APPENDIX I

CONTROLLED AND UNCONTROLLED AVERAGE SUMMER WEEKDAY COMMERCIAL MARINE VESSEL INVENTORIES FOR HOUSTON-GALVESTON-BRAZORIA AREA FOR SELECT YEARS 2012, 2014, 2017, 2020, 2023, 2026, AND 2028

Eastern Research Group, Inc.

Controlled and Uncontrolled Average Summer Weekday Commercial Marine Vessel Inventories for Houston-Galveston-Brazoria Area for Select years 2012, 2014, 2017, 2020, 2023, 2026, and 2028

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Controlled and Uncontrolled Average Summer Weekday Commercial Marine Vessel Inventories for Houston-Galveston-Brazoria Area for Select Years 2012, 2014, 2017, 2020, 2023, 2026, and 2028

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1.0 Introduction

The objective of this Texas Commission on Environmental Quality (TCEQ) project was to develop volatile organic compound (VOC) and nitrogen oxide (NO_X) controlled and uncontrolled commercial marine vessel (CMV) emissions estimates for 2012, 2014, 2017, 2020, 2023, 2026, and 2028 to aid in State Implementation Plan (SIP) development for the eight-county Houston-Galveston-Brazoria (HGB) 1997 eight-hour ozone nonattainment area. During project development, activity data for 2014 were not available. Therefore, Eastern Research Group, Inc. (ERG) obtained activity data from 2013 as this represented the most recent available data at the time the project began. ERG collected activity data for calendar year 2013 and used the data to develop ozone season weekday emission inventories for CMVs using updated emissions and activity-based projection factors.

One improvement of this inventory over previous efforts is its bottom-up approach that integrates significant amounts of locally provided data. While previous efforts have relied partially on a top-down approach to adjust national inventory data to quantify state and county level activity and emissions, recent trends in inventory development have emphasized increased spatial resolution that is not well served by modifying national-level data. For that reason, the TCEQ sought inventory efforts built on detailed, locally based activity and emissions data.

The Texas CMV SIP Emissions Inventory includes Category I, II, and III vessel activity and emissions by waterway for the eight HGB ozone nonattainment counties (Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller). The Marine categories are based on engine specifications and are divided into three categories based on engine cylinder displacement. Category 1 and Category 2 marine diesel engines typically range in size from about 500 to 8,000 kilowatt (kW) (700 to 11,000 horse power (hp)). These engines are used to provide propulsion power on many kinds of vessels including tugboats, pushboats, supply vessels, fishing vessels, and other commercial vessels in and around ports. They are also used as stand-alone generators for auxiliary electrical power on many types of vessels. Category 3 marine diesel engines typically range in size from 2,500 to 70,000 kW (3,000 to 100,000 hp). These are very large marine diesel engines that run on residual fuel and are used for propulsion power on ocean-going vessels such as container ships, oil tankers, bulk carriers, and cruise ships. The following sections describe the inventory approach, including initial collection of local data, emission calculations, and spatial allocations used to develop the SIP CMV emissions inventory.

2.0 Data Collection

2.1 PortVision Automatic Identification System (AIS) Data

As a first step in data collection, ERG obtained Automatic Identification System (AIS) activity data for commercial marine vessels from PortVision. PortVision, a service of AIRSIS, Inc., is one of the largest international providers of satellite and terrestrial AIS data. AIS transponders serve as GPS units that report vessel location, speed, and other information every 2 seconds to nearby receivers and are available on most marine vessels due to increasing regulations and decreasing cost. AIS signals cover activities both in port as well as in state, federal, and international waters, providing a more complete picture of each vessel's activity. While there are a number of vessel activity data sources available, many publicly available datasets are highly aggregated and include only vessel origins and destinations (or entrances and clearances) with no indication of how the distance was traversed. Hours of operation using these datasets can only be crudely estimated based on an estimate of vessel speed and the length of the shortest route between the origin and destination.

In contrast, AIS data provide individual vessel identification information along with both geographic location and time stamps, allowing for spatially and temporally accurate vessel routes. Using these data enables one to map individual trips for each vessel to calculate actual hours of operation resulting in a more refined estimate of CMV activity.

As AIS data is primarily geared toward traffic control and accident avoidance, it is not ideally formatted for use in inventory efforts. The dataset ERG obtained from PortVision for this effort includes observations every 15 minutes for every vessel in the area of interest during 2013 (31,841,919 unique observations associated with 9,584 vessels) to provide a clearer picture of vessel movement and to avoid data gaps.

2.2 Other Vessel Activity Data

AIS data, while far more comprehensive than in the past, may not capture all CMVs within the study area. In particular, smaller vessels that are not required to carry AIS transponders may not be well represented in the dataset. ERG identified three categories of vessels with insufficient data in AIS: military, dredging, and commercial fishing vessels. The following sections describe the additional data sources that ERG used to complement, gap-fill, or replace AIS data where needed.

2.2.1 Government Vessels

The Department of Homeland Security limits the ability to collect activity data and estimate emissions. In the Gulf of Mexico, military vessel activity is implemented by the

U.S. Navy and the U.S. Coast Guard. ERG assumed that Navy vessel activities in Texas state waters were relatively few, since the last Navy base located in Texas was closed in 2006 and most military vessel exercises occur in federal waters.

ERG obtained information about Coast Guard vessels operating in Texas waters using fleet profiles obtained from their websites (USCG, 2014).

2.2.2 Dredging Activity

ERG obtained information concerning dredging operations occurring in Texas state waters from the U.S. Army Corps of Engineers Dredging Activity Database (USACE, 2014).

2.2.3 Commercial Fishing Activity

Commercial fishing activities can be difficult to estimate since fishing vessels tend to consider the locations of their fishing spots confidential business information. ERG estimated commercial fishing activity based on the following data sources. ERG obtained fish landings from the National Marine Fisheries Service (NMFS, 2015), obtained fishing vessel counts from the National Transportation Safety Board (NTSB, 2010), obtained fishing vessel activity assumptions (Wells 2012) and obtained values of fish landing from the Texas Parks and Wildlife (TPW, 2014). Using these four datasets, ERG estimated and spatially allocated commercial fishing activity.

2.3 Vessel Characteristics Data

In addition to activity data, emission calculations require information about the vessels themselves, particularly the engine category (derived from the cylinder displacement) and its kilowatt (kW) rating to determine which subset of emission factors to use. The kilowatt rating is multiplied by the hours of operation to estimate the kilowatt-hours (kWh), which can then be multiplied by the kWh-based emission factors. These data elements are available in the Information Handling Services (IHS) Vessel Database, which ERG purchased for use in this project.

3.0 Local Activity Data Processing

3.1 PortVision AIS

The AIS data file received from PortVision included 31,841,919 unique observations, in 15 minute intervals, associated with 9,584 vessels, provided in monthly files. Data were examined in their raw monthly format as both a QA check as well as to determine if there was significant seasonality between months. In terms of vessel observations, each month represented between 7.7 % and 8.8% of the total annual observations. The average was 8.3% with a standard deviation of 0.36%. The average summer month observations was 8.6%. This analysis indicated that the data files were complete and that commercial marine vessel traffic within the Gulf does not have a significant seasonal variation.

To obtain activity data that could be used for annual and daily estimates, data processing steps included consolidating monthly data files into a single dataset in Structured Query Language (SQL) Server and organizing the dataset by vessel and time stamp. ERG performed a quality assurance review of the records and removed records that could not be used, including the following:

- 12 records with no date;
- 11 records with an invalid Maritime Mobile Service Identity (MMSI); and
- 2,564 vessels that each had a single observation in the year, which is insufficient for routing.

ERG mapped the points in a geographic information system (GIS) and removed 2,523,130 records that plotted more than one nautical mile outside of Texas state waters. ERG selected a buffer distance of one nautical mile to ensure vessel movements near the edge of the nine-mile state waters area were included. This method aimed to capture data points just outside of the area of interest in order to represent the movements as vessels enter and exit state waters.

Summary statistics performed on the AIS data in SQL server indicated that 72.8 percent of the records indicated speeds of less than 0.2 knots. Discussions with PortVision clarified that speeds of 0.2 knots or less could indicate vessels maintaining position or otherwise not moving. As a result, ERG consolidated consecutive records with vessel speeds of less than or equal to 0.2 knots by averaging the coordinates and speeds to reduce the record count. These processing steps further reduced the size of the dataset to 5,667,338 records.

3.1.1 Vessel Characteristics

The AIS data contain identifying information including International Maritime Organization (IMO) number, Maritime Mobile Service Identity (MMSI), vessel name, and vessel type. ERG used these identifiers to match individual vessels to their characteristics in the IHS Vessel Database (IHS 2014). The best method to match vessels is by matching IMO numbers between the two datasets; however, the IMO number is not fully populated in AIS data. As a result, ERG conducted additional rounds of matching using vessel names, call signs, and vessel type to match as many vessels as possible to their detailed vessel characteristics and to validate matches made by IMO number.

Ultimately, ERG successfully matched 4,152 vessels to the IHS database to obtain kW ratings and maximum speeds. IHS data, while comprehensive, may not have fully populated engine characteristics. For vessels that matched to IHS but did not have kilowatt rating or maximum speed data, ERG calculated average values (excluding zeros) by vessel type and category. For vessels that lacked a category, ERG used the vessel type to assign a category, and average kW rating and maximum speeds were gap-filled based on the type and category.

Vessels that could still not be matched, for example, because they were lacking IMO number, vessel type, and vessel category, were considered most likely to be Category 2 vessels that do not meet the IMO requirements but have invested in AIS technology. Note that vessels equipped with Category 3 engines have a very high match rate as they tend to include IMO or MMSI codes. Smaller Category 1 vessels are less likely to participate in the AIS. Therefore, vessels that could not be matched, because they were lacking both vessel type and category were considered to be Category 2 vessels. This assumption may potentially result in an over estimation of emissions as there are a few Category 1 vessels in the AIS dataset. Therefore, ERG developed average values for Category 2 vessels to gap-fill engine data for vessels that could not be matched to detailed vessel characteristics. For the 2,155 vessels that could not be matched to detailed vessel characteristics, ERG averaged the kW and maximum speed data values for the 253 Category 2 vessels present in the Texas IHS data to gap-fill engine data. Outliers were accounted for and removed before averaging. The averages were 3,201 for engine kW rating and 12.68478 for maximum speed

3.1.2 Load Factors

Previous inventories used default load factors in estimating emissions. This is a common practice and has been the established practice for the TCEQ and the United States Environmental Protection Agency (EPA) for previous CMV emissions inventories.

Vessels tend to operate at an optimal and consistent load while cruising, but their engine loads can vary significantly while they are transiting reduced speed zones or shifting in a port area. AIS data include actual vessel speed, which ERG used in conjunction with the maximum vessel speed as provided by IHS data to accurately calculate engine load using the Propeller law:

$$LF = (AS/MS)^3$$

Where:

LF	=	load factor
AS	=	actual vessel speed
MS	=	maximum vessel speed

After linking the vessels to the IHS database, ERG calculated load factors using the maximum vessel speed and the observed (actual) vessel speed for individual route segments. In some cases, however, the actual speed reported in AIS data exceeded the maximum speed reported in IHS data. In these cases, the actual speed was set equal to the maximum speed and their load factors, which exceeded 1.0, were replaced by averages derived from IHS data by vessel type. Load factors under 20% were rounded to the nearest percent for later processing as described in Section 5.

3.1.3 Auxiliary Engines

Data on auxiliary engines were obtained for all Category 3 vessels from the IHS data. Category 1 and 2 vessels are smaller and as such tend not to have auxiliary engines or turn their engines off while dockside, so no gap-filling of Category 2 and 3 auxiliary engines was necessary.

3.1.4 Kilowatt-hour Calculations and Data Quality Checks

With kW ratings, maximum speeds, and loading factors fully populated, the kilowatt hours (kWh) were calculated as follows:

$$A = MCR \times LF \times H$$

Where:

A	=	vessel activity in kWh
MCR	=	maximum continuous rated engine power, kW
LF	=	load factor
H	=	hours of operation

Activity for propulsion engines were calculated using the kW rating of the main engines for all records with an AIS-reported speed over ground greater than 0.2 knots. For Category 3 vessels, all records indicating movement were considered underway activities. For Category 1 and 2 vessels, the activity associated with speeds over 0.2 knots was split between port and underway Source Category Codes (SCCs) to account for hoteling (operations while stationary at dock). 11.75% of the activity was considered hoteling while the remaining 88.25% was considered underway as identified in a previous Category 2 Census Report from the EPA (U.S. EPA, 2007). Activity in the reduced speed zone (RSZ) was calculated using the kW rating of the auxiliary engines for all Category 3 vessels with a recorded speed greater than 0.2 knots. Hoteling activity was calculated using the kW rating of the auxiliary engines for all Category 3 AIS observations where the speed was less than or equal to 0.2 knots.

3.2 Government Vessels

Table 3-1 shows information ERG obtained about Coast Guard vessels operating in Texas waters using fleet profiles obtained from their websites and from direct communication with Coast Guard staff in 2011 (USCG, 2014). ERG obtained the list of vessels in 2015 from the Coast Guard, but was not able to contact anyone at the Coast Guard to obtain or confirm activity information at this time. Therefore, ERG used the original assumptions which are listed in Table 3-1 from the 2011 inventory as surrogates. For three new vessels that were not included in the 2011 inventory, ERG assigned activity hours to these vessels to be consistent with other similar Coast Guard Classes. For example navigational aid boats were assumed to have annual operating hours less than larger vessels involved in inland construction and lighter faster medium response boats were assumed to be used slightly more often than larger coastal patrol boats.

The Coast Guard's Eighth District is responsible for safety and security of the full length of the Mississippi River, as well as the Gulf of Mexico (Peschke, 2015). In the HGA area, the District operates 10 vessels from the Freeport and Galveston ports, as listed in Table 3.1.

Table 3-1. Coast Guard Vessel Characteristics and Associated Ports

Port	Vessel ID	Class	Vessel Name	Vessel Type	Horsepower (hp)	State Water Hours	Source of Hours
Freeport	WPB 87320	WPB-87	Manta	Coastal Patrol Boat - Marine Protector Class	3000	360	2011 TX Inventory
Galveston	WPB 87330	WPB-87	Man-O-War	Coastal Patrol Boat - Marine Protector Class	3000	360	2011 TX Inventory
Galveston	45630	RB-M	Response Boat-Medium	Response Boat-Medium	825	640	Engineering Judgment
Galveston	ANB 55103	ANB-55	55-foot Aids to Navigation Boat	Aids to Navigation Boat	1080	500	Engineering Judgment
Galveston	WMEC 624	WMEC 210	Dauntless	Medium Endurance Cutter	5000	240	2011 TX Inventory
Galveston	WLIC 75309	WLIC-75	Hatchet	Inland Construction Tenders	1320	1700	2011 TX Inventory
Galveston	WLIC 75306	WLIC-75	Clamp	Inland Construction Tenders	1320	1700	2011 TX Inventory
Galveston	WLM 561	WLM-175	Harry Claiborne	Coastal Buoy Tender - Keeper Class	3400	240	2011 TX Inventory
Galveston	45618	RB-M	Response Boat-Medium	Response Boat - Medium	825	640	Engineering Judgment
Galveston	WPB 87353	WPB-87	Skipjack	Coastal Patrol Boat - Marine Protector Class	3000	360	2011 TX Inventory

Table 3-1 notes for each Coast Guard vessel the home port, vessel ID number, name, type, horsepower rating of the propulsion engines, and an estimate of the number of hours these vessels operate in state waters. The Coast Guard provided a past estimate of the annual hours of operation and the percentage of time the vessels operated within state waters for 2011. ERG was not able to obtain 2013 data. ERG used these 2011 data to estimate the horsepower hours (hp hr) of operation within state waters using the following equation:

$$hp\ hr = Vn \times hp \times Ao$$

Where:

hp hr	=	kilowatt hours
Vn	=	number of vessels
hp	=	total horsepower rating of the Coast Guard vessel's propulsion engines
Ao	=	annual operating hours in Texas state waters

Example: Military Vessel Activity Calculation

The 87-foot coastal patrol boat, Steelhead, operates out of Corpus Christi; it is equipped with two 1,475 horsepower (hp) engines. The vessel operates 1,800 hours per year; 20 percent of operations are in Texas state waters. Using the equation above, ERG calculated the horsepower hours for this vessel:

$$hp\ hr = Vn \times hp \times Ao$$
$$hp\ hr = 1 \times 2950\ hp \times 360\ hrs$$
$$hp\ hr = 1{,}062{,}000$$

ERG developed emission estimates for NO_x and non-methane volatile organic compounds (NMVOC) using the following equation:

$$DE = AH \times CF_1 \times LF \times EF \times CF_2 \times D$$

Where:

DE	=	daily emissions (tons per day)
AH	=	annual activity (hp hr)
CF_1	=	conversion factor (0.7455 kW/hp)
LF	=	engine load factor
EF	=	emission factor (g/kWh)

CF_2	=	conversion factor (1.10231 E-6 ton/g)
D	=	conversion of Annual hours to summer season daily hours (1 year / 365 days)

Example: Military Vessel Emission Calculation

The Steelhead has annual hp hrs of 1,062,000, which it operates at a load factor of 0.80. Using the equation directly above, ERG estimated the NO_x emissions using a NO_x emission factor of 13.2 g/kWh:

$$DE = AH \times CF_1 \times LF \times EF \times CF_2 \times D$$

$$DE = 1{,}062{,}000 \text{ hp hrs per year} \times 0.745 \text{ kW/hp} \times 0.80 \times 13.2 \text{ g/kWh} \times 1.10231 \text{ E-6 ton/g} \times 1/365$$

$$DE = 0.025 \text{ tons per day}$$

ERG assumed that the underway load factor for propulsion engines of Coast Guard vessels was 80 percent. To estimate emissions, ERG used emission factors that the EPA developed in support of recent marine vessel rule making (EPA 2010). ERG spatially allocated Coast Guard activity and emissions based on the district associated with each base and assigned them to appropriate counties based on the geographic information system (GIS) shapefiles. Similar to the data processing for the AIS Category 1 and 2 vessels, total activity was split between port and underway SCCs to account for hoteling. 11.75% of the activity was considered hoteling while the remaining 88.25% was considered underway as identified in a previous Category 2 Census Report from the EPA (U.S. EPA, 2007).

3.3 Dredging Operations

ERG obtained information concerning dredging operations occurring in Texas state waters for 2012 through 2014 from the U.S. Army Corps of Engineers Dredging Activity Database (USACE, 2015). The 14 dredging projects that ERG identified were implemented by both the Army Corps as well as private contractors. The Army Corps of Engineers private company data set included the following information:

- the name of the dredging site;
- the type of dredging equipment used;
- the dates on which dredging was planned to be initiated and completed;
- the dates when dredging was actually initiated and completed;
- the amount of material dredged and the disposal method; and
- information about the private company (including address) that was awarded the work.

ERG used the actual dredging start and completion dates to estimate the total hours of operation for the dredging equipment. In some cases, the completion dates were not documented in the database, in which case ERG assumed the project was ongoing and would continue until December 31, 2014.

Though this equipment operates 24 hours per day seven days per week, ERG assumed that dredging engines operate 90 percent of the time to account for vessel positioning, minor maintenance, and refueling activities.

Three different dredging types are used in state waters: cutter suction (pipeline), hopper, and cutter and hopper combination vessels. Cutter suction dredges use a rotating drill to bring sediment up. Hopper vessels use a vacuum device that transports sediments from the ocean floor into the vessel's hold. ERG assumed that cutter suction dredges are equipped with engines rated from 5,000 to 15,000 horsepower (for this project ERG used a value of 9,600 horsepower (7,161 kW) based on data provided by dredging services that implemented similar dredging activities). Hopper dredges with a horsepower rating of 7,500 to 12,000 horsepower (5,593 to 8,951 kW), based on data provided by dredging companies that implemented identified dredging activities, with an average value of 9,814 horsepower (7,272 kW). This value was used for hopper dredges (TCEQ 2011). ERG found only one example of a combination dredger at Marine Aggregate Levy Sustainability Fund (MALSF) website, which had an assumed horsepower of 5,476 horsepower (4,080 kW) (MALSF, 2015).

ERG obtained limited information concerning the dredging vessels from websites of the companies implementing the dredging contracts. Ideally engine kW ratings would be available for each of the dredging vessels used in the dredging projects. However, very few websites did included this data. Therefore, the average kW ratings of 7,272 kW were used. ERG compiled the information that was available in the project database. To clarify, the U.S. Army Corps of Engineers' Dredging Activity Database included the estimated project arrival and departure dates (based on the proposal for the dredging project) and actual project arrival and departure dates. For this inventory, ERG estimated hours of operation based on the actual arrival and departure dates.

ERG estimated total kilowatt hours using the following equation:

$$TKW = THP \times 0.745 \text{ KW/hp} \times (DP\text{-}AR) \times 24 \text{ hrs/day} \times 0.90$$

Where:

TKW	=	total kilowatt hours (kWh)
THP	=	total maximum horsepower rating of the engine (hp)
0.745	=	conversion of hp to kW
DP	=	departure date

AR	=	arrival date
24	=	hours per day
0.90	=	total fraction of time operating (considering ongoing maintenance activities and refueling)

Example: Dredging Activity Calculation

A hopper vessel equipped with a 9814 hp engine arrived at the site on January 1, 2014, and departed on January 11, 2014. Using the equation above, ERG calculated the operating kilowatt hours for this vessel:

$$kWh = THP \times 0.745 KW/hp \times (DP\text{-}AR) \times 24\ hrs/day \times 0.90$$
$$kWh = 9{,}814\ hp \times 0.745\ KW/hp \times (1/1/14 – 1/11/14) \times 24 \times 0.90$$
$$kWh = 1{,}570{,}790\ kWh$$

ERG calculated the total operating kilowatt hours based on the hours of operation applied to the vessel and horse power rating. For future SIP years, ERG used the 2013 data as the base year for the growth factors. Similar to the data processing for the AIS Category 1 and 2 vessels, total activity was split between port and underway SCCs to account for hoteling. 11.75% of the activity was considered hoteling while the remaining 88.25% was considered underway as identified in a previous Category 2 Census Report from the EPA (U.S. EPA, 2007).

ERG developed emissions estimates for NO_x and VOC using the following equation:

$$DE = AH \times EF \times CF \times D$$

Where:

DE	=	daily emissions (tons per day)
AH	=	annual activity (kWh)
EF	=	emission factor (g/kWh)
CF	=	conversion factor (1.10231 E-6 ton/g)
D	=	conversion of annual emissions to summer season daily emissions (1 year / 365 days)

Example: Dredging Emission Calculation

Using the equation directly above, ERG estimated the NO_x emissions of a dredging vessel with annual operations of 829,487 kWh. The NO_x emission factor is 19.54 g/kWh.

$$DE = AH \times LF \times EF \times CF \times D$$

$$DE = 829{,}487 \text{ kWhs} \times 19.54 \text{ g/kWh} \times 1.10231 \times 10^{-6} \text{ ton/g} \times 1/365$$

$$DE = 0.049 \text{ tons of } NO_x \text{ per day}$$

There is little data currently available to quantify engine operating loads for dredging propulsion engines. ERG assumed that vessel operators would attempt to optimize fuel consumption rates which, for diesel engines, would be associated with operating loads around 80 percent based off the EPA's Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories (April 2009).

3.4 Commercial Fishing

ERG based commercial fishing activity on a variety of data sources for commercial fishing in Texas. More information on the data will be discussed in this section. ERG estimated fishing vessel ship calls as a function of vessel purpose and its type of fishery. Table 3-7 summarizes vessel operating characteristics for the four main types of fishing operations, specifically the number of vessel port calls per year, distance traveled in state waters per call, vessel speed, kilowatt rating of the engine, calculated hours of operation in state waters, and calculated kilowatt hours. These data in table 3-7 were provided by an expert consultant on marine vessel activity (Wells 2012)

Table 3-2. Vessel Operating Characteristics by Fishing Operation Type

Fishery Operation	Vessels	Calls/Yr	Distance	Speed	Hours	kW	kW/ Vessel - Yr
Snapper	84	40	20	7.5	2.7	224	16,247
Shrimp	1,086	20	20	7.5	2.7	522	18,931
Oyster	252	100	40	7.5	5.3	224	81,133
Other	195	50	30	7.5	4.0	186	25,354
Total	1,617						141,646

ERG obtained the number of vessels from information from the Texas Parks and Wildlife Commercial Fishing License Buyback Programs (TPWD, 2015). To estimate annual kilowatt-hours of operation per vessel, ERG multiplied the number of calls by the vessel's kilowatt rating, the hours per call, and a load factor of 68 percent. Most fishing vessels have a governor and "trolling gear" to lower engine loads to 68 percent optimizing diesel fuel consumption. For this component of the TCEQ emission inventory, ERG assumed the load factor to be 68 percent. ERG calculated fishing vessel kilowatt hours using the following equation:

$$Actf = Kw \times Dt / Sp \times Cf \times Lf$$

Where:

Actf	=	annual activity per vessel in terms of adjusted kilowatt hours
Kw	=	typical kilowatt rating of fishing boats' propulsion engines by type of fishing vessel operation
Dt	=	distance traveled in state waters per trip (nautical miles)
Sp	=	vessel speed (nautical miles per hour)
Cf	=	number of calls per year
Lf	=	load factor (percent)

Example: Fishing Vessel Activity Calculation

A vessel involved in fishing operations for snappers is equipped with a 224 kW propulsion engine, has 40 calls per year where they transit 20 nautical miles per call and operate at a speed of 7.5 nautical miles per hour. ERG used the equation directly above to calculate the total horsepower hours of operation:

$$Actf = Kw \times Dt / Sp \times Cf \times Lf$$

$$Actf = 224 \text{ kw} \times 20 \text{ NM}/7.5 \text{ NM/hr} \times 40 \times 68/100$$
$$\text{hp hr} = 16{,}247$$

The fleet of Gulf of Mexico fishing vessels involved in pelagic fishing (e.g., red snapper and other ground fish), long-line tuna and swordfish, and shrimping operations actually operate most of the time in federal waters. Many of these fishing boats go out into the Gulf and stay out for a week to 3 months. When returning to Texas ports, each vessel operates for only 2 to 3 hours within Texas waters (Wells 2012).

Fishing operations within state waters are dominated by the oyster fishery in the upper Texas Coast with most vessels operating in the Galveston area. These vessels rarely leave the bays or Texas waters and can include bait shrimping, black drum, blue crabs, flounder, and other inshore fisheries (Wells 2012). These boats spend 100 percent of the time within Texas waters and are basically regulated by the fishing season, fishing permits, and the TPWD. ERG obtained the number of vessels associated with each type of fishing operations using the TPWD buyback program in Table 3-7.

The main fishery ports in the Houston-Galveston-Brazoria area are Freeport, Galveston, and Houston. ERG obtained 2013 fish landings for each port from the National Marine Fisheries Service (NMFS, 2015); these numbers are presented in Table 3-8. Table 3-8 presents each port's percentage of the total, both as total catch and by fishery operations (e.g., snapper, shrimp, oyster, and other).

Table 3-3. 2013 Port Landings for Port Allocations

Port	County	Millions of Pounds	Percent by Poundage	Snapper Vessels	Shrimp Vessels	Oyster Vessels	Other Vessel
Freeport	Brazoria	2.7	10.5%	3	39	9	7
Galveston	Galveston	22.6	88.3%	25	329	76	59
Houston	Harris	0.3	1.2%	1	5	1	1
Total		**25.6**	**100.0%**	**29**	**373**	**86**	**67**

NMFS, 2015.

ERG used the fractions and number of vessels in Table 3-8 to estimate the portion of the Texas fleet for each of the fisheries operations. Also, ERG applied the vessel count data presented in Table 3-8 to the per vessel annual kWhs data presented in Table 3-7 to estimate the kWhs associated with the different fishing operations and port which are presented in Table 3-9.

Table 3-4. Kilowatt Hours for Texas Fishing Vessel Fleet by Port and Fishing Operation

Port	County	Snapper kWh	Shrimp kWh	Oyster kWh	Other Vessel kWh	2014 Total kWh
Freeport	Brazoria	48,680	738,315	730,201	177,479	1,694,676
Galveston	Galveston	405,667	6,228,347	6,166,145	1,495,899	14,296,058
Houston	Harris	16,227	94,656	81,133	25,354	217,370
Total		470,574	7,061,318	6,977,479	1,698,732	16,208,104

ERG applied these kilowatt hours to the EPA's emission factors to estimate VOC and NO_X emissions using the following equation:

$$DEf = Actf \times EF \times CF \times D$$

Where:

DEf = daily emissions associated with fishing vessels (tons per day)

Actf = annual activity (kWh)

EF = emission factor (g/kWh)

CF = conversion factor (1.10231 E-6 ton/g)

D = conversion of annual emissions to summer season daily emissions (1 year / 365 days)

Example: Fishing Vessel Emission Calculation

Snapper fishing vessels in 2013 account for 1,363,043 kWhs. Using the equation directly above, ERG calculated fishing vessel emissions:

$$DEf = Actf \times EF \times CF \times D$$

$$\begin{aligned} DEf &= 1{,}363{,}043 \text{ kWh} \times 14.30 \text{ g/kWh} \times 1.10231\text{E-6 ton/gr} \times 1/365 \\ &= 0.059 \text{ tons of } NO_x \text{ per day} \end{aligned}$$

ERG used 2013 as the base year for all the SIP inventory years. ERG used fish landings to allocate the activity data spatially to the ports and their surrounding areas. Similar to the data processing for the AIS Category 1 and 2 vessels, total activity was split between port and underway SCCs to account for hoteling. 11.75% of the activity was considered hoteling while the remaining 88.25% was considered underway as identified in a previous Category 2 Census Report from the EPA (U.S. EPA, 2007).

4.0 Emission Factors

EPA reviewed CMV emission factors (USEPA 2010) for planned use with the 2014 National Emission Inventory (NEI) as shown below in Table 4-1. ERG developed controlled emission factors (EF) from EPA data which took into account fleet turnover and the implementation of regulatory programs.

Table 4-1. CMV Controlled and Uncontrolled Emission Factors (g/kWh)

Vessel Category	Year	VOC EF(g/kwh)-Controlled	VOC EF(g/kwh)-Uncontrolled	NO_x EF(g/kwh)-Controlled	NO_x EF(g/kwh)-Uncontrolled
1	2012	0.37752221	0.414246439	11.87915089	13.67405715
1	2014	0.344530113	0.414246439	10.91841802	13.67405715
1	2017	0.286655015	0.414246439	9.283438348	13.67405715
1	2020	0.22981902	0.414246439	7.578271349	13.67405715
1	2023	0.183826734	0.414246439	6.272283478	13.67405715
1	2026	0.147721047	0.414246439	5.23155296	13.67405715
1	2028	0.132037217	0.414246439	4.708707722	13.67405715
2	2012	0.216885092	0.216885092	15.71832872	18.13310412
2	2014	0.210026583	0.216885092	14.30384093	18.13310412
2	2017	0.188774682	0.216885092	12.43740304	18.13310412
2	2020	0.164228307	0.216885092	10.63451944	18.13310412
2	2023	0.14112125	0.216885092	8.989550799	18.13310412
2	2026	0.119410144	0.216885092	7.577245665	18.13310412
2	2028	0.105671573	0.216885092	6.703434571	18.13310412
3	2012	0.623530845	0.623530845	15.33941522	16.05531595
3	2014	0.623530845	0.623530845	14.79396063	16.05531595
3	2017	0.623530845	0.623530845	13.50968287	16.05531595
3	2020	0.623530845	0.623530845	11.23791401	16.05531595
3	2023	0.621711121	0.623530845	9.551909679	16.05531595
3	2026	0.620200071	0.623530845	8.114494301	16.05531595
3	2028	0.619070859	0.623530845	7.425013114	16.05531595

Appendix A includes a summary table of the various control programs associated with CMV. These control programs and their reductions are already taken into account by the emission factors in Table 4-1.

5.0 Emissions Calculations

ERG estimated emissions as a function of vessel power demand multiplied by an emission factor, where the emission factor is expressed in terms of grams per kilowatt hour (g/kWh). ERG then applied emission factors and propulsion engine load to the activity data to estimate emissions. Below is the basic equation used to estimate port emissions:

$$DE = MCR \times LF \times A \times EF \times D$$

Where:

DE	=	emissions from the engine(s), usually calculated as grams of emissions per day
MCR	=	maximum continuous rated engine power, kW
LF	=	load factor
A	=	activity, hours
EF	=	emission factor (g/kWh)
D	=	conversion of annual emissions to summer season daily emissions (1 year / 365 days)

Both controlled and uncontrolled emissions estimates were calculated using the emission factors in Section 4.0. Because the AIS data note the actual vessel speed and the IHS data provide maximum design speed, the engine load can be calculated directly. Where the engine load is below 20 percent, the emission factors in Table 4-1 were adjusted for low load using the adjustment factors presented in Table 5-1, obtained from 2009 EPA port emissions inventory guidance (EPA 2009). The emissions estimates were multiplied by the adjustment factors to estimate the increase in emissions associated with low operating loads. Since data review indicated no significant seasonality in the AIS data, the annual values were divided by 365 to obtain ozone season daily emissions values.

Table 5-1. Emissions Adjustment Factors for Operating Loads Less than 20%

Load	NO_x	VOC
1%	11.47	62.32
2%	4.63	22.27
3%	2.92	12.28
4%	2.21	8.11
5%	1.83	5.90
6%	1.60	4.57
7%	1.45	3.70
8%	1.35	3.10
9%	1.27	2.65
10%	1.22	2.31
11%	1.17	2.06
12%	1.14	1.85
13%	1.11	1.68
14%	1.08	1.55
15%	1.06	1.43
16%	1.05	1.32
17%	1.03	1.24
18%	1.02	1.17
19%	1.01	1.10
20%	1.00	62.32

6.0 Projection Factors

ERG based projected commercial marine vessel activities for Texas ports on the carbon dioxide (CO_2) emission estimates from the business as usual (BAU) Global Scenario 13 developed in the International Maritime Organization's (IMO) Third Green House Gas Study (2014). CO_2 tends to be strongly correlated to fuel combustion as it is based on the carbon content of the fuel which tends to be relatively constant over time. It should be noted that the projection profiles in the IMO study represent the most current economic information on the marine vessel activities developed by an international consortium of leading experts. Studies that have been implemented prior to the global economic decline in 2008 and the uncertain period of recovery (2009-12) tend to overestimate projected growth in the sector. The IMO team addressed the still lingering uncertainties about future trends by providing four different BAU scenarios (13, 14, 15, and 16). All four of the BAU scenarios assumed modest engine efficiency improvement (no control options), no further expansion of global Emission Control Areas (ECA) and limited use of liquefied natural gas (LNG). To insure that projected activities were not underestimated, BAU Scenario 13 was used as it assumed the highest level of projected growth.

A wide range of control studies were also included in the projection scenarios 1-12. It should be noted that none of these control scenarios were used in projecting marine vessel activities for this TCEQ project. Additional research supported this assessment, including the assessment developed by the Center for Transportation Research and Texas Transportation Institute for the "Trade Flows and Texas Gulf Ports: Panama Canal Expansion and South American Markets" (August 2013) report. This assessment suggests that international cargo volume will gradually increase as noted in the IMO BAU projections concurrent with an increase in vessel size due to the Panama Canal expansion, providing less vessel traffic with fewer emissions per cargo ton-mile. ERG reviewed other references such as the U.S. Department of Transportation Bureau of Transportation Statistics 2014 (TranStat 2014), the U.S. Department of Energy's Annual Energy Outlook (EIA 2014), and the Organisation for Economic Co-operation and Development (OECD) Economic Outlook (2014) to ensure that projected vessel traffic estimates are reasonable.

Note the projections provided in the IMO report did not account for recent changes in fuel costs. ERG anticipates that these changes may have limited impact on marine vessel activities as projected fuel usage in Texas ports will require fuels that comply with emissions control area standards. Conversely, if vessels use high sulfur content fuels, they will need to install scrubbers to ensure that emissions are comparable with those from the use of low sulfur fuels. Table 6-1 lists forecasting and backcasting factors.

Table 6-1. 2013-Based Commercial Marine Vessel Activity Growth Factors using Uncontrolled CO_2

Year	CO2 Emissions (million tonnes)	Growth ratio from 2013 base year
2012	816	1.01
2014	816	1.00
2017	850	1.04
2020	910	1.12
2023	1024	1.25
2026	1120	1.37
2028	1160	1.42

ERG matched projected activity to the appropriate future year emission factors in Table 6-1 to account for federal rules that are implemented relative to the year that the marine engine was originally manufactured, such that full benefit of the rule would occur in the future once fleet turnover was completed. ERG made additional adjustments to future year emissions estimates to account for compliance with emissions control area fuel sulfur standards and Texas Emissions Reduction Plan (TERP) investments. Appendix A includes a complete list of control programs addressed in this inventory.

7.0 Results

Table 7-1 through 7-4 presents the total daily CMV emissions (tons per day) for each pollutant by county. Table 7-1 and 7-2 present the controlled and uncontrolled daily emissions for NO_X and Tables 7-3 and 7-4 presents the controlled and uncontrolled daily emissions for VOC. It should be noted that the emissions for 2012 were significantly higher than the other years due to the higher level of dredging activity that occurred in 2012. It should also be noted that only the emissions from the eight counties in the HGB nonattainment areas are included.

Table 7-1. Ozone Season Daily Controlled NO_X Emissions (tons) by Year for the Houston-Galveston-Brazoria Area

County Name	Ozone Season Daily NO_X Emissions (tons/day)						
	2012	2014	2017	2020	2023	2026	2028
Brazoria	14.684	2.125	1.934	1.771	1.673	1.547	1.425
Chambers	0.276	0.249	0.225	0.207	0.196	0.181	0.166
Galveston	28.663	20.648	19.203	17.379	16.457	15.266	14.280
Harris	12.375	8.006	7.404	6.722	6.356	5.892	5.492
Total	55.998	31.028	28.766	26.079	24.682	22.886	21.363

Table 7-2. Ozone Season Daily Uncontrolled NO_X Emissions (tons) by Year for the Houston-Galveston-Brazoria Area

County Name	Ozone Season Daily NO_X Emissions (tons/day)						
	2012	**2014**	**2017**	**2020**	**2023**	**2026**	**2028**
Brazoria	17.302	2.918	2.864	2.974	3.305	3.621	3.753
Chambers	0.326	0.321	0.331	0.354	0.395	0.433	0.448
Galveston	32.485	24.539	25.204	26.921	30.043	32.918	34.116
Harris	14.182	9.694	9.942	10.617	11.836	12.972	13.445
Total	64.295	37.472	38.341	40.866	45.579	49.944	51.762

Table 7-3. Ozone Season Daily Controlled VOC Emissions (tons) by Year for the Houston-Galveston-Brazoria Area

County Name	Ozone Season Daily VOC Emissions (tons/day)						
	2012	**2014**	**2017**	**2020**	**2023**	**2026**	**2028**
Brazoria	0.252	0.079	0.075	0.073	0.072	0.070	0.067
Chambers	0.010	0.010	0.009	0.009	0.008	0.008	0.007
Galveston	0.836	0.731	0.738	0.767	0.826	0.875	0.887
Harris	0.390	0.331	0.331	0.340	0.362	0.379	0.381
Total	1.488	1.151	1.153	1.189	1.268	1.332	1.342

Table 7-4. Ozone Season Daily Uncontrolled VOC Emissions (tons) by Year for the Houston-Galveston-Brazoria Area

County Name	Ozone Season Daily VOC Emissions (tons/day)						
	2012	**2014**	**2017**	**2020**	**2023**	**2026**	**2028**
Brazoria	0.252	0.081	0.084	0.091	0.102	0.111	0.115
Chambers	0.010	0.010	0.010	0.011	0.013	0.014	0.014
Galveston	0.837	0.740	0.770	0.829	0.925	1.014	1.051
Harris	0.391	0.336	0.349	0.376	0.420	0.460	0.477
Total	1.49	1.167	1.213	1.307	1.46	1.599	1.657

8.0 References

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Appendix A. CMV 2008 to 2040 Control Programs*

Year	Programs	Application	Notes	Source
2008	TERP	Statewide	Reduction by 1,632 tons this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf
2009	TERP	Statewide	Reduction by 1,688 tons this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf
	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 3 tons this year, VOC reduced by 7 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2010	TERP	Statewide	Reduction by 1,190 tons this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf
	MARPOL Annex VI - SOx reduction	North America (excluding Mexico)	1.50% mass/mass (m/m) prior to 1 July 2010	http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-(SOx)-%E2%80%93-Regulation-14.aspx
	MARPOL Annex VI - SOx reduction	North America (excluding Mexico)	1.00% m/m on and after 1 July 2010	http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-(SOx)-%E2%80%93-Regulation-14.aspx
	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 6 tons this year, VOC reduced by 14 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2011	TERP	Statewide	Reduction by 1,140 tons this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf
	MARPOL Annex VI - NOx reduction	North America (excluding Mexico)	Tier II NO_x reductions, ships constructed on or after Jan 1, 2011; $n < 130$: 14.4, n = 130-1999: $44 \cdot n^{(-0.23)}$, $n \geq 2000$: 7.7; n = engine's rated speed (rpm), units are g/kWh	http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Nitrogen-oxides-(NOx)-%E2%80%93-Regulation-13.aspx

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Year	Programs	Application	Notes	Source
	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 8 tons this year, VOC reduced by 22 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2012	TERP	Statewide	Reduction by 850 tons this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf
	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 76 tons this year, NO_x reduced by 1,463 tons this year, VOC reduced by 152 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2013	TERP	Statewide	Reduction by 767 tons this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf
	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 321 tons this year, NO_x reduced by 4,935 tons this year, VOC reduced by 383 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2014	TERP	Statewide	Reduction by 595 tons this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf
	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 776 tons this year, NO_x reduced by 17,326 tons this year, VOC reduced by 837 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2015	TERP	Statewide	Reduction by 428 tons this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf

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Year	Programs	Application	Notes	Source
	MARPOL Annex VI - SOx reduction	North America (excluding Mexico)	0.10% m/m on and after 1 January 2015	http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-(SOx)-%E2%80%93-Regulation-14.aspx
	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 1,149 tons this year, NO_x reduced by 29,723 tons this year, VOC reduced by 1,290 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2016	TERP	Statewide	Reduction by 296 tons this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf
	MARPOL Annex VI - NOx reduction	In ECA only (North America excluding Mexico)	Tier III NO_x reductions, ships constructed on or after Jan 1, 2016; $n < 130$: 3.4, n = 130-1999: $9 \cdot n^{(-0.2)}$, $n \geq 2000$: 2.0; n = engine's rated speed (rpm), units are g/kWh	http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Nitrogen-oxides-(NOx)-%E2%80%93-Regulation-13.aspx
	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 1,740 tons this year, NO_x reduced by 49,151 tons this year, VOC reduced by 1,848 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2017	TERP	Statewide	Reduction by 249 tons this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf
	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 2,469 tons this year, NO_x reduced by 71,006 tons this year, VOC reduced by 2,497 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2018	TERP	Statewide	Reduction by 217 tons this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf

Appendix A. CMV 2008 to 2040 Control Programs*

Year	Programs	Application	Notes	Source
	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 3,245 tons this year, NO_x reduced by 94,975 tons this year, VOC reduced by 3,183 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2019	TERP	Statewide	Reduction by 217 tons this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf
	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 4,019 tons this year, NO_x reduced by 118,882 tons this year, VOC reduced by 3,867 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2020	TERP	Statewide	Reduction by 33 tons this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf
	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 4,808 tons this year, NO_x reduced by 142,666 tons this year, VOC reduced by 4,545 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2021	TERP	Statewide	Reduction by 33 tons this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf
	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 5,644 tons this year, NO_x reduced by 166,339 tons this year, VOC reduced by 5,218 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2022	TERP	Statewide	Reduction by 23 tons this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf

Appendix A. CMV 2008 to 2040 Control Programs*

Year	Programs	Application	Notes	Source
	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 6,491 tons this year, NO_x reduced by 189,855 tons this year, VOC reduced by 5,883 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2023	TERP	Statewide	Reduction by 1 ton this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf
	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 7,347 tons this year, NO_x reduced by 213,181 tons this year, VOC reduced by 6,539 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2024	TERP	Statewide	Reduction by 1 ton this year to various counties (listed in detail in the TERP table)	https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/079_08.pdf
	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 8,210 tons this year, NO_x reduced by 236,257 tons this year, VOC reduced by 7,183 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2025	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 9,064 tons this year, NO_x reduced by 258,828 tons this year, VOC reduced by 7,794 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2026	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 9,899 tons this year, NO_x reduced by 280,771 tons this year, VOC reduced by 8,360 tons this year	http://www.epa.gov/nonroad/420d07001.pdf

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Year	Programs	Application	Notes	Source
2027	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 10,711 tons this year, NO_x reduced by 301,951 tons this year, VOC reduced by 8,880 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2028	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 11,503 tons this year, NO_x reduced by 322,410 tons this year, VOC reduced by 9,360 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2029	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 12,277 tons this year, NO_x reduced by 341,797 tons this year, VOC reduced by 9,811 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2030	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 13,027 tons this year, NO_x reduced by 359,780 tons this year, VOC reduced by 10,225 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2031	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 13,752 tons this year, NO_x reduced by 376,481 tons this year, VOC reduced by 10,605 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2032	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 14,458 tons this year, NO_x reduced by 392,324 tons this year, VOC reduced by 10,960 tons this year	http://www.epa.gov/nonroad/420d07001.pdf

Appendix A. CMV 2008 to 2040 Control Programs*

Year	Programs	Application	Notes	Source
2033	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 15,151 tons this year, NO_x reduced by 407,598 tons this year, VOC reduced by 11,300 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2034	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 15,834 tons this year, NO_x reduced by 422,367 tons this year, VOC reduced by 11,625 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2035	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 16,500 tons this year, NO_x reduced by 436,542 tons this year, VOC reduced by 11,936 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2036	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 17,126 tons this year, NO_x reduced by 449,899 tons this year, VOC reduced by 12,228 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2037	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 17,686 tons this year, NO_x reduced by 461,578 tons this year, VOC reduced by 12,490 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2038	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 18,198 tons this year, NO_x reduced by 471,739 tons this year, VOC reduced by 12,728 tons this year	http://www.epa.gov/nonroad/420d07001.pdf

Appendix A. CMV 2008 to 2040 Control Programs*

Year	Programs	Application	Notes	Source
2039	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 18,664 tons this year, NO_x reduced by 480,787 tons this year, VOC reduced by 12,947 tons this year	http://www.epa.gov/nonroad/420d07001.pdf
2040	Control of Emissions of Air Pollution for Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	Nationwide	PM2.5 reduced by 19,063 tons this year, NO_x reduced by 488,838 tons this year, VOC reduced by 13,143 tons this year	http://www.epa.gov/nonroad/420d07001.pdf

*Note: only the NO_x and VOC reductions were used in the development of future emissions estimates for this report.