Background Document

Reducing Emissions from Goods Movement via Maritime Transportation in North America

Update of the Mexican Port Emissions Data

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List of Abbreviations and Acronyms

CHE	cargo handling equipment
CO	carbon monoxide
CO_2	carbon dioxide
ECA	Emission Control Area
GREET	Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
g/l	grams/liters
HP	horsepower
IMO	International Maritime Organization
kW	kilowatt
kWe	kilowatt electric
kW-hr	kilowatt-hour
kg	kilogram
LPG	liquefied petroleum gas
MWe	megawatt electric
MWe-hr	megawatt electric-hour
NA-ECA	North American Emission Control Area
NOx	nitrogen oxides
PM	particulate matter
PM_{10}	particulate matter less than 10 microns (micrometers) in diameter
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
ppm	parts per million
SCC	Source Classification Code
Semarnat	*Secretaría de Medio Ambiente y Recursos Naturales* (Ministry of Environment and Natural Resources, Mexico)
SIP	State Implementation Plan
SO_2	sulfur dioxide
SO_X	sulfur oxide
VOC	volatile organic compound

Abstract

The present update of Mexico's port emissions estimates was derived from a joint effort between the *Secretaría de Medio Ambiente y Recursos Naturales* (Semarnat) and Eastern Research Group, Inc. (ERG), in the context of a project undertaken by the Commission for Environmental Cooperation (CEC). The basis for this work was an unpublished CEC report entitled, *Inventario Nacional de Emisiones de Fuentes de Area 2008 (National Emissions Inventory for Area Sources)* (CEC 2011), which was produced to support the development of Mexico's National Emissions Inventory. More recent marine engine and cargo handling equipment (CHE) emissions data were identified and applied to the Mexican CHE and vessel data provided by Semarnat to generate a more up-to-date and comprehensive port emissions inventory. A revised Mexican port inventory was developed for 2011, with projections to 2030.

Disclaimer

The data presented in this report were accessed from databases and other sources prior to December 2014. As such, they represent the information available at that time and do not reflect revisions and updates that may have occurred since then. Before citing or using the information from this report, therefore, readers are cautioned to consider the temporal nature of the source data, as well as the findings based on those data, which in some cases may no longer be valid.

Executive Summary

In 2008, the International Convention for the Prevention of Pollution from Ships (Marpol Convention) adopted new amendments to Annex VI, which addresses the prevention of air pollution from ocean-going vessels. As part of these amendments, a country (or collection of countries) can propose an Emission Control Area (ECA), a buffer area a defined distance from shore where stricter emission standards apply. These standards control emissions of sulfur oxides (SO_X), particulate matter (PM) and/or nitrogen oxides (NO_X) within the ECA in order to reduce air pollution transported to populated areas and lessen other environmental impacts such as deposition of air pollutants into water and soil. In 2009, the United States and Canada (later joined by France) submitted a joint ECA proposal (referred to as the North American ECA) to the International Maritime Organization (IMO). The Mexican government has since expressed its commitment to developing a Mexican ECA. To support this objective, Mexico's environment ministry, Semarnat, developed a national port emissions inventory for marine vessel operations within the ports and for cargo handling equipment (CHE). These data were included in an unpublished report by the Commission for Environmental Cooperation (CEC) entitled, *Inventario Nacional de Emisiones de Fuentes de Área, 2008* (National Emissions Inventory for Area Sources) (CEC 2011).

For the current CEC project, local activity data provided by Semarnat were applied to more recent marine engine and CHE emission factors, providing a more up-to-date and comprehensive port emissions inventory. In order to estimate CHE emissions, the type of freight handled at Mexican ports was evaluated, with the assumption that Mexican ports tend to handle a significant quantity of liquid cargo, whereas many US ports deal primarily with container and bulk cargo types. This information was useful in matching Mexican ports to similar ports in the United States, providing a profile that better represents CHE activity in Mexico. Noting that smaller ports were unlikely to have some of the equipment types available at larger ports, Semarnat recommended the removal of specific equipment types for ports that handled less than one million metric tons of cargo. CHE emissions estimates were developed using the latest version of the US EPA's NONROAD model for the years 2011 and 2030.

In the original study, vessel emissions estimates were developed for ships approaching, maneuvering in, or leaving a port, as well as for while they were hoteling at the dock. The 2008 inventory had provided detailed fuel usage data for individual vessels as they transited Mexican port waters. To these local fuel usage data were applied emission factors recently derived for use in the Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) system. Vessel dockside emissions estimates were revised for the original 13 ports included in the 2008 inventory by updating the vessel daily fuel usage rates and emission factors, with the revised daily fuel usage rates linked to the vessel-days-at-port data provided by Semarnat. The GREET emission factors were applied to the revised vessel fuel data for both vessel movements and dockside hoteling to get revised emissions estimates.

As the new Mexican port inventory was expanded to include 35 ports, an adjustment factor was developed based on port cargo handling data to approximate port emissions from all 35 Mexican ports. The revised 2008 Mexican port vessel emission inventory was also expanded to reflect activity and emissions in 2011, with projections to 2030. Emissions estimates were adjusted to account for new IMO global fuel standards that would be implemented in 2020.

1. Introduction

Port emissions from cargo handling equipment (CHE) and marine vessels can be significant, having negative impacts on local air quality, particularly for communities located adjacent to port facilities. The pollutants of greatest concern include SO_X, NO_X, PM, and hazardous air pollutants. For this project, ERG staff reviewed the unpublished report by the Commission for Environmental Cooperation (CEC) entitled, *Inventario Nacional de Emisiones de Fuentes de Área, 2008* (National Emissions Inventory for Area Sources) (CEC 2011), which included emission estimates for vessels entering, maneuvering in, hoteling at, and departing Mexican ports, as well as the CHE required to load and unload freight from these vessels. The activity data used in the 2008 inventory appeared to be appropriate and of good quality. These local activity data were applied to new marine vessel and CHE fuel and emissions data, to provide up-to-date and comprehensive emission inventories for 2011 and 2030.

2. Cargo Handling Equipment

As port-specific inventories of landside CHE were not available for Mexican ports, ERG chose to develop a default equipment profile to estimate emissions associated with these equipment sources. ERG collected a number of US emissions inventories that contained data on the kinds of landside equipment associated with different cargo types, such as containers, bulk, and liquid cargo. Seven US port inventories were identified that included data on the total cargo tonnage by cargo type, as well as associated CHE emissions. Cargo tonnage data by type for 40 different Mexican ports for the year 2010 were obtained from the *Secretaría de Comunicaciones y Transportes* (SCT 2014) (the data provided are included in Appendix B). The breakdown by cargo type was compared to identify US ports that most closely resembled Mexican port activities. The data indicated that many Mexican ports handled significant quantities of liquid cargo, whereas many US ports deal primarily with container and bulk cargo types. Given these differences, Mexico's total national cargo data were compared against US port data to develop a single CHE profile that might reasonably represent equipment used at Mexican ports, as shown in Table 1.

Table 1. Percentage of Cargo Tonnage by Port and by Type

Cargo Type	Bulk	Container	Liquids	Other
Mexico (Nationally)	**30.72%**	**13.20%**	**49.42%**	**6.65%**
West Sacramento, CA (2010)	100%	0%	0%	0%
Long Beach, CA (2012)	23.35%	14.38%	62.27%	0.00%
San Diego, CA (2006)	61.93%	17.93%	5.80%	14.34%
New York/New Jersey (2010)	38.15%	36.83%	0%	25.02%
Houston, TX (2007)	31.79%	56.07%	0%	12.14%
Georgia Port Authority (2012)	14.85%	85.15%	0%	0%
Port of Virginia (2011)	2.23%	97.77%	0%	0%

Based on its similar composition of cargo type, the Port of Long Beach was identified as the most appropriate US port to use as a surrogate. ERG downloaded the latest Port of Long Beach's port emissions inventory from the Port of Long Beach's website, which, when this report was being prepared, was for the 2012 calendar year (Port of Long Beach 2013).[1] The report *2012 Engine Characteristics for All CHE Operating at the Port of Long Beach* identified all CHE operating at the port in 2012. CHE data from the Long Beach study are presented in Table 2.

Table 2. Engine Characteristics for All CHE Operating at the Port of Long Beach, CA, in 2012

Equipment	Engine Type		Power (horsepower)			Model Year			Annual Operating Hours		
		Count	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Yard tractor	Gasoline	91	335	335	335	2011	2011	2011	2	3,659	1,654
Forklift	Propane	125	43	122	89	1976	2010	1997	0	1,500	368
Tractor	Propane	6	101	101	101	1996	1996	1996	764	764	764
Sweeper	Propane	7	50	135	77	1982	2005	1999	0	750	165
Miscellaneous	Propane	3	101	101	101	1997	1998	1997	246	621	416
Yard tractor	Propane	8	173	173	173	2009	2009	2009	0	0	0
Excavator	Diesel	4	322	371	347	2002	2010	2005	222	891	453
Crane	Diesel	2	177	334	256	1985	1991	1988	25	1,334	680
RTG crane	Diesel	65	515	1,043	719	1998	2011	2004	0	4,975	1,735
Truck	Diesel	18	165	525	274	1981	2011	2002	0	1,547	401
Reach stacker	Diesel	3	330	330	330	1994	1998	1995	0	0	0
Loader	Diesel	14	50	430	289	1985	2012	2003	0	2,403	1,063
Tractor	Diesel	1	59	59	59	2009	2009	2009	80	80	80
Bulldozer	Diesel	4	92	285	194	1995	2012	2004	0	1,500	444
Skid steer loader	Diesel	3	49	76	65	2006	2008	2007	141	2,114	800
Man lift	Diesel	6	48	100	67	1997	2009	2005	0	121	54
Forklift	Diesel	110	31	210	126	1979	2012	2003	0	3,157	619
Side handler	Diesel	19	120	240	205	1982	2011	2002	93	2,375	1,143
Top handler	Diesel	169	174	375	295	1979	2012	2005	0	6,760	1,841
Sweeper	Diesel	11	39	230	152	1999	2009	2004	0	540	237
Material handler	Diesel	8	268	717	377	2000	2008	2006	0	1,177	618
Miscellaneous	Diesel	3	13	110	45	2007	2010	2009	191	1,531	1,001
Yard tractor, offroad	Diesel	136	173	245	179	2003	2012	2004	0	2,242	1,287
Rail pusher	Diesel	2	100	300	200	1997	2003	2000	678	1,099	889
Yard tractor, onroad	Diesel	388	173	250	206	2004	2012	2008	0	3,338	1,828
Crane	Electric	2	NA	NA	NA	1980	2006	1993	79	359	219
Electric pallet jack	Electric	3	NA	NA	NA	1997	1997	1997	300	300	300
Forklift	Electric	9	NA	NA	NA	1995	2007	2001	0	600	333
Material handler	Electric	1	NA	NA	NA	1995	1995	1995	326	326	326
Miscellaneous	Electric	6	NA	NA	NA	1994	2008	2002	0	1,268	233
Sweeper	Electric	1	NA	NA	NA	NA	NA	NA	NA	NA	NA
Truck	Electric	5	NA	NA	NA	2008	2009	2008	0	100	44
Truck	Gasoline	1	NA	NA	NA	1977	1977	1977	NA	NA	NA

These equipment pieces were assigned to an appropriate nonroad source classification code (SCC), according to the SCCs available in the US EPA NONROAD model. These SCC assignments are shown in Table 3.

[1] More recent inventories (through 2015) are now available at that website.

Table 3. Cargo Handling Equipment and Associated Source Classification Codes

Equipment	Engine Type	SCC Assignment	SCC Description
Yard tractor	Gasoline	2265003070	4-Stroke Terminal Tractors
Forklift	Propane	2267002057	LPG - Rough Terrain Forklift
Tractor	Propane	2267002066	LPG - Tractors/Loaders/Backhoes
Sweeper	Propane	2267003030	LPG - Sweepers/Scrubbers
Miscellaneous	Propane	2267003050	LPG - Other Material Handling Eqp
Yard tractor	Propane	2267003070	LPG - Terminal Tractors
Excavator	Diesel	2270002036	Diesel - Excavators
Crane	Diesel	2270002045	Diesel - Cranes
RTG crane	Diesel	2270002045	Diesel - Cranes
Truck	Diesel	2270002051	Diesel - Off-highway Trucks
Reach stacker	Diesel	2270002057	Diesel - Rough Terrain Forklifts
Loader	Diesel	2270002060	Diesel - Rubber Tire Loaders
Tractor	Diesel	2270002066	Diesel - Tractors/Loaders/Backhoes
Bulldozer	Diesel	2270002069	Diesel - Crawler Tractor/Dozers
Skid steer loader	Diesel	2270002072	Diesel - Skid Steer Loaders
Man lift	Diesel	2270003010	Diesel - Aerial Lifts
Forklift	Diesel	2270003020	Diesel - Forklifts
Side handler	Diesel	2270003020	Diesel - Forklifts
Top handler	Diesel	2270003020	Diesel - Forklifts
Sweeper	Diesel	2270003030	Diesel - Sweepers/Scrubbers
Material handler	Diesel	2270003050	Diesel - Other Material Handling Eqp
Miscellaneous	Diesel	2270003050	Diesel - Other Material Handling Eqp
Yard tractor, offroad	Diesel	2270003070	Diesel - Terminal Tractors
Rail pusher	Diesel	2285002015	Diesel - Railway Maintenance
Yard tractor, onroad	Diesel	OMIT	ONROAD VEHICLE
Crane	Electric	OMIT	ELECTRIC
Electric pallet jack	Electric	OMIT	ELECTRIC
Forklift	Electric	OMIT	ELECTRIC
Material handler	Electric	OMIT	ELECTRIC
Miscellaneous	Electric	OMIT	ELECTRIC
Sweeper	Electric	OMIT	ELECTRIC
Truck	Electric	OMIT	ELECTRIC
Truck	Gasoline	OMIT	No Gasoline Trucks in NONROAD

In cases where multiple equipment types were mapped to a single SCC, the populations were summed and a weighted average horsepower (HP) by HP bin was calculated. In some instances, the average HP exceeded the highest HP bin available for that SCC. In these instances, the maximum available HP was used as the average HP.

For activity, a weighted average activity in terms of annual hours was calculated for each SCC. These values were then used to update the population and activity files for the NONROAD model. The population, average HP, and activity are presented in Table 4.

ERG updated the allocation files so that all equipment and associated emissions were assigned to a single county (municipio) of interest. The NONROAD inputs for climate data were updated using typical weather for Mexico City. The model inputs were updated to reflect a typical minimum temperature of 43°F (6.1ºC), a maximum temperature of 81°F (27ºC), and an average temperature of 67°F (19.4ºC) (WeatherSpark 2014).

ERG also updated the diesel fuel sulfur percentage for use in the NONROAD modeling. To obtain the 2011 baseline, ERG obtained diesel fuel sulfur data from TransportPolicy.net (2014), which noted that the nonroad diesel sulfur limit is 5000 ppm. For modeling the year 2030 projections, ERG assumed Mexico would be fully in line with the 15 ppm standard for the United States. Once the population, activity, spatial allocation, climate, and fuel inputs were updated, ERG executed the NONROAD model to produce annual emissions in metric tons per year for both the 2011 and 2030 calendar year.

Table 4. Cargo Handling Equipment Horsepower and Activity Values

SCC Assignment	SCC Description	HP Bin	Population	Average HP	Activity (hrs/yr)
2265003070	4-Stroke Terminal Tractors	175-300	91	300 (max HP in NONROAD)	1,654
2267002057	LPG - Rough Terrain Forklift	75-100	125	89	368
2267002066	LPG - Tractors/Loaders/Backhoes	75-100	6	100 (max HP in NONROAD)	764
2267003030	LPG - Sweepers/Scrubbers	75-100	7	77	165
2267003050	LPG - Other Material Handling Eqp	75-100	3	100 (max HP in NONROAD)	416
2267003070	LPG - Terminal Tractors	100-175	8	173	0
2270002036	Diesel - Excavators	300-600	4	347	453
2270002045	Diesel - Cranes	175-300	2	256	1,704
2270002045	Diesel - Cranes	600-750	65	719	
2270002051	Diesel - Off-highway Trucks	175-300	18	274	401
2270002057	Diesel - Rough Terrain Forklifts	300-600	3	330	0
2270002060	Diesel - Rubber Tire Loaders	175-300	14	289	1,063
2270002066	Diesel - Tractors/Loaders/Backhoes	50-75	1	59	80
2270002069	Diesel - Crawler Tractor/Dozers	175-300	4	194	444
2270002072	Diesel - Skid Steer Loaders	50-75	3	65	800
2270003010	Diesel - Aerial Lifts	50-75	6	67	54
2270003020	Diesel - Forklifts	100-175	110	126	1,345
2270003020	Diesel - Forklifts	175-300	188	285.9 (weighted average)	
2270003020	Diesel - Forklifts				
2270003030	Diesel - Sweepers/Scrubbers	100-175	11	152	237
2270003050	Diesel - Other Material Handling Eqp	300-600	8	377	722
2270003050	Diesel - Other Material Handling Eqp	25-40	3	40 (no 40-50 HP range in NONROAD)	
2270003070	Diesel - Terminal Tractors	175-300	136	179	1,287
2285002015	Diesel - Railway Maintenance	175-300	2	200	889

The NONROAD model was used to calculate emission estimates for the Port of Long Beach, and those emissions were then divided by the total cargo tonnage for the port to create the tonnage-based emissions shown in Tables 5 for 2011 and 6 for 2030, using the following equation:

$$EF = N/C$$

Where:

EF	=	Emission factor (metric tons of pollutant/cargo metric ton)
N	=	NONROAD-calculated emissions (metric tons)
C	=	2010 port total cargo (metric tons)

These new emission factors were multiplied by the cargo tonnage for each port to derive emissions by equipment type by port, as shown in the following equation:

$$E = T \times EF$$

Where:

E	=	Emissions (metric tons)
T	=	2010 total cargo (metric tons) for the port
EF	=	Emission factor (tons of pollutant/cargo ton)

After an initial review, Semarnat provided additional information indicating that smaller ports were unlikely to have some of the equipment types available at larger ports, such as large tractors, excavators, and railway maintenance equipment. Given this, it was decided to use a limited equipment profile for ports that handled less than 1 million metric tons of cargo per year. The additional equipment types that were included in calculations for larger ports are indicated with an asterisk in Table 5. SCT also provided annual cargo tonnage data for 35 ports that were used in the calculations above (Appendix A).

Table 5. 2011 Cargo Tonnage-based Emission Factors for CHE (Metric Tons of Pollutant/Metric Ton of Cargo)

SCC	Equipment Description	HP	THC-Exhaust	CO-Exhaust	NO_X-Exhaust	CO_2-Exhaust	SO_2-Exhaust	PM-Exhaust	Fuel Consumption
2265003070	4-Stroke Terminal Tractors*	300	1.85E-05	5.59E-04	4.02E-05	2.90E-03	5.98E-07	2.44E-07	3.02E-01
2267002057	LPG - Rough Terrain Forklift	100	6.23E-07	1.22E-05	3.03E-06	1.69E-04	3.29E-09	1.43E-08	2.53E-02
2267002066	LPG - Tractors/Loaders/Backhoes	100	5.35E-08	1.05E-06	2.59E-07	1.44E-05	2.80E-10	1.23E-09	2.16E-03
2267003030	LPG - Sweepers/Scrubbers*	100	1.52E-08	2.97E-07	7.41E-08	4.14E-06	8.05E-11	3.48E-10	6.21E-04
2267003050	LPG - Other Material Handling Eqp*	100	1.60E-08	3.14E-07	7.77E-08	4.34E-06	8.43E-11	3.66E-10	6.50E-04
2267003070	LPG - Terminal Tractors	175	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2270002036	Diesel - Excavators*	600	1.90E-08	1.56E-07	3.69E-07	1.91E-05	5.86E-08	5.10E-08	1.69E-03
2270002045	Diesel - Cranes	300	3.35E-08	8.47E-08	3.78E-07	1.91E-05	5.84E-08	4.38E-08	1.69E-03
2270002045	Diesel - Cranes	750	3.05E-06	7.69E-06	3.44E-05	1.74E-03	5.33E-06	3.95E-06	1.55E-01
2270002051	Diesel - Off-highway Trucks*	300	7.27E-08	2.66E-07	1.04E-06	6.01E-05	1.84E-07	9.20E-08	5.33E-03
2270002057	Diesel - Rough Terrain Forklifts	600	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2270002060	Diesel - Rubber Tire Loaders	300	1.58E-07	9.99E-07	2.42E-06	1.31E-04	4.00E-07	3.23E-07	1.16E-02
2270002066	Diesel - Tractors/Loaders/Backhoes	75	2.19E-10	8.43E-10	1.06E-09	6.57E-08	2.01E-10	1.34E-10	5.87E-06
2270002069	Diesel - Crawler Tractor/Dozers	300	1.89E-08	7.94E-08	1.94E-07	1.04E-05	3.20E-08	2.20E-08	9.28E-04
2270002072	Diesel - Skid Steer Loaders*	75	1.11E-08	4.00E-08	3.38E-08	2.16E-06	6.62E-09	7.17E-09	1.94E-04
2270003010	Diesel - Aerial Lifts	75	1.13E-09	3.44E-09	6.79E-09	3.02E-07	9.25E-10	9.05E-10	2.70E-05
2270003020	Diesel - Forklifts	175	1.28E-06	5.49E-06	1.43E-05	5.65E-04	1.73E-06	1.74E-06	5.02E-02
2270003020	Diesel - Forklifts	300	4.95E-06	2.13E-05	5.53E-05	2.19E-03	6.71E-06	6.74E-06	1.95E-01
2270003030	Diesel - Sweepers/Scrubbers*	175	1.87E-08	5.27E-08	2.32E-07	8.65E-06	2.65E-08	1.97E-08	7.69E-04
2270003050	Diesel - Other Material Handling Eqp*	40	7.44E-09	2.49E-08	1.35E-08	1.20E-06	3.67E-09	3.62E-09	1.08E-04
2270003050	Diesel - Other Material Handling Eqp*	600	1.15E-07	3.64E-07	6.86E-07	2.72E-05	8.35E-08	1.03E-07	2.44E-03
2270003070	Diesel - Terminal Tractors*	300	2.14E-06	9.22E-06	2.40E-05	9.48E-04	2.91E-06	2.93E-06	8.43E-02
2285002015	Diesel - Railway Maintenance*	300	1.61E-08	7.92E-08	8.28E-08	4.45E-06	1.36E-08	1.66E-08	3.98E-04

* Indicates an equipment type not calculated for smaller ports.

Table 6. 2030 Cargo Tonnage-based Emission Factors for CHE (Metric Tons of Pollutant/Metric Ton of Cargo)

SCC		HP	THC-Exhaust	CO-Exhaust	NO_x-Exhaust	CO_2-Exhaust	SO_2-Exhaust	PM-Exhaust
2265003070	4-Stroke Terminal Tractors*	300	3.12E-06	1.09E-04	9.06E-06	5.99E-03	1.24E-06	6.16E-07
2267002057	LPG - Rough Terrain Forklift	100	8.83E-08	3.07E-06	5.86E-07	3.46E-04	6.72E-09	3.61E-08
2267002066	LPG - Tractors/Loaders/Backhoes	100	7.45E-09	2.56E-07	4.97E-08	2.95E-05	5.73E-10	3.10E-09
2267003030	LPG - Sweepers/Scrubbers*	100	7.09E-09	1.90E-07	3.45E-08	8.67E-06	1.68E-10	8.78E-10
2267003050	LPG - Other Material Handling Eqp*	100	2.33E-09	8.12E-08	1.52E-08	8.87E-06	1.72E-10	9.26E-10
2267003070	LPG - Terminal Tractors	175	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2270002036	Diesel - Excavators*	600	1.50E-08	6.06E-08	1.36E-07	4.84E-05	3.54E-10	9.19E-09
2270002045	Diesel - Cranes	300	1.10E-06	1.18E-06	2.41E-06	4.42E-03	2.91E-08	9.83E-08
2270002045	Diesel - Cranes	750	1.21E-08	6.99E-09	2.57E-08	4.84E-05	3.19E-10	1.09E-09
2270002051	Diesel - Off-highway Trucks*	300	4.29E-08	8.25E-08	2.46E-07	1.52E-04	1.05E-09	1.42E-08
2270002057	Diesel - Rough Terrain Forklifts	600	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2270002060	Diesel - Rubber Tire Loaders	300	8.16E-08	7.42E-08	1.74E-07	3.31E-04	2.18E-09	7.33E-09
2270002066	Diesel - Tractors/Loaders/Backhoes	75	9.06E-11	5.10E-10	8.82E-10	1.68E-07	1.25E-12	5.00E-11
2270002069	Diesel - Crawler Tractor/Dozers	300	7.11E-09	1.14E-08	3.35E-08	2.65E-05	1.81E-10	1.87E-09
2270002072	Diesel - Skid Steer Loaders*	75	3.16E-09	1.87E-08	2.93E-08	5.54E-06	4.14E-11	2.34E-09
2270003010	Diesel - Aerial Lifts	75	4.19E-10	2.33E-09	4.09E-09	7.71E-07	5.76E-12	2.33E-10
2270003020	Diesel - Forklifts	175	1.37E-06	1.25E-06	2.92E-06	5.57E-03	3.67E-08	1.24E-07
2270003020	Diesel - Forklifts	300	3.54E-07	3.81E-07	7.53E-07	1.44E-03	9.45E-09	3.20E-08
2270003030	Diesel - Sweepers/Scrubbers*	175	8.06E-09	1.89E-08	6.91E-08	2.20E-05	1.63E-10	4.07E-09
2270003050	Diesel - Other Material Handling Eqp*	40	2.93E-08	1.23E-07	1.92E-07	6.97E-05	5.09E-10	1.70E-08
2270003050	Diesel - Other Material Handling Eqp*	600	7.67E-10	3.06E-09	1.43E-08	3.08E-06	2.11E-11	3.52E-10
2270003070	Diesel - Terminal Tractors*	300	5.94E-07	5.42E-07	1.27E-06	2.41E-03	1.59E-08	5.38E-08
2285002015	Diesel - Railway Maintenance*	300	5.44E-09	1.84E-08	3.10E-08	1.14E-05	8.31E-11	3.28E-09

* Indicates an equipment type not calculated for smaller ports.

3. Vessel Port Approach, Departure, and Maneuvering Emissions

On 20 March 2014, ERG received documentation (CEC 2008) and marine vessel data files (*Embarcaciones Maritimas Comerciales 2008*.rar) from Hugo Landa Fonseca of Semarnat. These data were used in developing the *Inventario Nacional de Emisiones de Fuentes de Área 2008*. The data set included emission estimates developed for criteria air pollutants (CO, NO_X, SO_X, PM_{10}, $PM_{2.5}$, VOC) for marine vessels operating in Mexico for the calendar year 2008. The emission estimates were based on fuel consumption for individual vessels. The emission factors used to estimate emissions were compared to a set of residual fuel emission factors recently developed for the GREET model, as shown in Table 7. Note the GREET residual fuel emission factors were developed assuming a sulfur concentration of 27,000 ppm and fuel consumption rate of 195 g/kw-hr.

Table 7. Emission Factor Comparison (g/liter of residual fuel)

	VOC	CO	NO_X	SO_X	PM_{10}	$PM_{2.5}$
Mexican factors	0.99	11.10	112.62	0.34	2.68	2.62
GREET factors	2.90	6.78	87.62	49.81	6.87	6.34

There are significant differences between the two emission factor data sets; compared to the GREET factors, VOC (122%), SO_X (895%), PM_{10} (77%), and $PM_{2.5}$ (67%) emissions increased significantly, while CO (53%) and NO_X (41%) emissions decreased.

For this project, the original Mexican fuel consumption data were applied to the more recent GREET residual emission factors. The marine vessel emissions were calculated using the following equation:

$$E = F \times EF*1000$$

Where:

E	=	Emissions (kg)
F	=	Fuel consumption (liters)
EF	=	Emission factor (g/l)
1000	=	Conversion factor for grams to kilograms

Example Calculation:

On 12 December 2008, "Contenedores" located at Ensenada consumed 102.3 liters of fuel. The emission factor for NO_X is 87.62256 kg/1000 liters.

$$E = 102.3 / 1{,}000 \times 87.62256$$
$$E = 8.96 \text{ kg}$$

Pollutant-specific comparisons of the emissions from the original Mexican Inventory and the updated emissions using the GREET factors are presented for individual ports in Table 8.

Table 8. 2008 Emissions Inventory Comparison by Mexican Port

Port	Estimates based on GREET Emission Factors (kg)						Emissions based on Mexican Emission Factors (kg)					
	VOC	CO	NO_X	SO_X	PM_{10}	$PM_{2.5}$	VOC	CO	NO_X	SO_X	PM_{10}	$PM_{2.5}$
Altamira	4,912	11,461	148,175	84,239	11,625	10,724	263	825	11,783	59,778	5,216	5,100
Coatzacoalcos	420	980	12,669	7,202	994	917	23	75	1,056	5,095	447	436
Dos Bocas	54,077	126,181	1,631,334	927,427	127,983	118,069	4,134	24,821	286,398	606,211	56,914	55,550
Ensenada	280	654	8,457	4,808	663	612	36	319	3,375	2,516	288	281
Manzanillo	865	2,018	26,088	14,831	2,047	1,888	52	221	2,825	10,276	915	895
Mazatlán	159	371	4,803	2,730	377	348	16	124	1,355	1,615	164	162
Puerto Vallarta	688	1,605	20,753	11,798	1,628	1,502	36	105	1,545	8,407	732	715
Salina Cruz	183	427	5,525	3,141	433	400	10	30	431	2,232	195	190
Tampico	5,343	12,466	161,173	91,628	12,645	11,665	365	1,898	22,782	61,720	5,075	5,509
Topolobampo	2,679	6,251	80,815	45,944	6,340	5,849	274	2,113	22,982	27,117	2,778	2,719
Veracruz	1,083	2,526	32,656	18,565	2,562	2,364	60	205	2,828	13,098	1,151	1,123
Sauzal	53	123	1,592	905	125	115	18	198	2,008	19	49	48
Lázaro Cárdenas	441	1,030	13,313	7,568	1,044	964	27	113	1,443	5,244	468	457
Total	**71,183**	**166,093**	**2,147,353**	**1,220,786**	**168,466**	**155,417**	**5,314**	**31,047**	**360,811**	**803,328**	**74,392**	**73,185**

The updated inventory included additional ports not considered in the original inventory. This was problematic because vessel activity data were not available for the additional ports. To approximate the emissions in the new ports, the revised emission values for the original 13 ports were divided by each port's 2008 cargo tonnage to develop emission factors in metric tons of pollutant divided by cargo tonnage handled. These emission factors were then combined into two sets of averages: one for ports handling more than 2 million metric tons of cargo and one for ports handling less than 2 million metric tons of cargo to develop "large" and "small" port profiles, as noted in Table 9.

Table 9. Cargo-based Emission Factors Based on Original 2008 Vessel Movement Data

Port	Emission Factors (metric tons/cargo tonnage)					
	VOC	CO	NO_X	SO_X	PM_{10}	$PM_{2.5}$
Coatzacoalcos	5.42E-09	1.26E-08	1.64E-07	9.30E-08	1.28E-08	1.18E-08
Manzanillo	1.42E-08	3.31E-08	4.28E-07	2.43E-07	3.36E-08	3.10E-08
Lázaro Cárdenas	2.23E-08	5.20E-08	6.73E-07	3.82E-07	5.28E-08	4.87E-08
Veracruz	6.42E-08	1.50E-07	1.94E-06	1.10E-06	1.52E-07	1.40E-07
Altamira	1.10E-07	2.57E-07	3.33E-06	1.89E-06	2.61E-07	2.41E-07
Salina Cruz	8.75E-09	2.04E-08	2.64E-07	1.50E-07	2.07E-08	1.91E-08
Dos Bocas	5.62E-06	1.31E-05	1.70E-04	9.64E-05	1.33E-05	1.23E-05
Tampico	9.66E-08	2.26E-07	2.92E-06	1.66E-06	2.29E-07	2.11E-07
Topolobampo	1.58E-08	3.68E-08	4.76E-07	2.71E-07	3.73E-08	3.44E-08
Mazatlán	1.75E-08	4.09E-08	5.29E-07	3.01E-07	4.15E-08	3.83E-08
Ensenada	1.03E-07	2.40E-07	3.10E-06	1.76E-06	2.43E-07	2.25E-07
Sauzal	1.51E-07	3.53E-07	4.56E-06	2.59E-06	3.58E-07	3.3E-07
> 2 million metric tons	**5.53E-07**	**1.29E-06**	**1.67E-05**	**9.48E-06**	**1.31E-06**	**1.21E-06**
< 2 million metric tons	**1.51E-07**	**3.53E-07**	**4.56E-06**	**2.59E-06**	**3.58E-07**	**3.30E-07**

These new cargo emission factors were multiplied by the 2010 cargo tonnage provided by the *Secretaría de Comunicaciones y Transportes* (SCT 2014) for each port using the following equation:

$$E2 = T \times EF$$

Where:

E2 = Emissions (metric tons)
T = 2010 total cargo (metric tons) for the port
EF = Emission factor (metric tons of pollutant/cargo tonnage)

Example Calculation:

For example, the port of Tampico handled 4,328,498 metric tons of cargo in 2010. The VOC emission factor for a large port is 5.53E-07.

E2 = 4,328,498 x 5.53E-07
E2 = 2.392408

These 2010 estimates were scaled to 2011 based on a 5 percent growth rate (Corbett 2012). To develop the 2030 data, the same annual growth rate was used. For 2030, it was assumed that a global distillate/residual fuel blend will be used with a sulfur concentration of 5,000 ppm. The projected emission factors are shown in Table 10. 2011 and 2030 emissions from port vessel movements are summarized in Appendix B.

Table 10. Fuel-based Marine Vessels Emission Factors (grams of pollutant/liter of fuel)

Year	VOC	CO	NO_X	SO_X	PM_{10}	$PM_{2.5}$
2011	2.90	6.78	87.62	49.81	6.87	6.34
2030	2.73	6.36	66.50	8.22	1.39	1.25

4. Vessel Dockside Emissions

Dockside emissions occur when vessels are hoteling in a port while cargo is removed or added to the vessel. The dockside estimate included in the *Inventario Nacional de Emisiones de Fuentes de Área 2008* were provided as an aggregated value for all 13 ports included in the study. The number of vessels visiting Mexican ports and the time spent at dockside seemed to be reasonable and was used in this update.

The original Mexican inventory used dockside fuel usage data from the 1992 US EPA's State Implementation Plan (SIP) guidance (2,498 liters per day). As ports consider using cold ironing to reduce dockside emissions, there are new data available that better quantify vessel energy demand. Vessel dockside energy demand data for different vessel types were obtained from an international study of cold ironing (Papoutsoglou 2012) and converted to fuel data assuming a conversion rate of 0.02 kg of fuel per kW-hr. These energy demand data were reported by ship type and weighted for this study using vessel type traffic data provided by Semarnat. These weighted fuel demand data were converted to daily fuel usage rate as noted in Table 11.

Table 11. Dockside Vessel Energy Demand

Mexican Vessel Calls	Fraction	Vessel Type	Power Requirement	kW	hrs	kW-hrs/ day	liters/ day	Weighted liters/day factors
2503	0.484	Container	1 to 4 MWe	2,500	24	60,000	12,128	5,870.73
350	0.068	Cruise	5 to 10 MWe	7,500	24	180,000	36,385	2,462.75
103	0.020	Reefer	2 to 5 MWe	2,500	24	60,000	12,128	241.58
81	0.016	RO-RO	700 kWe	700	24	16,800	3,396	53.20
1601	0.310	Tanker	5 to 6 MWe	5,500	24	132,000	26,683	8,261.24
533	0.103	Bulk	300 kWe to 1 MWe	650	24	15,600	3,153	325.04
5171	1.000							**17,214.53**

kWe = kilowatt electric
MWe = megawatt electric

The new daily fuel usage rate was 17,214.5 liters per day compared to the US EPA SIP rate of 2,498 liters per day. Given the age of the SIP data and the improved data quality of the new fuel demand rate, the new rate was applied to Mexico's vessel traffic count and days at port data set to estimate hoteling fuel usage. The updated fuel data were applied to the GREET emission factors noted in Section 3 of this report to get the revised 2008 emission estimates.

Since the new port list was increased to 35 ports, the total cargo tonnage for the original port list and the new port list were compared to develop an adjustment factor to approximate the additional emissions for new platforms. The original tonnage for 13 ports was 107,918,357 metric tons, and the total tonnage for all 35 ports totaled 210,621,747 metric tons, so the dockside emission values were adjusted up by a factor of 1.9517 to account for the additional ports. The original and revised emissions and tonnage values are shown in Table 12.

Table 12. Total Dockside Emissions for Mexican Ports for 2010 (metric tons)

Dock-side Emissions	VOC	CO	NO_X	SO_X	PM_{10}	$PM_{2.5}$	Cargo Tonnage
Revised 2008 13 Ports	4,678	10,916	141,129	80,233	11,072	10,214	258,501,351
Total 35 ports	9,131	21,305	275,439	156,589	21,609	19,935	210,621,747

These 2010 estimates were scaled to 2011 emissions based on a 5 percent growth rate (Corbett 2012). To develop data projections for 2030, the same annual growth rate was used. For 2030, it was assumed that a global distillate/residual fuel blend will be used with a sulfur concentration of 5,000 ppm. The projected emission factors are shown in Table 13. 2011 and 2030 port vessel dockside emissions are summarized in Appendix B.

Table 13. Total Dockside Emissions for Mexican Ports for 2011 and 2030 (Metric Tons)

Dockside Emissions (Metric Tons)		
	2011	**2030**
VOC	9,131	21,685
CO	21,305	50,520
NO_X	275,439	528,235
SO_X	156,589	65,294
PM_{10}	21,609	11,041
$PM_{2.5}$	19,935	9,929

5. Results

A summary of Mexico's revised port inventory is provided in Table 14. Most of the marine vessel pollutants are projected to increase from 2011 to 2030 due to anticipated increase in vessel traffic. On the other hand, the decline in SO_X and PM emissions is associated with marine vessel use of lower sulfur fuels from 2020 onward. There is a similar decline in emissions for CHE due to the use of ultra low sulfur fuels and application of NO_X controls.

Table 14. Mexican Port Emission Estimates for 2011 and 2030 (Metric Tons per Year)

Pollutants	Vessel Movements		Vessel Dockside		Cargo Handling		Total	
	2011	2030	2011	2030	2011	2030	2011	2030
VOC	120	286	9,131	21,685	6,773	1,426	16,024	23,397
CO	281	666	21,305	50,520	134,285	24,064	155,871	75,250
NO_X	3,631	6,963	275,439	528,235	38,865	3,752	317,935	538,950
SO_X	2,064	861	156,589	65,294	3,996	276	162,649	66,431
PM_{10}	285	146	21,609	11,041	3,589	213	25,483	11,400
$PM_{2.5}$	263	131	19,935	9,929			20,198	10,060

The port vessel and CHE emission estimates presented in Table 14 appear reasonable when compared to 2011 US ports that show CHE NO_X and PM emissions tend to be between 10 and 50 percent of vessel emissions, as noted in Table 15.

Table 15. Comparison of US Port Vessel and Cargo Handling Equipment (CHE) Emissions

Region	Port	Marine Freight Vessel Emissions		Port CHE Emissions	
		NO_x	PM_{10}	NO_x	PM_{10}
Baltimore	Port of Baltimore	2,399	141	916	50
Chicago	Port of Chicago	1,901	160	298	13
Detroit	Port of Detroit	247	18	221	9
Houston	Port of Houston	10,576	694	1,011	74
	Port of Galveston	403	21	179	9
	Port of Freeport	461	20	228	12
	Port of Texas City	1,294	73	200	10
	Subtotal	12,734	808	1,618	106
Los Angeles	Port of Los Angeles	8,687	614	1,892	113
	Port of Long Beach	9,660	647	2,371	147
	Subtotal	18,347	1,261	4,263	260

Total port estimates appear reasonable as they are significantly less than the Corbett estimate for offshore vessel movement in the Mexican ECA (i.e., 317,935 metric tons of NO_X for Mexican ports versus 4,855,000 metric tons of NO_X for Mexican ECA).

6. References

CEC. 2011. *Inventario Nacional de Emisiones de Fuentes de Área, 2008,* anexo 2: "Fuentes móviles no carreteras" (Unpublished). Montreal, Canada. Commission for Environmental Cooperation.

Corbett, James. 2012. Ship Emission Inventory Scenarios for US Mexico Technical Exchange on Reducing Shipping Emissions (Memorandum), 17 December.

DOE. 2013. The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model. US Department of Energy, Argonne National Laboratory. October. <https://greet.es.anl.gov>.

EPA. 2009. NONROAD 2008a model. US Environmental Protection Agency. July.

Papoutsoglou, Theodoros G. 2012. A Cold Ironing Study on Modern Ports, Implementation and Benefits Thriving for World Ports. School of Naval Architecture and Marine Engineering, National Technical University of Athens.

SCT. 2014. Informe Estadístico Mensual; Movimiento de Carga, Buques, y Pasajeros. Enero – enero, 2013-2014. *Secretaría de Comunicaciones y Transportes.* <www.sct.gob.mx/fileadmin/CGPMM/U_DGP/estadisticas/2014/Mensuales/01_enero_2014.pdf>. Accessed June 2, 2014.

Starcrest Consulting Group LLC. 2013. Port of Long Beach Air Emissions Inventory – 2012. July.

TransportPolicy.net: Mexico: Fuels: Diesel and Gasoline. Accessed May 2014. Available online at <http://transportpolicy.net/index.php?title=Mexico:_Fuels:_Diesel_and_Gasoline>.

WeatherSpark Meterological data <http://weatherspark.com/averages/32574/Mexico-City-Distrito-Federal>. Accessed June 2014.

Appendix A – Emissions Associated with Cargo Handling Equipment

	2011 Emissions (Metric Tons)						2030 Emissions (Metric Tons)					
	THC	CO	NO_X	CO_2	SO_2	PM	THC	CO	NO_X	CO_2	SO_2	PM
Acapulco, Gro.	6.3241	30.4329	68.6532	3,011.0530	8.8776	7.9888	1.7918	3.6909	4.1220	7,233.7134	0.0505	0.1801
Altamira, Tamps.	491.6069	9,799.3918	2,803.3773	139,640.9904	287.2319	258.0011	103.2885	1,757.0059	272.0426	315,627.8880	20.1777	15.4610
Campeche, Camp.	9.2002	44.2733	99.8756	4,380.4323	12.9151	11.6219	2.6067	5.3695	5.9966	10,523.4919	0.0734	0.2621
Cayo Arcas, Camp.	1,587.3027	31,640.3221	9,051.5576	450,873.4819	927.4157	833.0350	333.4983	5,673.0288	878.3724	1,019,100.7983	65.1499	49.9206
Ciudad del Carmen, Camp.	0.0993	0.4780	1.0783	47.2915	0.1394	0.1255	0.0281	0.0580	0.0647	113.6124	0.0008	0.0028
Coatzacoalcos, Ver.	143.5558	2,861.5539	818.6238	40,777.0431	83.8756	75.3398	30.1616	513.0693	79.4401	92,167.5787	5.8922	4.5148
Cozumel, Q. Roo	8.1926	39.4246	88.9375	3,900.7029	11.5006	10.3491	2.3212	4.7814	5.3398	9,370.9963	0.0654	0.2334
Dos Bocas, Tab.	301.1320	6,002.5821	1,717.1986	85,536.5851	175.9429	158.0376	63.2690	1,076.2476	166.6387	193,336.7245	12.3598	9.4706
El Sauzal, B.C.	3.8071	18.3205	41.3289	1,812.6416	5.3443	4.8092	1.0787	2.2219	2.4814	4,354.6658	0.0304	0.1084
Ensenada, B.C.	162.5258	3,239.6894	926.7995	46,165.4607	94.9592	85.2954	34.1473	580.8680	89.9376	104,346.9171	6.6708	5.1114
Frontera, Tab.	0.0014	0.0066	0.0148	0.6505	0.0019	0.0017	0.0004	0.0008	0.0009	1.5627	0.0000	0.0000
Guaymas, Son.	184.7304	3,682.3037	1,053.4211	52,472.6984	107.9327	96.9487	38.8126	660.2276	102.2251	118,603.0472	7.5821	5.8098
Guerrero Negro, B.C.S.	225.0619	4,486.2463	1,283.4104	63,928.8533	131.4973	118.1151	47.2864	804.3725	124.5435	144,497.1773	9.2375	7.0782
Isla Cedros, B.C.	444.6833	8,864.0444	2,535.7962	126,312.3218	259.8158	233.3750	93.4296	1,589.3005	246.0762	285,501.3505	18.2518	13.9853
Isla Holbox, Q. Roo	0.3070	1.4772	3.3324	146.1533	0.4309	0.3878	0.0870	0.1792	0.2001	351.1168	0.0024	0.0087
Isla San Marcos, B.C.S.	9.7841	47.0830	106.2139	4,658.4234	13.7347	12.3595	2.7721	5.7102	6.3771	11,191.3341	0.0781	0.2787
La Paz, B.C.S.	139.6673	2,784.0423	796.4495	39,672.5059	81.6036	73.2990	29.3446	499.1717	77.2883	89,671.0142	5.7326	4.3925
Lázaro Cárdenas, Mich.	261.4391	5,211.3667	1,490.8504	74,261.7927	152.7514	137.2063	54.9293	934.3847	144.6736	167,852.5247	10.7306	8.2222
Manzanillo, Col.	580.3026	11,567.3964	3,309.1621	164,834.9938	339.0542	304.5496	121.9238	2,074.0046	321.1245	372,573.4170	23.8182	18.2505
Mazatlán, Sin.	103.5264	2,063.6319	590.3569	29,406.6822	60.4875	54.3319	21.7513	370.0039	57.2888	66,467.3672	4.2492	3.2559
Playa del Carmen. Q. Roo	276.6436	5,514.4444	1,577.5538	78,580.6393	161.6350	145.1858	58.1239	988.7258	153.0874	177,614.3318	11.3547	8.7004
Progreso, Yuc.	142.0513	2,831.5632	810.0441	40,349.6760	82.9965	74.5502	29.8455	507.6920	78.6075	91,201.6091	5.8304	4.4675
Puerto Chiapas,	0.4715	2.2691	5.1189	224.5100	0.6619	0.5957	0.1336	0.2752	0.3073	539.3598	0.0038	0.0134

	2011 Emissions (Metric Tons)						2030 Emissions (Metric Tons)					
	THC	**CO**	**NO_X**	**CO_2**	**SO_2**	**PM**	**THC**	**CO**	**NO_X**	**CO_2**	**SO_2**	**PM**
Chis.												
Puerto Libertad, Son.	6.2706	30.1755	68.0726	2,985.5880	8.8026	7.9212	1.7767	3.6597	4.0871	7,172.5366	0.0500	0.1786
Puerto Morelos, Q. Roo	0.6737	3.2421	7.3139	320.7801	0.9458	0.8511	0.1909	0.3932	0.4391	770.6378	0.0054	0.0192
Rosarito, B.C.	82.4684	1,643.8753	470.2743	23,425.1650	48.1840	43.2804	17.3269	294.7426	45.6359	52,947.4572	3.3849	2.5936
Salina Cruz, Oax.	429.3975	8,559.3471	2,448.6294	121,970.3961	250.8847	225.3528	90.2180	1,534.6690	237.6175	275,687.3781	17.6244	13.5045
San Carlos, B.C.S.	1.8258	8.7863	19.8210	869.3276	2.5631	2.3065	0.5173	1.0656	1.1901	2,088.4611	0.0146	0.0520
San Felipe, B.C.	0.0055	0.0266	0.0599	2.6273	0.0077	0.0070	0.0016	0.0032	0.0036	6.3118	0.0000	0.0002
Santa Rosalia, B.C.S.	0.3830	1.8432	4.1580	182.3664	0.5377	0.4838	0.1085	0.2235	0.2496	438.1146	0.0031	0.0109
Tampico, Tamps.	141.1849	2,814.2925	805.1034	40,103.5696	82.4903	74.0955	29.6635	504.5954	78.1281	90,645.3395	5.7948	4.4403
Topolobampo, Sin.	167.1401	3,331.6687	953.1127	47,476.1629	97.6552	87.7171	35.1168	597.3597	92.4910	107,309.4724	6.8602	5.2565
Tuxpan, Ver.	360.8985	7,193.9292	2,058.0152	102,513.2395	210.8627	189.4037	75.8261	1,289.8531	199.7119	231,708.7353	14.8129	11.3502
Veracruz, Ver.	499.9512	9,965.7209	2,850.9601	142,011.1741	292.1072	262.3802	105.0416	1,786.8283	276.6601	320,985.1693	20.5202	15.7234
Total	**6,773**	**134,285**	**38,865**	**1,932,856**	**3,996**	**3,589**	**1,426**	**24,064**	**3,752**	**4,372,001**	**276**	**213**

Appendix B – Annual Cargo Totals and Associated Vessel Emissions

Annual cargo totals were provided to ERG by Semarnat in the file "Puertos de altura y cabotaje final.xlsx"

Port Name	Cargo Tonnage (2010)	2011 Emissions (Metric Tons)						2030 Emissions (Metric Tons)					
		VOC	CO	NO_x	SO_x	PM_{10}	$PM_{2.5}$	VOC	CO	NO_x	SO_x	PM_{10}	$PM_{2.5}$
Cayo Arcas, Camp.	48,664,121	28.242044	65.898113	851.968412	484.351088	66.839510	61.661809	67.075982	156.264861	1633.901486	201.964523	34.152276	30.712485
Manzanillo, Col.	17,791,133	10.325019	24.091714	311.471429	177.074083	24.435880	22.542962	24.522332	57.128925	597.338615	73.836281	12.485742	11.228188
Veracruz, Ver.	15,327,690	8.895369	20.755863	268.343647	152.555582	21.052374	19.421559	21.126855	49.218589	514.628333	63.612566	10.756908	9.673481
Altamira, Tamps.	15,071,869	8.746904	20.409446	263.864959	150.009411	20.701008	19.097411	20.774246	48.397124	506.039124	62.550864	10.577374	9.512029
Isla Cedros, B.C.	13,633,266	7.912016	18.461373	238.679169	135.691082	18.725106	17.274572	18.791353	43.777641	457.737921	56.580413	9.567769	8.604111
Salina Cruz, Oax.	13,164,629	7.640044	17.826772	230.474687	131.026766	18.081439	16.680767	18.145410	42.272806	442.003399	54.635488	9.238881	8.308348
Tuxpan, Ver.	11,064,560	6.421277	14.982982	193.708535	110.124904	15.197023	14.019791	15.250789	35.529295	371.493426	45.919839	7.765062	6.982971
Dos Bocas, Tab.	9,232,219	5.357884	12.501732	161.629529	91.887724	12.680328	11.698050	12.725189	29.645484	309.972440	38.315306	6.479133	5.826559
Playa del Carmen. Q. Roo	8,481,443	4.922174	11.485075	148.485607	84.415295	11.649147	10.746750	11.690360	27.234675	284.765080	35.199456	5.952241	5.352736
Lázaro Cárdenas, Mich.	8,015,297	4.651648	10.853848	140.324734	79.775772	11.008902	10.156101	11.047850	25.737838	269.114194	33.264870	5.625102	5.058546
Guerrero Negro, B.C.S.	6,900,032	4.004408	9.343621	120.799661	68.675606	9.477100	8.742960	9.510629	22.156622	231.669088	28.636327	4.842413	4.354689
Guaymas, Son.	5,663,535	3.286812	7.669229	99.152164	56.368825	7.778788	7.176207	7.806309	18.186119	190.153609	23.504650	3.974645	3.574322
Topolobampo, Sin.	5,124,244	2.973836	6.938952	89.710734	51.001294	7.038080	6.492877	7.062980	16.454408	172.046874	21.266499	3.596173	3.233969
Ensenada, B.C.	4,982,776	2.891736	6.747385	87.234037	49.593272	6.843775	6.313624	6.867988	16.000141	167.297075	20.679383	3.496891	3.144687
Coatzacoalcos, Ver.	4,401,188	2.554213	5.959832	77.052109	43.804761	6.044972	5.576700	6.066359	14.132610	147.770215	18.265692	3.088735	2.777640
Progreso, Yuc.	4,355,061	2.527444	5.897370	76.244558	43.345662	5.981617	5.518253	6.002780	13.984492	146.221497	18.074257	3.056364	2.748529
Tampico, Tamps.	4,328,498	2.512028	5.861399	75.779517	43.081282	5.945133	5.484595	5.966167	13.899196	145.329643	17.964016	3.037722	2.731765
La Paz, B.C.S.	4,281,972	2.485027	5.798397	74.964981	42.618211	5.881230	5.425643	5.902038	13.749797	143.767529	17.770925	3.005070	2.702402
Mazatlán, Sin.	3,173,951	1.841991	4.297979	55.566728	31.590145	4.359379	4.021681	4.374802	10.191842	106.565641	13.172446	2.227465	2.003117
Rosarito, B.C.	2,528,348	1.467318	3.423741	44.264082	25.164497	3.472652	3.203644	3.484938	8.118752	84.889472	10.493082	1.774384	1.595669
Isla San Marcos,	916,683	0.145627	0.339798	4.393096	2.497512	0.344652	0.317953	0.345871	0.805765	8.425062	1.041411	0.176103	0.158366

Port Name	Cargo Tonnage (2010)	2011 Emissions (Metric Tons)						2030 Emissions (Metric Tons)					
		VOC	CO	NO_X	SO_X	PM_{10}	$PM_{2.5}$	VOC	CO	NO_X	SO_X	PM_{10}	$PM_{2.5}$
B.C.S.													
Campeche, Camp.	861,980	0.136937	0.319520	4.130938	2.348473	0.324085	0.298980	0.325231	0.757681	7.922297	0.979265	0.165594	0.148916
Cozumel, Q. Roo	767,579	0.121940	0.284527	3.678533	2.091276	0.288592	0.266236	0.289613	0.674703	7.054675	0.872020	0.147459	0.132607
Acapulco, Gro.	592,514	0.094129	0.219634	2.839554	1.614310	0.222772	0.205515	0.223560	0.520820	5.445685	0.673134	0.113827	0.102363
Puerto Libertad, Son.	587,503	0.093333	0.217777	2.815539	1.600657	0.220888	0.203777	0.221669	0.516416	5.399630	0.667442	0.112865	0.101497
El Sauzal, B.C.	356,691	0.056665	0.132219	1.709400	0.971808	0.134108	0.123719	0.134582	0.313532	3.278280	0.405224	0.068524	0.061622
San Carlos, B.C.S.	171,066	0.027176	0.063411	0.819814	0.466071	0.064317	0.059335	0.064544	0.150367	1.572236	0.194342	0.032863	0.029553
Puerto Morelos, Q. Roo	63,123	0.010028	0.023399	0.302510	0.171979	0.023733	0.021894	0.023817	0.055485	0.580152	0.071712	0.012126	0.010905
Puerto Chiapas, Chis.	44,179	0.007018	0.016376	0.211723	0.120366	0.016610	0.015324	0.016669	0.038833	0.406041	0.050190	0.008487	0.007632
Santa Rosalia, B.C.S.	35,886	0.005701	0.013302	0.171979	0.097772	0.013492	0.012447	0.013540	0.031544	0.329821	0.040769	0.006894	0.006200
Isla Holbox, Q. Roo	28,760	0.004569	0.010661	0.137829	0.078357	0.010813	0.009975	0.010851	0.025280	0.264328	0.032673	0.005525	0.004969
Ciudad del Carmen, Camp.	9,306	0.001478	0.003450	0.044598	0.025354	0.003499	0.003228	0.003511	0.008180	0.085530	0.010572	0.001788	0.001608
San Felipe, B.C.	517	0.000082	0.000192	0.002478	0.001409	0.000194	0.000179	0.000195	0.000454	0.004752	0.000587	0.000099	0.000089
Frontera, Tab.	128	0.000020	0.000047	0.000613	0.000349	0.000048	0.000044	0.000048	0.000113	0.001176	0.000145	0.000025	0.000022
Punta Santa María, B.C.S.	0	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Total	210,621,747	120.363897	280.849136	3630.977884	2064.240955	284.861245	262.794561	285.869056	665.980390	6963.474325	860.746369	145.552530	130.892593