Daily Fuel Consumption and Greenhouse Gas Emissions by Bulk Carriers Anchoring in the Southern Gulf Islands

Prepared for the
Salt Spring Island Climate Action Council
January, 2020 (v1.2)

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Southern Gulf Islands

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Executive Summary:

Expansion of anchoring activity from the Port of Vancouver into the nearby Southern Gulf Islands has become an increasing environmental concern. Estimating the daily fuel consumption of anchoring bulk freighters in this area is an important part of assessing impacts.

A generalized equation related to engine power was used with specific parameters reported in other studies.

Engine power is a function of vessel size, and was derived from the mandatory minimum power requirements for safely maneuvering as prescribed by the International Maritime Organization (IMO). The size distribution of vessels in the study area was obtained from data by the Pacific Pilotage Authority (PPA).

The resulting estimates reveal that a typical bulk freighter anchored in the Southern Gulf Islands will burn at least 2 tons of fuel oil every day, based on auxiliary and boiler power for electricity and other demands on board.

An estimated amount of 10 tons of CO2 will be produced by one anchoring vessel every single day (the estimate for toxic sulphur emissions SOx is 6.2 kg per vessel and day). There were over 3000 anchoring days of bulk carriers in the Southern Gulf Islands in 2018.

Moving vessels may consume 20 times more fuel than anchoring vessels, but accurate predictions in the area of the Southern Gulf Islands are difficult without applying more specific models that include speed and other factors.

The anchoring locations are within an archipelago that is dominated by land, and right next to ecologically sensitive areas and local communities. Local implications and solutions are discussed, particularly regarding the climate emergency, air quality, and acidification of the marine environment.

Introduction and Objectives

To assess some of the environmental impact of bulk carriers anchoring in the ecologically sensitive Southern Gulf Islands (SGI), estimates of fuel consumption need to be known.

There is much variation in fuel consumption among different vessels, therefore a robust and realistic estimate is required, which can be used consistently and holds up to scrutiny.

A direct estimate of ***daily fuel consumption in metric tons*** of fuel oil is a basic expression of pollution, which is easily understandable by the public and can be put into direct comparisons with dimensions we are used to in our daily lives.

Such an estimate of fuel consumption can be used by local committees working on action plans for climate emergency. It is a basic component for further estimates and suitable for modeling environmental impacts.

Methods

Main Engine (ME)

Fuel consumption in shipping can be described as Equation (1):

Daily Fuel Consumption [t] = Engine Power [kW] * SFOC [g/kWh] * 24[h] / (1000*1000) *(Eq. 1)*

SFOC is the Specific Fuel Oil Consumption (also called SFC or FOC).

Main Engine power is usually described as 'Specified Maximum Continuous Rating (SMCR)' [1]. In general, larger vessels require more powerful engines (Fig. 1).

During operation of a vessel, the actual power used depends on a variety of factors such as speed, draft, wind resistance, environmental conditions, and many others. These have been described in many functional relationships, and different studies have used a variety of ways of assessing the load factor on power used in different phases of travel.

A simplified scenario could use the minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions, as required by the International Maritime Organization (IMO).[2]

These guidelines determine that the minimum power line values of total installed ME, in kW, for different types of ships should be calculated as follows:

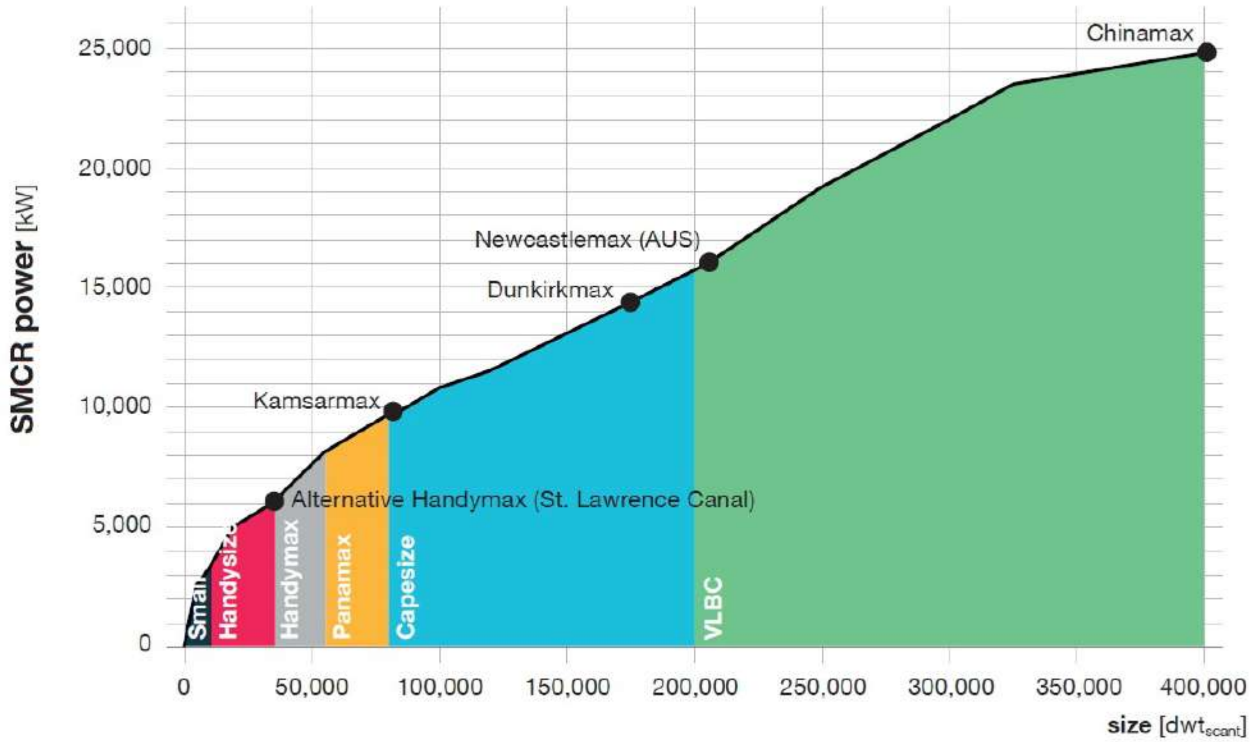

Fig. 1: Larger vessels require more powerful engines: Propulsion SMCR power as a generalized function of vessel size (described as deadweight tonnage, dwt or DWT), with the names of size classes of bulk carriers given. Vessels in the Southern Gulf Islands are up to approximately 200,000 DWT. From 'Propulsion Trends in Bulk Carriers' [1].

Minimum Power Line Value = a * (DWT) + b *(Equation 2)*

where:

DWT is the deadweight tonnage of the ship in metric tons; and a and b are the parameters given in Table 1 for tankers, bulk carriers and combination carriers.

Table 1: Regression parameters for estimating minimum power requirements as a function of DWT [2].

Ship type	**a**	**b**
Bulk carrier which DWT is less than 145,000	0.0763	3374.3
Bulk carrier which DWT is 145,000 or over	0.05	7329

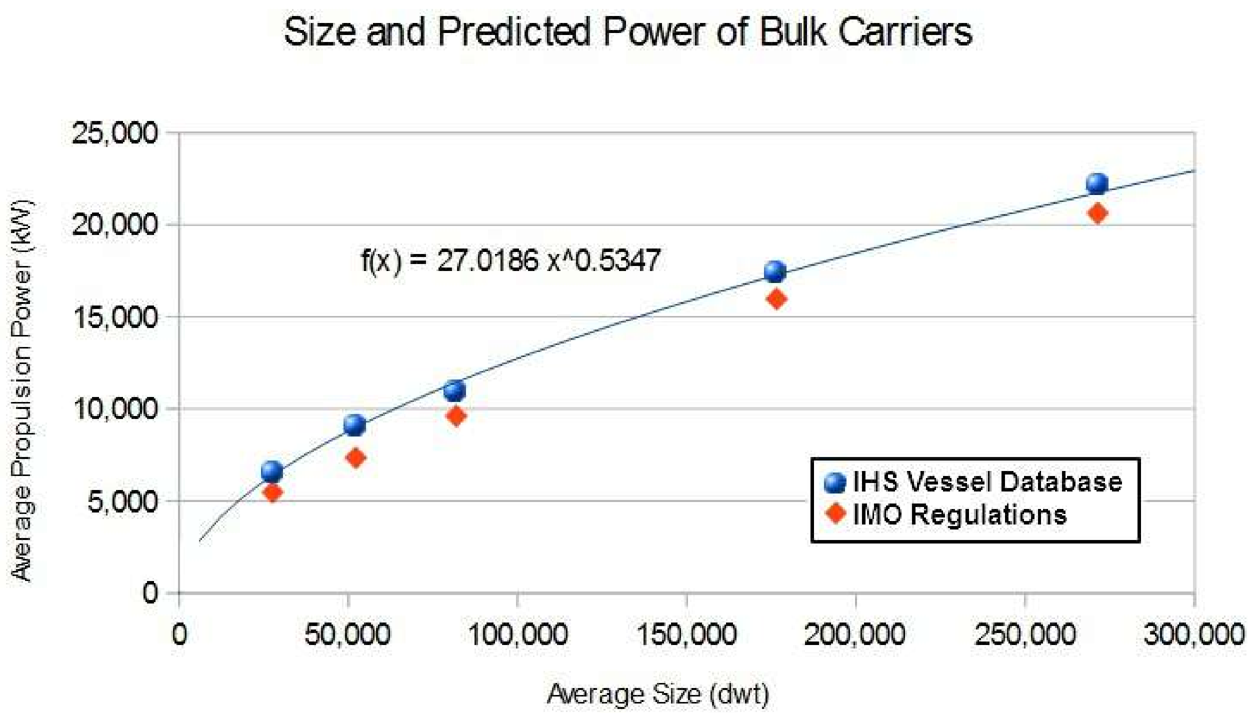

Fig. 2: Averages of bulk carrier size classes according to the IHS vessel registry[3] in blue, with polynomial regression calculated in order to predict the power of main engines. In comparison, the more conservative estimates in Table 1 based on IMO regulations and used in this study are shown in red.

Therefore, with the given DWT for a vessel, the propulsion power can be estimated for input into Equation (1) for the Daily Fuel Consumption.

An alternative method can be based on data from the Information Handling Services (IHS) vessel database. In the Third IMO Greenhouse Gas Study 2014 the average DWT was given for each size class used in Table 14.[3] These averages were used in Fig. 2 to calculate a polynomial regression that can predict the power of a bulk carrier of a given size (Power = 27.0186 * $DWT^{0.5347}$, $R^2 = 0.99$).

The Specific Fuel Oil Consumption (SFCO) depends on engine load, but is a relatively constant parameter of how many grams of fuel are used per kWh at maximum continued rating across engines mostly used in bulk carriers. Usually a range of 160-195 g/kWh is given in specifications by engine manufacturers and studies that assess emissions for air quality.[3][4][5][6][7][8][9]A recent review summarizes the results for specific engine types.[10] Vessels built before the year 2000 had higher average values of up to 225 g/kWh.[4]

We used a conservative value for SFOC of 175 g/kWh that was used by the IMO and the U.S. Energy Information Administration (EIA) for optimal engine loads.[2][4]

Auxiliary Engines (AE) and Auxiliary Boilers

Large seagoing vessels have supporting engines that serve several purposes. Anchoring bulk carriers use AE to generate electrical power and to start up main engines (Fig. 3).[8]

Auxiliary Boilers are used for fresh water generation (evaporators), fuel oil heating and purification, heat for accommodation and galley, cargo heat, washing and general cleaning (Fig. 3).[11] Boilers are not a major source of fuel consumption for bulk carriers when the Main Engines are running due to heat recovery. At anchor, however, the portion of fuel used for Auxiliary Boilers can be considerable.[3]

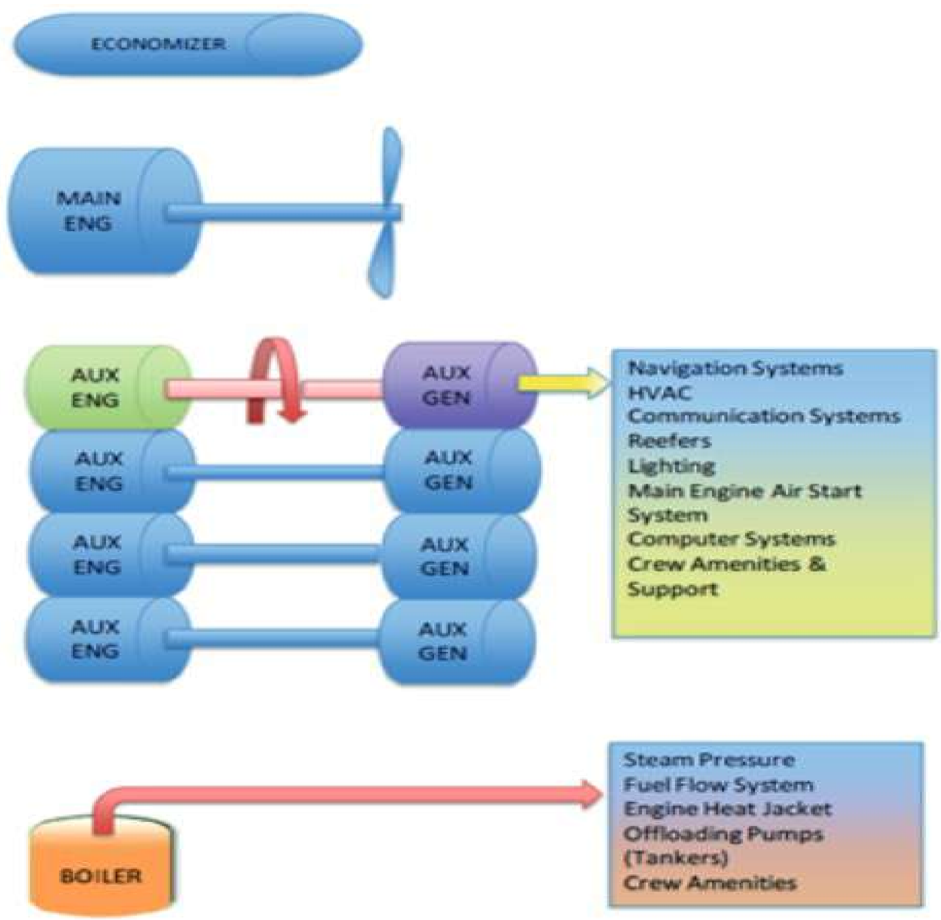

Fig. 3: Auxiliary Engines (AE) and Boiler as part of the generalized energy system of a seagoing vessel during the phase of anchoring or berthing. From: IAPH (2018).[15]

For estimating fuel consumption, we can use Equation (1), but with the input of different values than for the Main Engine (ME).

Three different methods are compared for the estimation of the engine power demands of supporting engine systems of anchoring bulk freighters:

(a) The US Energy Information Administration based estimates on engine specifications, using a generally accepted assumption that AE run at approximately 5% of the power of the ME.[4]

(b) The Third IMO Greenhouse Gas Study 2014 used data from the EU and from a vessel boarding program in the US to assign approximate kW ratings to vessels of different DWT-classes and separate activity phases.[3]

(c) The 2016 Puget Sound Maritime Air Emissions Inventory used updated estimated parameters for 'hoteling' bulk carriers at anchor, with the simplification of pooling all size classes together.[12]

(d) A methodology for port emissions inventories by the US Environmental Protection Agency from 2009 used a similar approach to (a) above: AE of bulk carriers were assumed to have an auxiliary power ratio of 0.222 compared to ME, with an average load factor of 0.22 at anchor.[14] This method was favoured by a recent comparison of estimating auxiliary power schemes.[13]

There is less variation in SFOC for supporting engines than for ME, because AE are usually running at an optimal speed, and power is reduced by turning some of these engines off.[3]

Reported SFOC are usually within 195-225 g/kWh for auxiliary engines (290-305 g/kWh for boilers), depending on the type of engine. We followed the studies (a)-(c) above and used 225 g/kWh for auxiliary engines and 300 g/kWh for boilers.[2][4]

Fuel types

The study area is within the North American ECA (Emissions Control Area) of 200 nm from shore, which prescribes the use of fuel with a sulphur content of less than 0.1% [16].

All vessels in the area are required to comply and use Low Sulphur Fuel Oils (LSFO), which are usually blends of Heavy Fuel Oil (HFO) and Marine Gas Oil (MGO, also referred to as Distillate).[4]

Most Main and Auxiliary Engines can use all of these fuel types [17][14]. Marine Gas Oil (MGO) is approximately 5% higher in caloric value, but the specific oil fuel consumption (SFCO) depends more on engine type and load than fuel type.[3] By using conservative values for SFCO in this study, variation between fuel types will have been taken into account.

Some vessels may be using scrubbers for treating Heavy Fuel Oil (HFO) to meet ECA emissions limits, and these scrubbers will increase fuel consumption by 1.5-2%.[18]

The accuracy of estimates is discussed in Appendix A.

Observed Vessel Size

All bulk freighters in the study area required a pilot on board. The trips were recorded by the Pacific Pilotage Authority (PPA) and were made accessible in the form of a database.[19] Information on anchoring vessels in the SGI area from 2018 and 2019 (without 4th quarter) was extracted, DWT was retrieved, and listed by vessel name and visit.

Results

The size of 475 bulk freighters anchoring in the Gulf Islands in 2018 and 2019 ranged from smaller Handysize of 170m length to Capesize bulkers of 300m length. The most common class was 80,000 – 90,000 DWT, with the overall median of 81,756 metric tons (Fig. 3).

The mean DWT of all vessels in the SGI was 94,726 – but because the size distribution in Fig. 3 did obviously not follow a normal distribution, this value may not be accurate, and the median value should be used instead.

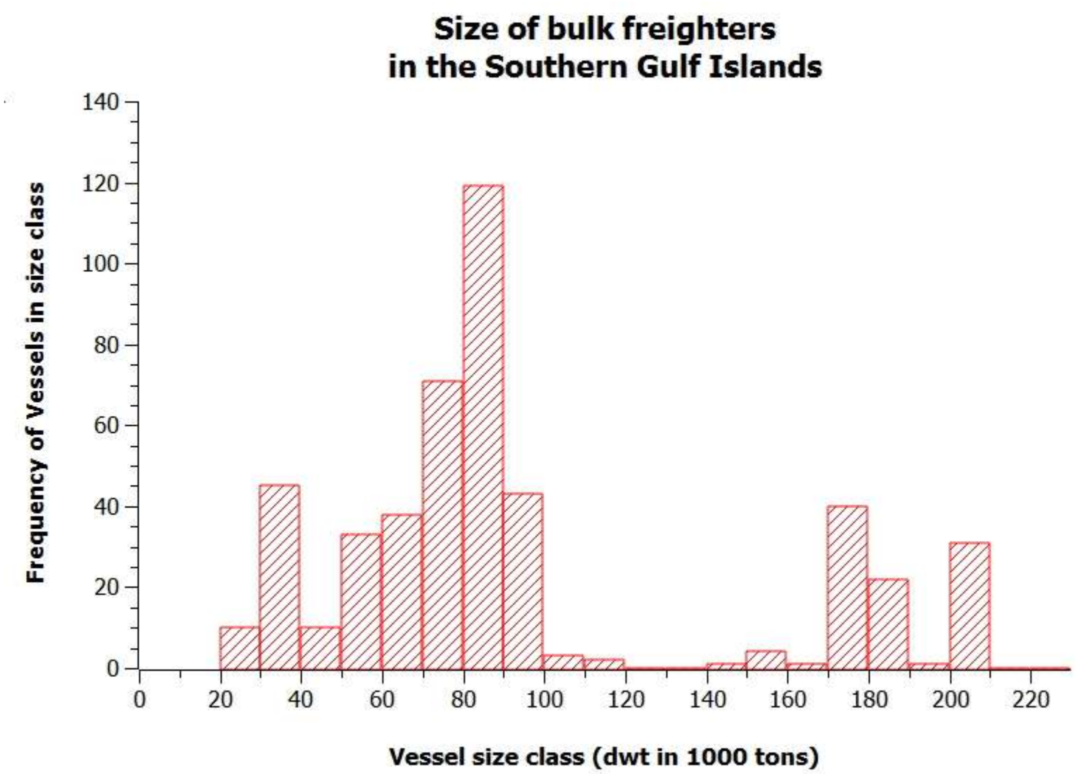

Fig. 3: Distribution of vessel size classes anchoring in the Southern Gulf Islands, 2018 and 2019.

Table 2: Results for estimated Daily Fuel Consumption of *moving* bulk freighters (near maximum continuous engine rating), using minimum mandatory power requirements [2]. The most common size class in the study area (at median DWT) is highlighted in bold.

Bulk Carrier Size	dwt [t]	Min Power [kW]	SFOC [g/kWh]	Fuel consumption Main Engine [t/d]
Handysize	35,000	6,044.8	175	25.4
Handymax	50,000	7,189.3	175	30.2
Handymax	60,000	7,952.3	175	33.4
Panamax	***80,000***	***9,478.3***	***175***	***39.8***
Capesize	100,000	11,004.3	175	46.2
Capesize	180,000	16,149.0	175	67.8
Capesize	200,000	17,129.0	175	71.9

Knowing more about observed vessel sizes, we can use this information in Equation (1) for estimating daily fuel consumption. The results for moving vessels using minimum prescribed propulsion power are summarized in Table 2.

According to the most common vessel sizes, the daily fuel consumption was approximately 40 tons of fuel oil per day when a bulk freighter is moving. Smaller vessels may use approximately 25 tons per day, and large vessels may consume up to about 70 tons of fuel per day.

These estimates are to be considered with caution, because of the great variability of factors when vessels are moving, as discussed later.

Different numbers are expected for estimates for vessels at anchor. Table 3 summarizes the estimated results for three different methods of calculation. Overall and based on the most common vessel sizes in the study area, anchoring bulk freighters are using at least 2-3 tons of fuel per day when anchoring and running average loads on auxiliary engines for power generation and boilers.

Table 3: Results for estimated Daily Fuel Consumption of bulk freighters *at anchor,* using four different methods used in recent air emissions studies.[4][3][12][13][14]

Method (Agency)	Year Published	Aux Power [kW]	Boiler [kW]	SFOC (Aux) [g/kWh]	SFOC (Boiler) [g/kWh]	Fuel consumption [t/d]
US Energy Information Agency	2015	473.9	-	225	-	**2.6**
International Maritime Organization (IMO)	2015	420.0	200.0	225	300	**3.7**
Puget Sound Maritime Air Forum	2018	253.0	125.0	225	300	**2.3**
US Environmental Protection Agency	2009, 2019	462.9	109.0	217	300	**3.2**
Average		**402.5**	**144.7**			**2.9**

Discussion

Environmental considerations

Several local governments in the Southern Gulf Islands and adjacent Vancouver Island have declared a State of Climate Emergency and are working on action plans.

The islands with natural and residential areas are interlaced with surrounding water, from where anchoring bulk vessels started intruding within 0.5 – 3 km of residential areas, at over 30 known anchorage sites.

It may come as a sobering surprise to local planning committees that each anchoring bulk freighter is not only bringing noise pollution, but also burns such substantial amounts of fuel every day, that even shorter stays will easily cancel out the efforts of the local population to reduce carbon emissions in their area.

The numbers supplied in this study will facilitate the evaluation of this situation.

Lineups and waiting times at the Port of Vancouver cause anchoring overflow, with idling ships at anchor, due to inefficiencies in the supply chain and the scheduling of arriving vessels.[23][28] Instead of displacing the emissions elsewhere, they could be avoided almost entirely by improving logistics and planning in these areas.

Local climate action committees could use the results to further assess greenhouse gas emissions, for example in the form of CO2, SOx, NOx, or Black Carbon, based on emission factors published in recent emissions studies, as presented in Appendix B.

According to the results in Appendix B, ***one typical bulk carrier at anchor and burning fuel in the Southern Gulf Islands will produce about 10 tons of CO2 every single day*** - an unnecessary contribution to greenhouse gases and climate heating that could be avoided by better planning and management actions by exporters and at port.

Illustrating the annual impact of emissions, and not including vessels moving, there were over 3000 anchoring days of bulk carriers in the Southern Gulf Islands in 2018 (based on data from PPA[5]). This is equivalent to about half of the estimated annual greenhouse gas emissions for Salt Spring Island.[24]

As examples at a more personal level, ***one single day of a typical freighter anchoring at Salt Spring Island*** is equivalent and will cancel out each of the following efforts:[24]

* 10 years of recycling by a family of three;
* Sacrificing one annual return flight Vancouver-London for 10 years;
* Driving an electrical vehicle instead of a standard vehicle during 5 years.

CO2, NO2, SO2 and similar emissions are very reactive and will (particularly during our winters) return as acid rain right into local waters and contribute to acidification and detrimental changes in the marine environment.[26][27] A typical bulk freighter anchoring in the Southern Gulf Islands will release 6.2 kg of highly toxic SOx every single day (assuming the cleanest ECA fuel oils of 0.1% sulphur content).

Such high emission rates that are brought by anchoring ships into the heart of local communities are a concern for air quality and human health.[25] South-East Vancouver Island and the Southern Gulf Islands are already struggling with air quality because of cumulative pollution from burning, residential wood heating, and industrial emissions from a pulp mill.

On islands surrounded by colder water, it is common that local winds will follow a daily cycle and transport pollutants up to certain elevations and then down again towards sea level[27]. There, pollutants are trapped particularly at colder temperatures, and can cause health concerns for the local population.

By provincial regulation, residents have to observe fire bans while a monitored ventilation index is low. Canadian provinces have jurisdiction to regulate air quality, and further legal powers exist for local governments in British Columbia to protect the air quality for its population.

In contrast, the federal government of Canada is allowing the marine shipping industry to expand into an archipelago where land is dominant and separated only by narrow waterways, and anchor and burn fuel at will and without limitation, right in the centre of a group of protected islands, and in between residential areas and territories of First Nations, where emissions and pollution affect all aspects of life in these local rural communities.

The amount of emissions reported in this study, and the close proximity of ecologically sensitive and residential areas, raise the question whether it is appropriate that the federal government of Canada is treating such an area of unique diversity as if it was the open ocean, without considerations about the health of local environments as well as resident citizens and First Nations.

Background of the problem

Overflow anchoring of large seagoing vessels had not occurred in large numbers in the Southern Gulf Islands and was not a major challenge at the time when the first Salt Spring Island Climate Action Plan was completed in 2011.[24][29][30]

Anchorages are used primarily by bulk carriers (freighters), which are contracted for transporting commodities such as grain, coal, and forestry products, from delivery at port terminals to their foreign destinations. Container ships operate on much stricter liner schedules and rarely need anchorages.

The myth is that the freighters appearing in the Southern Gulf Islands in the past decade merely reflect the growth at the Port of Vancouver, that we all need trade, and that we cannot rewind the wheel of time.

The fact is that economic growth does not explain the explosive pattern of anchorage requirements. Ten years of shipping data shows that time spent at anchorage is growing at a rate of multiple times the growth of bulk commodity exports through the Vancouver Port.[31] Also, other ports such as Rotterdam or Singapore have shown that innovative management can limit or even reverse anchorage requirements and environmental impacts despite growth.

The real reasons are inefficiencies at port in handling changes in the market. One of the main events was the privatization of the Canadian Wheat Board (CWB)[32]. There was an efficient planning and logistics unit in place with a central-desk system for scheduling vessels and loading at harbour. This system was dismantled and not replaced by alternative logistics. Private grain companies now compete for business and do not share information on their scheduling of export and shipping contracts. The result was a chaos emerging around 2014. Vessel line-ups became the new norm in Vancouver, with regular overflow into the Southern Gulf Islands.

Currently these inefficiencies are causing economic damage to grain farmers in the prairies in the form of over $20 million in annual fees for late delivery to vessels (demurrage fees)[23], and they are causing ecological damage to coastal communities in the form of pollution, reduced air quality, ocean acidification, and noise disturbance by ships at anchor in the Southern Gulf Islands and along the east side of southern Vancouver Island.

Inefficiencies, chaos in lineups, idling ships at anchor, and unpredictable and delayed exports are not good for business. Grain farmers and coastal communities are not the only ones criticizing the lack of efficiency in the shipping of commodities. For example, Westshore Terminals which operates the coal shipping from Point Roberts (and frequently uses the Gulf Islands for anchoring), was named multiple times for inefficiencies by their main supplier of coal, and investors predicted falling stock prices for this company[33].

Possible solutions

(a) Elimination of interim anchorage sites in the Southern Gulf Islands: Despite promises, the industry has not delivered on improving the flow of shipping, and continued to use overflow anchoring in the Southern Gulf Islands as an easier solution. Stopping this route will give an incentive to the industry to put effective measures into place to fix the efficiency problems and find management options for improved scheduling of shipping exports.

(b) Regulating the industry in the absence of a central-desk system: The root cause of the problem is that competing companies don't share 'sensitive' information with each other, resulting in problems with railway supply, inefficient scheduling of vessels, and unnecessary vessel lineups at port. The inefficiencies are aided by a 'first come first served' principle for port anchorages, which are free for users[34]. Other countries have more regulations in place. For example, in the US it is a requirement to report grain contracts to the federal government.[23]

Anchorage sites are limited in port, and they should be carefully managed, without a need for overflow. For example, with a booking system to be used by exporters and terminals, with time-sensitive fees to discourage a lack of planning, or a requirement for terminals to provide their own docking or anchorage at their sites. Imagine the chaos if airlines or hotels used a 'first come first served' business system instead of centralized and flexible booking options. Some regulation or system is required after dismantling the Wheat Board's central-desk system.

(c) Federal and industry investments into a digital port information and Vessel Arrival System: Numerous studies and examples have shown that port efficiency and certainty in export business is aided by information sharing. Sensitive information can be protected. Export and shipping contracts as well as vessel arrival can be better scheduled and create more profits. Vessel arrival can be delayed with instructions to reduce speed for incoming ships, resulting in reduced costs for fuel and reduced emissions.

(d) Federal and industry investments into supply chain and logistics technology: Sufficient railway supply and terminal stocks are needed to overcome gaps. Some minimum requirements for terminal stocks may have to be regulated to prevent the contracting of vessels when supply is not available for loading. Loader systems that can operate and serve vessels during rain and snow are a necessity for efficient and competitive exports in a northern nation like Canada.

(e) More efficient inspections of vessels: Inspections are necessary for customs and immigration (CBSA), Structural integrity of ships (Transport Canada), readiness for loading of cargo holds (Canadian Food Inspection Agency, CFIA), and quality of grain (CFIA). Delays appear to occur because of inefficiency in the process of inspections. Solutions for the federal government include hiring more inspectors and coordinating inspections. Arriving vessels could be guided into specific inspection berths or port anchorages, so that cleaning of cargo holds, fumigations, and inspections are conducted centrally instead of sending inspectors out to distant anchorages. The arrival of ships must be limited to the available capacity for processing.

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Appendix A: Accuracy of estimates

Stationary phase at anchor:

For a typical bulk freighter at anchor in the Southern Gulf Islands, a daily fuel consumption of at least 2 tons of fuel can be considered a solid minimum estimate.

These estimates assume that supporting engines are run at optimal loads, however, in reality this is not always the case, and the IMO is running training courses for improving ship-board energy management.[11]

Also, a study found that the commonly used interviews with chief engineers to determine auxiliary loads gave lower estimates than systematic tests of marine electric power systems in use.[22]

It is possible that future developments in shipbuilding targeting Tier III emissions will bring bulk vessels to a consumption rate of less than 2 tons per day, but it will likely take decades until all vessels of the global fleet are replaced.

In the meantime, many bulk vessels will burn considerably more fuel than 2 tons per day while at anchor. About 25% of the bulkers in the Southern Gulf Islands were larger Capesize. Data from the US vessel boarding program suggest that there is an increase in fuel consumption with size (although not linear and leveling off towards very large bulk carriers)[16]. The somewhat lower fuel consumption value of the Puget Sounds Air Emission Inventory may be due to the fact that their size data is lumped together and contains fewer large coal bulk carriers on the US side of the Salish Sea.

Moving Phase:

The overall estimate of approximately 40 tons of fuel oil consumed daily by a typical bulk freighter in the Southern Gulf Islands should be interpreted with some caution and within the assumptions made.

There is variability dependent on size: The smallest bulk freighters in our area are closer to 25 tons of fuel per day, and the largest seen in the study area may use up to 70 tons of fuel per day when moving.

These estimates are close to a full load of the specific maximum continuous power for Main Engines (SMCP). The minimum power requirements mandated by the IMO will be lower than the actual power installed in a vessel.

While bulk freighters are estimated to burn these amounts of fuel when they are relatively close to long distance travel capacity, the actual amount used in our study area is less clear. Distances are short range, and speed within the islands is lower than for average longterm travel, which can reduce fuel consumption considerably.

On the other hand, higher power demands for manoeuvrability may come into play when cornering around smaller islands.[5] More accurate predictions would need to involve specific models incorporating speed from recorded vessel positions using the AIS-System and other factors.[20][21]

Appendix B: Daily Greenhouse Gas Emissions of one typical bulk carrier anchoring in the Southern Gulf Islands. Emission factors vary depending on engine type and age, and are given separately for auxiliary engines and boilers in g/kWh, expressed as minimum and maximum values from recent studies for cleanest ECA fuel oils of 0.1% sulphur content.[5][12] Daily emissions were calculated using average emission factors and average power demands in kW from Table 3.

Emissions	$Auxiliary_{Min}$	$Auxiliary_{Max}$	$Auxiliary_{Avg}$	$Boiler_{Min}$	$Boiler_{Max}$	$Boiler_{Avg}$	Total kg/day
CO_2	656	696	676	922	962	942	9,800.1
NO_x	7.7	13.82	10.76	2	2	2	110.9
HC	0.4	0.4	0.4	0.1	0.1	0.1	4.2
CO	0.54	1.1	0.82	0.2	0.2	0.2	8.6
So_x	0.43	0.44	0.435	0.57	0.6	0.585	6.2
N_2O	0.029	0.029	0.029	0.04	0.075	0.0575	0.5
CH_4	0.008	0.008	0.008	0.002	0.002	0.002	0.1
PM_{10}	0.24	0.24	0.24	0.16	0.16	0.16	2.9
$PM_{2.5}$	0.23	0.23	0.23	0.15	0.15	0.15	2.7
DPM	0.19	0.24	0.215	0	0.1	0.05	2.3
Black Carbon	0.0138	0.06	0.0369	0.0089	0.06	0.03445	0.5