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2023 Texas Statewide Commercial Marine Vessel Emissions Inventory and 2011 through 2050 Trend Inventories

Final Report

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ACRONYMS AND ABBREVIATIONS

AERR	Air Emissions Reporting Requirements
AIS	Automatic Identification System
CAGR	compound annual growth rate
CAP	criteria air pollutants
CARB	California Air Resources Board
CERS	Consolidated Emissions Reporting Schema
CMV	commercial marine vessel
CO	carbon monoxide
ECA	North American Emission Control Area
ECAs	emission control areas
EGR	exhaust gas recirculation
EI	emissions inventory
EIDP	Emissions Inventory Development Plan
EPA	U.S. Environmental Protection Agency
GIS	geographic information system
GSP	gross state product
HAPs	Hazardous air pollutants
HSC	Houston Ship Channel
IMO	International Maritime Organization
MARINER	MARINE Emissions Resolver
MMSI	Maritime Mobile Service Identity
NEI	National Emissions Inventory
NO_X	Nitrogen oxides
PM	particulate matter
PM_{10}	particulate matter with an aerodynamic diameter equal to or less than 10 microns
$PM_{2.5}$	particulate matter with an aerodynamic diameter equal to or less than 2.5 microns
QA	quality assurance
SCC	Source Classification Code
SIP	State Implementation Plan
SO_2	sulfur dioxide
TCEQ	Texas Commission on Environmental Quality
TERP	Texas Emission Reduction Plan
TexAER	Texas Air Emissions Repository
TIGER	Topologically Integrated Geographic Encoding and Referencing
TxLED	Texas Low Emissions Diesel
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
VOCs	volatile organic compounds
XML	Extensible Markup Language

PROJECT SUMMARY

Ship traffic in the Gulf of Mexico and Texas ports can produce emissions that influence Texas air quality. Ramboll improved how the MARINe Emissions Resolver (MARINER) estimates shipping emissions by combining vessel tracking data with ship characteristics data. Ramboll developed 2023 commercial marine emission inventories for Texas. MARINER can be used to estimate current, past, and future emissions from commercial marine vessels for Texas air quality planning.

EXECUTIVE SUMMARY

Ramboll developed calendar year 2023 commercial marine vessel (CMV) emission inventories (EI) for the Texas Commission on Environmental Quality (TCEQ) using year-specific vessel tracking data from the Automatic Identification System (AIS) and vessel characteristics data from the Sea-web Ships database following the latest applicable United States Environmental Protection Agency (EPA) guidance and methodologies. This EI was developed by utilizing the MARINe Emissions Resolver (MARINER) with several updates to improve the generation of the base year EI:

- Integration of the more up to date S&P Global Sea-web Ships Database.
- Adoption of either the EPAs default or California Air Resources Board's harbor craft load factors.
- Expansion of the number of Source Classification Codes (SCCs) used to report emissions by vessel type.
- Incorporation of Texas Emission Reduction Plan (TERP) project data.
- Accounting for shore power emission reductions.

Marine emission trends through 2050 are developed based on predicted changes in vessel activity and anticipated emission reductions from regulatory measures and fleet turnover. We aligned future activity estimates with broad economic growth indicators, such as the gross state product, and analyzed historical commodity shipment trends from 2011 through 2023 to understand how different cargo types influenced vessel activity. Emissions rates were adjusted using historical data and future projections, considering emission controls and fuel sulfur limits as per EPA estimates. This approach enabled us to develop scaling values to adjust the 2023 AIS-derived emission inventories to reflect anticipated changes through 2050. Two additional local control measure reductions, the Houston Shipping Channel Expansion Project and the Texas Low Emissions Diesel, are incorporated into the trend emission inventories.

To evaluate the quality of the MARINER 2023 EI and the MARINER 2023 Trend EI, Ramboll compared the resulting emission estimates to MARINER EIs developed previously as well as EPAs CMV EI. The CMV EIs used for comparison are:

1. The *2020 Texas CMV Emissions Inventory and 2011 through 2050 Trend Inventories* project (Ramboll, 2021).
2. The updated 2019 EI developed as part of the *Updating the Marine Emissions Resolver* project (Ramboll, 2023).
3. The CMV component of the EPAs 2020 National Emissions Inventory (NEI). In April 2024, EPA released the draft 2022v1 Emissions Modeling Platform which is based on the 2020 National Emissions Inventory. Projection years have not been released at the time of this project.

The comparisons find that the current CMV emission estimates are generally comparable to other inventories. Specifically, the MARINER 2023 EI using CARBs load factors aligns more closely with the EPA 2022 EI than does the MARINER 2023 EI using EPAs load factors.

Ramboll provided 2011 through 2050 controlled and uncontrolled annual and ozone season daily statewide CMV EIs in a format that meets the requirements for upload into the TCEQ Texas Air Emissions Repository database. In addition, Ramboll provided the 2023 controlled annual and ozone season daily statewide CMV EIs in a format that fulfills the federal Air Emissions Reporting Requirements.

1.0 INTRODUCTION

The Texas Commission on Environmental Quality (TCEQ) needs a 2023 calendar year commercial marine vessel (CMV) emissions inventory (EI) of the highest possible quality for fulfilling federal Air Emissions Reporting Requirements (AERR) and to support State Implementation Plan (SIP) development. The MARINe Emissions Resolver (MARINER) was previously developed by Ramboll to support the production of a detailed CMV EI for use in photochemical modeling (Ramboll, 2020). In 2021, Ramboll developed 2019 and 2020 Texas statewide CMV EIs using MARINER (Ramboll, 2021). Since then, MARINER has been updated in subsequent work orders (Ramboll, 2022b and 2023). This project extends the capabilities of MARINER to support the generation of detailed 2023 Texas CMV EIs and 2011 through 2050 Trend EIs, compatible with the air emissions reporting interfaces utilized by the United States Environmental Protection Agency (EPA) and the TCEQ.

1.1 Automatic Identification System

Since 2009, the U.S. Coast Guard (USCG) has collected Automatic Identification System (AIS) data in real time to track the locations and characteristics of large vessels operating in both U.S. and international waters. These AIS datasets cover expansively across U.S. territories and surrounding oceanic regions. The level of detail included in AIS data sets has expanded over time. Starting in 2015, the Maritime Mobile Service Identity (MMSI) and International Maritime Organization (IMO) identification codes became readily accessible within AIS datasets. Starting in March 2016, all commercially active vessels were required to install AIS transponders, including many smaller vessels that operate primarily within harbors and near-shore waters.[1] The high-resolution AIS tracking system provides the activity data for estimating emissions.

The AIS records provide a variety of attributes associated with vessel movements, including position, date and time, speed over ground, course over ground, instantaneous draft, vessel identification codes, and vessel type. These attributes serve as vital inputs for emission calculations, enabling several functionalities:

- Spatial and temporal allocations are facilitated by leveraging position data and timestamps.
- Estimation of ocean-going vessel propulsion engine load is achieved through the Admiralty formula, utilizing speed over ground and draft.
- Vessel specifications can be determined by relating MMSI and/or IMO codes to a vessel characteristics database.
- Operating mode can be approximated by analyzing speed over ground.
- In cases where vessel specifications are unavailable, vessel type information from the AIS records can serve to relate a vessel to EPA default vessel characteristics.

[1] Vessel Requirements for Notices of Arrival and Departure, and Automatic Identification System, 80 Fed. Reg. 5281 (March 2, 2015).

1.2 Vessel Characteristics Data

Vessel engine characteristics can be acquired from multiple suppliers, with the Sea-web Ships database standing out as one of the most comprehensive registries available. This database, provided by S&P Global Market Intelligence, offers detailed insights into specific vessel attributes. The fields pertinent to emission estimation primarily revolve around insights into engine attributes (e.g., bore, stroke, total installed power), design characteristics (e.g., service speed, maximum draft, keel laid date), and vessel use information (e.g., ship type detail, capacities). Depending on the intended application of emission results, supplementary fields could prove valuable. Such fields may include vessel owner, country flag, or other design features (e.g., number of reefer plugs, shore power capability flag). Ramboll gained access to the Sea-web Ships database on March 1st, 2024, which included comprehensive data up to the date of acquisition but does not provide access to any subsequent updates or future data releases.

1.3 MARINER

AIS tracking data and vessel characteristics are the two essential components for developing a high-resolution CMV EI. Both the AIS and Sea-web data sets are comprehensive, but they are not readily available in a "plug-in" format for automating EI calculations. MARINER was developed to combine, process, and quality assure the AIS and Sea-web data sets and produce a full suite of CMV emissions inventory for the vessels available in the AIS data. MARINER follows the EPA (2022) guidance for preparing CMV EIs and therefore is consistent with the EPA default approach. TCEQ can use the output of MARINER to conduct more detailed air quality planning for this sector, while also providing CMV EIs to EPA to satisfy AERR. MARINER provides commercial marine emissions by vessel type with grid-level spatial allocation and temporal allocation that are useful for air quality modeling and planning. This work converts the more detailed output of MARINER into the more general Texas Air Emissions Repository (TexAER) and AERR report formats.

A general overview of the MARINER processing steps is shown in Figure 1-1.

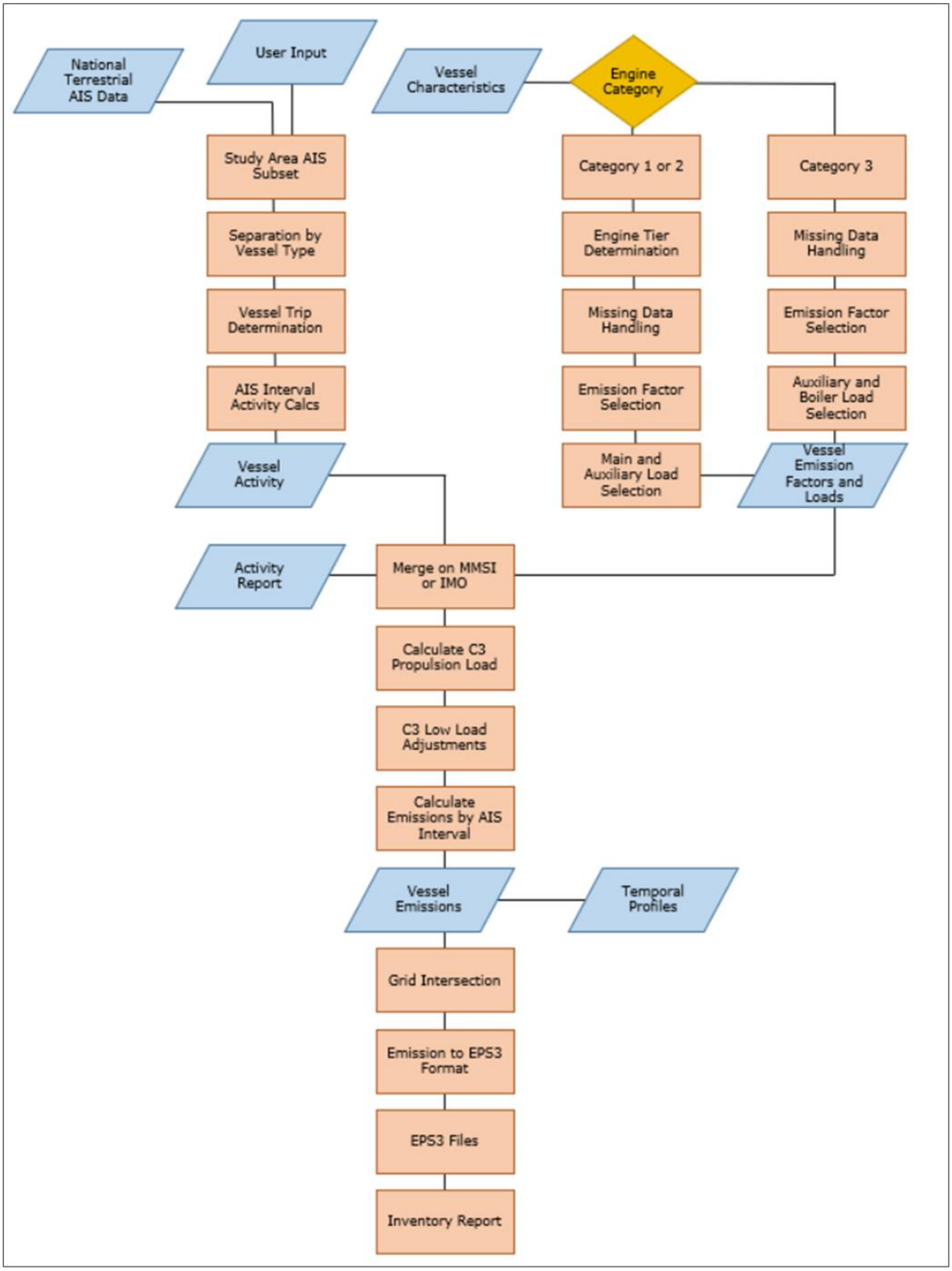

Figure 1-1. General overview of MARINER processing steps.

2.0 SUMMARY OF TASKS

This report includes documentation of all pertinent activities related to the completion of Tasks 3 through 7.

Under Task 3, Ramboll developed an Emissions Inventory Development Plan (EIDP) that describes in detail how the various parameters (e.g., source categories, geographic level, emission factors) would be developed and how Ramboll would complete each task. The TCEQ Project manager reviewed and approved the EIDP.

Under Task 4, Ramboll processed 2023 AIS data records and developed Texas statewide annual (tons per year) and ozone season daily (tons per day) controlled and uncontrolled CMV EIs for the base year 2023. The EIs include all criteria air pollutants (CAPs, i.e., nitrogen oxides (NO_x), carbon monoxide (CO), particulate matter with an aerodynamic diameter equal to or less than 10 microns and equal to or less than 2.5 microns (PM_{10} and $PM_{2.5}$), and sulfur dioxide (SO_2)), CAP precursors (i.e., volatile organic compounds (VOCs)), and hazardous air pollutants (HAPs)[2]. HAPs were calculated from basis pollutants, either VOC or $PM_{2.5}$, by multiplying an appropriate basis emission factor by the fraction listed in Table D.1 of EPA guidance Appendix D (EPA, 2022b). Details on the base year EIs can be found in Chapter 3.

Under Task 5, Ramboll developed controlled and uncontrolled Trend EIs for calendar years 2011 through 2050 by forecasting and backcasting from the base year 2023 EIs. Details on the Trend EIs can be found in Chapter 4. Ramboll also provided all EIs electronically as Consolidated Emissions Reporting Schema (CERS) Extensible Markup Language (XML) formatted files for upload to the TCEQ TexAER database. The TCEQ Project Manager confirmed that the file could be successfully entered into the TexAER test environment.

Under Task 6, Ramboll analyzed and quality assured (QA) all EIs developed in Tasks 4 and 5. Details on the data analysis and QA results can be found in Chapter 5.

Under Task 7, Ramboll provided all EIs as XML files formatted as non-point inventories for upload to the EPAs AERR for the 2023 controlled statewide CMV EI.

[2] List of (hazardous air pollutants (HAPs) provided in Table D.1 of EPA guidance Appendix D (EPA, 2020b)

3.0 TEXAS 2023 CMV EI

Ramboll developed a calendar year 2023 CMV EI using 2023 AIS data from the Marine Cadastre website and the S&P Global Sea-web vessel database. The AIS data are also available from the USCG via Freedom of Information Act requests, but the data provided by the Marine Cadastre site has been quality assured via the Authoritative Vessel Identification System which corrects vessel identification codes and vessel type indicators. This EI was developed by utilizing MARINER, which was last updated in the previous *Updating the Marine Emissions Resolver* project (Ramboll, 2023). Several updates were made to improve the generation of the base year EI, such as incorporating the expanded EPA CMV SCCs and capturing emission reductions from control programs.

3.1 Methodology

The commercial marine emissions calculations follow the latest Port Guidance (EPA, 2022b). Ramboll combined AIS activity data with Sea-web registration data by individual vessel to develop a complete base year Texas-specific CMV activity dataset. These data were combined by matching IMO vessel identification code or MMSI number. If AIS and/or Sea-web records have missing fields that are needed for subsequent calculations, Ramboll populated these missing fields with appropriate EPA or California Air Resources Board (CARB) best practice information, or other reasonable values derived from a literature review of leading research and government publications.

MARINER was updated to follow the latest EPA guidance for estimating port emissions (EPA, 2022b) under the *Updating the Marine Emissions Resolver* project (Ramboll, 2023). Ramboll added the following enhancements to the base year EI:

- Integration of the new S&P Global Sea-web Ships Database.
- Adoption of either the EPAs default or CARBs harbor craft load factors.
- Expansion of the number of SCCs used to report emissions by vessel type.
- Incorporation of TERP project data.
- Accounting for shore power emission reductions.

CARB (2020) also conducted a study of harbor craft vessel activity, analyzing fuel consumption rates of 3200 vessels and engine control module records from 34 engines. The CARB study revised the load factors for propulsion and auxiliary engines used in the California emissions inventory. The CARB load factors are generally lower than EPAs load factors, as shown in Table 3-1. Since barges do not have propulsion engines, load factors for propulsion are not applicable. EPA did not provide estimates for dredge propulsion engines, and CARB did not provide estimates for Miscellaneous (C1/C2) vessel engines. After consulting with the TCEQ Project Manager, Ramboll generated two versions of the 2023 base year EI: one using the EPAs harbor craft load factors and the other using those developed by CARB.

Table 3-1. Default Harbor Craft Propulsion and Auxiliary Engine Load Factors (EPA, 2022b and CARB, 2021)

Vessel Type	Main/Propulsion Engine		Auxiliary Engine	
	EPA	CARB	EPA	CARB
Barge	None	None	0.43	0.31
Crew/Supply	0.45	0.26	0.43	0.40
Dredge	N/A	0.44	0.43	0.57
Excursion	0.42	0.27	0.43	0.40
Fishing	0.52	0.29	0.43	0.45
Government[1]	0.45	0.32	0.43	0.44
Harbor Ferry (C1/C2)	0.42	0.31	0.43	0.39
Miscellaneous (C1/C2)	0.52	N/A	0.43	N/A
Pilot	0.51	0.33	0.43	0.32
Tugboat-ATB[2]	0.68	0.50	0.43	0.50
Tugboat	0.50	0.16	0.43	0.34
Towboat/Pushboat	0.68	0.33	0.43	0.37
Workboat	0.45	0.33	0.43	0.32

[1] CARB Research Vessel is mapped as Government.

[2] EPA doesn't distinguish Tugboat-ATB, so Towboat/Pushboat load factors apply.

EPA expanded the list of CMV SCCs in 2023 and 2024 by adding more detailed vessel type information. Table 3-2 shows an example list of SCCs associated with Diesel Tanker. The new SCCs carry the following information:

- Vessel type: 16 vessel types.
- Engine type: primarily powered by category 1 and 2 (C1C2)[3] or larger category 3 (C3)[4] engines; main engine or auxiliary engines.
- Spatial definition: port or underway.
- Fuel type: diesel or residual oil.

[3] C1C2 engines are smaller bore and are primarily used in harbor craft vessels like tugs.

[4] C3 are larger bore engines that are primarily used in large deep draft ships used for open ocean transit and are also called ocean-going vessels, OGV.

Table 3-2. SCC Definitions for Diesel Tanker

SCC	SCC Level One	SCC Level Two	SCC Level Three	SCC Level Four
2280211113	Mobile Sources	Marine Vessels, Commercial	Diesel Tanker	C1C2 Port Emissions: Main Engine
2280211114	Mobile Sources	Marine Vessels, Commercial	Diesel Tanker	C1C2 Port Emissions: Auxiliary Engine
2280211123	Mobile Sources	Marine Vessels, Commercial	Diesel Tanker	C1C2 Underway emissions: Main Engine
2280211124	Mobile Sources	Marine Vessels, Commercial	Diesel Tanker	C1C2 Underway emissions: Auxiliary Engine
2280211313	Mobile Sources	Marine Vessels, Commercial	Diesel Tanker	C3 Port Emissions: Main Engine
2280211314	Mobile Sources	Marine Vessels, Commercial	Diesel Tanker	C3 Port Emissions: Auxiliary Engine
2280211323	Mobile Sources	Marine Vessels, Commercial	Diesel Tanker	C3 Underway emissions: Main Engine
2280211324	Mobile Sources	Marine Vessels, Commercial	Diesel Tanker	C3 Underway emissions: Auxiliary Engine

Since January 1, 2015, the North American Emission Control Area (ECA) regulation has required that vessels use 0.1% sulfur or less in US waters. Residual fuels are heavy fuel oils with high sulfur content (up to 3.5%) that does not meet the ECA requirement. Therefore, only diesel SCCs are used in the 2023 EI, but this does not necessarily mean that diesel fuel is used to satisfy this fuel quality requirement. The complete list of CMV SCCs can be found in Appendix A, including details on whether each SCC is included in the CMV EIs developed for this project.

MARINER outputs emissions at high spatial and temporal resolution, encompassing a diverse array of vessel types and operating modes. The spatial analyses, described in detail in Section 3.2, would allocate emissions to appropriate SCCs and aggregate emissions to the county level as required by the AERR. Furthermore, MARINER can process and summarize emissions for a defined temporal period. For the 2023 base year EI, emissions for all applicable Texas counties are reported for 1) summer work weekday (ozone season) in tons per day (i.e., averaged emissions from June through August, Monday through Friday) and 2) annual in tons per year for all 8,760 hours that occur in a 365-day calendar year.

3.1.1 Incorporating TERP Project data

TCEQ's grant program, known as TERP, offers grants to individuals, businesses, and local governments for new and upgraded vehicles and equipment, to reduce pollution and improve the air quality in Texas[5]. The TERP project dataset includes grants to repower and retrofit commercial marine vessels with Category 1 and 2 engines meeting lower emissions standards. TCEQ[6] provided Ramboll with a detailed list of projects affecting marine vessels that had replaced engines or entire vessels using TERP funding. The TERP commercial marine project data included larger commercial vessels that appear in the AIS records and so are included in Ramboll's analysis and EI development. But TERP also funded engine upgrades for smaller vessels (such as charter fishing, limited passenger excursion, and short

[5] TERP Grant Programs website. https://www.tceq.texas.gov/airquality/terp/programs

[6] Email from Cody McLain, April 25, 2024 that forwarded an email from Brandon Greuilich with 'pbi-oracle-data-4.25.2024.xlsx' file attached.

commercial vessels) that do not appear in the AIS records or EI results. Each project was sorted by start and end date to include only those projects valid for the 2023 base year. Ramboll then identified the vessels' MMSI numbers, used by AIS as unique vessel identifiers, so that the vessels transiting and berthing activity could be paired with the vessels' engine power and model year.

The TERP project data also included the engine make and model, from which Ramboll determined the cylinder displacement. Combined with the engine model year, cylinder displacement allowed Ramboll to identify the appropriate EPA (2022b) emission factor estimates for both the new and old engines. The emission factors for the TERP-affected vessels were included in the MARINER emissions calculations. Emission estimates for the 2023 base year were presented with and without the TERP-funded vessel retrofits.

3.1.2 Shore Power Emission Reductions

For the vessels identified as using shore power while at Texas berths, emissions were eliminated when AIS signals indicated that these vessels were stationary at their home berths. Ramboll (2022a) identified the vessels known to use shore power at their home berths, including the MARAD Ready-Reserve Ships at the Port of Beaumont and the McFadden Bend Cutoff facility on the Neches River, as well as vessels owned and operated by Texas A&M University at Galveston.

Areas at or near the home berths for these vessels were identified and emissions were assumed to be zero when the vessels were at near-zero speed (less than 0.5 knots) within these areas. Emissions for these vessels while transiting were included in the emissions estimates.

3.2 Spatial Analyses

MARINER uses the latitude and longitude obtained from the AIS data to intersect with a geographic information system (GIS) shapefile (or set of multiple shapefiles) for spatial analysis. Four shapefiles were used to generate the 2023 CMV EI (see Table 3-3):

- Coastal Shapefile: The coastal shapefile provides a sea margin boundary which was used by the Propeller Law and admiralty formula to adjust propulsion operating powers for coastal operations (EPA, 2022b).
- NEI Ports Shapefile: As part of the 2020 NEI CMV supporting documents, the EPA released an NEI Ports shapefile for states to assign emissions related to port activities. AIS records found to be located within port polygons were assigned port SCCs, while all others were assigned underway SCCs. A subset of the Texas ports is shown in Figure 3-1.
- County Shapefile: Following the same methodology as in the 2020 NEI, the 2020 Topologically Integrated Geographic Encoding and Referencing (TIGER) County Shapefile was used to assign emissions within counties (EPA, 2022a). It includes state waters applicable to the coastal counties in Texas. State waters generally extend 3-10 nautical miles from the coastal lines as shown in Figure 3-2.
- Shore Power Shapefile: Ramboll created this shapefile to identify areas at or near the home berths for vessels that use shore power. The polygons were created by following a previous analysis of shore power vessels (Ramboll, 2022a).

Table 3-3. Shapefiles Used in Spatial Analysis

Shapefile	Function	Data Source
Coastline Shapefile	Define Sea Margin	GIS Basemap https://catalog.data.gov/dataset/tiger-line-shapefile-2019-nation-u-s-coastline-national-shapefile
NEI Ports Shapefile	Assign emissions related to port or underway activities	EPAs 2020 CMV Shapefile (see Figure 3-1) https://gaftp.epa.gov/Air/nei/2020/doc/supporting_data/nonpoint/CMV/NEI_Ports_2021_Update.zip
County Boundary	Assign emissions to county	U.S. Census. TIGER Shapefile (see Figure 3-2) https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html
Shore Power Shapefile	Identify areas where shore power is being used	Ramboll, 2022a (see Figure 3-3)

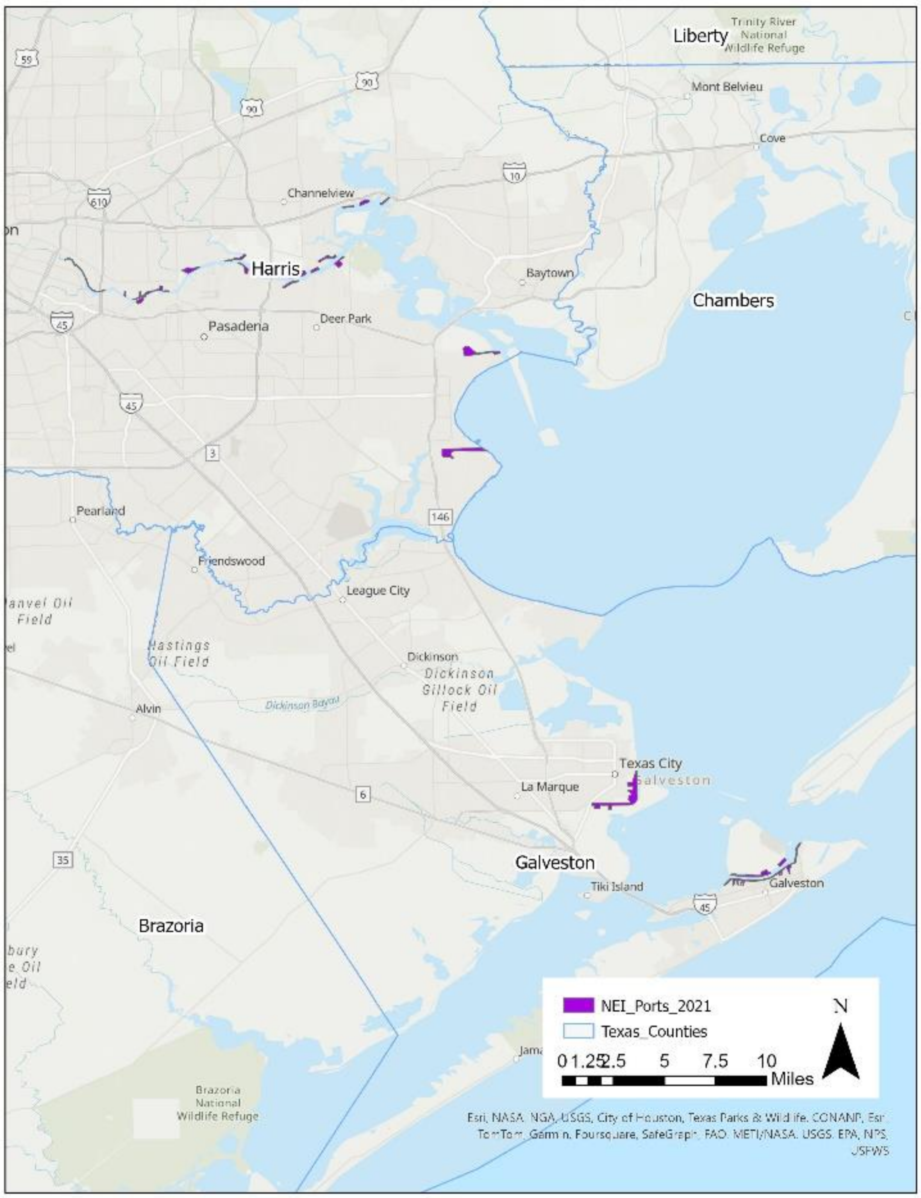

Figure 3-1. A subset of Texas ports in the 2021 NEI Ports Shapefile.

Figure 3-2. County boundary defined by the TIGER County Shapefile.

Figure 3-3. Locations of shore power usage at Port of Galveston, Port of Beaumont, and McFadden Bend Cutoff.

3.3 Resulting 2023 EI

Ramboll used MARINER to generate two versions of the 2023 base year EI, each with a controlled and uncontrolled scenario. One version incorporated EPAs default harbor craft load factors, while the other utilized CARBs harbor craft load factors. Several additional steps were taken to develop the controlled and uncontrolled EIs. In the uncontrolled scenario, any federal or state/local control measures were excluded. Consequently, this uncontrolled scenario omitted the TERP retrofits and shore power usage. Table 3-4 summarizes the difference between each EI.

Table 3-4. Base Year (2023) EI Scenario Definitions

Scenario	Harbor Craft Load Factors	TERP Projects	Shore Power
CARB Controlled	CARB	Applied	With
EPA Controlled	EPA	Applied	With
CARB Uncontrolled	CARB	Not Applied	Without
EPA Uncontrolled	EPA	Not Applied	Without

Ramboll conducted a spatial analysis to confirm the reasonableness of the CMV emissions distribution. Figure 3-4 displays all counties with emissions reported in the MARINER 2023 EI. Extended coastal counties, as defined by TCEQ, are overlaid with a pink mesh grid. While most emissions originate from coastal counties, some inland counties also show emissions, likely due to AIS data outliers. Based on TCEQ guidance, Ramboll removed inland counties, as listed below, where no CMV emissions are expected. Additionally, in the following discussions on emissions by county, Hardin County, Hidalgo County, Jasper County, Liberty County, and Refugio County are not listed explicitly but are referenced as the remaining counties.

- Archer County
- Atascosa County
- Austin County
- Bastrop County
- Bee County
- Bexar County
- Brooks County
- Clay County
- Comal County

- Cooke County
- Fayette County
- Fisher County
- Fort Bend County
- Goliad County
- Gonzales County
- Haskell County
- Hays County
- Jackson County
- Jim Wells County
- Jones County
- La Salle County
- Live Oak County
- Mitchell County
- Montague County
- Montgomery County
- Newton County
- Polk County
- San Jacinto County
- Scurry County
- Starr County
- Throckmorton County
- Trinity County
- Waller County
- Washington County
- Wharton County
- Young County
- Zapata County

Figure 3-4. Map of Texas counties in the MARINER 2023 EI.

Table 3-5 and Table 3-6 summarize the statewide annual and ozone season daily emissions for the four scenarios, respectively. For both controlled and uncontrolled EIs, using EPAs harbor craft load factors results in higher emissions. Specifically, NO_x emissions are 9,392 tons or 26% less in the control EI with CARBs harbor craft load factors than the control EI with EPAs. Between the control and uncontrol EIs with EPAs harbor craft load factors, the controlled NO_x emissions are 544 tons less than the uncontrolled, which reflects the benefits of shore power and TERP retrofits.

Table 3-5. 2023 Annual Statewide Emissions by Pollutant for Different Scenarios (tons per year)

Scenario	NO_x	VOC	CO	PM_{10}	$PM_{2.5}$	SO_2
CARB Controlled	31,062	1,022	4,455	665	626	949
EPA Controlled	40,454	1,135	6,273	820	777	955
CARB Uncontrolled	31,586	1,037	4,501	674	634	966
EPA Uncontrolled	40,998	1,151	6,321	830	785	972

Table 3-6. 2023 Ozone Season Daily Statewide Emissions by Pollutant for Different Scenarios (tons per day)

Scenario	NO_x	VOC	CO	PM_{10}	$PM_{2.5}$	SO_2
CARB Controlled	138	5	19	3	3	5
EPA Controlled	162	6	23	3	3	5
CARB Uncontrolled	140	5	19	3	3	5
EPA Uncontrolled	164	6	23	3	3	5

Statewide annual (tons per year) controlled CMV emissions by ship type for 2023 using CARBs or EPAs harbor craft load factors are summarized in Table 3-7 and Table 3-8, respectively.

Table 3-7. 2023 Annual Statewide Controlled Emissions (tons per year) by Ship Type Using CARB Harbor Craft Load Factors

Vessel Category	Vessel Class	Ship Type	NO_x	VOC	CO	PM_{10}	$PM_{2.5}$	SO_2
Harbor Craft	C1/C2	Crew and Supply	199	6	33	4	4	0
		Dredge	2,429	60	404	42	41	1
		Excursion	4	0	1	0	0	0
		Fishing (C1/C2)	408	10	67	7	7	0
		Government	63	2	11	1	1	0
		Harbor Ferry (C1/C2)	334	4	63	6	6	0
		Miscellaneous (C1/C2)	1,303	50	249	31	30	2
		Pilot	89	3	20	2	2	0
		Towboat/Pushboat	7,758	109	1,391	134	129	4
		Tug Boat	2,002	43	380	39	38	1
		Tug Boat ATB	293	7	67	7	7	0
		Work Boat	37	1	6	1	1	0
	C3	Dredge	8	0	1	0	0	0
		Tug Boat	5	0	0	0	0	0
		Tug Boat ATB	103	4	10	2	2	4
		Work Boat	10	0	1	0	0	0
		Subtotal	**15,044**	**301**	**2,705**	**277**	**268**	**14**
Ocean-Going Vessels	C1/C2	Bulk Carrier	0	0	0	0	0	0
		Chemical Tanker	371	4	69	6	6	0
		General Cargo	4	0	1	0	0	0
		Liquified Gas Tanker	1	0	0	0	0	0
		Offshore Support/Drillship	340	11	53	8	8	0
		Other Tanker	3	0	1	0	0	0
		Bulk Carrier	1,207	52	125	24	22	56
		Chemical Tanker	4,991	223	540	101	93	235
		Container Ship	1,423	77	157	26	24	64
		Cruise	742	27	67	12	11	27
		General Cargo	1,394	53	130	23	21	54

Vessel Category	Vessel Class	Ship Type	NO_x	VOC	CO	PM_{10}	$PM_{2.5}$	SO_2
	C3	Liquified Gas Tanker	1,143	69	141	51	47	140
		Miscellaneous (C3)	18	1	2	0	0	1
		Offshore Support/Drillship	1	0	0	0	0	0
		Oil Tanker	3,657	175	398	122	113	321
		Other Tanker	265	11	25	7	7	19
		Reefer	27	1	3	1	0	1
		RORO	429	17	39	7	7	18
		Subtotal	**16,018**	**721**	**1,750**	**388**	**358**	**935**
		Total	**31,062**	**1,022**	**4,455**	**665**	**626**	**949**

Table 3-8. 2023 Annual Statewide Controlled Emissions (tons per year) by Ship Type Using EPA Harbor Craft Load Factors

Vessel Category	Vessel Class	Ship Type	NO_x	VOC	CO	PM_{10}	$PM_{2.5}$	SO_2
Harbor Craft	C1/C2	Crew and Supply	295	9	50	6	6	0
		Dredge	1,930	47	323	33	32	1
		Excursion	5	0	1	0	0	0
		Fishing (C1/C2)	412	10	68	7	7	0
		Government	67	2	12	2	1	0
		Harbor Ferry (C1/C2)	381	5	72	7	7	0
		Miscellaneous (C1/C2)	1,303	50	249	31	30	2
		Pilot	135	4	30	3	3	0
		Towboat/Pushboat	14,658	187	2,668	244	237	7
		Tug Boat	4,715	85	945	87	84	3
		Tug Boat ATB	336	7	81	8	8	0
		Work Boat	50	2	8	1	1	0
	C3	Dredge	7	0	1	0	0	0
		Tug Boat	8	0	1	0	0	0
		Tug Boat ATB	119	5	11	2	2	4
		Work Boat	14	1	1	0	0	1

Vessel Category	Vessel Class	Ship Type	NO_x	VOC	CO	PM_{10}	$PM_{2.5}$	SO_2
		Subtotal	**24,436**	**415**	**4,522**	**432**	**419**	**20**
Ocean-Going Vessels	C1/C2	Bulk Carrier	0	0	0	0	0	0
		Chemical Tanker	371	4	69	6	6	0
		General Cargo	4	0	1	0	0	0
		Liquified Gas Tanker	1	0	0	0	0	0
		Offshore Support/Drillship	340	11	53	8	8	0
		Other Tanker	3	0	1	0	0	0
	C3	Bulk Carrier	1,207	52	125	24	22	56
		Chemical Tanker	4,991	223	540	101	93	235
		Container Ship	1,423	77	157	26	24	64
		Cruise	742	27	67	12	11	27
		General Cargo	1,394	53	130	23	21	54
		Liquified Gas Tanker	1,143	69	141	51	47	140
		Miscellaneous (C3)	18	1	2	0	0	1
		Offshore Support/Drillship	1	0	0	0	0	0
		Oil Tanker	3,657	175	398	122	113	321
		Other Tanker	265	11	25	7	7	19
		Reefer	27	1	3	1	0	1
		RORO	429	17	39	7	7	18
		Subtotal	**16,018**	**721**	**1,750**	**388**	**358**	**935**
		Total	**40,454**	**1,135**	**6,273**	**820**	**777**	**955**

Statewide annual (tons per year) controlled CMV emissions by vessel class, mode, and engine for 2023 using CARBs or EPAs harbor craft load factors are summarized in Table 3-9 and Table 3-10, respectively.

Table 3-9. 2023 Annual Statewide Controlled Emissions (tons per year) by Vessel Class, Mode, and Engine Using CARB Harbor Craft Load Factors

Vessel Class	Mode	Engine	NO_x	VOC	CO	PM_{10}	$PM_{2.5}$	SO_2
C1/C2	Port	Prop	257	4	52	4	4	0
	Port	Aux	1,471	43	239	33	32	1
	Underway	Prop	8,743	110	1,702	141	137	5
	Underway	Aux	5,166	155	823	111	107	3
	Subtotal		**15,637**	**311**	**2,816**	**289**	**280**	**10**
C3	Port	Prop	25	4	4	0	0	1
	Port	Aux	5,351	218	546	147	135	373
	Underway	Prop	4,005	236	459	55	50	122
	Underway	Aux	6,045	253	630	174	160	444
	Subtotal		**15,425**	**710**	**1,639**	**376**	**346**	**939**
	Total		**31,062**	**1,022**	**4,455**	**665**	**626**	**949**

Table 3-10. 2023 Annual Statewide Controlled Emissions (tons per year) by Vessel Class, Mode, and Engine Using EPA Harbor Craft Load Factors

Vessel Class	Mode	Engine	NO_x	VOC	CO	PM_{10}	$PM_{2.5}$	SO_2
C1/C2	Port	Prop	553	8	114	9	9	0
	Port	Aux	1,516	44	247	34	33	1
	Underway	Prop	17,878	219	3,469	289	280	10
	Underway	Aux	5,059	153	802	111	108	3
	Subtotal		**25,007**	**424**	**4,631**	**444**	**430**	**15**
C3	Port	Prop	25	4	4	0	0	1
	Port	Aux	5,351	218	546	147	135	373
	Underway	Prop	4,030	237	462	55	51	123
	Underway	Aux	6,042	252	630	174	160	443
	Subtotal		**15,448**	**711**	**1,642**	**376**	**346**	**940**
	Total		**40,454**	**1,135**	**6,273**	**820**	**777**	**955**

Table 3-11 and Table 3-12 summarize annual emissions at the county level using CARBs or EPAs harbor craft load factors, respectively. Emissions from Hardin County, Hidalgo County, Jasper County, Liberty County, and Refugio County are grouped as the remaining counties.

Table 3-11. 2023 Annual Statewide Controlled Emissions (tons per year) by County Using CARB Harbor Craft Load Factors

County	NO_x	VOC	CO	PM_{10}	$PM_{2.5}$	SO_2
Aransas	454	11	75	8	8	4
Brazoria	1,445	39	225	32	31	39
Calhoun	656	14	112	12	11	4
Cameron	354	11	53	7	7	7
Chambers	2,165	75	329	35	34	31
Galveston	7,332	241	1,004	134	126	169
Harris	8,539	298	1,146	201	188	352
Jefferson	4,509	148	665	101	95	145
Kenedy	135	2	25	2	2	0
Kleberg	56	1	11	1	1	0
Matagorda	890	15	161	15	15	1
Nueces	3,666	142	512	98	92	180
Orange	616	17	103	12	12	9
San Patricio	182	6	23	4	4	6
Victoria	13	0	2	0	0	0
Willacy	52	1	9	1	1	0
Total of remaining counties	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total	**31,062**	**1,022**	**4,455**	**665**	**626**	**949**

Table 3-12. 2023 Annual Statewide Controlled Emissions (tons per year) by County Using EPA Harbor Craft Load Factors

County	NO_x	VOC	CO	PM_{10}	$PM_{2.5}$	SO_2
Aransas	721	14	126	13	12	5
Brazoria	2,202	49	367	45	43	40
Calhoun	1,014	17	179	17	17	4
Cameron	451	12	71	9	8	8
Chambers	2,789	81	451	45	43	31
Galveston	9,139	263	1,345	164	155	171
Harris	10,668	324	1,555	236	222	353
Jefferson	5,919	165	945	124	118	146
Kenedy	248	3	46	4	4	0
Kleberg	109	1	20	2	2	0
Matagorda	1,558	22	285	26	25	1
Nueces	4,329	152	658	110	103	181
Orange	991	22	176	19	18	9
San Patricio	203	7	27	5	4	6
Victoria	19	0	3	0	0	0
Willacy	93	1	17	2	2	0
Total of remaining counties	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total	**40,454**	**1,135**	**6,273**	**820**	**777**	**955**

As a preliminary QA step, the results were compared to the 2019 CMV emission estimates produced by Ramboll (2021) to assess the appropriateness of the emission totals. Table 3-13 compares the controlled 2023 EI using EPAs harbor craft load factors with the 2019 scenario. The 2019 annual NO_x emissions totaled 36,872 tons, which is 3,582 tons less than the 2023 NO_x emissions. The 2019 annual VOC emissions were 1,043 tons, 92 tons less than the 2023 VOC emissions. Differences in the emissions between the 2019 and 2023 EIs can be attributed to several factors: 1) different levels of activities, 2) the use of the new Sea-web Ships database, and 3) the use of the TIGER County shapefile. The previous study used the TCEQ County Boundary Shapefile, which includes fewer counties (Ramboll, 2021). Chapter 5 documents more detailed QA results.

Table 3-13. Comparison of Statewide Controlled 2019 and 2023 NO_x and VOC Emissions

Period	Vessel Class	NO_x - 2023	NO_x - 2019	VOC - 2023	VOC - 2019
Annual (tons per year)	C1/C2	25,007	22,625	424	366
	C3	15,448	14,247	711	677
	Total	**40,454**	**36,872**	**1,135**	**1,043**
O3D (tons per day)	C1/C2	73	62	1	1
	C3	89	68	4	3
	Total	**162**	**130**	**6**	**4**

4.0 2011 THROUGH 2050 CMV TREND EI

The marine emissions forecasts are based on the predicted changes in vessel activity and anticipated emission reductions due to regulatory measures and fleet turnover. To estimate future vessel activity, projections were aligned with broad economic growth estimates, such as the gross state product (GSP). Ramboll analyzed trends in commodity shipments from 2011 through 2023 to understand how different types of cargo influenced vessel activity. This historical data helped identify trends by ship type and assess how the tonnage of cargo moved by these ships varied over the years. Ramboll then compared these trends with the GSP over the same period to evaluate future activity estimates.

For emissions rates, Ramboll focused on engine emissions, especially NO_x, and considered the impacts of emission controls and fuel sulfur limits as per EPA default estimates. By evaluating historical activity and emission rates from 2011 to 2023, and forecasting these metrics through 2050, Ramboll developed scaling values that were used to adjust the AIS-derived 2023 EIs to reflect anticipated changes in both activity levels and existing emission regulations.

4.1 Economic Trends

The broad economic growth trends and forecasts used to develop the marine emissions projections are sourced from the Texas GSP estimates presented in Table 4-1, prepared by the Texas Comptroller's Office. The GSP relative to 2023 serves as a key mechanism to forecast AIS-derived 2023 activity and emissions for future years or to backcast to previous years.

From 2011 to 2019, the compound annual growth rate (CAGR) for the Texas GSP was approximately 3.5%. The COVID-19 pandemic negatively impacted the Texas economy in 2020, causing a downturn. However, the economy recovered in 2021 and 2022, achieving annual growth rates of 3.8% and 3.4%, respectively. Economic slowdowns are anticipated in 2024 and 2025, with annual growth rates expected to decrease to 2% and 1.8%. Looking ahead, the Texas Comptroller's Office forecasts that the economy will stabilize with an average annual growth rate of about 2.3% from 2025 to 2050.

Table 4-1. Texas Gross State Product (GSP, Billion 2012$) (Texas Comptroller of Public Accounts, 2023)

Calendar Year	GSP	Rate of Change	Relative to 2023		Calendar Year	GSP	Rate of Change	Relative to 2023
2011	1,354	3.3%	0.691		2031	2,343	2.1%	1.196
2012	1,421	4.9%	0.725		2032	2,398	2.3%	1.224
2013	1,485	4.5%	0.758		2033	2,453	2.3%	1.252
2014	1,530	3.0%	0.781		2034	2,513	2.4%	1.282
2015	1,606	5.0%	0.820		2035	2,572	2.3%	1.313
2016	1,620	0.9%	0.827		2036	2,630	2.3%	1.342
2017	1,659	2.4%	0.847		2037	2,688	2.2%	1.372
2018	1,728	4.2%	0.882		2038	2,747	2.2%	1.402
2019	1,780	3.0%	0.908		2039	2,809	2.3%	1.434
2020	1,748	-1.8%	0.892		2040	2,874	2.3%	1.467
2021	1,815	3.8%	0.926		2041	2,942	2.4%	1.501
2022	1,876	3.4%	0.958		2042	3,012	2.4%	1.537
2023	1,959	4.4%	1.000		2043	3,082	2.3%	1.573
2024	1,998	2.0%	1.020		2044	3,153	2.3%	1.609
2025	2,033	1.8%	1.038		2045	3,226	2.3%	1.646
2026	2,079	2.3%	1.061		2046	3,300	2.3%	1.684
2027	2,131	2.5%	1.088		2047	3,377	2.3%	1.723
2028	2,188	2.7%	1.117		2048	3,455	2.3%	1.763
2029	2,243	2.5%	1.145		2049	3,536	2.3%	1.804
2030	2,294	2.3%	1.171		2050	3,618	2.3%	1.846

The Texas ports are influenced by global and regional trends in addition to the general business climate in Texas, as discussed below. The overall business activity growth over the past few years has been mirrored in the port traffic. Various factors, such as trade disputes, infrastructure developments, and other economic conditions, may impact future vessel activity. Additionally, unique factors affect port traffic by freight type. For example, tanker traffic is a significant freight category for Texas ports, encompassing the transport of crude oil, petroleum gases, and refined petroleum products. This segment has been notably influenced by increased domestic oil and gas production, the lifting of export restrictions on crude oil, and improvements in natural gas export infrastructure.

To assess type-specific trends in vessel activity, tonnage data (USACE, 2022) for the Texas ports were used to compare yearly shipments from 2011 through 2022, as shown in Table 4-2. The recent trend of freight tonnage through Texas ports, growing at an average rate of 2.6% per year, has been comparable but consistently lower than the overall Texas economic activity, which grew at 3.0% per year between 2011 and 2022. Texas intracoastal traffic, exclusively served by smaller Category 1 and 2 (C1/C2) vessels, experienced a peak in 2014 after rising from 2011 levels and then declined through 2022. The overall growth rate for this period averaged 0.84% per year, which is slightly below but still comparable to the 0.9% per year growth rate forecasted by the EPA (2008) for smaller C1/C2 engine-powered vessels.

Table 4-2. Shipments Through Major Texas Freight Ports (short tons/yr) (US Coast Guard, 2024)

Summary	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Brownsville	5,907,041	5,612,890	5,542,691	6,947,890	7,779,109	7,275,272	7,763,455	8,348,358	6,631,912	6,781,993	8,860,199	9,104,782
Corpus Christi Ship Channel	70,537,732	69,001,357	76,157,693	84,928,330	85,674,966	81,981,061	87,325,501	93,468,323	111,291,438	150,755,485	164,443,599	174,297,682
Houston Ship Channel, TX	237,798,639	238,185,582	229,246,833	234,304,391	240,933,410	247,981,663	224,373,631	302,388,549	317,862,290	303,643,119	290,005,168	320,866,188
Freeport	23,311,868	22,084,551	19,716,053	22,327,032	21,132,931	19,635,949	24,484,399	25,258,109	29,608,995	38,748,662	42,243,269	*n/a
Galveston	13,883,382	11,676,572	11,425,188	10,692,932	10,390,388	9,900,575	7,843,530	9,118,300	10,958,425	11,945,182	12,011,826	13,530,166
Sabine-Neches Waterway	137,217,861	141,090,169	159,426,717	160,164,823	159,032,698	158,309,165	178,506,826	193,735,364	192,438,408	163,920,882	173,267,489	189,187,824
Texas City, TX (PORT)	57,956,255	56,798,640	49,864,610	48,149,851	43,427,443	41,968,466	40,223,184	43,194,083	41,338,934	33,721,312	27,951,143	32,855,222
Victoria, TX	2,344,964	2,944,359	4,646,088	5,607,680	5,788,812	4,080,552	3,356,994	2,861,711	2,672,649	2,032,848	1,855,234	1,994,768
Major Ports Subtotal	548,957,742	547,394,120	556,025,873	573,122,929	574,159,757	571,132,703	573,877,520	678,372,797	712,803,051	711,549,483	720,637,927	741,836,632
Ports Trend	**2.6% per year**											
Gulf Intracoastal Waterway, Sabine River to Galveston	59,131,793	59,577,157	60,540,011	67,560,374	64,893,380	62,940,576	64,955,410	63,509,367	63,366,609	59,849,447	57,624,572	65,058,488
Gulf Intracoastal Waterway, Galveston to Corpus Christi	25,560,943	29,313,821	29,943,854	33,788,775	29,342,116	25,834,871	23,759,783	24,285,093	24,011,355	22,548,228	23,800,532	24,625,512
Gulf Intracoastal Waterway, Corpus Christi to Mexican Border	2,211,700	1,920,242	1,772,809	1,808,531	1,516,728	1,613,635	2,030,352	2,193,040	2,897,546	3,811,979	5,212,068	4,163,600
Intracoastal Subtotal	86,904,436	90,811,220	92,256,674	103,157,680	95,752,224	90,389,082	90,745,545	89,987,500	90,275,510	86,209,654	86,637,172	93,847,600
Intracoastal Trend	**0.85% per year**											

*n/a: data not available

For an investigation into the other cargo types, the Port of Houston provided an overview of recent activity through a subset of Houston facilities, as shown in Table 4-3. Almost all cargo types, except bulk cargo, experienced a drop in tonnage in 2020, likely due to the impact of COVID-19. In 2023, there was a general downward trend across most cargo types, with the exception of containerized cargo. Among different cargo types, steel has seen rapid growth in recent years, achieving a 100% increase in tonnage in 2023 compared to 2016. Overall, general cargo tonnage increased by 64% from 2016 to 2023, while bulk cargo remained relatively stable over the same period. Most of the liquid bulk cargo comes through private terminals in Houston and was not reported by the Port of Houston.

Table 4-4 shows cruise ship activity at the Ports of Houston and Galveston in recent years. Following the Port of Houston's decision to abandon its cruise ship terminal business in 2016 (Houston Chronicle, 2016), there was a noticeable shift in cruise traffic to Galveston. The suspension of cruise ship operations in 2020 due to the COVID-19 pandemic led to a dramatic decrease in activity, with a 78% drop in 2020 and a 74% drop in 2021 compared to 2019. However, with the reopening of cruise operations in 2022, substantial growth was observed, and passenger ship activity levels nearly returned to pre-pandemic levels, reaching only 5% less than the peak in 2019. By 2023, cruise ship activity had surpassed the 2019 levels, showing an 18% increase.

Table 4-3. Port Houston Freight by Type (excluding private facilities; short tons/yr) (Port of Houston, 2024)

Cargo Type (tons)	2016	2017	2018	2019	2020	2021	2022	2023	2023/2016
Containerized	21,907,270	24,290,910	26,587,883	29,064,799	28,750,334	29,940,940	34,965,655	35,557,667	1.62
Gen. Cargo: Steel	2,231,515	3,694,676	4,363,788	4,013,157	2,253,366	3,503,324	5,213,813	4,463,794	2.00
Gen. Cargo: Other General Cargo	870,556	892,217	701,029	890,466	704,431	1,247,077	1,756,596	924,016	1.06
Total General Cargo	25,009,341	28,877,803	31,652,700	33,968,422	31,708,131	34,691,341	41,936,064	40,945,477	1.64
Total Bulk Cargo (exclude Bayport Chemical complex)	10,053,452	9,396,090	9,210,586	9,267,268	9,979,479	10,429,870	10,608,111	9,377,787	0.93
Total Tonnage	**35,062,793**	**38,273,893**	**40,863,286**	**43,235,690**	**41,687,610**	**45,121,211**	**52,544,175**	**50,323,264**	**1.44**

Table 4-4. Texas Cruise Passenger Ship Activity (passengers/yr) (Port of Galveston, 2024)

Port	2016	2017	2018	2019	2020	2021	2022	2023
Houston[a]	83,810							
Galveston	1,730,289	1,861,549	1,966,176	2,195,648	476,123	565,090[b]	2,082,814[b]	2,600,000[b]
Total	**1,814,099**	**1,861,549**	**1,966,176**	**2,195,648**	**476,123**	**565,090**	**2,082,814**	**2,600,000**
Relative to 2016		1.08	1.14	1.27	0.28	0.33	1.20	1.50

[a] Port of Houston closed the cruise terminal in 2016.

[b] Port of Galveston 2021-2023 estimates are based on incoming passenger ship values.

There are reasons to anticipate variations in commercial marine activity relative to the overall Texas business activity. Container and cruise passenger growth, despite disruptions in 2020 and 2021, could exceed the general business activity, as shown in Table 4-3 and Table 4-4. In contrast, solid bulk activity in Houston has stagnated over the past decade, and overall port traffic, including crude petroleum, has lagged behind Texas's GSP growth. Both EPA (2008) and evidence from intracoastal waterway activity suggest that the activity of smaller C1/C2 vessels will increase at a slower rate than general economic activity.

In summary, Ramboll chose to rely on historic freight movement data to backcast vessel activity and Texas GSP to forecast the activity of larger Category 3 (C3) vessels. Ramboll used container traffic tonnage for the historic container ship activity trend. Solid bulk materials like sand, gravel, grain, cement, and limestone have shown slower growth compared to the overall economy, with this lower demand included in the projections. Cruise ship activity, severely curtailed in 2020 and 2021, returned to previous levels in 2022 and kept growing in 2023. Ramboll expects that total freight tonnage best represents the activity of the remaining vessel activity (primarily tankers but also general cargo) in recent years, with Texas GSP representing future demand.

The activity of smaller C1/C2 powered vessels has historically lagged behind economic growth, particularly for long-haul intracoastal freight. It is often challenging to separate C1/C2 activity from overall port freight statistics, which are predominantly carried by C3 vessels. Other C1/C2 vessel types, such as offshore support, ship assist, and short-haul movements, may have grown faster than the historical trend along the intracoastal waterway. For these reasons, Ramboll chose to rely on the EPA (2008) estimated average growth rate for smaller C1/C2 vessel activity.

Table 4-5 summarizes the selection of activity surrogates (presented in Table 4-1 through Table 4-4) to project 2023 AIS vessel activity to past and future years.

Table 4-5. Surrogate to Develop Vessel Activity Trends

<table>
<tr><th>Engine Category</th><th>3</th><th>3</th><th>3</th><th>3</th><th>1 & 2</th></tr>
<tr><th>Year \ Type</th><th>Container</th><th>Solid Bulk</th><th>Cruise</th><th>All Others</th><th>All</th></tr>
<tr><td>2011-2015</td><td>Texas GSP</td><td>Texas GSP</td><td rowspan="6">Galveston and Houston Passenger Statistics</td><td rowspan="6">Texas Major Ports Tonnage Trend</td><td rowspan="7">EPA (0.9% per year)</td></tr>
<tr><td>2016-2019</td><td rowspan="5">Houston Statistics (Containerized Cargo)</td><td rowspan="5">Houston Statistics (Bulk Cargo)</td></tr>
<tr><td>2020</td></tr>
<tr><td>2021</td></tr>
<tr><td>2022</td></tr>
<tr><td>2023</td></tr>
<tr><td>2024+</td><td>Texas GSP</td><td>Texas GSP</td><td>Texas GSP</td><td>Texas GSP</td></tr>
</table>

4.2 Emissions Forecasting

4.2.1 Category 3 Engine Emission Rates

Emissions from ship engines and boilers have been regulated by the IMO, which has limited fuel sulfur levels and new ship engine NO_x emission rates as well as other air emissions from ships including those from incineration, tanker venting, and ozone-depleting substances. IMO regulations set worldwide maximum fuel sulfur levels and NO_x emission rates, and more stringent emission standards when ships operate within emission control areas (ECAs).

For the US waters, an ECA was declared and began implementation, with the first level of fuel sulfur limits that began in August 2012 with further control beginning in 2015:

- Late 2012, <10,000 ppm (1.0%) sulfur
- 2015 onwards, <1,000 ppm (0.1%) sulfur

NO_x emission standards for Tier I and II engines apply worldwide and Tier III engine NO_x emission rate limits apply when operating within an ECA. The Tier emissions standards are outlined in Table 4-6. Applying these emission levels for current, and especially future years, requires estimates of the ship fleet age distributions.

Table 4-6. International NO_x Emission Limits for Ship Engines (g/kWh)

Tier	Ship Construction Date (on or after)	n < 130	n = 130 - 1999	n ≥ 2000
I	January 1, 2000	17.0	$45 \times n^{(-0.2)}$ e.g., 720 rpm – 12.1	9.8
II	January 1, 2011	14.4	$44 \times n^{(-0.23)}$ e.g., 720 rpm – 9.7	7.7
III	January 1, 2016 when operating in an ECA	3.4	$9 \times n^{(-0.2)}$ e.g., 720 rpm – 2.4	2.0

Note:
n = engine's rated speed (rpm)

The emission factors used for the 2023 emission inventory estimates assumed 0.1% sulfur content fuel. The application or determination of the fleet age distribution is not straightforward because individual ship transits were used in this work and have a unique activity profile as well as a ship or engine model year.

The PM emission control scenarios for C3 vessels used for this work are based on the EPA (2009) forecasted emission factor adjustments shown in Table 4-7. The ECA includes the entire region modeled, and therefore all activity was assumed to be governed by the ECA. The ECA was declared in EPA rulemaking with international approval in 2009, and emissions and fuel controls within the ECA began in August 2012 with a fuel sulfur limit of 1.0%. Additional fuel sulfur limits to 0.1% sulfur began in 2015, and NO_x controls were required for new ships built in 2016 or later. The relative PM emission factors shown in Table 4-7 are specific to the operational sulfur levels in each calendar year.

Table 4-7. PM and NO_x Emission Factor Scaling (EPA 2009, Table 2-12)

Engine Type\ EF Adjustments	2010 – 2012	2013 – 2014	2015+		2010	2015	2020	2025	2030
	PM EF	PM EF	PM EF		NO_x EF	NO_x EF	NO_x EF	NO_x EF	NO_x EF
	ECA	ECA	ECA		ECA	ECA	ECA	ECA	ECA
Main Engine	1.0*	0.3169	0.1352		0.8750	0.8020	0.5958	0.4278	0.3184
Auxiliary Engine (except cruise)	1.0*	0.3403	0.1250		0.8767	0.8059	0.5842	0.4108	0.2989

*1.0 is precontrolled

These estimates, shown in Table 4-7, form the basis for determining the relative 2023 NO_x fleet average emission rates. Table 4-8 shows the average NO_x emission factor adjustments that reflect the implementation of emission standards starting with Tier I for new ships in 2000, followed by Tier II in 2011, and Tier III in 2016. These adjustments account for the progressive tightening of emission standards and natural fleet turnover as older vessels are replaced by newer, more efficient ones.

Table 4-8. Emission Factor Adjustment of Category 3 NO_x Emission Rates to 2023

Year	Relative to 2023		Year	Relative to 2023		Year	Relative to 2023
2011	1.521		**2025**	0.880		**2039**	0.514
2012	1.479		**2026**	0.825		**2040**	0.502
2013	1.439		**2027**	0.773		**2041**	0.490
2014	1.401		**2028**	0.724		**2042**	0.479
2015	1.365		**2029**	0.677		**2043**	0.468
2016	1.331		**2030**	0.633		**2044**	0.458
2017	1.298		**2031**	0.618		**2045**	0.447
2018	1.267		**2032**	0.604		**2046**	0.437
2019	1.238		**2033**	0.590		**2047**	0.427
2020	1.209		**2034**	0.577		**2048**	0.417
2021	1.135		**2035**	0.564		**2049**	0.408
2022	1.065		**2036**	0.551		**2050**	0.398
2023	1		**2037**	0.538			
2024	0.938		**2038**	0.526			

4.2.2 Category 1 and 2 Engine Average Emission Rates

Emissions from the lower displacement engines, specifically those less than 30 liters per cylinder C1 and C2 engines, are primarily associated with domestic harbor craft vessel activity. These vessels include tugs, towboats, dredges, ferries, excursion boats, fishing boats, and other workboats. The C1 and C2 vessels with AIS records are typically larger commercial marine vessels, though still smaller than those equipped with Category 3 main engines. These vessels are distinct from recreational boats and very small commercial boats.

New C1/C2 engines are regulated by the EPA (2024), with fleet emissions decreasing over time as older vessels and engines are replaced by newer models that meet increasingly stringent emission limits. International standards have been in place for new marine engines since 2000, and the EPA introduced additional emission controls for new engines starting in 2004 and became progressively stricter through the 2018 model year.

Using the EPA (2008) estimates of baseline emissions (without emission regulations) and forecasted emissions (with emission regulations), Ramboll calculated the relative emissions rates in comparison to the AIS baseline year of 2023. The backcasted and forecasted emissions were then compared with the fleet-average emissions levels in 2023, with the ratio of these comparisons shown in Table 4-9.

Table 4-9. Fleet Average C1/C2 Emission Factors Relative to 2023

Year	PM_{10}	$PM_{2.5}$	NO_x	VOC	HC	CO	SO_2
2002	1.638	1.638	1.559	1.699	1.698	1.000	1.099
2003	1.638	1.638	1.559	1.699	1.698	1.000	1.099
2004	1.638	1.638	1.559	1.699	1.698	1.000	1.099
2005	1.638	1.638	1.559	1.699	1.698	1.000	1.099
2006	1.638	1.638	1.559	1.699	1.698	1.000	1.099
2007	1.638	1.638	1.559	1.699	1.698	1.000	1.099
2008	1.622	1.622	1.541	1.699	1.698	1.000	1.099
2009	1.605	1.605	1.525	1.698	1.698	1.000	1.099
2010	1.587	1.587	1.510	1.698	1.698	1.000	1.099
2011	1.569	1.569	1.495	1.698	1.698	1.000	1.099
2012	1.536	1.536	1.479	1.685	1.684	1.000	1.099
2013	1.494	1.494	1.462	1.663	1.662	1.000	1.099
2014	1.443	1.443	1.419	1.610	1.610	1.000	1.099
2015	1.413	1.413	1.389	1.556	1.556	1.000	1.099
2016	1.368	1.368	1.350	1.495	1.495	1.000	1.082
2017	1.313	1.313	1.304	1.425	1.425	1.000	1.048
2018	1.257	1.257	1.254	1.350	1.350	1.000	1.022
2019	1.206	1.206	1.202	1.276	1.276	1.000	1.020
2020	1.155	1.155	1.151	1.204	1.204	1.000	1.049
2021	1.103	1.103	1.100	1.134	1.134	1.000	1.029
2022	1.051	1.051	1.050	1.066	1.066	1.000	1.013
2023	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2024	0.949	0.949	0.951	0.937	0.936	1.000	0.988
2025	0.899	0.899	0.905	0.878	0.878	1.000	0.976
2026	0.851	0.851	0.860	0.825	0.825	1.000	0.964
2027	0.805	0.805	0.817	0.778	0.778	1.000	0.952
2028	0.762	0.762	0.776	0.736	0.736	1.000	0.941
2029	0.721	0.721	0.739	0.698	0.698	1.000	0.930
2030	0.682	0.682	0.705	0.665	0.665	1.000	0.919

Year	PM_{10}	$PM_{2.5}$	NO_x	VOC	HC	CO	SO_2
2031	0.646	0.646	0.674	0.635	0.635	1.000	0.909
2032	0.612	0.612	0.645	0.609	0.609	1.000	0.899
2033	0.579	0.579	0.619	0.585	0.585	1.000	0.889
2034	0.548	0.548	0.594	0.564	0.564	1.000	0.879
2035	0.519	0.519	0.571	0.544	0.544	1.000	0.870
2036	0.492	0.492	0.550	0.526	0.526	1.000	0.861
2037	0.469	0.469	0.534	0.512	0.512	1.000	0.852
2038	0.448	0.448	0.523	0.501	0.501	1.000	0.845
2039	0.431	0.431	0.514	0.492	0.492	1.000	0.838
2040	0.418	0.418	0.506	0.485	0.485	1.000	0.833
2041	0.388	0.388	0.474	0.456	0.456	1.000	0.821
2042	0.369	0.369	0.458	0.442	0.442	1.000	0.812
2043	0.351	0.351	0.443	0.428	0.428	1.000	0.804
2044	0.334	0.333	0.428	0.415	0.414	1.000	0.796
2045	0.317	0.317	0.414	0.401	0.401	1.000	0.788
2046	0.302	0.302	0.400	0.389	0.389	1.000	0.781
2047	0.287	0.287	0.387	0.376	0.376	1.000	0.773
2048	0.273	0.273	0.374	0.365	0.365	1.000	0.765
2049	0.259	0.259	0.361	0.353	0.353	1.000	0.757
2050	0.247	0.247	0.349	0.342	0.342	1.000	0.750

Note:
EFs for years 2041-2050 were extrapolated from EFs for the period 2031-2040

4.3 Local Control Measure Reductions

The Houston Ship Channel (HSC) is a critical waterway, connecting the largest petrochemical complex in the United States to global markets. To enhance safety and efficiency, Port Houston has partnered with the U.S. Army Corps of Engineers (USACE) on Project 11, an initiative to expand the HSC. This expansion will widen the channel by 170 feet along its Galveston Bay reach, increasing its width from 530 feet to 700 feet. It will also deepen some upstream segments to 46.5 feet, make other safety and efficiency improvements, and craft new environmental features.

The Texas Low Emissions Diesel (TxLED) regulations are designed to reduce NO_x emissions from diesel-powered motor vehicles and non-road equipment. These regulations apply to all diesel fuel sold or supplied in 110 central and eastern Texas counties. The TxLED Program mandates the use of cleaner diesel fuels to mitigate NO_x emissions, contributing to improved air quality in the region.

The following sections discuss how the HSC expansion and the TxLED are incorporated into the trend emission inventories.

4.3.1 Houston Shipping Channel Expansion Project

The USACE has projected annual NO_x emission reductions from the completion of the HSC expansion project, expected in 2029. For example, the NO_x emission reductions are projected to grow from 147 tons in 2029 to 334 tons in 2040. The emission reductions can be interpolated between 2029 and 2040, and a consistent level of reduction is expected to be maintained beyond 2040. Table 4-10 presents the annual emission reductions for each pollutant from 2029 to 2050. However, it is worth noting that directly using the USACE estimated emission reductions carries the risk of inconsistent assumptions in activity and emission factors.

Table 4-10. Annual Emission Reductions from Houston Shipping Channel Expansion Project

Year	PM_{10}	$PM_{2.5}$	NO_x	VOC	CO	SO_2
2029	15.61	14.24	147	3.53	7.74	17.98
2030	17.06	15.57	164	3.87	8.49	19.67
2031	18.52	16.89	181	4.21	9.25	21.35
2032	19.97	18.22	198	4.55	10.00	23.04
2033	21.43	19.55	215	4.89	10.75	24.73
2034	22.88	20.88	232	5.23	11.51	26.41
2035	24.34	22.20	249	5.57	12.26	28.10
2036	25.79	23.53	266	5.91	13.02	29.78
2037	27.25	24.86	283	6.25	13.77	31.47
2038	28.70	26.19	300	6.59	14.52	33.16
2039	30.16	27.51	317	6.93	15.28	34.84
2040	31.61	28.84	334	7.27	16.03	36.53
2041	31.61	28.84	334	7.27	16.03	36.53
2042	31.61	28.84	334	7.27	16.03	36.53
2043	31.61	28.84	334	7.27	16.03	36.53
2044	31.61	28.84	334	7.27	16.03	36.53
2045	31.61	28.84	334	7.27	16.03	36.53
2046	31.61	28.84	334	7.27	16.03	36.53
2047	31.61	28.84	334	7.27	16.03	36.53
2048	31.61	28.84	334	7.27	16.03	36.53
2049	31.61	28.84	334	7.27	16.03	36.53
2050	31.61	28.84	334	7.27	16.03	36.53

The emission reductions will be realized for ocean-going vessels operating along the segments of the shipping channel. These segments include the stretch from the entrance to Galveston Harbor to Barbours Cut (segments 1A, 1B, 1C, and 3) and Bayport (segment 2), as well as the sections from Boggy Bayou to Sims Bayou (segment 4) and Sims Bayou to the Turning Basin (segments 5 and 6), as illustrated in Figure 4-1.

To allocate the emissions reductions proportionally along the affected segments of the shipping lane, Ramboll first determined the total NO_x emissions in these segments. This was done by summing the NO_x emissions from each segment of the shipping channel impacted by the project. Ramboll then divided the estimated emission reduction from the project, as detailed in Table 4-10, by this total to obtain the proportional reduction for each segment. This method ensures that the emissions reductions are accurately distributed according to the emissions profile of the affected areas, thereby reflecting the impact of the project on each specific segment of the shipping lane.

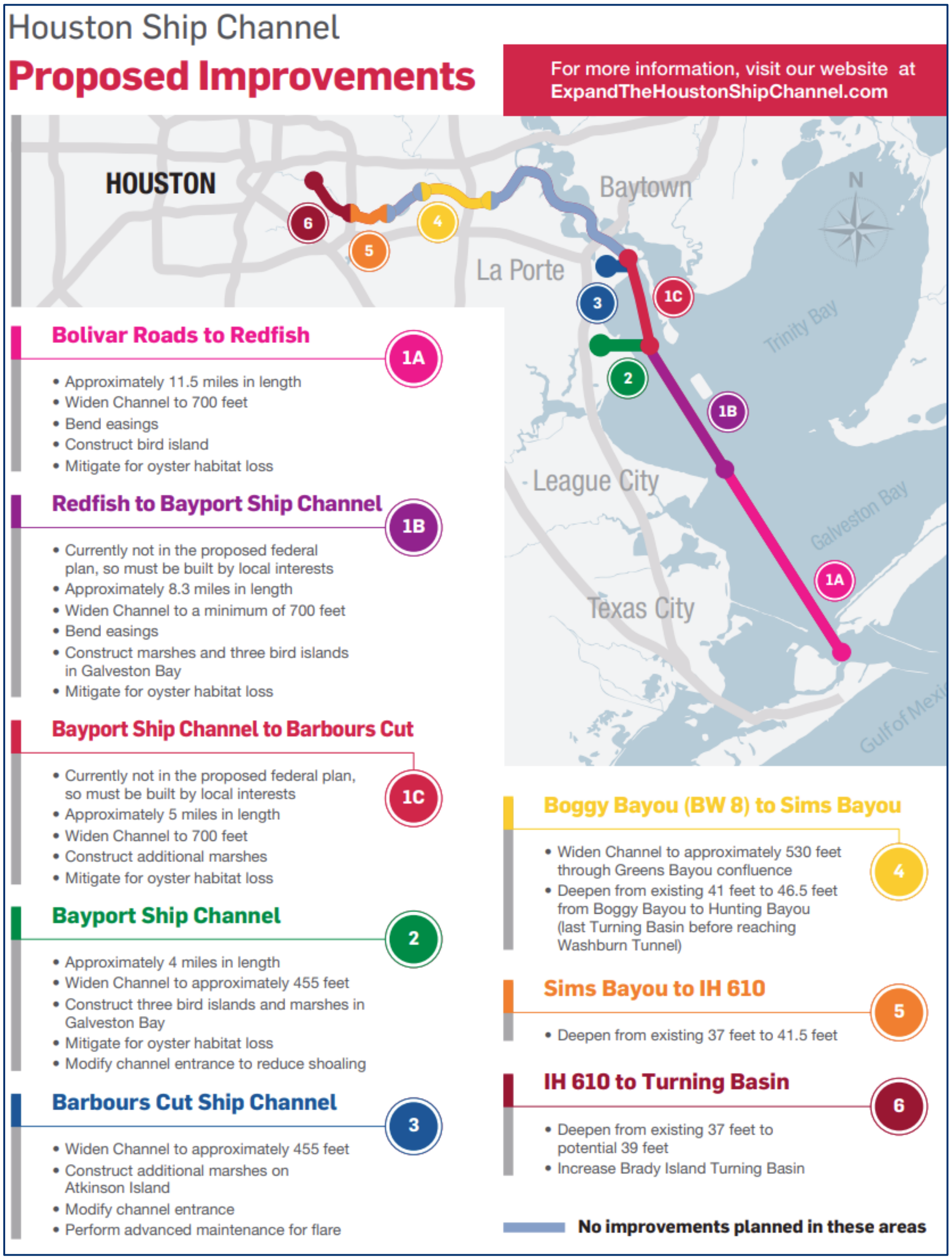

Figure 4-1. Map of HSC segments.

4.3.2 TxLED

The introduction of TxLED in Texas was aimed at reducing NO_x emissions through the regulation of diesel fuel composition. Specifically, TxLED mandates a minimum cetane number of 48 and a maximum aromatic hydrocarbon content of 10% in diesel fuel for 110 counties in central and eastern Texas.

Initially, the EPA (2001) estimated that TxLED would result in a 6.2% reduction in NO_x emissions for engines without exhaust gas recirculation (EGR) and a 4.8% reduction for engines with EGR. However, a subsequent EPA study in 2003 revised these estimates. It lowered the cetane benefit for engines without EGR and found no benefit for engines with EGR. The expected benefit of TxLED is an increase in cetane levels by about eight, assuming a base cetane level of at least 40. According to the 2003 EPA study, this cetane increase would result in approximately a 3.0% reduction in NO_x emissions for engines. This 3.0% estimate was for only Tier 2 and earlier and was considered conservative, given the nonlinear correlation with the data and the fact that not all Tier 3 engines would use EGR or NO_x reduction after-treatment technology.

In recent guidance, the EPA (2023) eliminated the NO_x emissions benefit of cetane increases for Tier 3 and Tier 4 engines, which are expected to use EGR or other NO_x reduction technologies. However, for Tier 2 or earlier engines, the EPA provided a method to calculate NO_x reductions that could exceed 3.0%, especially if the reference cetane level is 42 or lower and with a cetane increase of 8.

Based on data from the TERP, the Tier 3 emission standards for primary propulsion C1 and C2 marine engine types began in 2013. There was likely a lag before Tier 3 powered vessels entered service due to the time required to build vessels. EPA (2008) estimated an average lifespan for C1 engines of 13 years and for C2 engines of 23 years, which would produce limited fleet turnover from 2013 to 2020, i.e., less than half of the fleet. Lower emitting Tier 3 and 4 vessels represent an even smaller fraction of NO_x emissions than vessel population. Therefore, NO_x emissions from Tier 2 or older engines dominate the fleet NO_x emissions through at least calendar year 2020. Considering these factors, it was conservatively estimated that the NO_x benefit of TxLED for C1C2 commercial marine vessels refueled in affected Texas counties would be around 3.0% for calendar years 2011 – 2020. For calendar years 2021 and later, no TxLED benefit was modeled.

4.4 Trend Results

Figure 4-2 and Figure 4-3 present the controlled and uncontrolled Trend EIs with alternative harbor craft load factors. In all scenarios, a dip is observed between 2020 and 2021 due to the effects of the COVID-19 pandemic on activity levels. EIs using CARB harbor craft load factors consistently show lower emissions for almost all pollutants, except for SO_2 where the difference is minimal.

In the controlled scenario, NO_x emissions decrease from 2011 to 2050, with a faster reduction between 2011 and 2030 compared to the period from 2030 to 2050 due to compliance with the EPAs engine exhaust standards.

There are no marine standards targeting VOC and CO emissions, although the EPA expects limited VOC reductions with new technology C1/C2 engines but no CO emission reductions. As a result, the emissions trends for VOC and CO are driven by economic factors. In the controlled scenarios, VOC emissions increase by 43% and 65% from 2011 to 2050 using EPA and CARB harbor craft load factors, respectively. Similarly, CO emissions increase by 77% and 94% over the same period with EPA and CARB harbor craft load factors, respectively.

SO_2 and PM emissions decline sharply from 2011 to 2015 due to the fuel-related ECA standards for C3 vessels and lower PM emissions from new technology for C1/C2 powered vessels. SO_2 emissions have slowly increased since 2015 with increasing activity levels. PM emissions are expected to remain steady after 2015 as activity growth is offset by the introduction of lower-emitting C1/C2 engines into the fleet.

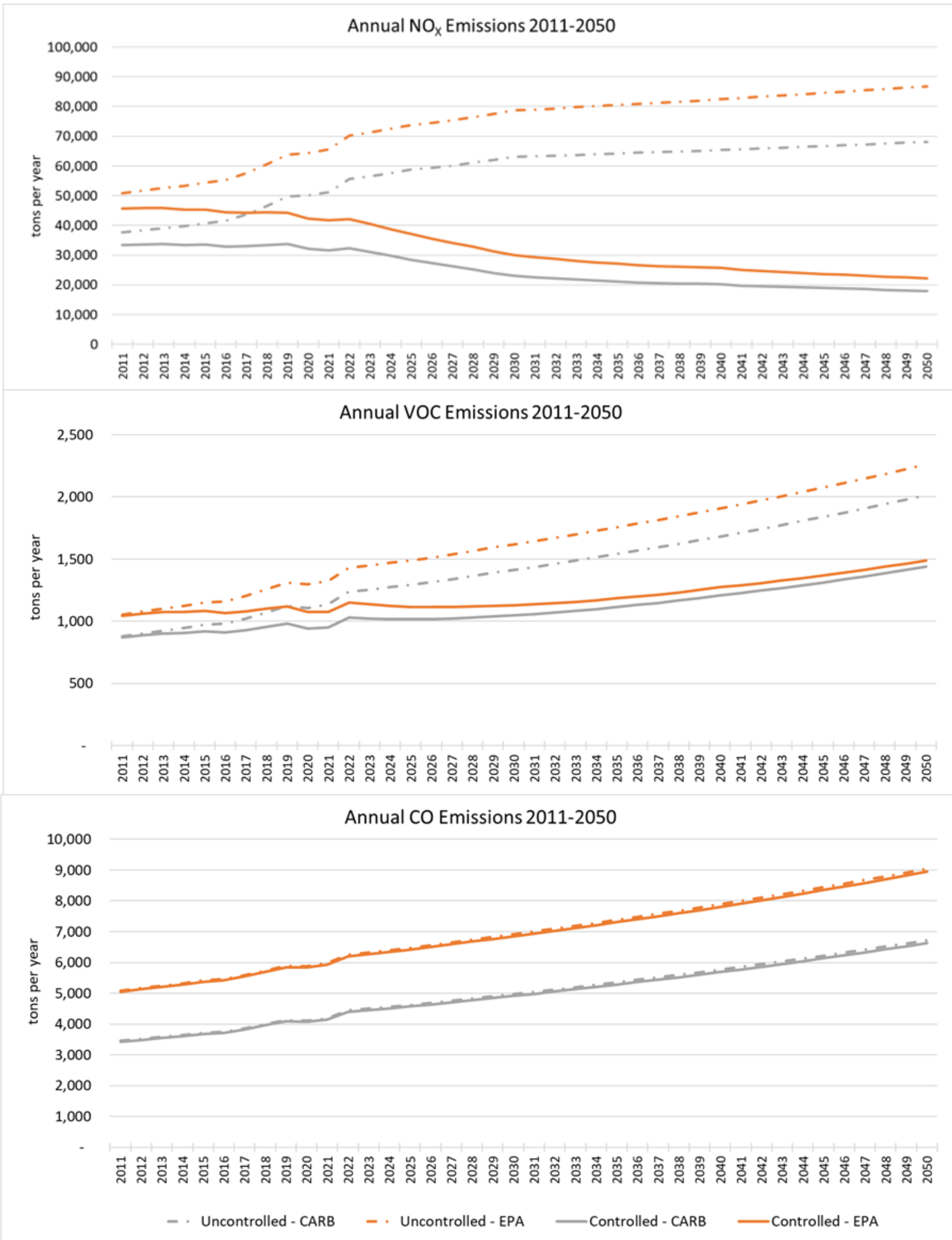

Figure 4-2. Statewide annual controlled (solid line) and uncontrolled (dashed line) emissions by year for NO_x (top), VOC (middle), and CO (bottom).

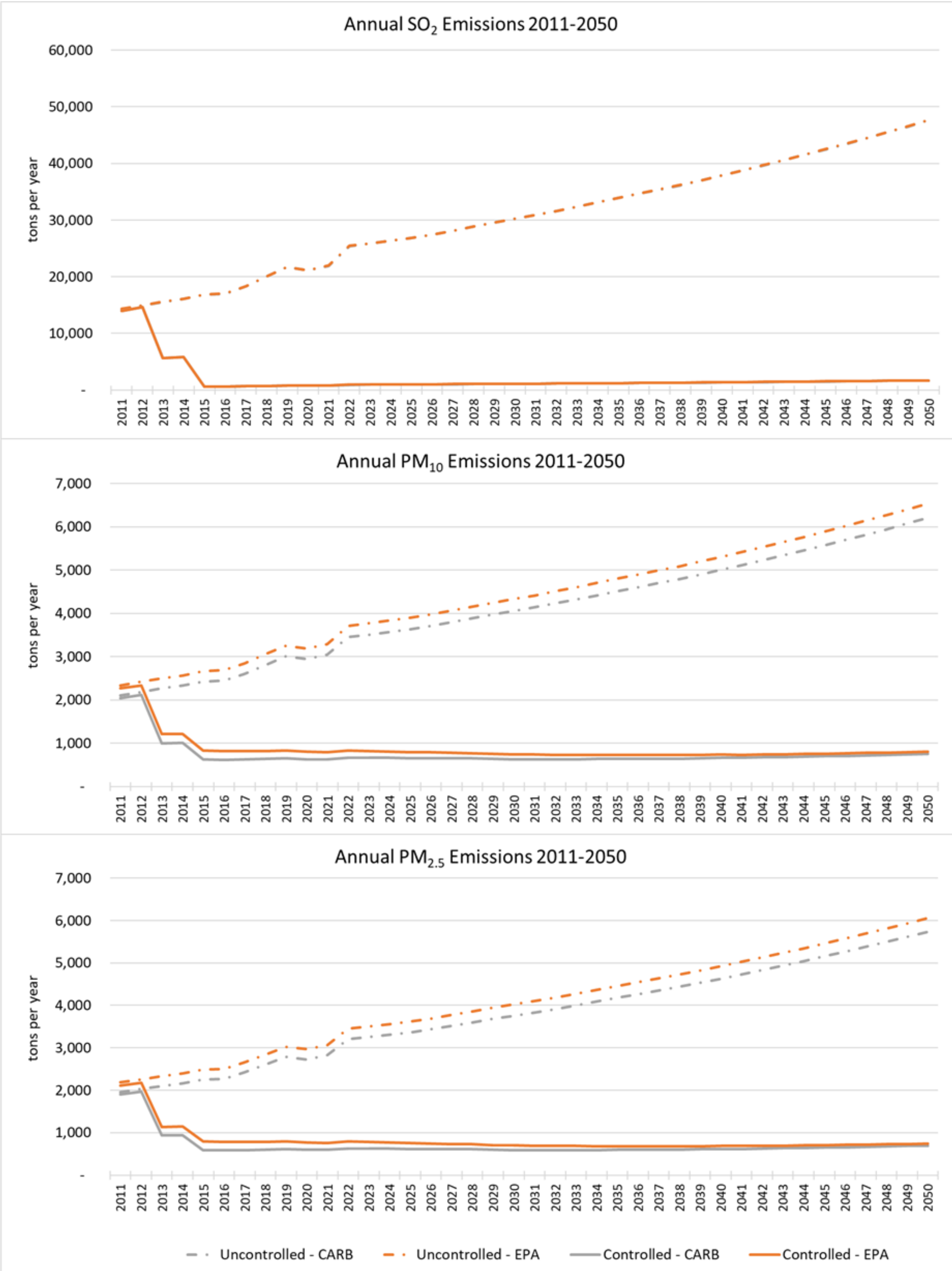

Figure 4-3. Statewide annual controlled (solid line) and uncontrolled (dashed line) emissions by year for SO_2 (top), PM_{10} (middle), and $PM_{2.5}$ (bottom).

5.0 DATA ANALYSIS AND QUALITY ASSURANCE

Ramboll compared the base year EIs and Trend EIs, as described in Chapters 3.0 and 4.0, to MARINER EIs developed previously as well as EPAs CMV EI to assess whether the current MARINER emission estimates are reasonable. The CMV EIs used for comparison are as follows:

1. The *2020 Texas CMV Emissions Inventory and 2011 through 2050 Trend Inventories* project (Ramboll, 2021).
2. The updated 2019 EI developed as part of the *Updating the Marine Emissions Resolver* project (Ramboll, 2023).
3. The CMV component of the EPAs 2020 NEI. In April 2024, EPA released the draft 2022v1 Emissions Modeling Platform which is based on the 2020 National Emissions Inventory. Projection years have not been released at the time of this project.

Table 5-1 lists the data sources of the CMV EIs as well as the "short name" used to reference each EI in the remainder of this memorandum.

Table 5-1. List of CMV EI Data Sources and Short Names

Data Sources	Short Name
Task 4 Technical Memorandum (developed as part of this project)	MARINER 2023 EI
Task 5 Technical Memorandum (developed as part of this project)	MARINER 2023 Trend EI
2020 Texas CMV Emissions Inventory and 2011 through 2050 Trend Inventories Project (Ramboll, 2021)	MARINER 2019 Trend EI
Updating the Marine Emissions Resolver Project (Ramboll, 2023)	MARINER 2019 EI
EPA 2022v1 Emissions Modeling Platform https://www.epa.gov/air-emissions-modeling/2022v1-emissions-modeling-platform (last accessed 06/26/2024)	EPA 2022 EI

To evaluate the quality of the MARINER 2023 EI and the MARINER 2023 Trend EI, the following QA analyses were conducted:

- Comparison of Activity: The activity data, including hours and nautical miles, were compared between the MARINER 2023 EI and the MARINER 2019 EI.
- Comparison of Emissions: Emissions from the MARINER 2023 EI were compared to both the EPA 2022 EI and the MARINER 2019 EI by vessel type and other aggregate characteristics.
- Trend Emissions Comparison: Emissions from the MARINER 2023 Trend EI were compared to those from the MARINER 2019 Trend EI for the years 2011 through 2050.

5.1 Quality Assurance OF MARINER 2023 EI

5.1.1 Activity Comparison

Ramboll compared vessel activity levels for the MARINER 2023 EI and MARINER 2019 EI focusing on vessel count, hours, and nautical miles travelled.

Table 5-2 compares CMV vessel counts by ship type between the MARINER 2023 and MARINER 2019 inventories. The MARINER 2019 inventory was based on the IHS Ships database, while the MARINER 2023 inventory used the more recent S&P Global Ships database. This newer database includes a broader range of vessel types and more up-to-date information on newer vessels. The MARINER 2023 EI identifies 7,832 vessels, with 3,110 vessels in the C1/C2 category and 4,722 vessels in the C3 category. The MARINER 2019 EI identifies 7,574 vessels, with 3,239 vessels in the C1/C2 category and 4,335 vessels in the C3 category. Compared to MARINER 2019, the MARINER 2023 inventory shows a slight decrease in the number of C1/C2 vessels but an increase in C3 vessels, resulting in a net increase of 258 vessels.

New C1/C2 vessel types included in MARINER 2023, but not included in MARINER 2019, are bulk carrier, chemical tanker, excursion, general cargo, liquified gas tanker, offshore support/drillship, other tanker, and tugboat ATB. In both inventories, the top three vessel types by count are towboat/pushboat, fishing vessels (C1/C2), and miscellaneous (C1/C2) vessels, with towboat/pushboat having the highest counts. Notably, the number of vessels in the Miscellaneous (C1/C2) category reduced by 44% in MARINER 2023 compared to MARINER 2019, with many vessels being reassigned to the offshore support/drillship category. This reduction in Miscellaneous (C1/C2) category vessels is attributed to improved vessel type assignment due to the more comprehensive S&P Global Ships database.

In the C3 category, new vessel types included in MARINER 2023 but not in MARINER 2019 are dredge, ferry/roll-on/passenger, tugboat, tugboat ATB, and work boat. Among the major C3 vessel types, only general cargo vessels experienced a reduction (by 10%), while all other types saw increases in vessel counts. Notable increases include bulk carrier, chemical tanker, container ship, liquified gas tanker, and oil tanker. The number of liquified gas tanker vessels increased by 246 vessels (50%) in MARINER 2023 compared to MARINER 2019.

Table 5-2. Comparison Between MARINER 2023 and MARINER 2019 Vessel Counts

Vessel Class	EPA Ship Type	SCC Ship Type	MARINER 2023	MARINER 2019
C1/C2	Bulk Carrier	Bulk Carrier	1	-
	Chemical Tanker	Tanker	26	-
	Crew and Supply	Offshore support	199	190
	Dredge	Miscellaneous	47	14
	Excursion	Tour Boat	4	-
	Fishing (C1/C2)	Commercial Fishing	549	655
	General Cargo	General Cargo	6	-
	Government	Government	60	4
	Harbor Ferry (C1/C2)	Ferry	5	5
	Liquified Gas Tanker	Tanker	1	-
	Miscellaneous (C1/C2)	Miscellaneous	437	782
	Offshore Support/Drillship	Offshore support	256	-
	Other Tanker	Tanker	1	-
	Pilot	Government	15	11
	Towboat/Pushboat	Tug	1,065	1,233
	Tug Boat	Tug	345	310
	Tug Boat ATB	Tug	51	-
	Work Boat	Miscellaneous	42	35
	Subtotal		**3,110**	**3,239**
C3	Bulk Carrier	Bulk Carrier	969	872
	Chemical Tanker	Tanker	1,109	1,063
	Container Ship	Container Ship	312	250
	Cruise	Cruise	13	8
	Dredge	Miscellaneous	1	-
	Ferry/Roll-on/Passenger (C3)	Passenger Other	1	-
	General Cargo	General Cargo	460	510
	Liquified Gas Tanker	Tanker	738	492
	Miscellaneous (C3)	Miscellaneous	17	29
	Offshore Support/Drillship	Offshore support	14	24
	Oil Tanker	Tanker	860	778
	Other Tanker	Tanker	80	145
	Reefer	Refrigerated	3	5
	RORO	RollOn RollOff	130	159
	Tug Boat	Tug	1	-
	Tug Boat ATB	Tug	11	-
	Work Boat	Miscellaneous	3	-
	Subtotal		**4,722**	**4,335**
	Total		**7,832**	**7,574**

Figure 5-1 and Figure 5-2 present a detailed comparison of vessel activity, specifically focusing on hours traveled as recorded in the MARINER 2023 and MARINER 2019 EI. The data is categorized by county, SCC ship type, and vessel class.

Figure 5-1 provides a bar chart comparing the hours traveled by vessels within several counties. Harris County consistently shows the highest vessel activity in both the MARINER 2023 and MARINER 2019 EIs, followed by Galveston and Jefferson counties. This high level of activity is attributed to the significant marine operations and major ports located in these counties. The comparison indicates a general increase of about 3% in vessel activity in the MARINER 2023 EI compared to the MARINER 2019 EI. This increase is particularly noticeable in counties such as San Patricio, Aransas, and Chambers.

Figure 5-2 shows the hours traveled by vessels, further broken down by ship type and vessel class. The chart highlights that tug (C1/C2) and miscellaneous (C1/C2) vessel types remain substantial contributors to the total vessel hours in both inventories. Overall, the comparison shows a high level of consistency of hours traveled in the two EIs.

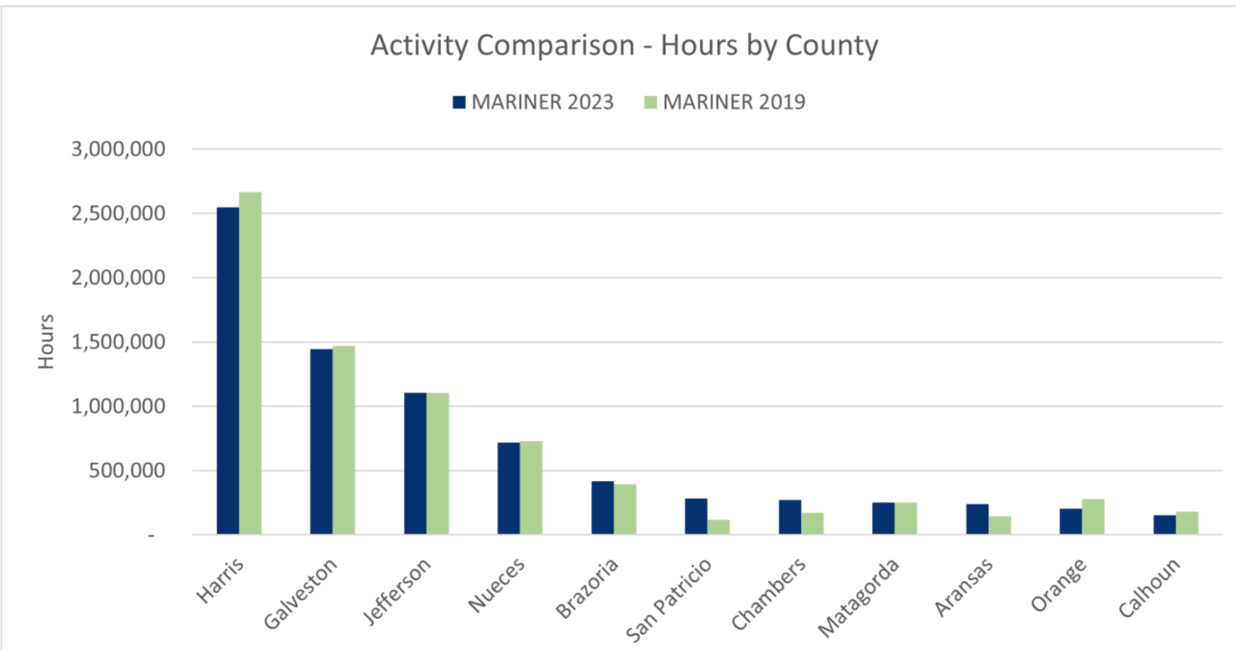

Figure 5-1. MARINER 2023 and MARINER 2019 CMV hours by county.

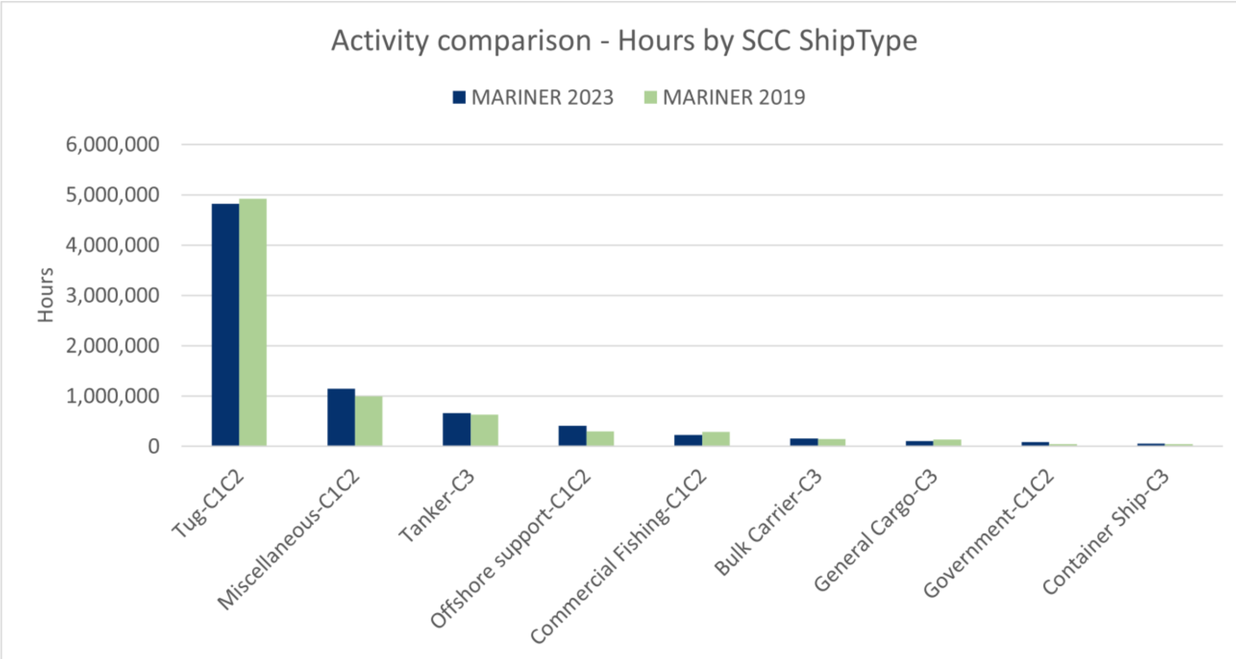

Figure 5-2. MARINER 2023 and MARINER 2019 CMV hours by SCC Ship Type and Vessel Class.

Figure 5-3 and Figure 5-4 present a detailed comparison of vessel activity, specifically focusing on the nautical miles traveled, as recorded in the MARINER 2023 and MARINER 2019 EI. The data is categorized by county, SCC ship type, and vessel class.

Figure 5-3 shows a bar chart comparing the nautical miles traveled by vessels within several counties. Galveston County consistently shows the highest vessel activity in both the MARINER 2023 and MARINER 2019 EIs, followed by Harris and Jefferson counties. This high level of activity is likely due to the significant marine traffic and major ports located in these counties. Notably, Galveston County, while showing fewer hours traveled than Harris County, records much higher nautical miles traveled. A similar relationship is observed in Chambers County, suggesting that vessels in Galveston and Chambers Counties travel longer distances despite fewer operating hours, likely due to relatively faster travel facilitated by the Intracoastal Waterway.

Figure 5-4 displays the nautical miles traveled by vessels, further broken down by ship type and vessel class. Similar to Figure 5-2, tug (C1/C2) and miscellaneous (C1/C2) vessel types remain substantial contributors to the total vessel nautical miles in both inventories.

Overall, the comparison shows a general decrease of about 4% in nautical miles traveled in the MARINER 2023 EI compared to the MARINER 2019 EI. The slight reduction in nautical miles traveled in the MARINER 2023 EI compared to MARINER 2019 could be attributed to various factors, including changes in vessel routing, operational efficiencies, and possibly shifts in economic activities influencing marine traffic patterns.

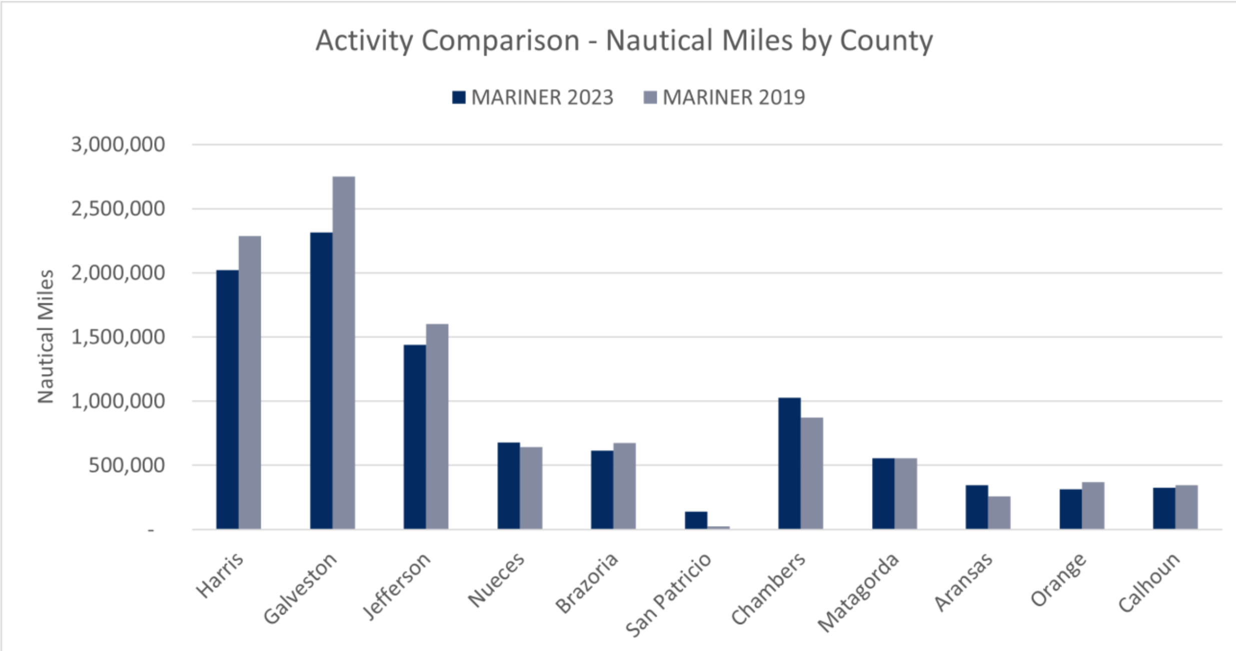

Figure 5-3. MARINER 2023 and MARINER 2019 CMV nautical miles by county.

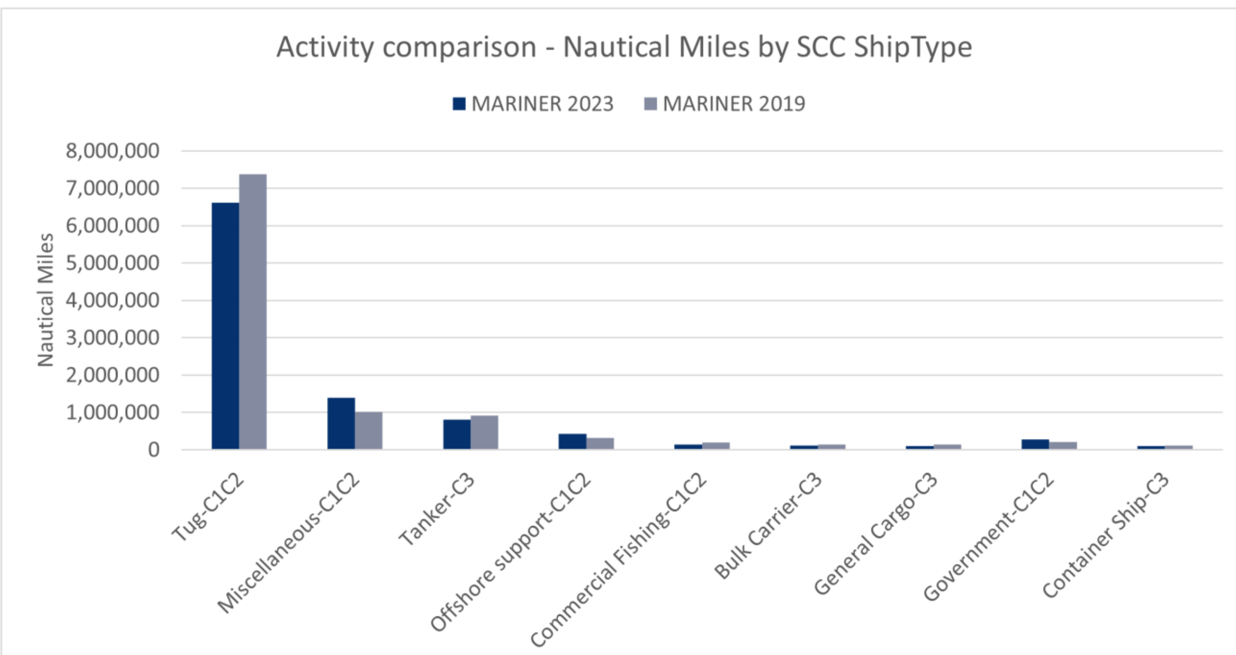

Figure 5-4. MARINER 2023 and MARINER 2019 CMV nautical miles by SCC Ship Type and Vessel Class.

5.1.2 Emissions Comparison

The MARINER controlled CMV emissions for 2023 were compared to the MARINER 2019 and EPAs 2022 CMV EI for Texas from the 2022v1 Emissions Modeling Platform (EPA, 2024). The following analysis provides a comparison of emission totals among emission inventories, with a focused discussion on NO_x emissions.

Figure 5-5 presents the comparison of MARINER 2023 emissions with EPA 2022 and MARINER 2019 EI by pollutant for all vessels. MARINER 2023 NO_x emissions were 7% higher than MARINER 2019 EI. Specifically, when comparing MARINER EIs using CARB harbor craft load factors to the EPAs 2022 NO_x emissions, Ramboll found that the MARINER EI using EPA load factors resulted in 34% higher NO_x emissions, while the MARINER EI using CARB load factors resulted in 3% higher NO_x emissions. For other pollutants, the differences between MARINER 2023 EI using CARBs load factors and EPA 2022 EI are 24% in VOC, 11% in CO, 17% in PMs, and 0.1% in SO_2 emissions, and the differences between MARINER 2023 EI using EPAs load factors and EPA 2022 EI are 15% in VOC, 56% in CO, 3% in PMs, and 1% in SO_2 emissions.

Overall, the EPA's 2022 CMV EI is more comparable to the MARINER 2023 EI using CARBs harbor craft load factors than the MARINER 2023 EI using EPAs default load factors.

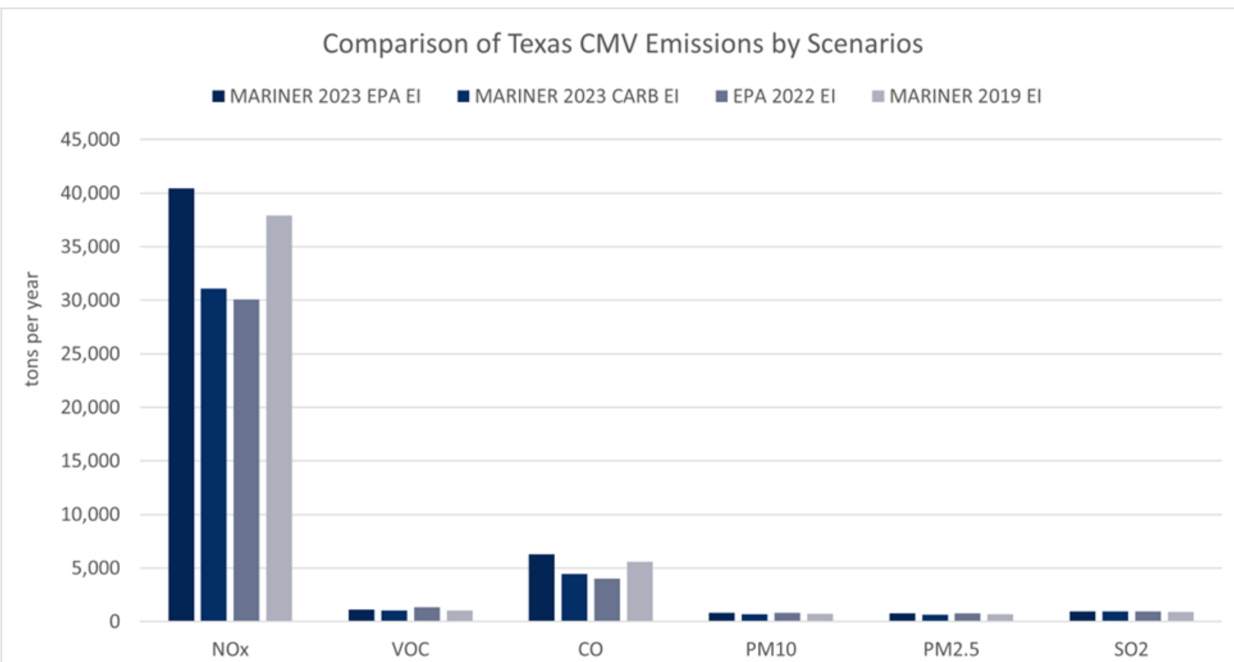

Figure 5-5. MARINER 2023, EPA 2022, and MARINER 2019 CMV emissions by pollutants.

Table 5-3 lists NO_x emissions by SCC ship type for the different EIs, and Figure 5-6 compares the NO_x emissions for the ship types with substantial emissions. Notably, three ship types (tug, miscellaneous, and general cargo) demonstrate substantial differences between MARINER 2023 using CARBs harbor craft load factors and the EPA 2022 EI. The EPA inventory attributes nearly 6,422 tons of NO_x emissions to tug vessels, while the MARINER 2023 EI using CARBs load factors reports 10,053 tons. For general cargo, the EPA reports 4,818 tons for C1/C2, and 52 tons for C3, whereas MARINER reports 1,349 tons for C3. The difference in tug and general cargo emissions is most likely due to the EPA categorizing more tugboats as general cargo. Additionally, the MARINER inventory indicates substantially higher emissions for the miscellaneous ship type compared to the EPA 2022 EI.

Table 5-3. MARINER 2023, EPA 2022, and MARINER 2019 CMV NO_x Emissions by Ship Type (tons/year)

Category	SCC Ship Type	MARINER 2023 EPA EI	MARINER 2023 CARB EI	EPA 2022 EI	MARINER 2019 EI
C1/C2	Bulk Carrier	0	0	-	-
	Commercial Fishing	412	408	329	518
	Container Ship	-	-	1	-
	Ferry	381	334	-	-
	General Cargo	4	4	4,818	-
	Government	202	152	822	118
	Miscellaneous	3,283	3,769	1,149	2,129
	Offshore support	634	539	1,054	245
	RollOn RollOff	-	-	139	-
	Tanker	375	375	672	-
	Tour Boat	5	4	604	-
	Tug	19,710	10,053	6,422	18,968
	Subtotal	**25,007**	**15,637**	**16,008**	**21,978**
C3	Bulk Carrier	1,207	1,207	1,428	1,092
	Container Ship	1,423	1,423	1,455	1,172
	Cruise	742	742	557	649
	General Cargo	1,394	1,394	52	1,794
	Miscellaneous	39	37	273	-
	Offshore support	1	1	488	25
	Refrigerated	27	27	40	35
	RollOn RollOff	429	429	292	789
	Tanker	10,056	10,056	9,454	10,368
	Tug	127	108	35	-
	Subtotal	**15,448**	**15,425**	**14,074**	**15,924**
	Total	**40,454**	**31,062**	**30,082**	**37,902**

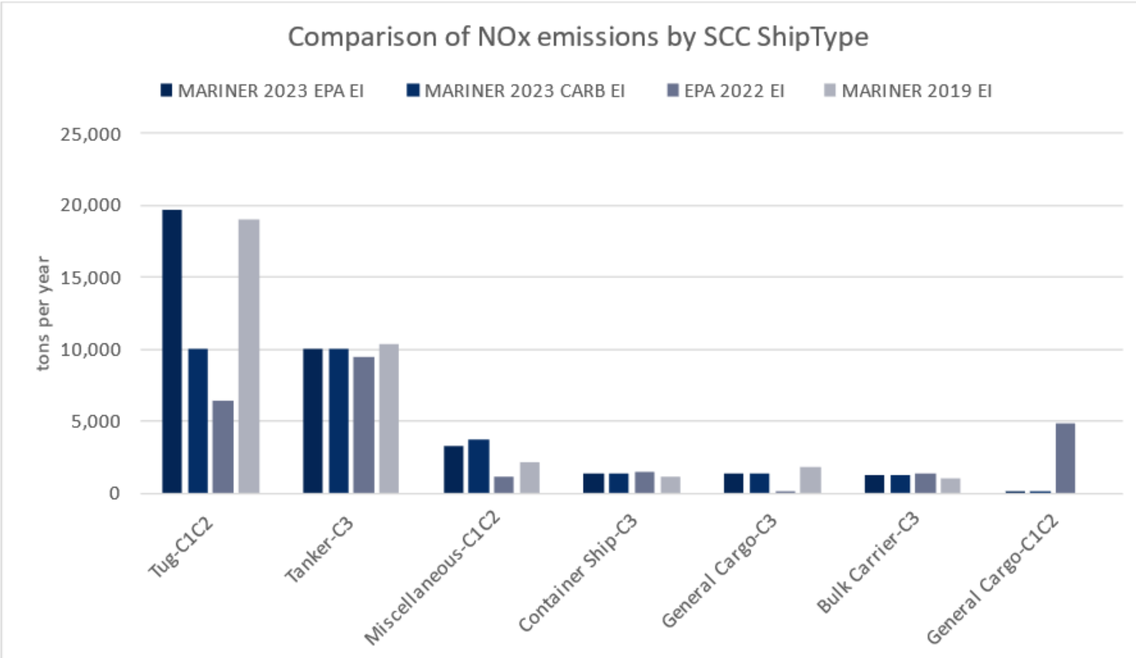

Figure 5-6. MARINER 2023, EPA 2022, and MARINER 2019 CMV emissions by ship type.

Figure 5-7 compares NO_x emissions across several counties with substantial emissions in Texas for each inventory. Given the variability in vessel activity from year to year, discrepancies among counties are anticipated. MARINER 2019 EI differs in county assignment methodology by utilizing the TCEQ 4 km modeling grids, whereas other EIs rely on precise county boundaries. In MARINER 2023 EI, using EPAs load factors results in consistently higher NO_x emissions across nearly all counties, whereas using CARBs load factors shows closer alignment with EPA 2022 EI.

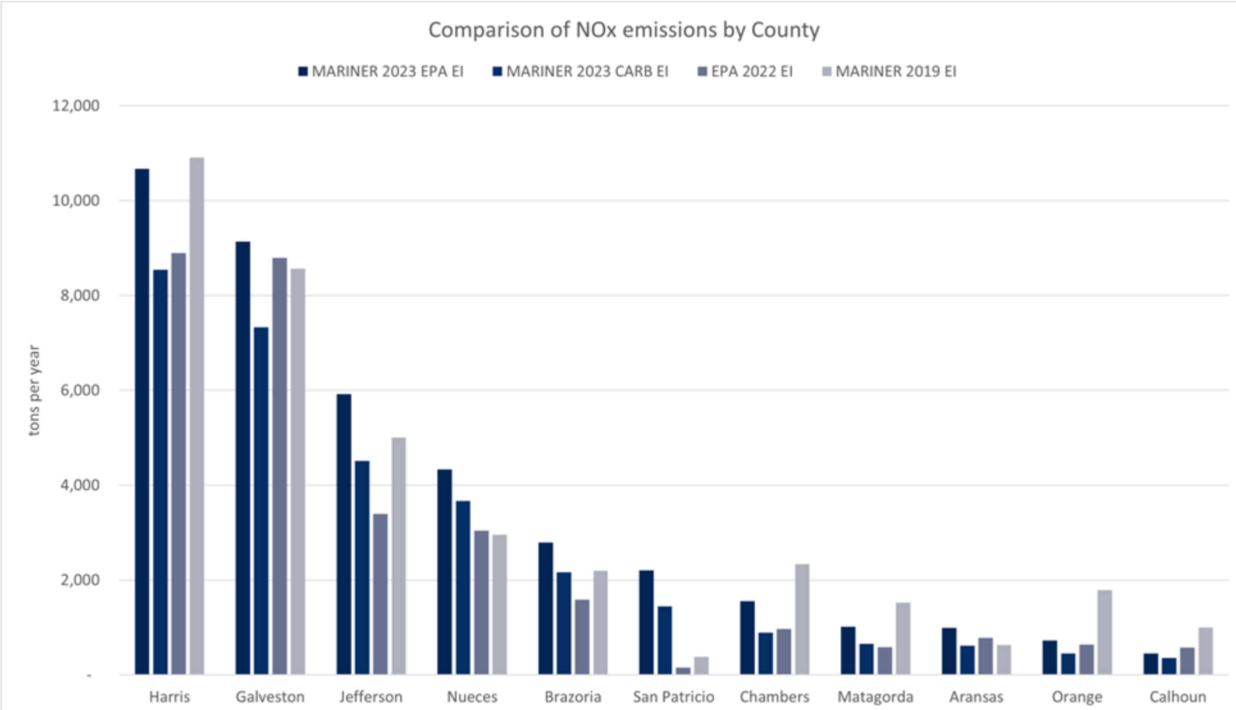

Figure 5-7. MARINER 2023, EPA 2022, and MARINER 2019 CMV emissions by county.

Figure 5-8 and Figure 5-9 present NO_x emissions by engine, mode, and vessel class. For C1/C2 vessels, EPA reports higher NO_x emissions from auxiliary engines but lower emissions from propulsion engines. The most substantial variance appears in propulsion engine emissions underway, where MARINER 2023 EI using EPAs load factors shows a 268% increase and an 80% increase when using CARBs load factors compared to EPA 2022 EI. In contrast, for C3 vessels, emissions align more closely between the different EIs than for C1/C2 vessels. The differences between MARINER EIs and EPA 2022 EI range from 7% to 12%.

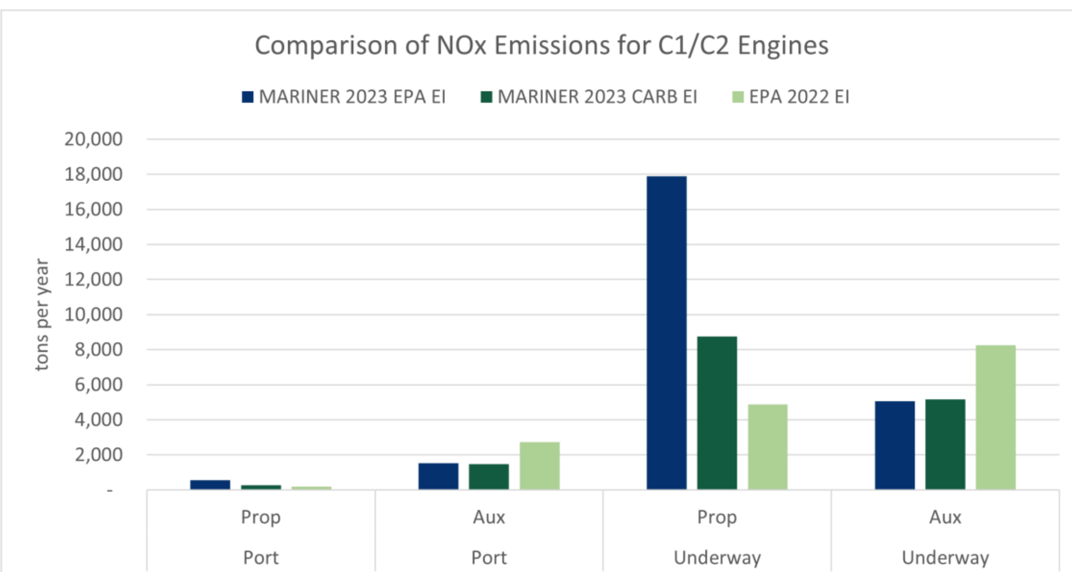

Figure 5-8. MARINER 2023 and EPA 2022 CMV emissions by engine and mode for C1/C2 vessels.

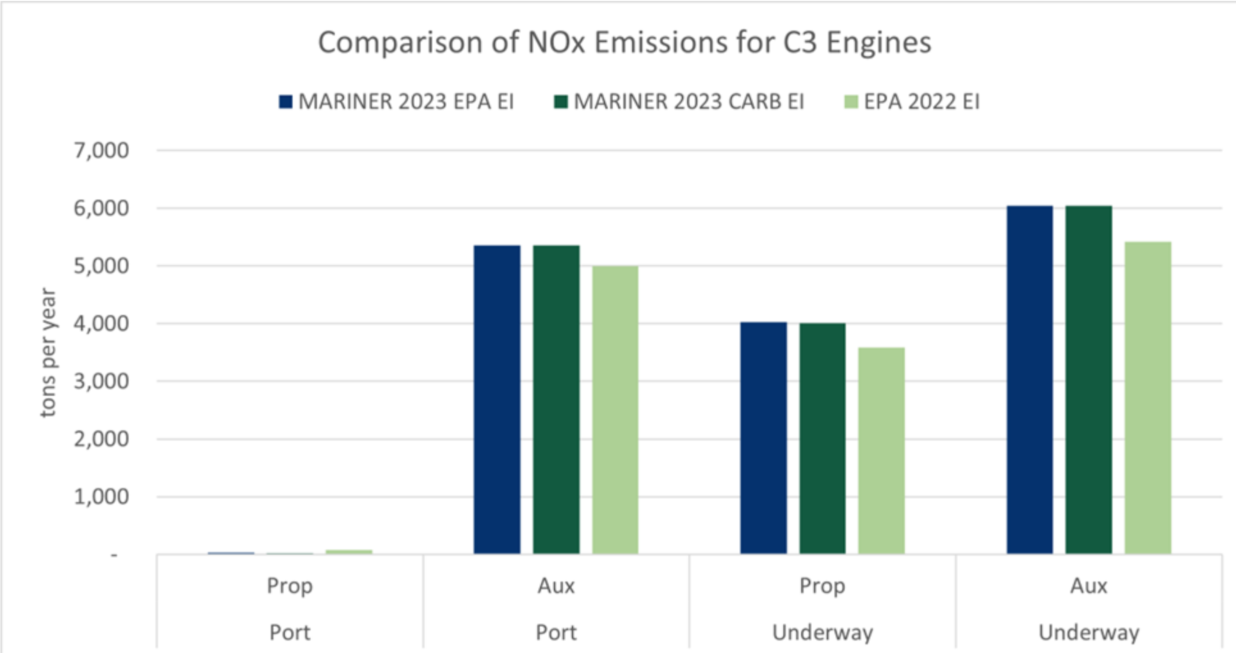

Figure 5-9. MARINER 2023 and EPA 2022 CMV emissions by engine and mode for C3 vessels.

5.2 Quality Assurance of MARINER 2023 Trend EI

Back-cast and forecast emissions developed using MARINER in this study were compared to the MARINER 2019 Trend EI. Analysis in this section focuses on comparing total emissions given differences in vessel identification and classification between these EIs, discussed above.

Figure 5-10 and Figure 5-11 illustrate the projected annual NO_x and VOC emissions, respectively, comparing three different EIs: the MARINER 2023 Trend EI using EPAs harbor craft load factors, the MARINER 2023 Trend EI using CARBs harbor craft load factors, and the MARINER 2019 Trend EI.

For NO_x emissions, as shown in Figure 5-10, the MARINER 2023 Trend EI using EPAs harbor craft load factors consistently shows higher emissions than the MARINER 2023 Trend EI using CARBs load factors, although both exhibit the same rate of decline over time. The MARINER 2019 Trend EI initially demonstrates a steeper decline in NO_x emissions compared to the MARINER 2023 Trend EIs. After 2023, all EIs show similar rates of decline, indicating alignment in long-term NO_x reduction trends.

Figure 5-11 presents the VOC emissions, which show a general increase over time across all inventories. The MARINER 2023 Trend EI using EPAs harbor craft load factors again shows higher emissions than the version using CARBs load factors. The MARINER 2019 Trend EI exhibits the highest emissions after 2035. Notably, there is a dip in emissions in 2021 and 2022 across all inventories, reflecting the economic impact of the COVID-19 pandemic on marine activity.

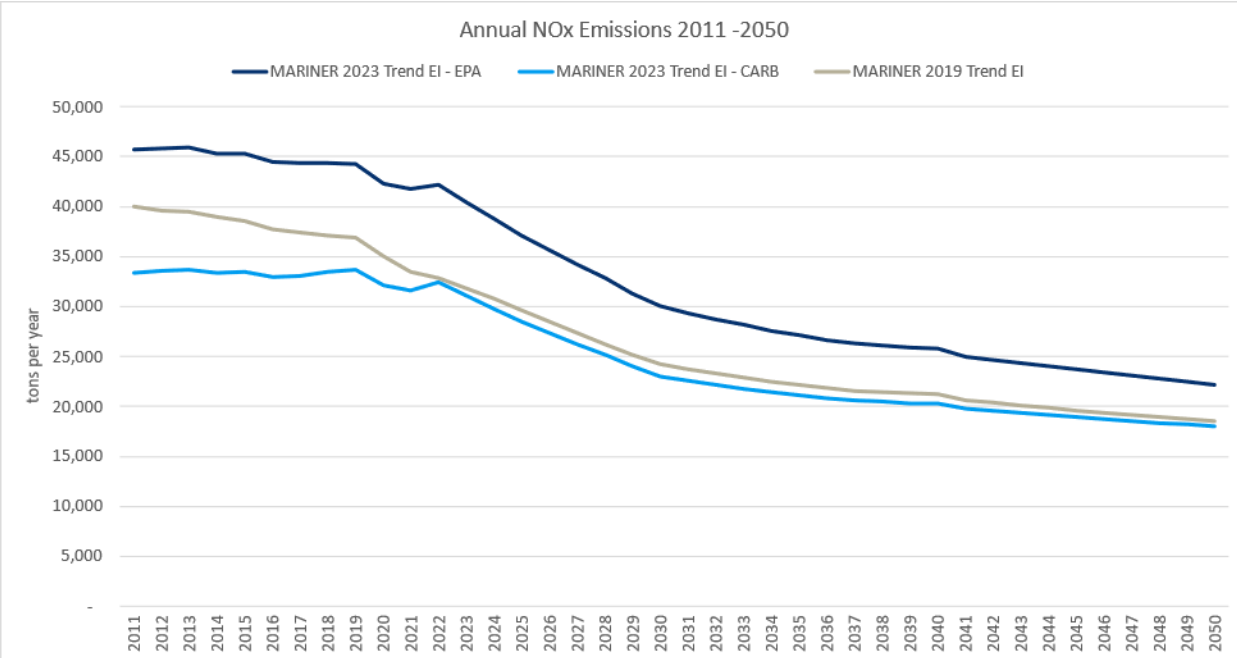

Figure 5-10. Comparison of 2011 through 2050 NO_x emissions for different EIs.

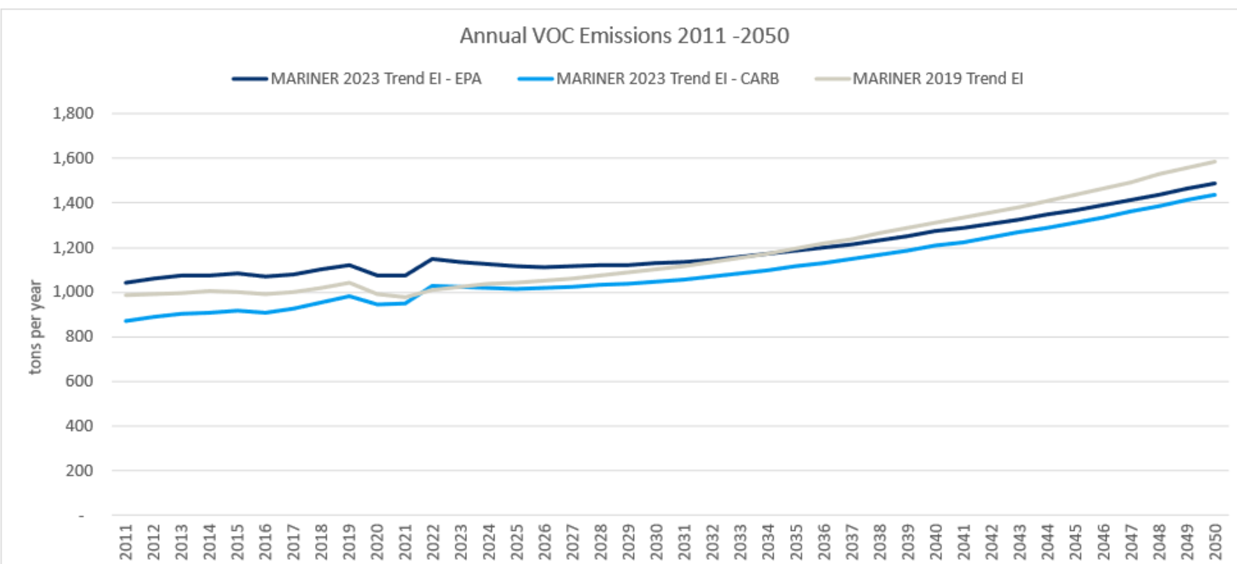

Figure 5-11. Comparison of 2011 through 2050 VOC emissions for different EIs.

5.3 Conclusion

As a QA step, the MARINER 2023 EI and Trend EIs developed under Task 4 and Task 5 were compared with emissions from previous MARINER projects as well as EPAs CMV EI. The QA comparisons find that the current CMV emission estimates are generally comparable to other inventories. Specifically, the MARINER 2023 EI using CARBs load factors aligns more closely with the EPA 2022 EI than does the MARINER 2023 EI using EPAs load factors.

While our emission estimates compare well with other inventories, differences can be attributed to several factors: 1) variations in levels of activities specific to each year, 2) differences in vessel characteristics databases and categorization methods, and 3) variations in gap-filling approaches used.

6.0 RECOMMENDATIONS

The following recommendations are presented to further improve the accuracy of MARINER EIs in future projects:

- Leveraging Artificial Intelligence (AI) and Machine Learning (ML) techniques to enhance the quality and utility of AIS data, thereby improving the accuracy and precision of marine emission estimates. For instance, AI can perform QA on large datasets, detecting anomalies and inconsistencies more efficiently and in greater detail than a person, ensuring higher data integrity for emission modeling.

- Collecting vessel data (i.e., logs of fuel consumption and hours of operation) by collaborating with trade organizations such as the American Waterway Operators and vessel operators based in Texas, to better understand harbor craft load factors. Currently, the EPA estimated load factors for harbor craft vessels are significantly higher than those used by the CARB. Harbor craft vessels, which include tugs and barges (also known as pushboats or towboats), offshore support vessels, tugs assisting ships, and other types, account for the majority of marine vessel emissions in Texas waters.

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APPENDIX A

Marine Vessel Source Classification Codes

SCC	SCC Level One	SCC Level Two	SCC Level Three	SCC Level Four	Include in the MARINER 2023 EI
2280201113	Mobile Sources	Marine Vessels, Commercial	Diesel Barge	C1C2 Port Emissions: Main Engine	N
2280201114	Mobile Sources	Marine Vessels, Commercial	Diesel Barge	C1C2 Port Emissions: Auxiliary Engine	N
2280201123	Mobile Sources	Marine Vessels, Commercial	Diesel Barge	C1C2 Underway emissions: Main Engine	N
2280201124	Mobile Sources	Marine Vessels, Commercial	Diesel Barge	C1C2 Underway emissions: Auxiliary Engine	N
2280201313	Mobile Sources	Marine Vessels, Commercial	Diesel Barge	C3 Port Emissions: Main Engine	N
2280201314	Mobile Sources	Marine Vessels, Commercial	Diesel Barge	C3 Port Emissions: Auxiliary Engine	N
2280201323	Mobile Sources	Marine Vessels, Commercial	Diesel Barge	C3 Underway emissions: Main Engine	N
2280201324	Mobile Sources	Marine Vessels, Commercial	Diesel Barge	C3 Underway emissions: Auxiliary Engine	N
2280202113	Mobile Sources	Marine Vessels, Commercial	Diesel Offshore support	C1C2 Port Emissions: Main Engine	Y
2280202114	Mobile Sources	Marine Vessels, Commercial	Diesel Offshore support	C1C2 Port Emissions: Auxiliary Engine	Y
2280202123	Mobile Sources	Marine Vessels, Commercial	Diesel Offshore support	C1C2 Underway emissions: Main Engine	Y
2280202124	Mobile Sources	Marine Vessels, Commercial	Diesel Offshore support	C1C2 Underway emissions: Auxiliary Engine	Y
2280202313	Mobile Sources	Marine Vessels, Commercial	Diesel Offshore support	C3 Port Emissions: Main Engine	N
2280202314	Mobile Sources	Marine Vessels, Commercial	Diesel Offshore support	C3 Port Emissions: Auxiliary Engine	Y
2280202323	Mobile Sources	Marine Vessels, Commercial	Diesel Offshore support	C3 Underway emissions: Main Engine	N
2280202324	Mobile Sources	Marine Vessels, Commercial	Diesel Offshore support	C3 Underway emissions: Auxiliary Engine	Y
2280203113	Mobile Sources	Marine Vessels, Commercial	Diesel Bulk Carrier	C1C2 Port Emissions: Main Engine	Y
2280203114	Mobile Sources	Marine Vessels, Commercial	Diesel Bulk Carrier	C1C2 Port Emissions: Auxiliary Engine	Y
2280203123	Mobile Sources	Marine Vessels, Commercial	Diesel Bulk Carrier	C1C2 Underway emissions: Main Engine	Y
2280203124	Mobile Sources	Marine Vessels, Commercial	Diesel Bulk Carrier	C1C2 Underway emissions: Auxiliary Engine	Y
2280203313	Mobile Sources	Marine Vessels, Commercial	Diesel Bulk Carrier	C3 Port Emissions: Main Engine	Y
2280203314	Mobile Sources	Marine Vessels, Commercial	Diesel Bulk Carrier	C3 Port Emissions: Auxiliary Engine	Y
2280203323	Mobile Sources	Marine Vessels, Commercial	Diesel Bulk Carrier	C3 Underway emissions: Main Engine	Y
2280203324	Mobile Sources	Marine Vessels, Commercial	Diesel Bulk Carrier	C3 Underway emissions: Auxiliary Engine	Y
2280204113	Mobile Sources	Marine Vessels, Commercial	Diesel Commercial Fishing	C1C2 Port Emissions: Main Engine	Y
2280204114	Mobile Sources	Marine Vessels, Commercial	Diesel Commercial Fishing	C1C2 Port Emissions: Auxiliary Engine	Y
2280204123	Mobile Sources	Marine Vessels, Commercial	Diesel Commercial Fishing	C1C2 Underway emissions: Main Engine	Y
2280204124	Mobile Sources	Marine Vessels, Commercial	Diesel Commercial Fishing	C1C2 Underway emissions: Auxiliary Engine	Y
2280204313	Mobile Sources	Marine Vessels, Commercial	Diesel Commercial Fishing	C3 Port Emissions: Main Engine	N

SCC	SCC Level One	SCC Level Two	SCC Level Three	SCC Level Four	Include in the MARINER 2023 EI
2280204314	Mobile Sources	Marine Vessels, Commercial	Diesel Commercial Fishing	C3 Port Emissions: Auxiliary Engine	N
2280204323	Mobile Sources	Marine Vessels, Commercial	Diesel Commercial Fishing	C3 Underway emissions: Main Engine	N
2280204324	Mobile Sources	Marine Vessels, Commercial	Diesel Commercial Fishing	C3 Underway emissions: Auxiliary Engine	N
2280205113	Mobile Sources	Marine Vessels, Commercial	Diesel Container Ship	C1C2 Port Emissions: Main Engine	N
2280205114	Mobile Sources	Marine Vessels, Commercial	Diesel Container Ship	C1C2 Port Emissions: Auxiliary Engine	N
2280205123	Mobile Sources	Marine Vessels, Commercial	Diesel Container Ship	C1C2 Underway emissions: Main Engine	N
2280205124	Mobile Sources	Marine Vessels, Commercial	Diesel Container Ship	C1C2 Underway emissions: Auxiliary Engine	N
2280205313	Mobile Sources	Marine Vessels, Commercial	Diesel Container Ship	C3 Port Emissions: Main Engine	Y
2280205314	Mobile Sources	Marine Vessels, Commercial	Diesel Container Ship	C3 Port Emissions: Auxiliary Engine	Y
2280205323	Mobile Sources	Marine Vessels, Commercial	Diesel Container Ship	C3 Underway emissions: Main Engine	Y
2280205324	Mobile Sources	Marine Vessels, Commercial	Diesel Container Ship	C3 Underway emissions: Auxiliary Engine	Y
2280206113	Mobile Sources	Marine Vessels, Commercial	Diesel Ferry	C1C2 Port Emissions: Main Engine	Y
2280206114	Mobile Sources	Marine Vessels, Commercial	Diesel Ferry	C1C2 Port Emissions: Auxiliary Engine	Y
2280206123	Mobile Sources	Marine Vessels, Commercial	Diesel Ferry	C1C2 Underway emissions: Main Engine	Y
2280206124	Mobile Sources	Marine Vessels, Commercial	Diesel Ferry	C1C2 Underway emissions: Auxiliary Engine	Y
2280206313	Mobile Sources	Marine Vessels, Commercial	Diesel Ferry	C3 Port Emissions: Main Engine	N
2280206314	Mobile Sources	Marine Vessels, Commercial	Diesel Ferry	C3 Port Emissions: Auxiliary Engine	N
2280206323	Mobile Sources	Marine Vessels, Commercial	Diesel Ferry	C3 Underway emissions: Main Engine	N
2280206324	Mobile Sources	Marine Vessels, Commercial	Diesel Ferry	C3 Underway emissions: Auxiliary Engine	N
2280207113	Mobile Sources	Marine Vessels, Commercial	Diesel General Cargo	C1C2 Port Emissions: Main Engine	Y
2280207114	Mobile Sources	Marine Vessels, Commercial	Diesel General Cargo	C1C2 Port Emissions: Auxiliary Engine	Y
2280207123	Mobile Sources	Marine Vessels, Commercial	Diesel General Cargo	C1C2 Underway emissions: Main Engine	Y
2280207124	Mobile Sources	Marine Vessels, Commercial	Diesel General Cargo	C1C2 Underway emissions: Auxiliary Engine	Y
2280207313	Mobile Sources	Marine Vessels, Commercial	Diesel General Cargo	C3 Port Emissions: Main Engine	Y
2280207314	Mobile Sources	Marine Vessels, Commercial	Diesel General Cargo	C3 Port Emissions: Auxiliary Engine	Y
2280207323	Mobile Sources	Marine Vessels, Commercial	Diesel General Cargo	C3 Underway emissions: Main Engine	Y
2280207324	Mobile Sources	Marine Vessels, Commercial	Diesel General Cargo	C3 Underway emissions: Auxiliary Engine	Y
2280208113	Mobile Sources	Marine Vessels, Commercial	Diesel Government	C1C2 Port Emissions: Main Engine	Y
2280208114	Mobile Sources	Marine Vessels, Commercial	Diesel Government	C1C2 Port Emissions: Auxiliary Engine	Y
2280208123	Mobile Sources	Marine Vessels, Commercial	Diesel Government	C1C2 Underway emissions: Main Engine	Y

SCC	SCC Level One	SCC Level Two	SCC Level Three	SCC Level Four	Include in the MARINER 2023 EI
2280208124	Mobile Sources	Marine Vessels, Commercial	Diesel Government	C1C2 Underway emissions: Auxiliary Engine	Y
2280209113	Mobile Sources	Marine Vessels, Commercial	Diesel Miscellaneous	C1C2 Port Emissions: Main Engine	Y
2280209114	Mobile Sources	Marine Vessels, Commercial	Diesel Miscellaneous	C1C2 Port Emissions: Auxiliary Engine	Y
2280209123	Mobile Sources	Marine Vessels, Commercial	Diesel Miscellaneous	C1C2 Underway emissions: Main Engine	Y
2280209124	Mobile Sources	Marine Vessels, Commercial	Diesel Miscellaneous	C1C2 Underway emissions: Auxiliary Engine	Y
2280209313	Mobile Sources	Marine Vessels, Commercial	Diesel Miscellaneous	C3 Port Emissions: Main Engine	Y
2280209314	Mobile Sources	Marine Vessels, Commercial	Diesel Miscellaneous	C3 Port Emissions: Auxiliary Engine	Y
2280209323	Mobile Sources	Marine Vessels, Commercial	Diesel Miscellaneous	C3 Underway emissions: Main Engine	Y
2280209324	Mobile Sources	Marine Vessels, Commercial	Diesel Miscellaneous	C3 Underway emissions: Auxiliary Engine	Y
2280210113	Mobile Sources	Marine Vessels, Commercial	Diesel RollOn RollOff	C1C2 Port Emissions: Main Engine	N
2280210114	Mobile Sources	Marine Vessels, Commercial	Diesel RollOn RollOff	C1C2 Port Emissions: Auxiliary Engine	N
2280210123	Mobile Sources	Marine Vessels, Commercial	Diesel RollOn RollOff	C1C2 Underway emissions: Main Engine	N
2280210124	Mobile Sources	Marine Vessels, Commercial	Diesel RollOn RollOff	C1C2 Underway emissions: Auxiliary Engine	N
2280210313	Mobile Sources	Marine Vessels, Commercial	Diesel RollOn RollOff	C3 Port Emissions: Main Engine	Y
2280210314	Mobile Sources	Marine Vessels, Commercial	Diesel RollOn RollOff	C3 Port Emissions: Auxiliary Engine	Y
2280210323	Mobile Sources	Marine Vessels, Commercial	Diesel RollOn RollOff	C3 Underway emissions: Main Engine	Y
2280210324	Mobile Sources	Marine Vessels, Commercial	Diesel RollOn RollOff	C3 Underway emissions: Auxiliary Engine	Y
2280211113	Mobile Sources	Marine Vessels, Commercial	Diesel Tanker	C1C2 Port Emissions: Main Engine	Y
2280211114	Mobile Sources	Marine Vessels, Commercial	Diesel Tanker	C1C2 Port Emissions: Auxiliary Engine	Y
2280211123	Mobile Sources	Marine Vessels, Commercial	Diesel Tanker	C1C2 Underway emissions: Main Engine	Y
2280211124	Mobile Sources	Marine Vessels, Commercial	Diesel Tanker	C1C2 Underway emissions: Auxiliary Engine	Y
2280211313	Mobile Sources	Marine Vessels, Commercial	Diesel Tanker	C3 Port Emissions: Main Engine	Y
2280211314	Mobile Sources	Marine Vessels, Commercial	Diesel Tanker	C3 Port Emissions: Auxiliary Engine	Y
2280211323	Mobile Sources	Marine Vessels, Commercial	Diesel Tanker	C3 Underway emissions: Main Engine	Y
2280211324	Mobile Sources	Marine Vessels, Commercial	Diesel Tanker	C3 Underway emissions: Auxiliary Engine	Y
2280212113	Mobile Sources	Marine Vessels, Commercial	Diesel Tour Boat	C1C2 Port Emissions: Main Engine	Y
2280212114	Mobile Sources	Marine Vessels, Commercial	Diesel Tour Boat	C1C2 Port Emissions: Auxiliary Engine	Y
2280212123	Mobile Sources	Marine Vessels, Commercial	Diesel Tour Boat	C1C2 Underway emissions: Main Engine	Y
2280212124	Mobile Sources	Marine Vessels, Commercial	Diesel Tour Boat	C1C2 Underway emissions: Auxiliary Engine	Y
2280213113	Mobile Sources	Marine Vessels, Commercial	Diesel Tug	C1C2 Port Emissions: Main Engine	Y

SCC	SCC Level One	SCC Level Two	SCC Level Three	SCC Level Four	Include in the MARINER 2023 EI
2280213114	Mobile Sources	Marine Vessels, Commercial	Diesel Tug	C1C2 Port Emissions: Auxiliary Engine	Y
2280213123	Mobile Sources	Marine Vessels, Commercial	Diesel Tug	C1C2 Underway emissions: Main Engine	Y
2280213124	Mobile Sources	Marine Vessels, Commercial	Diesel Tug	C1C2 Underway emissions: Auxiliary Engine	Y
2280213313	Mobile Sources	Marine Vessels, Commercial	Diesel Tug	C3 Port Emissions: Main Engine	Y
2280213314	Mobile Sources	Marine Vessels, Commercial	Diesel Tug	C3 Port Emissions: Auxiliary Engine	Y
2280213323	Mobile Sources	Marine Vessels, Commercial	Diesel Tug	C3 Underway emissions: Main Engine	Y
2280213324	Mobile Sources	Marine Vessels, Commercial	Diesel Tug	C3 Underway emissions: Auxiliary Engine	Y
2280214113	Mobile Sources	Marine Vessels, Commercial	Diesel Refrigerated	C1C2 Port Emissions: Main Engine	N
2280214114	Mobile Sources	Marine Vessels, Commercial	Diesel Refrigerated	C1C2 Port Emissions: Auxiliary Engine	N
2280214123	Mobile Sources	Marine Vessels, Commercial	Diesel Refrigerated	C1C2 Underway emissions: Main Engine	N
2280214124	Mobile Sources	Marine Vessels, Commercial	Diesel Refrigerated	C1C2 Underway emissions: Auxiliary Engine	N
2280214313	Mobile Sources	Marine Vessels, Commercial	Diesel Refrigerated	C3 Port Emissions: Main Engine	Y
2280214314	Mobile Sources	Marine Vessels, Commercial	Diesel Refrigerated	C3 Port Emissions: Auxiliary Engine	Y
2280214323	Mobile Sources	Marine Vessels, Commercial	Diesel Refrigerated	C3 Underway emissions: Main Engine	Y
2280214324	Mobile Sources	Marine Vessels, Commercial	Diesel Refrigerated	C3 Underway emissions: Auxiliary Engine	Y
2280215313	Mobile Sources	Marine Vessels, Commercial	Diesel Cruise	C3 Port Emissions: Main Engine	Y
2280215314	Mobile Sources	Marine Vessels, Commercial	Diesel Cruise	C3 Port Emissions: Auxiliary Engine	Y
2280215323	Mobile Sources	Marine Vessels, Commercial	Diesel Cruise	C3 Underway emissions: Main Engine	Y
2280215324	Mobile Sources	Marine Vessels, Commercial	Diesel Cruise	C3 Underway emissions: Auxiliary Engine	Y
2280216313	Mobile Sources	Marine Vessels, Commercial	Diesel Passenger Other	C3 Port Emissions: Main Engine	N
2280216314	Mobile Sources	Marine Vessels, Commercial	Diesel Passenger Other	C3 Port Emissions: Auxiliary Engine	N
2280216323	Mobile Sources	Marine Vessels, Commercial	Diesel Passenger Other	C3 Underway emissions: Main Engine	N
2280216324	Mobile Sources	Marine Vessels, Commercial	Diesel Passenger Other	C3 Underway emissions: Auxiliary Engine	N
2280301313	Mobile Sources	Marine Vessels, Commercial	Residual Barge	C3 Port Emissions: Main Engine	N
2280301314	Mobile Sources	Marine Vessels, Commercial	Residual Barge	C3 Port Emissions: Auxiliary Engine	N
2280301323	Mobile Sources	Marine Vessels, Commercial	Residual Barge	C3 Underway emissions: Main Engine	N
2280301324	Mobile Sources	Marine Vessels, Commercial	Residual Barge	C3 Underway emissions: Auxiliary Engine	N
2280302313	Mobile Sources	Marine Vessels, Commercial	Residual Offshore support	C3 Port Emissions: Main Engine	N
2280302314	Mobile Sources	Marine Vessels, Commercial	Residual Offshore support	C3 Port Emissions: Auxiliary Engine	N
2280302323	Mobile Sources	Marine Vessels, Commercial	Residual Offshore support	C3 Underway emissions: Main Engine	N

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2280302324	Mobile Sources	Marine Vessels, Commercial	Residual Offshore support	C3 Underway emissions: Auxiliary Engine	N
2280303313	Mobile Sources	Marine Vessels, Commercial	Residual Bulk Carrier	C3 Port Emissions: Main Engine	N
2280303314	Mobile Sources	Marine Vessels, Commercial	Residual Bulk Carrier	C3 Port Emissions: Auxiliary Engine	N
2280303323	Mobile Sources	Marine Vessels, Commercial	Residual Bulk Carrier	C3 Underway emissions: Main Engine	N
2280303324	Mobile Sources	Marine Vessels, Commercial	Residual Bulk Carrier	C3 Underway emissions: Auxiliary Engine	N
2280304313	Mobile Sources	Marine Vessels, Commercial	Residual Commercial Fishing	C3 Port Emissions: Main Engine	N
2280304314	Mobile Sources	Marine Vessels, Commercial	Residual Commercial Fishing	C3 Port Emissions: Auxiliary Engine	N
2280304323	Mobile Sources	Marine Vessels, Commercial	Residual Commercial Fishing	C3 Underway emissions: Main Engine	N
2280304324	Mobile Sources	Marine Vessels, Commercial	Residual Commercial Fishing	C3 Underway emissions: Auxiliary Engine	N
2280305313	Mobile Sources	Marine Vessels, Commercial	Residual Container Ship	C3 Port Emissions: Main Engine	N
2280305314	Mobile Sources	Marine Vessels, Commercial	Residual Container Ship	C3 Port Emissions: Auxiliary Engine	N
2280305323	Mobile Sources	Marine Vessels, Commercial	Residual Container Ship	C3 Underway emissions: Main Engine	N
2280305324	Mobile Sources	Marine Vessels, Commercial	Residual Container Ship	C3 Underway emissions: Auxiliary Engine	N
2280306313	Mobile Sources	Marine Vessels, Commercial	Residual Ferry	C3 Port Emissions: Main Engine	N
2280306314	Mobile Sources	Marine Vessels, Commercial	Residual Ferry	C3 Port Emissions: Auxiliary Engine	N
2280306323	Mobile Sources	Marine Vessels, Commercial	Residual Ferry	C3 Underway emissions: Main Engine	N
2280306324	Mobile Sources	Marine Vessels, Commercial	Residual Ferry	C3 Underway emissions: Auxiliary Engine	N
2280307313	Mobile Sources	Marine Vessels, Commercial	Residual General Cargo	C3 Port Emissions: Main Engine	N
2280307314	Mobile Sources	Marine Vessels, Commercial	Residual General Cargo	C3 Port Emissions: Auxiliary Engine	N
2280307323	Mobile Sources	Marine Vessels, Commercial	Residual General Cargo	C3 Underway emissions: Main Engine	N
2280307324	Mobile Sources	Marine Vessels, Commercial	Residual General Cargo	C3 Underway emissions: Auxiliary Engine	N
2280309313	Mobile Sources	Marine Vessels, Commercial	Residual Miscellaneous	C3 Port Emissions: Main Engine	N
2280309314	Mobile Sources	Marine Vessels, Commercial	Residual Miscellaneous	C3 Port Emissions: Auxiliary Engine	N
2280309323	Mobile Sources	Marine Vessels, Commercial	Residual Miscellaneous	C3 Underway emissions: Main Engine	N
2280309324	Mobile Sources	Marine Vessels, Commercial	Residual Miscellaneous	C3 Underway emissions: Auxiliary Engine	N
2280310313	Mobile Sources	Marine Vessels, Commercial	Residual RollOn RollOff	C3 Port Emissions: Main Engine	N
2280310314	Mobile Sources	Marine Vessels, Commercial	Residual RollOn RollOff	C3 Port Emissions: Auxiliary Engine	N
2280310323	Mobile Sources	Marine Vessels, Commercial	Residual RollOn RollOff	C3 Underway emissions: Main Engine	N
2280310324	Mobile Sources	Marine Vessels, Commercial	Residual RollOn RollOff	C3 Underway emissions: Auxiliary Engine	N
2280311313	Mobile Sources	Marine Vessels, Commercial	Residual Tanker	C3 Port Emissions: Main Engine	N

SCC	SCC Level One	SCC Level Two	SCC Level Three	SCC Level Four	Include in the MARINER 2023 EI
2280311314	Mobile Sources	Marine Vessels, Commercial	Residual Tanker	C3 Port Emissions: Auxiliary Engine	N
2280311323	Mobile Sources	Marine Vessels, Commercial	Residual Tanker	C3 Underway emissions: Main Engine	N
2280311324	Mobile Sources	Marine Vessels, Commercial	Residual Tanker	C3 Underway emissions: Auxiliary Engine	N
2280313313	Mobile Sources	Marine Vessels, Commercial	Residual Tug	C3 Port Emissions: Main Engine	N
2280313314	Mobile Sources	Marine Vessels, Commercial	Residual Tug	C3 Port Emissions: Auxiliary Engine	N
2280313323	Mobile Sources	Marine Vessels, Commercial	Residual Tug	C3 Underway emissions: Main Engine	N
2280313324	Mobile Sources	Marine Vessels, Commercial	Residual Tug	C3 Underway emissions: Auxiliary Engine	N
2280314313	Mobile Sources	Marine Vessels, Commercial	Residual Refrigerated	C3 Port Emissions: Main Engine	N
2280314314	Mobile Sources	Marine Vessels, Commercial	Residual Refrigerated	C3 Port Emissions: Auxiliary Engine	N
2280314323	Mobile Sources	Marine Vessels, Commercial	Residual Refrigerated	C3 Underway emissions: Main Engine	N
2280314324	Mobile Sources	Marine Vessels, Commercial	Residual Refrigerated	C3 Underway emissions: Auxiliary Engine	N
2280315313	Mobile Sources	Marine Vessels, Commercial	Residual Cruise	C3 Port Emissions: Main Engine	N
2280315314	Mobile Sources	Marine Vessels, Commercial	Residual Cruise	C3 Port Emissions: Auxiliary Engine	N
2280315323	Mobile Sources	Marine Vessels, Commercial	Residual Cruise	C3 Underway emissions: Main Engine	N
2280315324	Mobile Sources	Marine Vessels, Commercial	Residual Cruise	C3 Underway emissions: Auxiliary Engine	N
2280316313	Mobile Sources	Marine Vessels, Commercial	Residual Passenger Other	C3 Port Emissions: Main Engine	N
2280316314	Mobile Sources	Marine Vessels, Commercial	Residual Passenger Other	C3 Port Emissions: Auxiliary Engine	N
2280316323	Mobile Sources	Marine Vessels, Commercial	Residual Passenger Other	C3 Underway emissions: Main Engine	N
2280316324	Mobile Sources	Marine Vessels, Commercial	Residual Passenger Other	C3 Underway emissions: Auxiliary Engine	N