting traditional uses that have been in place for thousands of years (Gamble, 2017).

4.3 Potential Impacts from Hybrid and Residual Blend Fuel Spills

4.3.1 Response Considerations

Newly emerging residual blends are being developed to have reduced air emissions, comparable to distillate fuels, but from an oil spill preparedness and response perspective, they have more in common with HFO. Hybrid fuels have a similar density to HFO, and some are nearly as viscous. When spilled, they emulsify like heavy fuel oil, which can make them difficult to recover with mechanical skimmers.



Low sulphur fuel oil spilled from a pipeline in Hawaii looks very similar to heavy fuel oil. Laboratory and meso-scale studies in Norway confirm that hybrid fuels behave more like HFO than like distillates when spilled to the marine

Because these blends are relatively new, there is not much information on their characteristics or behavior when spilled to the marine environment. A 2017 Norwegian study evaluated the physical and chemical properties of two hybrid fuel oils – Exxon HDME 50 and Shell ULSFO – to compare their behavior when spilled in cold climates to marine gas or diesel oils. The hybrid fuels have much higher boiling points, and evaporate much more slowly than distillate fuels (HelstrØm, 2017).

Experimental data showed that after 5 days of exposure to winter conditions, only about 2% of HDME 50 evaporated; about 18% of ULSFO evaporated (compared to 95% of gas oil). Both fuels emulsify when spilled to seawater, forming mousse similar to heavy fuel oils. After 5 days in winter conditions, HDME 50 had formed 40% water in oil emulsion, and ULSFO had formed 58% water in oil emulsion. In summer conditions, the emulsions were 60% and 78%, respectively. Winter emulsions were highly viscous; summer emulsions were moderate to high viscosity. After one day of weathering in cold water, the ULSFO doubled in volume because of emulsion (HelstrØm, 2017).

In January 2018, a pipeline in Hawaii leaked 500 gallons of low sulphur fuel oil. The spill occurred on land, impacting a few private homes (Mai, 2018). News reports described the spilled substance as "sticky ooze," and press photos show a substance that appears very similar to black HFO (Nagaoka, 2018).

4.3.2 Similarities to Diluted Bitumen and Orimulsion

Residual fuel oil blends are relatively new, and with the exception of the recent study out of Norway, there is little empirical data about how these fuel blends may behave when spilled to the marine environment. Based on the manner in which these blends are formed, it is possible that they could behave similarly to other heavy/residual fuel blends, such as diluted bitumen (tarry bitumen mixed with a light distillate – condensate or light crude oil – to meet pipeline specifications) or orimulsion (a mixture of heavy Venezuelan crude oil and water that is used to ship the product in tankers). One study estimated that diluted bitumen contains about 30% residuum, higher than even heavy crude oils (MathPro, Inc., 2015).

4.3.3 Ecological Impacts

There is very little information available about the toxicity of residual blend and hybrid fuel oils to marine species.

5 Estimating the Cost Impact of an Arctic HFO Spill

A great deal of emphasis has been placed on the relationship between an HFO ban and the cost of goods in northern communities. A less obvious cost consideration, but one that bears further exploration, is the potential cost of an Arctic HFO spill to northern communities and Canadian taxpayers. Since HFO spills are typically much more persistent, they are also more expensive to clean up than distillate fuel spills, with more extensive damages to wildlife, habitat, subsistence foods, and socio-economic values.

The "polluter pays" system that governs the financial responsibility of vessel owners and operators to pay for the cleanup costs and damages associated with oil spills – particularly fuel oil spills – may not provide adequate assurance that all costs will be paid by the polluter's insurance. Additional funds are available through Canadian and international trust funds, but disbursements from these sources are also limited. Any costs above these financial responsibility limits would fall to the governments, communities, individuals, and private companies that incur expenses to clean up oil spills or suffer damages from the spill impacts.

5.1 Oil Spill Response Costs

5.1.1 Types of Costs

The costs associated with oil spill response are generally grouped into the following three categories: (1) cleanup costs; (2) environmental costs; and (3) socioeconomic costs. This approach is the basis for the foundational work in oil spill cost modeling (Etkin,1999; Etkin, 2004). The three categories of costs, examples of the types of expenses they cover, and an identification of who pays the costs under the present Canadian ship-source oil spill system are summarized in Table 5-1. Each element is discussed in subsequent sections.

Table 5-1. Summary of Financial Responsibility for Ship-Source Oil Spills in the Canadian Arctic

Types of Costs Associated with Ship-Source Oil Spills and Who Pays them in the Canadian Arctic			
Cost Category	**Example of types of costs incurred**	**Ship Owner's Responsibility**	**Who Pays for the Rest**
Cleanup Costs	Direct response costs – costs of on-water containment and recovery, clean up of oiled shorelines, wildlife response and treatment, and all associated equipment, people, vessels, logistics, command posts, incident management team, oily waste storage and disposal.	Ship owner must pay for clean up costs up to the insurance limit carried based on Canadian law. For fuel oil spills, insurance levels will vary based on vessel size and the amount of fuel capacity. Rarely exceeds $100M.	Government of Canada pays all costs if ship owner is not known or does not comply, and all costs in excess of ship owner's insurance. Canadian ship-source pollution fund pays up to $171M per incident (less for fuel oil spill). International Oil Pollution Fund will pay for claims up to a certain limit based on vessel size and type (less for fuel oil spills than tanker spills).
Environ-mental Costs	Costs involved with repairing or restoring damages to the ecology, environment, or wildlife caused by an oil spill.	Once ship owner has spent up to insurance limit, there may not be funding available for environmental damages. Canada does not have a system for assessing damages to natural resources. Civil courts could be a remedy.	Government of Canada (ship-source oil pollution fund) and International Oil Pollution Fund may pay for claims, up to established limits. Individuals or communities may have uncompensated losses.
Social, cultural, and economic costs.	Costs associated with damages to tourism, commercial fishing, recreational use, cultural resources, subsistence use of resources, socio-cultural impacts.	Once ship owner has spent up to insurance limit, there may not be funding available for socio-economic damages. Canada does not have a system for assessing damages to social and economic resources. Civil courts could be a remedy.	Government of Canada (ship-source oil pollution fund) and International Oil Pollution Fund may pay for claims, up to established limits. Individuals, communities or businesses may have uncompensated losses.

Within or in addition to these "big three" cost categories, there are a number of oil spill costs that are not always taken into consideration in oil spill cost models. For an Arctic ship-source fuel oil spill, these may include (Cohen, 2010):

- Private costs incurred by the spiller (damage to or loss of vessel, including salvage costs; cargo loss or damage; and litigation costs);
- Morbidity or mortality impacts to individuals involved in the shipping accident;
- Costs incurred by government agencies involved in the response;
- Cost of repairing damaged public infrastructure;
- Losses by affected businesses;
- Lost consumer value from shifting purchases or behavior;
- Natural resource damages;

- Cost of litigation (both to government and injured parties, including individuals or businesses);
- Societal costs associated with focusing government and public resources on the spill response and away from other day-to-day functions); and
- Social costs that cannot be compensated through a transfer of funds from one party to another (e.g. cultural and social value inputs, community mental health impacts, interruption to traditional use of land and resources).

5.1.2 Comparative Costs of Oil Spills from Residual vs. Distillate Oils

There is general consensus among experts that HFO spills are more expensive to clean up and cause more extensive damages than distillate oil spills. Various studies have attempted to quantify the difference in costs, but none of the data from which these coefficients are drawn come from Arctic oil spills. An oil spill risk analysis for the U.S. Arctic used a cost factor of 1.64 to simplify the difference in impacts between heavy and light oil spills – meaning that a heavy fuel oil spill would be 1.64 times more damaging than a distillate spill (Reich et al., 2014).

The most commonly cited oil spill cost model – which is about 15 years old and based on worldwide data, so it is arguably a conservative estimate for Arctic spills – estimates the cost per volume of spill cleanup for HFO compared to distillate, as shown in the table below. Depending upon the volume spilled, the cost per gallon to clean up shorelines in a scenario where 0% and 10% of the oil is recovered was modeled. Table 5-2 summarizes the results, which were originally calculated in 2003 U.S. dollars and have been converted to 2018 U.S. dollars based on inflation rates[28] (Etkin, 2004).

The Etkin model estimates the cost per tonne of an HFO spill at between $106,000 and $512,000 per tonne spilled, including shoreline clean up costs, socio-economic costs, and environmental costs. By comparison, the per-tonne costs estimated for a distillate spill range from U.S.$32,000 to $193,000 per tonne. The Etkin model also suggests modifiers for adjusting oil spill cost estimates based on the impacted shoreline type, the socio-cultural impact severity, habitat and wildlife sensitivity, and the effectiveness of spill response. Each factor may increase or reduce the per-gallon (or per-tonne) cost estimate, though none of these cost multipliers are Arctic-specific.

[28] 2018 value calculated using 35.6% inflation.

Table 5-2. Comparative spill costs for HFO vs. Distillate Fuels

Cost per gallon estimates based on spill size and oil type (2003 U.S.$)					Total Cost Estimate (2018 U.S.$)[29]	
Type	**Volume Spilled (gallons)**	**Shoreline cleanup costs**	**Socio-economic costs**	**Environ-mental costs**	**Per gallon[30]**	**Per tonne[31]**
HFO	<500	$440	$150	$95	**$930**	**$246,000**
	500-1,000	$438	$600	$90	**$1,160**	**$307,000**
	1,000-10,000	$436	$900	$85	**$1,930**	**$512,000**
	10,000-100,000	$410	$500	$75	**$1,340**	**$355,000**
	100,000-1,000,000	$179	$200	$40	**$570**	**$151,000**
	>1,000,000	$87	$175	$35	**$400**	**$106,000**
Volatile Distillates[32]	<500	$103	$65	$48	**$290**	**$77,000**
	500-1,000	$102	$265	$45	**$560**	**$148,000**
	1,000-10,000	$100	$400	$35	**$730**	**$193,000**
	10,000-100,000	$55	$180	$30	**$360**	**$95,000**
	100,000-1,000,000	$23	$90	$15	**$170**	**$45,000**
	>1,000,000	$7	$70	$10	**$120**	**$32,000**

The UK Offshore Oil and Gas Industry Association evaluated potential oil spill costs associated with an offshore well blowout, taking into account more detailed cost categories, including: cost of establishing command centers; response costs for offshore dispersant application, offshore mechanical recovery, nearshore mechanical recovery, nearshore protective booming, shoreline cleanup, wildlife response, shoreline assessment teams, liaison functions, surveillance, and disposal costs. The model also considered cost impacts to fishing and aquaculture, tourism, and other claims. The resulting cost estimate for the smallest spill modeled – a 180,000 barrel crude oil spill – estimated that total response costs could range from U.S.$180M to $280M in 2010 currency (Oil & Gas UK, 2012). This actually computes as a lower per-tonne cost range than the Etkin model (between $11,000 and $17,000 in 2018 U.S.D); however the spill size equates to nearly 5 million gallons spilled, which is much higher than the ranges in the Etkin model, and consistent with the general assumption that per-tonne clean-up costs decrease as spill volume increases.

A probabilistic spill cost model developed for the Gulf of Finland[33] generated higher total cleanup cost estimates than Etkin for a 5,000 tonne spill of medium crude oil, and slightly lower for a 30,000 tonne spill of heavy crude oil. It does not take into consideration the potential impacts of sea ice, but the authors recommend further research to develop models that

[29] 2018 value calculated using 35.6% inflation.
[30] Rounded to nearest $10.
[31] Rounded to the nearest $1,000 using 265 gallons per tonne as conversion factor for both fuel types, recognizing that in fact density differences between fuel types make universal conversion factors less accurate, but appropriate for the purpose of rounding costs to the nearest thousand dollars.
[32] Etkin (2004) does not model 0% recovery, so cost per gallon reflects 10% of oil being removed (evaporated) before reaching shore.
[33] The model is specific to the geographic area for which it was developed.

consider the potential for Arctic conditions to influence oil spill response costs (Montewka et al., 2013).

5.1.3 Anecdotal Cost Data

Existing oil spill cost models typically derive their algorithms from actual fuel cost data. Another way to consider the cost of oil spills is to look directly at specific incidents with similarities to the risk scenarios of concern. In this case, there are no Arctic HFO spills to evaluate. However, other heavy fuel oil spills in sub-Arctic regions confirm the assumption that the combination of residual oil and harsh cold-water climates can exacerbate spill cleanup costs.

The 1988 *Nestucca* spill, which impacted the coasts of BC and Washington (U.S.), was a relatively small spill with a high price tag. The spill – approximately 800 tonnes of heavy fuel oil – resulted in shoreline cleanup costs of approximately U.S.$126.5M in 1988 (approximately U.S.$267M in 2018). Applying this single data point to a present-day HFO spill, the cleanup costs would work out to U.S.$333,750 per tonne of oil spilled.

More recently, a relatively small (3,000 gallon, about 11.4 tonne) fuel oil spill in Shuyak, Alaska[34] cost a reported U.S.$9M to clean up (Desroches, 2018). This amounts to over $800,000 per tonne. In this example, these costs do not extend beyond the direct cleanup expenses.

5.2 Funding Fuel Oil Spill Response in the Canadian Arctic

5.2.1 Polluter Pays Principle

The Canadian oil spill liability regime follows the "polluter pays" principle, which is well established in international and national law. The International Convention on Civil Liability for Bunker Oil Pollution Damage (BUNKER convention) provides a free-standing instrument that requires ship owners to pay for pollution damage caused by their bunker (fuel) oils.[35] Damages are defined as:

> *"(a) loss or damage caused outside the ship by contamination resulting from the escape or discharge of bunker oil from the ship, wherever such escape or discharge may occur, provided that compensation for impairment of the environment other than loss of profit from such impairment shall be limited to costs of reasonable measures of reinstatement actually undertaken or to be undertaken; and*
>
> *(b) the costs of preventive measures and further loss or damage caused by preventive measures."*

[34] This spill occurred in U.S. waters and was therefore influenced by the U.S. regulatory regime. The cited costs are limited to cleaning up the spill; assuming that Canadian regulators would hold the spiller to a similar standard of cleanup, then the total costs of the Shuyak spill might have been incurred if it had occurred in Canada.

[35] There are additional liability regimes and funds that apply to oil cargo spills for tankers, but these are outside of the scope of this analysis, which focuses specifically on spill costs associated with fuel oil spills.

Owners of ships over 1,000 gross tons (GT) are required to maintain insurance or financial security up to a liability limit established through international and national policy. The BUNKER convention, implemented in Canada under the Marine Liability Act, allows compensation claims for pollution damage to be brought directly against an insurer. Liability limits are based on the ship's tonnage, as summarized in Table 5-3. For example, for a 6,000 GT cargo vessel (typical of a community resupply/sealift ship serving communities), the total liability limit for a bunker fuel spill would be approximately $7.2M. The vessel operator would be required to carry sufficient liability insurance to cover pollution damage costs up to that amount.

Table 5-3. Liability limits for fuel oil spills from ships in Canadian waters

Vessel tonnage	Liability limit (SDR)[36]	Liability limit (CAD)
Up to 2,000 GT	1.51M total	$2.78M
Each additional ton up to 30,000 GT	604 per tonne	$1,111 per tonne
Each ton from 30,000 GT to 70,000 GT	453 per tonne	$834 per tonne
Each ton above 70,000 GT	302 per tonne	$556 per tonne

5.2.2 Canada's Ship-source Oil Pollution Fund

The Ship-source Oil Pollution Fund (SOPF) is both a "fund of last resort" intended to provide supplemental funding in the event that oil spill costs exceed the funds available through the ship's insurance, and a "fund of first resort" in which claimants may choose to apply directly to the fund in lieu of the shipowner. The fund balance was initially created in the early 1970s by assessing a 15 cent-per-tonne levy on oil companies and other industrial entities that imported or exported, by ship, more than 300 tonnes of oil per year. No fees have been assessed since 1976, although the Minister of Transport maintains the authority to reinstate a levy of up to 51 cents per tonne.

The initial fund balance of approximately $34M has been earning income for the 42 years since, through the Consolidated Revenue Fund of Canada. The Consolidated Revenue Fund is the account into which taxes and revenue are deposited, and from which funds are withdrawn in order to defray the costs of public services.

SOPF revenue is expended to cover fund administration, premiums paid to international compensation funds, and any claims awarded. At the end of the 2016/2017 fiscal year, the SOPF surplus was valued at $404M. From the fund's inception through 2017, about $19M in claims had been paid out; and an equivalent amount was paid over the same time for fund administration. Since 1976, the revenue earned from the Consolidated Revenue Fund has been $458M, with an additional $5M contributed through recovery of costs (SOPF, 2018).

[36] SDR (Special Drawing Right) is a reserve asset created by the International Monetary Fund. It is converted into Canadian dollars based on the currency calculation values for May 8, 2018.

Any person, corporation or government in Canada that has incurred costs or damages as a result of oil pollution may file a claim to the SOPF. Claims are time-limited (within two years of the time the damage occurs and five years of the event that causes the damage) and can be filed for any location within Canada and its Exclusive Economic Zone (EEZ). The maximum liability per incident is adjusted annually; the 2017 limit is approximately $172M. This is the maximum total amount that can be paid out across all claims for a single oil spill. Unlike tanker spills, fuel oil spills from cargo ships and other non-tank vessels are not eligible for claims compensation under international funds, beyond the ship owner's required insurance (Boulton, 2010).

The SOPF assesses and pays claims based on four criteria: (1) all clean-up measures taken must be reasonable measures; (2) all costs and expenses must have actually been incurred; (3) all costs and expenses must be reasonable; and (4) all claims filed with the SOPF must be investigated by the Administrator. The second parameter has the potential to limit or exclude certain claims related to lost use, such as lack of opportunity to gather subsistence foods, loss of recreational opportunities, or socio-cultural impacts that cannot be monetized. The Marine Liaibility Act does provide a mechanism for claims from loss of income, but claimants are limited to individuals engaged in specific fisheries-related activities.[37]

The SOPF website includes three active reports for Arctic oil spills. A 2010 spill from the cruise ship *Clipper Adventure*, which ran aground in Coronation Gulf, resulted in a $468,802 claim from the Department of Fisheries and Oceans to cover monitoring costs and expenses incurred by the Canadian Coast Guard. The claim is still pending due to ongoing litigation between the Crown and the shipowner. Two other spills were reported in 2016 – one from community gasoline resupply in Rankin Inlet and the other from a fuel barge grounding near Tuktoyaktuk. No claims have been filed to date in association with these incidents (SOPF, 2018).

5.2.3 Gaps in Oil Spill Liability and Compensation Coverage for HFO Spills in Canada

Referring back to the estimated spill costs for HFO spills derived from the Etkin model (Table 5-2) or the actual costs of the *Nestucca* and Shuyak spill responses described in Section 5.1.3, the Canadian liability limits for fuel oil spills seem quite low. The estimated $7.2M total liability insurance for a 6,000 GT cargo vessel resupplying Northern communities would not have been sufficient to cover the cleanup costs for the 11.4 tonne spill in Shuyak, Alaska (estimated at U.S.$9M, or about $11.5M CAD[38]).

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[37] Section 107(2) of the Marine Liaibility Act defines claimants eligible for Loss of Income claims as "(a) an individual who derives income from fishing, from the production, breeding, holding or rearing of fish, or from the culture of harvesting of marine plants; (b) the owner of a fishing vessel who derives income from the rental of fishing vessels to holders of commercial fishing licences issued in Canada; (c) an individual who derives income from the handling of fish on shore in Canada directly after they are landed from fishing vessels; (d) an individual who fisher or hunts for food or animal skins for their own consumption or use; (e) a person who rents or charters boats in Canada for sport fishing; or (f) a worker in a fish plant in Canada, excluding a person engaged exclusively in supervisory or managerial functions, except in the case of a family-type co-operative operation that has a total annual throughput of less than 1400 metric tons or an annual average number of employees of fewer than 50."

[38] Conversion rate of $1.28CAD to $1.00USD based on bank rates for May 10, 2018.

Assuming the fuel capacity for a 6,000 GT cargo vessel is 570 tonnes, the liability limit on the vessel owner would calculate to about $13,000/tonne. This is significantly lower than the $307,000/tonne cost estimate derived from the 2004 Etkin model, or the anecdotal cost data from the Shuyak, Alaska spill, which cost $800,000 per tonne to clean up. Table 5-4 calculates the potential cleanup costs based on the Etkin model for various spill sizes, and indicates the estimated gap (in 2018 CAD) between the ship's insurance and the estimated spill response costs.

Table 5-4. Gaps Between Ship Owner Liability Coverage for Fuel Oil Spills and Estimated Spill Response Costs

Hypothetical Spill from 6,000 GT cargo vessel with 570-tonne fuel capacity	Estimated response costs (Etkin, 2004)[39]	Ship owner's liability limit in Canada	Gap between ship owner's insurance and estimated costs
10% - 57 tonnes	$14M	$7.2M	**$6.8M**
25% - 143 tonnes	$35.2M	$7.2M	**$28M**
50% - 285 tonnes	$70.1M	$7.2M	**$62.9M**
75% - 428 tonnes	$105.3M	$7.2M	**$98.1M**
100% - 570 tonnes	$175M	$7.2M	**$167.8M**

Table 5-4 shows that for even a relatively small spill (10% of fuel capacity on a small cargo ship, which is estimated at 57 tonnes), the liability limit of the vessel owner under Canadian law would be $6.8M lower than the estimated response costs derived from the Etkin model, which is not Arctic-specific, and therefore may underestimate Arctic spill costs. This gap grows to over $167M in the event of a total cargo loss. If the anecdotal cost data from the recent Shuyak, Alaska spill were applied, the gap would increase by nearly threefold.

The SOPF provides a secondary funding mechanism to make up some or all of the gap, depending upon the spill size. The fund can pay up to $172M per incident, which would be sufficient even to cover the conservatively estimated gap for the 100% fuel loss scenario. This would be an order of magnitude greater than any claims paid out of the fund to date (total expenditures since 1972 have been about $19M for all claims combined). Paying a significant portion of oil spill response costs for an Arctic heavy fuel oil spill out of the Canadian fund would transfer the cost burden from the polluter to the government and taxpayers.[40]

The Government of Canada is updating the SOPF claims process as part of the Oceans Protection Plan implementation. This update may address some of the gaps in fuel oil spill liability.

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[39] Converted from 2018 USD (see Table 5-2) to 2018 CAD ($1.28 exchange rate for May 10, 2018).

[40] While the initial capital investment in the SOPF was derived from industry, there have not been any direct payments into the fund by operators since 1976. The interest earned on the fund balance is derived from the Consolidated Revenue Fund of Canada, which is taxpayer-funded.

6 Mitigation Options

6.1 Cost of Goods to Northern Communities

Banning HFO use and carriage for use through Canada's delicate marine ecosystem offers a number of benefits to ecological and human health. HFO emissions contain harmful pollutants, including black carbon, which also accelerates polar ice melt. An HFO spill could devastate the Arctic ecosystem, harming fish and marine mammals, and compromising the food security of Inuit communities that have subsisted on these resources for millennia.

The benefits to the environment and to Arctic peoples are clear – yet, there are also economic costs associated with requiring that Arctic ships switch to cleaner burning fuels. While the per-tonne costs associated with switching from IFO 380 to MGO will likely decline over time as the global marine fuels market adjusts to new regulatory requirements, it is likely that shipping companies will pass along some measure of cost increase to communities. A higher cost of goods may seem like a reasonable trade-off for slowing ice melt and protecting ecological and human health, yet high north communities are understandably concerned that any increases will threaten their economic well-being.

Policy options that mitigate the impacts to Canadian Arctic communities from higher sealift fuel costs should be explored alongside the implementation planning for an HFO ban.

6.1.1 Address Uncertainties

The data exploration presented in Section 3 of this report suggests that the relationship between fuel prices and cost of goods in the Canadian Arctic is not necessarily linear. Reduced fuel prices from 2014-2017 corresponded with increased food prices for most items in most communities year-over-year.

When the price difference between IFO 380 and MGO (based on 2017 averages) is spread across a single cargo load for a resupply vessel, the per-tonne increase is about $11.[41] This is about $0.01/kg of goods transported by sealift. If IFO prices rise and MGO prices fall as predicted, this margin becomes smaller over time. An important part of the conversation around mitigating impacts to communities should be refining estimates of how marine fuel price increases are actually passed along to communities.

6.1.2 Government Subsidies

The Government of Canada already has measures in place to subsidize the high cost of living to northern communities. These may provide models for how to structure a sealift subsidy and avoid common pitfalls experienced by other programs.

Nutrition North Canada (NNC) is a retail subsidy program implemented in 2012 to reduce the cost of nutritious food to residents in remote, northern communities. It subsidizes air freight costs associated with the transport of perishable, healthy food to 128 communities. The

[41] Section 3 uses 2015 US dollars as a standard for comparison; converting to 2018 US dollars and then to Canadian dollars works out to: US$33 2015 → US$34.75 2018 → CAD$45.17.

program is implemented through agreements between retailers in northern communities and Indigenous and Northern Affairs Canada, or INAC.

The NNC program was recently audited, and a number of concerns raised about how the program operated and the metrics used to ensure that the program is meeting its goals. Among issues noted were accountability, inadequately updating or adjusting rates, and ensuring that retailers passed all subsidies along to customers. Following a 2016 audit, the program has undergone additional changes to address some of the noted shortcomings (Galloway, 2017).

There are different ways that the Government of Canada could consider subsidizing the cost differential borne by sealift operators in the event of an HFO ban, and the NNC model provides a tangible starting point.

6.1.3 Phased or Adaptive Implementation

The proposed Arctic HFO ban would follow on the heels of the 2020 global sulphur emissions cap. This will remove HFO as a fuel option for all vessels that are not retrofitted with scrubbers, an option that most experts agree is unlikely to be widely adopted. This leaves vessel operators with a choice between alternative fuels (e.g., LNG, biofuels, electric), distillate fuels, or residual fuel blends. Assuming that the current ECA exemption will not be extended to the sulphur cap, Arctic resupply companies will be faced with the need to comply with the emissions cap in advance of the HFO ban. A phased implementation that considers both requirements, with the goal of encouraging Arctic resupply ships to switch to cleaner burning fuels as an ultimate compliance strategy, could mitigate fuel cost impacts to shipping companies and, to the extent that these are transferred to the cost of goods, minimize cost increases spurred by the HFO ban.

A phased and adaptive implementation process could help to address some of the uncertainties at play between the community impacts of the HFO ban and global sulphur cap to the cost of goods. The Montreal Protocol, which incorporates mechanisms for swift adjustment based on empirical data, could provide a model for how to implement a fuel switching policy in the Canadian Arctic.

A critical first step in this process is to evaluate more precisely the relationship between fuel prices and the cost of goods. The most direct approach to understanding this relationship would be to include the shipping industry in this dialogue. Phased implementation strategies could provide an incentive for the shipping industry to collaborate with regulators, stakeholders, and northern communities on approaches that achieve the ultimate goal of eliminating the use and carriage for use of HFO in the Canadian Arctic.

6.2 Oil Spill Impacts in the Canadian Arctic

The impact of any marine fuel oil spill to Arctic ecosystems, human health, and socio-economic systems could be catastrophic. An Arctic HFO spill has the potential to cause more significant impacts to all sensitive receptors, and these impacts may persist for much longer than would a distillate fuel spill. Banning HFO use and carriage for use in Arctic waters will eventually eliminate this hazard, and reduce Arctic oil spill risks. However, an HFO ban does not remove the potential for other types of marine fuel oils or bulk oil shipments to spill and impact Arctic waters. Many of the issues raised in this study bear consideration even after an HFO ban takes effect.

6.2.1 Building Arctic Oil Spill Response Capacity and Enhancing Prevention Measures

The oil spill response capacity currently in place in the Canadian Arctic is inadequate to mitigate a marine oil spill. The Coast Guard is the lead response agency for all oil spills north of the 60th parallel, and while there are significant efforts underway to expand Arctic spill response capacity, the reality is that if an oil spill occurred today, there would be very little equipment and virtually no trained personnel available for immediate response.

Because oil spill containment and recovery is a race against time, building a distributed response capacity across the Canadian Arctic would provide the best opportunity to mitigate the impacts of marine oil spill. Understanding the limits to existing spill response technologies and implementing additional prevention measures to account for gaps in response viability would also mitigate spill risks and potential impacts.

6.2.2 Creative Funding Mechanisms to Cover Arctic Marine Fuel Oil Spill Mitigation

Liability limits for bunker fuel spills in Canada are not adequate to cover the magnitude of cost impacts that could result from a fuel oil spill. The obvious solution is to require additional financial security for operators, which would require changes to the liability limits under the Marine Liability Act. In addition to changing the national framework for fuel oil spill liability, specific measures could be adopted that recognize the unique risks and potential impacts of an Arctic oil spill, at least until an Arctic HFO ban takes effect.

A recent study that considers the Canadian permitting context for Arctic tour operators points to a complex permitting system and regulatory disincentives as potentially stifling to tourism growth. While that particular study advocates streamlining permitting for tourism, it also highlights the practice of charging a premium for operating in Arctic waters to defer the high costs of resource protection. Several of the required permits include user fees to support, for example, wildlife management agencies that aim to preserve populations and support long-term wildlife viewing opportunities (Dawson et al., 2017).

Along the same lines, as Arctic adventure tourism has grown in popularity, private insurance companies have begun to offer policies to cover evacuation and rescue for polar expeditions (Douglas, 2016). This reflects the high cost of emergency response in these remote regions.

While permitting and adventure insurance policies may seem unrelated, both point to the precedent of paying to access the Arctic. Tour operators seeking to enter certain areas must pay for access to parks, heritage sites, and other attractions. Adventure tourists who undertake Arctic wilderness expeditions pay for coverage that will increase the likelihood of rescue in the event of an emergency or disaster. A similar model could be developed and applied to Arctic shipping routes, to allocate some of the costs of preparing for and responding to heavy fuel oil spills directly to the operators who are creating a spill risk in this fragile environment. This should include the growing recreational boating and cruise ship industries.

The Government of Canada could also implement a penalty system for vessels that discharge oil or other pollutants in Arctic waters. The assessment of civil and/or criminal penalties for marine pollution is a well-established practice across many Arctic nations, and can provide an incentive for safe operating procedures and spill prevention measures.

6.3 Oil Spill Costs

6.3.1 Creating Cost Incentives to Prevent or Avoid Spills

It is nearly impossible to associate dollar values with spill damages, as the impacts of a spill are experienced subjectively, and when resources such as subsistence are factored in, it is hard to find a currency-based proxy for their value as food and cultural integrity. Models that compare costs of HFO and distillate spills estimate that HFO spills could cost two times, ten times, or even more, than distillate spills. Still, from the perspective of a vessel owner who may never experience an oil spill, the comparative cost of avoiding an HFO spill by switching to distillate fuel is not a compelling economic argument. The Canadian system caps a ship owner's liability regardless of the type of fuel used, and the cap for a fuel oil spill is relatively low; this is another disincentive for a ship owner to switch to less polluting fuels.

The parties that benefit most from avoiding an HFO spill are the potentially impacted people and resources, not the ship operators. The fact that so many of the costs of an oil spill are borne by government and society makes the cost/benefit equation more complex, and worth considering through a different lens. Incentives that reward risk-reduction and spill prevention measures could be created to offset additional fuel costs associated with the HFO ban.

6.3.2 Response vs. Cleanup

Much of the emphasis in evaluating spill costs is on the direct cost of spill response. Cleanup cost analyses typically aggregate the costs of removing oil from the sea surface and cleaning up oil off the shoreline. However, oil recovery and removal at sea often occurs before sensitive resources are impacted, while shoreline cleanup nearly always occurs after initial damage has been sustained.

Real-world experience responding to HFO spills has demonstrated that in most cases, very little oil is recovered before it reaches the shoreline – meaning that all of the remediation occurs post-impact. The 2004 *Selendang Ayu* oil spill in the Aleutian Islands illustrates this point. Of the 1,200 tonnes of IFO 380 spilled, not a drop was recovered from the marine environment. All of the cleanup was beach cleanup to remove the sticky, tarry oil that had washed ashore. The majority of the oil spilled was not recovered – it broke into tar balls and tar patties and either washed ashore or eventually submerged or sank in the Bering Sea.

This is an important – if unpleasant – distinction to make when contemplating fuel oil spills in the Arctic. "Spill response" is often limited to cleaning shoreline after it has already been fouled by the oil. Working from the reasonable assumption that very little, possibly none, of the spilled oil is going to get recovered before it impacts the shoreline or the ice edge, the behavior and fate of the spilled oil becomes a key consideration, and one where the distinction between HFO and distillate fuels becomes particularly relevant. HFO will literally "stick around" for a very long time, particularly in Arctic conditions. Distillate fuels may be acutely toxic in the short term, but the harmful components are volatile, and they will dissipate more readily. In the first 48 hours, up to half of the volume of an MGO or MDO spill – in cold conditions – may evaporate. If there is enough sea energy, the total volume can evaporate within about a week. Returning to the site of an untreated diesel spill two years later, it would difficult to find evidence of the oil in the environment; conversely, if it had been an HFO spill, it is more likely that the shoreline would still have some lingering oil or tar coating present.

6.4 Issues for Further Consideration

6.4.1 Categorization of Low Sulphur Residual Blends and Hybrid Fuels in the Context of an Arctic HFO Ban

It is unclear whether residual fuel blends or hybrid fuels will be captured under the pending Arctic HFO ban. Theoretically, these oils could be blended to fall below the HFO density and viscosity thresholds established under MARPOL. Yet, they are substantially similar to HFO from a spill risk and response perspective. If an Arctic HFO ban were to go into effect, this might create an incentive for refineries to keep the viscosity of these products below 900 (MARPOL threshold for HFO); however, an LSFO with a density of 899 will still behave more like HFO when spilled than it would like a distillate fuel – so the oil spill risk/impacts are not equivalent to a distillate fuel. This issue could be resolved by refining the HFO ban language and definitions.

6.4.2 Risk Tolerance

The ability to anticipate the potential impacts – ecological, sociocultural, or economic – of an Arctic oil spill is limited by a lack of data and a lack of reliable models. Additional work could be done to evaluate the potential impacts of an HFO fuel spill to the Arctic ecosystem and the communities that rely on its health and integrity, but it is virtually impossible to try to quantitatively estimate the potential impacts of a persistent fuel spill into the Arctic Ocean. Ultimately, the issue becomes one of risk tolerance, and of determining whether the potential benefits of continuing to allow HFO to be transported through Arctic waters merits the risks of a potential Arctic HFO spill. The liability discussion and cost analyses presented in this report provide some insight into how risks and impacts are borne differently by communities, shipping companies, and governments.

6.4.3 Impacts of the 2020 Sulphur Cap on Marine Fuel Costs

Shipping companies are already contemplating how to comply with the phase out of high sulphur heavy fuel oils. Most analysts agree that the changing regulatory framework for ship bunkers will result in changes to fuel costs, and potentially to the cost spread between residual and distillate fuels. The Montreal fuel price data presented in Section 3 shows that recent

MGO prices have actually been lower than past IFO 380 prices, indicating that shipping companies have been able to continue with Arctic community resupply against wide fluctuations in heavy fuel oil costs, and are therefore able to adapt to an HFO ban. Continuous evaluation of fuel costs and differentials is a necessary component of an adaptive approach to implementing the HFO ban. It is possible that in the long-term, HFO and MGO prices could equalize or that HFO could eventually become more expensive due to reduced demand in the marine sector.

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Appendix A: Data

Table A-1 presents monthly fuel price data for Montreal from November 2013 through December 2017 as calculated based on daily price data provided by Bunkerworld (November 2013-December 2015) and Ship and Bunker (January 2016-Decemeber 2017) subscription services.

Table A-1. Average monthly fuel price data

Month	Price by Fuel Type ($U.S./tonne)		Spread	
	MGO	IFO 380	By price	By %
Nov-13	1058	654	404	62%
Dec-13	1097	652	445	68%
Jan-14	1116	637	479	75%
Feb-14	1170	648	522	81%
Mar-14	1133	641	492	77%
Apr-14	1123	632	491	78%
May-14	1087	637	450	71%
Jun-14	1070	649	421	65%
Jul-14	1055	637	418	66%
Aug-14	1040	617	423	69%
Sept-14	1003	592	411	69%
Oct-14	956	547	409	75%
Nov-14	932	475	457	96%
Dec-14	879	384	495	129%
Jan-15	777	321	456	143%
Feb-15	788	346	443	129%
Mar-15	818	345	474	137%
Apr-15	782	348	434	125%
May-15	777	376	401	107%
Jun-15	747	364	383	105%
Jul-15	683	319	365	115%
Aug-15	608	266	342	129%
Sep-15	616	257	359	140%
Oct-15	618	243	375	155%
Nov-15	636	242	395	164%
Dec-15	595	187	408	222%
Jan-16	526	152	374	247%
Feb-16	526	161	365	227%
Mar-16	562	183	379	208%
Apr-16	557	193	364	189%

Month	Price by Fuel Type ($U.S./tonne)		Spread	
	MGO	IFO 380	By price	By %
May-16	582	239	344	146%
Jun-16	613	261	352	135%
Jul-16	594	267	328	123%
Aug-16	568	271	297	110%
Sep-16	539	272	268	98%
Oct-16	575	299	276	92%
Nov-16	640	269	372	148%
Dec-16	634	266	368	148%
Jan-17	627	263	365	149%
Feb-17	602	249	354	153%
Mar-17	618	258	359	149%
Apr-17	592	240	352	157%
May-17	603	249	354	153%
Jun-17	592	240	352	156%
Jul-17	590	238	352	159%
Aug-17	592	239	353	158%
Sep-17	587	238	349	158%
Oct-17	587	238	349	158%
Nov-17	587	240	347	155%
Dec-17	592	248	344	148%

Appendix B: Acronyms and Abbreviations

C	Celcius
CARB	California Air Resource Board
CPI	Consumer price index
DMA	Abbreviation for a form of marine diesel oil
DMB	Abbreviation for a form of marine diesel oil
DMX	Abbreviation for a form of marine diesel oil
ECA	Emission control area
EEZ	Exclusive economic zone
EPPR	Emergency Prevention, Preparedness and Response (Arctic Council)
g	Gram
GT	Gross tons
HFO	Heavy fuel oil
ICCT	International Council on Clean Transportation
IFO	Intermediate fuel oil
IMO	International Maritime Organization
INAC	Indigenous and Northern Affairs Canada
ISO	International Standards Organization
kg	Kilogram
LDO	Abbreviation for a form of marine diesel oil
LLC	Limited Liability Company
LNG	Liquefied natural gas
LSMFO	Low sulphur marine fuel oil
M	Million
m^3	Cubic meter
MARPOL	International Convention for the Prevention of Pollution from Ships
MEPC	Marine Environmental Protection Committee (IMO)
MDO	Marine diesel oil
MDC	Abbreviation for a form of marine gas oil
MGO	Marine gas oil

mm^2	Square millimeter
NBS	Nunavut Bureau of Statistics
NDT	Net deadweight tons
NEI	Northern Economics, INC
NNC	Nutrition North Canada
SOPF	Ship-Source Oil Pollution Fund
t	Tonne
UK	United Kingdom
UNCTAD	United Nations Council on Trade and Development
US	United States
USEIA	United States Energy Information Agency