Ogden Point Deep-Water Terminal

Emissions Inventory

2010, 2014 & 2018

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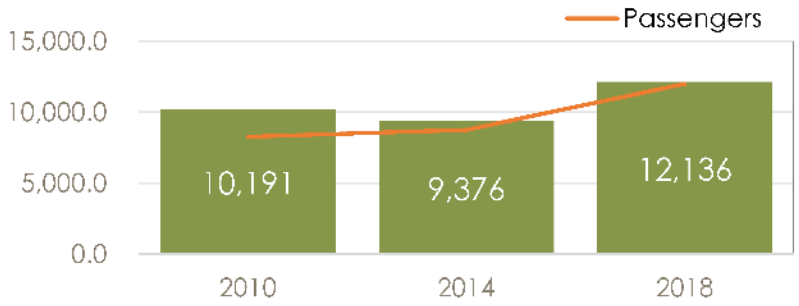
Completed	10/15/2019

GREATER VICTORIA HARBOUR AUTHORITY

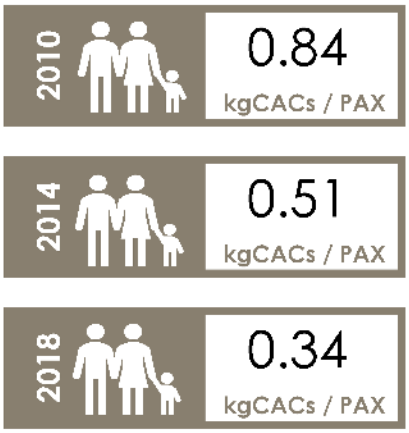
synergy

Executive Summary

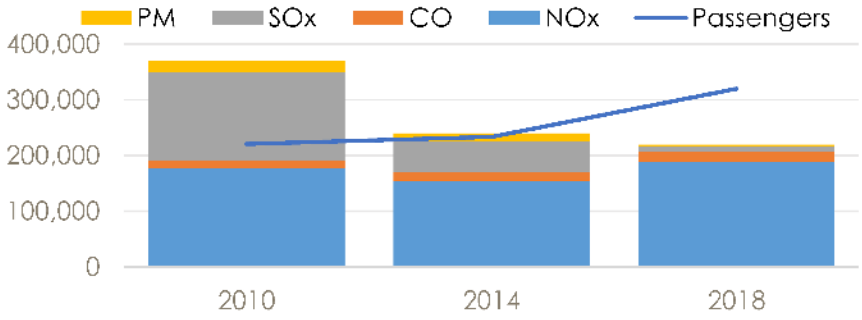
Annual GHG Emissions (tCO_2e)



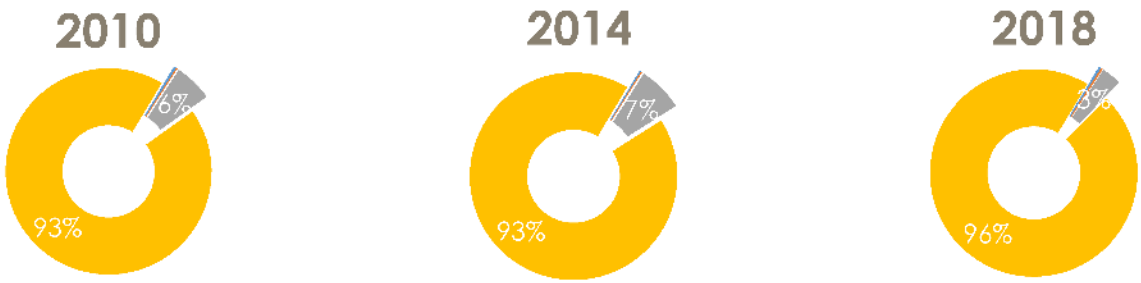
Since 2010, cruise ship passengers through Ogden Point have increased 45% while Greenhouse Gas (GHG) emissions from all terminal activities have only increased 19.1%. Meanwhile, due to increasingly stringent fuel emission standards, emissions of Criteria Air Contaminants (CACs) such as NO_X & SO_X have decreased by 41%.



Annual CAC Emissions
(PM, SOx, CO & NOx in kg)



GHG Emissions by Category



About This Report

The Greater Victoria Harbour Authority (GVHA) owns and operates deep water, marina, and upland holdings throughout Victoria's harbour. GVHA's Ogden Point terminal is currently the busiest cruise ship port-of-call in Canada. Under GVHA's stewardship, cruise tourism has grown from 212 ship calls carrying 440,000 passengers in 2010 to a record number of 243 cruise ships and 640,000 passengers welcomed during the 2018 season. This growth in cruise tourism has become an important economic driver for the capital region.

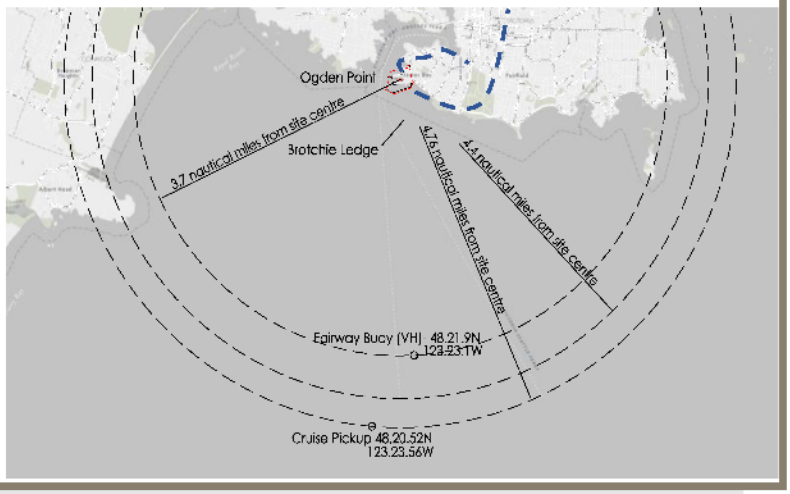
Over the years, GVHA has made strides to reduce the environmental impact of the terminal through contracts mandating electric bus transportation, lighting and equipment. This emissions inventory traces the historical, current and future Greenhouse Gas (GHG) emissions from buildings, equipment, and transportation, and Criteria Air Contaminant (CAC) and GHGs from cruise operations at Ogden Point in 2010, 2014 and 2018.

Geographic Boundary

All buildings and equipment located at Ogden Point have been included in the inventory.

Transportation of all passengers ashore to common tourist destinations has been estimated.

Cruise ship emissions have been measured to a point 4.4 nautical miles outside the terminal, 2 nm south of the 'VH' buoy. This is the pilot boarding location for cruise vessels.



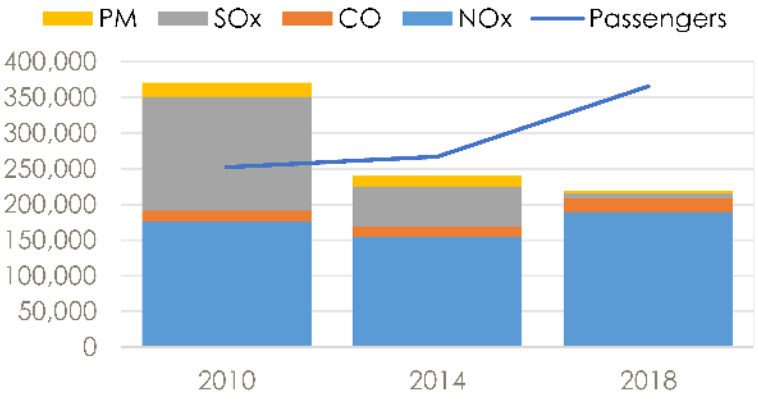
Emission Sources

In accordance with the GHG protocol, emissions from GVHA and Western Stevedoring have been included in Scope 1, because Western's services are contracted directly by GVHA to support cruise operations. Cruise and other Tenant emissions make up Scope 3. Within each scope, emissions have been grouped into categories including buildings, equipment, ground transportation and ocean going vessels.

	Buildings	Equipment	Transportation	OGVs	
GVHA Owns & operates Ogden Point	Maintenance Shop GVHA office (2010 & 2014)	Vehicles Ground Service Equipment Propane Heaters	Leased Shuttles (2014)		Scope 1 & 2
Western Stevedoring Responsible for cruise services	Western's office Pier A Warehouse	Ground Service Equipment	CVS Tours (2010) PNWTS Buses & Shuttles (2018)		Scope 1 & 2
Cruise 20-30 ship arrivals per year				Ocean Going Vessels (OGVs)	Scope 3
Other Tenants Various tenant businesses	Helijet CVS Tours Victoria Harbour Ferries	Food Trucks Harbour Crafts (GMS Cable Innovator)	Taxis Buses Shuttles		Scope 3

Criteria Air Contaminant (CAC) Summary

Annual CAC Emissions
(PM, SOx, CO & NOx, in kg)



**Note: CACs have not been measured for landside emission sources.*

2010: IMO's revised Annex VI entered into force, requiring new engines installed on vessels constructed after 2000 to comply with Tier 1 NOx emission standards, after 2011 with Tier 2 standards, and after 2016 with Tier 3

2012: Low sulphur fuel requirements limiting sulphur content to 1% in Emissions Control Areas

2015: Low sulphur fuel requirements in 2015 limiting sulphur content to 0.1% in Emissions Control Areas

Criteria Air Contaminants from cruise ship emissions do not contribute significantly to climate change, however, they do impact air quality and in high concentrations can pose risks to human health. The International Maritime Organization (IMO) has been steadily increasing regulations on fuel and engine emissions in order to avoid unhealthy concentrations of pollutants in the air.

Between 2010 and 2018 total passenger arrivals at Ogden Point increased 45%. At the same time, total annual air contaminants decreased 41% and contaminants per passenger decreased 59% due to two factors:

1. The North American Emissions Control Area (ECA) came into effect in 2012, resulting in stricter controls on emissions for ships trading off the coasts of Canada and the US.

2. Vessels continue to be built using more efficient engines and auxiliary power systems.

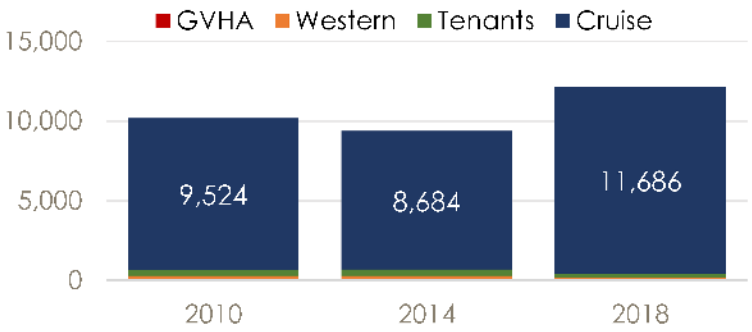
Hourly readings of air emissions taken at the James Bay monitoring station reveal a decrease in the number of days in which average sulphur emissions were either 'Moderate' or 'Unhealthy for Sensitive Groups', from 15 days in 2011, to 9 days in 2014, to 0 days in 2017. There have been no 'Unhealthy' readings at this station since it was installed in 2011.

Intensity Metrics		Grams of CAC emissions per cruise ship passenger			Kilograms of CAC emissions per cruise ship call		
Year		2010	2014	2018	2010	2014	2018
NOx	Nitrogen Oxides	**400.42**	**332.08**	**296.17**	**807.00**	**761.09**	**779.77**
CO	Carbon Monoxide	**32.77**	**29.72**	**28.78**	**66.05**	**68.11**	**75.78**
SOx	Sulphur Oxides	**361.75**	**121.21**	**11.63**	**729.07**	**277.79**	**30.62**
$PM_{2.5}$	Particulate Matter w. diameter	**35.74**	**23.66**	**6.13**	**72.04**	**54.24**	**16.14**
PM_{10}	</= 2.5/10 microns	**44.68**	**29.58**	**6.40**	**90.05**	**67.80**	**16.84**
DPM	Diesel Particulate Matter	**44.68**	**29.58**	**6.40**	**90.04**	**67.80**	**16.84**
TOTAL CAC		**839.62**	**512.58**	**342.98**	**1,854.25**	**1,296.82**	**935.99**

NOx	7% Increase since 2010	**SOx**	-95% Reduction since 2010	**PM**	-79% Reduction since 2010	**CACs** (Total)	-41% Reduction since 2010

Greenhouse Gas (GHG) Summary

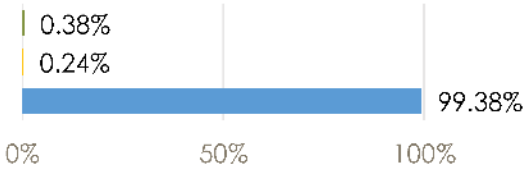
Annual GHG Emissions (tCO_2e)



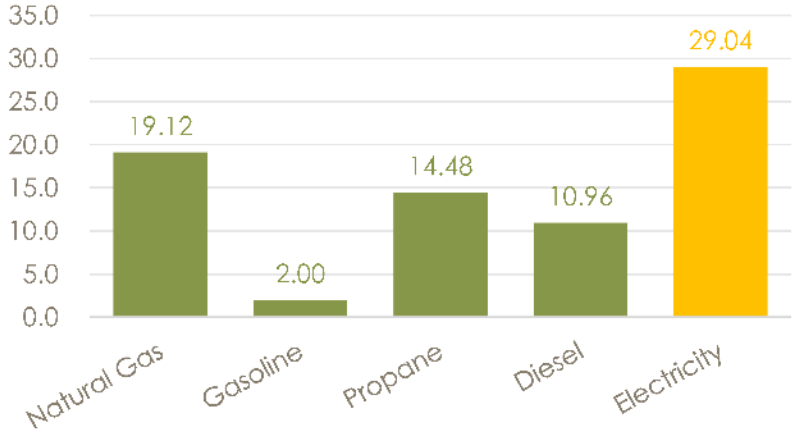
In terms of responsibility, the largest contributor to port emissions are cruise ship tenants, accounting for 96% of the total in 2018. This is followed by other tenant emissions at 3%, which mostly includes ground transportation from local tour operators. Western Stevedoring's emissions have historically made up between 3 and 1% of the total, while GVHA's onsite emissions account for the remaining <1%.

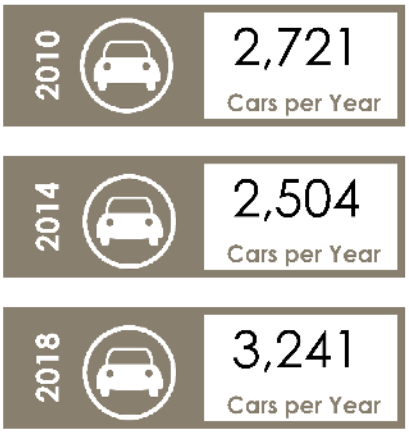
Inventory Results	2010	2014	2018
Scope 1 (Direct)	48	30	47
Scope 2 (Indirect)	8	7	29
Scope 3 (Indirect)	10,135	9,340	12,060
TOTAL EMISSIONS	10,191	9,376	12,136

2018 Emissions by Scope



2018 Scope 1 & 2 Emissions by Source (tCO_2e)





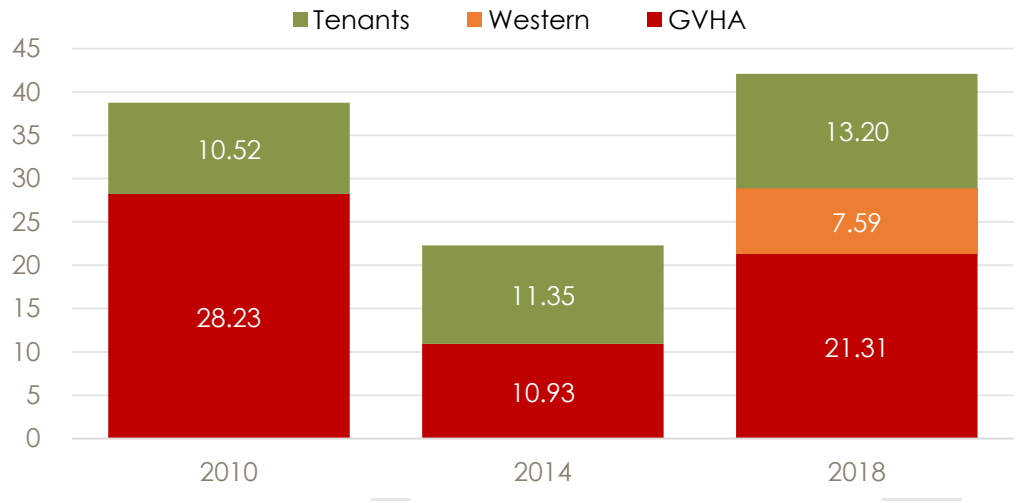
The Greenhouse Gas (GHG) inventory includes common gases known to cause climate change, including Carbon Dioxide (CO_2), Methane (CH_4), and Nitrous Oxides (N_2O). These gases are produced with the combustion of fossil fuels such as natural gas, gasoline, diesel and propane. In response to increased activity at the terminal, Ogden Point's carbon footprint has increased 19.1% since 2010. At the same time, total emissions from ground transportation and emissions per cruise ship passenger have decreased.

Scope 1 and 2 emissions (from operations under GVHA's direct control) account for just 2% of the inventory, and are made up of emissions from natural gas, gasoline, propane, diesel and electricity.

tCO_2e 2010	10,191
tCO_2e 2014	9,376
tCO_2e 2018	12,136
% Change	19.1%

Building Emissions

Annual Building Emissions (tCO_2e)

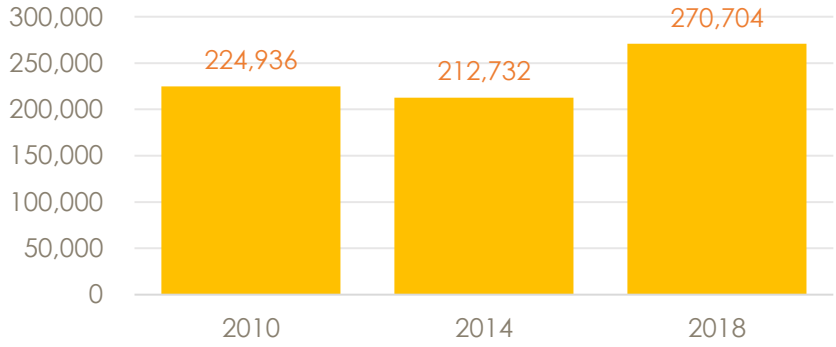


Buildings On Site
GVHA Office
Maintenance Shop
Western Office
Gift Shop & CBSA
Pier A Warehouse
Helijet
James Bay Anglers
BC Pilots House

** Note: Electricity use has been attributed to Western & tenants when GVHA bills tenants directly for metered use. This practice has been increasing since 2010, as meter information becomes more clear.*

Although GVHA has been making efforts to reduce electricity by upgrading parking lot lighting, overall electricity use has increased 20% since 2010. Three additional electricity accounts were opened at Ogden Point between 2014 and 2018, including the GVHA maintenance shop, the BC Pilots House and one in the North parking lot.

GVHA Electricity (kWh)



Buildings emit greenhouse gases through heating, lighting and equipment use. Many buildings onsite are heated with electricity, which has a low emissions intensity due to relatively clean hydro-power in BC. The GVHA maintenance shop and the old GVHA office (189 Dallas Rd.) are both heated with natural gas, while the Helijet building uses propane to supplement electric baseboards. Propane for heating the barge during public events was also included in 2017, after these events began.

Building emissions decreased in 2014 due to reduced activity at the terminal, then increased as the GVHA maintenance shop expanded and tenant operations ramped up. GVHA should continue to eliminate fossil fuel heating where possible, and encourage tenants to take responsibility for their emissions by passing on utility costs and communicating reduction goals.

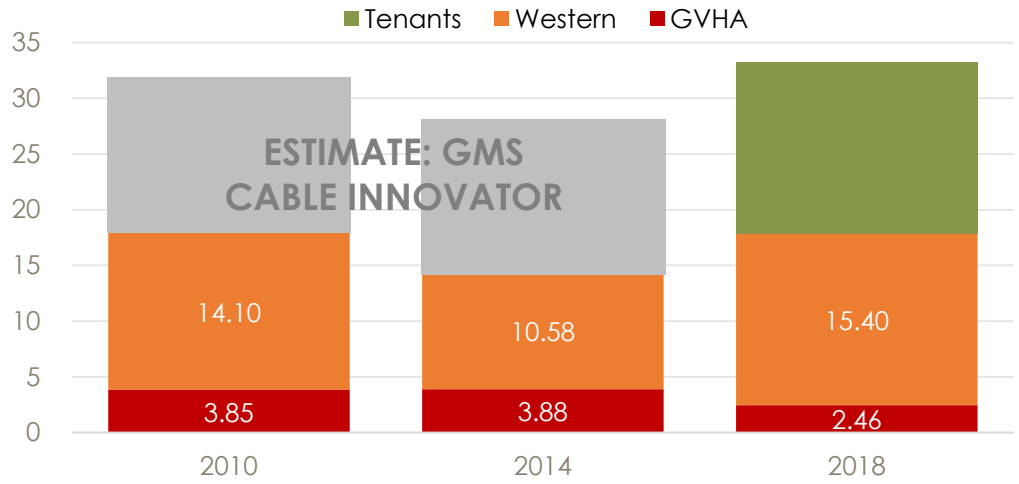
Building emissions are mostly the responsibility of GVHA

2018

% Change	9% since 2010	% Change	89% since 2014	% of Total	0.3%		42.1 tCO_2e

Equipment Emissions

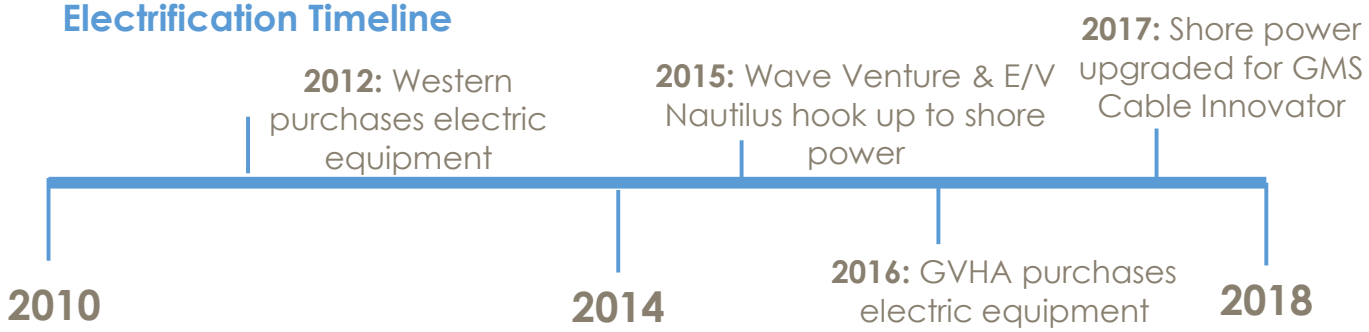
Annual Equipment Emissions (tCO_2e)



Equipment On Site
6 Vehicles
1 Electric Vehicle
1 Forklift
2 Golf Carts
1 Scooter
6 Fork Lifts
4 Electric Golf Carts
1 Backup Generator
Food Truck Generators
GMS Cable Innovator

** Note: 8% of GVHA's total fuel purchases have been included here, to reflect the % of equipment that is used at Ogden Point. This allocation comes directly from GVHA's Maintenance Manager, and is updated regularly.*

Electrification Timeline



Equipment emissions result from the burning of fossil fuels like gasoline and diesel to power stationary and mobile equipment. Emissions from electrified equipment and one electric harbour craft, the GMS Cable Innovator, have also been included here.

GVHA's purchases of fuel for Ogden Point have been declining steadily since 2010 as the organization makes efforts to electrify vehicles and ground equipment. As a result, GVHA has saved 1.65 tCO_2e per year since 2010.

Western Stevedoring has also been electrifying equipment used for servicing cruise ships. Western has larger forklifts and rents additional equipment throughout the busy season, which is reflected in their higher fuel consumption.

In 2017, the terminal began hosting food trucks. Emissions from food truck generators have been included in 2018 tenant equipment emissions.

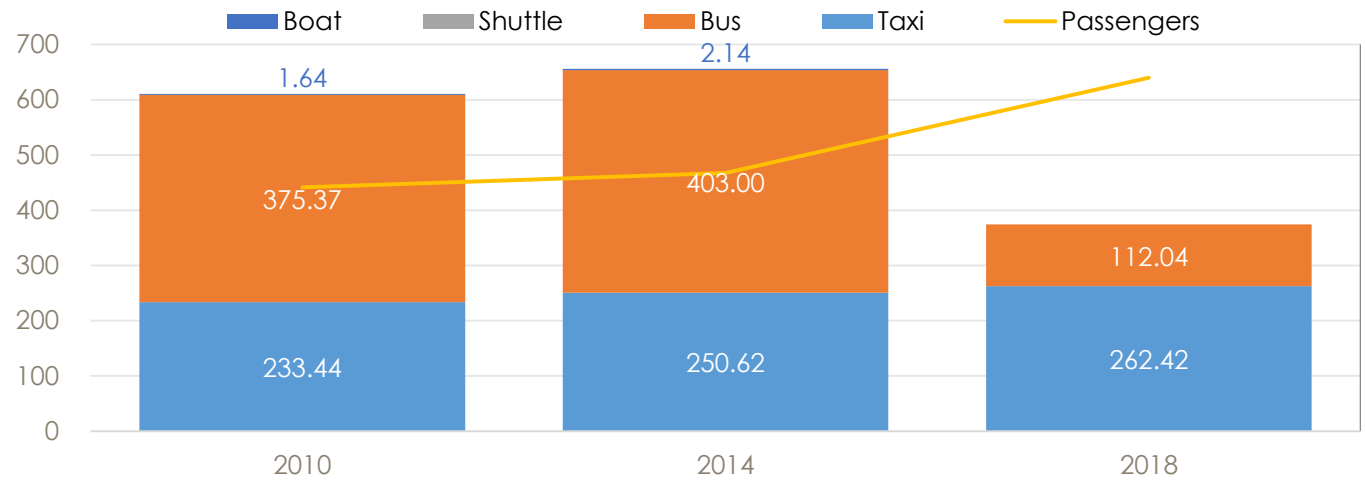
Equipment emissions are mostly the responsibility of Western

2018

% Change	85% since 2010	% Change	130% since 2014	% of Total	0.3%		33.3 tCO_2e

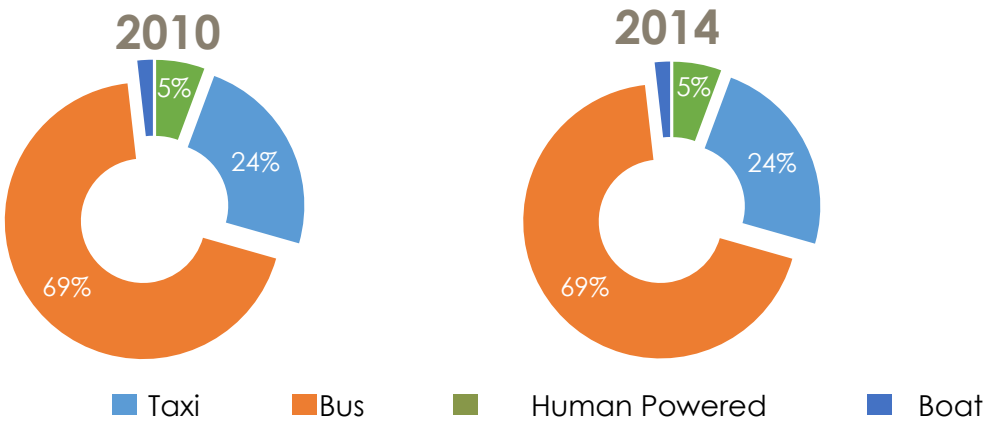
Transportation Emissions

Annual Transportation Emissions (tCO_2e)



By mandating tour operators use efficient and low-emissions vehicles, GVHA has been able to reduce transportation emissions by 41% since 2010.

% of Passengers by Mode



Transportation is the emissions category that has decreased the most since 2010, due to improved vehicle efficiency and electrification. GVHA's shuttle contracts saw an increase in emissions in 2014, followed by a slight decreased in 2018 as more efficient buses were purchased.

While the % of trips taken by taxi appears to be increasing, average emissions per taxi have decreased as the majority of vehicles have switched from internal combustion engine to hybrid models. In 2018, 68% of all permits issued for taxis at Ogden Point went to hybrid vehicles.

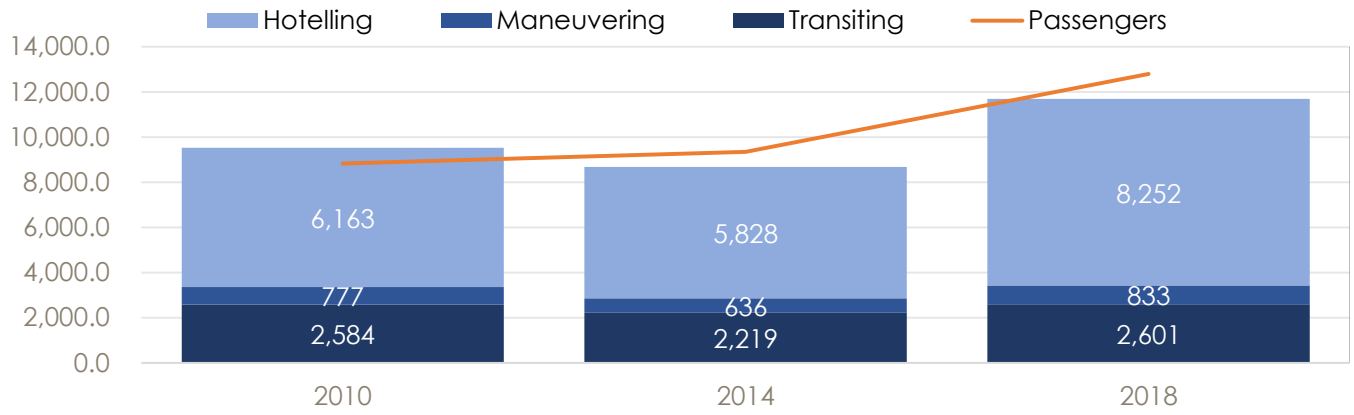
**Note: Information on 2010 permits and trips was not available, so an estimate was made using 2014 data, weighted by the number of cruise ship passengers in that year.*

Transportation emissions are mostly the responsibility of tenants

% Change	-39% since 2010	% Change	-43% since 2014	% of Total	3.1%	374.7 tCO_2e

Ocean Going Vessel (OGV) Emissions

Annual Cruise Ship Emissions (tCO_2e)



2010 Cruise Calls	
# of Calls	219
% Increase in Cruise Calls	-
Passenger Count	441,372
% Increase in Passengers	-

2014 Cruise Calls	
# of Calls	204
% Increase in Cruise Calls	-6.8%
Passenger Count	467,549
% Increase in Passengers	5.9%

2018 Cruise Calls	
# of Calls	243
% Increase in Cruise Calls	11.0%
Passenger Count	639,771
% Increase in Passengers	45.0%

2010	23.09 $kgCO_2e$/ PAX
2014	20.05 $kgCO_2e$/ PAX
2018	18.97 $kgCO_2e$/ PAX

Cruise ships are the largest source of GHG emissions at Ogden Point, accounting for 96.3% of the total in 2018. Emissions have increased 23% since 2010, while the number of cruise calls has increased 11% and the number of passengers 45%.

Cruise ship engines release different emissions intensities when operating at sea speed (in transit), maneuvering speed, and hotelling. The majority of emissions comes from hotelling. Hotelling emissions have been increasing since 2010, as the average vessel stays in port longer; total hotelling time almost doubled between 2010 and 2018.

OGV emissions are the responsibility of Cruise

2018

% Change	23% since 2010
% Change	35% since 2014
% of Total	96.3%
	11,685.8 tCO_2e

Inventory Information

Prepared For	Greater Victoria Harbour Authority		
Contact Information	Lindsay Gaunt	lgaunt@gvha.ca	250-383-8300
Description	Air emissions inventory analysing Greenhouse Gas (GHG) and Criteria Air Contaminant (CAC) emissions from the Ogden Point Deep-Water Terminal in Victoria, BC.		
Reporting Period	January 1st, 2010 - December 31st, 2013		
	January 1st, 2014 - December 31st, 2014		
	January 1st, 2018 - December 31st, 2018		
Inventory Boundary	**Scope 1 (Direct Emissions)** - Natural Gas, Gasoline, Propane, Diesel, Marine Diesel		
	Scope 2 (Indirect Emissions from Purchased Electricity) - Purchased Electricity (BC Hydro)		
	Scope 3 (Indirect Emissions from Other Sources) - Tenant Scope 1 & Scope 2, Ground Transportation, Ocean Going Vessels		
Consolidation Approach	Operational Control: Accounting for 100% of emissions from operations over which the organization has operational control.		
Primary Measurement	Carbon Dioxide Equivalent (CO_2e)		
Reporting Guidelines	Aligned with those defined in *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard, Revised Edition (The GHG Protocol, www.ghgprotocol.org)* . Landside emissions factors reviewed by Offsetters. Ocean Going Vessel methodology peer reviewed.		

Policy for Base Year Recalculation:
Base year emissions, and other previous emissions, shall be retroactively recalculated if a change in organisational structure or data quality is expected to exceed a significance threshold of 10% of base year emissions. These changes may arise from structural changes such as mergers, acquisitions, divestments, outsourcing or insourcing, changes in calculation methodology and improvements in accuracy, or discovery of significant errors.

Landside Data Limitations, Estimates & Assumptions

Fuel: Food trucks use a 7kW generator operating @ a 1/2 load. Calculated based on 4hrs operation/day (confirmed by Western). GVHA fuel calculated based on $$ spent.

Ground Transportation: Main trip destinations are Butchart Gardens, Butchart & Butterfly Gardens, Craigdarroch Castle and City Tours.

Ground Transportation: Avg. vehicle & bus mpg calculated based on average vehicle make/model from permits issued. No permit info available for 2010, so 2014 data was used (weighted by cruise ship pax).

Scope 3 Tenants: Emissions from three tenants (Whitehall Sail, Mercury Sales & Service and the Breakwater Café) were not included in the inventory as data was not available for the inventory years in question.

GMS Cable Innovator Fuel: Fuel use from the GMS cable maintenance ships prior to connecting to shore power in 2015 was not included due to data availability.

Ocean Going Vessel Methodology

In the absence of a public, established methodology for estimating mobile marine emission sources in Canada, Synergy's methodology for calculating GHGs and CACs from Ocean Going Vessels (OGVs) was based heavily on the approach outlined in the World Ports Climate Initiative (WPCI) Carbon Footprinting for Port Guidance Document (2010). In particular, Synergy employed the recommended surrogate approach using a combination of GVHA data, simplified assumptions, world fleet averages and data published in the latest detailed port inventories.

According to this methodology, OGV emissions are a function of vessel power demand (energy) multiplied by an emissions factor:

Emissions (g) = Total Energy (kWh) x EF (g/kWh)

Ships will use varying amounts of energy while in transit/at sea, maneuvering, and hotelling (referred to as the 'mode' the ship is in). This is because the ship's power systems (propulsion & auxiliary) are used differently in each mode. Therefore, total energy is the sum of all energy from the ship's propulsion and auxiliary power systems in each mode*.

Total Energy = Propulsion Energy (Transit) + Auxiliary Energy (Transit) + Propulsion Energy (Maneuvering) + Auxiliary Energy (Maneuvering) + Auxiliary Energy (Hotelling)

**Note: Emissions from auxiliary boilers were not included. The 2016 Puget Sound Maritime Air Emissions Inventory suggests that large diesel-electric cruise ships use waste heat recovery to provide steam during vessel operations, and based on data from the Vessel Boarding Program (VBP), auxiliary boilers are typically off during transiting, maneuvering and hoteling unless ships are connected to shore power. Synergy was not able to access VBP data for the specific ships calling at Ogden Point, however because many of the ships also call at the Port of Seattle, it was assumed that the ships had similar characteristics to the ones in the Puget Sound inventory.*

Energy is a result of the ship's power (Maximum Continuous Rated load, or MCR), times a load factor (LF) times the length of time in a given mode.

Energy = MCR (kW) x LF (%) x Time (hrs)

Where LF = Speed (knots) / (Maximum Speed (knots)^3)
and Time = Distance (nm) / Speed (knots).

Synergy's methodology has been peer reviewed for accuracy and consistency.

Ocean Going Vessel Data, Estimates & Assumptions

Synergy's calculations are based on data from the following sources:

GVHA provided a list of cruise ship calls, including the ship name, number of calls/year, the average number of passengers per call and the average time at port.

The 4.4nm inventory boundary was established through discussions with the Pacific Pilotage Authority Canada, and is based on the point at which cruise vessels are required to be boarded. Transit and maneuvering distances within the inventory boundary (3.4 and 1 nm respectively) were based on an estimate of typical cruise ship activity obtained from GVHA after discussions with neighbouring ports.

Ocean Going Vessel Data, Estimates & Assumptions

Ship characteristics including age (keel laid date), propulsion/auxiliary system type and deadweight tonnage were found on www.ship-technology.com. Where specific propulsion and auxiliary system information was not available, a diesel-electric configuration was assumed.

Maximum Continuous Rated (MCR) power, maximum transit speed and maximum rated speed are estimates from the WPCI Guidance Document. Auxiliary engine load defaults for different ship modes are based on estimates from the Puget Sound Maritime Air Emissions Inventory 2016.

World Fleet Population MCR, Max Rated Speed & Sea-Speed			
Subtype (Cruise)	MCR (kW)	Max Rated Speed	Sea-Speed
< 5,000 DWT	16,613	19.5	18.3
5,000 to 9,999 DWT	40,736	21.0	19.7
> 10,000 DWT	68,890	22.3	21.0

Source: WPCI Carbon Footprinting for Ports, Guidance Document, June 30, 2010. pg. 79, Table 5.12

2016 Cruise Ship Auxiliary Engine Load Defaults, kW				
Passenger Range			Transit	Maneuv	Hotelling
1,499	>		5,733	6,800	3,267
1,500	<	1,999	7,000	9,000	5,613
2,000	<	2,499	11,000	11,350	6,900
2,500	<	2,999	9,781	8,309	6,089
3,000	<	3,499	8,313	10,116	8,313
3,500	<	3,999	9,934	11,764	10,600
4,000	<	4,499	12,500	14,000	12,000
4,500	<	4,999	13,000	14,500	13,000
5,000	<	5,499	13,500	15,500	13,500
5,500	<	5,999	14,000	16,000	14,000
6,000	<	6,499	14,500	16,500	14,500
6,500	+		15,000	17,000	15,000

Source: Puget Sound Maritime Air Emissions Inventory (2016), Appendix B Table B.9

Fuel types were estimated based on the IMO fuel regulation in place during the inventory year. Because Ogden Point is located in an Emission Control Area (ECA), it was assumed that all ships were complying with North American ECA rules, either by using fuels with low sulphur content or exhaust gas cleaning systems that limit sulphur emissions.

Engine tiers were assigned based on the year the ship's keel was laid, according to IMO tier regulations. If engine speeds could not be found, medium speed (>130 rpms) was assumed.

Inventory Year	Fuel Type	Engine Tiers
2010	HFO with 2.7% sulphur content	Tier 1 for all ships built 2001 - 2010
2014	MDO with 1.0% sulphur content	Tier 2 for all ships built 2011 - 2015
2018	MDO with 0.1% sulphur content	Tier 3 for all ships built 2016 - 2018

Ocean Going Vessel Emissions Factors

Synergy used emissions factors and fuel correction factors from the WPCI Guidance Document for the 2010 inventory, the Port of Los Angeles Inventory of Air Emissions (2013) for the 2014 inventory & the Puget Sound Maritime Air Emissions Inventory (2016) for the 2018 inventory.

CAC Emissions Factors - 2010 Inventory

Emission Factors for Propulsion Engines using 2.7% S HFO, g/kW-hr								
Engine Category	Model Year Range	NO_x	HC	CO	SO_x	PM_{10}	$PM_{2.5}$	DPM
Slow speed (Tier 0)	< 1999	18.1	0.6	1.4	10.5	1.5	1.2	1.5
Slow speed (Tier 1)	2000 to 2010	17.0	0.6	1.4	10.5	1.5	1.2	1.5
Slow speed (Tier 2)	2011 to 2015	15.3	0.6	1.4	10.5	1.5	1.2	1.5
Medium speed (Tier 0)	< 1999	14.0	0.5	1.1	11.5	1.5	1.2	1.5
Medium speed (Tier 1)	2000 to 2010	13.0	0.5	1.1	11.5	1.5	1.2	1.5
Medium speed (Tier 2)	2011 to 2015	11.2	0.5	1.1	11.5	1.5	1.2	1.5
Gas turbine	All	6.1	0.1	0.2	16.5	0.1	0.0	0.0
Steam main & boiler	All	2.1	0.1	0.2	16.5	0.8	0.6	0.0

Source: Port of Los Angeles Inventory of Air Emissions (2013), Table 3.5 & 3.6 (pg. 76)

Emission Factors for Auxiliary Engines using 2.7% S HFO, g/kW-hr								
Engine Category	Model Year Range	NO_x	HC	CO	SO_x	PM_{10}	$PM_{2.5}$	DPM
Tier 0	< 1999	14.7	0.4	1.1	12.3	1.5	1.2	1.5
Tier 1	2000 to 2010	13.0	0.4	1.1	12.3	1.5	1.2	1.5
Tier 2	2011 to 2015	11.2	0.4	1.1	12.3	1.5	1.2	1.5

Source: Port of Los Angeles Inventory of Air Emissions (2013), Table 3.10 & 3.11 (pg. 82)

GHG Emissions Factors - 2010 Inventory

Emission Factors for Propulsion Engines using 2.7% S HFO, g/kW-hr					
Engine Category	Model Year Range	CO_2	N_2O	CH_4	gCO_2e
Slow speed (Tier 0)	< 1999	620	0.031	0.012	629.862
Slow speed (Tier 1)	2000 to 2010	620	0.031	0.012	629.862
Slow speed (Tier 2)	2011 to 2015	620	0.031	0.012	629.862
Medium speed (Tier 0)	< 1999	683	0.031	0.010	692.820
Medium speed (Tier 1)	2000 to 2010	683	0.031	0.010	692.820
Medium speed (Tier 2)	2011 to 2015	683	0.031	0.010	692.820
Gas turbine	All	970	0.080	0.002	994.842
Steam main & boiler	All	970	0.080	0.002	994.842

Source: Port of Los Angeles Inventory of Air Emissions (2013), Table 3.5 & 3.6 (pg. 76)

Emission Factors for Auxiliary Engines using 2.7% S HFO, g/kW-hr					
Engine Category	Model Year Range	CO_2	N_2O	CH_4	gCO2e
Tier 0	< 1999	722	0.031	0.0008	731.627
Tier 1	2000 to 2010	722	0.031	0.0008	731.627
Tier 2	2011 to 2015	722	0.031	0.0008	731.627

Source: Port of Los Angeles Inventory of Air Emissions (2013), Table 3.10 & 3.11 (pg. 82)

Global Warming Potentials*		
CO_2	N_2O	CH_4
1	**310**	**21**

**Used for 2010, 2014 & 2018 inventories*

Ocean Going Vessel Emissions Factors

CAC Emissions Factors - 2014 Inventory

Emission Factors for Propulsion Engines using 0.5% S MDO, g/kW-hr								
Engine Category	Model Year Range	NO_x	HC	CO	SO_x	PM_{10}	$PM_{2.5}$	DPM
Slow speed (Tier 0)	< 1999	17	0.6	1.4	1.9	0.38	0.35	0.38
Slow speed (Tier 1)	2000 to 2010	16	0.6	1.4	1.9	0.38	0.35	0.38
Slow speed (Tier 2)	2011 to 2015	14.4	0.6	1.4	1.9	0.38	0.35	0.38
Medium speed (Tier 0)	< 1999	13.2	0.5	1.1	2.1	0.38	0.35	0.38
Medium speed (Tier 1)	2000 to 2010	12.2	0.5	1.1	2.1	0.38	0.35	0.38
Medium speed (Tier 2)	2011 to 2015	10.5	0.5	1.1	2.1	0.38	0.35	0.38
Gas turbine	All	5.7	0.1	0.2	3.1	0.01	0.01	0
Steam main & boiler	All	2	0.1	0.2	3.1	0.2	0.18	0

Source: Port of Los Angeles Inventory of Air Emissions (2013), Table 3.17 (pg. 88)

Emission Factors for Auxiliary Engines using 0.5% S MDO, g/kW-hr								
Engine Category	Model Year Range	NO_x	HC	CO	SO_x	PM_{10}	$PM_{2.5}$	DPM
Tier 0	< 1999	13.8	0.4	1.1	2.3	0.38	0.35	0.38
Tier 1	2000 to 2010	12.2	0.4	1.1	2.3	0.38	0.35	0.38
Tier 2	2011 to 2015	10.5	0.4	1.1	2.3	0.38	0.35	0.38

Source: Port of Los Angeles Inventory of Air Emissions (2013), Table 3.10 & 3.11 (pg. 82)

GHG Emissions Factors - 2014 Inventory

Emission Factors for Propulsion Engines using 0.5% S MDO, g/kW-hr					
Engine Category	Model Year Range	CO_2	N_2O	CH_4	gCO_2e
Slow speed (Tier 0)	< 1999	589	0.029	0.012	598.242
Slow speed (Tier 1)	2000 to 2010	589	0.029	0.012	598.242
Slow speed (Tier 2)	2011 to 2015	589	0.029	0.012	598.242
Medium speed (Tier 0)	< 1999	649	0.029	0.010	658.200
Medium speed (Tier 1)	2000 to 2010	649	0.029	0.010	658.200
Medium speed (Tier 2)	2011 to 2015	649	0.029	0.010	658.200
Gas turbine	All	922	0.075	0.002	945.292
Steam main & boiler	All	922	0.075	0.002	945.292

Source: Port of Los Angeles Inventory of Air Emissions (2013), Table 3.5 & 3.6 (pg. 76)

Emission Factors for Auxiliary Engines using 0.5% S MDO, g/kW-hr					
Engine Category	Model Year Range	CO_2	N_2O	CH_4	gCO2e
Tier 0	< 1999	686	0.029	0.008	695.158
Tier 1	2000 to 2010	686	0.029	0.008	695.158
Tier 2	2011 to 2015	686	0.029	0.008	695.158

Source: Port of Los Angeles Inventory of Air Emissions (2013), Table 3.10 & 3.11 (pg. 82)

CAC Emissions Factors - 2018 Inventory

Emission Factors for Propulsion Engines using 0.1 %S MDO, g/kW-hr								
Engine Category	Model Year Range	NO_x	HC	CO	SO_2	PM_{10}	$PM_{2.5}$	DPM
Slow speed (Tier 0)	< 1999	17.00	0.60	1.40	0.38	0.24	0.23	0.24
Slow speed (Tier 1)	2000 to 2011	16.00	0.60	1.40	0.38	0.24	0.23	0.24
Slow speed (Tier 2)	2011 to 2016	14.40	0.60	1.40	0.38	0.24	0.23	0.24
Slow speed (Tier 3)	2016 +	3.40	0.60	1.40	0.38	0.24	0.23	0.24

Ocean Going Vessel Emissions Factors

CAC Emissions Factors - 2018 Inventory (Cont'd)

Emission Factors for Propulsion Engines using 0.1 %S MDO, g/kW-hr								
Engine Category	Model Year Range	NO_x	HC	CO	SO_2	PM_{10}	$PM_{2.5}$	DPM
Medium speed (Tier 0)	< 1999	13.20	0.50	1.10	0.42	0.24	0.23	0.24
Medium speed (Tier 1)	2000 to 2011	12.20	0.50	1.10	0.42	0.24	0.23	0.24
Medium speed (Tier 2)	2011 to 2016	10.50	0.50	1.10	0.42	0.24	0.23	0.24
Medium speed (Tier 3)	2016 +	2.60	0.50	1.10	0.42	0.24	0.23	0.24
Gas turbine	All	5.70	0.10	0.20	0.60	0.01	0.01	0.00
Steam main & boiler	All	2.00	0.10	0.20	0.60	0.16	0.15	0.00

Source: Puget Sound Maritime Air Emissions Inventory (2016), Appendix B Table B.2

Emission Factors for Auxiliary Engines using 0.1 %S MDO, g/kW-hr								
Engine Category	Model Year Range	NO_x	HC	CO	SO_2	PM_{10}	$PM_{2.5}$	DPM
Medium speed (Tier 0)	< 1999	13.80	0.40	1.10	0.44	0.24	0.23	0.24
Medium speed (Tier 1)	2000 to 2011	12.20	0.40	1.10	0.44	0.24	0.23	0.24
Medium speed (Tier 2)	2011 to 2016	10.50	0.40	1.10	0.44	0.24	0.23	0.24
Medium speed (Tier 3)	2016 +	2.60	0.40	1.10	0.44	0.24	0.23	0.24
High speed (Tier 0)	< 1999	10.90	0.40	0.90	0.44	0.24	0.23	0.24
High speed (Tier 1)	2000 to 2011	9.80	0.40	0.90	0.44	0.24	0.23	0.24
High speed (Tier 2)	2011 to 2016	7.70	0.40	0.90	0.44	0.24	0.23	0.24
High speed (Tier 3)	2016 +	2.00	0.40	0.90	0.44	0.24	0.23	0.24

Source: Puget Sound Maritime Air Emissions Inventory (2016), Appendix B Table B.7

GHG Emissions Factors - 2018 Inventory

Emission Factors for Propulsion Engines using 0.1 %S MDO, g/kW-hr					
Engine Category	Model Year Range	CO_2	N_2O	CH_4	gCO_2e
Slow speed (Tier 0)	< 1999	589	0.029	0.012	598.242
Slow speed (Tier 1)	2000 to 2011	589	0.029	0.012	598.242
Slow speed (Tier 2)	2011 to 2016	589	0.029	0.012	598.242
Slow speed (Tier 3)	2016 +	589	0.029	0.012	598.242
Medium speed (Tier 0)	< 1999	649	0.029	0.01	658.2
Medium speed (Tier 1)	2000 to 2011	649	0.029	0.01	658.2
Medium speed (Tier 2)	2011 to 2016	649	0.029	0.01	658.2
Medium speed (Tier 3)	2016 +	649	0.029	0.01	658.2
Gas turbine	All	922	0.075	0.002	945.292
Steam main & boiler	All	922	0.075	0.002	945.292

Source: Puget Sound Maritime Air Emissions Inventory (2016), Appendix B Table B.2

Emission Factors for Auxiliary Engines using 0.1 %S MDO, g/kW-hr					
Engine Category	Model Year Range	CO_2	N_2O	CH_4	gCO2e
Medium speed (Tier 0)	< 1999	686	0.029	0.008	695.158
Medium speed (Tier 1)	2000 to 2011	686	0.029	0.008	695.158
Medium speed (Tier 2)	2011 to 2016	686	0.029	0.008	695.158
Medium speed (Tier 3)	2016 +	686	0.029	0.008	695.158
High speed (Tier 0)	< 1999	656	0.029	0.008	665.158
High speed (Tier 1)	2000 to 2011	656	0.029	0.008	665.158
High speed (Tier 2)	2011 to 2016	656	0.029	0.008	665.158
High speed (Tier 3)	2016 +	656	0.029	0.008	665.158

Source: Puget Sound Maritime Air Emissions Inventory (2016), Appendix B Table B.7

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Glossary of Terms

GHG	Greenhouse Gas (emissions): Atmospheric gasses contributing to the greenhouse effect, including Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O).
GJ	**Gigajoule**: Unit of natural gas equal to 26.137 m^3 or 0.947 MMBtu
HVAC	**Heating, Ventilation & Air Conditioning**
kWh	**Kilowatt-Hour**: Common unit for measuring electrical consumption
psg-km	**Passenger-Kilometer**: Unit separating total emissions between passengers per km
t-km	**Tonne-Kilometer**: A unit of measurement used in shipping
tCO_2e	**Tonnes of Carbon Dioxide Equivalent**: GHGs have different warming potentials, measured collectively as CO_2 equivalent (hence "e")
CAC	**Criteria Air Contaminants:** Emissions of criteria air contaminants contribute to smog, poor air quality and acid rain.
OGV	**Ocean Going Vessel**
IMO	**International Maritime Organization**
ECA	**Emission Control Area**

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