NORTH AMERICAN WATERBORNE TRANSPORTATION CARBON FOOTPRINT

Report Prepared by Blue Sky Maritime Coalition

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BLUE SKY
MARITIME COALITION

EXECUTIVE SUMMARY

This analysis of the carbon footprint and emissions-free fuel requirement for the North American Waterborne Transportation ("NAWT") business is undertaken by the Blue Sky Maritime Coalition ("BSMC").

Waterborne transportation encompasses both the movement of goods within the United States ("U.S") and Canada as well as the waterborne imports and exports from the U.S. and Canada. This paper focuses on the emissions from movements on the inland and coastal waterways and in North American ports. It excludes emissions from internationally flagged vessels on their way to and from North America although emissions from U.S.-flagged vessels trading internationally and in the non-contiguous domestic trade are included.

Annual CO_2 emissions from the NAWT fleet and from ports in North America were estimated to amount to 66 million tonnes in 2018, approximately 1.0% of the 6,657[1] million tonnes of total North American CO_2 emissions in that year. Of that 66 million tonnes, 47 million tonnes are attributable to fuel consumed by the NAWT fleet and 19 million tonnes by North American ports.

BSMC's principal conclusions are summarized below and explained in the body of the report:

- Approximately 31 million tonnes of "green" methanol would be required to replace the diesel fuel now burned by the NAWT fleet.[2] Green methanol is produced in limited quantities in North America. For example, Montreal-based Enerkem produces bio-methanol from municipal solid waste feedstock, and Maersk has announced an investment in a Texas facility to produce green methanol for its fleet.
- Annual emissions of approximately 47 million tonnes of CO_2 would be eliminated by replacing diesel with an emissions-free alternative fuel. That amounts to 0.7% of total North American CO_2 emissions.
- The value of a one (1) tonne reduction in CO_2 emissions in the voluntary carbon market is, at the time of writing, approximately $5/tonne.[3] The value of eliminating the NAWT fleet's CO_2 emissions is nearly $250 million per year on that basis, a present value of $2.3 billion at a 10% discount rate. Currently no mechanism exists by which the value of CO_2 emissions can be monetized.

Although the emissions reduction potential is significant, there is no existing commercial structure or agreement in place that aligns the interests of charterers, owners, and investors to decarbonize the NAWT business. BSMC is collaborating with leading decision makers in the industry to create such an arrangement.

The core of this analysis is a detailed assessment of the fuel requirements for each of the major segments of the NAWT fleet. That analysis began with a review of a database of all documented vessels in the U.S. that is published annually by the Institute for Water Resources at the U.S. Army Corps of Engineers ("Army Corps"). This database review was also

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[1] Net U.S. GHG emission (CO_2e) is 5,917 and Canada is 740 million tonnes in 2018.

[2] Alternatively, 27.5 million tonnes of "green" ammonia, 5.2 million tonnes of "green" hydrogen, or 12.9 million tonnes of bioLNG.

[3] Based on the CBL GEO index.

correlated with other government publications produced by several other agencies including the Maritime Administration. Finally, a variety of privately maintained databases were reviewed to further refine the vessel list into the logical segments presented in this report. Leading operators in each market segment were interviewed to identify representative trading patterns and daily fuel consumption for representative vessels in each segment. Fuel consumption was then converted to CO_2 emissions on the basis of International Maritime Organization ("IMO") emissions factors.

This report also includes a brief review of recently published research sponsored by the Ocean Conservancy on fuel consumption by the U.S. Flag fleet.

THE FLEET

Total CO_2 emissions from the 9,500 vessels in the NAWT fleet amounted to approximately 47 million tonnes in 2018. That amounts to 0.7% of total emissions from the U.S. and Canada, 2.4% of total emissions from the transportation sectors of North America, and 4.5% of total CO_2 emissions from the global shipping fleet (as reported by the IMO in the 4th Greenhouse Gas Study). NAWT CO_2 accounts for 15% of CO_2 emissions from shipping within national boundaries, as reported by IMO.

- The largest single contributor to NAWT emissions is the offshore support vessel fleet, amounting to 29% of total emissions. Although the offshore support vessels comprise approximately 17% of the NAWT fleet, the vessels have relatively high fuel consumption and utilization.
- The inland tug and pushboat fleet is the second largest CO_2 emissions contributor, at 9.3 million tonnes or 19% of total emissions.
- The coastal and harbor tug fleet and ferries are the third and fourth largest contributors, at 6.8 million tonnes and 6.4 million tonnes respectively, or 14% apiece of total emissions.
- Tankers and Articulated Tug-Barges ("ATBs") account for just 3.1 million tonnes or 6% of total NAWT CO_2 emissions.

PORTS AND TERMINALS

The ports of Houston, New York/New Jersey, Los Angeles, and Long Beach provide comprehensive information on both tonnage throughput and emissions. Total tonnage throughput for the U.S. amounts to 2,349 million short tonnes; these four ports accounted for 25% of the cargo movements into and out of the U.S. in 2018.

Ports report emissions in CO_2-equivalent (CO_2e) terms, thereby accounting for the impact of methane and other emissions on a greenhouse gas equivalent basis.

Total CO_2e emissions from the U.S. ports can be estimated by applying the ratio of emissions to throughput for the four ports to the total U.S. tonnage. The ratio for total emissions is 0.007; applying that to the 2,349 million short tonne U.S. throughput yields a total port related emissions of 16.6 million tonnes of CO_2e.

Total Canadian port tonnage was 335 million tonnes in 2017. Applying the 0.007 ratio derived from the four U.S. ports, total CO_2e emissions from Canadian ports is estimated to be 2.4 million tonnes.

Total North American port related emissions thus amount to 18.9 million tonnes of CO_2e.

According to the IMO GHG4 study, CO_2e emissions from shipping amounted to 1,076 million tonnes in 2018, while CO_2 emissions amounted to 1,056 million tonnes or 98% of CO_2e emissions. Applying that 98% ratio yields an estimate of 18.6 million tonnes of CO_2 for ports in the U.S. and Canada.

Figure 1 below shows the CO_2 emissions by vessel type.

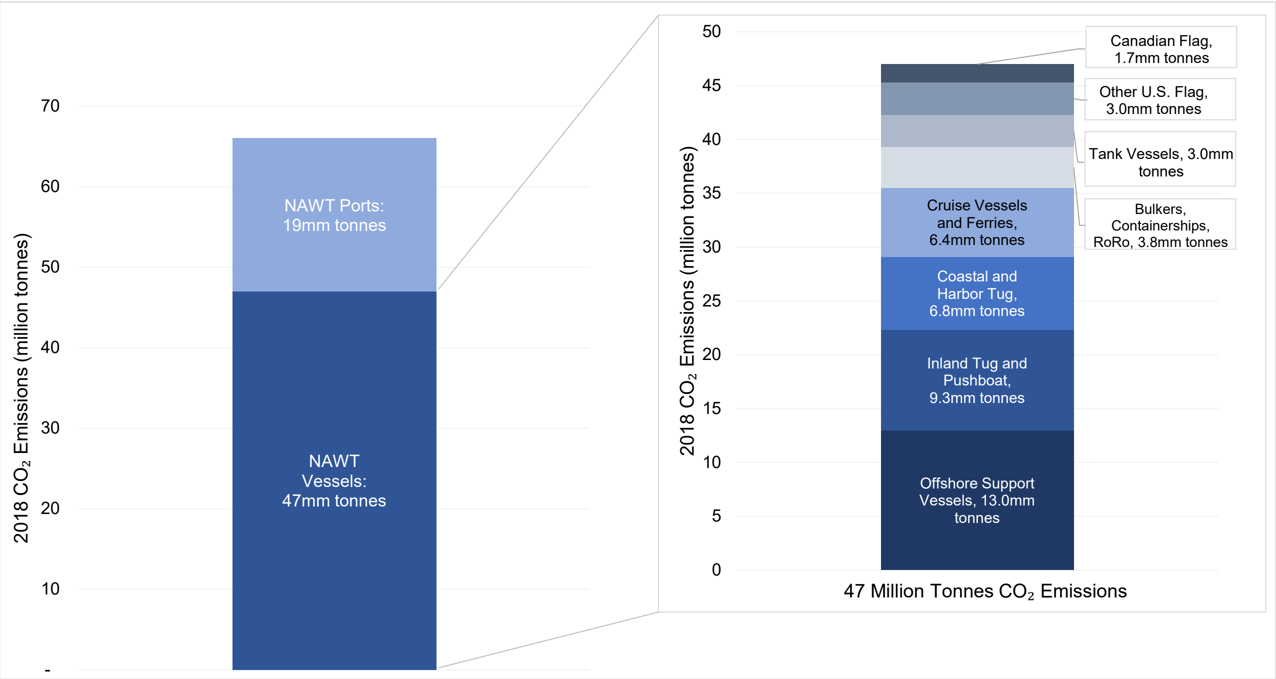

Figure 1. NAWT Fleet's CO_2 Emissions by Vessel Type

NET-ZERO FUEL AND ELECTRICITY REQUIREMENT

The NAWT fleet can achieve its goal of net-zero CO_2 emissions by 2050 by replacing fuel now consumed with an equivalent net-zero fuel: bio-LNG, or "e-fuels" which include methanol, ammonia, and hydrogen. The net-zero fuel and electricity requirements of the NAWT fleet are reviewed in the third chapter of this report. Achieving net-zero by 2050 may be supported by other means such as carbon capture, or other methods not yet known to the authors, but we believe fuel replacement is the primary route.

The table below shows, in million tonnes and terawatt-hour (TWh), the net-zero emission fuels and the renewable energy needed to produce the equivalent of fuel oil to power 25% of the NAWT fleet. The 25% baseline is based on Maersk's announced target to have 25% of their fleet running on green fuels such as methanol, biodiesel and ammonia by 2030.[4]

Fuels	25% of Fleet Using Green Fuels in 2030 (million tonnes)	Renewable Energy Needed for 25% NAWT Fleet in 2030 (TWh)
Fuel Oil	3.9	-
eLNG	3.2	76.3
Methanol	7.8	79.3
Ammonia	6.9	76.3
Hydrogen	1.3	58.7

Figure 2. Zero Emissions Fuel Requirement of the NAWT Fleet

Total green methanol production funded by Maersk is reported to amount to 0.7 million tonnes/year by 2025 of green methanol bunker fuel and 6 million tonnes/year by 2030 globally (meeting approximately 25% of their fuel requirement). The electricity required to produce net-zero fuels is immense. For example, 317 TWh would be required to produce the 31 million tonnes of methanol necessary to replace all the high carbon-content, oil-based fuel now consumed by the NAWT fleet. 317 TWh would amount to more than 10% of the projected renewable electricity production of the U.S. in 2030.

These net-zero calculations illustrate the challenge of converting the NAWT fleet to zero emissions. But they also show a path to achieving that goal. LNG is already making a significant headway in the NAWT fleet (see the comments in the offshore supply vessel and containership sections). Methanol is also being championed by Maersk, a key industry leader with whom many in the NAWT business already have close commercial relationships.

The U.S. Gulf of Mexico region is a natural place to focus BSMC's attention on "breakthrough" projects which will demonstrate how the energy transition can take place in practical and commercial terms. The state of Texas has abundant renewable energy and concentrated CO_2 emissions that are a necessary input to the production of net-zero fuels. Many leading consumers of the offshore supply vessel and inland tug and pushboat fleet are based in the area.

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[4] Maersk: Our Methanol Demand Could Reach 6 Million MT/Year by 2030 - Ship & Bunker (shipandbunker.com)

OPERATIONAL FACTORS

Advances in cellular, satellite, and internet-based communications over the past decade have opened up new opportunities to optimize the use of existing vessels. Such optimizations could now be based on real-time, high quality data on vessel traffic, weather forecasts, port and berth congestion to provide predictive models. These models would require the involvement of all elements of the supply chain to provide up-to-date information to a shared clearinghouse.

The benefit of these models is that vessels could be confidently operated at the best economic speed (lowest fuel consumption and therefore emissions) available to get the cargo to the berth for a specific time slot rather than next open availability. Current business practice causes vessels to arrive as quickly as possible consuming more fuel in transit and then in most instances to wait at anchor where more fuel is consumed generating onboard electricity.

Although a detailed study of those measures is beyond the scope of this report several promising opportunities have been highlighted in that regard.

THE OCEAN CONSERVANCY REPORT

In January 2022, the Ocean Conservancy ("OC") and UMAS (a sector focused, commercial advisory service) produced a white paper titled, The Maritime Fleet of the USA – the current status and potential for the future, that provides an inventory of estimated CO_2 emissions from the U.S. Maritime Industry.[5,6]

The OC report used a methodology based on those used by the IMO and others in the global shipping industry. This method of estimating vessel emissions differs significantly from that used by the Blue Sky Maritime Coalition and yielded different emissions estimates for most segments analyzed, though in some segments the estimates are quite closely aligned. While OC and BSMC may have differing policy suggestions, both recognize the urgent need to decarbonize the maritime sector. BSMC welcomes OC's efforts and the perspective it brings to the emissions issues at hand and looks forward to continued dialogue on how to accelerate the transition to clean shipping.

While a more detailed comparison is presented in the final chapter of this report, it is noteworthy that the CO_2 emissions estimates derived by the BSMC are more than twice those estimated by UMAS. Reconciling the OC and BSMC reports will help to shed light on NAWT emissions.

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5 Bonello, J., Velandia Perico C., Taylor, J., and Smith, T. (2022) The Maritime Fleet of the USA – current status and options for the future – Rev 2.0. UMAS, London

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INTRODUCTION

This analysis of CO_2 emissions from the North American Waterborne Transportation ("NAWT") business is undertaken by the Blue Sky Maritime Coalition ("BSMC"). The analysis is intended to show the scale of total NAWT emissions relative to various benchmarks and to identify the emissions contribution of the various segments of the diverse NAWT business.

Chapter 1 of the report focuses on the emissions from the U.S. and Canadian Flag fleets. It includes a detailed analysis of the fleets with the greatest CO_2 emissions. The analysis of the U.S. Flag fleet began with the U.S. Army Corp of Engineer's Institute for Water Resources which produces an annual data set of Vessel Characteristics and Inventory By Type. Our study was based on their data for calendar year 2018 which was the latest available when we began our study. This data is available at https://usace.contentdm.oclc.org/utils/getfile/collection/p16021coll2/id/7440.

The U.S. Army Corp database was also correlated with other government publications produced by several other agencies including the Maritime Administration. Finally, a variety of privately maintained databases were reviewed to further refine the vessel list into the logical segments presented in this report. We believe the 2018 baseline is representative of today's emissions.

The CO_2 emissions were estimated on the basis of expert analysis of the consumption and operating profile of the vessels in that fleet. The experts contributing to the analysis have many years of experience in the industry and, in many cases, were able to draw upon information from their own fleet. The number of vessels, as well as their consumption and operating profile, are detailed in the following chapters.

Chapter 2 of the report extends the analysis to emissions from North American ports. The emissions-to-throughput ratio is estimated from detailed emissions and throughput data available for four U.S. ports. Applying that ratio to total North American throughput provides an estimate of total port emissions.

Chapter 3 shifts the focus from historically observed fuel consumption and emissions to the net-zero fuels required to replace existing fuels and the amount of electricity that would be required to produce the net-zero fuels.

In **Chapter 4**, the authors discuss various operational factors that complement the fuel transition described in Chapter 3. In some cases, these operational modifications could accomplish the transition more quickly than just fuel modifications alone.

Chapter 5 identifies and addresses differences between BSMC's analyses and those of the OC and UMAS.

Chapter 6 provides background on the voluntary carbon markets and the important role it plays for NAWT businesses.

CHAPTER 1: THE U.S. FLAG FLEET

This chapter provides an in-depth review of the U.S. Flag fleet.

OFFSHORE SERVICE VESSELS

Offshore support vessels are included in International Classification of Ships by Type ("ICST") code 422 (Offshore Support Vessel). The MARAD[7] database lists a total of 1,664 offshore support vessels ("OSV") in the fleet. The majority of the OSV fleet in the U.S. is working in the Gulf of Mexico supporting the oil and gas exploration and production industry.
The emissions profile of this fleet reflects several factors, including the load on the engines and the horsepower ("HP") of the fleet, the age of the fleet, the technology being utilized to decrease fuel consumption and emissions, and the preventative maintenance programs in place.

Real-time monitoring is essential to obtain an accurate emissions profile and was used in the calculations summarized below. This technology was provided by SailPlan Maritime Inc. and is being utilized by several OSV owners, including Harvey Gulf International Marine.

Most OSVs spend at least half of their life utilizing dynamic positioning alongside an offshore oil rig or drillship. Due to risk assessments, most OSVs will run the engines under low load conditions between 5%-30%. See Figure 3 below for estimated engine utilization. At low loads, the emissions profile is significantly worse (but has less mass) while at high loads the emissions profile is much better (but has more mass). This is one important reason why OSVs will have higher emission profiles relative to other marine vessels.

Load	25%	50%	75%	100%
Time	50%	25%	10%	15%

Figure 3. Time Spent at Engine Load

When determining the total horsepower of the OSV fleet, it is imperative to estimate the usage of the vessel and number of engines being utilized. Since an OSV's time in port is a very small portion of the vessel's operation, we believe that 365 days in operation with two engines is a representative starting point for the CO_2 emissions estimates. During transit, most vessels will utilize three to five engines. While on DP, vessels will utilize two to three engines. For this study, the data used was two engines running with 50% usage and one engine running with 50% usage. Estimated CO_2 emissions per year and per vessel are shown in Figure 4 below.

Days in Operation	CO_2 Emissions[8] (kg/hour/engine)	CO_2 per Engine per Year (kg/year/engine)	CO_2 per Vessel per Year (kg/year)
365	197.61	4,327,848	6,491,772

Figure 4. Estimates of Annual CO_2 Emissions per Offshore Support Vessel

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[7] United States Maritime Administration

[8] Basis engine technical files from manufacturers, adjusted for load/time percentages

These estimates have been verified by a combination of technical files and real-time emission data from SailPlan Maritime Inc.

The estimated emissions of 6,491,772 kg/year per vessel (6,492 MT) understates the average annual emissions from the fleet as many ships are equipped with three to five engines. In order to capture the variety of vessel size and horsepower, a 20% factor was used to account for these emissions. Figure 5 below shows the inputs to the calculation of total CO_2 emissions from the offshore support fleet.

CO_2 per Vessel per Year (tonnes/year)	Number of OSVs in the US Flag Fleet	Adjustment to Account for OSVs with 3 to 5 engines	CO_2 Emissions from the Offshore Support Fleet (million tonnes/year)
6,492	1,664	20%	12.96

Figure 5. Calculation of Total CO_2 Emissions from the Offshore Supply Vessel Fleet

Total CO_2 emissions from the offshore supply vessel fleet amounts to 13.0 million tonnes per year.

Alternative fuels are the number one factor that can drastically impact the emission profile of an engine. Just five out of the 1,664 OSVs operate on clean fuel technology in the U.S., and all of them are owned and operated by Harvey Gulf International Marine. Harvey Gulf's "green fleet" utilizes LNG and Bio-LNG as the main fuel sources; these vessels have the potential to operate as carbon neutral. Harvey Gulf is also the only operator in the world with Tri-Fueled (Battery/LNG/Diesel) Offshore Vessels.

INLAND TUG AND PUSHBOATS

The tug fleet, as reported in ICST category 431 consolidates coastal and inland tugs as well as tugs dedicated to the Articulated Tug Barges (ATB) tanker vessel trades. A total of 1,878 tugs are listed there. A review of the fleet was undertaken to split the fleet between the coastal, inland, and ATB trades. Another 3,198 vessels are listed under ICST code 432 (pushboat), all of which are assumed to operate in the inland trades. A total of 5,076 tugs and pushboats were allocated to the inland fleet. Our assessment of the CO_2 emissions from the inland tug and pushboat fleet draws extensively from the 2021 report, Decarbonization of the Inland Waterway Sector in the United States, prepared by Vanderbilt University for ABS. Please refer to that report for a comprehensive view of the inland waterway industry.

THE INLAND WATERWAY INDUSTRY

In 2019, 514 million tons of cargo were shipped along the inland waterways with coal, oil, and oil products accounting for 46% of the trade.

The inland tug business has four main segments:

- Along the Gulf Intracoastal Waterway, a narrow channel, smaller towboats of approximately 2,000 hp are employed.
- On the upper Mississippi and Ohio rivers, locks dictate the size of barges and towboats. The fleet deployed on the rivers with locks consisted of 4,000 to 6,000 hp boats.
- The Mississippi River between St. Louis and New Orleans is navigable without locks and dams. The maximum safe tow size is about 40 jumbo barges and requires a towboat of 9,000 to 10,500 hp.
- Assembling groups of barges together – often with different barges serving different customers – permitted operators to achieve the maximum efficiency possible during the linehaul portion of the voyage. This assembly process requires a network of hundreds of docks as well as fleets to load and stage the barges. Each dock and fleet require one or more smaller towboats (800-1,400 hp), often referred to as "fleet boats," to efficiently assemble the barges

ESTIMATED EMISSIONS – 3 APPROACHES

The Vanderbilt report estimated emissions from the inland waterway fleet to be 5.67 million tonnes. The estimate is derived by scaling up detailed reports from a large inland tug operator (see page 16 of the report):

> *For this report we obtained accurate annual fuel burn data for one of the largest inland barge companies in the U.S. Based on the market share that company represents, we extrapolated total industry fuel and validated that data against fuel tax receipts as reported by the Federal Government. Some estimation was required because not all fuel used in the inland sector is subject to fuel tax (only fuel used for propulsion is taxed and some operating segments are exempt from taxation). Based on total fuel consumption of approximately 550 million gallons, and 10.21 kg of* CO_2 *released per gallon, total* CO_2 *emissions of the inland waterway sector is approximately 5.67 billion kilograms of* CO_2*.*

For this study we took two approaches to estimate emissions from the inland fleet. The first, similar to the Vanderbilt study, relied on data from the fuel tax paid by vessel owners operating on the inland waterways. Like Vanderbilt, we interviewed a leading vessel operator on the incidence of the tax relative to the total fuel consumed on the inland waterways. According to that operator only 50% of the fuel consumed on the inland waterways was taxed. The Waterways Council provided a summary of receipts paid and gallons taxed – see Figure 6 below.

Year	Receipts	Gallons
2014	$81,700,000.00	281,724,137.93
2015	$97,900,000.00	337,586,206.90
2016	$110,900,000.00	382,413,793.10
2017	$113,700,000.00	392,068,965.52
2018	$115,000,000.00	396,551,724.14
2019	$117,000,000.00	403,448,275.86
2020	$111,700,000.00	385,172,413.79
Average	**$106,842,857.14**	**368,423,645.32**

Figure 6. Summary of Fuel Taxes Paid by Inland Waterway Operators and Gallons Taxed (Source: Waterways Council)

Focusing on the period between 2018 – 2020, average annual fuel taxes amounted to $114.6 million and 395 million gallons taxed. The gallons taxed do not, however, represent the total gallons consumed by the inland fleet. One reason is that the tax is not applied for fuel consumed on some important portions of the inland waterway, specifically the Mississippi River below Baton Rouge, the Houston Ship Channel, and the Willamette River. Another reason is that the tax applies only to fuel consumed for propulsion and does not apply to fuel used to power generators or barge-mounted pumps and boilers.

For example, based on discussions with leading tug operators, the horsepower of the genset aboard a tug amounts to about 10% of the main engine, and the utilization of the genset is 100% versus a lower average figure for the main engine. The Inland Waterways Tax is thus very likely to apply to less than 85% of the total fuel consumption. Still, the non-taxed status of the lower Mississippi and Houston trades is likely to be the more significant.

A leading owner operating throughout the inland waterways estimated that the incidence of the tax amounted to 50% - i.e., that the actual fuel consumed by the inland fleet was twice that reported as taxed. Applying the 50% tax incidence estimate from the owner interviewed the total gallons consumed on the inland waterways is about 790 million gallons, or 3 million tonnes.[9]

One tonne of fuel consumed emits about 3.1 tonnes of CO_2 so the estimate based on this approach is 9.3 million tonnes.
It is noteworthy that the estimate obtained in this manner is 44% higher that Vanderbilt's. We believe the main reason for the difference is the estimated tax incidence; the authors report that their sources reported an 80% tax incidence for their operations.

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[9] Using a conversion factor of 264.17 gallons per metric tonne.

To help resolve the difference we took a different approach, based on the fleet size, the fleet composition and the fuel consumption by vessel size using data reported in the Vanderbilt report; see Figure 7 below.

Size Range	Number of Vessels	Fuel Consumption (gallons/vessel/year)		Fuel Consumption (gallons/fleet/year)	
		Low	High	Low	High
400 – 1299	1,650	75,000	125,000	123,750,000	206,250,000
1300 - 1999	600	150,000	275,000	90,000,000	165,000,000
2000 – 3999	1,050	325,000	450,000	341,250,000	472,500,000
4000 – 6499	325	425,000	650,000	138,125,000	211,250,000
6500 – 10999	100	650,000	1,900,000	65,000,000	190,000,000
Total (Gallon/Fleet/year)				758,125,000	1,245,000,000
Gallons/tonne: 261.47		In (million tonnes)		2.90	4.76

Figure 7. Number of Vessels and Fuel Consumption by Vessel in the Inland Tug fleet (Source: Vanderbilt Figure 14 and Table 3, Page 17)

This approach yields a range of estimated fuel consumption from 2.90 million tonnes (758 million gallons) to 4.76 million tonnes (1,245 million gallons). In terms of CO_2 emissions, that range is from 9 million tonnes to 14.8 million tonnes.

The range of estimated CO_2 emissions summarized here is wide – from 5.6 million tonnes to 14.8 million tonnes. For the purposes of this report, we use the 9.3 million tonnes based on reported fuel taxes and an estimated tax incidence of 50%.

This review highlights the need for more accurate fuel consumption measures. One possibly fruitful line of attack in that regard would be to review AIS data on time spent by the inland fleet in the taxed versus non-taxes trades.

COASTAL AND HARBOR TUGS

The tug fleet as reported in ICST category 431 consolidates coastal and inland tugs as well as tugs dedicated to the ATB tanker vessel trades. A total of 1,878 tugs are listed there. A review of the fleet was undertaken to split the fleet between the coastal, inland, and ATB trades. A total of 820 tugs were allocated to the coastal fleet.

Vessel Type	Days per Year		Consumption (tonnes/day)		# Vessels	Total Fuel Consumed (tonnes/year)	CO_2 Emissions[10] (tonnes/year)
	Steaming	In Port	Steaming	In Port			
Large > 5,000 HP	210	145	22	0.2	127	590,000	1,830,000
Medium 1,000 < HP < 5,000	175	180	15	0.1	593	1,567,000	4,859,000
Small < 1,000 HP	125	230	3	0	100	37,500	116,000
TOTAL					**820**	**2,194,000**	**6,805,000**

Figure 8. Fuel Consumption and Emissions from the Coastal Tug Fleet

The development of fuel consumption profiles for each class of tug began with the nature of the service in which the tugs were employed. For example, most Harbor Tugs, engaged in ship assist business, are operated on a daily basis with the exception of periodic maintenance periods and a modest number of idle days. Thus, a Harbor Tug can be expected to consume fuel and generate emissions for between 330 and 345 days per year. In contrast, coastwise tugs typically spend time in harbor while cargo is being handled on their associated barges or waiting for their next towing opportunity.

The profile for Large > 5,000 HP tugs is a blend of Ship Assist and Coastwise tugs that reflects these two profiles. The estimated daily steaming consumption of 22 tons equates to the consumption of a 5,500 HP tug at full power for 24 hours. Clearly these tugs do not operate at full power 24 hours per day, but this is offset by the fact that tugs in this class range from 5,000 HP to 12,000 HP. The average reflects both elements. In addition, the lower consuming Ship Assist tugs typically operate for 330-345 days per year rather than 210 days.

The Medium 1,000 < HP < 5,000 segment is also comprised of a combination of Coastwise and Harbor Tugs and 15 Tons per steaming day would equate to a 4,000 HP tug operated at full power for 24 hours. This estimate has the same caveat as was described for the large tug segment and reflects a similar weighting of the nature of the work performed by these tugs. Many of these tugs are engaged in shorter haul transportation of liquid and dry bulk products where the waiting time for cargo accounts for a greater percentage of their total employment. This was factored in by the lower number of estimated steaming days.

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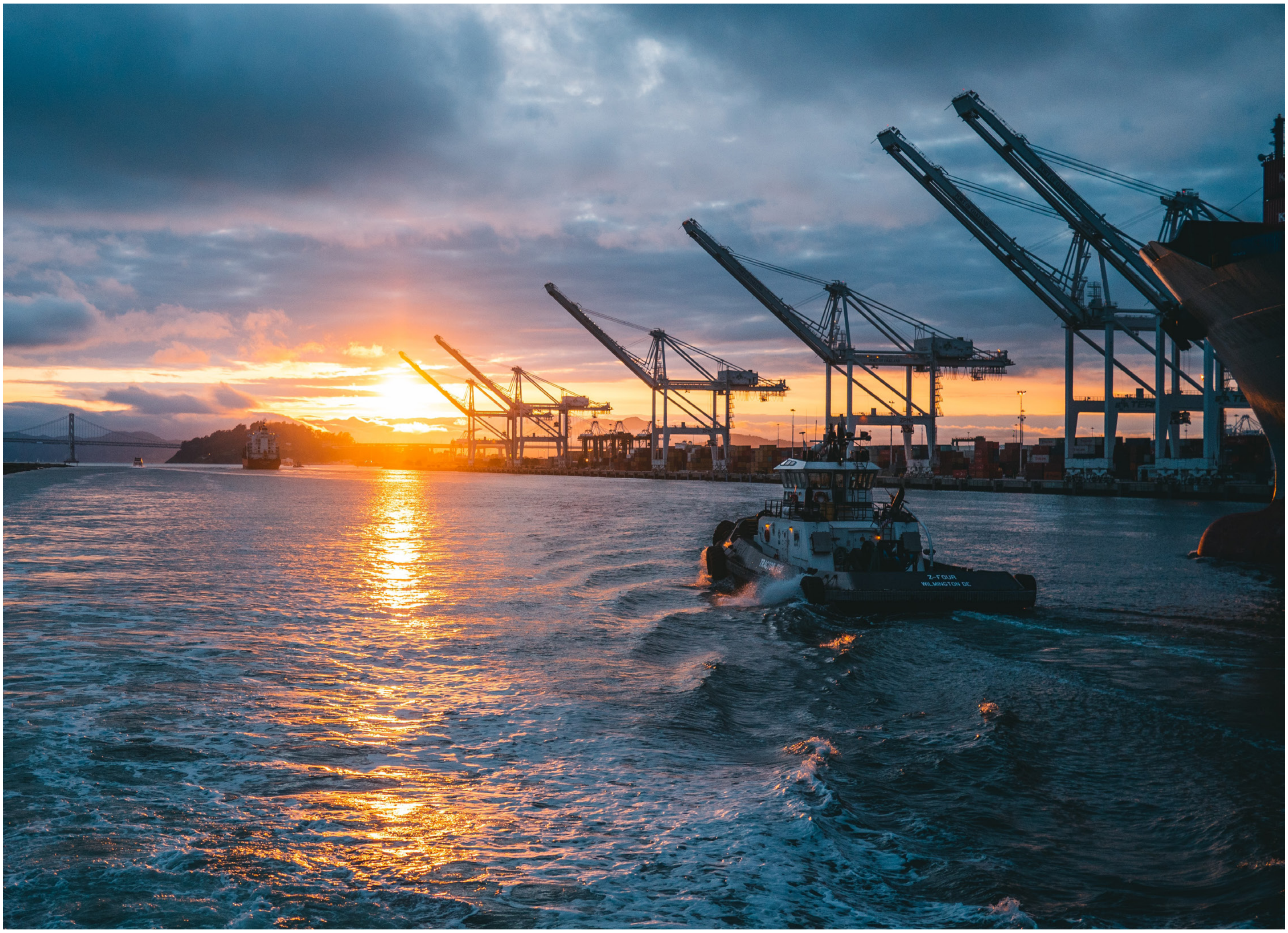
[10] Emissions converted at 3.1 tonnes Co_2 per tonne of diesel.

Finally, the Small < 1,000 HP segment is generally employed in marine construction and shifting of small cargo and work barges. This work results in considerable periods of idle time and time working at low loads. Three tons of steaming consumption would equate to the consumption of a 750 HP Tug working at full load for 24 hours. This estimate is de-rated by the assumption of steaming days to arrive at a representative consumption during an actual working period for a small tug. Nearly all of these tugs operate in a small geographic area and do not have multi-days transits.

Each of the estimated consumption rates for these groups was then compared to actual fuel consumed by a number of specific vessels in each class to test if the assumptions were reasonable. These tests confirmed the overall appropriateness of these estimates.

Given the comparatively small number of tugs in this class combined with the similarly modest total number of operators (particularly of tugs greater than 3,000 HP) a reasonable avenue for further study would be an estimate based on an analysis of each of the tugs in a segment which could be used to further refine this estimate.

Total CO_2 emissions from the coastal tug fleet are **6.8 million tonnes** per year.



CRUISE VESSELS AND FERRIES

The cruise vessel and ferries fleet consolidates ships in ICST categories 335 (General Cargo/Passenger), 351 (Passenger/Cruise), and 359 (Passenger/Other). Figure 9 below shows the composition of the fleet.

Vessel Type	# of Ships	Average Horsepower
General Cargo/Passenger	115	2,400
Passenger/Cruise	456	1,000
Passenger/Other	405	975

Figure 9. Composition of the Cruise Vessels and Ferry Fleet

Our estimate of CO_2 emissions for the cruise vessel and ferry fleet is based on expert assessment of the number of steaming days and fuel consumption per day, for three size classes of the fleet, as shown in Figure 10 below.

Vessel Type	Days per Year		Consumption (tonnes/day)		# Vessels	Total Fuel Consumed (tonnes/year)	CO_2 Emissions[11] (tonnes/year)
	Steaming	In Port	Steaming	In Port			
Large > 5,000 HP	325	30	25	0	35	284,000	880,000
Medium 1,000 < HP < 5,000	275	80	13	0	286	1,022,000	3,168,000
Small < 1,000 HP	230	125	5	0	655	753,000	2,334,000
TOTAL					**976**	**2,059,000**	**6,382,000**

Figure 10. Fuel Consumption and Emissions from the Cruise Vessel and Ferry Fleet

Total CO_2 emissions from the cruise vessel and ferry fleet amounts to **6.4 million tonnes** per year.

The Washington State ferry system is the largest ferry system in North America based on annual passenger count. According to the 2019 Centennial Accord Plan, CO_2 emissions from the ferry system amounted to approximately 190,000 tonnes in 2019, which is approximately 3% of total CO_2 emissions from the Cruise Vessels and Ferry fleet.[12] The plans to electrify the fleet are projected to reduce emissions by 80% by 2040.

The Ferry fleet is particularly challenging to precisely estimate due to the large number of vessels under 1,000 HP. It is believed that most of these vessels might be more properly categorized as "excursion vessels" providing support in recreational environments such as at resorts and small communities where the vessels could be idle for considerable periods of time on a weekly or annual basis. An additional complexity is getting an accurate picture of the allocation of the Medium

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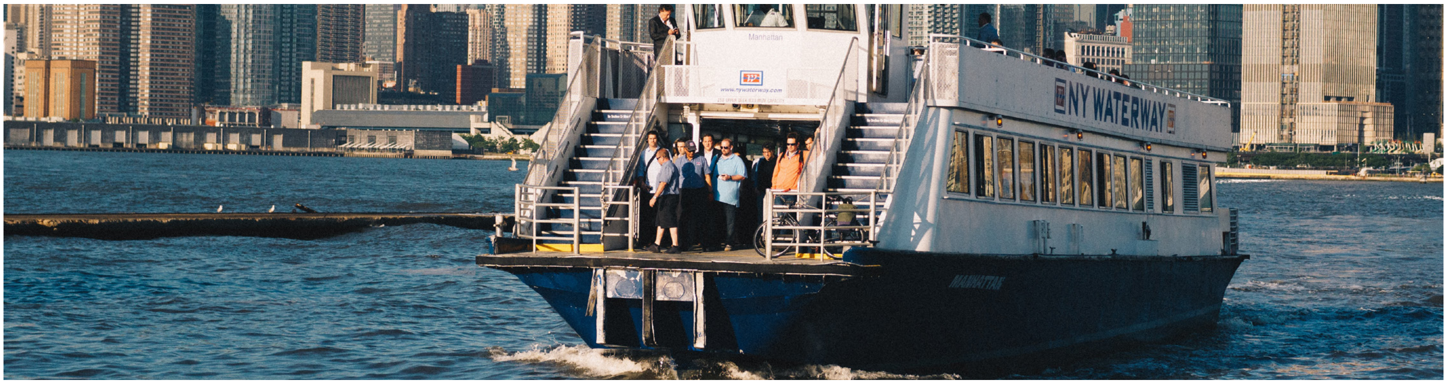
[11] Emissions converted at 3.1 tonnes CO_2 per tonne of diesel

[12] See page 99 of WSF - Long Range Plan - 2040 Plan (wa.gov)

and Large vessel classes between High Speed (20+ knot service) using planning hulls and slow speed displacement services. In general, the high speed ferries will operate almost at full power and thus have significantly more emissions during operations.



During the course of this study, BSMC had limited access to Ferry Operators and thus an area for further study could include working with the Passenger Vessel Association to refine fleet operational profiles for this segment of the NAWT fleet.

TANK VESSEL FLEET

U.S. flag product tankers are listed in ICST code 114 (Liquid Oil Tanker (Oil/Chemical), 120 (Liquid Chemical Carrier), and 199 (Liquid Other Carrier). Tugs dedicated to the ATB trades are listed in ICST code 431; the 108 ATBs were identified after reviewing the 1,878 tugs listed in ICST 431.

The Jones Act tank vessel fleet is deployed in the following trades:

- Cross-U.S. Gulf to South Atlantic Clean Petroleum Products: primarily gasoline to Florida. U.S Gulf Coast refineries to Tampa, Port Everglades, Port Canaveral, and Jacksonville, with some clean products moving to Savannah, GA, and further north.
- Intra-West Coast Clean & Dirty Petroleum: primarily clean products from San Francisco Bay Area and Puget Sound-based refineries to the Southern California market (plus some to the Portland market). Dirty products, crude oil, and refinery feed plus blend stocks also move between the three major refining areas and are included in the West Coast deployment category, as are vessels employed in the Alaskan crude oil trade and vessels trading to/from Hawaii.
- Chemicals and Specialty Products: primarily along the U.S. Gulf and Atlantic Coasts. Renewable diesels moves are included in this category.
- Lower 48 Crude Oil Trades: primarily involving the movement of shale oil, e.g., Eagle Ford or WTI (West Texas Intermediate) crude from Corpus Christi to Gulf Coast refineries (either directly or via LOOP) and Philadelphia / New Jersey / Delaware (Northeast) area refineries. There is also demand for shuttle tankers to move crude oil from deepwater Offshore Gulf of Mexico production vessels (FPSOs) that are not connected to the Gulf of Mexico pipeline gathering systems.
- Military Sealift Command (MSC) Service for the U.S. Navy plus U.S. Government Agency for International Development charters.

The commercially relevant U.S. flag tank vessel fleet includes: 10 crude tankers, 43 product tankers each with a cargo capacity of about 330,000 barrels, and a total of 82 ATBs, each with a cargo capacity of 150,000 barrels to 260,000 barrels.[13] However, the Army Corps' database includes another four "liquid other" tankers, 58 smaller ATB units and six larger ATB units. For consistency with the figures used elsewhere in this report the additional units are included in the carbon footprint calculations.

Leading tanker and ATB owner/operators were consulted to estimate representative voyage parameters and fuel consumption were accurately estimated. The following parameters are used to calculated CO_2 emissions for the tank vessel fleet:

- Steaming Days: number of days per year in which the vessel is underway either delivering oil or returning to pick up another cargo.
- Port Days: number of days per year in which the vessel is in port discharging or loading cargo; fuel is consumed in port to power generators and cargo handling equipment.
- Fuel Consumed Steaming: tonnes per day of fuel consumed including main engine and auxiliaries
- Fuel Consumed in Port: tonnes per day of fuel consumed by auxiliaries and other equipment.

Figure 11 below summarizes the main parameters of our CO_2 emissions estimates. An individual vessel's fuel consumption is the sum of consumption steaming (calculated as the product of days steaming and consumption steaming) and consumption in port (the product of days in port and consumption in port). Note that 10 days per year offhire is assumed, during which no fuel is consumed. Total CO_2 emissions from the tank vessel fleet are estimated to be **3.0 million tonnes per year**.

Vessel Type	Days per Year		Consumption (tonnes/day)		# Vessels	Total Fuel Consumed (tonnes/year)	CO_2 Emissions (tonnes/year)
	Steaming	In Port	Steaming	In Port			
Crude Tanker	250	105	60	15	10	169,000	523,000
Product Tanker	178	177	32	10	48	353,000	1,096,000
ATB (> 140,000 bbls)	145	210	28	4	50	245,000	760,000
ATB (< 140,000 bbls)	145	210	20	3	58	203,000	629,000
TOTAL					**166**	**970,000**	**3,008,000**

Figure 11. Voyage Parameters, Fleet Size, Fuel Consumed and CO_2 Emitted by Tank Vessel Fleet

One 'BBLS' Denotes One Barrel.

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[13] Articulated tug barges consist of a tank vessel (barge) and a large, powerful tug that is positioned in a notch in the stern of the barge, which enables the tug to propel and maneuver the barge. An ATB has an articulated or "hinged" connection system between the tug and barge. This allows movement in the critical area of fore and aft pitch. Operating costs for ATBs are lower than for tankers as a result of lower capital and crew cost.

BULKERS, CONTAINERSHIPS AND ROROS

The bulker, containership, and RoRo fleet is reported in ICST categories 229 (Dry Bulk, Other), 310 (Containership, Specialized), 325 (Other Carriers (Specialized)), and 333 (General Cargo RORO/Container).

These categories include vessels that are engaged in the domestic non-contiguous trade, the international trade, as well as self-unloading ships trading in the Great Lakes. Figure 12 below summarizes the deployment of the fleet.

	Bulker		Containership		RoRo	
	Geared	Self-Unloader	Domestic	International	Domestic	International
Number of Vessels	28	25	19	41	26	3

Figure 12. Composition and Allocation of the Bulker, Containership, and RoRo Fleet

Total emissions from the bulker, containership and RoRo fleet are calculated on the basis of the trading patterns and fuel consumption of representative vessels as shown in Figure 13 below. Note that the steaming and port days for the self-unloaders amount to just 290 days per year because the ships cannot trade during the ice season on the Great Lakes. All other ships are presumed to trade 355 days per year.

Note that this tally includes U.S. flag ships trading internationally.

Vessel Type	Days per Year		Consumption (tonnes/day)		# Vessels	Total Fuel Consumed (tonnes/year)	CO_2 Emissions (tonnes/year)
	Steaming	In Port	Steaming	In Port			
Bulker	270	85	30	10	28	251,000	777,000
Self-Unloader	230	60	30	10	25	188,000	581,000
Containership	270	85	33	2	60	545,000	1,689,000
RoRo	270	85	30	6	29	250,000	774,000
TOTAL					**142**	**1,234,000**	**3,821,000**

Figure 13. Fuel Consumption and CO_2 Emissions of the Bulker, Containership, and RoRo Fleet

Domestic containership operators Pasha, Crowley, Tote, and Matson have made or are in the process of making huge changes in the use of LNG vessels. Conversion to LNG power represents a potential 25% reduction of GHG and between 90-97% reduction of NOx, SOx, and PM emissions. By 2024, two-thirds of the containerships operating in the U.S. domestic market are expected to be powered by LNG.

Total CO_2 emissions from the bulker, containership, and RoRo fleets, as of 2018, amount to **3.8 million tonnes per year**.

REMAINING U.S. AND CANADIAN FLAG FLEET

Emissions calculations based on representative voyage and vessels could be calculated for the bulk of the U.S. Flag fleet. Less detailed information is available on the remaining vessels in the fleet; our estimates for that residual are summarized below. Canadian emissions reporting did provide information by specific vessel type but did not provide the flag for the vessel; we used the following assumptions.

REMAINING U.S. FLAG FLEET

ICST code 329 (Other Carriers (Specialized)) lists almost 600 vessels for which no further trading information is available.

The operating profile and fuel consumption of the remaining vessels in the U.S. Flag fleet are assumed to match the profile of the coastal and harbor tug fleet. See Figure 14 below.

Vessel Type	Days per Year		Consumption (tonnes/day)		# Vessels	Total Fuel Consumed (tonnes/year)	CO_2 Emissions (tonnes/year)
	Steaming	In Port	Steaming	In Port			
Large > 5,000 HP	210	145	22	0.2	65	302,000	937,000
Medium 1,000 < HP < 5,000	175	180	15	0.1	243	642,000	1,991,000
Small < 1,000 HP	125	230	3	0	249	19,000	58,000
TOTAL					**557**	**963,000**	**2,986,000**

Figure 14. Fuel Consumption and CO_2 Emissions of the Remaining U.S. Flag Fleet

Total CO_2 emissions from the remaining U.S. Flag fleet amount to **3 million tonnes per year**.

EMISSIONS FROM CANADIAN FLEET

Environment Canada publishes the Marine Emissions Inventory Tool (https://ec-meit.ca/) that details emissions by type of ship, origin and destination of the ship, and by region within Canada.

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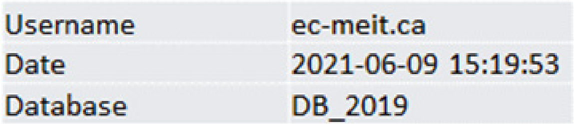

Username	ec-meit.ca
Date	2021-06-09 15:19:53
Database	DB_2019

The report does not differentiate emissions by flag. We associated Canadian flag merchant vessels with selected vessel types: Merchant Ferry, General, and Tug, Tug Supply, Merchant Auto, Ocean Tug, Special Purpose, Merchant Coastal, and Excursion, Rail/Trailer Ferry, Special Purpose Pilot.

Total CO_2 emissions from the Canadian flag fleet thus defined amount to **1.7 million tonnes per year**.

FLEET SUMMARY

Total CO_2 emissions from the 9,500 vessels in the NAWT fleet amounted to approximately 47 million tonnes in 2018, as summarized below in Figure 15.

Fleet	Fuel Consumption[14] (million tonnes)	CO_2 Emissions (million tonnes)
Offshore Supply Vessels	4.2	13.0
Inland Tug Fleet	3.0	9.3
Coastal and Harbor Tug Fleet	2.2	6.8
Cruise Vessels and Ferries	2.1	6.4
Tank Vessel Fleet	1.0	3.0
Bulker, Containership, and RoRo	1.2	3.8
Remaining U.S. Flag	1.0	3.0
Canadian Flag	0.5	1.7
TOTAL	**15.2**	**47.0**

Figure 15. Summary of North American Waterborne Transportation Fleet Fuel Consumption and Emissions

That amounts to just 0.13% of global CO_2 emissions[15], 0.7% of emissions from the U.S. and Canada[16], and 4.5% of total CO_2 emissions from the international fleet (as reported by the IMO in the 4th Greenhouse Gas Study).

The largest single contributor to NAWT emissions is the offshore support vessel fleet, amounting to 28% of total NAWT emissions. Although the offshore support vessel fleet accounts for about 17% of the NAWT fleet, the vessels have relatively high fuel consumption and utilization.

The inland tug and pushboat fleet is the second largest contributor, at 9.3 million tonnes or 19% of total NAWT emissions. The coastal and harbor tug fleet and ferries are the third and fourth largest contributors, at 6.8 million tonnes and 6.4 million tonnes respectively, or 14% apiece of total NAWT emissions.

Tankers and ATBs account for just 3.1 million tonnes or 6% of total NAWT CO_2 emissions.

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[14] When not estimated directly as part of the emissions calculation fuel consumption was estimated by dividing CO_2 emissions by 3.1 (the number of tonnes of CO_2 emitted by burning 1 tonne of bunker fuel).

[15] Total Global GHG CO_2 emissions in 2018 is 36,573 million mt (IMO 4th GHG Study)

[16] Gross U.S. CO_2 emission is 5,916.6, and Canada is 740 million mt.

CHAPTER 2: EMISSIONS FROM NORTH AMERICA PORTS

This chapter reviews port emissions data from North American ports.

The U.S. Bureau of Transportation statistics provide data on port throughput (in short tons) for U.S. Water Ports and for the top 50 Water Ports dated 2018.[17] Tonnage totals include both domestic and foreign waterborne trade.

The top 25 tonnage ports handled a total of 1,880 million tons of cargo, 80% of the total tonnage handled by all U.S. ports. The Houston Ship Channel port complex and its public and private terminals, collectively known as the Port of Houston, is the number one port in the U.S. in terms of total throughput, accounting for 12% of total tonnage throughput in the U.S. in 2019.

Three out of the top 10 ranked tonnage ports, New York/New Jersey, Long Beach and Los Angeles published emission inventory reports for 2018, and the Port of Houston published data for 2019, which are used for this evaluation. The port-published annual Emission Inventory Reports following the EPA Port Emissions Inventory Guidance, usually contain categories of the following emission sectors and total emissions:

1. Ocean-Going vessels
2. Harbor Craft
3. Cargo Handling Equipment
4. (rail) Locomotives
5. Heavy-duty Vehicles

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[17] The DoT reports also show throughput in teu; we chose to focus solely on tonnes for this report.

Emissions are reported in CO_2e terms in which methane and nitrous oxide are converted to CO_2 terms by applying a weight of 25 and 298 respectively. (CO_2 has a weight of 1.0.)

Total U.S. port throughput in 2018 is approximately 2,349 million tons. Total Canadian port tonnage is 335 million tons, based on the 2017 reporting. With the CO_2e emissions and throughput known at each port, the ratio of CO_2e to tonnage can be established. The aggregate emission/tonnage ratios (the sum of emissions for the four ports divided by total throughput for the four ports) are shown in Figure 16.

	Houston (Complex)[18]	New York / New Jersey	Long Beach	Los Angeles	Total
Throughput (million short tons)	285.0	140.3	86.5	67.8	563.6
CO_2e Emissions (mm tonnes)					
Total	1.64	0.68	0.84	0.93	4.09
Ocean Going Vessels	0.94	0.17	0.30	0.21	1.61
Cargo Handling Equip.	0.07	0.12	0.12	0.19	0.50
Emissions/Tonnage Ratio					
Total	0.006	0.005	0.010	0.014	0.007
Ocean Going Vessels	0.003	0.001	0.003	0.003	0.003
Cargo Handling Equip.	0.0003	0.001	0.001	0.003	0.001

Figure 16. Throughput and CO_2e Emissions in Selected U.S. Ports

With the four-port baseline established we estimate the total CO_2 emissions at all North American ports by applying the four-port emissions ratios to the total North American throughput to yield 18.6 million tonnes of CO_2e emissions at North American ports – see Figure 17 below.

	Throughput (million short tons)	Emission CO_2e (mm tonnes)		
		Total Port	Ocean-Going Vessels	Cargo Handling Equipment
Total U.S.	2,348.8	16.6	6.5	2.0
Total Canada	335.0	2.4	0.9	0.3
Total North America	2,683.8	18.9	7.5	2.3
Total North America CO2 (mm tonnes)		18.6	7.3	2.3

Figure 17. North American Port CO_2e Emissions, Total and by Activity

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[18] Total tonnage here refers to the Houston Port Complex, which includes the Houston Ship Channel.

According to the IMO's fourth GHG study, CO_2e emissions from shipping amounted to 1,076 million tonnes in 2018, while CO_2 emissions amounted to 1,056 million tonnes or 98% of CO_2e emissions. [19]

Applying that 98% ratio leads to an estimate of CO_2 emissions from North American ports of **18.6 million tonnes per year** of which 7.3 million tonnes is attributable to foreign flag vessel loading or discharging in North American ports.

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[19] Fourth Greenhouse Gas Study 2020 (imo.org)

CHAPTER 3: FUTURE FUEL MARKET BASED ON EMISSIONS

This chapter reviews the net-zero fuels required to replace existing fuels and the amount of electricity that would be required to produce them.

The above chapters help us understand the current emissions profile of the NAWT industry. In order to provide a perspective on the implications of decarbonization of our industry, we estimate in this chapter the tonnes of zero emissions fuel required to replace diesel and bunker oil and the electricity required to produce the zero-emissions fuel.

The NAWT fleet consumed 15.0 million tonnes of fuel in 2018 and emitted 47 million tonnes of CO_2. For the purpose of the net zero-fuel requirements, we focus solely on replacing the 15.0 million tonnes of petroleum-based fuel with e-fuels: eLNG (methane), methanol, ammonia, and hydrogen.

ZERO-EMISSIONS FUEL REQUIREMENTS

Net-zero fuels are essential to decarbonize the North American waterborne transportation business. The net-zero, alternative fuels considered for this chapter are (bio-)LNG, methanol, ammonia, and hydrogen. The equivalent quantity of the alternative fuels are determined through two properties: lower heating value (kg) and energy density as liquid (m3). This is meant to provide a comparison in energy consumption, with fuels as energy carriers. The energy conversion efficiency is not taken into consideration for this analysis.

The table below shows in million tonnes and million cubic meters of net-zero emission fuels to produce the equivalent energy to 15.2 million tonnes of fuel oil to power the NAWT fleet.

Fuels[20]	**Equivalent Weight By Lower Heating Value**[21] **(million tonnes)**	**Equivalent Volume By Energy Density (million m3)**	**25% of Fleet Using Green Fuels in 2030 (million tonnes)**
Fuel Oil (40.2 MJ/kg, 39.80 MJ/L, 991 kg/m3)	15.2	15.5	3.9
eLNG (48.0 MJ/kg, 20.6 MJ/L, 430 kg/m3)	12.9	30.0	3.2
Methanol (19.9 MJ/kg, 15.7 MJ/L, 790 kg/m3)	31.1	39.4	7.8
Ammonia (22.5 MJ/kg, 15.7 MJ/L, 790 kg/m3)	27.5	39.5	6.9
Hydrogen (120.2 MJ/kg, 8.51 MJ/L, 696 kg/m3)	5.2	72.7	1.3

Figure 18. Zero Emissions Fuel Requirement of the NAWT Fleet

Net-zero fuels are not currently produced in North America at scale. Small quantities of “grey” (i.e., CO_2 is emitted in production) methanol, ammonia and hydrogen is in production for other industrial uses, but they are well below the tonnes of net-zero, green fuels needed to power the NAWT fleet.[22]

Total green methanol production funded by Maersk is reported to amount to 0.7 million tonnes/year by 2025[23] fuel and 6 million tonnes/year by 2030 globally. Additionally, Maersk has set a target to have 25% of their fleet running on green fuels such as methanol, biodiesel, and ammonia.[24] Applying that 25% green fuels target to the NAWT fleet would imply that 7.8 million tonnes of methanol, 6.9 million tonnes of ammonia, or 1.3 million tonnes of hydrogen would be required.

ELECTRICITY REQUIREMENTS FOR NET-ZERO FUEL PRODUCTION

To achieve net-zero emissions in 2050, alternative fuels are considered due to their low/zero carbon property. However, to achieve a net-zero footprint, the alternative must either utilize carbon capture or renewable energy sources.

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[20] Fuel characteristics are from ABS Whitepaper: Hydrogen as a Marine Vessel Fuel

[21] The lower heating value is also known as calorific value of a fuel, it shows the amount of heat released during combustion with a specific quantity of fuel at a specific temperature range (initially at 25C and returning at 150C). This value disregards the latent heat for water vaporization during the process

[22] Total Grey Methanol produced in United States in 2019 is 9.4 million tonnes/year; see U.S. Energy Information Administration - EIA - Independent Statistics and Analysis

[23] Manifold Times | Maersk secures methanol bunker fuel supply for newbuilds with strategic partnerships

[24] Maersk: Our Methanol Demand Could Reach 6 Million MT/Year by 2030 - Ship & Bunker (shipandbunker.com)

The recently published report, *Fuelling the Fourth Propulsion Revolution*,[25] by the International Chamber of Shipping, estimates the electricity generation (in kWh) needed to produce one kWh of hydrogen-based fuels for the maritime sector from different sources. The authors calculated a range of values based on the International Energy Agency's 2030 outlook as shown in Figure 19.

Fuel	Avg Min.	Average	Avg Max.
eMethane	1.55	**1.78**	2.00
Methanol	1.62	**1.85**	2.07
Ammonia	1.55	**1.78**	2.00
Hydrogen	1.19	**1.37**	1.54

Figure 19. Renewable Energy Required to Produce Hydrogen-Based Fuels (kWh)

The diesel and bunker fuels consumed by the NAWT fleet is equivalent to 619 petajoules (TJ)[26] or 172 terawatt-hours (TWh)[27] in energy. Applying the average energy needed to produce the hydrogen-based net zero fuels from Figure 19 above, Figure 20 shows the total quantity of renewable energy needed for each particular fuel.

Fuel	Quantity (million tonnes)	Renewable Energy Needed for Production (TWh)	Renewable Energy Needed for 25% NAWT Fleet in 2030 (TWh)
eMethane	12.9	305.24	76.3
Methanol	31.1	317.28	79.3
Ammonia	27.5	305.24	76.3
Hydrogen	5.2	234.73	58.7

Figure 20. Energy (GWh) Required to Produce Net-Zero Emissions Fuels for the NAWT Fleet

To provide some perspective, the 2022 Annual Energy Outlook,[28] published by the EIA, documents the total amount of renewable energy produced in the U.S. with forecasts to 2030. Renewable energy produced in 2021 is 1418 TWh, and the projected total renewable energy doubles by 2030.

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[25] "Fuelling the Fourth Propulsion Revolution, An Opportunity For All," International Chamber of Shipping, Dr. Stefan Ulreich, University of Applied Sciences May 2022.Fuelling-the-Fourth-Propulsion-Revolution_Full-Report.pdf (ics-shipping.org)

[26] Petajoules (PJ) is 10^15 Joules (J)

[27] Terawatt-hour (TWh) is 10^12 watt-hour (Wh)

[28] U.S. Energy Information Administration - EIA - Independent Statistics and Analysis

If hydrogen were the energy carrier used to power the entire NAWT fleet, (174 TWh), 9% of U.S.'s renewable energy would be consumed to produce 5.2 million tonnes of hydrogen in 2030. See Figure 21 below.

Year	Renewable Electricity Production (TWh)	% Needed to Produce All Hydrogen for NAWT	% Needed to Produce for 25% NAWT Fleet
2021	1,418	16.7%	4.1%
2030	2,761	8.6%	2.1%

Figure 21. NAWT Demand for Electricity to Produce Net-Zero Fuels

The Biden administration has set a target for offshore wind projects to reach 30 GW by 2030. The U.S. has a 30.7 GW pipeline of offshore wind projects, a sufficient amount to meet the target.[29] Assuming a 35% capacity factor for U.S. offshore wind, the 30.7 GW of offshore wind capacity planned would be equivalent to 94 TWh. It would take 62% of all U.S. offshore wind capacity to produce enough hydrogen to power 25% of the NAWT fleet.

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[29] U.S. offshore wind pipeline reaches 30.7 GW | S&P Global Market Intelligence (spglobal.com)

CHAPTER 4: OPERATIONAL MEASURES

This chapter identifies various operational factors that complement the fuel transition described above.

Although net-zero fuels are essential to reach net-zero emissions from the NAWT business, several operational factors can also have an important impact on fuel consumption. The operational measures complement the fuel transition described above and, in some cases, could be accomplished more quickly.

Advances in cellular, satellite, and internet-based communications over the past decade have opened up new opportunities to optimize the use of existing vessels. Such optimizations can now be based on real-time, high-quality data on vessel traffic, weather forecasts, port and berth congestion to provide predictive models. These models will require the involvement of all elements of the supply chain to provide up-to-date information to a shared clearinghouse.

The benefit of these models is that vessels could be confidently operated at the best economic speed (lowest fuel consumption and therefore emissions) available to get the cargo to the berth for a specific time slot rather than the next open availability. Current business practices cause vessels to arrive as quickly as possible, consuming more fuel in transit and then in most instances, only to wait at anchor where more fuel is consumed generating onboard electricity.

Operational factors discussed within the BSMC Commercial, Finance, and Chartering Workstream include:

- Speed and consumptions clauses in Time Charter contracts
    - Create financial payback mechanisms for investment in vessel modifications intended to reduce consumption
    - Co-ordination on voyage optimization software/vessel routing
- Change incentives to make voyage charters more efficient in the context of port delays and port congestion (i.e., slow down to reduce consumption on voyage and extra consumption while in port). This requires co-ordination with terminals to redefine NOR conditions for commencement of demurrage
- Financial incentives for alternatives to CO_2 as inert gas solutions in appropriate cases
- High level alignment of owners and charterers to remove ascendency of traders in chartering activities with “zero sum” approach to chartering
- Increase flexibility of discharging times, shoreside labor capacity, and shoreside trucking capacity to reduce the “hurry up and wait” character of the harbor tug business

These operational considerations are also important in the international trades and an innovative approach addressing both optimal voyage planning and commercial considerations has recently been announced by the Blue Visby Consortium.[30]The consortium includes leading stakeholders in the shipping industry, including the Ocean Conservancy, the Tankers International pool, Lloyd’s, NAPA OY, and Stephenson Harwood.

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[30] Home - Blue Visby Solution

CHAPTER 5: THE OCEAN CONSERVANCY REPORT

This chapter identifies and addresses differences between BSMC's analyses and those of the OC and UMAS.

In January 2022, the Ocean Conservancy ("OC") produced a white paper titled *The Maritime Fleet of the USA – The Current Status and Potential for the Future* that provides an inventory of estimated CO_2 emissions from the U.S. Maritime Industry. [31,32]

BSMC welcomes OC's efforts and the perspective it brings to the emissions issues at hand. The OC employed a different manner of estimating vessel emissions, which in certain circumstances yielded different emissions estimates, but in other segments aligns closely with BSMC estimates. While OC and BSMC may have differing policy suggestions, we do share the same ultimate goal. In fact, OC and BSMC have discussed the differences in carbon emissions estimates and have agreed that further dialogue would be productive. BSMC welcomes OC and others to join in this important conversation.

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[31] Bonello, J., Velandia Perico C., Taylor, J., and Smith, T. (2022) The Maritime Fleet of the USA – current status and options for the future – Rev 2.0. UMAS, London

[32] About Us - Ocean Conservancy

The OC estimates are based on their interpretation of Automatic Identification System (“AIS”) data, an approach pioneered by the study’s authors and adopted by the IMO, most recently, the GHG4 report. BSMC’s estimates are derived from an assessment of the operating profiles and fuel consumption by sector. The assessments were conducted by individuals drawn from the BSMC membership with significant experience as owner/operators in the respective sectors. They are deeply familiar with the operations of their fleet. Analysis of AIS data offers a direct measure of vessel utilization that complements the expert judgment methodology. Reconciling the OC and BSMC reports will help to shed light on NAWT emissions.

Although a comprehensive assessment of the OC report is beyond the scope of this analysis, it is noteworthy that the CO_2 emissions estimates derived by BSMC are more than twice those estimated by UMAS. Figure 22 below compares the BSMC and UMAS estimates for selected categories of the U.S. flag fleet. The UMAS datapoints are drawn from Figure C2 in the OC report.

BSMC Vessel Types	**CO_2 Emissions** (million tonnes)		**UMAS Vessel Type** (See OC's Figure C2)
	BSMC	UMAS	
Offshore Supply Vessels	13.0	3.5	Offshore
Inland Tug & Pushboat	9.3	3.5	Tug
Coastal & Harbor Tug	6.8		
Cruise Vessel and Ferries	6.4	1.4	Cruise, Pax only, Ro-Pax
Bulker, Containership, RoRo	3.8	7.1	Bulk Carrier, Chemical Tanker, Container
Tankers & ATBs	3.0	0.8	Oil Tanker
Other	3.0	4.0	
Subtotal	*45.3*	*20.4*	
Fishing		5.6	Fishing
Total	**45.3**	**26.0**	

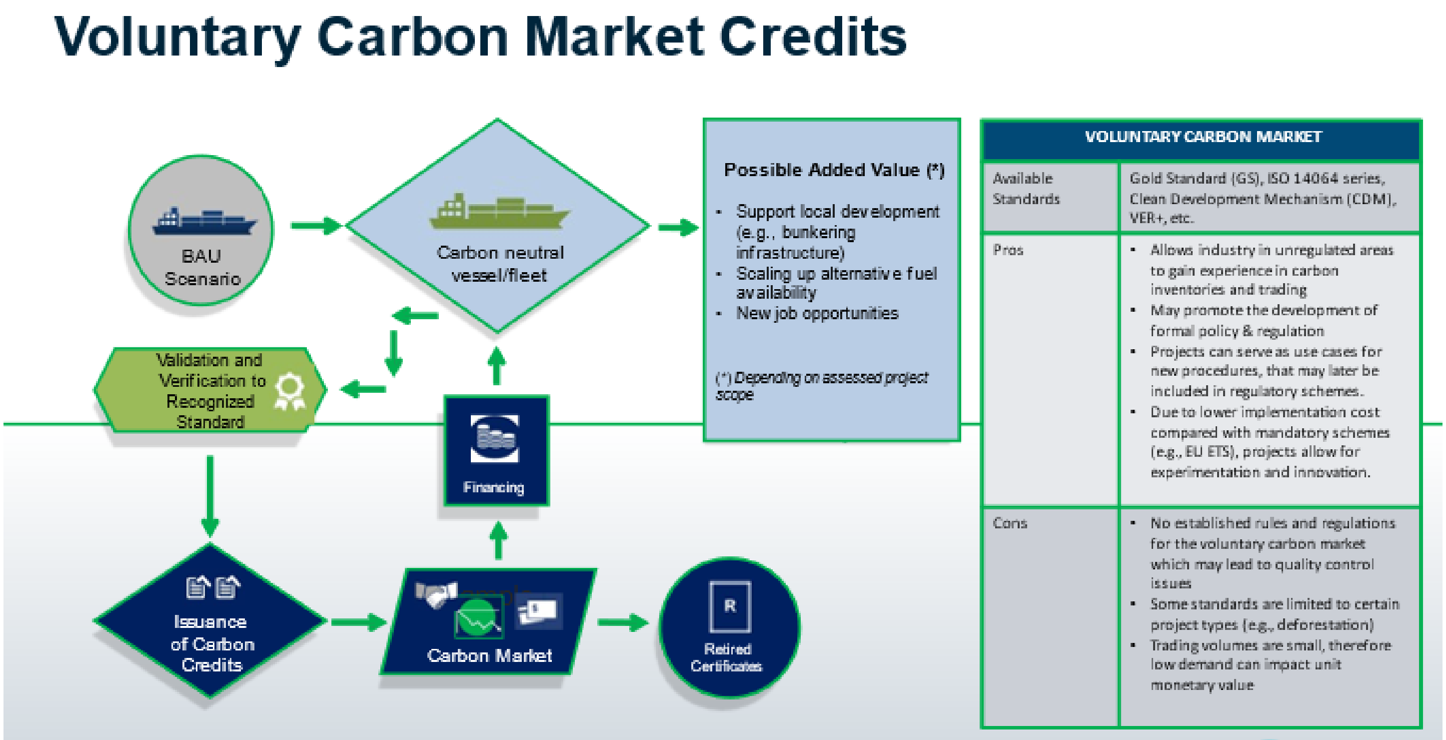
Figure 22. Comparison of BSMC and UMAS CO_2 Emissions Estimates for U.S. Only

Above table excludes Canadian Flag vessels as UMAS report focused only on U.S. Flag fleet.

CHAPTER 6: VOLUNTARY CARBON MARKETS

This chapter provides a background on the voluntary carbon market and the important role it plays for NAWT businesses.

The voluntary carbon credit market is a means for companies to meet their decarbonization targets. Figure 23 below displays key components of the carbon credits market. The Business As Usual ("BAU") Scenario is the baseline against which emissions reductions are measured. The actual emissions from a ship or other investment are recorded according to an agreed mechanism specified by a carbon registry (Gold Standard, VERA, etc.). An independent third party audit of the savings is performed by a Validation and Verification Body ("VVB"). Credits are issued by the carbon registry and sold in the international Voluntary Carbon Market ("VCM"). Proceeds from the sale of the credits are returned to the project thereby defraying some of the cost of the emission-reducing investment.



Possible Added Value (*)

- Support local development (e.g., bunkering infrastructure)
- Scaling up alternative fuel availability
- New job opportunities

(*) Depending on assessed project scope

VOLUNTARY CARBON MARKET	
Available Standards	Gold Standard (GS), ISO 14064 series, Clean Development Mechanism (CDM), VER+, etc.
Pros	▪ Allows industry in unregulated areas to gain experience in carbon inventories and trading ▪ May promote the development of formal policy & regulation ▪ Projects can serve as use cases for new procedures, that may later be included in regulatory schemes. ▪ Due to lower implementation cost compared with mandatory schemes (e.g., EU ETS), projects allow for experimentation and innovation.
Cons	▪ No established rules and regulations for the voluntary carbon market which may lead to quality control issues ▪ Some standards are limited to certain project types (e.g., deforestation) ▪ Trading volumes are small, therefore low demand can impact unit monetary value

Figure 23. Main Elements of the Voluntary Carbon Market[33]

The VCM is an increasingly important option for entities that have already reduced their direct emissions and seek to offset business operations which are difficult to decarbonize. They buy credits in the market and take credit for the emissions reduction from the approved project as a contribution to their net-zero emissions goals.

E&Y's report, *Essential, Expensive and Evolving: The Outlook for Carbon Credits and Offsets*, highlights the growing demand for carbon offsets in light of the rapid increase in corporate net zero pledges. The price of credits in the VCM is a function of the nature of the projects (some kinds of "nature based" or "removal" credits achieve higher valuations than "abatement" or "reduction" credits), the demand for credits and the available supply.

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[33] Source: Blue Sky Maritime Coalition

EY assigns a $25/tonne current value (USD) to nature-based carbon credits as of end-2021 and projects a future valuation of $80-150 USD by 2035, a little over one decade from the writing of this report. (See Figure 25.) Regardless of an initial price of $5 or $25/tonne, the carbon credit valuations will continue to increase as technologies evolve and society and industries' decarbonization goals progress.

Blackstone's recent $400 million investment in Xpansiv ([Homepage - Xpansiv]), the leading carbon exchange, indicates the perceived value of the VCM. Xpansiv publishes the CBL GEO and NGEO indexes which track CORSIA-compliant and nature-based credits respectively. Figure 24 below shows recent developments in the CBL GEO index.

Aviation Industry Carbon Offset

GEO's futures contracts follow the International Civil Aviation Organization's CORSIA standard. These carbon offsets from three major registries – Verra, the American Carbon Registry, and the Climate Action Reserve. Because it is based on high-quality carbon credits that adhere to the international aviation industry standard for emissions offsetting. They are sometimes referred to as "Aviation Industry Carbon Offsets".

Figure 24. Recent Developments in the CBL GEO Carbon Credit Price

The value of a 1 tonne reduction of CO_2 emissions in the voluntary carbon market has averaged approximately $5/tonne in 2022.[34]

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[34] Based on the CBL GEO index.

The value of eliminating the NAWT fleet's CO_2 emissions is nearly $250 million per year on that basis, a present value of $2.3 billion at a 10% discount rate.

BSMC is assessing the potential that carbon credits offer to finance emissions reduction in the NAWT fleet. Although the emissions reduction potential is significant, there is no existing commercial structure or agreement in place that aligns the interests of charterers, owners, and investors to decarbonize the NAWT business. BSMC is collaborating with leading decision makers in the industry to create such an arrangement.

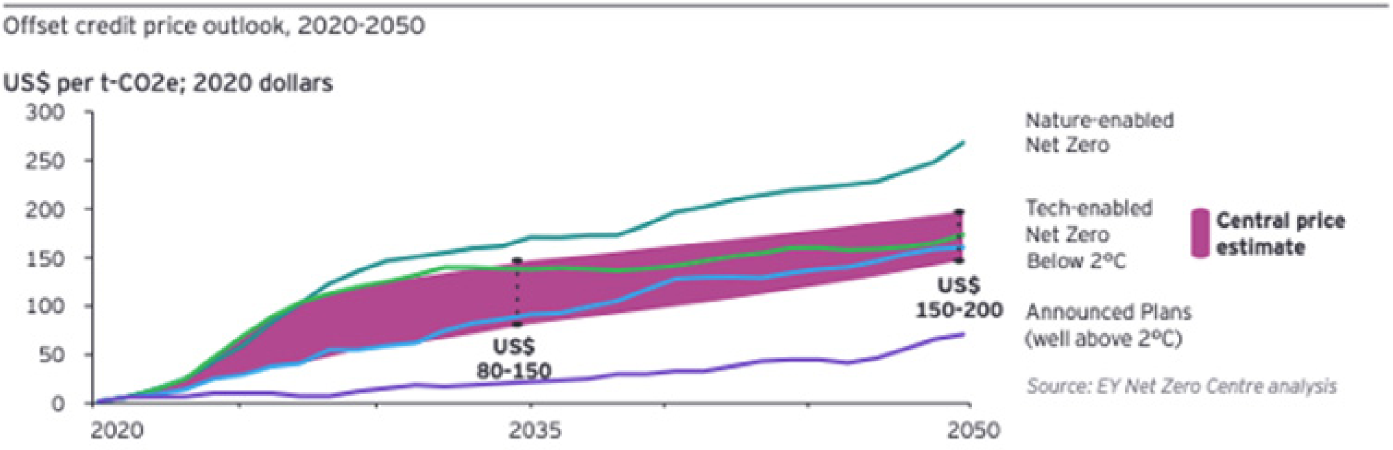

Figure 25. E&Y Carbon Offset Credit Price Outlook

REFERENCES

Type	Title	Link
Data	Tonnage of Top 50 U.S. Water Ports, Ranked by Total Tons	https://www.bts.gov/content/tonnage-top-50-us-water-ports-ranked-total-tons
Data	Canadian Port Authorities and Statistics	https://tc.canada.ca/en/marine/backgrounder-canada-s-port-system
Report	AAPA Port Industry Stats	https://www.aapa-ports.org/unifying/content.aspx?ItemNumber=21048
Report	Port of Houston 2021 Goods Movement Emissions Inventory	https://porthouston.com/wp-content/uploads/Port-Houston-2019-GMEI-Report_Dec-2021.pdf
Report	Port of LA Air Emission Inventory	https://www.portoflosangeles.org/environment/air-quality/air-emissions-inventory
Report	Port of Long Beach Air Emission Inventory	https://polb.com/environment/air/#emissions-inventory
Report	Port of NYNJ Air Emission Inventory	https://www.panynj.gov/port/en/our-port/sustainability/air-emissions-inventories-and-related-studies.html
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