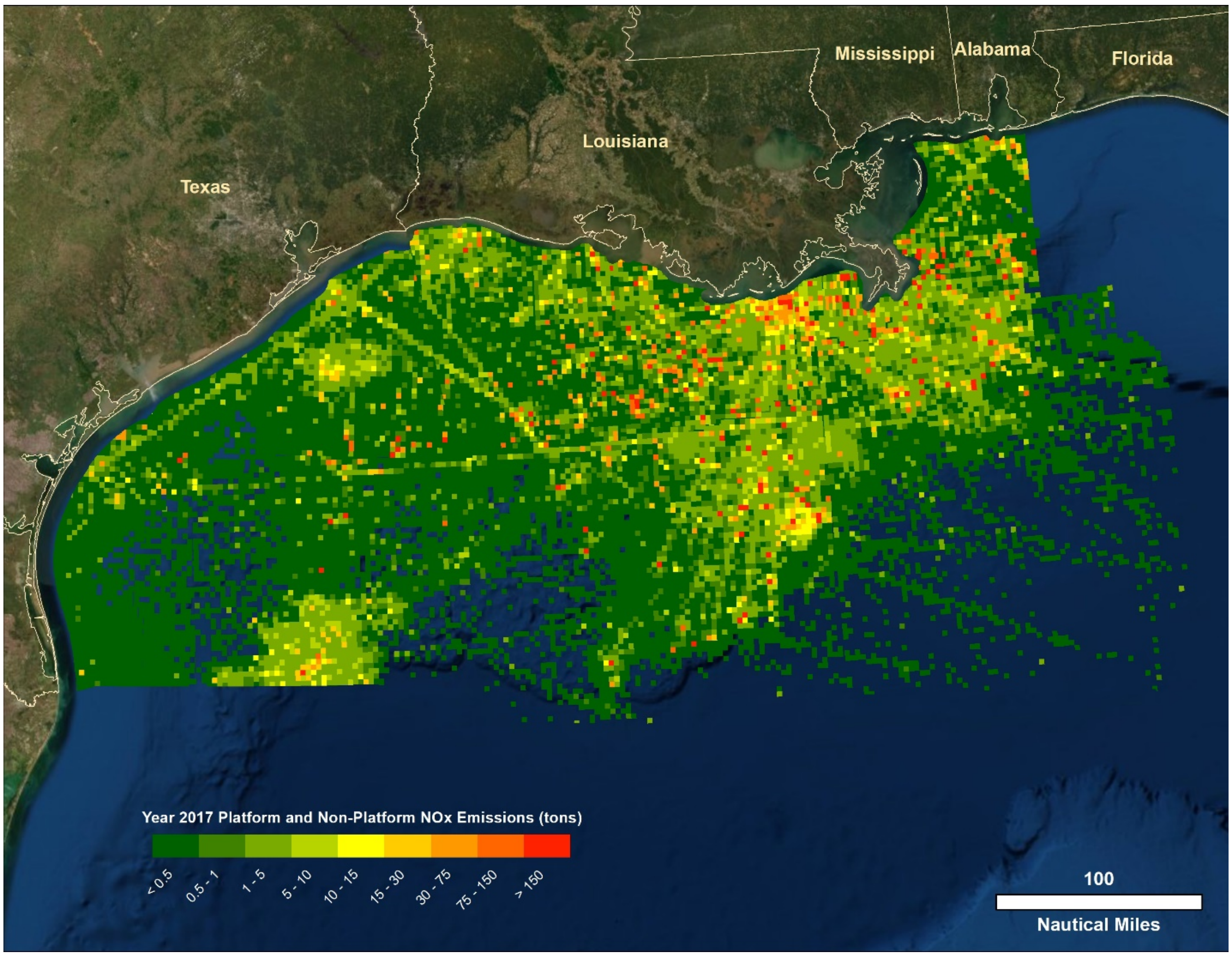
OCS Study
BOEM 2019-072

Year 2017 Emissions Inventory Study



US Department of the Interior
Bureau of Ocean Energy Management
Gulf of Mexico OCS Region

BOEM
Bureau of Ocean Energy Management

OCS Study
BOEM 2019-072

Year 2017 Emissions Inventory Study

October / 2019

Authors:
Darcy Wilson, Richard Billings, Roger Chang, Bebhinn Do, Stacie Enoch, Heather Perez, and Jennifer Sellers

Prepared under BOEM Contract M16PC00012
By
Eastern Research Group, Inc.
1600 Perimeter Park Drive, Suite 200
Morrisville, NC 27560

US Department of the Interior
Bureau of Ocean Energy Management
Gulf of Mexico OCS Region

DISCLAIMER

Study concept, oversight, and funding were provided by the US Department of the Interior, Bureau of Ocean Energy Management (BOEM), Environmental Studies Program, Washington, DC, under Contract Number M16PC00012. This report has been technically reviewed by BOEM, and it has been approved for publication. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the US Government, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

REPORT AVAILABILITY

To download a PDF file of this report, go to the US Department of the Interior, Bureau of Ocean Energy Management Data and Information Systems webpage (http://www.boem.gov/Environmental-Studies-EnvData/), click on the link for the Environmental Studies Program Information System (ESPIS), and search on 2019-072. The report is also available at the National Technical Reports Library at https://ntrl.ntis.gov/NTRL/.

CITATION

Wilson D, Billings R, Chang R, Do B, Enoch S, Perez H, Sellers J. 2019. Year 2017 emissions inventory study. New Orleans (LA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2019-072. 231 p.

ABOUT THE COVER

Total 2017 nitrogen oxides emissions from all sources in the Gulf of Mexico OCS Region.

ACKNOWLEDGMENTS

This report would not have been possible without the contributions of the following staff at Eastern Research Group, Inc: Lindsay Dayton, Karla Faught, Noel Hilliard, Steve Mendenhall, Jody Tisano, Robin Weyl, Regi Oommen, and Jeanette Alvis. Assistance was also provided by staff at COMM Engineering (Stephanie Myers and Rachelle Suir), Harris Corporation, and CGG NPA Satellite Mapping.

ABSTRACT

This report presents the results of a calendar year 2017 air pollutant emissions inventory for Outer Continental Shelf (OCS) oil and gas production sources in the Gulf of Mexico (GOM) west of 87.5 degrees longitude, as well as other sources that are not associated with oil and gas production. Pollutants covered in the inventory are the criteria air pollutants (carbon monoxide [CO], lead [Pb], nitrogen oxides [NO_x], sulfur dioxide [SO_2], particulate matter with a diameter less than 10 microns [PM_{10}], particulate matter with a diameter less than 2.5 microns [$PM_{2.5}$]); criteria precursor pollutants (PM precursor ammonia [NH_3], ozone precursor volatile organic compounds [VOCs]; major greenhouse gases (carbon dioxide [CO_2], methane [CH_4], and nitrous oxide [N_2O]); and select hazardous air pollutants (HAPs). This is the first GOM inventory cycle to include select HAPs for all relevant emission sources. Details are provided on the emission estimation methods for all sources.

This is the sixth in a series of GOM OCS emissions inventories developed by the Bureau of Ocean Energy Management (BOEM). Past emissions inventories include emissions estimates for calendar years 2000, 2005, 2008, 2011, and 2014.

The 2017 inventory results indicate that OCS oil and gas production platforms and production-related vessels and helicopters account for 99% of total CH_4 emissions, 74% of CO emissions, 59% of VOC emissions, 36% of PM emissions, 34% of NO_x emissions, and 21% of SO_2 emissions in the GOM inventory.

Comparison of the emission estimates between the BOEM calendar year 2014 inventory and the 2017 inventory indicate that the overall total emissions estimates for all sources included in the inventory decreased, except for a very slight increase in the N_2O emissions estimates due to the addition of boilers as an emission source on commercial marine vessels. The overall total criteria pollutant and greenhouse gas emission estimates for non-platform OCS oil and gas production sources decreased in 2017. The estimates for platform sources increased slightly from 2014 to 2017 for CO, NO_x, CO_2, and N_2O and decreased for PM, SO_2, VOC, and CH_4. The report discusses the limitations associated with the development of the 2017 inventory and recommendations for future improvements.

This report also presents the results of a detailed emissions trends analysis that analyzed BOEM inventories prepared for calendar years 2005 through 2017. Deepwater platforms account for an increasing portion of the emissions, despite only minor changes in the number of these platforms. As expected, the findings indicate that, overall, the emissions estimates are largely affected by three factors: activity and production levels, changes in inventory methodologies, and improvements in the emission factors used to estimate emissions.

Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

AEDT	Aviation Environmental Design Tool
AET	American Eagle Tankers
AIS	Automatic Identification Systems
API	American Petroleum Institute
BOADS	Breton Offshore Activities Data System
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CAAA	Clean Air Act Amendments
CARB	California Air Resources Board
CFR	Code of Federal Regulations
CH_4	methane
CMV	commercial marine vessel
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	CO_2 equivalents
CSG	corrected specific gravity of gas
DBMS	database management system
DMS	dimethylsulfide
DOI	Department of Interior
ECA	Emission Control Area
EIA	Energy Information Administration
EIIP	Emission Inventory Improvement Program
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ESPIS	Environmental Studies Program Information System
FAA	Federal Aviation Administration
FAQs	Frequently Asked Questions
FCC	Federal Communication Commission
FOCA	Federal Office of Civil Aviation
FPSO	Floating Production Storage and Offloading
FSO	Floating Storage and Offloading
GEIA	Global Emission Inventory Activity
GHG	greenhouse gas
GIS	Geographic Information Systems
GOADS	Gulfwide Offshore Activities Data System
GOM	Gulf of Mexico
GOR	gas-to-oil ratio
GPS	Global Positioning System
GRI	Gas Research Institute
GTI	Gas Technology Institute
GWP	global warming potential
H_2S	hydrogen sulfide
HAP	hazardous air pollutant
HC	hydrocarbon
hp	horsepower
HSAC	Helicopter Safety Advisory Conference
ID	Identification
IHS	Information Handling Service
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
km	kilometers
LDAR	Leak Detection and Repair

LNG	Liquefied Natural Gas
LOOP	Louisiana Offshore Oil Port
LPG	Liquified Natural Gas
LTO	landing and takeoff
MMS	Minerals Management Service
MOVES	MOtor Vehicle Emission Simulator
MPEH	Main Pass Energy Hub
MRIP	Marine Recreational Information Program
N_2O	nitrous oxide
NAAQS	National Ambient Air Quality Standards
NCDC	National Climate Data Center
NEI	National Emissions Inventory
NEPA	National Environmental Policy Act
NH_3	ammonia
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NO_x	nitrogen oxides
NTL	Notice to Lessees and Operators
NTRL	National Technical Reports Library
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
OEIS	Oversees Environmental Impact Statement
OGOR	Oil and Gas Operations Report
ONRR	Office of Natural Resources Revenue
OSMA	Offshore Marine Service Association
PAH	polycyclic aromatic hydrocarbons
Pb	lead
PM_{10}	particulate matter-10
PM_{10}-FIL	PM_{10} filterable
PM_{10}-PRI	PM_{10} primary
$PM_{2.5}$	particulate matter-2.5
$PM_{2.5}$-FIL	$PM_{2.5}$ filterable
$PM_{2.5}$-PRI	$PM_{2.5}$ primary
PM-CON	PM condensable
ppm	parts per million
PRI	PM primary
PVA	true vapor pressure (psia)
PTE	potential to emit
QA/QC	quality assurance/quality control
ROM	Regional Oxidant Model
RORO	roll-on/roll-off
ROS	Register of Ships
ROW	right-of-way
RUE	right-of-use easement
SAR	Synthetic Aperture Radar
SCC	Source Classification Code
SFSC	Southeast Fisheries Science Center
SIP	State Implementation Plan
SO_2	sulfur dioxide
SOP	Suspension of Production
SPT	Skaugen Petrotrans
THC	total hydrocarbons
TIMS	Technical Information Management System
TOC	total organic compounds
TORP	Terminal Offshore Regas Plant

USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USDOI	U.S. Department of Interior
USEPA	U.S. Environmental Protection Agency
VOC	volatile organic compounds

Equation Unit Definitions

Unit	Definition
avg	average
bbl	barrel
Btu	British thermal unit
C_{VOC}	concentration of VOC
CF	conversion factor
E_{CG}	USCG emissions
EF_C	emission factor for pollutant c
EF_{THC}	THC emission factor
E_{HAP}	HAP emission estimate
E_{THC}	THC emissions (in pounds per month)
°F	degrees Fahrenheit
fps	foot per second
ft	feet
ft^3	cubic feet
g	gram
gal	gallon
GOR	gas-to-oil ratio
GOR_U	gas-to-oil ratio (scf/bbl) for upstream vessel
GOR_V	gas-to-oil ratio (scf/bbl) for vessel
H_2S	hydrogen sulfide
hp	horsepower
hr	hour
HVO	vapor space outage (ft)
kW	kilowatt
kWh	kilowatt-hour
lb	pound
LF	load factor
LTO	landing and takeoff
m^2	meter squared
MMBtu	million British thermal unit
Mscf	thousand standard cubic feet
MMscf	million standard cubic feet
MMscfd	million standard cubic feet per day
ppm	parts per million
ppmv	parts per million volume
psia	pounds per square inch absolute
psig	pressure per square inch gauge
°R	degrees rankine
scf	standard cubic feet
sec	second
S_{TD}	surface area of all lease block in USCG district
T_{LA}	daily average liquid surface temperature
V_{LX}	tank maximum liquid volume (ft)
µmol	micromole
wt	weight

1 Introduction

1.1 Background

The U.S. Department of the Interior's Bureau of Ocean Energy Management (BOEM) is required under the Outer Continental Shelf Lands Act (OCSLA) (43 U.S.C. § 1334(a)(8)) to comply with the National Ambient Air Quality Standards (NAAQS) to the extent that OCS oil and gas exploration, development, and production sources do not significantly affect the air quality of any state. The Gulf of Mexico (GOM) Region's area of possible influence includes the States of Texas, Louisiana, Mississippi, Alabama, and Florida. The Clean Air Act Amendments (CAAA) of 1990 designate air quality authorities, giving BOEM air quality jurisdiction westward of longitude 87°30'W and the U.S. Environmental Protection Agency (USEPA) air quality jurisdiction eastward of longitude 87°30'W. Texas has a coastal area that is designated as nonattainment for the 2015 eight-hour ozone standard. Ozone forms in the presence of sunlight from the reaction of volatile organic compounds (VOCs) and oxides of nitrogen (NO_x). Texas also has three areas designated as nonattainment for sulfur dioxide (SO_2). Louisiana has an area that is designated as maintenance for the 2008 eight-hour ozone standard, and two areas designated as nonattainment for SO_2. Florida has three areas designated as nonattainment for the SO_2 NAAQS. Florida and Texas each have an area that is designated as nonattainment for lead (Pb). According to the Clean Air Act, a Class I area is one in which visibility is protected more stringently than under the NAAQS and includes national parks, wilderness areas, monuments, and other areas of special national and cultural significance. The GOM Region, along with air quality jurisdiction, nonattainment, and Class I areas, are displayed in Figure 1-1.

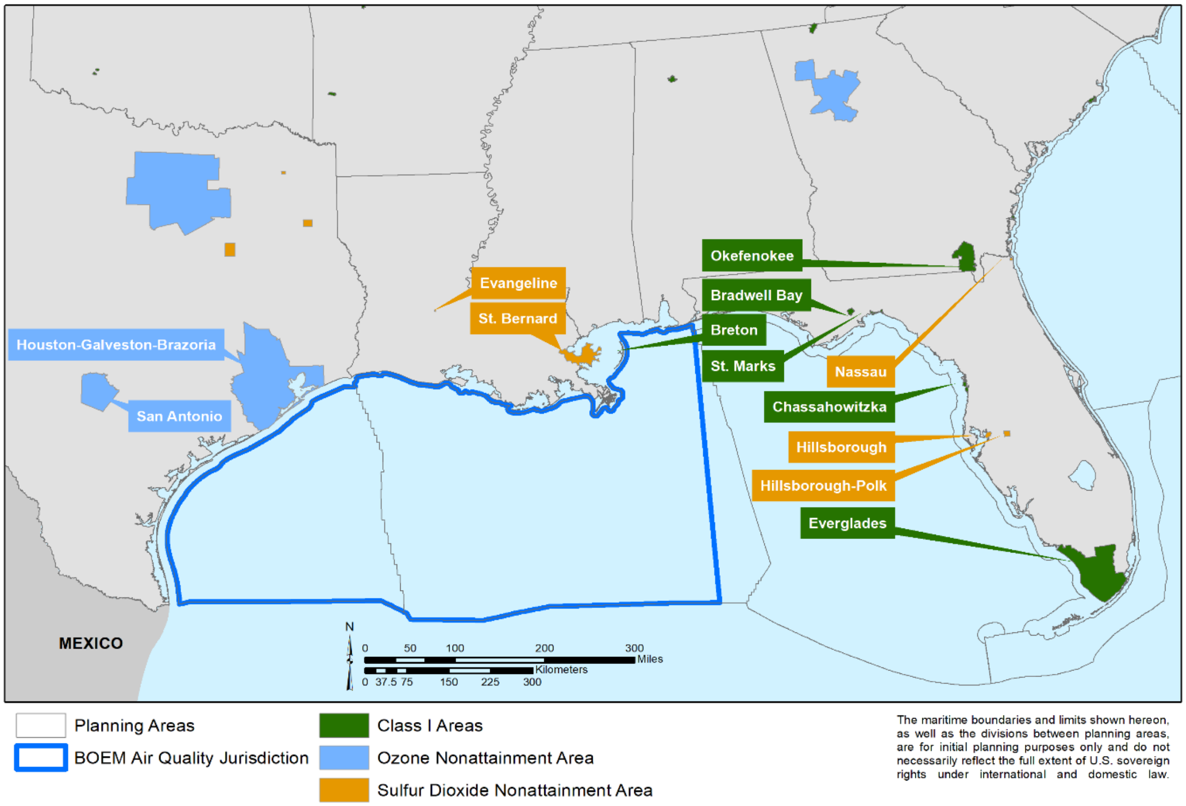


Figure 1-1. GOM Region with the Planning Areas, Nonattainment Areas (orange), Air Quality Jurisdiction, and Class I Areas (dark green)

The CAAA (CAAA Title VIII, Sec 801[b]) specifically mandate that BOEM conduct a research study to assess the potential for onshore impacts of certain types of air pollutant emissions from OCS oil and gas exploration, development, and production in regions of the GOM. This mandate grew out of concerns regarding the cumulative onshore impacts of air pollutant emissions from more than 3,000 offshore facilities on Federal waters in the central and western GOM. BOEM launched a series of studies, beginning in the 1980s, to assess the emissions of these OCS oil and gas platforms and their associated emissions. In 1991, BOEM sponsored a regional ozone modeling effort conducted by the USEPA using the Regional Oxidant Model (ROM). The Gulf of Mexico Air Quality Study was initiated that same year based on the CAAA mandate, and activity data for a Gulfwide emissions inventory were collected for a one-year period in 1991–1992 (Systems Applications International et al., 1995).

BOEM has sponsored six more recent air quality emission inventory projects. BOEM required affected platform operators to collect activity data used in these studies. One study affected only platforms within 100 kilometers (km) of the Breton National Wilderness Area in the GOM, where visibility and regional haze concerns apply. As part of its program to collect activity data, a Microsoft® Visual Basic® program was developed, known as the Breton Offshore Activities Data System (BOADS), for platform operators to submit activity data on a monthly basis. An Oracle® database management system (DBMS) was updated and used to develop the emissions estimates for calendar year 2000 (Billings and Wilson, 2004).

The *Gulfwide Emission Inventory Study for Regional Haze and Ozone Modeling Effort Study* (Wilson et al. 2004) built upon the previous BOEM studies with the goal of developing criteria pollutant and GHG emission inventories for all oil and gas production-related sources in the entire GOM OCS for calendar year 2000. The Gulfwide Offshore Activities Data System (GOADS) was developed from the BOADS Microsoft® Visual Basic® program; BOADS was modified to request activity data for additional emission sources. The emission estimation procedures in the Breton Oracle® DBMS were also expanded (Wilson et al., 2004). The 2005, 2008, 2011, and 2014 Gulfwide Emission Inventory Studies covered the same sources, pollutants, and geographic area as the 2000 inventory (Wilson et al., 2007; 2010; 2014; 2017). Updates were made to the GOADS-2005, GOADS-2008, GOADS-2011, GOADS-2014, and GOADS-2017 programs as needed.

The BOEM GOM OCS Region sponsored this project, the *Year 2017 Emissions Inventory Study* (BOEM Contract No. M16PC00012), with the goal of developing a calendar year 2017 air pollution emissions inventory for all OCS oil and gas production-related sources on the GOM OCS, along with an inventory of all non-oil and gas production-related sources for impacts assessment modeling purposes. Pollutants covered in this inventory are the following:

- Criteria pollutants—carbon monoxide (CO), Pb, NO_x, SO_2, particulate matter-10 (PM_{10}), $PM_{2.5}$
- Criteria precursor pollutants—ammonia (NH_3) and VOCs
- Greenhouse gases (GHGs)—carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)
- Select hazardous air pollutants (HAPs) and sources

1.2 Scope and Purpose of this Study

BOEM is responsible under OCSLA for determining if GOM OCS oil and natural gas platforms and other oil and natural gas production sources on Federal waters in the central and western GOM (west of longitude 87.5°) significantly influence the air quality of any state. The BOEM also has responsibilities under the National Environmental Policy Act (NEPA) to assess the cumulative air quality impacts of oil and natural gas production on the GOM OCS. Therefore, the collection and compilation of an emissions inventory for OCS sources for calendar year 2017 is imperative, in that it not only provides BOEM the essential tools to comply with the Congressional mandate to coordinate air pollution control regulations between OCS and states onshore sources, but it also provides BOEM the essential tools needed to assess OCS oil and gas activities impacts to the states as mandated by the OCSLA and provides the states inputs needed to perform their State Implementation Plan (SIP) demonstrations to the USEPA.

The goal of this project is to develop a calendar year 2017 air pollutant emissions inventory for all OCS oil and gas production-related sources in the GOM, including non-platform sources related to oil and gas production, as well as other sources in the GOM.

BOEM required affected platform lessees and operators to collect and submit the activity data needed to develop air pollutant emissions estimates from platform activities for calendar year 2017. The activity data were collected based on BOEM Notice to Lessees and Operators (NTL) No. 2016-N03, “2017 Outer Continental Shelf Emissions Inventory Gulf of Mexico and North Slope Borough of the State of Alaska.”

BOEM updated and distributed a Microsoft® Visual Basic® program (GOADS-2017) for platform operators to use to collect activity data for production platform emission sources on a monthly basis and submit to BOEM on an annual basis. Operators used the GOADS software to collect activity data for amine units; boilers, heaters, and burners; diesel engines; drilling equipment; fugitive sources; combustion flares; glycol dehydrators; loading operations; losses from flashing; mud degassing; natural gas engines; natural gas, diesel, and dual-fuel turbines; pneumatic pumps; pressure and level controllers; storage tanks; and cold vents.

These activity data were used to calculate CO, Pb, NO_x, SO_2, PM_{10}, $PM_{2.5}$, NH_3, and VOC emissions estimates, as well as CO_2, CH_4, N_2O, and select HAPs using the following methodologies. The Gulfwide

Oracle® DBMS calculates and archives the activity data and the resulting emissions estimates. Users can query the final platform emissions databases by pollutant, month, equipment type, platform, etc.

Emission estimates for non-platform sources on the GOM OCS include both oil and natural gas production-related sources, as well as non-oil and natural gas production sources. Production sources consist of survey vessels, drilling rigs, pipelaying operations, support vessels, and helicopters. Non-oil and natural gas production sources include commercial marine vessels, the Louisiana Offshore Oil Port (LOOP), and biogenic and geogenic sources. Users can query the final non-platform emissions databases by pollutant, month, source, etc.

1.3 Study Objectives

The objectives of this study were to:

- Review, modify, and provide support services for GOADS-2017 and the 2017 Gulfwide Oracle® DBMS.
- Collect, describe, quality check, quality assure, and archive activity data from all platform and non-platform sources on the OCS that emit air pollutants over the course of calendar year 2017. Activity data from platform sources were collected using GOADS-2017.
- Calculate and archive a calendar year 2017 total emissions inventory using the most current emission factors and the 2017 Gulfwide DBMS for all specified platform sources.
- Collect activity data for non-platform sources and develop emission estimates using the most recent emission factors.
- Estimate emissions for support helicopters using the Federal Aviation Administration's (FAA's) Nextgen flight management data, estimate marine vessel emissions using Automatic Information Systems (AIS) data, and spatially allocate emission estimates for geogenic oil seeps using satellite imagery.
- Conduct emissions trends analyses to compare the 2017 emissions inventory with previous BOEM Gulfwide emission inventories.
- Provide the GOM platform and non-platform emission inventory files in Microsoft® Access® format, along with documentation of the structure of the files in ReadMe Microsoft® Word files to BOEM. Provide BOEM's platform and non-platform emission inventory files to the USEPA for inclusion in the National Emissions Inventory (NEI).
- Provide air quality emissions support as requested for the BOEM Alaska OCS Region. (Currently all information on Alaska OCS Region oil and gas production activities are submitted directly to the Region, without the use of the GOADS software. No sources from the Alaska OCS Region are included in this report.)

1.4 Report Organization

Following this introduction, the *Year 2017 Emissions Inventory Study* report is organized as follows:

- Section 2 discusses how the platform activity data were collected and compiled.

- Section 3 summarizes the quality assurance/quality control (QA/QC) procedures that were implemented—after receipt of the platform activity data files—to prepare the data for use in developing emissions calculations and approaches used to fill in data gaps in the platform data.
- Section 4 presents calculation methods for each piece of platform equipment. For the most part, these calculation routines are performed in the Oracle® DBMS.
- Section 5 presents the collection of activity data, QA/QC, and calculation methods for non-platform sources.
- Section 6 summarizes the resulting platform and non-platform emission estimates by equipment type, source category, and pollutant. This section also notes the limitations associated with the data and the emission estimates and compares the results with the *Year 2014 Gulfwide Emission Inventory Study* (Wilson et al., 2017).
- Section 7 presents a detailed and comprehensive emissions trends analysis conducted using the past five consecutive inventory studies from 2005–2017 to assess the long-term emissions trends in the GOM OCS emissions.
- Section 8 presents literature cited throughout the report.
- Appendix A summarizes the methods used to develop HAP emissions estimates and resulting emission estimates for platform sources.
- Appendix B provides speciation profiles applied to develop the non-platform HAP emissions inventory for vessels, and criteria pollutant emission factors and HAP speciation profiles used to develop emission estimates for helicopters.

2 Data Collection for Platform Sources

2.1 Introduction

To develop a calendar year 2017 inventory of criteria pollutants, criteria precursor pollutants, GHGs, and HAPs emissions for all OCS oil and gas production-related platform sources in the GOM, BOEM collected monthly activity data for 2017 from platform operators using the GOADS-2017 software. On November 1, 2016, NTL 2016-N03 was published to introduce the “2017 Outer Continental Shelf Emissions Inventory Gulf of Mexico and North Slope Borough of the State of Alaska” and inform operators about the mandatory data collection. Affected operators were lessees, operators, right-of-use easement (RUE) holders, and pipeline right-of-way (ROW) holders of Federal oil, gas, and sulfur leases in the GOM OCS Region west of longitude 87°30', in the Chukchi and Beaufort Sea Planning Areas, and a portion of the Hope Basin Planning Area[1]. The USEPA has air quality jurisdiction east of longitude 87°30' in the GOM OCS.

This section of the report outlines the steps that BOEM took to collect the activity data, including modifying the data collection software, meeting with and training platform operators, and answering questions about data collection. Activity data were collected for the 2017 calendar year and were used to calculate and archive emissions data using the most current emission factors and calculation methods.

2.2 Improvement of the GOADS Data Collection Software

The GOADS data collection software that was used to collect calendar year 2000, 2005, 2008, 2011, and 2014 platform activity data was revised for this study to address several issues uncovered during its use preparing previous inventories. GOADS-2017 has several new features. Pressure and level controllers are now referred to as pneumatic controllers, and operators are required to indicate whether a pneumatic controller is high bleed, low bleed, intermittent, or zero-bleed. Fuel gas usage rate is now required for both pneumatic pumps and pneumatic controllers in GOADS-2017. For flares, GOADS-2017 allows operators to indicate whether the pilot feed rate is included in the reported volume flared to avoid double counting the emissions from the pilot. GOADS-2017 allows operators to provide more detailed information for fugitives: whether a Leak Detection and Repair (LDAR) program is in place, frequency and method of inspections; and whether the reported number of components are based on actual counts or the use of surrogates.

2.3 Working with Users

The *User’s Guide for the 2017 Gulfwide Offshore Activities Data System* (User’s Guide) (Wilson et al., 2018) was the primary source of information for operators regarding the use of the activity data reporting tool. The User’s Guide contains details about the GOADS-2017 program and instructions on installing, starting, and exiting the GOADS program, creating and editing data, quality control, and saving and backing up files. The guide is available on the BOEM website for downloading and printing (https://www.boem.gov/2017-Gulfwide-Emission-Inventory/), along with the GOADS Installation Guide and Frequently Asked Questions (FAQs). Users are also encouraged to contact BOEM directly for assistance with specific questions.

---

1 As noted previously, all information on Alaska OCS Region oil and gas production activities is submitted directly to the Region and is not included in this report.

3 QUALITY ASSURANCE/QUALITY CONTROL

3.1 Introduction

As detailed in Section 4 of this report, BOEM programmed automatic QA procedures into the software in an effort to minimize the submittal of incomplete and erroneous activity data by the platform operators. BOEM requested that operators submit an electronic copy of their Quality Assurance Summary Form along with their monthly activity files. The QA Summary focuses on identifying critical data that the operators need to complete prior to submitting their data to BOEM.

The software also automatically ran a series of QC checks (discussed in Section 4) on the data when the operator saved the data. If the operator left a field blank, provided data that are out of range, or entered a value that is not consistent on a month-to-month basis, an error message appeared. The operator could then correct the problem, override the QC check (and provide a comment), or ignore the message and save the changes. When operators entered data that appeared in the QC results or on the QA Summary Form, BOEM attempted to reconcile the missing, atypical, or suspect data by reviewing the comments, contacting the operators, or developing surrogate data as described in Section 4. Surrogate data were developed primarily for the stack parameters requested for the emission release point for each piece of equipment. These parameters are needed for air quality modeling efforts. The surrogates were developed based on GOM OCS industry averages and through discussions within BOEM.

Platform operators and lessees submitted data files and QA Summary Forms generated by the GOADS-2017 software. Fifty-seven companies submitted data for 1,842 platforms based on the combination of complex ID and structure ID. Data were submitted for 1,194 active platforms and 648 inactive platforms. As requested by BOEM, operators and lessees also identified an additional 193 platforms as being decommissioned prior to 2017.

Based on platform installation and removal dates reported in the Bureau of Environmental Enforcement and Safety (BSEE) Technical Information Management System (TIMS) database, it was expected that 2,102 platforms were active for all or part of 2017. Of the 1,842 platforms that submitted 2017 GOADS data, 1,813 were active based on the TIMS database installation and removal dates. GOADS data submittals were submitted for an additional 29 inactive platforms. Additionally, 39 of the expected platforms were reported as being decommissioned. Thus, 1,852 of the expected platforms were either reported with data or reported as being decommissioned. Approximately 250 of the expected platforms are unaccounted for in the year 2017 inventory. These 250 platforms were investigated to determine possible reasons they were not reported for 2017.

It was determined that 30 of the missing platforms were part of companies that had filed for some level of bankruptcy (i.e., Chapter 7 or Chapter 11). During bankruptcy/reorganization, staff turnover typically increases, and regular reporting can fall through the cracks. Of these 30 possible bankruptcies, nine of the platforms may have come under new ownership. In these cases, the new owners may not have had the 2017 activity data to report on behalf of the previous owner. For another 34 platforms, TIMS data indicated that the authority status as terminated, which would indicate a terminated lease. The owners for four of these platforms were found to have filed for a form of bankruptcy.

TIMS data further indicated that some of these platforms were removed during (25) or after (37) 2017. Another 19 platforms were previously reported as being decommissioned for the 2014 inventory effort but still do not show a removal date in TIMS. It is possible the operator failed to submit for these platforms because they were offline or poised to be offline by the GOADS submission deadline.

One platform had a comment in TIMS indicating the structure was destroyed by a hurricane; however, there is no removal date in TIMS.

A review of the companies associated with the non-reported platforms found indication that one company was sold since the 2014 inventory (one platform). Previous inventory reporting compliance reviews have shown that a change in ownership can be overlooked in reporting (i.e., the new owner overlooks reporting) or can cause confusion over who should report the data if purchased mid-inventory year.

One platform was installed in 2017 and may not have been fully operational prior to the end of the year and did not report any activity (support vessel activities are not requested via GOADS). During the review, it was also determined one platform was under a Suspension of Production (SOP). Similar to the new platform, because there was no activity on the platform, the operator did not report. There were also 11 platforms where operator notes from the 2014 inventory effort indicated the equipment was reported with another structure. It is likely these 11 platforms were combined with another structure again for 2017 reporting.

For ten platforms, TIMS indicated the authority was a state lease and likely does not need to report under GOADS. An additional 6 platforms were RUE and 36 were pipeline ROW.

Thirty-one platforms that were not reported for 2017 were also not reported for 2014. The TIMS installation date indicates data should been submitted for these platforms in both 2017 and 2014, and most of the previous inventories. The fact that these platforms were not reported for multiple inventories suggests these platforms are persistently not reported. Table 3-1 summarizes these counts, and Figure 3-1 provides a visual representation.

Table 3-1. Summary of Possible Reasons for Non-reporters

Reason for Omission	Count	Percentage of Total Non-reporters (%)
Possible bankruptcy	17	6.8
Possible bankruptcy and/or sale	9	3.6
TIMS data indicated terminated lease, possible bankruptcy	4	1.6
TIMS data indicated terminated lease	34	13.6
Previously non-reported	31	12.4
Installed in 2017	1	0.4
Removed after 2017	37	14.8
Removed during 2017	25	10.0
Possible removal (decommissioned with no TIMS removal date)	19	7.6
Possible sale	1	0.4
Destroyed by hurricane (no TIMS decommission or removal date)	1	0.4
Reported with another structure	11	4.4
ROW	36	14.4
RUE	6	2.4

Reason for Omission	Count	Percentage of Total Non-reporters (%)
State lease	10	4.0
SOP	1	0.4
Undetermined	7	2.8

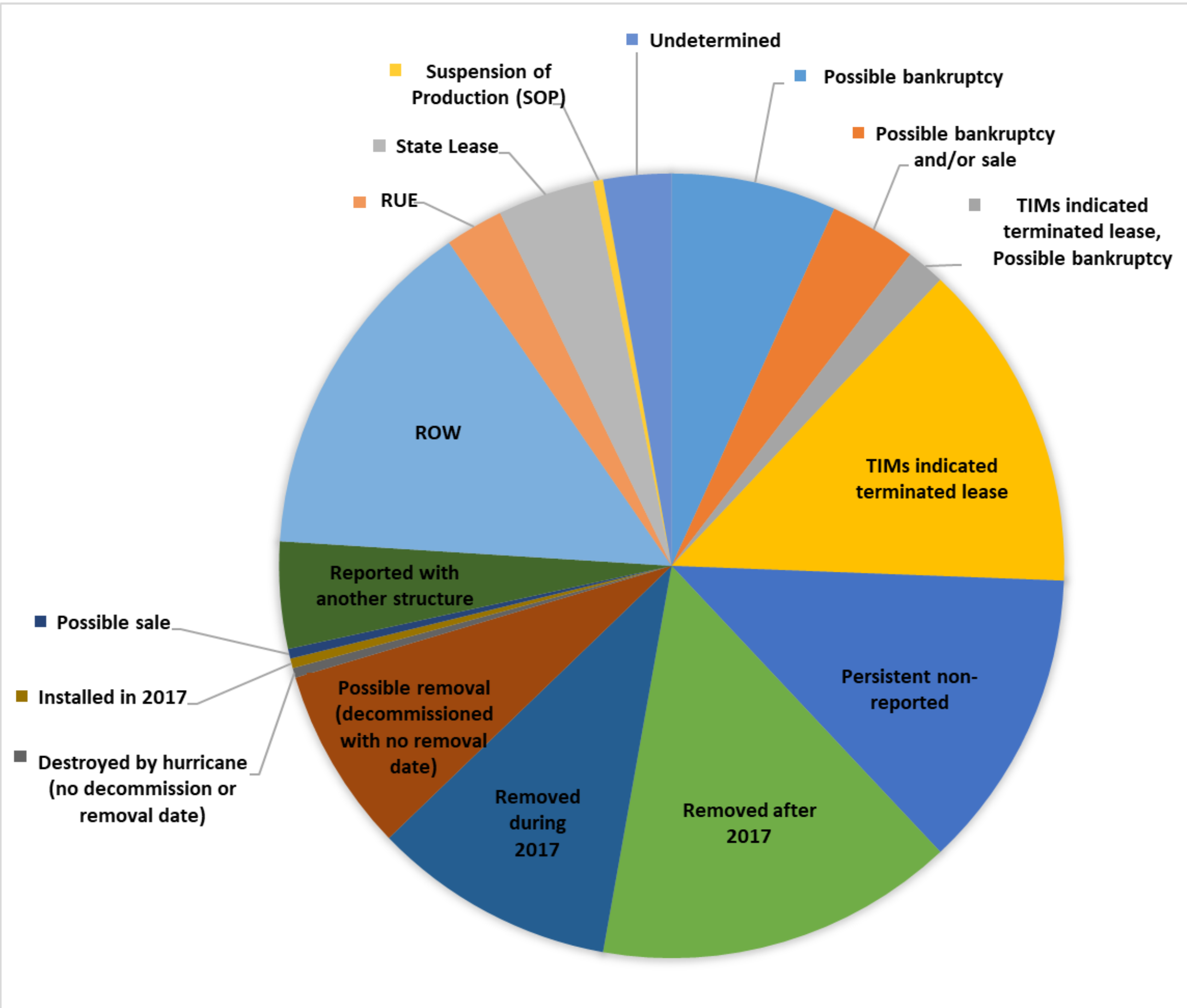


Figure 3-1. Summary of GOADS-2017 Non-reporters

Information on the QA/QC of the non-platform marine vessel emission estimates can be found in Section 5.4.

3.2 Checking File Integrity

BOEM received 60 unique data files for the 1,194 active platforms. All electronic data were in the prescribed Microsoft® Access® database format that was created by the GOADS-2017 software. For comparison, 85 unique data files were submitted for the calendar year 2014 inventory for 1,651 active platforms. More information on this reporting discrepancy is provided in Section 7, Emissions Trends Analysis.

The file integrity was checked to verify that the file submitted could be opened, and that it matched its QA Summary Form (same user, structure, and complex IDs). All files received could be opened and reviewed.

3.3 Equipment Summary Checks

Each GOADS-2017 submittal contained approximately 45 tables. The majority of these tables cover the descriptive and activity data for specific equipment types (amine units, boilers, etc.). The user-level, structure-level, and QC tables were appended along with the equipment tables into one composite database. Primary keys (user ID, month, year, complex ID, structure ID, and equipment ID) were retained in all tables to ensure that no duplicate data were added.

3.3.1 User-level Summary

The first data entry page in GOADS was for user information. The user ID should have been a company number assigned by BOEM. The user IDs submitted were checked against the BOEM master lease and company lists.

BOEM used these master lists to check and correct the lease, company, and platform IDs. Additionally, BOEM checked and corrected the locational data (latitude/longitude pairs) for each platform. Corrections were needed for two platforms' structure and/or complex IDs and corrections were made to the locational data for 54 platforms.

3.3.2 Structure-level Summary

For each survey, the user was required to enter platform-level data that included location coordinates, sales gas composition, total monthly platform fuel usage, and status (active or inactive for that month). A total of 22,698 records were submitted, and 13,339 were considered active (58.8%). For comparison, 18,971 active records were submitted for calendar year 2014.

It is important to note that some monthly platform records are submitted by more than one company, and some companies make multiple submittals. These counts include all records that were submitted. In the case of duplicate submittals, the operator comments and ownership information are reviewed in order to determine which records to use in the final inventory.

3.3.3 Equipment-level Summary

Equipment descriptive information and activity-level data for 16 different types of equipment can be populated for each platform. A list of all the platform equipment submitted per equipment type was compiled. This composite list includes a total of 196,259 equipment surveys, of which 164,338 were labeled as active (84%).

3.4 QA/QC CHECKS

BOEM performed a number of QA/QC steps to identify missing and out-of-range data for each type of equipment. The first step of the QA/QC task consisted of reviewing the reported sales gas compositions for validity and completeness. To check the validity and completeness, the GOADS software calculates the total of the reported sales gas compositions. However, not all submittals had the total field populated from the GOADS software. BOEM calculated the total of the reported sales gas composition outside of the GOADS-2017 software when this occurred. The sum of compositions that deviated from 100% were evaluated and corrected. Questionable or missing sales gas compositions were replaced with a default set of compositions. Approximately 2% of the monthly platform records required this correction.

Location coordinates from GOADS submittals were compared to location coordinates from TIMS. Where the reported coordinates did not match the TIMS coordinates, the coordinates were plotted to determine if they were in the correct area and block. If the reported coordinates were in the correct area and block, they were retained as reported. If the reported coordinates were not in the correct area and block, the TIMS coordinates were used in the inventory. TIMS coordinates were used for 54 of the reported platforms.

Another QA/QC task for the GOADS submittals was to identify incorrect and missing equipment descriptive and activity data, and to correct and populate the missing information with surrogates. Six types of data analyses were performed: 1) pre-processing of the data; 2) equipment survey consistency check; 3) data range checks; 4) stream analysis between certain equipment; 5) surrogate value application; and 6) post-processing of surrogates. After performing these QA/QC checks and developing draft emissions estimates, BOEM provided the draft emissions inventory to operators to review and provide corrections, and incorporated the corrections into the emissions inventory file. Revisions made as a result of the operator review comments are discussed in Section 3.4.7.

3.4.1 Pre-Processing

BOEM performed three pre-processing steps before beginning data analysis. First, the activity status of each survey was confirmed. Second, the reported number of operating hours for each piece of equipment was checked to make sure it did not exceed the maximum number of hours in the month. Third, the reported fuel usage at the equipment level was compared to the maximum capacity of the equipment and the reported fuel usage for the entire platform.

Operators had the opportunity to identify a platform or individual pieces of equipment as being inactive for each month by checking a “No Emissions to Report” checkbox. Otherwise, all platforms and equipment were treated as active. Inactive data are not considered for emissions calculations, so this step is extremely important. For equipment surveys that reported hours of operation, platform surveys were labeled as active if the operating hours for any of the equipment were reported as greater than zero. Conversely, a platform survey was labeled as inactive if all of the equipment operating hours were zero.

If a piece of equipment was flagged with “No Emissions to Report” but operating hours were reported, then the platform-level data were reviewed to determine if the platform was active, and the other equipment on the platform were reviewed to determine if there was other activity on the platform. For example, a drilling rig engine flagged as “No emissions to Report” was considered active for the month if an operator reported the hours of operation and diesel use at the platform level, and the combined total diesel use for the drilling rig engine and the other diesel combustion equipment on the platform was consistent with the fuel use reported for the platform.

Platform and equipment surveys were also considered active if any of the following were true: 1) in the fugitive equipment table, the component count provided was greater than zero and other active equipment records are reported; 2) in the losses from flashing equipment tables, the throughput was greater than zero; or 3) in the mud degassing equipment table, the drilling days per month were greater than zero.

BOEM revised the activity status for 15% of the monthly activity data records in these pre-processing QA/QC steps. It is important to note that this percentage is misleadingly high because the Microsoft® Access® database GOADS-2017 program automatically flags a record as active when a monthly record is created and zero values are entered for throughput, operating hours, and/or fuel use, but its status is actually inactive. Changing these records to inactive status accounts for the majority of the activity status changes.

For each month, operating hours were provided for most types of equipment. Typical errors included exceeding the maximum hours possible for a given month or not populating hours of operation. For both types of errors, data were corrected by populating with the maximum number of hours possible. The maximum number of hours for months with 31 days (January, March, May, July, August, October, and December) is 744; for months with 30 days (April, June, September, and November), the maximum number of hours is 720. The maximum number of hours for February (with 28 days) is 672. Two exceptions are also noted due to the implementation of daylight savings: 1) the number of hours possible for March is 743 hours; and 2) the number of hours possible for November is 721 hours. Corrections were made to less than 2% of the monthly equipment records.

Platform operators provided estimates of total fuel used for each month for the entire platform and for each boiler, heater, and burner, diesel engine, natural gas engine, natural gas turbine, and drilling rig operation. Additionally, operators were asked to provide fuel equipment parameters such as hours operated, fuel usage rate (average and maximum), operating horsepower (average and maximum), and heat input rate.

The average and theoretical maximum fuel usage values for each reported boiler, heater, and burner; diesel engine; natural gas engine; and natural gas, diesel, or dual-fuel turbine were calculated by multiplying the hours operated by the average or maximum heat input or fuel usage rate and operating horsepower, and dividing by the fuel heating value. Less than 1% of the monthly fuel usage records required corrections in this process.

3.4.2 Equipment Survey Consistency

Data submittals were reviewed to determine whether descriptive data were missing for months where equipment was active or if descriptive data were inconsistent for all 12 months. For example, a platform may contain several pieces of equipment that operate year-round, but data parameters may not have been populated for every month. In this situation, the entire platform equipment dataset would be examined. Eleven of the 12 monthly surveys may be populated for a boiler with the same fuel heating value, though one month, although marked active, may be null or provide a different fuel heating value. The GOADS-2017 software prevents this type of inconsistency by only requiring the operator to enter descriptive data once for the entire year. However, this error historically occurred when users worked directly in the Microsoft® Access® database file rather than using the GOADS software to enter data. No records required corrections for these types of inconsistencies for the 2017 inventory effort.

3.4.3 Data Range Checks

After the equipment surveys were checked for survey consistency, the parameters were checked to ensure that they were within an acceptable data range. Out-of-range values were reported for maximum horsepower or maximum fuel usage rates for combustion equipment (maximum value reported was less than the value reported for actual operating horsepower or average fuel use rate). In these cases, the maximum values were set equal to the operating or average values. Out-of-range stack parameters were also reported. Less than 1% of the monthly equipment records required corrections in this process.

The GOADS-2017 QC checks flag these incorrect data, as indicated by the limited number of corrections needed. Also, descriptive fields with out-of-range values may have been corrected for previous inventories, with the corrected values carried forward unchanged for the 2017 inventory effort. Operators also entered comments to confirm that some out-of-range values were actually correct, and updates were not needed.

The ranges were checked for the fields listed in Table 3-2. These ranges are based on the relationship between the parameters noted in Table 3-2 (e.g., actual fuel usage rate cannot exceed the reported maximum fuel usage rate), and typical fuel and control device efficiency values.

Table 3-2. Fields and Range Check Values

Field	Range Check
API specific gravity	Minimum value: 9 degrees API
Flare efficiency	Between 90–99%
Fuel heating value	Natural gas: 500–1,500 Btu/scf Diesel: 18,000–22,000 Btu/lb
Fuel usage rate	Not to exceed maximum fuel usage rate
Fuel hydrogen sulfide (H_2S) content	0–5 ppmv
Fuel sulfur content	0–5%
Heat input rate	Not to exceed maximum heat input rate
Inner diameter	Varies by equipment type
Operating horsepower	Not to exceed maximum rated horsepower
Stack angle	Between 0–180

3.4.4 Stream Analysis Between Certain Equipment

Certain pieces of equipment may not be vented locally, but rather the emissions are piped downstream to a cold vent or combustion flare. It is important for the downstream exhaust vents to be correctly identified; otherwise, the calculations may overestimate emissions. The amine unit, glycol dehydrator, loading operations, losses from flashing, pneumatic pumps, and storage tanks equipment may exhaust gases locally or downstream. If the emission destination was reported as vented remotely or flared remotely, then a downstream analysis was performed to verify the existence of the cold vent or combustion flare and to confirm it was active. For cold vent or combustion flare IDs that could not be traced to an existing active vent or flare, the survey was updated as to being vented or flared locally. Less than 1% of the monthly equipment records required corrections during this process.

3.4.5 Application of Surrogate Values and Post-Processing of Surrogate Values

Surrogate values were used to populate missing stack parameters that are not used to calculate emissions, but are needed for air quality modeling. These parameters are listed in Table 3-3 by equipment type. As shown in Table 3-3, surrogate values can be calculated for exit velocity and exhaust volume flow rate from the submitted data. Other surrogate data were developed from industry averages. For the 2017 inventory effort, the surrogate values used for previous inventories were updated as needed. The updated values are included in Table 3-3.

After populating all the missing data through QA checks and surrogates, BOEM performed two calculations to check the overall quality of the data. The first calculation was for exit velocity; the second was for total fuel usage. Both of these parameters were recalculated using a combination of corrected and originally submitted activity and descriptive data to yield values consistent with the interrelated, quality assured data parameters.

Approximately 12% of the monthly equipment records required corrections in this process.

Table 3-3. Surrogate Parameters Used to Supplement GOADS-2017 Data

Unit	Field	Default Value for Platforms in Water < 200 ft	Default Value for Platforms in Water > 200 ft
Amine Unit	Elevation (above sea level)	50 ft	50 ft
Amine Unit—ventilation system for acid gas from reboiler	Exit velocity (ft/sec)	Calculated with AMINECalc[a]	Calculated with AMINECalc[a]
Amine Unit—ventilation system for acid gas from reboiler	Exit temperature	110 °F	110 °F
Amine Unit—ventilation system for acid gas from reboiler	Combustion temperature	1,832 °F	1,832 °F
Boiler/Heater/Burner	Elevation (above sea level)	80 ft	80 ft
Boiler/Heater/Burner—exhaust system	Exit temperature	400 °F	500 °F
Boiler/Heater/Burner—exhaust system	Outlet orientation	0 degrees	0 degrees
Boiler/Heater/Burner—exhaust system	Outlet diameter	12 inches	20 inches
Boiler/Heater/Burner—exhaust system	Exit velocity	Calculated	Calculated
Diesel Engine	Elevation (above sea level)	70 ft	100 ft
Diesel Engine	Max rated fuel use	7,000 Btu/hp-hr	7,000 Btu/hp-hr
Diesel Engine	Avg fuel use	7,000 Btu/hp-hr	7,000 Btu/hp-hr
Diesel Engine—exhaust system	Outlet height	7 ft above engine	7 ft above engine
Diesel Engine—exhaust system	Exit velocity	Calculated	Calculated
Diesel Engine—exhaust system	Exit temperature	800 °F	800 °F
Diesel Engine—exhaust system	Outlet orientation	0 degrees	0 degrees
Diesel Engine—exhaust system	Outlet diameter	5 inches	8 inches
Flare	Combustion temperature (excluding upsets)	1,832 °F	1,832 °F
Flare	Stack orientation	0 degrees	0 degrees

Unit	Field	Default Value for Platforms in Water < 200 ft	Default Value for Platforms in Water > 200 ft
Flare	Outlet diameter	12 inches	12 inches
Flare[a]	Pilot feed rate	2.28 Mscf/day	7.3 Mscf/day
Flare	H_2S concentration	3.38 ppmv	3.38 ppmv
Glycol Dehydrator	Elevation (above sea level)	80 ft	140 ft
Glycol Dehydrator—flash tank	Temperature	120 °F	120 °F
Glycol Dehydrator—flash tank	Pressure	60 psig	60 psig
Glycol Dehydrator—ventilation system	Exit temperature	GLYCalc default (usually 212 °F)[b]	GLYCalc default (usually 212 °F)[b]
Glycol Dehydrator—ventilation system	Outlet orientation	0 degrees	0 degrees
Glycol Dehydrator—ventilation system	Flare feed rate (scf/hr)	Calculated with GLYCalc[b]	Calculated with GLYCalc[b]
Glycol Dehydrator—ventilation system	Combustion temperature	1,832 °F	1,832 °F
Glycol Dehydrator—ventilation system	Condenser temperature	110 °F (or calculated with GLYCalc)[b]	110 °F (or calculated with GLYCalc)[b]
Glycol Dehydrator—ventilation system	Condenser pressure	14.8 psia	14.8 psia
Losses from Flashing—ventilation system	Exhaust volume flow rate	Calculated	Calculated
Losses from Flashing—ventilation system	Exit velocity	Calculated	Calculated
Losses from Flashing—ventilation system	Exit temperature	70 °F	70 °F
Losses from Flashing—ventilation system	Outlet diameter	8 inches	8 inches
Natural Gas Engine	Max rated fuel usage	7,500 Btu/hp-hr	7,500 Btu/hp-hr
Natural Gas Engine	Avg fuel usage	7,500 Btu/hp-hr	7,500 Btu/hp-hr
Natural Gas Engine—exhaust system	Exit velocity	Calculated	Calculated
Natural Gas Engine—exhaust system	Exit temperature	4-cycle rich burn: 900 °F	4-cycle rich burn: 900 °F
Natural Gas Engine—exhaust system	Exit temperature	2-cycle lean burn: 700 °F	2-cycle lean burn: 700 °F

Unit	Field	Default Value for Platforms in Water < 200 ft	Default Value for Platforms in Water > 200 ft
Natural Gas Engine—exhaust system	Outlet diameter	9 inches	12 inches
Natural Gas Turbine	Max rated fuel use	10,000 Btu/hp-hr	10,000 Btu/hp-hr
Natural Gas Turbine	Avg fuel use	10,000 Btu/hp-hr	10,000 Btu/hp-hr
Diesel Turbine	Max rated fuel use	7,000 Btu/hp-hr	7,000 Btu/hp-hr
Diesel Turbine	Avg fuel use	7,000 Btu/hp-hr	7,000 Btu/hp-hr
Natural Gas Turbine—exhaust system	Exit velocity	Calculated	Calculated
Natural Gas Turbine—exhaust system	Outlet diameter	20 inches	36 inches
Natural Gas Turbine—exhaust system	Exit temperature	1,000 °F	1,000 °F
Pneumatic Pumps	Elevation (above sea level)	60 ft	75 ft
Pneumatic Pumps—ventilation system	Exit velocity	Calculated	Calculated
Pneumatic Pumps—ventilation system	Exit temperature	80 °F	80 °F
Pneumatic Controllers	Elevation (above sea level)	60 ft	60 ft
Storage Tank—general information	Roof Height above Shell (ft)	0.0625*(Tank Diameter, ft / 2)	0.0625*(Tank Diameter, ft / 2)
Storage Tank—ventilation system	Exit velocity	Calculated	Calculated
Storage Tank—ventilation system	Exit temperature	70 °F	70 °F
Storage Tank—ventilation system	Outlet orientation	0 degrees	0 degrees
Storage Tank—ventilation system	Flare feed rate	Calculated (or use the calculated storage tank exhaust vol. flow rate)	Calculated (or use the calculated storage tank exhaust vol. flow rate)
Vent	Outlet elevation (above sea level)	100 ft	100 ft
Vent	Outlet diameter	8 inches	8 inches
Vent	Exit temperature	80 °F	80 °F
Vent	Outlet orientation	0 degrees	0 degrees

3.4.6 Revisions by Equipment Type

Figure 3-2 shows the active equipment reported for each equipment type and the relative number of each equipment type that were revised during the QA/QC process. The revisions included in Figure 3-2 are a result of the QA/QC steps described above for operating hours, fuel usage, survey consistency, range checks, stream analysis, and application of surrogate values. There were four active amine units reported for the 2017 inventory, and three out of four were revised during the QA/QC process to correct operating hours or emission destination and stack parameters. The majority of revisions for combustion equipment were due to application of surrogate values or post-processing of surrogate corrections to exit gas velocity. Most revisions to cold vents were application of surrogate values, mostly populating missing or 0 exit gas velocities with calculated values. Most revisions to combustion flares were to correct 0 or to correct the field that indicates that there is a continuous pilot for flares with a reported pilot fuel feed rate greater than 0. Revisions for glycol dehydrators and losses from flashing were largely corrections based on the stream analysis and application of surrogate values. There were no revisions made to the fugitives, loading operations, or mud degassing data after minimal changes to the activity status in the initial review. Most of the revisions for pressure and level controllers were to populate the new bleed rate field, where it was null using the reported fuel gas usage rate. Most of the revisions for pneumatic pumps were due to the application of surrogate stack parameters and corrections based on the stream analysis. Revisions to storage tanks were based on the application of surrogate values, stream analysis, and range check QA steps.

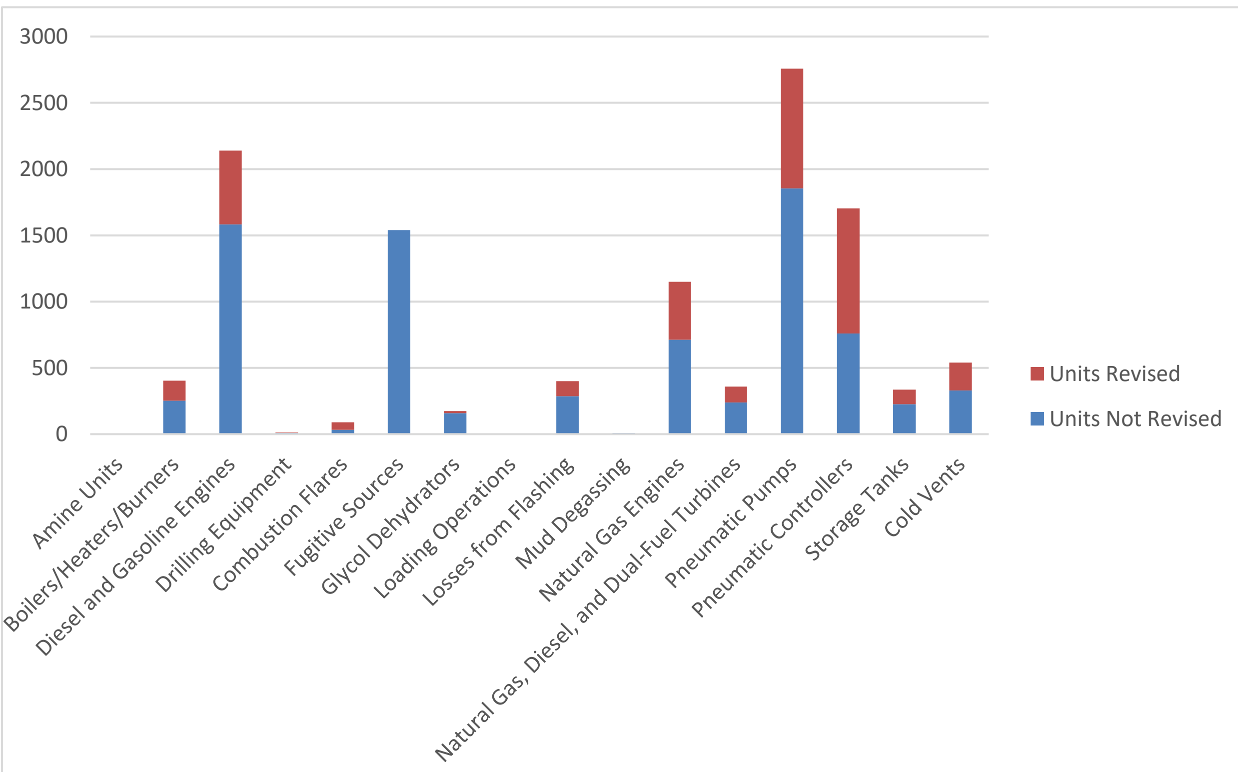


Figure 3-2. GOADS-2017 Revisions by Equipment Type

3.4.7 Incorporation of Draft Inventory Revisions

In November 2018, BOEM afforded platform operators the opportunity to review the draft 2017 Gulfwide emissions inventory data. Of the 57 companies that submitted GOADS-2017 files, 25 companies provided revisions, comments, or confirmation that the activity data used to develop the emissions estimates were correct and no revisions were needed. Revision files were provided by eight companies. The majority of revisions received were for fugitives, followed by pneumatic pumps. BOEM incorporated the revisions provided into the final emissions inventory. Two companies indicated that their data were missing for two platforms. BOEM added these platforms to the draft data and provided it for review, and no further revisions were needed. It was discovered that fugitive records were missing for several companies due to missing monthly records in the underlying database structure of the original submittals. The fugitives were added to the final inventory for these companies, and no other revisions were needed. BOEM discussed changes made to operating hours for combustion equipment with two companies. The operating hours were previously revised to yield values that were internally consistent with other parameters that were reported (fuel use rate, total fuel use, operating horsepower, fuel heat value). However, some of these parameters are variable and a single value for the entire year should not be used to estimate operating hours. BOEM reverted back to the original reported hours of operation for combustion equipment for all companies as long as the hours of operation did not exceed the number of hours in the month or were not originally missing.

4 DEVELOPMENT OF THE PLATFORM EMISSION INVENTORY

4.1 Introduction

The goal of this study is to develop criteria pollutants, including criteria precursor pollutants, key HAPs, and GHG emission inventories for all oil and gas production-related sources in the GOM OCS. To achieve this goal, BOEM revised the 2014 Gulfwide Oracle® DBMS to create the 2017 Gulfwide Oracle® DBMS. The 2017 Gulfwide DBMS imports the activity data provided by platform operators through the use of the GOADS-2017 software, and applies emission factors and emission estimation algorithms to calculate emissions from platform sources in the GOM. The database calculates emissions of CO, Pb, SO_2, NO_x, PM_{10}, $PM_{2.5}$, NH_3, VOC, CO_2, CH_4, N_2O, CO_2 equivalents (CO_2e), and key HAPs.

BOEM provided surrogates for values such as fuel sulfur content, fuel heating value, fuel density, and control efficiency. These surrogate values are based on industry averages or recommended values. For example, the diesel fuel sulfur content is consistent with readily available ultra-low sulfur diesel fuel. Table 4-1 presents the surrogate values applied.

Table 4-1. Surrogate Values Applied to GOADS Submittals

Data Field	Value
Natural gas H_2S content	3.38 parts per million volume (ppmv)
Diesel fuel sulfur content	0.0015 weight %
Natural gas heating value	1,050 Btu/scf
Diesel fuel heating value	19,300 Btu/pound (lb)
Diesel fuel density	7.1 lb/gallon (gal)
Gasoline fuel heating value	20,300 Btu/lb
Gasoline density	6.17 lb/gal
Flare efficiency for H_2S	98%
Vapor recovery/condenser (VR/C) efficiency for total hydrocarbons (THC) and VOCs	80%
Sulfur recovery (SR) + VR/C efficiency for THC and VOCs	80%
SR efficiency for THC and VOCs	0%

4.2 Emission Estimation Procedures

For the most part, the emission estimation procedures presented in this section are unchanged from those in the 2014 Gulfwide DBMS (Wilson et al., 2017). The exceptions are the default diesel fuel sulfur content used for diesel engines, turbines, and drilling equipment (the default was revised to 0.0015% to represent the use of ultra-low sulfur fuel, which is presumably the only fuel that operators can purchase for nonroad applications), VOC and CH_4 emission factors for combustion flares, addition of key HAPs to the inventory, and use of GLYCalc for all glycol dehydrators rather than regression equations. To estimate key HAP emissions for equipment types where HAP emission factors were not readily available, the speciation profile shown in Table 4-2 was applied to VOC emissions. This profile consists of average weight percent by pollutant obtained from a 2011 technical support document for the USEPA's oil and natural gas sector rulemaking (USEPA, 2011). The average weight percent shown is the percent each pollutant contributes to total organic compounds. To estimate HAP emissions, the VOC emissions estimates are multiplied by the ratio of the individual HAP average weight percent to the VOC average weight percent using the following equation:

$$E_{HAP} = E_{VOC} \times WtPctHAP/WtPctVOC$$

Where:

E_{HAP}	=	HAP emissions in pounds per month
E_{VOC}	=	VOC emissions in pounds per month
WtPctHAP	=	Weight percent of HAP
WtPctVOC	=	Weight percent of VOC

Table 4-2. Volatile HAP Speciation Profile

Pollutant	Average Weight %
Benzene	0.01855
Ethylbenzene	0.00115
Hexane	0.35195
Toluene	0.0028
2,2,4-Trimethylpentane	0.0007
Xylenes	0.0048
VOC	17.21

The following sections present the methods used to calculate criteria pollutant, GHG, and key HAP emissions from platform sources in the study.

4.2.1 Amine Units

Some platforms produce natural gas containing unacceptable amounts of hydrogen sulfide (H_2S). Although most platform operators pipe the sour gas onshore for sulfur removal, a few remove the sulfur on the platform using the amine process. Various amine solutions are used to absorb H_2S. After the H_2S has been separated, it is vented, flared, incinerated, or used for feedstock in elemental sulfur production (Systems Applications International et al., 1995).

Activity data were submitted for four amine units. Operators were required to use the "Model Inputs" tab. CH_4, CO_2, VOC, and key HAP emissions were estimated externally using AMINECalc (API, 1999) and loaded directly into the DBMS. Emissions were adjusted for any control devices that were reported, such as a combustion flare, a vapor recovery system/condenser, a sulfur recovery unit, or other user-specified control devices. Controlled emissions of VOC were calculated as follows:

$$E_{c,control} = E_{c,unc} \times \sum \frac{100 - Eff_{c,d}}{100\%}$$

Where:

$E_{c,control}$	=	Controlled VOC emissions (pounds per month)
$E_{c,unc}$	=	Uncontrolled VOC emissions (pounds per month)
$Eff_{c,d}$	=	Control efficiency of control device d for VOCs (%)

Devices that are intended to control H_2S emissions, such as sulfur recovery units or combustion flares, will produce emissions of SO_2 as a by-product. If a combustion flare is present, SO_2 emissions were calculated as follows (EIIP, 1999; Wilson et al., 2007).

$$E_{SO_2,\,control} = E_{H_2S}\left(\frac{lb \cdot mol_{H_2S}}{34\,lb_{H_2S}}\right) \times \left(\frac{64\,lb_{SO_2}}{lb \cdot mol_{SO_2}}\right) \times \left(\frac{Eff_{SO_2}}{100}\right)$$

Where:

$E_{SO_2,\,control}$	=	Resulting SO_2 emissions (pounds per month)
E_{H_2S}	=	Uncontrolled emissions of H_2S (pounds per month)
Eff_{SO_2}	=	Flare efficiency (%)

If a sulfur recovery unit was present, it was assumed that the Claus sulfur recovery process, in which one third of the H_2S emissions are burned to produce SO_2 and water, was used (EIIP, 1999). If a sulfur recovery unit is present, SO_2 emissions were calculated as follows (EIIP, 1999; Billings and Wilson, 2004):

$$E_{SO_2,control} = E_{H_2S}\left(\frac{lb \cdot mol_{H_2S}}{34\,lb_{H_2S}}\right) \times \left(\frac{64\,lb_{SO_2}}{lb \cdot mol_{SO_2}}\right) \times \left(\frac{Eff_{SO_2}}{100}\right) \times \left(\frac{1\,lb \cdot mol_{SO_2}}{3\,lb \cdot mol_{S}}\right) \times \left(1 - \frac{\%\,RE}{100}\right)$$

Where:

$E_{SO_2,\,control}$	=	Resulting SO_2 emissions (pounds per month)
E_{H_2S}	=	Uncontrolled emissions of H_2S (pounds per month)
% RE	=	Recovery efficiency of the sulfur recovery unit (%)

4.2.2 Boilers, Heaters, and Burners

Boilers, heaters, and burners provide heat and steam for many processes such as electricity generation, glycol dehydrator reboilers, and amine reboiler units (EIIP, 1999). Activity data were submitted for 403 boilers, heaters, or burners. The following equation was used to calculate uncontrolled emissions for liquid-fueled engines (waste oil or diesel) based on fuel use, $E_{fu,liq}$:

$$E_{fu,\,liq} = EF_{(lb/10^3\,gal)} \times 10^{-3} \times U_{liq} \div 7.1\,lb/gal$$

To calculate uncontrolled emissions for gas-fueled engines (natural gas, process gas, or waste gas) based on fuel use, $E_{fu,gas}$:

$$E_{fu,gas} = EF_{(lb/MMscf)} \times 10^{-3} \times U_{gas}$$

Where:

E	=	Emissions in pounds per month
EF	=	Emission factor
U_{liq}	=	Fuel usage (pounds/month)
U_{gas}	=	Fuel usage (Mscf/month)

If fuel usage was not provided or was not consistent with other related parameters as described in Section 3.4.1 above, it was calculated based on hours operated, maximum rated or average heat input, and fuel heating value. Fuel usage was calculated for 83 of the active units.

The following emission factors were used to estimate emissions (Tables 4-3 through 4-5). These factors come from *AP-42*, Sections 1.3 and 1.4 (USEPA, 2014a) and WebFIRE (USEPA, 2015). All boilers were assumed to be wall-fired boilers (no tangential-fired boilers). Emission factors for No. 6 residual oil were used to estimate emissions from waste-oil-fueled units. These emission factors were used regardless of the control device and max rated heat input, unless otherwise noted.

Table 4-3. Emission Factors for Liquid-fueled Units—Diesel

Pollutant	Emission Factors (lb/10^3 gal)
VOC	0.20
Pb	1.22E-03
SO_2[a]	142 × S
NO_x[b, c]	24.00
$PM_{2.5}$	0.25
PM_{10}	1.00
NH_3	0.80
CO	5.00
N_2O	0.26
CH_4	0.05
CO_2	22,300.00
Arsenic	1.32E-03
Benzene	2.14E-04
Beryllium	2.78E-05
Cadmium	3.98E-04
Chromium VI	2.48E-04
Chromium III[d]	5.97E-04
Ethylbenzene	6.36E-05
Formaldehyde	3.30E-02
Mercury	1.13E-04
Toluene	6.20E-03
Xylenes	1.09E-04

[a] S = Fuel sulfur content (wt%).
[b] NO_x emission factor = 20 where max rated heat input is less than 100 MMBtu/hr.
[c] NO_x emission factor = 10 for low NO_x burners and flue gas recirculation where max rated heat input is greater than 100 MMBtu/hr.
[d] The emission factor shown for chromium III is the difference between the *AP-42* emission factor for chromium (8.45E-04 lb/10^3 gal) and the emission factor shown for chromium VI.

Table 4-4. Emission Factors for Liquid-fueled Units—Waste Oil Where Max Rated Heat Input ≥ 100 MMBtu/hr

Pollutant	Emission Factors (lb/10^3 gal)
VOC	0.28
Pb	1.51E-03
SO_2[a]	157 × S
NO_x[b, c]	47.00
$PM_{2.5}$	5.23 × S + 1.73
PM_{10}	9.19 × S + 3.22
NH_3	0.80
CO	5.00
N_2O	0.53
CH_4	1.00

Pollutant	Emission Factors (lb/10^3 gal)
CO_2	24,400.00
Arsenic	1.32E-03
Benzene	2.14E-04
Beryllium	2.78E-05
Cadmium	3.98E-04
Chromium VI	2.48E-04
Chromium III[d]	5.97E-04
Ethylbenzene	6.36E-05
Formaldehyde	0.033
Mercury	1.13E-04
Toluene	6.20E-03
Xylenes	1.09E-04

[a] S = Fuel sulfur content (wt%).
[b] NO_x emission factor = 40 for low NO_x burners where max rated heat input is greater than 100 MMBtu/hr.
[c] NO_x emission factor = 55 where max rated heat input is less than 100 MMBtu/hr.
[d] The emission factor shown for chromium III is the difference between the *AP-42* emission factor for chromium (8.45E-04 lb/10^3 gal) and the emission factor shown for chromium VI.

Table 4-5. Emission Factors for Gas-fueled Units—Natural Gas, Process Gas, or Waste Gas

Pollutant	Emission Factors (lb/MMscf)
VOC	5.50
Pb	5.00E-04
SO_2	0.60
NO_x[a, b]	190.00
PM_{10}[c]	1.90
NH_3	3.20
CO	84.00
N_2O	2.20
CH_4	2.30
CO_2	120,000.00
Arsenic	2.00E-04
Benzene	2.10E-03
Beryllium	<1.2E-05
Cadmium	1.10E-03
Chromium	1.40E-03
Formaldehyde	0.075
Hexane	1.8
Mercury	2.60E-04
Toluene	3.40E-03

[a] NO_x emission factor = 140 for low NO_x burners and 100 for flue gas recirculation where max rated heat input is greater than 100 MMBtu/hr.
[b] Uncontrolled NO_x emission factor = 100, 50 for low NO_x burners, and 32 for flue gas recirculation where max rated heat input is less than 100 MMBtu/hr.
[c] Also represents $PM_{2.5}$.

Because the oxidation states of chromium have different health risks, BOEM developed estimates for both chromium III and chromium VI using a USEPA speciation profile. The profile for gas-fired boilers assigns 96% of the chromium emissions as chromium III and 4% as chromium VI (USEPA, 2016a).

4.2.3 Diesel and Gasoline Engines

Diesel and gasoline engines are used to run generators, pumps, compressors, etc. Diesel engines associated with drilling activities are reflected under drilling equipment in Section 4.2.4. Most of the pollutants emitted from these engines are from the exhaust. Evaporative losses are insignificant in diesel engines due to the low volatility of diesel fuels (USEPA, 2014a). Activity data were submitted for 2,143 engines. Emission estimates used a user-entered value for total fuel usage or a calculated value for total fuel usage based on operator-supplied hours of operation, average fuel usage (or a surrogate fuel consumption rate of 7,000 Btu/hp-hr), fuel heating value, and operating horsepower. The surrogate fuel consumption rate was applied to five active units during the QA/QC process.

The following equation was used to calculate uncontrolled emissions based on fuel use, E_{fu}:

$$E_{fu} = EF_{(lb/MMBtu)} \times 10^{-6} \times U \times \frac{7.1\,lb}{gal} \times H$$

Where:

E_{fu} = Emissions in pounds per month
EF = Emission factor (units are shown in parentheses)
U = Fuel usage (gallons/month)
H = Fuel heating value (Btu/lb)

The following emission factors were used to estimate emissions (Tables 4-6 through 4-8). These factors come from *AP-42,* Sections 3.3 and 3.4 (USEPA, 2014a) and WebFIRE (USEPA, 2015).

Table 4-6. Emission Factors for Gasoline Engines

Pollutant	EF_{fu} (lb/MMBtu)
VOC	3.030
SO_2	0.084
NO_x	1.630
PM_{10}[a]	0.100
CO	0.990
CO_2	154.000

[a] Also represents $PM_{2.5}$.

Table 4-7. Emission Factors for Diesel Engines Where Max HP < 600

Pollutant	EF_{fu} (lb/MMBtu)
VOC	0.330
SO_2	0.290
NO_x	4.410
PM_{10}[a]	0.310
CO	0.950
CO_2	164.000
Acetaldehyde	7.67E-04
Benzene	9.33E-04
Formaldehyde	1.18E-03
PAH	1.68E-04
Toluene	4.09E-04
Xylenes	2.85E-04

[a] Also represents $PM_{2.5}$.

Table 4-8. Emission Factors for Diesel Engines Where Max HP ≥ 600

Pollutant	EF_{fu} (lb/MMBtu)
VOC	0.080
SO_2[a]	1.01 × S
NO_x	3.200
$PM_{2.5}$[b]	0.056
PM_{10}	0.057
CO	0.850
CH_4	0.008
CO_2	165.000
Acetaldehyde	2.52E-05
Benzene	7.76E-04
Formaldehyde	7.89E-05
PAH	2.12E-04
Toluene	2.81E-04
Xylenes	1.93E-04

[a] S = Fuel sulfur content (wt%).
[b] < 3 µm.

If the corresponding field was null, a surrogate fuel consumption rate of 7,000 Btu/hp-hr was applied based on industry average.

4.2.4 Drilling Equipment

Drilling activities associated with an existing facility or from a jack-up rig adjacent to a platform are included because of their emissions associated with gasoline, diesel, and natural gas fuel usage in engines. Total emissions equal the sum of emissions due to gasoline, diesel, and natural gas fuel usage. Activity data were submitted for 12 drilling units, all of which reported only diesel fuel usage. The GOADS-2017 software allowed operators to enter a mobile platform drilling rig name, if applicable. Out of the 12 active drilling units, five provided mobile platform drilling rig names. The non-platform drilling rig emission estimates were adjusted to avoid overlap in the platform and non-platform inventories for these five mobile platform drilling rigs.

For gasoline fuel use, the following equation was used to calculate uncontrolled emissions, E_{gas} (Wilson et al., 2007):

$$E_{gas} = EF_{(lb/MMBtu)} \times 10^{-6} \times U \times \frac{6.17\,lb}{gal} \times \frac{20{,}300\,Btu}{lb}$$

Where:

E = Emissions in pounds per month
EF = Emission factor (units shown in parentheses)
U = Fuel usage (gallons)

For diesel fuel use, the following equation was used to calculate uncontrolled emissions, E_{die} (Wilson et. al., 2007):

$$E_{die} = EF_{(lb/MMBtu)} \times 10^{-6} \times U \times \frac{7.1\,lb}{gal} \times \frac{19{,}300\,Btu}{lb}$$

Where:

E	=	Emissions in pounds per month
EF	=	Emission factor (units shown in parentheses)
U	=	Fuel usage (gallons)

For natural gas fuel use, the following equation was used to calculate uncontrolled emissions, E_{ng}:

$$E_{ng} = EF_{(lb/MMscf)} \times 10^{-3} \times U$$

Where:

E	=	Emissions in pounds per month
EF	=	Emission factor (units shown in parentheses)
U	=	Fuel usage (Mscf)

The following emission factors were used to estimate emissions (Tables 4-9 through 4-11). These factors come from *AP-42*, Sections 3.2, 3.3 and 3.4 (USEPA, 2014a) and WebFIRE (USEPA, 2015). Diesel engines were assumed to be ≥ 600 hp. Natural gas engines were assumed to be four-cycle and evenly distributed between lean and rich burns (by averaging).

Table 4-9. Emission Factors for Gasoline Fuel Use

Pollutant	EF_{gas} (lb/MMBtu)
VOC	3.030
SO_2	0.084
NO_x	1.630
PM_{10} [a]	0.100
CO	0.990
CO_2	154.000

[a] Also represents $PM_{2.5}$.

Table 4-10. Emission Factors for Diesel Fuel Use

Pollutant	EF_{die} (lb/MMBtu)
VOC	0.080
SO_2 [a]	$1.01 \times S$
NO_x	3.200
$PM_{2.5}$ [b]	0.056
PM_{10}	0.057
CH_4	0.008
CO	0.850
CO_2	165.000
Acetaldehyde	2.52E-05
Benzene	7.76E-04
Formaldehyde	7.89E-05
PAH	2.12E-04
Toluene	2.81E-04
Xylenes	1.93E-04

[a] S = Fuel sulfur content (wt%).
[b] < 3 µm.

Table 4-11. Emission Factors for Natural Gas Fuel Use

Pollutant	EF_{ng} (lb/MMscf)
VOC	75.3
SO_2	0.6
NO_x	2,467.5
PM_{10}[a]	4.9
CO	2,127.3
CH_4	755.0
CO_2	112,200.0
Acetaldehyde	5.86
Benzene	1.06
Ethylbenzene	0.03
Formaldehyde	38.54
PAH	0.09
Toluene	0.51
Xylenes	0.20

[a] Also represents $PM_{2.5}$.

4.2.5 Combustion Flares

A flare is a burning stack used to dispose of hydrocarbon vapors. Flares can be used to control emissions from storage tanks, loading operations, glycol dehydration units, vent collection system, and amine units. Flares usually operate continuously; however, some are used only for process upsets (Systems Applications International et al., 1995). Activity data were submitted for 90 combustion flares. The GOADS-2017 software allowed operators to indicate whether the pilot feed rate is included in the reported volume flared for each month. About 42% of the active combustion flares were reported with the pilot feed rate already included in the reported volume flared.

Flare emissions for NO_x, PM_{10}, CO, and key HAPs were estimated according to the following equation:

$$E_{flare} = V_{tot} \times H \times EF_{flare} \div 1000$$

Where:

E_{flare}	=	Emissions in pounds per month
V_{tot}	=	Total volume of gas flared (Mscf, including upsets)
H	=	Flare gas heating value (Btu/scf)
EF_{flare}	=	Emission factor for flares (lb/MMBtu)

SO_2 emissions were estimated using the following equation:

$$E_{flare,SO_2} = \left(\frac{Eff_F\,\%}{100\%}\right) \times \frac{10^{-6}}{ppm} \times \frac{m_{SO_2}}{379.4\ \ scf/lb \cdot mol} \times 1000 \times \left(V' \times C_{H_2S}\right)$$

Where:

$E_{flare,\ SO_2}$	=	Emissions in pounds per month
$Eff_F\%$	=	The combustion efficiency of the flare (%)
m_{SO_2}	=	Molecular weight of SO_2 = 64 lb/lb·mol
V'	=	Volume of gas flared (Mscf)

C_{H_2S} = Concentration of H_2S in the flare gas (ppm)

Flare emissions for VOC and CH_4 were estimated according to the following equation:

$$E_{flare,VOC,CH_4} = V_{tot} \times \left(1 - \frac{Eff_F\%}{100\%}\right) \times \frac{1}{379.4 \text{ scf / lb} \cdot \text{mol}} \times m_{VOC,CH_4} \times 1000$$

Where:

E_{flare, VOC, CH_4}	=	Emissions in pounds per month
V_{tot}	=	Total volume of gas flared (Mscf, including upsets)
$Eff_F\%$	=	The combustion efficiency of the flare (%)
$m_{VOC, CH4}$	=	The mole weight of VOC or CH_4 in the flare gas (lb/lb-mol gas)

The VOC and CH_4 mole weights were estimated using the reported mole % of the volatile components and CH_4 from the reported sales gas composition, and the molecular weights of the volatile components and CH_4. Although operators are able to report CO_2 in the sales gas composition for each platform, BOEM used *AP-42* emission factors for CO_2 rather than the equation that was used for VOC and CH_4. Because a portion of the CH_4 emissions are converted to CO_2 in the flare gas, using the VOC and CH_4 equation to estimate CO_2 would likely underestimate CO_2 emissions.

If the user indicated there was a continuous flare pilot and did not indicate that the pilot feed rate was included in the reported volume flared, pilot light emissions were estimated as follows:

$$E_{pilot} = P \times D \times EF_{pilot} \div 1000$$

Where:

E_{pilot}	=	Pilot emissions in pounds per month
P	=	Pilot feed rate (Mscf/day)
D	=	Number of days in month
EF_{pilot}	=	Emission factor for pilot (lb/MMscf)

The following emission factors are used to estimate emissions (Tables 4-12 and 4-13). The VOC emission factor was used along with gas composition data from the Profile #FLR99 of the SPECIATE database (USEPA, 2014b) to create the HAP emission factors in Table 4-12. This procedure was used in USEPA's Nonpoint Oil and Gas Emission Estimation Tool to estimate formaldehyde emissions (ERG, 2017). All other factors come from *AP-42*, Sections 13.5 and 1.4 (USEPA, 2014a) and WebFIRE (USEPA, 2015).

Table 4-12. Emission Factors for Combustion Flares[a]

Pollutant	EF (lb/MMBtu)
NO_x	0.068
PM_{10}[b]	0; where flare smoke = none
	0.002; where flare smoke = light
	0.01; where flare smoke = medium
	0.02; where flare smoke = heavy
CO	0.310
N_2O	0.002
CO_2	114.285
Acetaldehyde	0.05519
Benzene	0.00159
Ethylbenzene	0.00009
Formaldehyde	0.08302
Hexane	0.00748
Toluene	0.00142
2,2,4 Trimethylpentane	0.00211
Xylenes	0.00040

[a] Factors for N_2O and CO_2 were derived from pilot emission factors.
[b] Also represents $PM_{2.5}$.

Table 4-13. Emission Factors for Pilots

Pollutant	EF (lb/MMscf)
VOC	5.5
Pb	5.0E-03
NO_x	100.0
PM_{10}[a]	1.9
NH_3	3.2
SO_2	0.6
CO	84.0
N_2O	2.2
CH_4	2.3
CO_2	120,000.0
Arsenic	2.00E-04
Benzene	2.10E-03
Beryllium	< 1.2E-05
Cadmium	1.10E-03
Chromium	1.40E-03
Formaldehyde	0.075
Hexane	1.8
Mercury	2.60E-04
Toluene	3.40E-03

[a] Also represents $PM_{2.5}$.

If the corresponding fields were null, the following surrogate values (based on industry defaults and confirmed with GOADS-2017 data) were applied:

Flare $\text{Smoke}_{\text{default}}$ = None
Pilot Fuel Feed Rate = 2.28 Mscf/day

The flare smoke and pilot fuel feed rate surrogates did not need to be assigned to any active flares for the 2017 inventory. The emission factors shown in Table 4-12 were assumed to be based on flares operating under stable conditions, with a combustion efficiency of approximately 98% (the range check value is between 90–99%). Based on a comment by a peer reviewer of a previous Gulfwide Emission Inventory Study report that platform flares may not all be operating under stable conditions, BOEM reviewed the flare velocities to determine if all were less than 400 feet per second (fps), reflective of stable conditions (TCEQ, 2011). The emissions were revised for three flares in the 2017 inventory, because the operators confirmed the high velocities and agreed the flares were achieving a lower efficiency.

For the 2017 inventory, operators could indicate whether a continuous pilot feed rate was included in the reported volume flared. Where operators made this indication, emissions were not estimated for the pilot using the emission factors in Table 4-12, except for the key HAPs that were not accounted for in the flaring emission factors: arsenic, beryllium, cadmium, chromium, and mercury.

A USEPA speciation profile will be applied to the flare pilot chromium emission estimates. The profile for natural gas combustion assigns 96% of the chromium emissions as chromium III and 4% as chromium VI (USEPA, 2016a).

4.2.6 Fugitive Sources

Fugitive emissions are leaks from sealed surfaces associated with process equipment. Specific fugitive source types include equipment components such as valves, flanges, and connectors (EIIP, 1999). Operators were required to delineate the stream type (gas, heavy oil, light oil, or water and oil) and average VOC weight percent of fugitives, and to provide an equipment inventory (number of components). Fugitive records were submitted for 94% of the active platforms. The GOADS-2017 software allowed operators to indicate whether a leak detection and repair (LDAR) program is in place for fugitive sources. Of the fugitive records for active platforms, 91% reported not having an LDAR program, 5% reported having an LDAR program, and 4% did not indicate whether or not there is an LDAR program. Operators could also indicate the number of months between inspections if there is an LDAR program and the method of inspection. Of the platforms that had an LDAR program, 91% reported having annual inspections and 9% monthly inspections. The monthly inspections were visual inspections, and the annual inspections were done by optical instrument. Operators could also indicate whether the fugitive component counts provided were based on default counts or actual counts. Of the fugitive records for active platforms, almost 95% were based on default counts, just under 1% were based on actual counts, and the remainder did not indicate whether the component counts were based on default or actual counts.

Fugitive THC emissions were estimated according to the following equation:

$$E_{THC} = \sum_{comp} \left(EF_{comp,stream} \times N_{comp} \right) \times D$$

Where:

E_{THC}	=	THC emissions in pounds per month
$EF_{comp,stream}$	=	Emission factor unique to the type of component and process stream (lb/component-day) (Table 4-14)
N_{comp}	=	Count of components of a given type present on the facility. (Note: Null values are treated as zero.)
D	=	Number of days in month

Fugitive VOC and CH_4 emissions were estimated based on the following equation:

$$E = E_{THC} \times WtFr_{comp,\ stream}$$

Where:

E	=	VOC or CH_4 emissions in pounds per month
E_{THC}	=	THC emissions in pounds per month
$WtFr_{comp,stream}$	=	Weight fraction of VOC or CH_4 unique to the process stream

Table 4-14. THC Emission Factors for Oil and Gas Production Operations (lb/component-day)[a]

Component	Gas	Natural Gas Liquid	Heavy Oil (<20 API Gravity)	Light Oil (≥ 20 API Gravity)	Water, Oil	Oil, Water, Gas[b]
Connector	1.1E-02	1.1E-02	4.0E-04	1.1E-02	5.8E-03	1.1E-02
Flange	2.1E-02	5.8E-03	2.1E-05	5.8E-03	1.5E-04	2.1E-02
Open-end	1.1E-01	7.4E-02	7.4E-02	7.4E-02	1.3E-02	1.1E-01
Other[c]	4.7E-01	4.0E-01	1.7E-03	4.0E-01	7.4E-01	7.4E-01
Pump	1.3E-01	6.9E-01	6.9E-01	6.9E-01	1.3E-03	1.3E-01
Valve	2.4E-01	1.3E-01	4.4E-04	1.3E-01	5.2E-03	2.4E-01

[a] Source: API, 1996.
[b] Assumed to be equal to either gas or water/oil, whichever is greater.
[c] Includes compressor seals, diaphragms, drains, dump arms, hatches, instruments, meters, pressure relief valves, polished rods, and vents.

If a component count was not provided, the following surrogate component counts were used (derived from API (1993), average number of offshore platform components, and percentage of total components by type):

Connectors:	9,194
Valves:	1,713
Open-Ends:	285
Others:	228

These surrogates were not applied to any platforms during the QA/QC process for the 2017 inventory. However, some operators reported component counts equal to the surrogate values. This is likely a result of surrogates used for previous inventories being carried forward in static descriptive data provided to the operators for the 2017 inventory, which were resubmitted without revisions for 2017. If stream type was not provided, emissions were calculated assuming the stream type is light oil. Similar to the component count surrogate, the stream type assumption was not applied in the 2017 inventory, possibly due to stream type being carried forward without revision from previous inventories. The default values in Table 4-15 were provided to operators in the GOADS-2017 User's Guide (Wilson et al., 2018), and some operators either reported these defaults or carried them forward unchanged from previous inventories. BOEM did not apply these defaults to any platforms during the QA/QC process for the 2017 inventory.

Table 4-15. Default Speciation Weight Fractions for THC Emissions by Stream Type

THC Fraction[a]	Gas	Natural Gas Liquid	Light Oil (≥ 20 API Gravity)	Heavy Oil (<20 API Gravity)	Water, Oil[b]	Oil, Water, Gas
CH_4	0.8816	0.612	0.612	0.942	0.612	0.612
VOC	0.0396	0.296	0.296	0.030	0.296	0.296

[a] Source: API 1996 for all stream types except gas. Emission factors for gas streams derived from default sales gas composition.

[b] Water, oil refers to water streams in oil service with a water content greater than 50% from the point of origin to the point where the water content reaches 99%. For water streams with a water content greater than 99%, the emission rate is considered negligible.

To estimate HAP emissions, BOEM applied the speciation profile from Table 4-2 to the VOC emissions.

4.2.7 Glycol Dehydrators

Glycol dehydrators remove excess water from natural gas streams to prevent the formation of hydrates and corrosion in the pipeline (EIIP, 1999). In previous inventory cycles, regression equations from GRI-GLYCalc version 4.0 (GTI, 2000) were used to estimate VOC and CH_4 emissions from glycol dehydrators. CO_2 estimates were included in the 2014 Gulfwide Inventory based on an emission factor used in the USEPA's Greenhouse Gas Reporting Program for petroleum and natural gas systems (40 Code of Federal Regulations [CFR] Part 98, Subpart W). In order to improve the accuracy of the glycol dehydrator emissions estimates, the GRI-GLYCalc version 4.0 program was run externally for each glycol dehydrator in the 2017 Gulfwide Inventory to estimate emissions of VOC, CH_4, and key HAPs. Activity data were reported for 174 glycol dehydrators for the 2017 inventory.

4.2.8 Loading Operations

Emissions from loading operations are generated by the displacement of the vapor space in the receiving cargo hold by liquid product. Loading losses are due to 1) liquids displacing vapors already residing in the cargo tank, and 2) vapors generated by the liquid being loaded into the cargo tank (EIIP, 1999; Boyer and Brodnax, 1996). The calculations below assume that ships arrive in ballasted condition and that the previously carried loads were crude oil. Activity data were submitted for one loading operation.

For marine loading of crude petroleum, the USEPA recommends the following equation from *AP-42*, Section 5.2 to calculate THC emissions due to loading of fresh cargo (USEPA, 2014a):

$$E_{THC} = \left(0.46 + 1.84 \times (0.44 \times P_{VA} - 0.42) \times \frac{mG}{T_b}\right) \times Q \times \frac{42.0\ \text{gal}}{\text{bbl}} \times 10^{-3}$$

Where:

E_{THC}	=	THC emissions (pounds per month)
P_{VA}	=	True vapor pressure of the loaded liquid (psia) = $\exp[A - (B/T_{LA})]$
m	=	Average molecular weight of vapors (lb/lb-mol)
G	=	Vapor growth factor = 1.02
T_b	=	Liquid bulk temperature (°R)
Q	=	The amount transferred (barrels (bbl))
A	=	Empirical constant = 12.82 – 0.9672 × ln(Reid VP)
B	=	Empirical constant = 7,261 – 1,216 × ln(Reid VP)
T_{LA}	=	Daily average liquid surface temperature (°R) = $0.44 \times T_{aa} + (0.56 \times T_b) + (0.0079 \times a \times I)$
T_{aa}	=	Daily average ambient temperature (°R) (T_{aa}, Table 4-16)

a = Tank paint solar absorptance (Table 4-17)
I = Daily solar insulation factor ($Btu/ft^2 \cdot day$) = 1,437 $Btu/ft^2 \cdot day$[a]

Table 4-16. Monthly 2017 Average Ambient Temperature[c]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
F[a]	60	65	67	73	76	81	84	83	80	74	67	57
R[b]	520	525	527	533	536	541	544	543	540	534	527	517

[a] °Fahrenheit
[b] °Rankine
[c] Source: NCDC, 2018.

Table 4-17. Tank Paint Solar Absorptance

	Solar Absorptance by Paint Color and Condition	
	Paint Condition	
Paint Color	Good	Poor
Aluminum or specular	0.39	0.49
Aluminum or diffuse	0.60	0.68
Grey or light	0.54	0.63
Grey or medium	0.68	0.74
Red or primer	0.89	0.91
White	0.17	0.34

VOC emissions (E_{VOC}, in pounds) were calculated as a percent of THC emissions:

$$E_{VOC} = TankVaporWeightPercentVOC/100 \times E_{THC}$$

The following surrogates based on industry standards were assigned or estimated if the corresponding fields were null:

Reid Vapor Pressure$_{default}$ = 5
$T_{b,default} = T_{aa} + 6 \times a - 1$
Tank VOC Molecular Weight$_{default}$ = 50
Tank Vapor Weight Percent VOC$_{default}$ = 85

4.2.9 Losses from Flashing

Flash gas is a natural gas that is liberated when an oil stream undergoes a pressure drop. Flash gas is associated with high-, intermediate-, and low-pressure separators, heater treaters, surge tanks, accumulators, and fixed roof atmospheric storage tanks. Flash gas emissions were estimated only for gas that was vented to the atmosphere or burned in a flare. No emissions were associated with flash gas that was routed back into the system (e.g., sales gas). Activity data for losses from flashing was provided for 400 platforms.

If a pressure drop occurs between vessels, flash gas emissions were estimated using the Vasquez-Beggs correlation equations to estimate tank vapors in standard cubic feet per barrel of oil produced. Operators were asked to report the following parameters for each part of the process:

- API gravity of stored oil

- Operating pressure (psig) of each vessel and immediately upstream (i.e., separator, heater treater, surge tank, storage tank)
- Operating temperature (°F) of each vessel and immediately upstream
- Actual throughput of oil for each vessel
- Disposition of flash gas from each vessel—routed to system (e.g., sales pipeline, gas-lift), vented to atmosphere, or burned in flare
- Scf of flash gas per barrel (bbl) of oil throughput (optional)

Flashing losses of THC, in pounds, were calculated according to the following equation:

$$L_f = (GOR_U - GOR_V) \times \text{Throughput} \times GD$$

Where:

L_f	=	Emissions in pounds per month
GOR_U	=	Gas-to-oil ratio (scf/bbl) for upstream vessel
GOR_V	=	Gas-to-oil ratio (scf/bbl) for vessel
Throughput	=	Throughput volume for each vessel (bbl/month)
GD	=	Gas density (lb/scf)

Gas-to-oil ratio (GOR) was calculated using the following equation:

$$GOR = C_1 \times (OP + Pa)^{C_2} \times CSG \times e^{\left(\frac{C_3 \times \text{API gravity}}{\text{Vessel temp} + 460}\right)}$$

Where:

GOR	=	Gas-to-oil ratio (scf/bbl)
C_1	=	Vasquez-Beggs constant = $\begin{cases} 0.0178; \text{if API gravity} > 30 \\ 0.0362; \text{otherwise} \end{cases}$
OP	=	Vessel operating pressure (psia)
Pa	=	Atmospheric pressure (psia)
C_2	=	Vasquez-Beggs constant = $\begin{cases} 1.187; \text{if API gravity} > 30 \\ 1.0937; \text{otherwise} \end{cases}$
CSG	=	Corrected specific gravity of gas (see below)
C_3	=	Vasquez-Beggs constant = $\begin{cases} 23.931; \text{if API gravity} > 30 \\ 25.724; \text{otherwise} \end{cases}$

Emissions of VOC, CO_2, and CH_4 were estimated using the following gas densities based on the average sales gas weight percent for OCS platforms:

$GD_{,VOC}$	= 0.0018 lb/scf
$GD_{,CO_2}$	= 0.000928 lb/scf
$GD_{,CH_4}$	= 0.04 lb/scf

If the corresponding field was null, a default API gravity of 37 was applied. A default tank molecular gas weight of 24.994 lbs/lb·mole was also assumed as an industry average.

Table 4-18 presents the surrogate values used for the corrected specific gravity of gas.

Table 4-18. Surrogate Specific Gravity Values

API Gravity	Gas Specific Gravity (at 100 psig)
> 30	0.93
< 30	1.08

To estimate HAP emissions, BOEM applied the speciation profile from Table 4-2 to the VOC emissions.

4.2.10 Mud Degassing

THC emissions from mud degassing occur when gas that has seeped into the well bore and dissolved or become entrained in the drilling mud is separated from the mud and vented to the atmosphere (EIIP, 1999). Activity data were reported for seven active mud degassing operations. To estimate mud degassing emissions, operators were asked to provide the following:

- Number of days that drilling operations occurred
- Type of drilling mud used (water-based, synthetic, oil-based)

Emissions were calculated using the following equation:

$$E_{THC} = EF_{THC} \times D_{drill}$$

Where:

E_{THC}	=	THC emissions (pounds per month)
EF_{THC}	=	THC emission factor (lbs/day)
D_{drill}	=	Number of days in the month that drilling occurred

For water- and oil-based muds, hydrocarbon emissions are estimated using emission factors provided in the USEPA report *Atmospheric Emissions from Offshore Oil and Gas Development and Production* (USEPA, 1977):

Water-based muds:	881.84 lbs THC/day
Oil-based muds:	198.41 lbs THC/day

For synthetic muds, no information is available regarding air emission rates. Synthetic muds are used as substitutes for oil-based muds, and may occasionally be used to replace water-based muds. Synthetic muds perform like oil-based muds, but with lower environmental impact and faster biodegradability (USEPA, 2000). No information was found, however, on a possible reduction in THC emissions. Because most emissions are associated with the release of entrained hydrocarbons, and the USEPA estimates no change in the amount of waste cuttings between synthetic and oil-based muds (USEPA, 2000), the oil-based mud THC emission factor was used for synthetic muds as well.

THC emissions were speciated as shown in Table 4-19 (USEPA, 1977).

Table 4-19. Mud Degassing Speciation Fractions

Component	Percent Composition by Weight (%)
Methane	64.705
Ethane (C_2)	7.834
Propane (C_3)	12.977
Butane (C_4)	8.973
Pentane (C_5)	4.873

CO_2 emissions were assumed to be 0.6% of the gases emitted. If the type of mud used was specified but the number of days that drilling occurred was left blank, a surrogate for number of drilling days per month, developed from the activity data submitted for all platforms, could be applied. A surrogate was not needed, because all active mud degassing operations were reported with mud type and the number of days that drilling occurred.

4.2.11 Natural Gas Engines

Like diesel and gasoline engines, natural gas engines are used to run generators, pumps, compressors, and well-drilling equipment. Most of the pollutants emitted from these engines are from the exhaust (USEPA, 2014a). Activity data were submitted for 1,150 natural gas engines.

Emission estimates used a user-entered value for total fuel usage or a calculated value for total fuel usage based on operator-supplied hours of operation, average fuel usage (or a surrogate fuel consumption rate of 7,500 Btu/hp-hr), fuel heating value, and operating horsepower. The surrogate fuel consumption rate was only used to estimate fuel use for three active units.

Emissions were calculated based on fuel use as:

$$E_{fu} = EF_{(lb/MMBtu)} \times H \times U \times 10^{-3}$$

Where:

E_{fu} = Emissions in pounds per month
EF = Emission factor (units are shown in parentheses)
H = Fuel heating value (Btu/scf)
U = Fuel usage (Mscf/month)

Tables 4-20 through 4-23 present the emission factors used to estimate natural gas engine emissions. These factors come from *AP-42*, Section 3.2 (USEPA, 2014a).

Table 4-20. Emission Factors for Natural Gas Engines Where Engine Stroke Cycle = 2-Cycle and Engine Burn Type = Lean

Pollutant	EF_{fu} (lb/MMBtu)
VOC	0.12
SO_2	5.88E-04
NO_x (<90% load)	1.94
PM_{10}[a]	3.84E-02
CO (<90% load)	0.353

Pollutant	EF_{fu} (lb/MMBtu)
CH_4	1.45
CO_2	110.00
Acetaldehyde	7.76E-03
Benzene	1.94E-03
Ethylbenzene	1.08E-04
Formaldehyde	5.52E-02
Hexane	4.45E-04
PAH	1.34E-04
Toluene	9.63E-04
2,2,4-Trimethylpentane	8.46E-04
Xylenes	2.68E-04

[a] Also represents $PM_{2.5}$

Table 4-21. Emission Factors for Natural Gas Engines Where Engine Stroke Cycle = 4-Cycle and Engine Burn Type = Lean

Pollutant	EF_{fu} (lb/MMBtu)[a]
VOC	0.12
SO_2	5.88E-04
NO_x (<90% load)	0.85
PM_{10}[a]	7.71E-05
CO (<90% load)	0.56
CH_4	1.25
CO_2	110.00
Acetaldehyde	8.36E-03
Benzene	4.40E-04
Ethylbenzene	3.97E-05
Formaldehyde	5.28E-02
Hexane	1.11E-03
PAH	2.69E-05
Toluene	4.08E-04
2,2,4-Trimethylpentane	2.50E-04
Xylenes	1.84E-04

[a] Also represents $PM_{2.5}$

Table 4-22. Emission Factors for Natural Gas Engines Where Engine Stroke Cycle = 4-Cycle and Engine Burn Type = Rich

Pollutant	EF_{fu} (lb/MMBtu)
VOC	0.03
SO_2	5.88E-04
NO_x (**<**90% load	2.27
PM_{10}[a]	9.50E-03
CO (<90 % load)	3.51
CH_4	0.23
CO_2	110.00
Acetaldehyde	2.79E-03
Benzene	1.58E-03
Ethylbenzene	2.48E-05

Pollutant	EF_{fu} (lb/MMBtu)
Formaldehyde	2.05E-02
PAH	1.41E-04
Toluene	5.58E-04
Xylenes	1.95E-04
Acetaldehyde	2.79E-03
Benzene	1.58E-03
Ethylbenzene	2.48E-05

[a] Also represents $PM_{2.5}$

Table 4-23. Emission Factors for Natural Gas Engines Where Engine Burn Type = Clean

Pollutant	EF_{fu} (lb/MMBtu)
VOC	0.12
SO_2	5.88E-04
NO_x	0.59
PM_{10}[a]	7.71E-05
CO	0.88
CH_4	1.25
CO_2	110.00
Acetaldehyde	3.52E-03
Benzene	6.00E-04
Ethylbenzene	4.19E-05
Formaldehyde	4.95E-02
Hexane	6.48E-04
Toluene	5.05E-04
2,2,4-Trimethylpentane	1.05E-04
Xylenes	1.71E-04

[a] Also represents $PM_{2.5}$

4.2.12 Natural Gas, Diesel, and Dual-Fuel Turbines

A turbine is an internal combustion engine that operates with rotary rather than reciprocating motion. Turbines are primarily used to power compressors and other equipment rather than generate electricity (Boyer and Brodnax, 1996). A turbine’s operating load has a considerable effect on the resulting emission levels. With reduced loads, there are lower thermal efficiencies and more incomplete combustion (USEPA, 2014a). Activity data were submitted for 359 turbines. Of these, 302 reported only natural gas use, 48 reported both natural gas and diesel fuel use, and 9 reported only diesel fuel use.

Emission estimates used a user-entered value for total fuel usage or a calculated value for total fuel usage based on operator-supplied hours of operation, average fuel usage (or a surrogate fuel consumption rate), fuel heating value, and operating horsepower. A surrogate natural gas fuel consumption rate of 10,000 Btu/hp-hr and a diesel fuel consumption rate of 7,000 Btu/hp-hr were applied as needed. The surrogate fuel consumption rates were not applied to any of the active units during the QA/QC process; however, some operators reported fuel use rates equal to the surrogate fuel consumption rates.

The following equation was used to calculate emissions based on fuel use:

$$E_{fu} = EF_{(lb/MMBtu)} \times 10^{-3} \times H \times U$$

Where:

E_{fu} = Emissions in pounds per month
EF = Emission factor (units are shown in parentheses)
H = Fuel heating value (Btu/scf)
U = Fuel usage (Mscf/month)

The following emission factors were used to estimate emissions for natural gas turbines (Table 4-24). These factors come from *AP-42* Section 3.1 (USEPA, 2014a) and WebFIRE (USEPA, 2015).

Table 4-24. Emission Factors for Natural Gas Turbines

Pollutant	EF (lb/MMBtu)
VOC	2.10E-03
SO_2[a]	0.94 × S
NO_x	0.32
PM_{10}[b]	1.90E-03
CO	8.20E-02
N_2O	0.003
CH_4	8.60E-03
CO_2	110.00
Acetaldehyde	4.00E-05
Benzene	1.20E-05
Cadmium	6.93E-06
Chromium	1.33E-05
Ethylbenzene	3.20E-05
Formaldehyde	7.10E-04
Mercury	6.63E-06
PAH	2.20E-06
Toluene	1.30E-04
Xylenes	6.40E-05

[a] S= Fuel sulfur content (wt%). If not available, EF is 3.47×10^{-3} lb/MMBtu.
[b] Also represents $PM_{2.5}$.

The following emission factors were used to estimate emissions for diesel turbines (Table 4-25). These factors come from *AP-42* Section 3.1 (USEPA, 2014a).

Table 4-25. Emission Factors for Diesel Turbines

Pollutant	EF (lb/MMBtu)
VOC	4.10E-04
Pb	1.40E-05
SO_2[a]	1.01 × S
NO_x	0.88
PM_{10}[b]	4.30E-03
CO	3.30E-03
CO_2	157.00
Arsenic	< 1.10E-05
Benzene	5.50E-05
Beryllium	< 3.10E-07
Cadmium	4.80E-06

Pollutant	EF (lb/MMBtu)
Chromium	1.10E-05
Formaldehyde	2.80E-04
Mercury	1.20E-06
PAH	4.00E-05

[a] S = Fuel sulfur content (wt%).
[b] Also represents $PM_{2.5}$.

Emissions for dual-fuel turbines were estimated separately for natural gas combustion and diesel combustion using the reported fuel usage for each fuel type.

A USEPA speciation profile was applied to estimate emissions of chromium III and chromium VI. The profile for natural gas combustion assigned 96% of the chromium emissions as chromium III and 4% as chromium VI. The profile for diesel combustion assigned 82% of chromium emissions as chromium III and 18% as chromium VI (USEPA, 2016b).

4.2.13 Pneumatic Pumps

A readily available supply of compressed natural gas is used to power gas actuated pumps. There is no combustion of the gas because the energy is derived from the gas pressure. These pumps include reciprocating pumps such as diaphragm, plunger, and piston pumps. Most gas actuated pumps vent directly to the atmosphere (Boyer and Brodnax, 1996). Activity data were submitted for 2,757 pneumatic pumps on 607 platforms.

Operators were asked to provide the following information for pumps that are in natural gas service:

- Manufacturer and model
- Fuel gas usage rate in scf/hr (no longer optional)
- Hours of operation in the reporting period
- Whether it is vented or flared locally, routed to a remote vent or flare, or routed to the system

CO_2, CH_4, and VOC emissions (in pounds) for pneumatic pumps were developed using Equation 10.4-3 from Chapter 10, “Preferred and Alternative Methods for Estimating Air Emissions from Oil and Gas Field Production and Processing Operations” (EIIP, 1999):

$$E = t \times FU \times (\text{mole weight of gas, lbs/lb-mole}) \times (1 \text{ lb-mole}/379.4 \text{ scf})$$

Where:

E	=	Emissions in pounds per month
t	=	Operating time (hours/month)
FU	=	Fuel usage rate (scf/hour)
Mole weight of gas	=	Mole percent of constituent/100 × mole weight of constituent/gas MW

To determine the mole percentage of each constituent (CH_4, CO_2, and VOC), operators were asked to provide the sales gas composition for their structure. Table 4-26 presents the default gas composition if not provided. The default gas composition was not applied for any platforms during QA/QC for 2017. Table 4-26 also presents the mole weight for each gas constituent. The C_3 through C_{8+} components are used to determine the mole percentage of VOC in the sales gas.

For 2017, the fuel use rate field was a required field. However, the fuel use rate was null for 11 active units with hours of operation greater than zero on six platforms. In these instances, BOEM estimated the exhaust volume flow rate to use as a surrogate for fuel use rate using the reported velocity, diameter, and temperature. This calculated surrogate was applied to five units. If there was not enough information to estimate a surrogate fuel use rate, and the make and model were not provided, then a default of 100 scf/hour was applied. The default was applied to six units.

Table 4-26. Default Sales Gas Composition

Component	Default Mole%	Mole Weight (lb/lb-mole)
CO_2	0.80	44.010
CH_4	94.50	16.043
Ethane (C_2)	3.33	30.070
Propane (C_3)	0.75	44.097
Isobutane (i-C_4)	0.15	58.124
n-Butane (n-C_4)	0.15	58.124
Isopentane (i-C_5)	0.05	72.150
n-Pentane (n-C_5)	0.05	72.150
Hexanes (C_6)	0.099	86.177
Heptanes (C_7)	0.011	100.272
Octanes and higher hydrocarbons (C_8+)	0.007	114.231

Source: Developed from prior inventories average sales gas weight percent for OCS platforms.

To estimate HAP emissions, BOEM applied the speciation profile from Table 4-2 to the VOC emissions.

4.2.14 Pneumatic Controllers

Devices that control both pressure and liquid levels on vessels and flow lines are used extensively in production operations. The units are designed to open or close a valve when a preset pressure or liquid level is reached. The valves are automatically actuated by bleeding compressed gas from a diaphragm or piston. The gas is vented to the atmosphere in the process. Most production facilities use natural gas to actuate the controllers. The amount of gas vented is dependent on several factors, including the manufacturer and application (Boyer and Brodnax, 1996). Activity data were submitted for 1,703 pneumatic controllers on 460 platforms. The GOADS-2017 software allowed operators to indicate whether pneumatic controllers were high bleed (greater than 6 standard cubic feet per hour), intermittent, low-bleed (less than 6 standard cubic feet per hour), or zero-bleed. Of the 1,703 active pneumatic controller units, 668 (39%) were reported as high-bleed, 685 (40%) were reported as low-bleed, 304 (18%) were reported as intermittent, and 44 (3%) were reported as zero-bleed.

Operators were asked to provide the following information for controllers that are in natural gas service:

- Service type (pressure control, level control, flow control, or other service)
- Manufacturer and model
- Number of equipment of this make and model
- Bleed rate (high, low, intermittent, or zero-bleed)
- Amount of natural gas used in scf/hr (no longer optional)
- Hours of operation in the reporting period

Similar to pneumatic pumps, CO_2, CH_4, and VOC emissions estimates (in pounds) for pneumatic controllers were developed using the following equation (EIIP, 1999):

$$E = \text{No. of units} \times t \times FU \times (\text{mole weight of gas, lbs/lb-mole}) \times (1 \text{ lb-mole}/379.4 \text{ scf})$$

Where:

E	=	Emissions in pounds per month
t	=	Operating time (hr/month)
FU	=	Fuel usage rate (scf/hr)
Mole weight of gas	=	mole percent of constituent/100 × mole weight of constituent/gas MW

To determine the mole percentage of each constituent (CH_4, CO_2, and VOC), operators were asked to provide the sales gas composition for their structure. Table 4-26 presents the default gas composition if not provided (not applied for any units in 2017). Table 4-26 also presents the mole weight for each gas constituent.

If the fuel usage rate was not provided, an average value for each make and model was assigned based on reported manufacturer data, or an average surrogate based on the manufacturer and service type is applied. This surrogate was applied for five units on four platforms.

To estimate HAP emissions, BOEM applied the speciation profile from Table 4-2 to the VOC emissions.

4.2.15 Storage Tanks

VOC and THC may be lost from storage tanks as a result of flashing, working, and standing losses. This discussion addresses only working and standing losses (L_w and L_s). Flashing losses were estimated separately. Activity data were submitted for 336 storage tanks.

Standing losses result from the expulsion of vapors due to vapor expansion and contraction resulting from temperature and barometric pressure changes. Working losses result from filling and emptying operations (Boyer and Brodnax, 1996). These calculations assume that all tanks are fixed roof tanks.

Standing losses of THC in pounds were calculated using the following equation:

$$L_{s,\,THC} = D \times V_V \times W_V \times K_E \times K_S$$

Where:

L_s	=	Standing losses (lbs/month)
D	=	Number of days in the month
V_V	=	Tank vapor space volume (cubic feet (ft^3))
W_V	=	Stock vapor density (lb/ft^3)
K_E	=	Calculated vapor space expansion factor (unitless)
K_S	=	Calculated vented vapor saturation factor (unitless)

Vapor space volume for a horizontal, rectangular tank was calculated as:

$$V_V = \text{Tank Shell Length} \times \text{Tank Shell Width}_1 \times H_{VO}$$

Where:

V_V	=	Vapor space volume (ft^3)
H_{VO}	=	Vapor space outage (ft) = Tank Shell Height – Tank Average Liquid Height

Vapor space volume for a vertical, rectangular tank was calculated as:

$$V_V = \text{Tank Shell Width}_1 \times \text{Tank Shell Width}_2 \times H_{VO}$$

Where:

V_V = Vapor space volume (ft^3)
H_{VO} = Vapor space outage (ft) = Tank Shell Height – Tank Average Liquid Height

Vapor space for a horizontal, cylindrical tank was calculated as:

$$V_v = \frac{\pi \times \text{Tank Shell Diam} \times \text{Tank Shell Length} \times H_{VO}}{4 \times 0.785}$$

Where:

V_V = Vapor space volume (ft^3)
H_{VO} = Vapor space outage (ft) = 0.5 × Tank Shell Diameter

Vapor space for a vertical, cylindrical tank was calculated as:

$$V_V = \frac{\pi}{4} \times \text{Tank Shell Diam}^2 \times H_{VO}$$

Where:

V_V = Vapor space volume (ft^3)
H_{VO} = Vapor space outage (ft) =

$$\begin{cases} \text{Tank Shell Hgt-Tank Avg Liquid Hgt} + \tfrac{1}{3}\text{Tank Roof Hgt}; \text{if Tank Roof Type} = \text{"cone" or "peaked"} \\ \text{Tank Shell Hgt-Tank Avg Liquid Hgt} + \text{Tank Roof Hgt}\left[\tfrac{1}{2} + \tfrac{1}{6}\left(\frac{\text{Tank Roof Hgt}}{\text{Tank Shell Diam}}\right)^2\right]; \text{if Tank Roof Type} = \text{"dome"} \end{cases}$$

TankShell Hgt-TankAvgLiquidHgt; if Tank Roof Type = “Flat”

Stock vapor density was calculated as:

$$W_v = (\text{Tank VOC Molecular Weight} \times P_{VA}) \div (10.731 \times T_{LA})$$

Where:

W_V = Stock vapor density (lb/ft^3)
P_{VA} = True vapor pressure (psia) = $\exp[A - (B/T_{LA})]$
A = Empirical constant = 12.82 – 0.9672 × ln(ReidVP)
B = Empirical constant = 7,261 – 1,216 × ln(ReidVP)
T_{LA} = Daily average liquid surface temperature (°R) = $0.44 \times T_{aa} + (0.56 \times T_b) + (0.0079 \times a \times I)$
T_{aa} = Daily average ambient temperature (°R) (See Table 4-16)
a = Tank paint solar absorptance (See Table 4-17)
T_b = Liquid bulk temperature (°R)
I = Daily solar insulation factor (Btu/square foot (ft^2)·day) = 1,437 Btu/ft^2·day

The vapor space expansion factor was calculated as:

$$K_E = (T_v/T_{LA}) + (P_v - P_b)/(P_a - P_{va})$$

Where:

K_E = Vapor space expansion factor
T_v = Daily vapor temperature range (°R) = $0.72 \times T_a + 0.028 \times a \times I$
T_{LA} = Daily average liquid surface temperature (°R)
P_v = Daily pressure range (psia) = $0.50 \times B \times P_{va} \times T_v/T_{LA}^2$
P_b = Breather vent pressure setting range (psig) = Breather vent pressure – breather vent vacuum
P_a = Atmospheric pressure (psia)
P_{va} = Vapor pressure at daily average liquid surface temperature (psia)

The vented vapor saturation factor was calculated as:

$$K_S = 1/(1 + 0.053 \times P_{VA} \times H_{VO})$$

Where:

K_S = Vented vapor saturation factor
P_{VA} = Vapor pressure at daily average liquid surface temperature (psia)
H_{VO} = Vapor space outage (ft)

Working losses of THC in pounds were calculated according to the following equation:

$$L_{w,\,THC} = 0.0010 \times \text{Tank VOC Mol Weight} \times P_{VA} \times \text{Throughput} \times K_P \times K_N$$

Where:

L_w = Working losses
P_{VA} = Vapor pressure at daily average liquid surface temperature (psia)
K_P = Working loss product factor (unitless) = 0.75
K_N = Working loss turnover factor (unitless) = $\begin{cases} 1; \text{for } N \le 36 \\ \frac{180+N}{6N}; \text{for } N > 36 \end{cases}$
N = Number of turnovers per month = $5.614 \times$ throughput/V_{LX}

V_{LX} = Tank maximum liquid volume (ft^3)

Tank maximum liquid volume for a horizontal, rectangular tank was calculated as:

$$V_{LX} = \text{Tank Shell Length} \times \text{Tank Shell Width}_1 \times \text{Tank Shell Height}$$

Tank maximum liquid volume for a vertical, rectangular tank was calculated as:

$$V_{LX} = \text{Tank Shell Width}_1 \times \text{Tank Shell Width}_2 \times \text{Tank Shell Height}$$

Tank maximum liquid volume for a horizontal, cylindrical tank was calculated as:

$$V_{LX} = \frac{\pi}{4} \times \text{Tank Shell Diam}^2 \times \text{Tank Shell Length}$$

Tank maximum liquid volume for a vertical, cylindrical tank was calculated as:

$$V_{LX} = \frac{\pi}{4} \times \text{Tank Shell Diam}^2 \times \text{Tank Shell Hgt}$$

Where:

V_{LX} = Tank maximum liquid volume (ft^3)

Emissions of CH_4 and VOC were estimated using the following speciation profiles (USEPA, 2008): 0.467 for VOC and 0.463 for CH_4. The remainder is ethane.

Table 4-27 presents the surrogate values assigned or estimated if the corresponding fields are null.

Table 4-27. Storage Tank Surrogate Values

Data Field	Value
Product Type	Crude Oil
Paint Color	Grey
Condition	Good
Roof Type	Fixed
Roof Shape	Cone
API Gravity$_{default}$	37
Reid VP$_{default}$	–1.699 + 0.179 × API Gravity (or 5, if no other information is available)
$T_{b,default}$	T_{aa} + 6 × a – 1 (or 530º R, if no other information is available)
Breather Vent Pressure$_{default}$	0.03
Breather Vent Vacuum$_{default}$	–0.03
Tank Bulk LiqT$_{default}$	T_{aa}
Tank VOC Mol Weight$_{default}$	50
Mole Fraction$_{default}$	0.9
Tank Avg Liquid Hgt$_{default}$	0.5 × Tank Shell Hgt

To estimate HAP emissions, BOEM applied the speciation profile from Table 4-2 to the VOC emissions.

4.2.16 Cold Vents

Production facilities often discharge natural gas to the atmosphere via vents, without combustion. The discharges can be due to routine or emergency releases. Vents receive exhaust streams from miscellaneous sources, as well as manifold exhaust streams from other equipment on the same platform, such as amine units, glycol dehydrators, loading operations, and storage tanks. Emissions from vents were calculated based on the volume of gas vented from miscellaneous equipment (including periods of upset venting but not including volume from equipment that are vented locally) and the chemical composition of the gas. Activity data were submitted for 540 cold vents.

Vent emissions of VOC were estimated using the following equation:

$$E_{\text{vent, VOC}} = C_{\text{VOC}} \times \frac{10^{-6}}{\text{ppm}} \times \frac{m_{\text{VOC}}}{379.4\ \text{scf/lb} \cdot \text{mol}} \times 1000 \times (V)$$

Where:

$E_{\text{vent, VOC}}$ = VOC emissions in pounds per month
C_{VOC} = Concentration of VOC in the vent gas (default = 12,700 ppmv)
m_{VOC} = Molecular weight of VOC (lb/lb·mol)
V = Volume of gas vented from miscellaneous sources (Mscf)

Vent emissions of CH_4 were estimated using the following equation:

$$E_{\text{vent, }CH_4} = W_{CH4} \times \frac{\text{sales gas mole weight (lbs/lb} \cdot \text{mol)}}{379.4\ \text{scf/lb} \cdot \text{mol}} \times 1000 \times (V)$$

Where:

$E_{\text{vent, }CH_4}$ = CH_4 emissions in pounds
W_{CH_4} = Weight percent CH_4 (default = 88.165592)
V = Volume of gas vented from miscellaneous sources (Mscf)

Vent emissions of CO_2 were estimated using the following equation:

$$E_{\text{vent, }CO_2} = W_{CO2} \times \frac{\text{sales gas mole weight (lbs/lb} \cdot \text{mol)}}{379.4\ \text{scf/lb} \cdot \text{mol}} \times 1000 \times (V)$$

Where:

$E_{\text{vent, }CO_2}$ = CO_2 emissions in pounds
W_{CO_2} = Weight percent CO_2 (default = 2.04796139)
V = Volume of gas vented from miscellaneous sources (Mscf)

To estimate HAP emissions, BOEM applied the speciation profile from Table 4-2 to the VOC emissions.

4.2.17 Minor Sources

To prepare a complete inventory of OCS oil and natural gas platforms and other sources in the GOM, BOEM requested that operators compiling the GOADS-2017 activity data files submit GOADS-2017 monthly activity records for minor sources (such as caissons, wellhead protectors, and living quarters) and provide information for the structure and complex ID, lease number, area and block number, and location coordinates. Previously, BOEM simply asked operators to identify these platforms as minor sources and assigned surrogate emission estimates. Similar to the 2014 inventory effort, platform operators were asked to provide information needed to develop emission estimates for 2017. If platform structure data were submitted but no equipment records were populated, the BSEE TIMS database was reviewed to confirm the platform type not applied to any platforms. There were 13 platforms submitted without equipment records for 2017. Although BOEM's TIMS database indicated that three of the platforms are minor sources, all 13 were considered to be inactive based on removal dates in TIMS; zero production, throughput, or fuel use reported at the platform level; or months flagged "No Emissions to Report" at the platform level. Surrogate emission estimates were not used for any platforms in 2017. The 13 platforms reported without equipment for the 2017 inventory are not platforms that are considered to be "missing" for the 2017 inventory.

4.2.18 PM Augmentation

The PM emission factors presented in this section for boilers, combustion flare pilots, natural gas engines, and turbines are specifically for PM_{10} filterable (PM_{10}-FIL) and $PM_{2.5}$ filterable ($PM_{2.5}$-FIL). In order to incorporate the data into the USEPA NEI, emission estimates for three additional PM species must be included: PM condensable (PM-CON), PM_{10} primary (PM_{10}-PRI), and $PM_{2.5}$ primary ($PM_{2.5}$-PRI).

The relationships between these PM species are:

$$PM_{10}\text{-PRI} = PM_{10}\text{-FIL} + PM\text{-CON}.$$

$$PM_{2.5}\text{-PRI} = PM_{2.5}\text{-FIL} + PM\text{-CON}.$$

Thus, PM_{10}-PRI is always greater than or equal to PM_{10}-FIL, and $PM_{2.5}$-PRI is always greater than or equal to $PM_{2.5}$-FIL. In addition, PM_{10}-PRI is always equal to or greater than $PM_{2.5}$-PRI.

Emission estimates for the additional PM species were generated using the USEPA Particulate Matter Augmentation Tool, Version 1.2 (USEPA, 2016b). The USEPA Particulate Matter Augmentation Tool is a Microsoft® Access-based utility that automatically calculates missing PM species. Inputs to the tool are process-level PM emissions and source classification codes (SCCs). The tool outputs emissions for any missing PM species. The tool uses size fractionation data from Appendices B.1 and B.2 of *AP-42* or conversion factors to estimate emissions for the missing PM species (USEPA, 2016b).

4.3 Hazardous Air Pollutants

In addition to developing emission estimates for criteria pollutants, criteria pollutant precursors, and GHGs, BOEM also conducted a HAP scoping task for the 2014 inventory effort that included selected oil and natural gas production platforms. For the 2017 inventory effort, BOEM estimated HAP emissions for all active platforms. HAP emission estimates were developed using the GOADS-2017 activity data combined with available HAP emission factors and speciation profiles as described above in Section 4.2. Details on the HAP emission estimation methods for production platforms and the resulting HAP emissions estimates are presented in Appendix A of this report.

5 DEVELOPMENT OF THE NON-PLATFORM EMISSIONS INVENTORY

BOEM developed emission estimates for criteria air pollutants, criteria pollutant precursors, GHGs, and HAPs for non-platform OCS sources operating in Federal waters of the GOM (i.e., west of longitude 87.5°) for the 2017 calendar year. The non-platform sources included in this study are listed below.

Non-platform oil and gas production sources:

- Drilling rigs
- Pipelaying operations
- Support helicopters
- Support vessels (including well stimulation vessels)
- Survey vessels

Non-platform non-oil and gas production sources:

- Biogenic and geogenic sources
- Commercial fishing vessels
- Commercial marine vessels (including cruise ships and lightering services)
- The LOOP
- Military vessels (U.S. Coast Guard)
- Recreational fishing vessels

BOEM developed the 2017 non-platform emission estimates by building upon and enhancing work previously performed in the *Year 2014 Gulfwide Emission Inventory* Study (Wilson et al., 2017). One important improvement was an innovative approach used to develop helicopter emissions. For this inventory, the FAA's NextGen flight management data were used to quantify individual helicopter movements and were derived from speed, location, and elevation data averaged to five-minute intervals. To estimate emissions, the five-minute interval data were linked to helicopter emission rates developed for the fleet of helicopters that provide services to offshore oil and gas operations. Emissions were allocated to the lease blocks where the activity occurred based on the NextGen latitude/longitude coordinates.

AIS data continue to be used in the 2017 inventory to track individual vessel movements and quantify kilowatt-hours of operation. The AIS dataset obtained from PortVision (PortVision, 2018) consists of hourly "snapshot" records that include the vessel name, type, International Maritime Organization (IMO) identification number, Maritime Mobile Service Identity, radio call sign, vessel type, position, actual speed, and time stamp of the data transmittal. As in previous Gulfwide inventories, emissions were calculated for all diesel-powered vessels by applying activity estimates in terms of kilowatt-hours to the USEPA's latest commercial marine vessel emission factors from the 2017 NEI that account for use of North America Emission Control Area (ECA) compliant fuels for both domestic- and foreign-registered vessels equipped with Category 3 engines and use of ultra-low sulfur fuels for U.S. flagged vessels equipped with Category 1 and 2 engines.

Notwithstanding, some vessel types were underrepresented in the AIS data, such that alternative activity and spatial representation approaches were required.

For example, Naval vessels typically turn off their AIS transponders while conducting training exercises and practices. However, the U.S. Navy provided a copy of their environmental impact assessment that documented very little activity in the GOM. This information allowed for the removal of Naval vessel data in the 2017 inventory.

After mapping of U.S. Coast Guard (USCG) AIS observations, it was clear that vessels were operating their AIS transmitters intermittently. Lacking consistent AIS observations, the data were insufficient for activity calculations and ultimately too limited to be representative of their operations. For those reasons, activity/emissions estimation and allocation methods from 2014 were used.

Similarly, commercial and recreational fishing appear to be undercounted in the AIS data, as these smaller vessels do not trigger mandatory participation in the program. Although overall activity reported in the AIS data was lower than anticipated, the spatial pattern of activity appeared representative of overall activity. As a result, the traffic pattern of fishing vessel activity derived from AIS data was used to spatially allocate 2017 fishing activity provided by National Oceanic and Atmospheric Administration (NOAA) (Maiello, 2018; Larkin, 2018; Hart, 2018).

For previous Gulfwide inventories, seabed anomaly data were used to determine possible locations of geogenic seepage of crude. The drawback of this approach was that it was difficult to determine when the events occurred. For this inventory, 2017 monthly satellite data were used to identify the locations and volume of surface water slicks associated with non-anthropogenic releases. The use of these monthly snapshots allowed for a more accurate assessment of seepage locations as well as improved temporal resolution. The 2017 inventory also provides better mapping of biogenic N_2O emissions to the hypoxic zone of the GOM where these emissions are most likely to occur (SEAMAP, 2017).

5.1 Marine Diesel Vessel Emission Estimation Approach, Emission Factors and Hazardous Air Pollutant Speciation Profiles

All marine vessel main propulsion and auxiliary engines are diesel powered, whether they are used on drilling rigs, vessels involved in platform and pipeline construction or removal, support or survey vessels, well stimulation vessels, large fishing boats, commercial marine vessels, or military ships. Diesel marine engine emissions were calculated for all vessel categories using the following equation:

$$E_C = Ah \times kW \times LF \times EF \times 1.10231 \times 10^{-6}$$

Where:

E_c	=	Criteria pollutant emissions (tons)
Ah	=	Duration (hours)
kW	=	Vessel power (totaling individual propulsion engines) (kW)
LF	=	Engine load factor (unitless)
EF	=	Emission factor (g/kWh)
1.10231×10^{-6}	=	Grams to tons conversion factor

The AIS data were requested in hourly increments for the area of interest. Note that some vessels are not observed hourly, due in part to interruptions in AIS transmittals or equipment error. To fill missing transmittal gaps, vessel records were arranged chronologically, and the duration between observations was calculated by comparing consecutive time stamps.

The kW rating for specific vessels was obtained for the most part from the Information Handling Service Registry of Ships (ROS) (IHS, 2015). Where vessels could not be matched to their specific engine characteristics, default power ratings were developed from available data by vessel type or obtained from citable references such as USEPA (2009), RigZone (2016), U.S. Coast Guard (2018), and Dudley (2018).

Where AIS data were used, the propulsion operating load factor was calculated by applying the actual speed and the vessel’s maximum design speed to the propeller law:

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

Where:

LF = Load factor (%)
AS = Actual speed (knots)
MS = Maximum speed (knots)

If actual load factors could not be calculated, default load factors were developed from the calculated loads by vessel type or obtained from citable sources.

BOEM also assumed that the auxiliary engines would be operating during cruising, maneuvering, and while idle (actual vessel speed less than 0.20 knots[2]). Table 5-1 presents typical power and operating loads matched to vessels included in this inventory based on USEPA port guidance (USEPA, 2009).

Table 5-1. Auxiliary Operating Loads

Vessel Types	Typical Power (kW)	Propulsion Engine Operating Fraction		
		Cruise	Maneuver	Hotelling
Auto Carrier	2,850	0.15	0.45	0.26
Bulk Carrier	1,776	0.17	0.45	0.10
Buoy Tender	-	-	0.45	0.22
Container	6,800	0.13	0.48	0.19
Crude Oil Tanker	1,985	0.24	0.33	0.26
Cruise Ship	11,000	0.80	0.80	0.64
Drilling	-	-	0.45	0.22
Fishing	-	-	0.45	0.22
Floating Production Storage and Offloading (FPSO)	-	-	0.45	0.22
General Cargo	1,776	0.17	0.45	0.22
Icebreaker	-	-	0.45	0.22
Jack-up	-	-	0.45	0.22
Liquified Natural Gas (LNG) Tanker	1,985	0.24	0.33	0.26
Liquified Petroleum Gas (LPG) Tanker	1,985	0.24	0.33	0.26
Miscellaneous	-	-	0.45	0.22
Pipelaying	-	0.15	0.45	0.22
Reefer	3,900	0.20	0.67	0.32
Research	-	-	0.45	0.22
Roll-On/Roll-Off (RORO)	2,850	0.15	0.45	0.26
Supply	-	-	0.45	0.22
Support	-	-	0.45	0.22
Tanker	1,985	0.24	0.33	0.26
Tug	-	0.17	0.45	0.22
Well Stimulation	-	-	0.45	0.22

2 For the purpose of this study, a value of 0.2 knots is used to identify stationary vessels, which is the same value used in the BOEM/NOAA AIS data handler (BOEM/NOAA, 2013) to denote the end of a voyage. Other speed definitions for stationary vessels range from 0.1 knots (Zhan et al., 2016) to 0.5 knots (Marinetraffic, 2018).

While the vessel was stationary, BOEM assumed that propulsion engines were operating at 10% load and the auxiliary engines were operating at the loads noted in Table 5-1. Figure 5-1 shows how vessel speed, engine information, and load factors are combined to calculate activity and emissions by mode.

The emission factors used in this inventory were obtained from the USEPA's 2017 and NEI (USEPA, 2016a, 2019). The USEPA emission factors vary depending upon the engine that the vessel uses for propulsion and fall into three categories based on engine size. Category 1 (C1) engines have a cylinder displacement less than 5 liters, Category 2 (C2) engines have a cylinder displacement between 5 and 30 liters, and Category 3 (C3) engines have a cylinder displacement greater than 30 liters. The IHS ROS includes data on the cylinder diameter and stroke length, which were used to calculate cylinder volume, allowing the engine to be assigned to an appropriate USEPA category. It should be noted that the ROS tends to document vessels equipped with C3 propulsion engines well but includes few vessels equipped with C1 and C2 engines. Therefore, if a vessel was not included in the ROS, it was believed to be one of the smaller C1 or C2 vessels. For these smaller vessels, a variety of alternative data sources were considered (e.g., literature or web searches, Federal Communications Commission (FCC) pleasure craft datasets, and USEPA studies) in determining the vessel category. Table 5-2 shows AIS vessel count by vessel type and USEPA category. Because of the declining price of Type B transmitters, the number of tugs that send AIS signals has increased since 2014.

Table 5-2. 2017 Vessel Count by Category and Type

Vessel Type	Vessel Engine Category			Vessel Count
	C1	C2	C3	
Auto Carrier	0	0	220	220
Bulk Carrier	0	0	2,183	2,183
Chemical Tanker	0	16	1,291	1,307
Container	0	0	337	337
Crude Oil Tanker	0	0	642	642
Cruise	0	1	44	45
Dredging	3	10	2	15
Drilling	161	4	14	179
Ferry	1	67	0	68
Fishing	351	0	0	351
Floating Production Storage and Offloading (FPSO)	0	1	1	2
General Cargo	0	8	706	714
Miscellaneous	112	0	0	112
Oil and Gas Support	1,035	66	6	1,107
Pilot	52	0	0	52
Pipelaying	0	14	10	11
Reefer	0	0	38	38
Research	33	0	0	33
Roll-On/Roll-Off (RORO)	0	3	60	63
Survey	2	32	3	37
Tanker, Liquified Natural Gas (LNG)/Liquified Petroleum Gas (LPG)	0	0	391	391
Tanker, Miscellaneous	0	1	98	99
Tug	90	2,260	13	2,363
Unknown	0	821	0	821
Well Stimulation	5	3	1	6

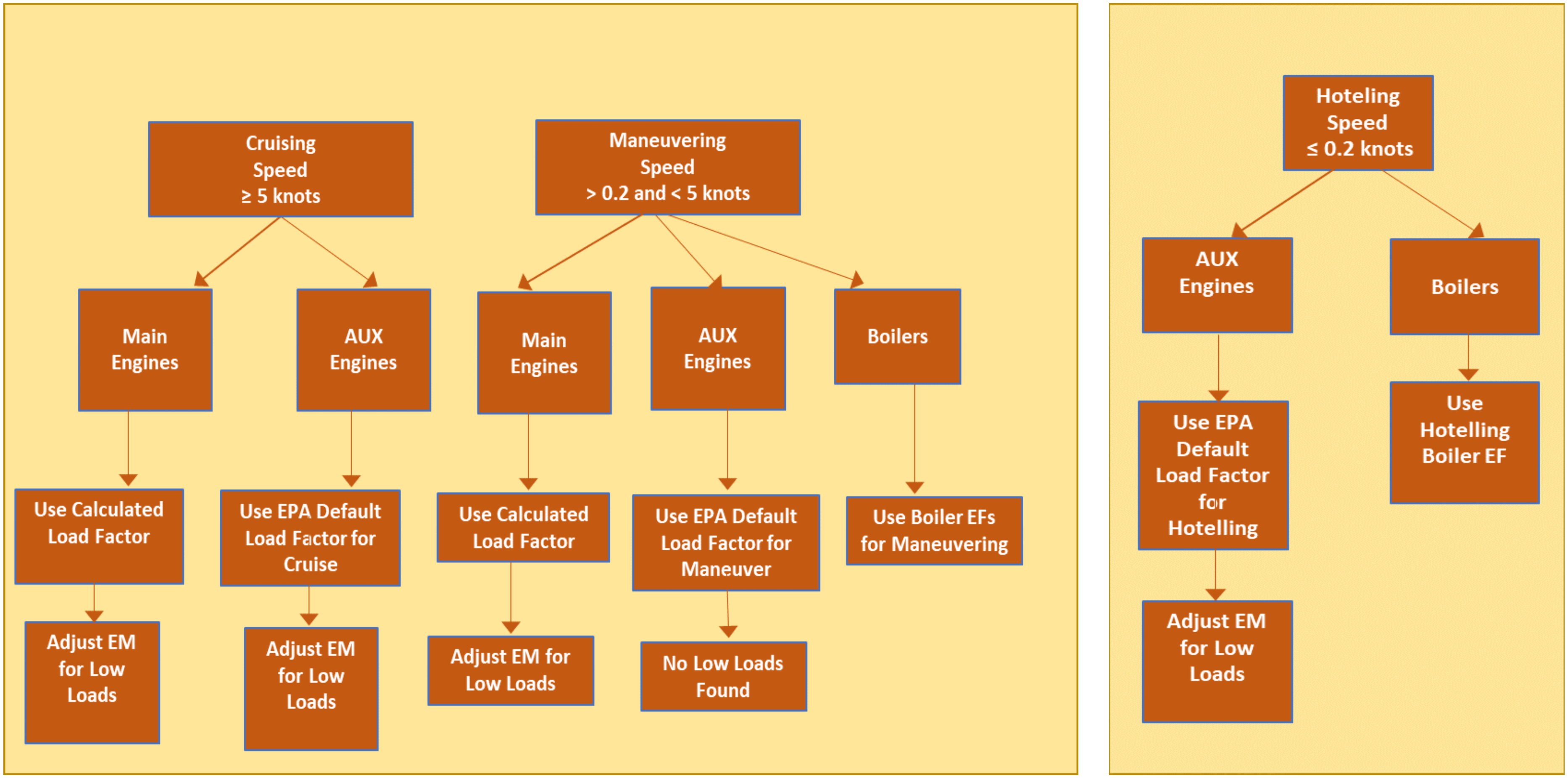


Figure 5-1. Flow Chart of Emission Calculations for Marine Vessels

The C1, C2, and C3 engine categories have different emission standards. Most offshore oil and gas vessels are equipped with C1 and C2 engines, which range in size from something equivalent to a diesel engine used in a bulldozer up to a locomotive engine. Commercial marine vessels involved in international trade tend to be equipped with C3 engines, which are similar to large utility diesel engines. BOEM assumed that marine distillate was used for the C1 and C2 vessels with an ultra-low fuel sulfur content of 15 ppm. For C3 vessels it was assumed that the fuel used was a distillate/residual fuel blend compliant with the requirements for the North America ECA with a sulfur content of 1,000 ppm. BOEM assumed commercial fishing vessels were all powered with C1 engines, and LOOP generators and pumps were assumed to have C2 engines. All U.S. Coast Guard larger buoy tenders and cutters were assumed to be C3, and patrol boats were assumed to be C2. Table 5-3 summarizes the C3 vessel engine emission factors. It was also assumed that these large vessels equipped with C3 propulsion engines were likely to use the same ECA-compliant fuel for their auxiliary engines.

This approach assumes that all vessels with C3 engines switched from the higher sulfur fuels to ECA-compliant fuels prior to entering the ECA area, which corresponds to the outer boundary of Federal waters. Vessel operators also have the option to use higher sulfur fuels in conjunction with scrubbers to reduce sulfur emissions to the level equivalent to fuel switching. For this inventory, it is assumed that there is minimal use of the scrubber option.

Table 5-3. Emission Factors for Vessels Equipped with Category 3 Propulsion Engines

Year Constructed	Tier	Engine Speed[a]	Emission Factors (g/kWh)										
			NO_x	VOC	CO	SO_2	CO_2	PM_{10}	$PM_{2.5}$	Pb	N_2O	CH_4	NH_3
Main Propulsion													
< 2000	0	MSD	13.2	0.53	1.1	0.40	657.23	0.19	0.17	0.00003	0.031	0.004	0.005
< 2000	0	SSD	17	0.63	1.4	0.36	593.11	0.19	0.17	0.00003	0.031	0.006	0.003
< 2000	0	GT	5.7	0.11	0.2	0.59	961.8	0.01	0.009	0.00005	0.08	0.002	0.0004
< 2000	0	ST	2	0.11	0.2	0.59	961.8	0.16	0.15	0.00005	0.08	0.002	0.0004
< 2000	0	LNG	1.3	0.002	1.3	0.32	456.5	0.03	0.03	0.00005	0.08	0.002	0.0004
2000	1	MSD	12.2	0.53	1.1	0.40	657.23	0.19	0.17	0.00003	0.031	0.004	0.005
2000	1	SSD	16	0.63	1.4	0.36	593.11	0.18	0.17	0.00003	0.031	0.006	0.003
2011–2016	2	MSD	10.5	0.53	1.1	0.40	657.23	0.19	0.17	0.00003	0.031	0.004	0.005
2011–2016	2	SSD	14.4	0.63	1.4	0.36	593.11	0.18	0.17	0.00003	0.031	0.006	0.003
≥ 2016	3	MSD	2.6	0.53	1.1	0.40	657.23	0.19	0.17	0.00003	0.031	0.004	0.005
≥ 2016	3	SSD	3.4	0.63	1.4	0.36	593.11	0.18	0.17	0.00003	0.031	0.006	0.003
Auxiliary													
< 2000	0	MSD	10.9	0.42	1.1	0.42	695.70	0.19	0.17	0.00003	0.031	0.004	0.005
< 2000	0	HSD	13.8	0.42	0.9	0.42	695.70	0.19	0.17	0.00003	0.031	0.004	0.005
< 2000	0	LNG	1.3	0.002	1.3	0.32	456.5	0.03	0.03	0.00003	0.031	0.004	0.005
2000	1	MSD	9.8	0.42	1.1	0.42	695.70	0.19	0.17	0.00003	0.031	0.004	0.005
2000	1	HSD	12.2	0.42	0.9	0.42	695.70	0.19	0.17	0.00003	0.031	0.004	0.005
2011–2016	2	MSD	7.7	0.42	1.1	0.42	695.70	0.19	0.17	0.00003	0.031	0.004	0.005
2011–2016	2	HSD	10.5	0.42	0.9	0.42	695.70	0.19	0.17	0.00003	0.031	0.004	0.005
≥ 2016	3	MSD	2	0.42	1.1	0.42	695.70	0.19	0.17	0.00003	0.031	0.004	0.005
≥ 2016	3	HSD	2.6	0.42	0.9	0.42	695.70	0.19	0.17	0.00003	0.031	0.004	0.005
Boiler													
All	0	Boiler	2	0.11	0.2	0.59	961.8	0.20	0.19	0.00005	0.08	0.002	0.0004

Source: USEPA, 2019

[a] MSD = medium speed diesel
HSD = high speed diesel
SSD = slow speed diesel
GT = gas turbine
ST = steam turbine
LNG = liquefied natural gas

Activity data for vessels equipped with C1 and C2 engines were aggregated to match the USEPA's approach used for the NEI, which uses C2 emission factors (Table 5-4) for these vessels, although these factors tend to provide slightly higher emission estimates. For C1 and C2 powered vessels, the emission factors need to take into consideration the USEPA Tier-based engine emission standards, which for this study are based on the IHS date of manufacture relative to the year that the rule was applicable (provided in Table 5-4).

Table 5-4. Tier Emission Factors for Vessels Equipped with Category 1 and 2 Propulsion Engines

Model Year	Tier	NO_x	VOC	CO	SO_2	CO_2	PM_{10}	$PM_{2.5}$	Pb	N_2O	CH_4	NH_3
Prior to 2003	0	13.36	0.14	2.48	0.006	648.16	0.32	0.31	0.00003	0.031	0.004	0.003
2004-2006	1	10.55	0.14	2.48	0.006	648.16	0.32	0.31	0.00003	0.031	0.004	0.003
2007-2013	2	8.33	0.14	2.00	0.006	648.16	0.32	0.31	0.00003	0.031	0.004	0.003
2014-2016	3	5.97	0.07	2.00	0.006	648.16	0.11	0.11	0.00003	0.031	0.004	0.003
2017	4	1.3	0.02	2.00	0.006	648.16	0.03	0.03	0.00003	0.031	0.004	0.003

Source: USEPA, 2016a

***Example Calculation*:**

$$E_C = Ah \times kW \times LF \times EF_C \times 1.10231 \times 10^{-6}$$

Where:

E_c	=	Emissions (tons) for pollutant c
Ah	=	Duration (hours)
kW	=	Vessel power (totaling individual propulsion engines) (kW)
LF	=	Engine load factor (unitless)
EF_C	=	Emission factor (g/kWh) for pollutant c
1.10231×10^{-6}	=	Grams to tons conversion factor

Emissions are estimated using the following formulas for the one-hour duration of a survey vessel constructed in 2014 that is equipped with a C2 engine and has a kW rating of 2,039, load factor of 0.23, and emission factor for NO_x for a C2 Tier 2 engine of 8.33 g/kWh:

$$E = 1\text{hr} \times 2{,}039\text{kW} \times 0.23 \text{ load factor} \times 8.33 \text{ g/kWh} \times 1.10231 \times 10^{-6}$$

$$E = 0.00431 \text{ tons of } NO_x$$

This example represents all AIS-based marine vessel emission calculations. For sources for which AIS data were not used, such as commercial and recreational fishing, additional examples are provided throughout this section.

Based on AIS operating speed data, if an engine load factor is less than 20%, the emissions were adjusted to account for operations outside the engine's optimal design load using the low-load adjustment factors from the USEPA port guidance (USEPA, 2009) provided in Table 5-5.

Table 5-5. Low-load Multiplicative Adjustment Factors

Load (%)	NO_x	HC	CO	PM	SO_2	CO_2
1	11.47	59.28	19.32	19.17	5.99	5.82
2	4.63	21.18	9.68	7.29	3.36	3.28
3	2.92	11.68	6.46	4.33	2.49	2.44
4	2.21	7.71	4.86	3.09	2.05	2.01
5	1.83	5.61	3.89	2.44	1.79	1.76
6	1.60	4.35	3.25	2.04	1.61	1.59
7	1.45	3.52	2.79	1.79	1.49	1.47
8	1.35	2.95	2.45	1.61	1.39	1.38
9	1.27	2.52	2.18	1.48	1.32	1.31
10	1.22	2.20	1.96	1.38	1.26	1.25
11	1.17	1.96	1.79	1.30	1.21	1.21
12	1.14	1.76	1.64	1.24	1.18	1.17
13	1.11	1.60	1.52	1.19	1.14	1.14
14	1.08	1.47	1.41	1.15	1.11	1.11
15	1.06	1.36	1.32	1.11	1.09	1.08
16	1.05	1.26	1.24	1.08	1.07	1.06
17	1.03	1.18	1.17	1.06	1.05	1.04
18	1.02	1.11	1.11	1.04	1.03	1.03
19	1.01	1.05	1.05	1.02	1.01	1.01
20	1.00	1.00	1.00	1.00	1.00	1.00

To estimate monthly emissions, the AIS time stamp data for each vessel record were used to aggregate monthly emission estimates.

In addition to commercial marine vessel emission factors noted above, diesel marine emission factors for recreational fishing vessels were obtained from the USEPA MOVES2014b model (USEPA, 2018) and are provided in Table 5-6.

Table 5-6. Recreational Fishing Vessel Emission Factors (g/kWh)

NO_x	VOC	CO	SO_2	CO_2	PM_{10}	$PM_{2.5}$	Pb	N_2O	CH_4	NH_3
7.113	0.373	1.407	0.007	712.986	0.154	0.150	3.00E-05	0.031	0.004	0.003

Select HAP emissions estimates are also included in this inventory. The following lists HAPs for which emissions-related data were available:

- Acetaldehyde
- Arsenic
- Benzene
- Beryllium
- Cadmium
- Chromium III
- Chromium VI
- Chrysene
- Ethylbenzene
- Formaldehyde
- Hexane
- Mercury
- Naphthalene
- Polycyclic aromatic hydrocarbons (PAHs)
- Toluene
- 2,2,4 Trimethylpentane
- Xylene

In order to estimate HAP emissions from commercial marine vessels, speciation profiles were obtained from the USEPA's NEI (USEPA, 2016a). These profiles estimate what fraction of the VOC emission is a specified organic HAP or the fraction of PM emissions is a specified metallic HAP. A complete list of HAP profiles for marine diesel engines is provided in Appendix B. The compiled speciation profiles were applied to the VOC or PM emission estimates to calculate the associated HAP emissions using the following equation.

$$E_{HAP\ i} = E_c \times SP_i$$

Where:

E_{HAP} = HAP Emission estimate (tons/year) for pollutant i:
E_c = Criteria pollutant emissions (VOC or PM tons /year)
SP_i = VOC or PM speciation fraction for pollutant i

Example HAP Calculation:

To estimate benzene from a vessel with underway VOC emissions of 4.7854 tons per year, the benzene/ VOC factor is 0.012715 and can be applied to the following equation:

$$E_{HAP\ i} = E_c \times SP_i$$

$E_{HAP\ benzene} = 4.7854 \times 0.012715$

$E_{HAP\ benzene} = 0.0608$ (tons/year)

5.2 Oil and Gas Production-Related Non-Platform Sources

Non-platform oil and gas production-related emission sources include:

- Survey vessels that identify oil-bearing locations and map ocean floors to support design and construction of production platforms
- Mobile drilling units such as jackups, submersibles, semisubmersibles, platform rigs, and drill ships
- Pipelaying vessels
- Support vessels that assist in exploration, construction and removal of production platforms, construction and maintenance of pipelines, development and maintenance of subsea systems (including well simulation vessels), and carry supplies, equipment, and personnel to production platforms
- Support helicopters that carry supplies and personnel to and from the platforms

5.2.1 Survey Vessels

Survey vessels are used in the GOM to map geologic formations and seismic properties. These survey mapping activities are needed to evaluate potential oil reserves, evaluate underwater topography, and assess platform construction issues. The most common survey technique uses blasts from underwater air guns. The sound waves from the air gun blasts are deflected by underground geologic strata and detected by sound wave receptors trailed behind the survey vessel. There are two types of surveys that can be performed: two dimensional (2-D) and three dimensional (3-D). 3-D surveys are the dominant and preferred exploration technique in the GOM. Most modern survey vessels tow multiple streamers (sound wave reception devices), such that for every linear mile traveled, they acquire data for a square mile of subsurface area (Brinkman, 2002).

Using AIS data for 2017 allowed BOEM to identify all 37 survey vessels. The AIS data include details concerning the locations where these vessels operated and the duration of their activities. Emission estimates were developed for individual vessels included in the AIS data and summed within lease blocks.

Emissions associated with survey vessels are primarily from marine diesel engines used for propulsion and to provide electricity and compressed air to operate the survey equipment. Emissions were estimated by applying the AIS-derived duration hours and load factors to the marine engine emission factors provided in Tables 5-3 and 5-4. Actual engine loads may be higher than what is calculated by the propeller law, as the vessel speed may be reduced because the vessels are pulling an array of sound wave receivers. Low-load adjustments were made for calculated propulsion operating loads based on AIS actual vessel speeds. For vessels with propulsion engine operating loads less than 20%, the adjustment factors in Table 5-5 were applied to the emissions estimate to account for increased emissions at low-load operations.

The estimates from survey operations were provided for each month based on the month indicated in the AIS date time stamp (Table 5-7).

Table 5-7. Monthly Survey Vessel Profile

Month	2017 Percent of Annual Activity (%)
January	5
February	7
March	4
April	4
May	1
June	1
July	1
August	2
September	13
October	24
November	26
December	12

5.2.2 Drilling Vessels

Drilling vessels are used for exploratory drilling to supplement the geologic information provided by survey vessels. The drilling rig bores into the ocean floor by turning a drill bit attached to lengths of tubular pipe. Several different types of drill rigs operate in the GOM, including barges, jackups, semisubmersibles, submersibles, platform rigs, and drill ships. For the 2017 inventories, no barges or submersibles were used in Federal waters of the GOM.

All drill ships and some of the semisubmersibles are self-propelled. Jackups and platform rigs are not self-propelled. Only self-propelled drilling vessels are included in the AIS dataset. Application of the appropriate drilling rig varies relative to the water depth where they operate. For example, jackups can work in water up to 375 feet deep, semisubmersibles operate in water with depths of 300 to 2,000 feet, drill ships operate in waters with depths greater than 2,000 feet, and drilling platforms can be attached to any rig or stationary platform regardless of depth.

BOEM's Engineering and Operations Division/Operation and Analysis Branch provided 2017 activity data for 104 drilling rigs by block (Mathews, 2018). Because only self-propelled drill ships and semisubmersibles are included in the AIS dataset, the BOEM dataset was used for the non-self-propelled vessels. Emission estimates were developed for 26 non-self-propelled rigs that were not identified in the platform GOADS submittals (as discussed in Section 4.2.4). Emissions were estimated for the top drive, mud pump, and 10% of thrusters; these were assumed to be running 24 hours a day for each day of drilling. For emergency power, previous assumptions of 500 hours annual were used again with the emergency power rating.

The drilling rig names and IMO identifying codes in the AIS dataset were matched to vessels in the RigZone database (RigZone Data Center, 2016) and other sources including IHS's ROS. RigZone is an oil and gas trade service that monitors drilling rigs; its database includes details concerning the drilling rig propulsion engines, prime engines, mud pumps, draw works, and emergency power. By matching the BOEM drilling rig vessels to vessel characteristics in the RigZone and IHS databases, accurate engine and equipment data were used to estimate emissions. Where RigZone or IHS did not include a vessel in the AIS dataset, the RigZone data were averaged by drilling rig type to gap-fill missing data. The average engine kW ratings used to gap-fill missing non-AIS data are shown in Table 5-8.

Table 5-8. Continuously Used Equipment kW Ratings by Drilling Rig Type

Rig Type[a]	Average Total Main Power (kW)	Average Total Emergency (kW)
Dynamic Positioning Semisubmersible	6,939	2,813
Jack-up	3,099	1,131
Platform Rig	8,239	[b]
Semisubmersible	2,810	2,813

[a] Not self-propelled, although some semisubmersibles are moved to site by support vessels; they maintain their stationary position using a dynamic positioning system.
[b] Unknown.

When the drilling rigs have reached their site as documented by BOEM (for non-self-propelled rigs) or have an AIS speed equal to or less than 0.2 knots indicating that they are stationary, BOEM assumed that the vessel's main power is applied to drilling operations (engine load of 80%) during this period. The operating load factor was applied to the kW rating of each rig and the hours that the rig spent at a block to estimate kW-hrs. These kWh values were applied to the emission factors provided in Tables 5-3 and 5-4 (USEPA, 2019) based on the engine category, and if the vessel was a U.S. flagged C1 or C2 powered vessel, by Tier level. The Tier 0 emission factors were used for foreign flagged C1 or C2 vessels as applicable regulatory compliance is unknown. The non-self-propelled, continuously used equipment were assumed to be working at 100% load 24 hours a day per day of drilling. The equipment kW ratings were applied to the hours of drilling.

Drilling rigs with propulsion engines include some semisubmersible rigs and all drill ships, both of which typically use their thrusters to maintain the vessel's drilling position at the drill site. These engines tend to operate at relatively low loads and/or run fewer engines at higher loads with electric-powered thrusters to keep the vessel in place (dynamic positioning). BOEM assumed that propulsion engines operate at 10% load to maintain the rig's position.

Transit emissions for drill ships and semisubmersibles were quantified by applying the kW rating of each vessel's propulsion engines to the duration and engine operating load developed from the AIS data. Jackups, platform rigs and some semisubmersibles are typically moved to and from drilling sites by tugs or other support vessels that are captured in the AIS support vessel data.

Emissions associated with emergency power generation were quantified using USEPA guidance for land-based emergency generators assuming operations of 500 hours per year to account for maintenance checks, operator training, and power outages (USEPA, 1995).

Drilling operations were mapped to the lease blocks where the activity occurred based on BOEM drilling logs and AIS data, as shown in Figure 5-2.

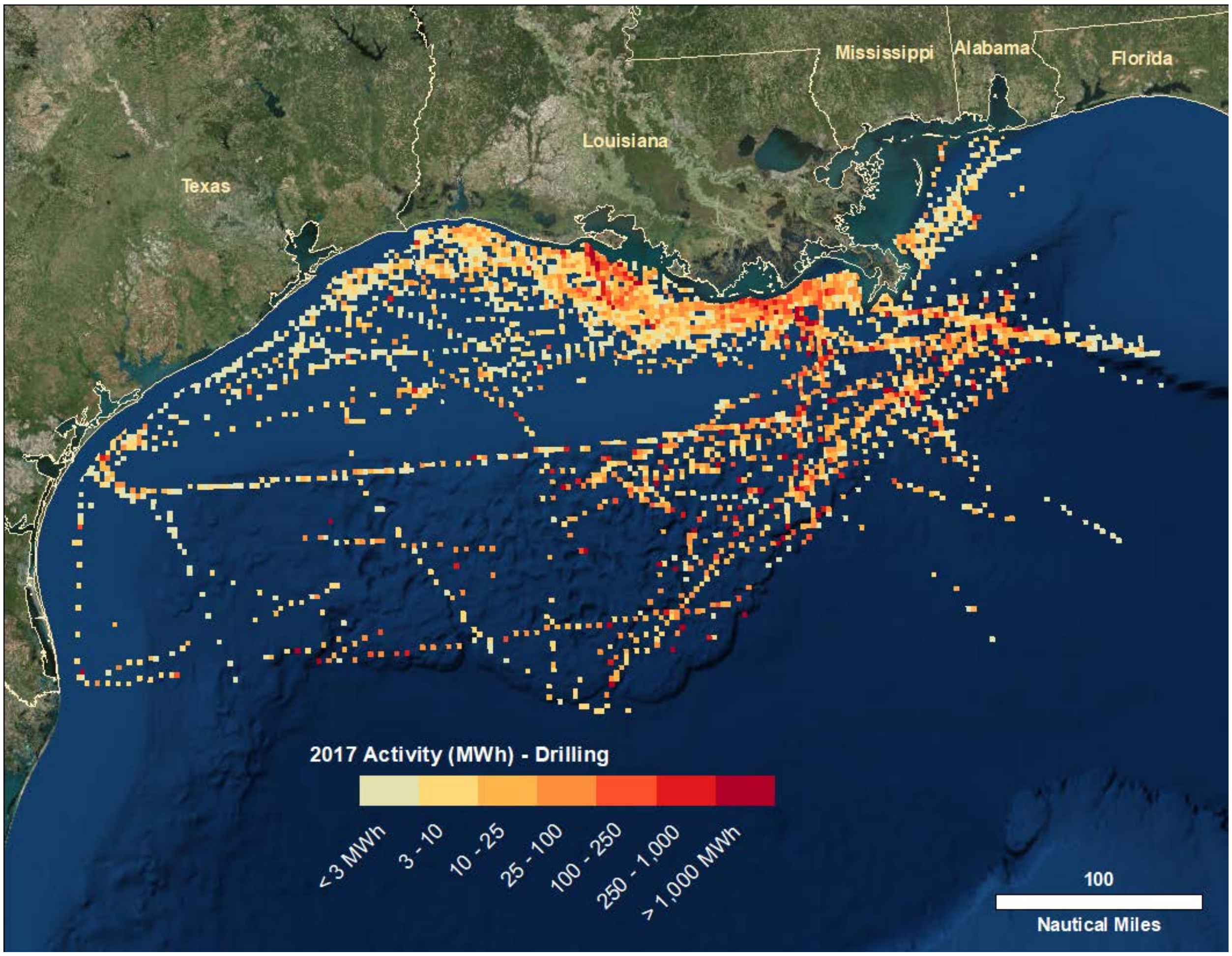


Figure 5-2. 2017 Self-propelled Drilling Vessel Activity

The monthly emission estimates for drilling operations were based on the AIS date time stamp or the month included in the BOEM drilling rig log (Table 5-9).

Table 5-9. Monthly Drilling Rig Activity as Percent of Annual 2017 Activity

Month	Non-Self-Propelled (%)	Self-Propelled (%)
January	7.6	23
February	7.0	8
March	7.1	16
April	6.2	10
May	7.0	13
June	7.9	14
July	8.1	3
August	8.7	2
September	9.0	3
October	8.9	6
November	10.2	1
December	12.4	1

5.2.3 Pipelaying Operations

Product from oil platforms is generally transported to shore through pipelines. New pipelines are constantly being laid, linking new wellheads and platforms to shore or increasing the capacity of the existing pipeline network. Pipelines also require occasional maintenance and repair. To install, maintain, or replace sections of pipeline, considerable vessel support is required. For the 2017 inventory, pipelaying vessels that operate in the GOM were identified in the AIS data and linked to their actual vessel power. Operating hours were estimated based on the period of time that the vessel was onsite as noted in the AIS data. Propulsion engine load was estimated using the propeller law in conjunction with the actual vessel speed and maximum design speed. As noted previously, many of the operational assumptions used in the past Gulfwide inventories have been replaced with actual engine power data, hours of operation, and engine operating loads.

AIS does not have data on the auxiliary engine operating loads; the load factors presented in Table 5-1 were therefore used (15% load while cruising, 45% load while onsite maneuvering, and 22% while stationary). A pipelaying vessel was considered cruising if its speed was greater than 0.2 knots and working onsite if the maneuvering speed was less or equal to than 0.2 knots.

Emissions associated with pipelaying vessels are attributed to the operation of the primary diesel engine used for propulsion and other smaller diesel engines that are used to run generators, air compressors, welding equipment, or small cranes and winches.

Accidental releases of gas or oil from pipelines during construction or maintenance were not considered in this study.

AIS pipeline construction and repair emissions were mapped to the lease blocks where the activity occurred (shown in Figure 5-3).

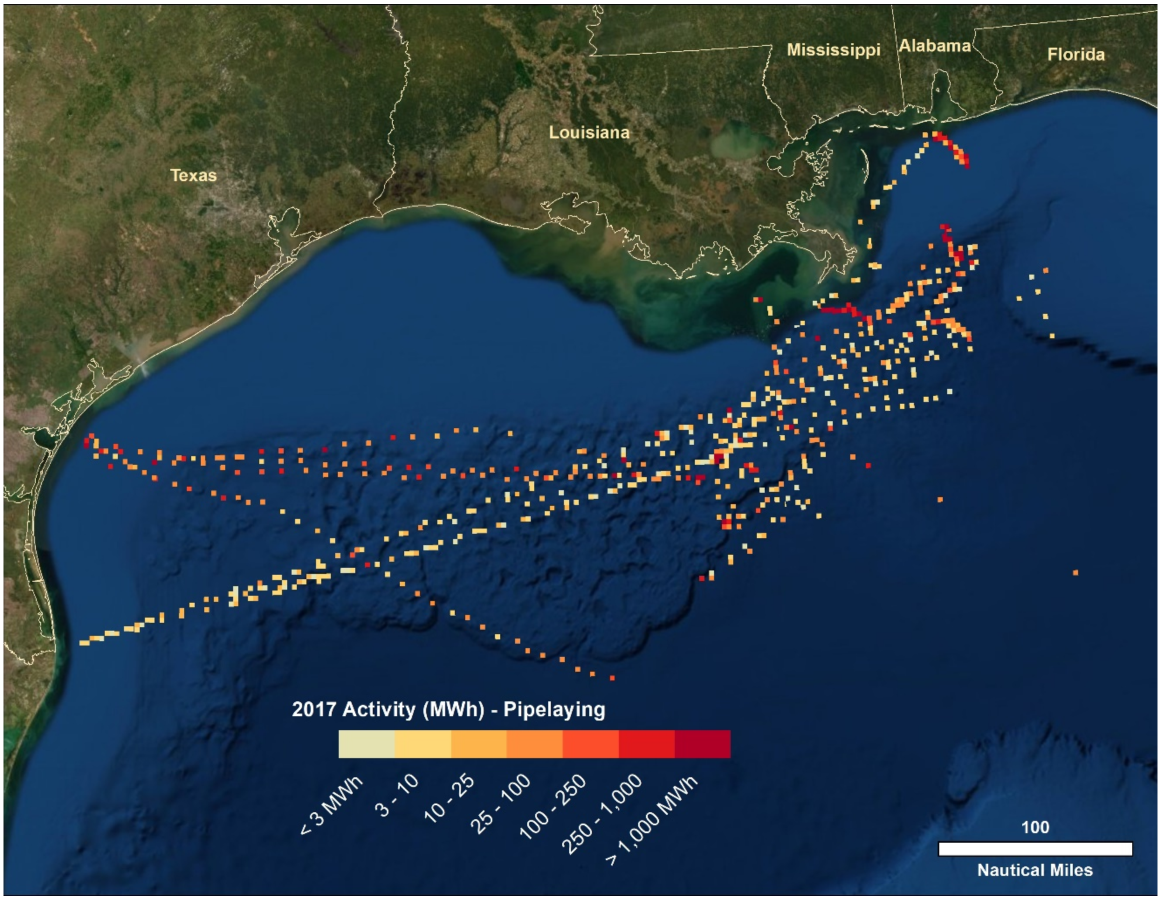


Figure 5-3. 2017 Pipelaying Vessel Activity

The estimates from pipelaying operations were provided for each month based on the month indicated in the AIS date time stamp (Table 5-10).

Table 5-10. Monthly Pipelaying Operation Profile

Month	Percent of Annual 2017 Activity (%)
January	1
February	2
March	3
April	3
May	1
June	2
July	20
August	2
September	3
October	5
November	17
December	42

5.2.4 Support Vessels

Support vessels include crew boats that transport workers to and from work sites, supply vessels that carry supplies to offshore sites, and tug and tow boats that transport heavy equipment and supplies. Emissions associated with support vessels are attributed to the operation of the primary diesel engine used for propulsion and other smaller diesel engines that are used to run generators or small cranes and winches for loading and unloading the vessels.

The 2017 support vessel data were derived from the AIS dataset. The AIS data included 1,107 vessels; to estimate the emissions for each support vessel, BOEM applied the calculated kW hours of operation to the USEPA emission factors provided in Tables 5-3 and 5-4. Where engine loads were less than 20%, low-load adjustments were made using the factors in Table 5-5.

Figure 5-4 shows the support vessel activity. As anticipated, activity is highest near the coast, where vessels are converging at ports that provide specialized support and supplies for offshore operations.

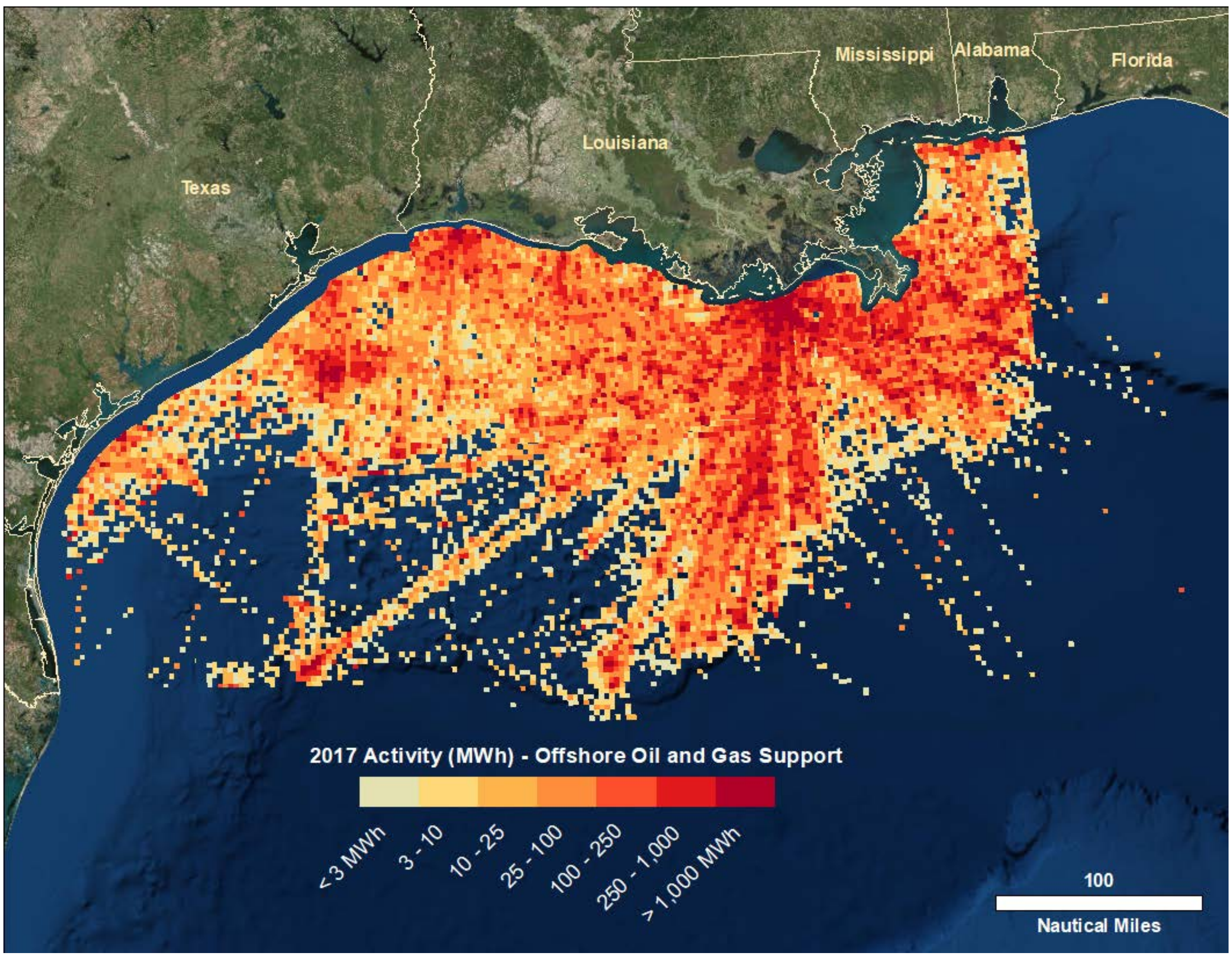


Figure 5-4. 2017 Support Vessel Activity

The estimates from support vessel operations were provided for each month based on the month indicated in the AIS date time stamp (Table 5-11).

Table 5-11. Monthly Support Vessel Profile

Month	Percent of Annual 2017 Activity (%)
January	9
February	9
March	10
April	11
May	12
June	10
July	6
August	16
September	6
October	7
November	7
December	6

Tugs are included in the support vessel emission estimates presented in Section 6. Figure 5-5 shows the 2017 activity for tugs.

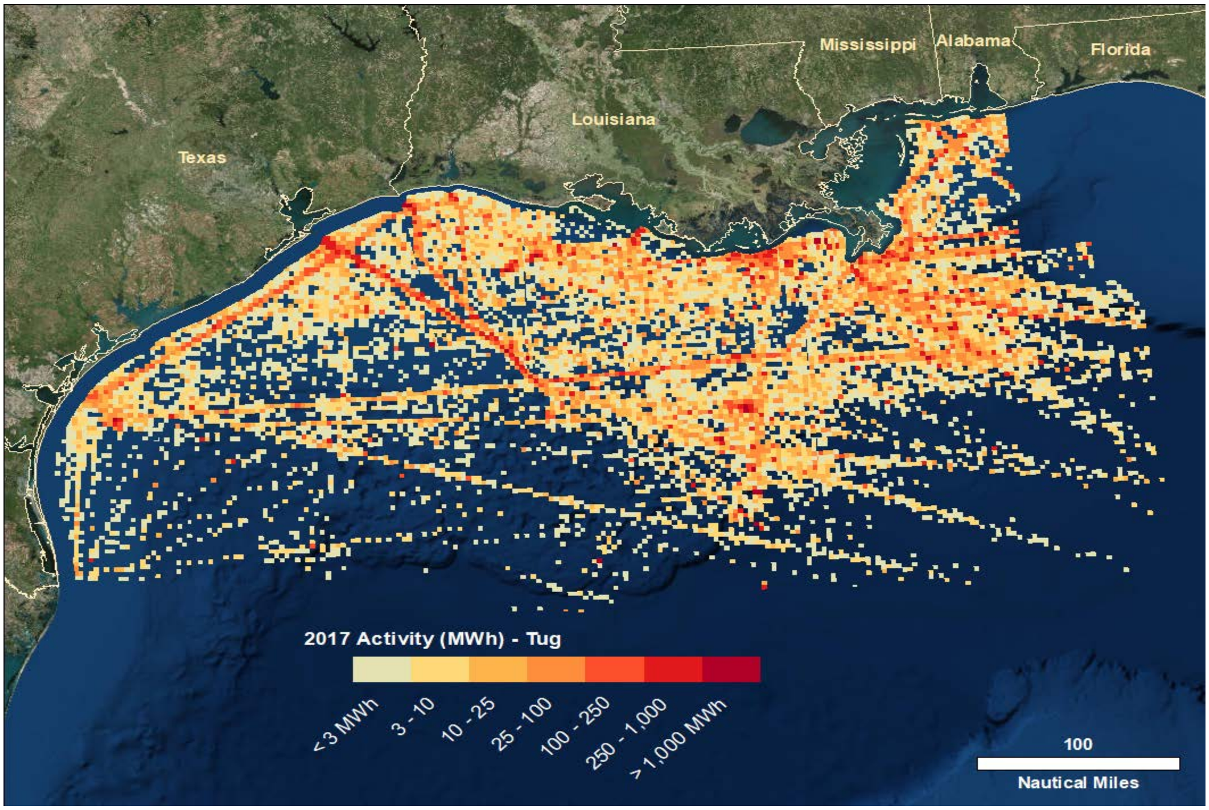


Figure 5-5. 2017 Tug Activity

5.2.5 Support Helicopters

Helicopters are used extensively in the GOM to move light supplies and personnel to and from platforms. In 2017, over 300 helicopters completed nearly 500,000 trips in the GOM, and transported approximately 1.3 million passengers (HSAC, 2017). This level of activity provides special aviation challenges for the GOM area, specifically regarding the navigation and the safety of these operations.

To address these types of challenges, the FAA's NextGen air traffic system is being introduced in select regions of the U.S. Because of the density of helicopter traffic in the GOM, it was selected as one of the locations for the early introduction of this enhanced air traffic management system. This new technology provides Global Positioning System (GPS) satellite-based tracking of the helicopters across the Gulf. When using Automatic Dependent Surveillance-Broadcast (ADS-B), helicopter data are relayed from the rotocraft to ground-based and satellite receivers and then to the Houston Center, where it is combined with radar data, allowing air traffic controllers the ability to accurately monitor helicopter positions and provide safer and more efficient services over the GOM airspace. Figure 5-6 provides an example trip showing the route, including changes in altitude. The red segment represents operations below 500 ft; the orange segment represents operations at 500 to 1,000 feet (approach and climb-out); the yellow segment represents operations at 1,000 to 2,000 feet, the light green segment represents operations at 2,000 feet to 4,000 feet, and the bright green segment represents operations above 4,000 feet (indicating cruising altitudes). Figure 5-6 also shows the location of surrounding platforms (blue dots) while the red dots note the platforms where the example helicopter lands.

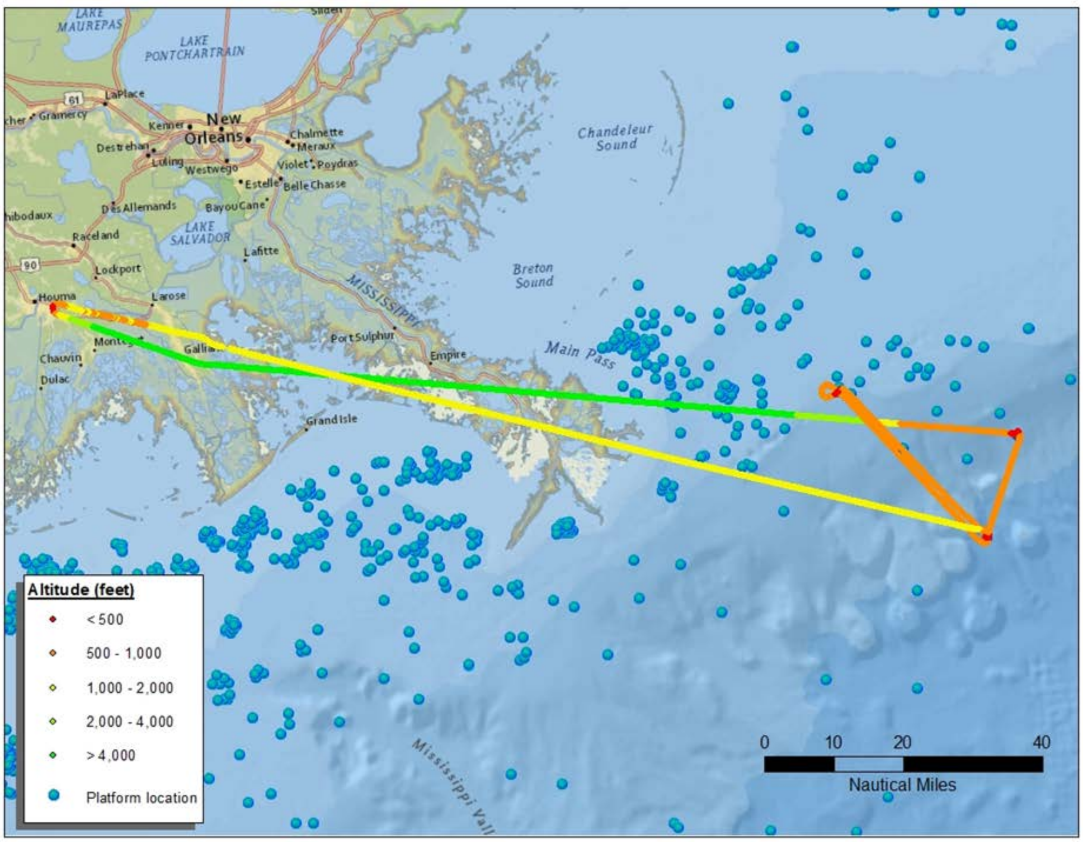


Figure 5-6. Example of Helicopter Tracking

In several ways, NextGen is similar to the AIS vessel tracking system, in that second-by-second data are compiled of individual helicopter movements. For this inventory, 2017 helicopter ADS-B data were preprocessed by the Harris Corporation to include location (latitude/ longitude), elevation, and speed. Because typical helicopter speeds are significantly faster than marine vessel speeds, the sampling frequency of the dataset represents five-minute episodes as opposed to hourly for vessels. Each 5-minute observation was mapped to the associated lease block based on the helicopter's latitude and longitude coordinates.

Helicopter operations differ from fixed wing aircraft, where the engine load varies relative to the operating mode (i.e., approach, landing, taxi, takeoff, climb out, and cruise). Helicopters tend to operate at maximum engine power during most of the trip. Thus, helicopter emission factors in terms of kilograms of pollutant emitted per flight hour were used in this study. These factors were obtained from the Switzerland Federal Office of Civil Aviation's Guidance on the Determination of Helicopter Emissions (FOCA, 2015). Additional emission factors were developed using the fuel usage data from FOCA and data from the U.S. Energy Information Administration (EIA, 2012). All helicopter emission factor data are provided in Appendix B for the helicopter models that operate in the GOM. Because the NextGen data did not provide enough information to identify individual helicopters, the emission factors were weighted based on known helicopters that fly in the GOM. Appendix B also includes the HAP speciation profiles used in the USEPA's 2014 NEI (USEPA, 2016a) for air taxis equipped with turbojet engines. The VOC helicopter emission factors were developed by converting the FOCA hydrocarbon (HC) factors. FOCA provided factors for non-volatile PM, which were considered to be equivalent to PM_{10}. $PM_{2.5}$ factors were speciated from PM_{10} using USEPA aircraft speciation data. SO_2 emission factors were developed based on typical jet fuel sulfur concentration of 0.05% (UNEP, 2012). CO_2, N_2O, and CH_4 emission factors were obtained from the U.S. Energy Information Administration Voluntary Reporting of Greenhouse Gas Program (EIA, 2012). The weighted criteria pollutant and GHG emission factors are provided in Table 5-12.

Table 5-12. Weighted GOM Helicopter Emission Factors (kg/hr)

NO_x	VOC	CO	PM_{10}	$PM_{2.5}$	SO_2	CO_2	N_2O	CH_4
2.392	1.267	1.357	0.068	0.066	0.271	835.818	0.027	0.024

To estimate helicopter emissions using ADS-B data, the compiled emission factors were applied to the 5-minute flight data associated with each observation using the following equation:

$$E = EF \times 0.0167 \times D_i \times 1.1102 \times 10^{-3}$$

Where:

E	=	Emissions for helicopter (tons per year)
EF	=	Emission factor representing the helicopter fleet for the offshore oil and gas operations (Table 5-12) (grams/hour)
0.0167	=	Factor to convert hourly emission rate to 1-minute emission rate
D	=	Duration for event for helicopter i (5 minutes)
1.1102×10^{-3}	=	Factor converting kilograms to tons
i	=	Individual helicopter

Example Calculation:

To estimate NO_x emissions from one 5-minute observation of a helicopter using the following equation:

$$E_i = EF_i \times 0.0167 \times D_i \times 1.1102 \times 10^{-3}$$

EF_i	=	2.392 kilgrams per hour
D	=	5 minutes

$$E_i = 2.392\ kg/hr \times 0.0167\ hr/min \times 5\ minutes \times 1.1102 \times 10^{-3}\ tons/kg$$

$$E_i = 0.22 * 10^{-4}\ tons$$

Helicopter emissions were assigned to lease blocks where the ADS-B observation occurred based on the latitude and longitude coordinate of the observation (Figure 5-7).

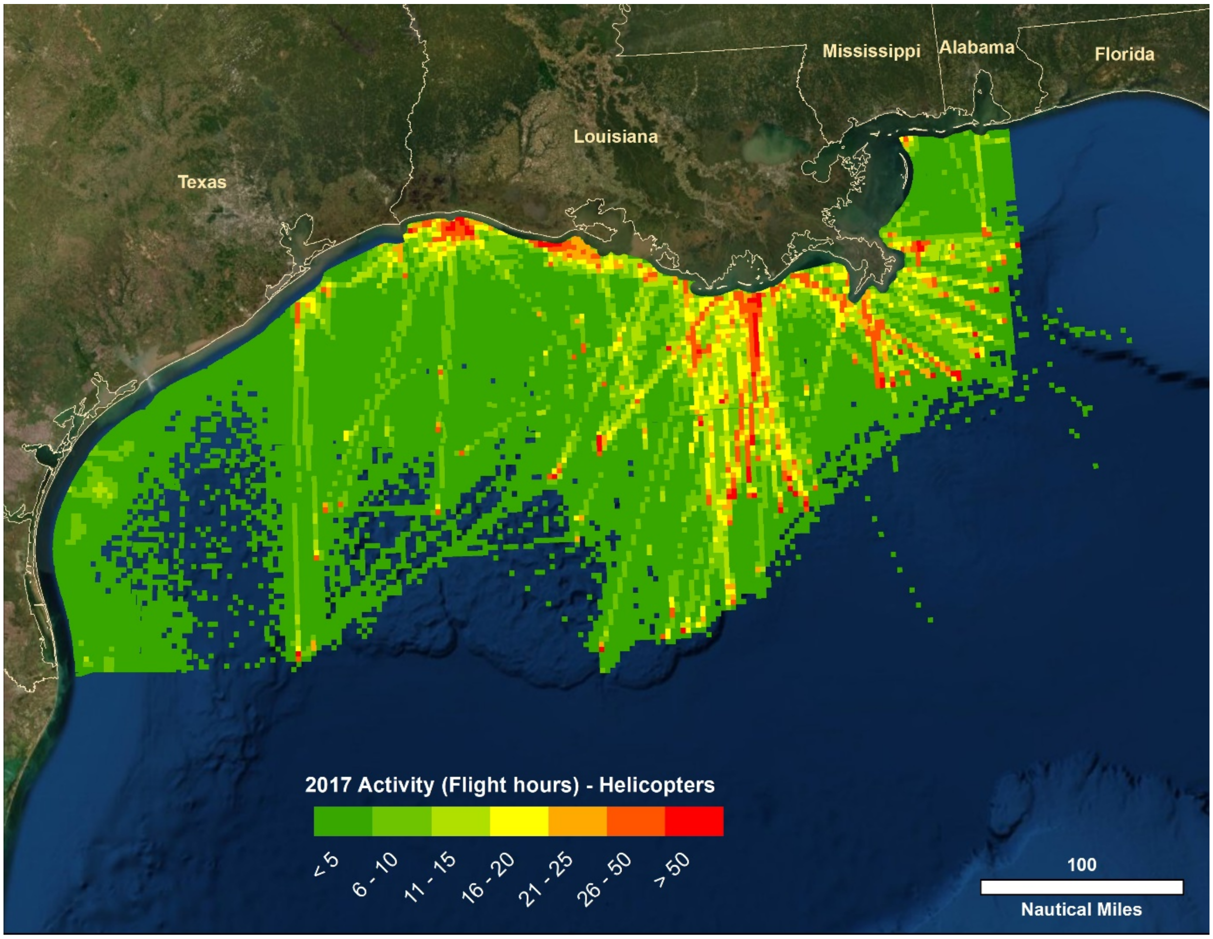


Figure 5-7. 2017 Helicopter Activity

Monthly helicopter data were developed by summing up the activity (hours) by month using the month indicated by the data time stamp included in the data (Table 5-13).

Table 5-13. Monthly Support Helicopter Profile

Month	2017 Monthly Percent of Total Hours (%)
January	7.9
February	7.1
March	7.8
April	7.8
May	8.7
June	8.2
July	9.0
August	8.4
September	9.3
October	9.6
November	8.5
December	7.8

Emissions were estimated for the following HAPs for which helicopter emissions data were available.

- Acetaldehyde
- Benzene
- Ethylbenzene
- Formaldehyde
- Naphthalene
- PAH
- Toluene
- 2,2,4 Trimethylpentane
- Xylene

In order to estimate helicopter HAP emissions, speciation profiles were obtained from the USEPA's 2017 NEI for air taxi turbojets. These profiles estimate what fraction of the VOC emissions is associated with a specified organic HAP or the fraction of PM emissions that is associated with a specified metallic HAP. These speciation profiles were converted into emission factors. A complete list of HAP speciation profiles for helicopters is provided in Appendix B. The compiled speciation profiles were applied to the VOC or PM emission estimates to calculate the associated HAP emissions using the following equation:

$$E_{HAP\ i} = E_c \times SP_i$$

Where:

E_{HAP} = HAP Emission estimate (tons/year) for pollutant i
E_c = Criteria pollutant emissions (VOC or PM tons)
SP_i = VOC or PM speciation fraction for pollutant i

Example HAP Calculation:

To estimate benzene from a helicopter with VOC emissions of 2.178 tons per year, the benzene/VOC factor is 0.01695582 and can be applied to the following equation:

$$E_{HAP\ i} = E_c \times SP_i$$
$$E_{HAP\ benzene} = 2.178 \times 0.01695582$$
$$E_{HAP\ benzene} = 0.0369 \text{ (tons/year)}$$

5.3 Non-Oil and Gas Production-Related Sources

Non-platform emission sources not directly associated with offshore oil and gas operations included in this inventory are:

- Commercial marine vessels (CMVs) that transit the GOM carrying passengers and cargo to and from Gulf ports
- Military vessels (U.S. Coast Guard)
- The LOOP
- Lightering zone operations
- Commercial fishing operations
- Recreational fishing operations
- Biogenic and geogenic sources

AIS data were considered complete for CMVs (including tankers that visit the LOOP and tankers that are involved in lightering operations). The LOOP and lightering zone sources also include non-combustion activities such as crude loading and unloading which generates evaporative emissions; emissions from these sources were also developed based on approaches used in the previous inventories as discussed in Sections 5.3.3 and 5.3.4. As mentioned previously, AIS coverage for military vessels and commercial and recreational fishing vessels does not appear to be complete. Therefore, military and fishing and vessels were identified in the AIS dataset and removed to avoid double counting, and emission estimates for these vessels were developed using approaches similar to those developed for the previous Gulfwide inventories.

5.3.1 Commercial Marine Vessels

CMVs transport a wide range of agricultural, manufacturing, and chemical products through the GOM. CMVs are powered by engines that combust marine diesel fuel which is a blend of distillate and residual oils that are compliant with the North America ECA requirements. These standards went into effect in 2012 limiting fuel sulfur content to 10,000 ppm. In 2015 this limit was further reduced to 1,000 ppm. For the 2017 inventory, AIS data were used to estimate emissions from larger vessels equipped with Category 3 engines that transit the Central and Western Planning Areas of the GOM and a portion of the Eastern Planning Area using North America ECA fuels with a sulfur content of 1,000 ppm. As noted previously, vessels can comply with the ECA standard using high sulfur fuels in conjunction with scrubbers as long as the emissions are at or below the level associated with use of low sulfur fuels; therefore, whether operators choose to use low sulfur fuels or a scrubber, the emissions should be equivalent. Smaller vessels equipped with Category 1 and 2 engines that are fueled at U.S. ports are dispensed ultra-low sulfur content fuels (15 ppm) that comply with a USEPA fuel regulation.

Figures 5-8 through 5-11 show the 2017 AIS CMV vessel traffic for major CMV categories (bulk carriers, cargo ships, containerships, and tankers as identified in the AIS dataset.

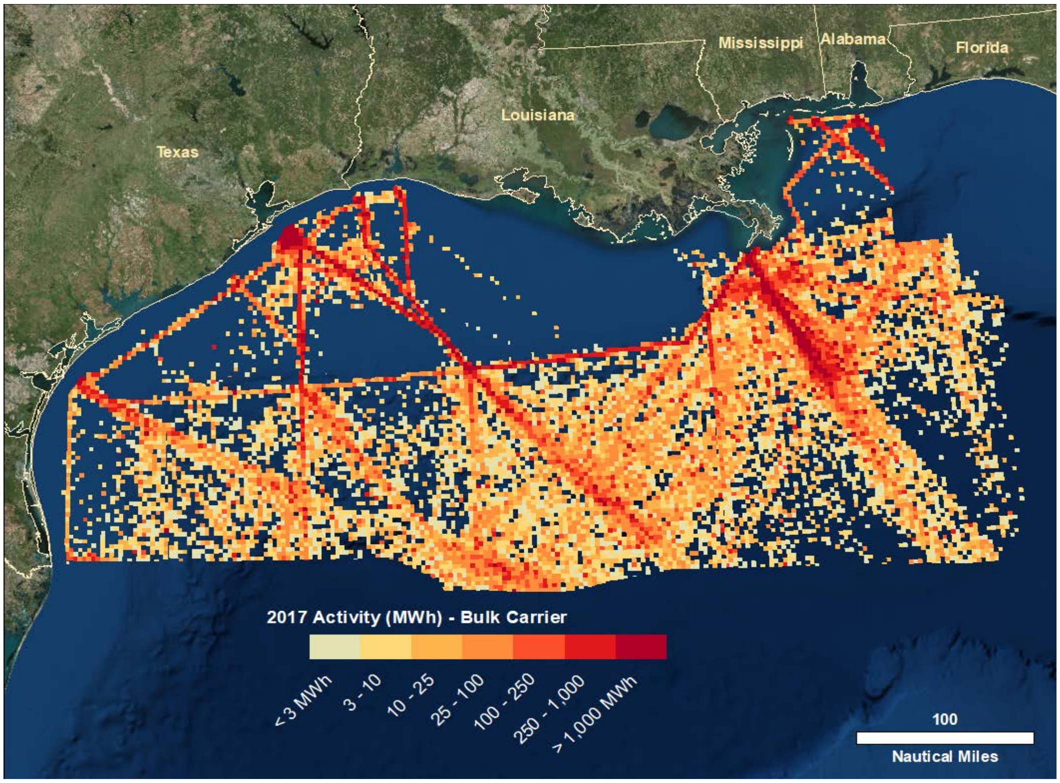


Figure 5-8. 2017 Bulk Carrier Activity

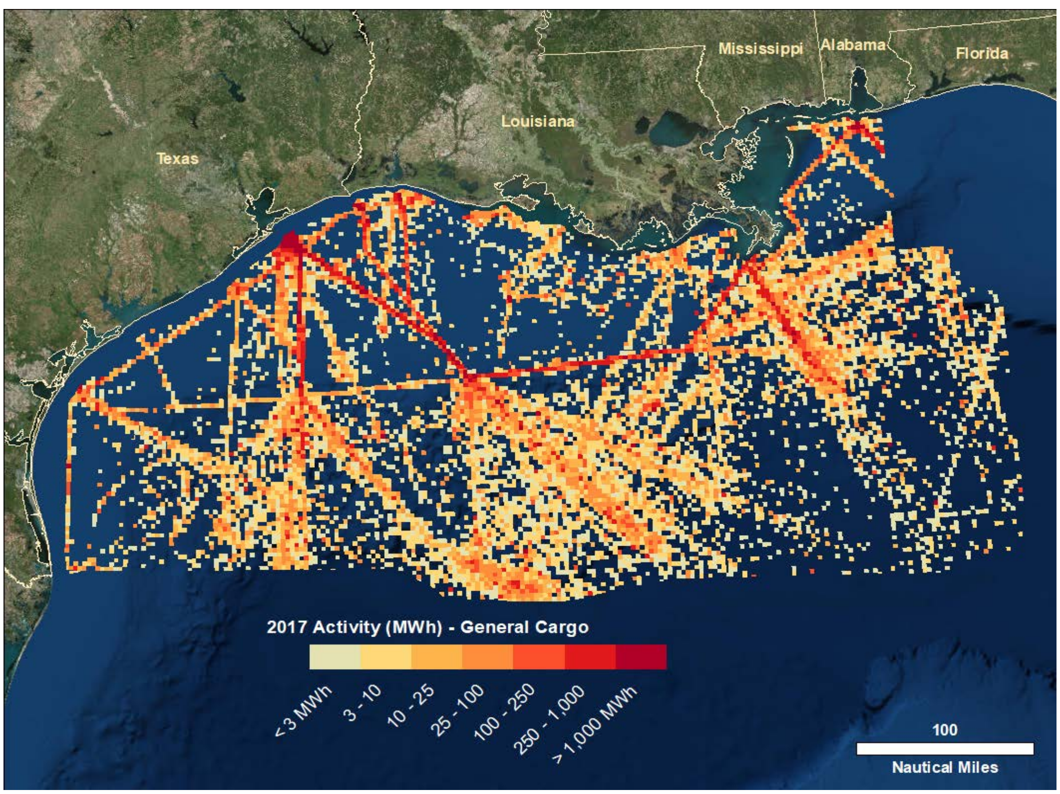


Figure 5-9. 2017 General Cargo Ship Activity

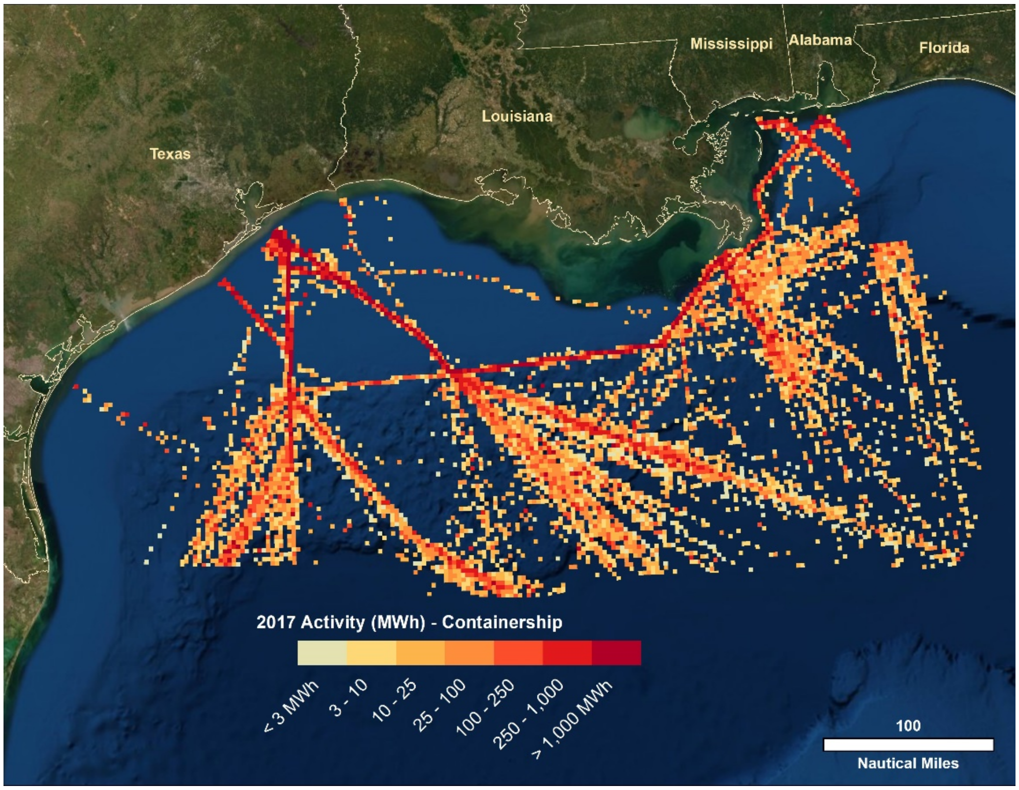


Figure 5-10. 2017 Containership Activity

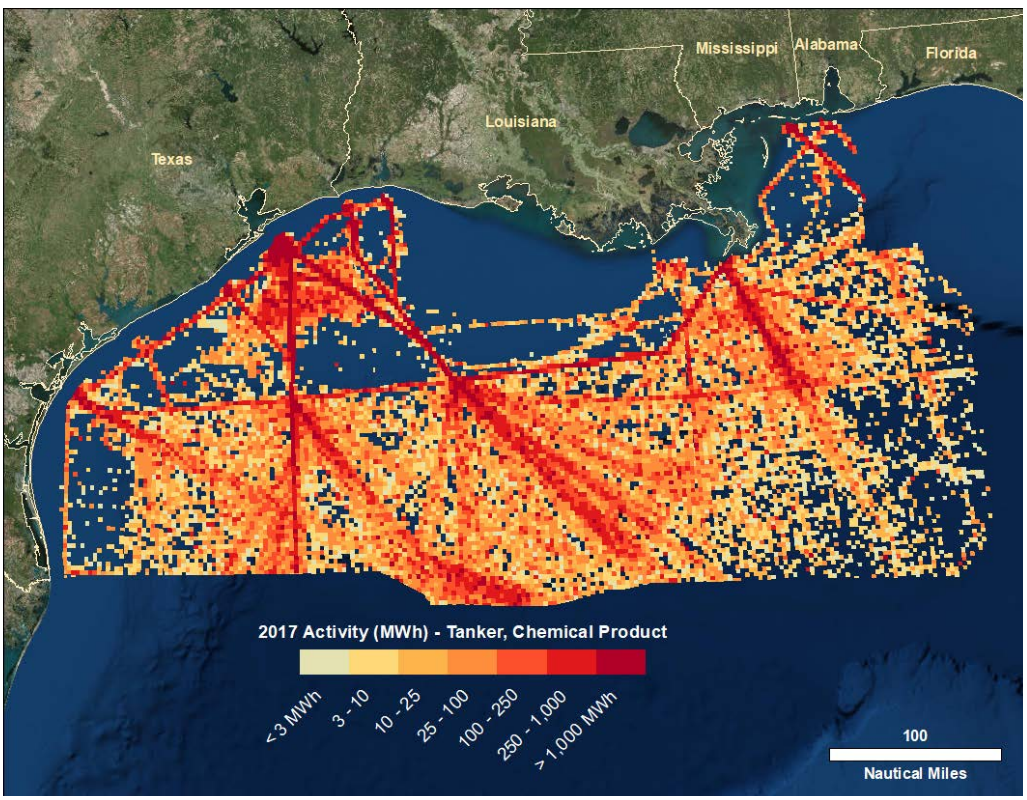


Figure 5-11. 2017 Chemical Product Tanker Activity

The vessel identification codes were matched to vessel and engine characteristics compiled in IHS ROS, including cylinder stroke length and diameter to estimate the USEPA category, vessel type, engine type, country of registration, date of manufacture, maximum speed (used to estimate hourly propulsion engine loads), propulsion engine power rating, and auxiliary engine power rating. Some vessels that could not be matched to vessels in the IHS dataset were matched using data compiled from earlier inventories and online web searches. Over 75% of vessels were matched to their individual characteristics. For vessels that could not be matched, surrogate values were developed using the matched vessels that operate in the GOM.

Emission estimates were developed by applying the AIS-derived vessel duration, propulsion engine load estimates, IHS ROS vessel and engine characteristics, and emission factors using the approach discussed in Section 5.1. Emissions at each AIS data point were then summed by BOEM lease block.

The estimates from CMV operations were provided for each month based on the AIS date time stamp (Table 5-14).

Table 5-14. Monthly Commercial Marine Vessel Profile

Month	2017 Percent Activity by Month (%)
January	8
February	7
March	9
April	8
May	9
June	8
July	8
August	9
September	8
October	9
November	8
December	9

5.3.2 Military Vessels

The U.S. Navy and USCG fleets consist of vessels powered by a variety of engines, including older residual-fueled steam turbines, marine diesel engines, and high-speed diesel turbines.

Over the years, the U.S. Navy's base closure program has shut down the remaining Naval installations in the central and western areas of the Gulf, such that there are no regular Naval operations in the area. Occasionally, the Navy does implement training exercises in the GOM. The U.S. Navy provided a copy of their environmental impact statement for the Atlantic Fleet Training and Testing program (U.S. Navy, 2018); this report noted all offshore areas in the GOM used for training operations. After additional exchanges with Navy staff, it was determined that only one ship training event has occurred in the GOM since 2009, and it took place in the Federal waters south of Pensacola Area, Florida, in BOEM's Eastern Planning Area, outside the area of interest for this inventory (Dobbins-Noble, 2017). BOEM considered this information from the Navy as justification for excluding Naval emissions from this inventory.

The USCG vessel power ratings and hours of operation at in open sea were obtained from the USEPA 2017 NEI. The activity data included kW-hrs of cutters and patrol vessels operating in Federal waters in the Central, the Western, and (a portion of) the Eastern Planning Areas of the GOM. Only data for USCG vessels with home ports in Texas, Mississippi, Louisiana, and Alabama were included. The current dataset accounts for two new vessels added since 2014 (i.e., *Benjamin Dailey* and *Jacob Poroo*), as well as five vessels that are now stationed to the GOM. Table 5-15 summarizes the average hours of operation and horsepower ratings.

Table 5-15. 2017 Horsepower Rating and Hours of Operations by USCG Vessel

Vessel ID	Vessel Name	Horsepower Rating	Engine Category	Hours of Operation
WPB 87305	*Stingray*	3,000	1/2	1,604
WPB 87311	*Cobia*	3,000	1/2	1,917
WLIC 803	*Saginaw*	500	1/2	832.5
WLM 559	*Barbara Mabrity*	3,400	1/2	1,223
WPB 87321	*Coho*	3,000	1/2	2,269
WPB 87372	*Aligator*	3,000	1/2	1,945
WPB 87336	*Sturgeon Bay*	3,000	1/2	1,651
WLIC 800	*Pamlico*	500	1/2	951
WPB 87332	*Razorbill*	3,000	1/2	2,149
WPB 87339	*Pompano*	3,000	1/2	1,867
WMEC 629	*Decisive*	5,000	1/2	3,385
WPB 87356	*Sailfish*	3,000	1/2	1,789
WPB 87359	*Tiger Shark*	3,000	1/2	1,493
WPB 87348	*Brant*	3,000	1/2	1,528
WPB 87363	*Manatee*	3,000	1/2	1,683
WPB 87320	*Manta*	3,000	1/2	1,956
WPB 87330	*Man-O-War*	3,000	1/2	1,968
WPB 87353	*Skipjack*	3,000	1/2	1,870
WLM 561	*Harry Claiborne*	3,400	1/2	1,045
WMEC 624	*Dauntless*	5,000	1/2	3,130
WPB-87325	*Beluga*	3,000	1/2	1,7565
WPC-1123	*Benjamin Dailey*	5,800	1/2	1,312
WPC-1125	*Jacob Poroo*	5,800	1/2	455.9

To estimate emissions from the USCG marine diesel engines, the emission factors presented in Section 5.1 were applied to the hours of operation and the vessel kW rating or kW-hrs. BOEM assumed that the USCG vessels typically operate at a load factor of 85% while in Federal waters.

No monthly USCG data were identified in this effort. BOEM assumed that activity was consistent throughout the year; therefore, annual emission estimates were temporally apportioned to individual months equally (i.e., 8.33%).

All USCG vessel emissions were allocated relative to each vessel's home port and the area where the vessels patrol (Figure 5-12). This allocation was made using the following equation:

$$E_{CGi} = E_{CG}\,(S_i/S_{TD})$$

Where:

E_{CGi} = USCG emissions associated with lease block i (tons)
E_{CG} = Total USCG emissions associated with the home port (tons)
S_i = Surface area of lease block i (square miles)
S_{TD} = Surface area of all lease blocks in USCG district (square miles)

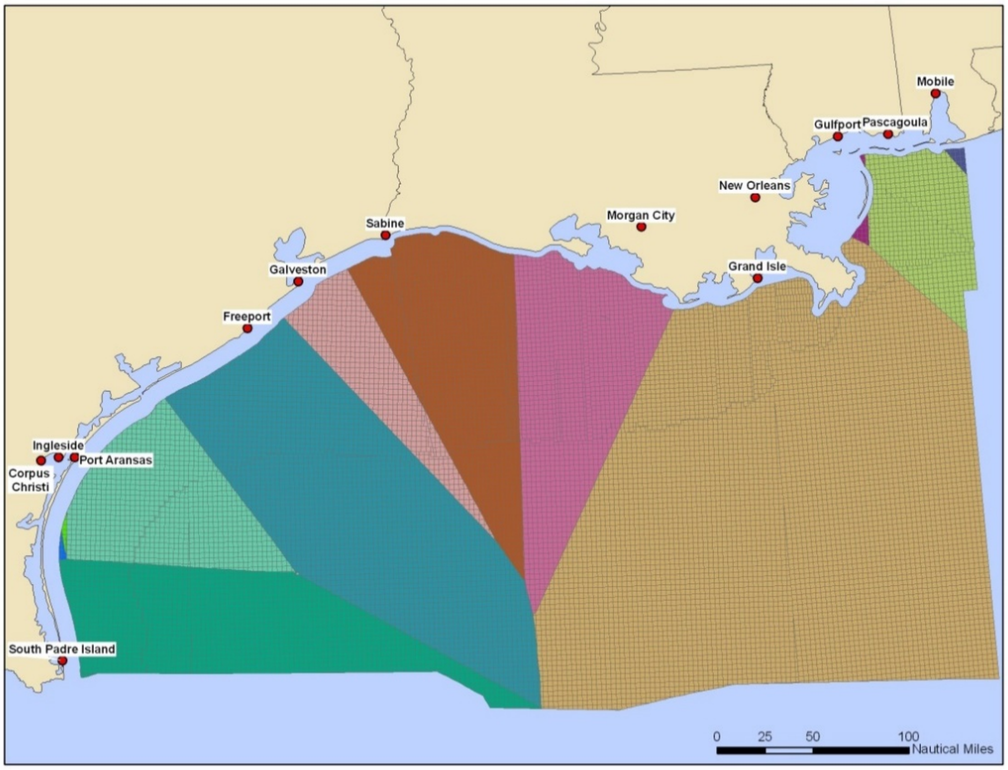


Figure 5-12. USCG Districts Used to Allocate Emissions

5.3.3 Louisiana Offshore Oil Port

The LOOP is located 18 nautical miles offshore from the town of Port Fourchon, LA. This offshore port allows up to three large oil tankers to simultaneously unload product without having to enter and maneuver inside urban ports with dense vessel traffic.

The LOOP consists of several emission sources: one 1,000 kW generator, four 7,500 hp pumps, as well as support vessels and the oil tankers that use the facility. Table 5-16 summarizes the engine characteristics for combustion sources located on the LOOP platform, including kW rating, load factors, and hours of operation.

Table 5-16. LOOP Hours of Operation, kW Rating, and Load Factors

Equipment Type	Hours of Activity	Average kW	Load Factor
Generator	8,566	1,000	0.50
Pumps	3,300	22,371	1.00

The tankers and support vessels associated with the LOOP were included in the AIS datasets; vessel emissions were not calculated separately for LOOP-related operations.

The LOOP was contacted repeatedly for 2017 throughput data to estimate evaporative emissions from offloading crude, but no data were provided. However, a 2017 study documented a decline of 35% in LOOP total crude imports between 2010 and 2016 (RB Energy, 2017; Fielden, 2018). This represents a continuation of the trend noted in the 2014 inventory, which is attributed to an increase in domestic production that has reduced the demand for imported oil. The 2014 LOOP platform activity and combustion emissions data and the evaporative emissions were reduced by 6.5% to account for the continued decline in activity levels in 2017.[3]

No monthly LOOP data were compiled in this effort; BOEM assumed that activity was consistent throughout the year, and therefore annual emission estimates were apportioned to each month equally. LOOP platform and evaporative emissions were all assigned to the latitude and longitude coordinates of the LOOP.

All tankers emit VOCs through evaporative losses from ballasting operations. Ballasting consists of pumping water into a vessel after the product has been removed, providing increased stability for the tanker; as water enters the hold, organic vapors are displaced into the atmosphere. Because evaporative emissions from ballasting were not accounted for in the AIS-based data, the 2014 ballasting emissions were adjusted (decline of 6.5%) to represent 2017 emissions.

5.3.4 Vessel Lightering

Lightering is the offshore transfer of cargo to smaller ships that bring the product into port. The recent increase in exporting crude from the U.S. has led to an increase in reverse lightering, which is the movement of product from port refineries using smaller tankers that carry the product to larger vessels positioned offshore. Lightering operations are critical for the Houston area, given the depth of the ship channel, increasing traffic density, and the complexity of navigating large tankers into and out of the port.

Lightering occurs offshore in three designated areas. Emissions associated with lightering are attributed to the propulsion engines of the vessels involved in lightering, auxiliary engines (e.g., winches and generators), boilers used for pumping, and evaporative emissions associated with ballasting of the large tankers and loading of crude into the shuttle tankers. Combustion emissions from the propulsion engines in large tankers and shuttle tankers involved in the lightering process are included in the AIS CMV data as tankers.

When product is transferred between tankers, vapors in the receiving tanker are displaced into the atmosphere; these evaporative emissions are known as loading losses. Ballasting emissions occur when tankers pump water into empty holds to enhance the stability of the vessel. As water enters the hold during ballasting, vapors are displaced into the atmosphere.

Since 2008, U.S. domestic oil production has increased such that in December 2015 the prohibition on exporting U.S. crude was lifted. For the 2014 inventory, the level of lightering activity was assumed to be 1.635 million barrels per day based on activity data provided by the lightering service companies. The U.S. EIA reported that, in 2017, the U.S. exported 1.1 million barrels per day of crude (EIA, 2018), of which approximately 40% (0.44 million barrels per day) was lightered through the GOM (ClipperData, 2018). To estimate 2017 evaporative emissions for lightering activities, the 2014 values were adjusted based on based on the ratio of lightering throughput between 2014 and 2017.

The evaporative VOC emissions were calculated using the following equations. The volume of crude transferred in barrels shown in Table 5-15 was applied to the equations listed below used to quantify ballasting and loading losses:

---

[3] This value was based on the observation that the reduction between 2010 and 2014, as documented in the previous inventory was 28.5% and an additional 6.5% reduction occurred between 2014 and 2016 to get a 35% reduction between 2010 and 2016.

Example Evaporative Loading Calculation:

$$Ev = \sum ST_c \times 43 \ / \ 1{,}000 \text{ conversion factor} \times TOC \times VOC/TOC \text{ conversion factor} \ / \ 2{,}000$$

Where:

Ev	=	Evaporative loading losses (tons)
ST_c	=	Capacity of shuttle tanker (barrels)
42	=	Barrels to gallons conversion factor
TOC	=	Emission factor for total organic compounds (TOC) emitted from thousand gallons of crude oil transferred (0.86 lb of TOC/10^3 gal of crude oil)
1,000	=	Conversion of gallons to 1,000 gallons to match TOC emission factor
VOC/TOC	=	TOC to VOC conversion factor (0.85)
2,000	=	Conversion of pounds to tons

Evaporative Ballasting:

$$Eb = \sum TP \ /1{,}000 \times 0.40 \times TOC \times VOC/TOC \ / \ 2{,}000$$

Where:

Eb	=	Ballasting emissions (tons)
TP	=	Total volume of product transferred (gal)
0.4	=	Volume of water needed for ballasting
1,000	=	Conversion of gallons to 1,000 gallons to match TOC emission factor
TOC	=	Emission factor for TOC emitted from thousand gallons of crude oil transferred (0.9 lb of TOC/10^3 gal of crude oil)
VOC/TOC	=	TOC to VOC conversion factor (0.85)
2,000	=	Conversion of pounds to tons

Boiler emissions for transfer pumping:

$$EB = \sum D \times 3{,}000 \times ST_{ef} \times VOC/TOC \times 1.10231 \times 10^{-6}$$

Where:

EB	=	Boiler emissions (tons)
D	=	Duration that the small tanker is adjacent to the larger tanker (hrs)
3,000	=	EPA assumption of boiler power rating for tanker (kW)
ST_{ef}	=	Steam turbine emission factor using ECA-compliant fuel (g/kWh)
1.10231×10^{-6}	=	Conversion grams to tons.

As with previous Gulfwide inventories, evaporative emissions were assigned to the center of the lightering zones (Figure 5-13). No monthly vessel lightering data were identified in this effort. BOEM assumed that activity was consistent throughout the year; therefore, annual emissions estimates were temporally apportioned to each month equally.

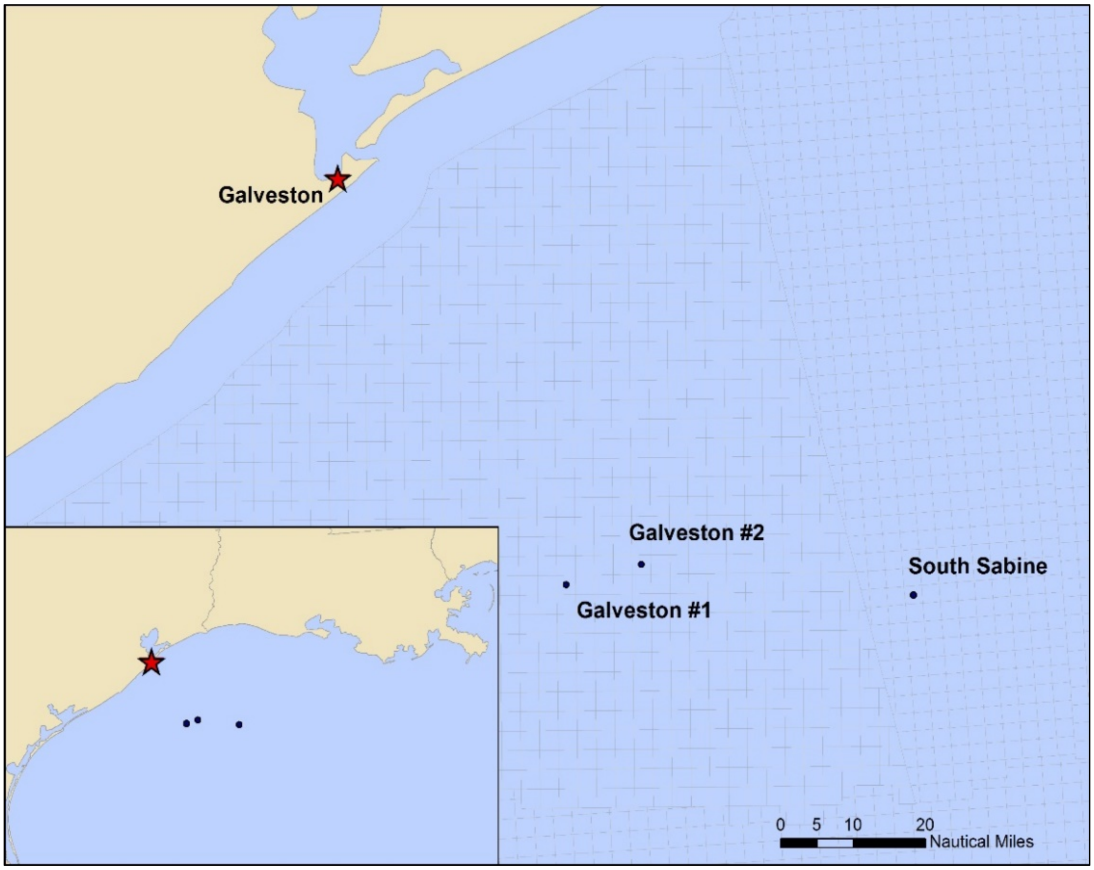


Figure 5-13. Vessel Lightering Zone Centroids

5.3.5 Commercial Fishing Vessels

The GOM is an active commercial fishing area, providing a wide range of fish and seafood products. Detailed commercial fishing data were obtained from the NOAA National Marine Fisheries Service (NMFS), including separate activity data for the three types of offshore fishing activities that occur in the GOM: pelagic longline, reef, and shrimp operations (Maiello, 2018; Larkin, 2018; Hart, 2018).

The activity data for these fishing operations were provided as a total for the western GOM for pelagic longline fishing operations, and as a total by NMFS statistical zone for reef and shrimp fishing operations. The activity data for pelagic longline fishing operations were provided as latitude and longitude; however, due to confidential business procedures, the data could be provided only as a total for 2017. Table 5-17 presents the activity data for fishing operations.

Table 5-17. 2017 Fishing Vessel Activity Data

Fishing Category	NMFS Zones	2017 Fishing Vessel Hours
Shrimp	10–12	135,028[a]
Shrimp	13–17	821,778[a]
Shrimp	18–21	633,606[a]
Reef	11–21	233,208[a]
Longline	N/A	34,848

[a] 2016 data were used as a surrogate for reef fish and shrimp, as 2017 data were not available.
N/A = not applicable

Emissions associated with commercial fishing vessels were attributed to the operation of diesel engines used for propulsion and to run generators or small cranes and winches to lift nets and lines onto the vessel. Emissions from operating these diesel engines were estimated using the emission factors provided in Table 5-4.

Average fishing vessel horsepower for longline (397 hp), reef (446 hp), and shrimp vessels (574 hp) were obtained from the average horsepower of the 2017 permitted fishing vessels (Dudley, 2018). These typical horsepower ratings were converted to kilowatts to match the units of the USEPA emission factors. The typical operating loads were assumed to be 80% for underway operations and 10% for maneuvering while setting the nets (Systems Applications International et al., 1995). These load factors were applied to the kW rating of the typical vessel engines and the total annual hours of operation to determine kilowatt-hours, which were used to calculate emissions for this source category using the approach discussed in Section 5.1. Below is an example of how the equation in Section 5.1 was used for this vessel category.

Example Calculation:

$$E = Ah \times kW \times LF \times EF \times CF$$

Where:

E	=	Emissions (tons)
Ah	=	Annual hours per mode of operation (underway, maneuvering, hotelling) (hours)
kW	=	Average vessel kW (totaling individual propulsion engines) (kW)
LF	=	Load factor (fraction from 0 to 1)
EF	=	Emission factor (g/kWh)
CF	=	Conversion factor (1.10231 E-6 tons/g)

Shrimp fishing vessels spent 1,590,412 hours at sea in 2017. The average kW rating for a shrimp boat is 574, the underway load factor is 0.80, and the emission factor for NO_x is 13.6 g/kWh.

$$E = 1{,}590{,}412 \text{ hrs} \times 574 \text{ kw} \times 0.80 \times 13.6 \text{g/kWh} \times 1.10231 \times 10\text{-}6 \text{ tons/g}$$

$$E = 8{,}170 \text{ tons of } NO_x$$

Commercial fishing activities vary monthly by fishing season. To quantify temporal variations, monthly adjustment factors were calculated based on NOAA monthly fisheries landing data for 2017. The monthly adjustment factors were applied to the annual emission estimates to calculate the monthly emissions. Table 5-18 presents the monthly adjustment factors.

Table 5-18. Monthly Commercial Fishing Profile

Month	2017 Percent Activity by Month (%)
January	4
February	4
March	5
April	4
May	10
June	15
July	12
August	14
September	10
October	9
November	8
December	5

For line fishing operations, operating hours were estimated based on the assumption that it takes approximately 24 hours to tend each set. The Southeast Fisheries Science Center (SFSC) (Maiello, 2018) provided activity data as an annual total of sets in the central and western GOM for line fishing operations. SFSC included all activity west of longitude 87.5° as part of the central and western areas of the GOM plus the Eastern Planning Area. The commercial fishing emission estimates were spatially allocated based on the fishing activity data available from AIS (Figure 5-14).

Commercial fishing emission estimates were spatially allocated using the following formula:

$$ECFi = ECFt\ (Si/SCFt)$$

Where:

ECFi	=	Commercial fishing emissions for lease block i (tons)
ECFt	=	Total Commercial fishing emissions (tons)
Si	=	AIS Fishing Activity in lease block i (kWhr)
SCFt	=	Total AIS Fishing Activity (kWhr)

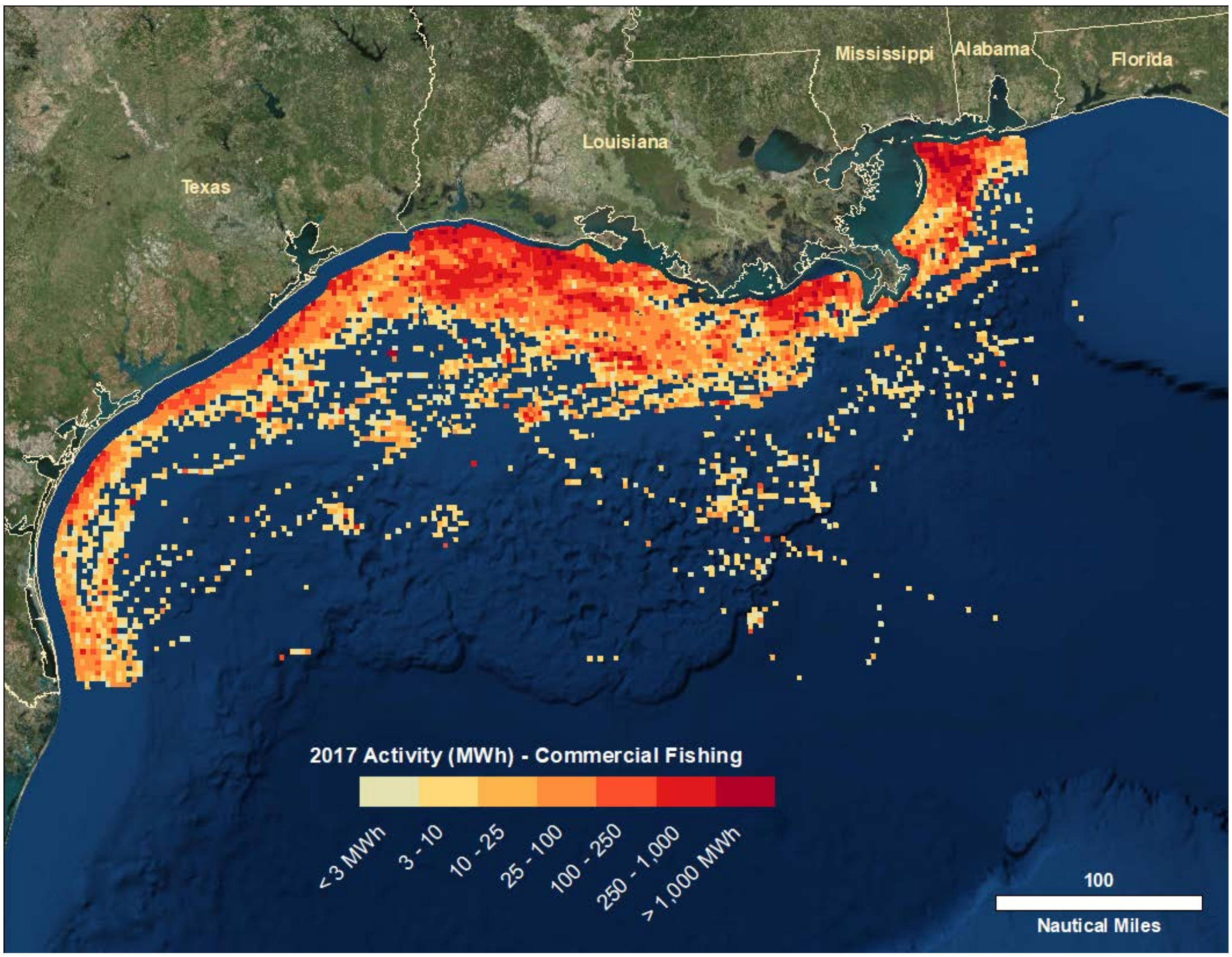


Figure 5-14. 2017 Commercial Fishing Activity

5.3.6 Recreational Fishing Vessels

The GOM is also an active recreational fishing area, providing a wide range of opportunities to recreational anglers. Energy platforms in the Gulf act as artificial reefs at which fish gather, which make the platforms prime destinations for anglers. Detailed recreational fishing data were obtained from the NOAA Marine Recreational Information Program (MRIP) (NOAA, 2018). Fishing data were available for Alabama and Mississippi only. The data were disaggregated into fishing areas (inland, ocean is ≤ 3 miles, and ocean is > 3 miles); for this inventory of Federal waters, only the ocean data > 3 miles from shore were used. To estimate the number of trips into Federal waters for Texas and Louisiana, the average percent growth in trips between 2014 and 2017 were calculated for Alabama and Mississippi and then applied to Texas and Louisiana. Table 5-19 summarizes the number of recreational fishing trips to Federal waters. BOEM assumed that four hours per trip are underway at 80% load, and six hours per trip are maneuvering at 30% load. Table 5-20 presents the underway hours and maneuvering hours based on the trips.

Table 5-19. Number of Trips Near Platforms

State	2014 Trips	2017 Trips	Percent Growth	Notes
Alabama	161,290	372,399	231%	Known
Louisiana	189,060	322,831	171%	Calculated
Mississippi	42,642	47,172	111%	Known
Texas	91,666	156,525	171%	Calculated

Table 5-20. 2017 Activity Hours Based on Number of Trips

State	2017 Trips	Underway Hours	Maneuvering Hours
Alabama	372,399	1,489,596	2,234,394
Louisiana	322,831	1,291,324	1,936,986
Mississippi	47,172	188,688	283,032
Texas	156,525	626,100	939,150

The average weighted hp was estimated for diesel inboard engines from the USEPA's MOVES 2014b model (USEPA, 2018) average hp/bin dataset and population distribution dataset shown in Table 5-21.

Table 5-21. USEPA Nonroad Recreational Marine Vessel Horsepower (HP) Profile

Min HP	Max HP	Avg HP	Vessel Count	Average HP x Count
6	11	9.74	9,199	89,598.26
11	16	14.92	4,514	67,348.88
16	25	21.41	9,987	213,821.67
25	40	31.20	5,464	170,476.80
40	50	42.40	1,010	42,824.00
50	75	56.19	8,854	497,506.26
75	100	94.22	7,456	702,504.32
100	175	144.90	61,116	8,855,708.40
175	300	223.10	100,498	22,421,103.80
300	600	387.10	4,132	1,599,497.20
600	750	677.00	2,925	1,980,225.00
750	1,000	876.50	5,546	4,861,069.00
1,000	1,200	1,154.00	452	521,608.00
1,200	2,000	1,369.00	1,586	2,171,234.00
2,000	3,000	2,294.00	971	2,227,474.00
Avg HP Weighted by Population				207.51

The emission factors used to calculate the emissions were obtained from the MOVES2014b model for pleasure craft diesel inboard/sterndrive. Table 5-6 lists the emission factors.

Example Calculation:

$$E = Ah \times HP \times CF1 \times LF \times EF \times CF$$

Where:

E	=	Emissions (tons)
Ah	=	Annual hours of operation
HP	=	Horsepower
CF1	=	kW to HP conversion factors (1 HP = 0.7457 kW)
LF	=	Engine load factor for specified mode of operation (35%)
EF	=	Emission factor (g/kWh)
CF	=	ton/gram conversion factor (1g = 1.10231 E-6 ton)

For example, recreational fishing vessels in Alabama spent 3,723,990 hours at sea in 2017. The average HP is 207.5, the load factor is 0.35, and the emission factor for CO_2 is 713 g/kWh.

$$E = 1{,}489{,}596 \times 207.5 \times 0.7457\times 0.80 \times 713 \times 1.10231 \times 10^{-6}$$

$$E = 158{,}516 \text{ tons of } CO_2$$

Recreational fishing emission estimates were spatially allocated using the following formula:

$$ECFi = ECFt\ (Si/SCFt)$$

Where:

ECFi	=	Commercial fishing emissions for lease block i (tons)
ECFt	=	Total Commercial fishing emissions (tons)
Si	=	AIS Fishing Activity in lease block i (kWh)
SCFt	=	Total AIS Fishing Activity (kWh)

The recreational fishing emission estimates were spatially allocated based on the fishing activity data available from AIS (Figure 5-15). It was assumed that recreational fishing vessels would stay within 40 nautical miles of the shore given an average vessel speed of 20 knots/hour and a typical trip of 2 hours.

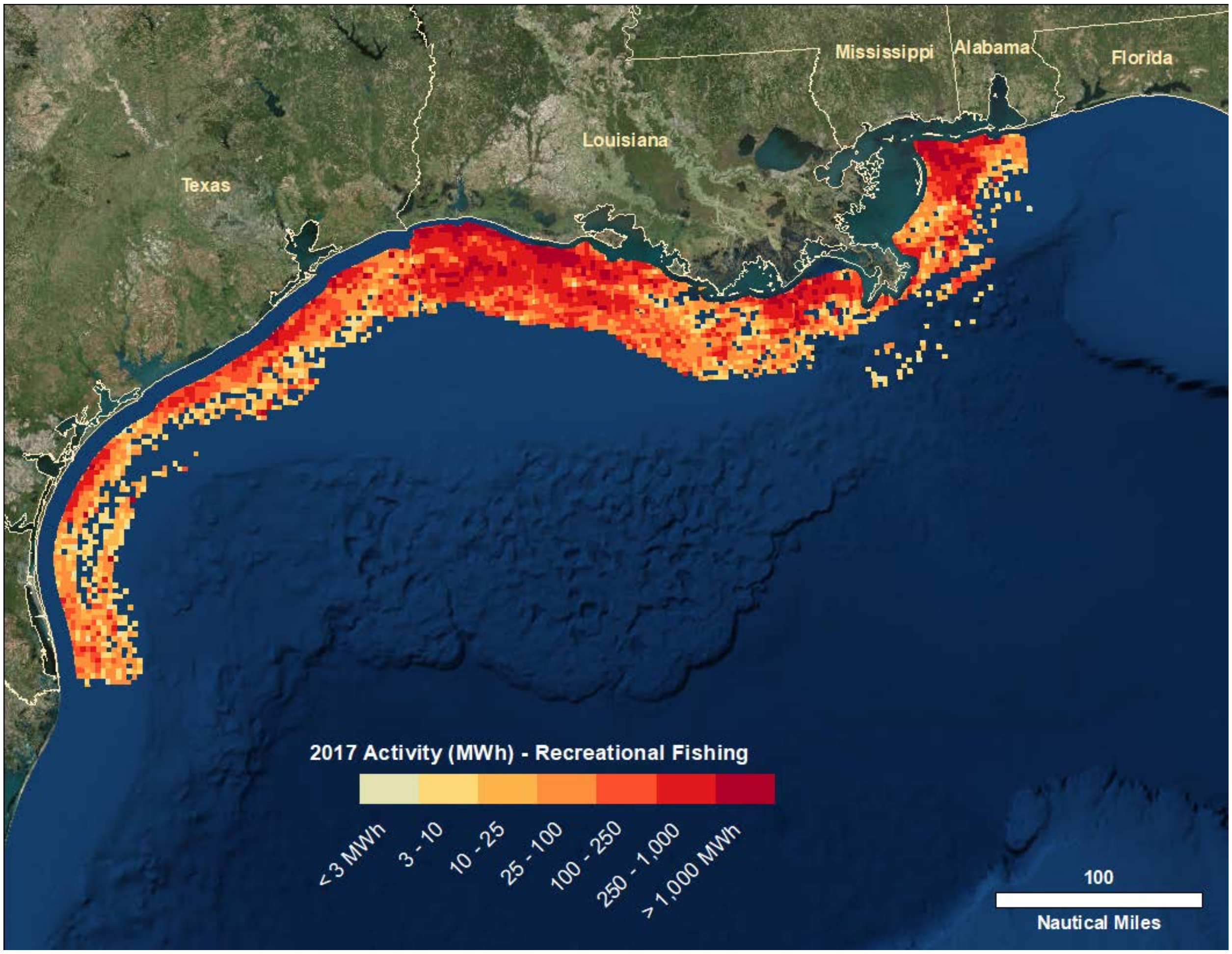


Figure 5-15. 2017 Recreational Fishing Activity

No monthly recreational fishing data were compiled in this effort; BOEM assumed that activity was consistent throughout the year, and therefore annual emission estimates were apportioned to each month equally.

5.3.7 Biogenic and Geogenic Emissions

The biogenic and geogenic sources of air pollution that were evaluated for this study are subsurface seeps of crude oil, bacterial processes, and mud volcanoes. BOEM searched for additional published studies or new data sources for these source categories. New information was found to better quantify subsurface seeps of crude oil using satellite data, validating the Gulfwide estimates that were used in the previous inventory efforts.

Subsurface Seeps of Crude Oil

Subsurface seeps, more commonly referred to as oil seeps, occur when crude oil deposits beneath the ocean floor escape into the surrounding waters because of cracks and vents in the seabed. These cracks and vents open and close as the result of geological activities. The volume of oil seeping into the Gulf can be significant. The total quantity of oil that is released into the ocean does not, however, find its way to the surface. Ocean-dwelling biota develop communities surrounding oil seeps that use the hydrocarbons as a source of nutrients (Earth Institute, 2016). Approximately 50% of the seepage is entrained in a deep-water plume. An additional 10% is removed by free-floating organisms during microbial hydrocarbon oxidation occurring in the water column, where gas/oil bubbles ascend at a rate of 0.25 meters/sec. This leaves approximately 40% to form a surface water slick, of which 5% of the original hydrocarbon seepage volatilizes into the atmosphere (Joye, 2015). The remaining slick undergo weathering, where additional microbial degradation occurs along with photo oxidation, emulsification, deposition back onto the seabed (ITOPF, 2017; UNEP, 2017). The volatilization of the surface slick includes release of VOC, CH_4, CO_2, and organic air toxics. Based on the data found in the literature, only VOC emissions can be estimated at this time.

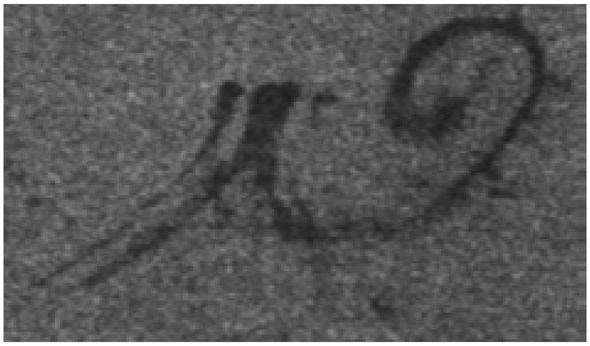


Figure 5-16. Example of Seepage Surface Slick Corkscrew or Nested Pattern Resulting from Multiple Emission Points

BOEM and other researchers have conducted a significant amount of work to study the extent of oil seepage in the GOM and off the coast of California. Much of this investigation has focused on the occurrence of communities of chemosynthetic organisms in relationship to surface water oil slicks. The total quantity of oil seeping into ocean waters has been estimated based on studies of oil slicks derived from site visits and from satellite and space shuttle photography (Figure 5-16). These estimates have been input to models that estimating overall oil seepage rates. Crucial variables in the models include wind speed, oil layer thickness, and the oil degradation half-life. Over the last 10 years, several different and sometimes highly variable estimates of total oil seepage into the GOM have been prepared. Work by Mitchell et al. provided a 1999 estimates of oil seepage in the northern GOM of 2.5–6.9 × 10^5 barrels/yr (Mitchel, 1999). A more recent assessment implemented by McDonald et. al provided an estimate for the northwest quadrant of the Gulf, which includes the Central and Western Planning Areas, to be 1.06 × 10^5 (lower bound) to 4.12 × 10^5 barrels/year (upper bound) (McDonald, 2015).

Using the average of McDonald's lower and upper-bound estimates, VOC emissions were estimated using the oil seepage emission factor (105 lbs of VOC/barrel oil released) developed by the California Air Resources Board (CARB, 1993).

Applying these methods provides results in similar mass emission estimates as shown below.

$$2.59 \times 10^5 \text{ barrels per year} \times 105 \text{ lbs of VOC /barrel /2000 lbs per ton} = 13{,}597.5 \text{ tons of VOC/year}$$

This estimate compares well to the 2014 value of 13,561 tons of VOC per year.

McDonald's study is based on 10 years of satellite mapping. McDonald's spatial distribution of surface water slicks appear to be similar to a set of images developed by CGG NPA Satellite Mapping for 2017 (Figure 5-17). The CGG data were specifically developed for this inventory and are based on interpretation of monthly Satellite Synthetic Aperture Radar (SAR) images. The detection of oil slicks is dependent upon physical properties of the oil, subsurface and surface currents, as well as wave conditions at low to moderate wind speeds (2 to 5 m/sec). CGG provided imagines for the optimal detection conditions to ensure that the identified slicks could be correctly categorized as naturally occurring or derived from anthropogenic discharges. CGG digitized each slick quantifying the volume and mapping the shape to a GIS projection. These imagines were applied to BOEM's lease block grid and used to spatially distribute the calculated VOC emissions from subsurface seeps based on the volume of slick associated with individual lease blocks.

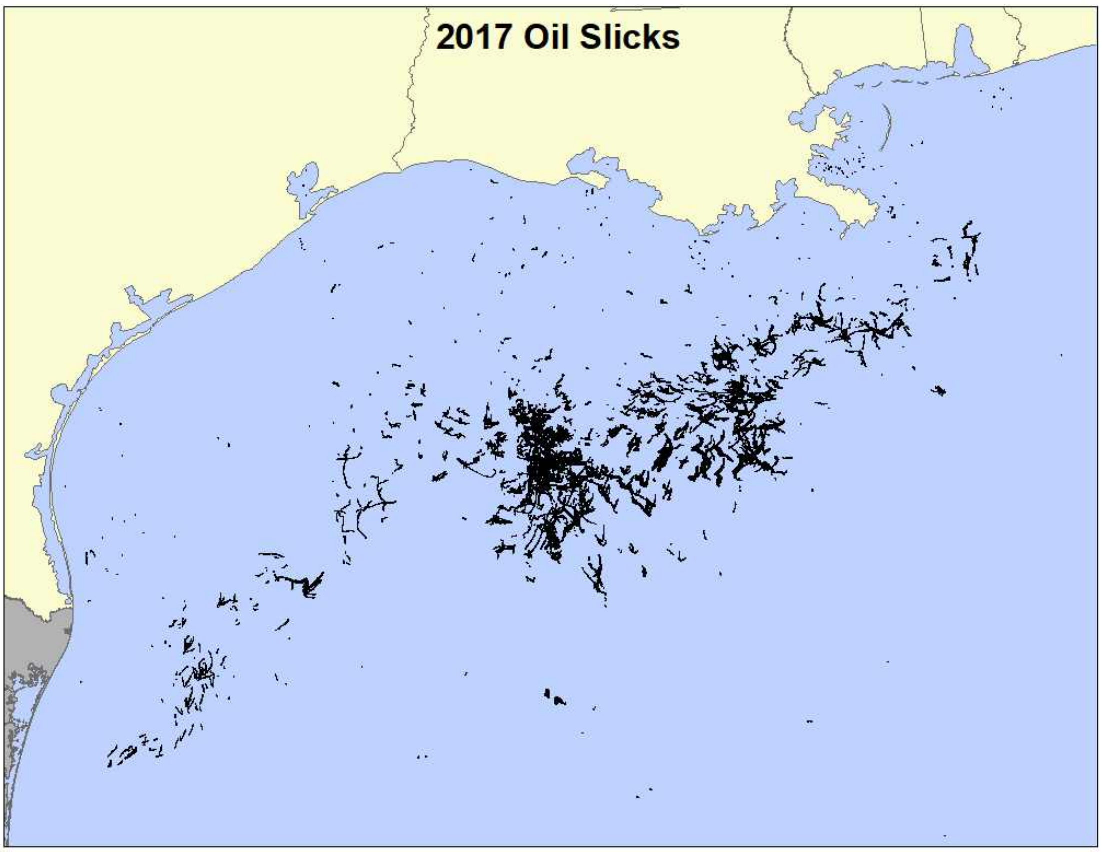


Figure 5-17. 2017 Distribution of Surface Water Slicks

Because seepage is spread out over hundreds of square kilometers of seabed, these releases are episodic, varying in magnitudes according to prevailing environmental conditions and rarely continuous, making it difficult to assess temporal variances throughout the year. For these reasons, it will be assumed that emissions are constant from day to day, and actual emissions may be significantly less than or greater than the aggregated values developed for this inventory.

Bacterial Processes

Bacterial process sources include plankton producing dimethylsulfide (DMS) and sediment bacteria producing methane. DMS released from protozoa and zooplankton has been linked to the formation of tropospheric aerosols and cloud condensation nuclei, which can negatively affect global warming (Gabric et al., 1993). Estimates of DMS flux from the GOM range from 9.2 μmol/m^2/day (in January) to 13.8 μmol/m^2/day (in July). Note, DMS is not one of the pollutants included in this study. As described previously, sediment bacteria methane generation and potential atmospheric release is not well characterized and cannot be estimated for the purposes of this inventory.

N_2O, a potent GHG, is produced in hypoxic coastal zones by deep-water bacteria and is transferred to the atmosphere through upwelling and air-sea transfer mechanisms (Nevison et al., 1995). The large nitrogen inputs and deoxygenation typical of these hypoxic systems create the potential for large N_2O emissions (Walker et al., 2010). Bouwman et al. (1995) compared several earlier inventories of ocean N_2O to create a gridded annual N_2O inventory available as part of the Global Emission Inventory Activity (GEIA) dataset. Based on this information, total annual emissions for the GOM study area have been estimated to be 3,710 tons N_2O as nitrogen /year (Bouwman et al., 1995). When adjusted to represent only the western and central areas of the GOM, the N_2O estimate is 1,948 tons per year.

As the hypoxic area is reasonably well defined (Figure 5-18) (SEAMAP, 2017; NOAA, 20017a), a shapefile of the zone was obtained from NOAA (NOAA, 2017b) and overlaid with BOEM's lease block grid to spatially allocate N_2O emissions. Emissions were assigned to each lease block based on surface area of the block. Although the large, record-setting hypoxic "dead zone" in July of 2017 is well documented (NOAA, 2017a), the NOAA shapefile presented in Figure 5-18 covers a much larger overall area of the GOM.

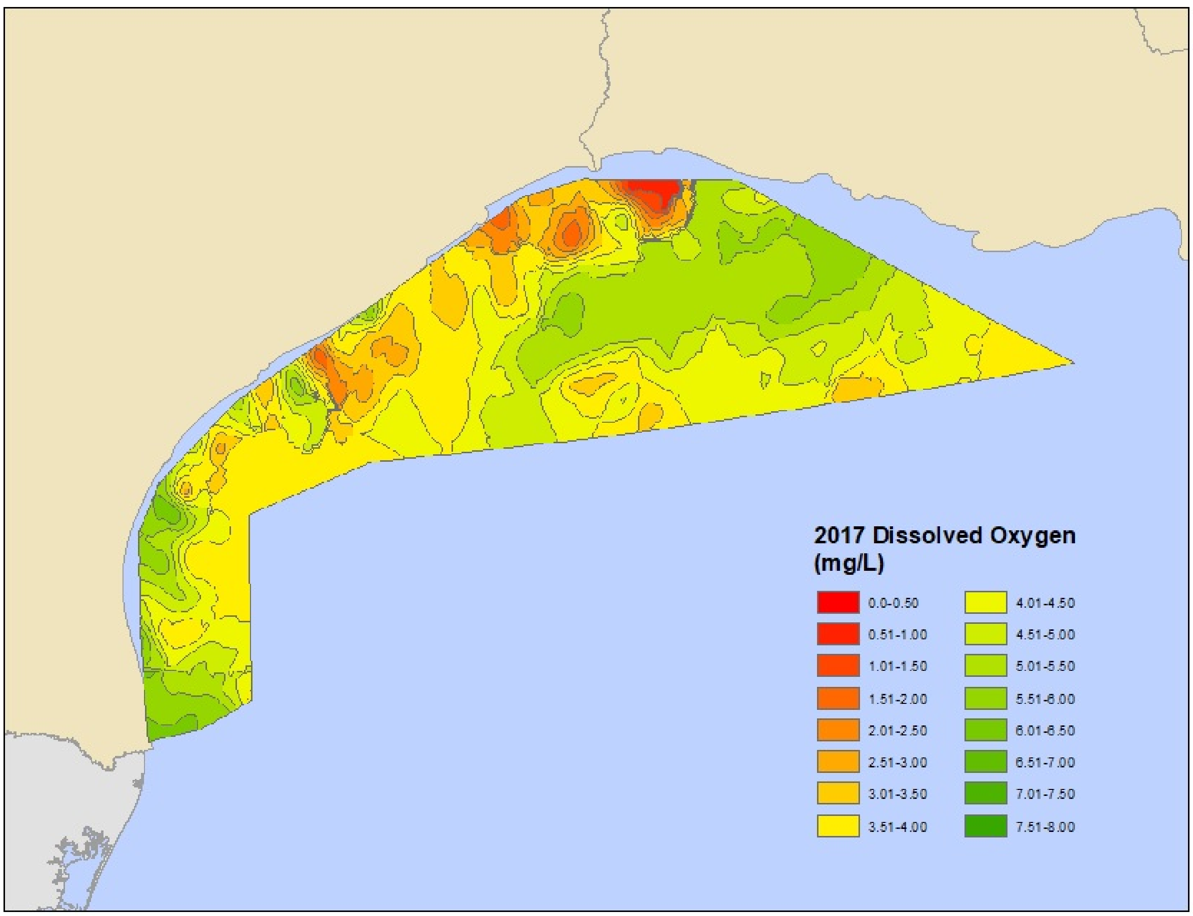


Figure 5-18. Hypoxic Area of the GOM

Additionally, it was noted that N_2O production occurs during nitrification and denitrification processes, which are dependent upon oxygen (O_2) concentrations. These concentrations can vary throughout the year, with the lowest O_2 level occurring during the warmer months, which would also represent periods of higher N_2O production (Kim et al., 2013). A study implemented by Babin and Rabalais (2009) provided monthly average dissolved oxygen concentrations for the GOM's hypoxic area derived from data spanning the period from 1989 to 2008. These data were used as surrogates to quantify monthly N_2O productions fractions as noted in Table 5-22. The N_2O production fractions were used to apportion the annual N_2O emissions to the appropriate month (Table 5-22). Note that the months of July and August were allocated the highest N_2O production fractions.

Table 5-22. Monthly Dissolved Oxygen Concentrations

Month	Dissolved Oxygen (DO) Level	1/DO	Fraction of 1/DO
January	5	0.20	0.04
February	4.5	0.22	0.04
March	4	0.25	0.05
April	3	0.33	0.07
May	2.5	0.40	0.08
June	1.9	0.53	0.11
July	1	1.00	0.20
August	1	1.00	0.20
September	2	0.50	0.10
October	4.2	0.24	0.05
November	6	0.17	0.03
December	6.3	0.16	0.03

Mud Volcanoes

Mud volcanoes are submarine formations that emit gases or liquids. The gases they release often contain CH_4, CO_2, and VOCs. Four mud volcanoes have been identified in the GOM (Kohl and Roberts, 1994). As information about the pollutant release rates for each specific volcano were not readily available, BOEM obtained data concerning typical volumetric emission release rates of 3,600,000 cubic meters/yr for mud volcanoes from a study performed by Dimitrov (2003). The Dimitrov study also provided speciation values to allow for estimation of the CH_4 (90%), CO_2 (8%), and VOC (2%) releases. The volume of CH_4, CO_2, and VOC were converted to mass emissions using the chemical density of each pollutant. Most VOCs emitted from mud volcanoes are higher carbon compounds such as isobutane, so the isobutane density was used as a surrogate for the VOC mass emission estimate. The CH_4 estimate was adjusted to account for the observation that 80% of the CH_4 emitted by mud volcanoes is consumed by biologic organisms, as reported by Zhang and Noakes (2006). The emission estimates for mud volcanoes were assigned equally to where they are located in Garden Banks Block 382, Garden Canyon Block 143, Green Canyon Block 272, and Mississippi Canyon Block 929.

BOEM assumed that emissions associated with mud volcanoes are consistent throughout the year and therefore temporally apportioned annual emission estimates to individual months equally.

BOEM's Gulf of Mexico Resource Studies Section has published seismic water bottom anomalies datasets (BOEM, 2016). These datasets provide information about anomalies in the seabed that would indicate seepage or underwater explosions related to the release of hydrocarbons. These anomalies were mapped in a geographic information system (GIS) and joined to the lease block grid to specify which lease blocks contained activity (Figure 5-19).

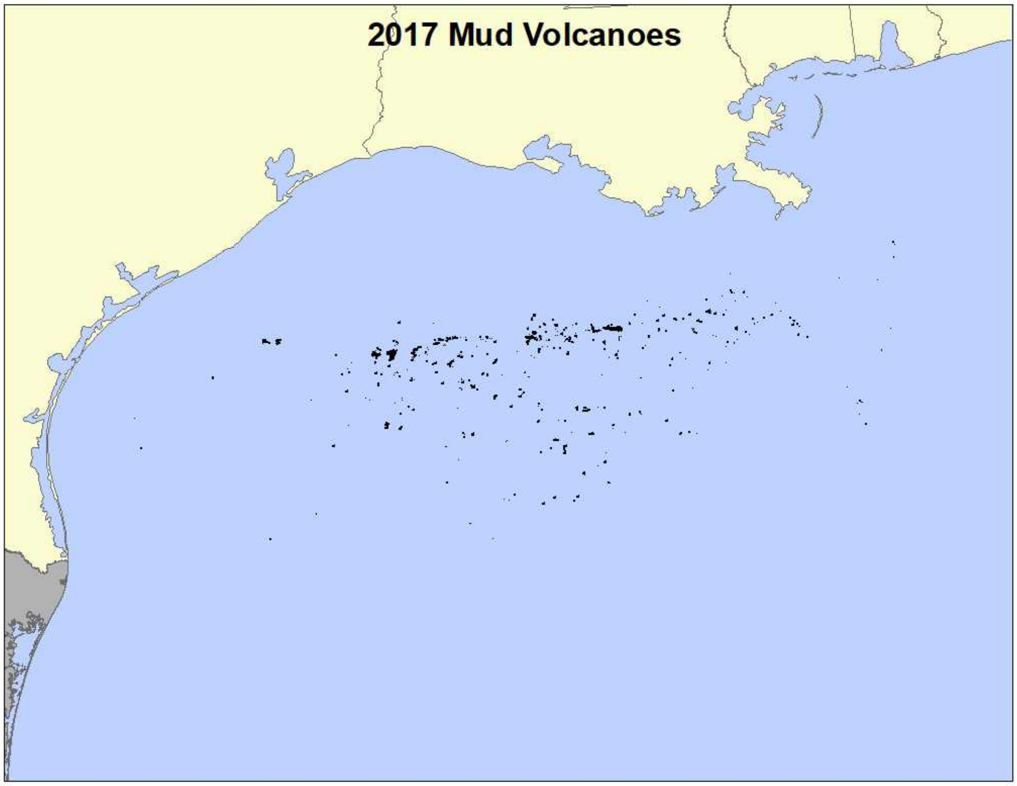


Figure 5-19. Location of Mud Volcanoes

BOEM assumed that if a lease block does not contain anomalies, there is no evidence of biogenic and geogenic activity in that lease block, and emissions were not be mapped to these lease blocks. Note this approach does not quantify the magnitude or the temporal period of the release, but it does identify locations where there is no evidence of activity, providing an improvement over the previous methodology.

5.4 Non-platform QA/QC Checks

ERG implemented QA/QC checks at critical points in the development of the non-platform inventory, starting with review of the data compiled for this effort. Data sources were checked to ensure they represented the latest available data for the 2017 base year. The transferred data files were compared to the original data to ensure that the complete dataset was transferred and the data files were not corrupted during the transfer process. Transferred data were archived on a shared drive, and a working copy was developed for calculations.

Because the non-platform activity and vessel characteristics tend to be very large datasets, calculations are implemented in relational databases such as Microsoft Access® or SQL®. The queries or scripts used to make calculations are reviewed by experienced staff who were not directly involved in the original calculations. Additional queries specifically designed for QA were included throughout the calculations, including confirming record counts between processes and checking activity sums before and after spatial allocation. Special attention was given to unit conversions. Additional QA/QC were done in GIS to ensure that the spatial distribution was consistent with expectations and in-line with other data sources. Finally, results were compared to previous Gulfwide inventories.

6 Results

6.1 Annual Emission Estimates

Table 6-1 presents the platform emission estimates developed for criteria pollutants, with the highest values by equipment type shown in bold. For an overview of the results, Table 6-1 summarizes the total platform criteria pollutant emission estimates in tons per year (tpy). Figure 6-1 depicts the locations of active platforms in 2017 included in this inventory. Figures 6-2 through 6-5 indicate the spatial locations of the $PM_{2.5}$, NO_x, SO_2, and VOC platform emission estimates for 2017.

Table 6-1. Total Platform 2017 Emission Estimates for Criteria Pollutants and Precursors

Equipment	CO Emissions (tpy)	Pb Emissions (tpy)	NO_x Emissions (tpy)	PM_{10}-PRI Emissions (tpy)	$PM_{2.5}$-PRI Emissions (tpy)	NH_3 Emissions (tpy)	SO_2 Emissions (tpy)	VOC Emissions (tpy)
Amine units	-	-	-	-	-	-	23	6.47E-02
Boilers, heaters, and burners	200	1.61E-03	243	12	12	**8**	4	13
Diesel engines	1,151	-	4,791	213	212	-	**381**	241
Drilling equipment	133	-	501	9	9	-	0.24	13
Combustion flares	1,362	8.46E-05	303	0.36	0.36	0.54	0.07	994
Fugitive sources	-	-	-	-	-	-	-	13,408
Glycol dehydrators	-	-	-	-	-	-	-	851
Loading operations	-	-	-	-	-	-	-	70
Losses from flashing	-	-	-	-	-	-	-	181
Mud degassing	-	-	-	-	-	-	-	36
Natural gas engines	**46,190**	-	**32,945**	**281**	**281**	-	11	1,074
Natural gas, diesel, and dual-fuel turbines	2,836	**2.09E-03**	11,178	121	121	-	44	73
Pneumatic pumps	-	-	-	-	-	-	-	3,370
Pneumatic controllers	-	-	-	-	-	-	-	2,222
Storage tanks	-	-	-	-	-	-	-	556
Cold vents	-	-	-	-	-	-	-	**15,732**
Total emissions[a]	51,872	3.79E-03	49,962	636	635	8	462	38,833

[a] Totals may not sum due to rounding.
Note: Highest values by equipment type shown in bold.

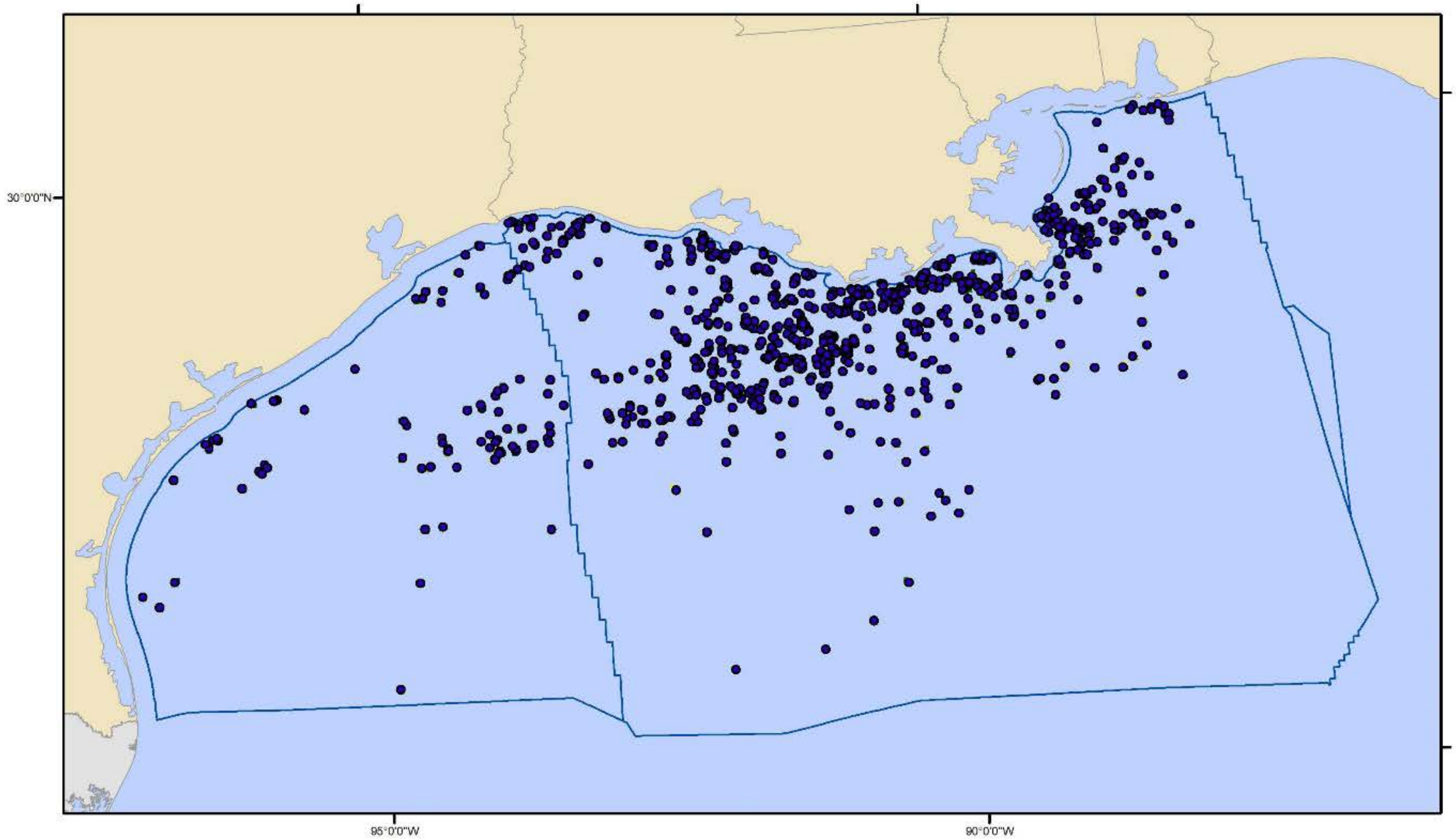


Figure 6-1. Active Production Platform Locations Reported in GOADS for 2017

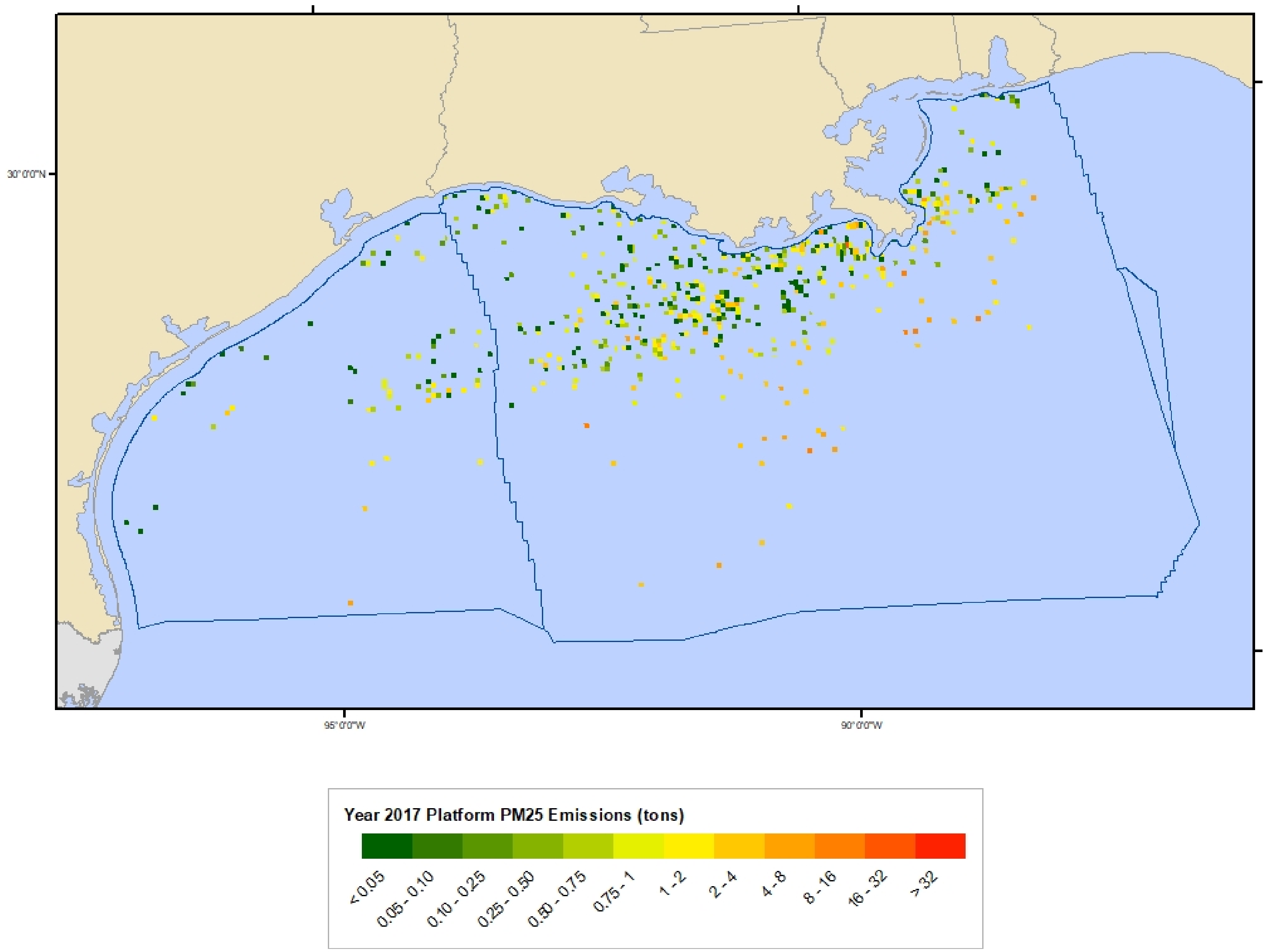


Figure 6-2. Platform $PM_{2.5}$ 2017 Emission Estimates

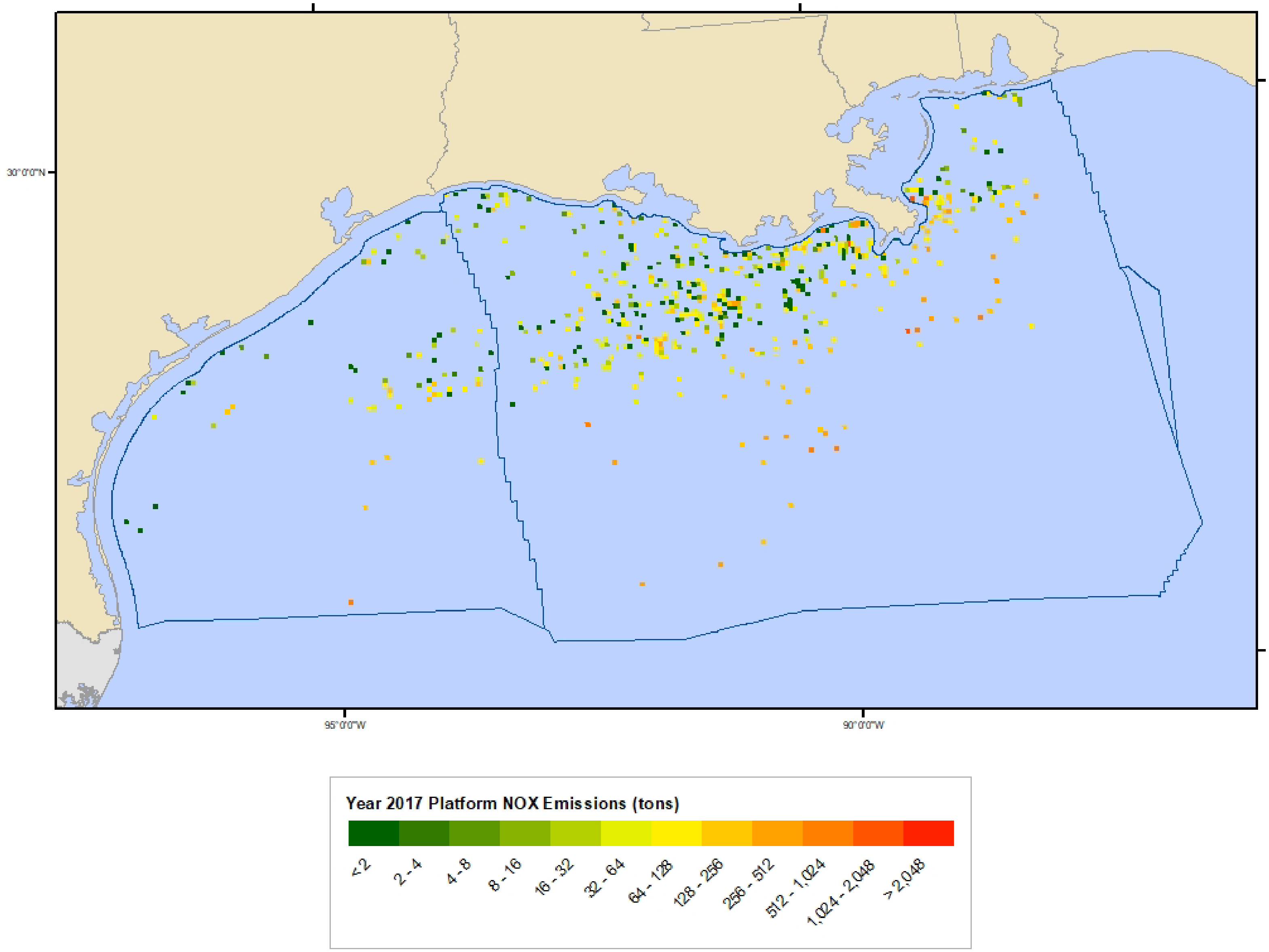


Figure 6-3. Platform NO_x 2017 Emission Estimates

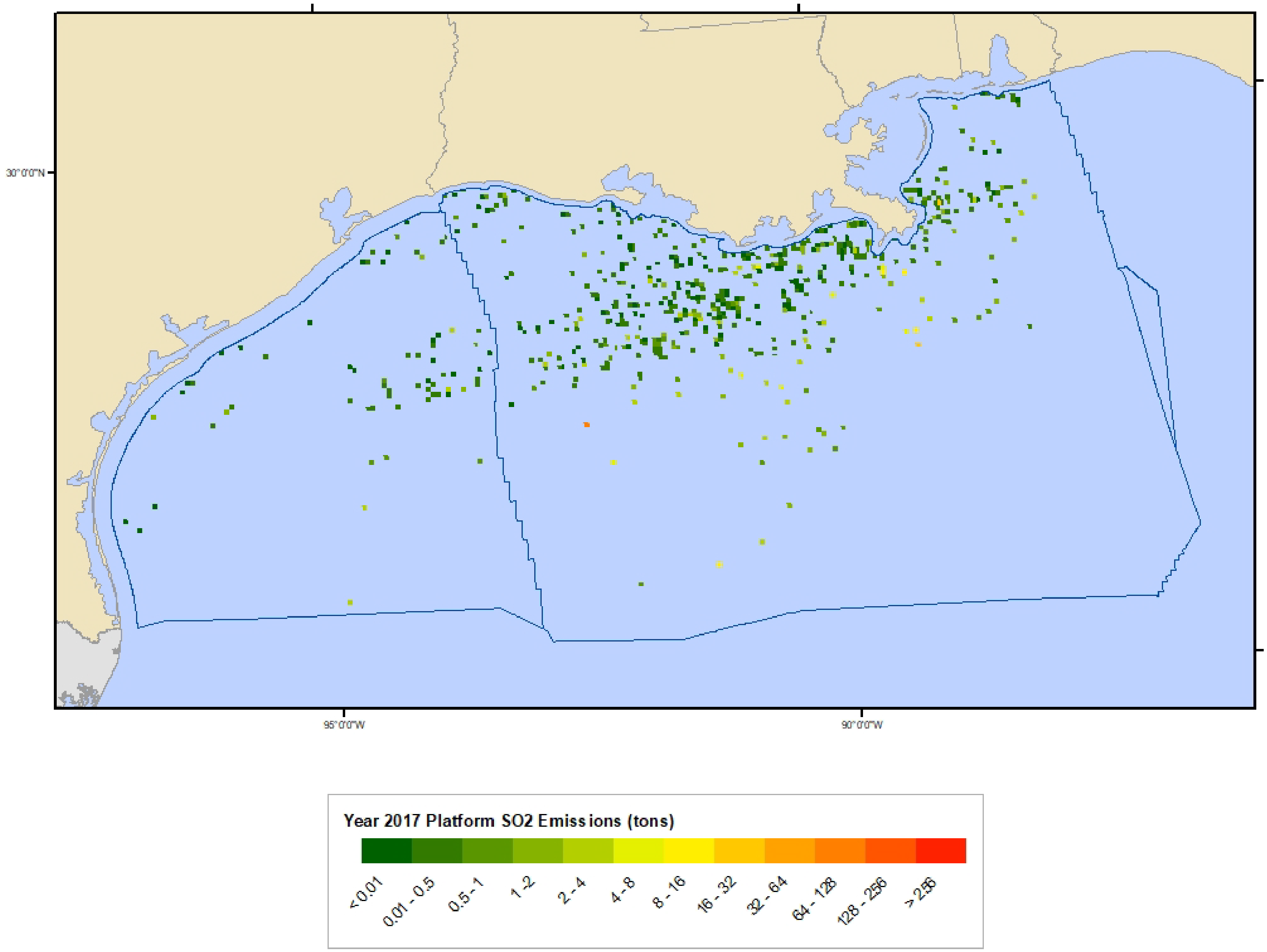


Figure 6-4. Platform SO_2 2017 Emission Estimates

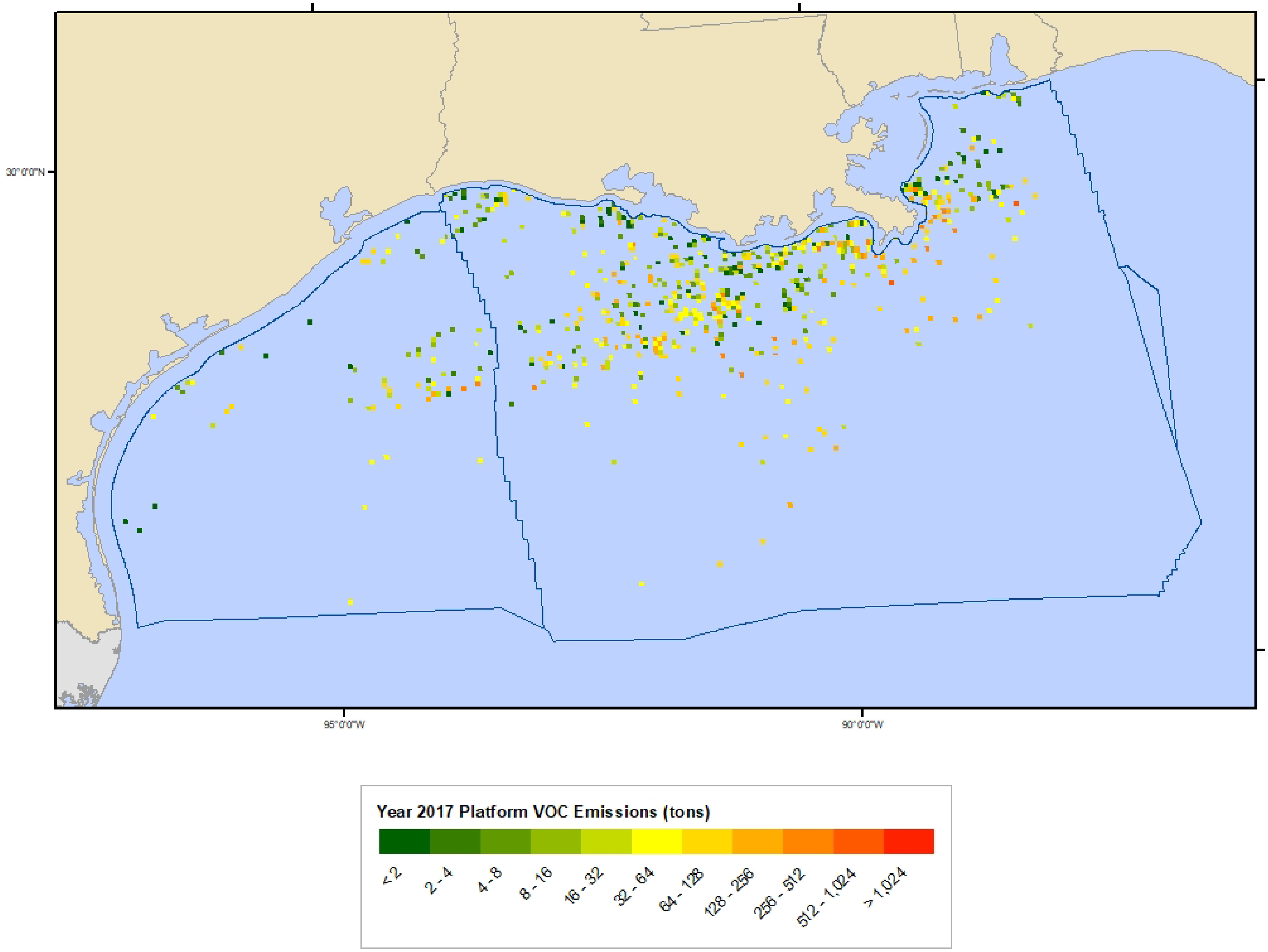


Figure 6-5. Platform VOC 2017 Emission Estimates

Table 6-2 summarizes the total non-platform criteria pollutant emission estimates, with the highest source category values shown in bold. Figures 6-6 through 6-9 indicate the spatial locations of the $PM_{2.5}$, NO_x, SO_2, and VOC non-platform oil and gas production-related emission estimates for 2017. There are several important changes in the 2017 inventory that significantly impacted the non-platform emission estimates. For example, the North America ECA fuel sulfur standard went into effect in 2015 reducing the sulfur content by 90%, which reduced SO_2 emissions as well as sulfate PM emissions in 2017. In 2017 domestic C1 and C2 vessels, including offshore support vessels, were already complying with the nonroad fuel standard, which is why the SO_2 and PM emission reductions in 2017 primarily occur in the larger commercial marine vessels.

Drilling activities have been declining over the last decade. Based on BOEM's drilling data, there were 39,805 days of drilling in 2008; 19,863 in 2011; 20,013 in 2014; and 16,459 in 2017. Additionally, for previous inventories these were grouped together as a drilling rig, but for the 2017 inventory these were handled separately and compared to the latitude and longitude coordinates of production platforms to identify possible double counting with the drilling platform emission estimates. Thus, the 2017 inventory includes a more accurate assessment of mobile platform rigs that operate on production platforms. Where platform operators provided drilling data for the specific mobile drilling rigs identified in GOADS, their non-platform drilling rig data were removed to avoid double counting. This accounted for a reduction of 2,399 drilling days in 2017 (approximately 15% of the drilling activity). Both the reduction in activity and adjustments for possible double counting reduced the non-platform drilling rig emission estimates.

As discussed previously, a new approach was used to estimate helicopter emissions in the 2017 inventory based on the FAA's NextGen flight management data which was used to quantify individual helicopter movements. The helicopter traffic data were applied to emission rates developed specifically for the fleet of helicopters that provide services to offshore oil and gas platforms. Emissions were allocated to the lease blocks based on the NextGen latitude/longitude coordinates where helicopters are actually operating. This approach quantified a general decline in helicopter activities, but also indicated that approximately half of the helicopter operations were in state waters, compared to the assumption used in previous inventories that all offshore helicopter operations were in Federal waters. Both the decline in activity and more refined tracking data provided significantly lower emission estimates for 2017.

Table 6-2. Total Non-platform 2017 Emission Estimates for Criteria Pollutants and Precursors

Source Category	CO Emissions (tpy)	Pb Emissions (tpy)	NO_x Emissions (tpy)	PM_{10}-PRI Emissions (tpy)	$PM_{2.5}$-PRI Emissions (tpy	NH_3 Emissions (tpy)	SO_2 Emissions (tpy)	VOC Emissions (tpy)
Drilling rigs	1,320	2.31E-02	6,418	148	141	3	142	213
Pipelaying operations	319	8.25E-03	2,924	55	51	1	117	169
Support helicopters	84	-	149	4	4	-	17	79
Support vessels	5,221	1.04E-01	21,651	765	731	6	594	503
Survey vessels	618	1.26E-02	3,163	98	94	1	79	89
Total OCS oil and gas production sources (tpy)	7,563	1.48E-01	34,304	1,070	1,021	11	948	1,053
Biogenic and geogenic sources	-	-	-	-	-	-	-	**13,561**
Commercial fishing vessels	1,682	2.03E-02	9,061	217	211	2	4	96
Commercial marine vessels	**17,555**	**4.15E-01**	**149,704**	**2,725**	**2,516**	**43**	**5,261**	8,859
LOOP	210	2.59E-03	936	35	33	1	12	281
Military vessels	216	2.61E-03	1,163	28	27	0.40	1	12
Vessel lightering[a]	-	-	-	-	-	-	-	4,603
Recreational vessels	755	1.61E-02	3,817	83	80	2	4	200
Total Non-OCS oil and gas production sources	20,418	4.56E-01	164,681	3,087	2,867	48	5,281	27,612
Total non-platform emissions[b]	27,980	6.04E-01	198,986	4,157	3,888	59	6,228	28,665

[a] Evaporative lightering emissions only. Vessel estimates are reflected in commercial marine vessels category.
[b] Totals may not sum due to rounding.
Note: Highest source category values shown in bold.

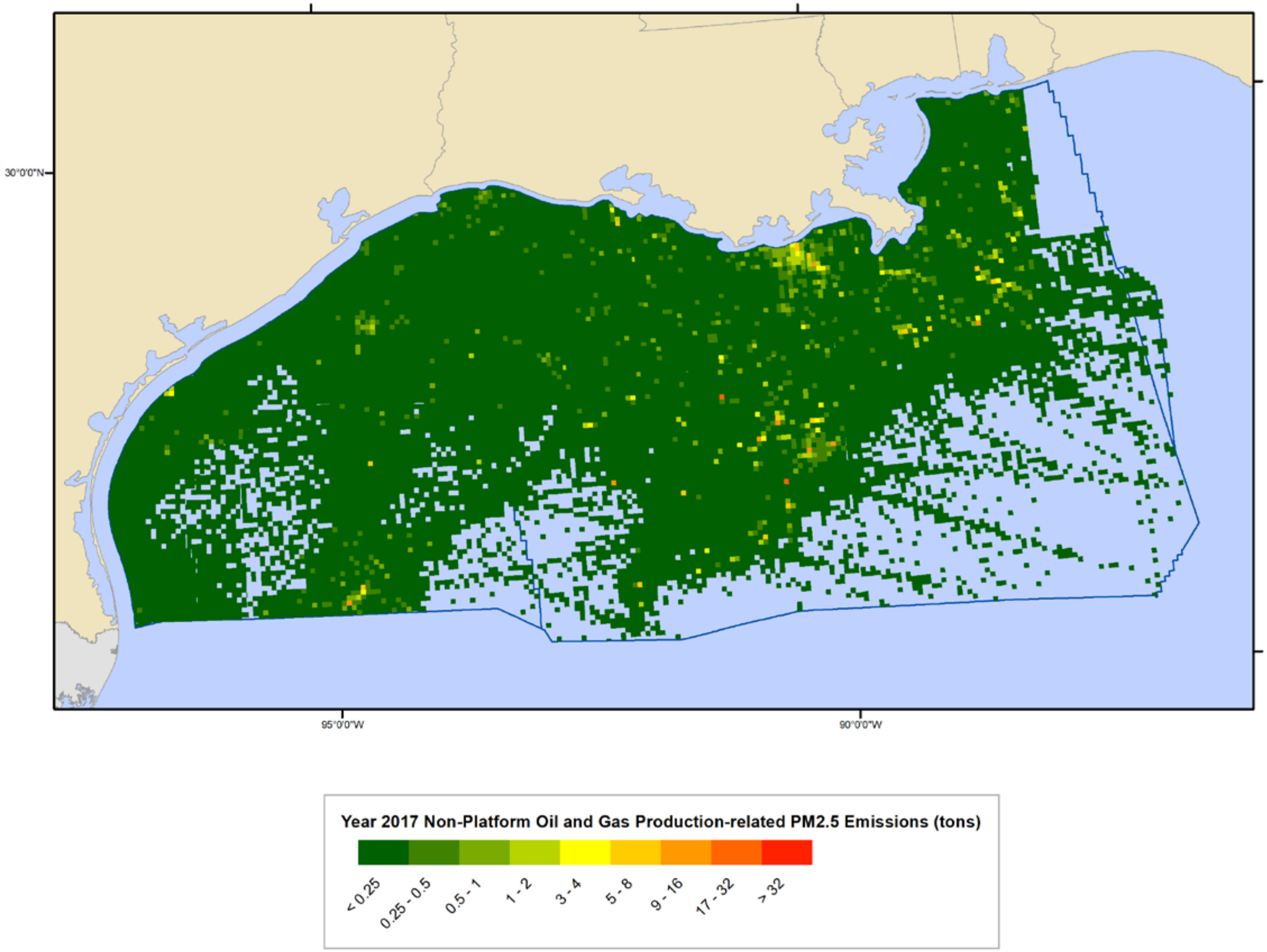


Figure 6-6. Non-platform Oil and Gas Production-related $PM_{2.5}$ 2017 Emission Estimates

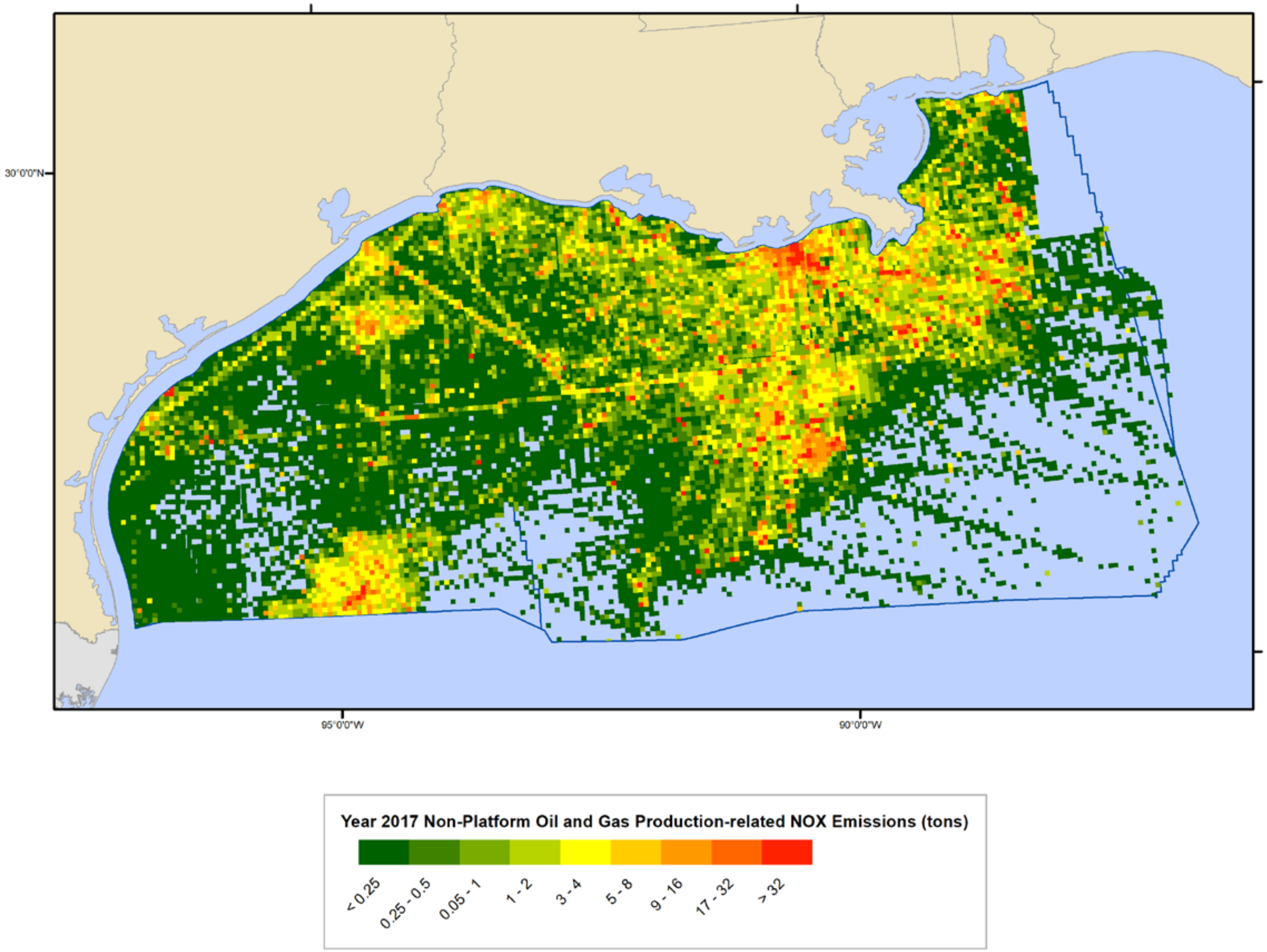


Figure 6-7. Non-platform Oil and Gas Production-related NO_x 2017 Emission Estimates

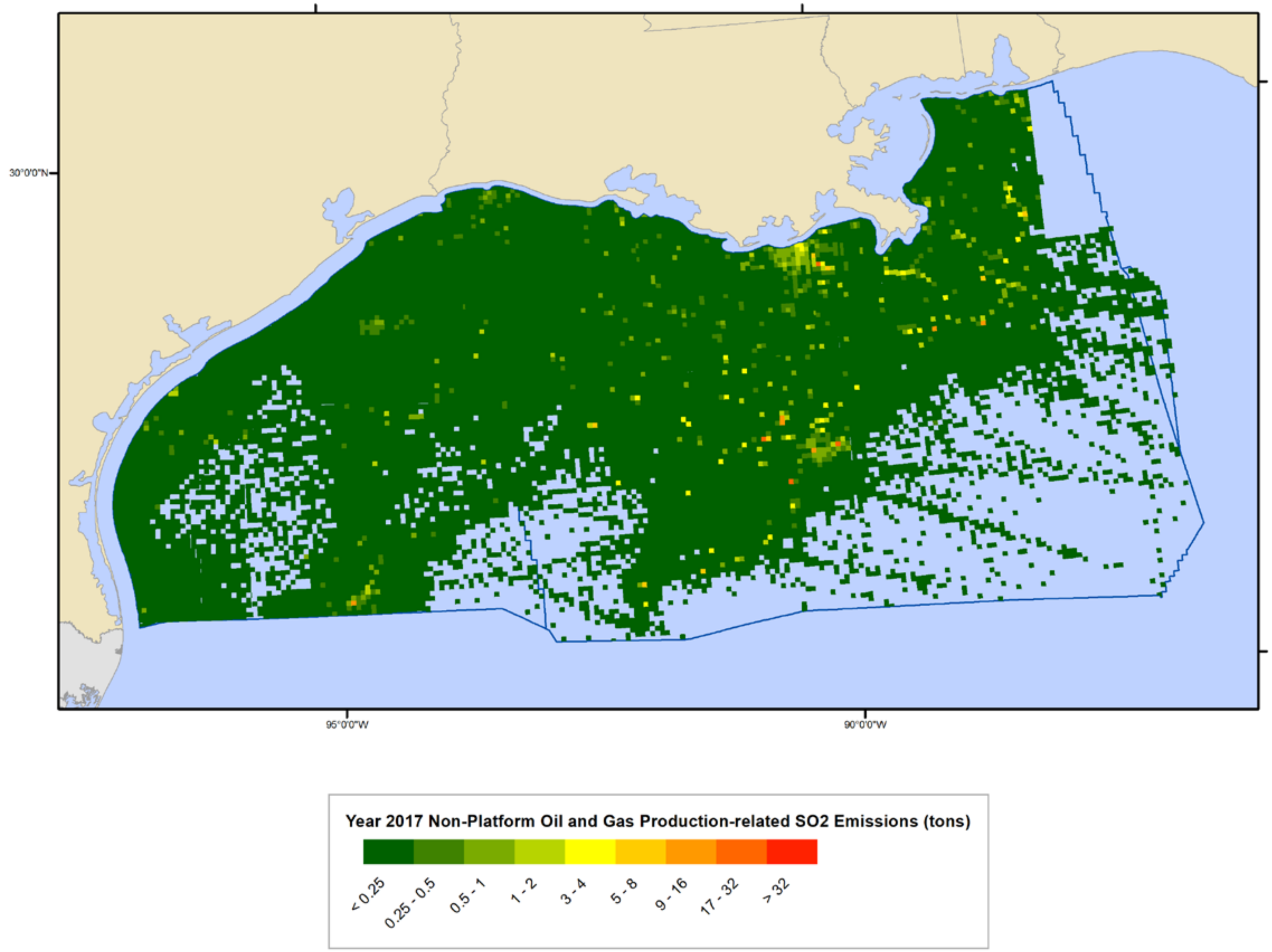


Figure 6-8. Non-platform Oil and Gas Production-related SO_2 2017 Emission Estimates

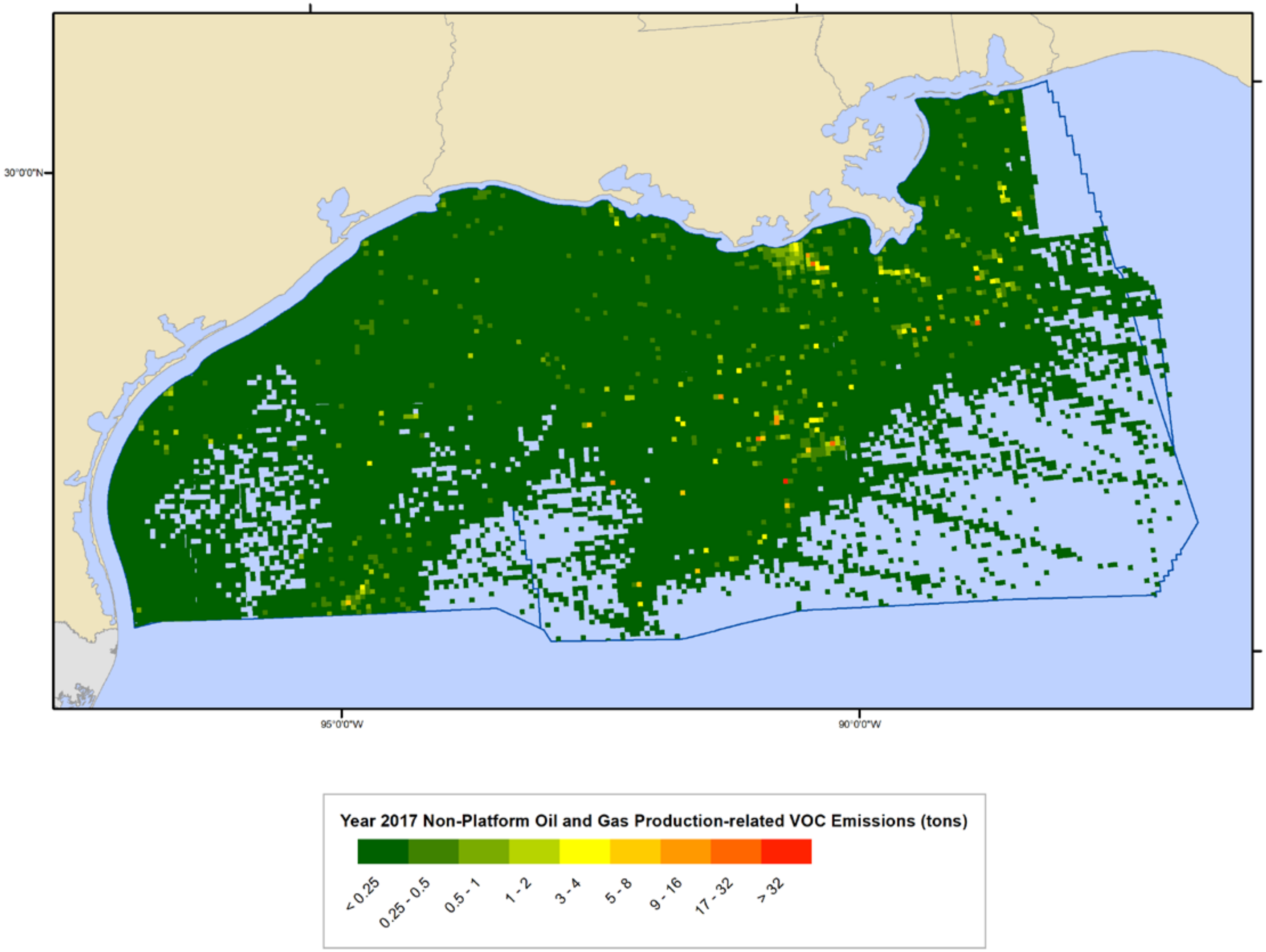


Figure 6-9. Non-platform Oil and Gas Production-related VOC 2017 Emission Estimates

Table 6-3 presents the combined platform and non-platform criteria pollutant estimates. Figures 6-10 through 6-13 indicate the spatial locations of the $PM_{2.5}$, NO_x, SO_2, and VOC total platform and non-platform (oil and gas production-related sources) emission estimates for 2017. To facilitate more detailed review, Tables 6-4 through 6-10 present platform and non-platform emission estimates by pollutant. Figures 6-14 through 6-20 depict the emission sources for each criteria pollutant and precursor.

Table 6-3. Total Platform and Non-platform 2017 Emission Estimates for Criteria Pollutants and Precursors

Source Category	CO (tpy)	Pb (tpy)	NO_x (tpy)	PM_{10}-PRI (tpy)	$PM_{2.5}$-PRI (tpy)	NH_3 (tpy)	SO_2 (tpy)	VOC (tpy)
Total platform emissions	51,872	3.79E-03	49,962	636	635	8	462	38,833
Drilling rigs	1,320	2.31E-02	6,418	148	141	3	142	213
Pipelaying operations	319	8.25E-03	2,924	55	51	1	117	169
Support helicopters	84	-	149	4	4	-	17	79
Support vessels	5,221	1.04E-01	21,651	765	731	6	594	503
Survey vessels	618	1.26E-02	3,163	98	94	1	79	89
Total OCS oil and gas production source emissions	59,435	1.52E-01	84,266	1,707	1,656	19	1,410	39,886
Total non-OCS oil and gas production source emissions	20,418	4.56E-01	164,681	3,087	2,867	48	5,281	27,612
Total emissions[a]	79,852	6.08E-01	248,948	4,794	4,523	68	6,691	67,498

[a] Totals may not sum due to rounding.

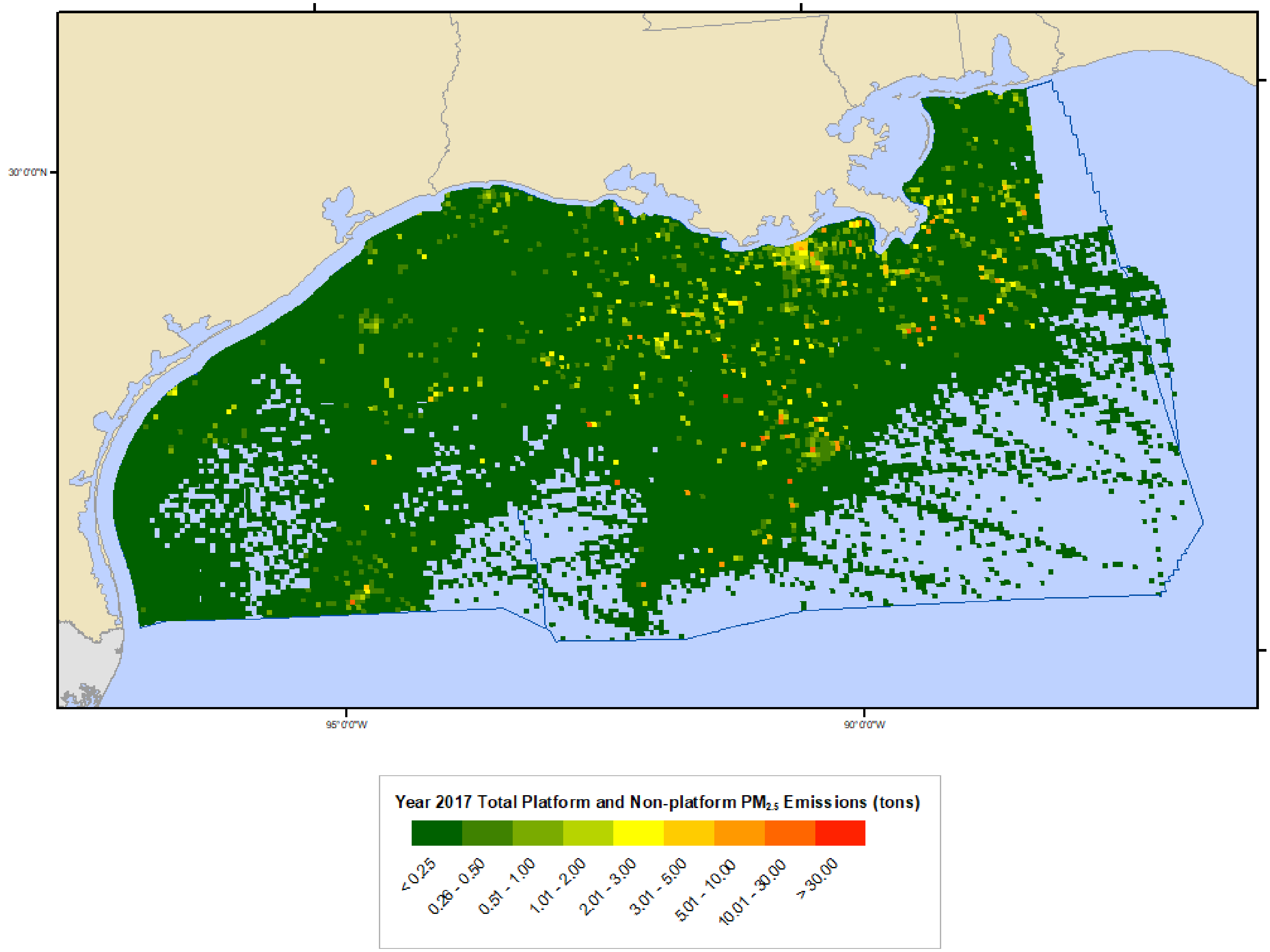


Figure 6-10. Total Platform and Non-platform (Oil and Gas Production-related Sources) $PM_{2.5}$ 2017 Emission Estimates

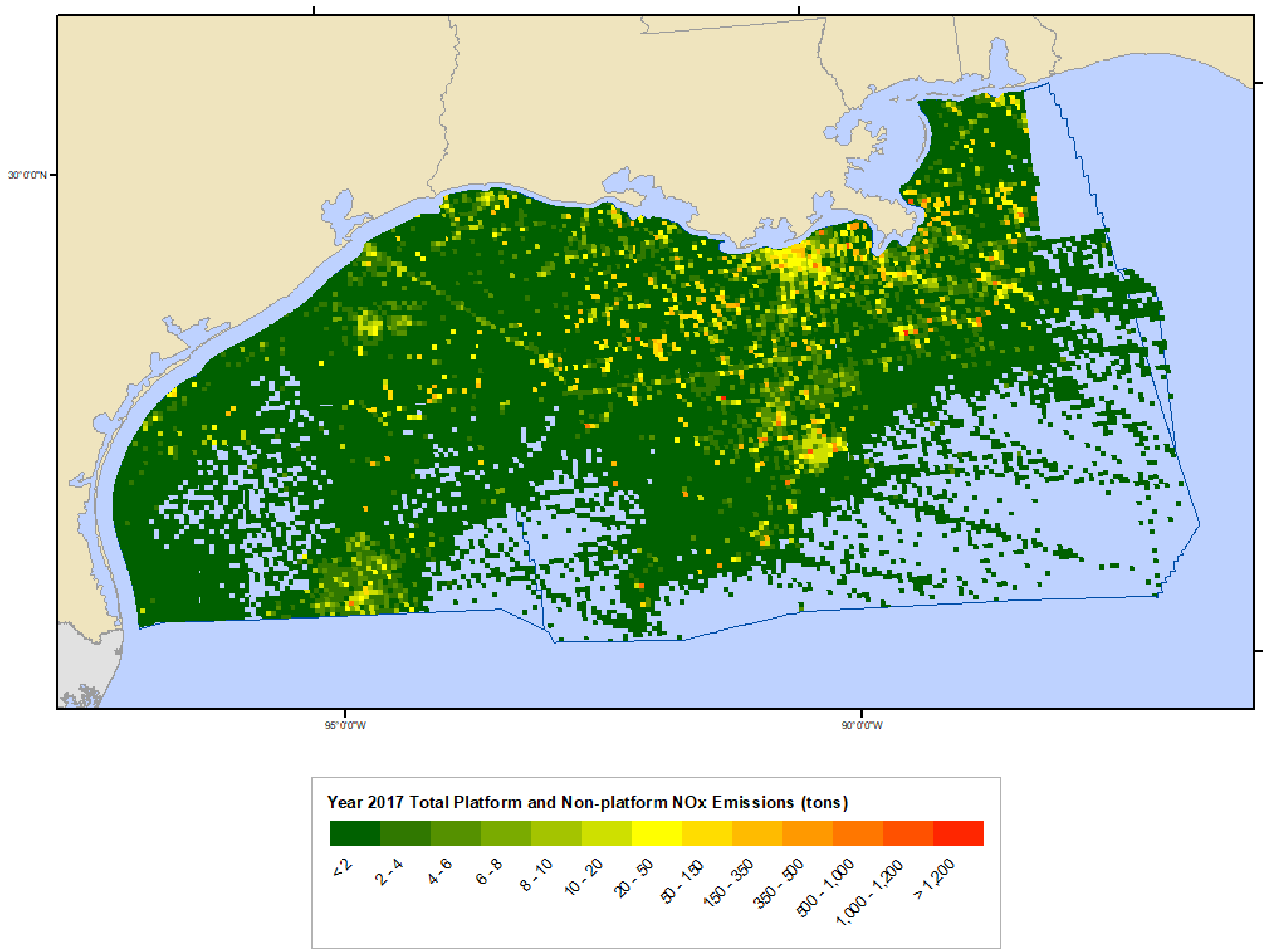


Figure 6-11. Total Platform and Non-platform (Oil and Gas Production-related Sources) NO_X 2017 Emission Estimates

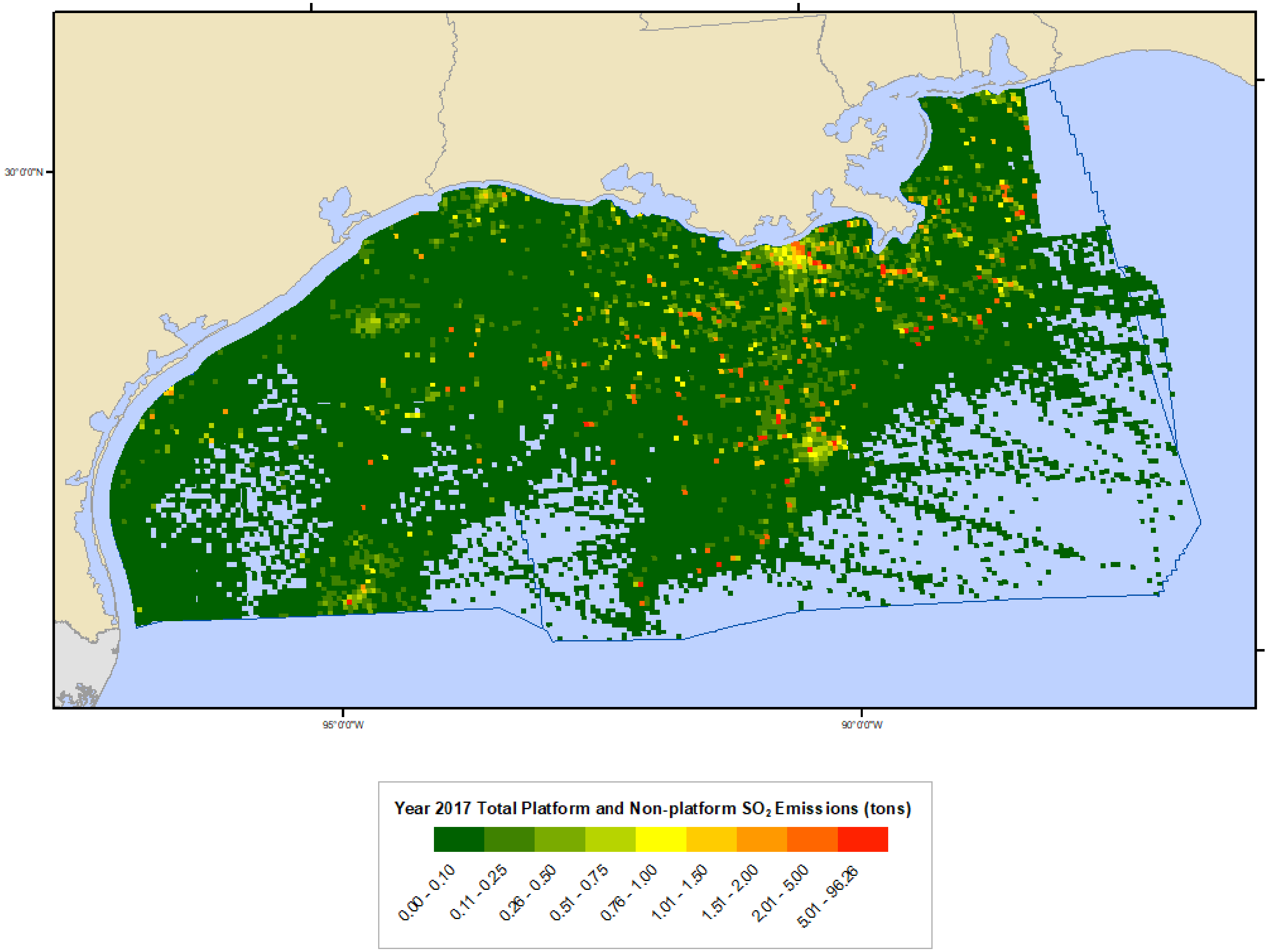


Figure 6-12. Total Platform and Non-platform (Oil and Gas Production-related Sources) SO_2 2017 Emission Estimates

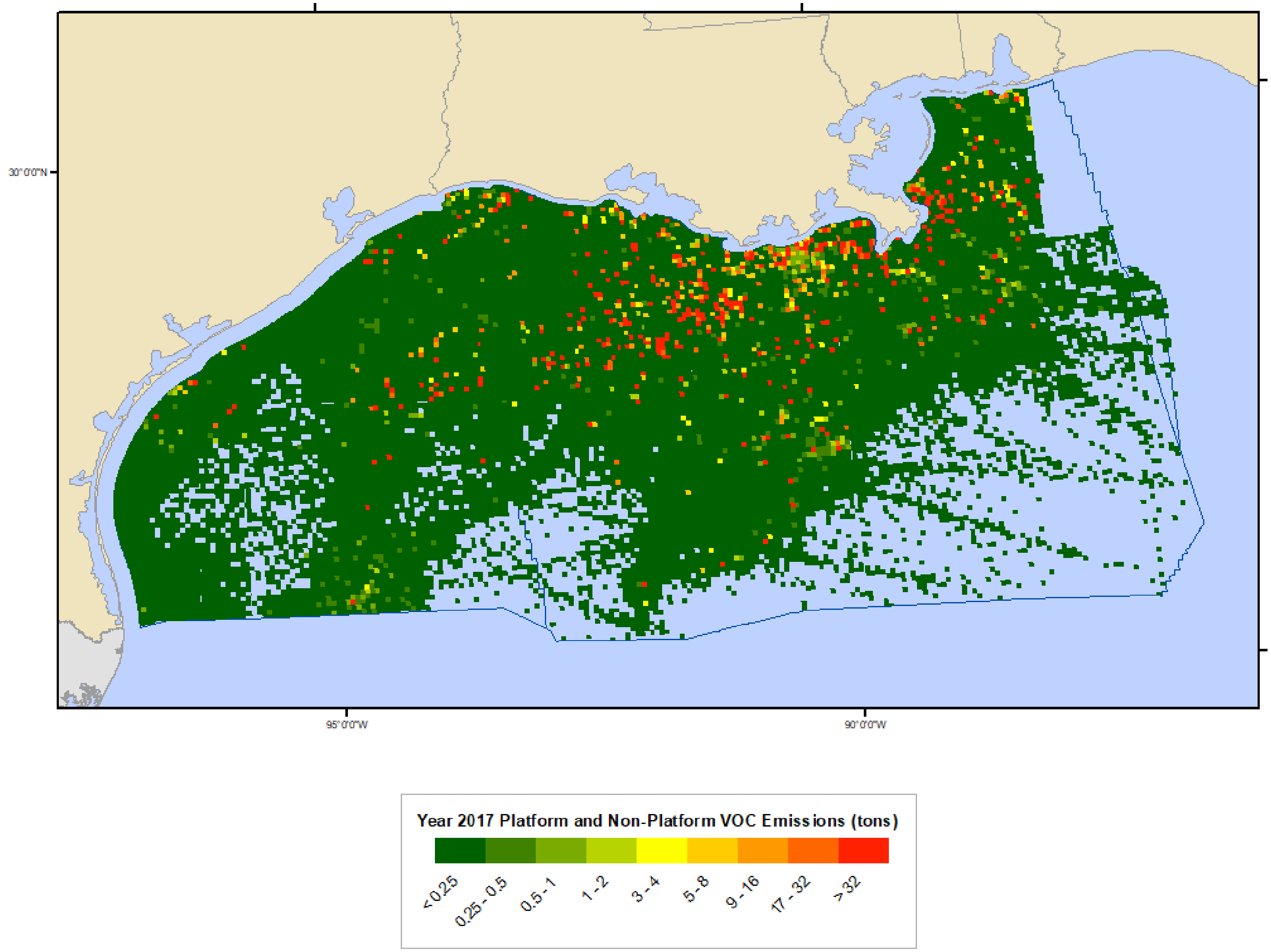


Figure 6-13. Total Platform and Non-platform (Oil and Gas Production-related Sources) VOC 2017 Emission Estimates

Table 6-4. CO 2017 Emission Estimates for All Sources

Equipment and Source Category	CO Emissions (tpy)
Natural gas engines	46,190
Commercial marine vessels	17,555
Support vessels	5,221
Natural gas, diesel, and dual-fuel turbines	2,836
Commercial fishing vessels	1,682
Combustion flares	1,362
Drilling rigs	1,320
Diesel engines	1,151
Recreational vessels	755
Survey vessels	618
Pipelaying operations	319
Military vessels	216
LOOP	210
Boilers, heaters, and burners	200
Drilling equipment	133
Support helicopters	84
Total Emissions[a]	79,852

[a] Totals may not sum due to rounding.

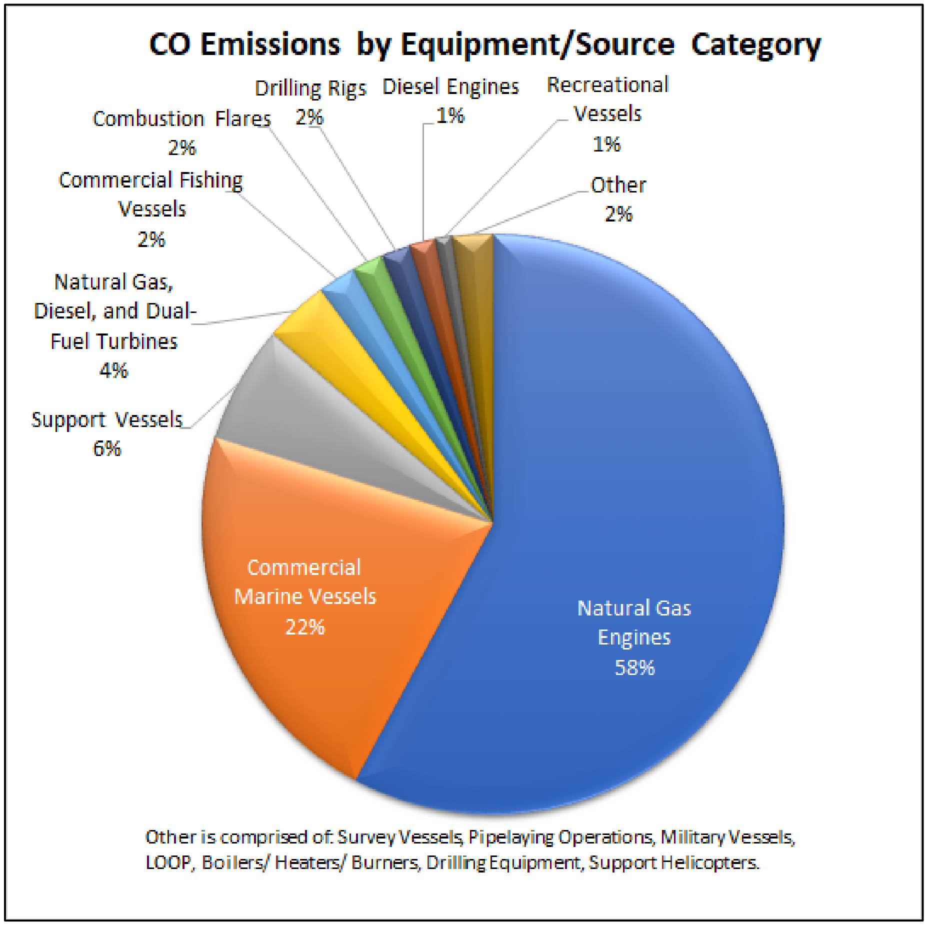


Figure 6-14. CO 2017 Emissions by Source Type

Table 6-5. Pb 2017 Emission Estimates for All Sources

Equipment and Source Category	Pb Emissions (tpy)
Commercial marine vessels	4.15E-01
Support vessels	1.04E-01
Drilling rigs	2.31E-02
Commercial fishing vessels	2.03E-02
Recreational vessels	1.61E-02
Survey vessels	1.26E-02
Pipelaying operations	8.25E-03
Military vessels	2.61E-03
LOOP	2.59E-03
Natural gas, diesel, and dual-fuel turbines	2.09E-03
Boilers, heaters, and burners	1.61E-03
Combustion flares	8.46E-05
Total Emissions[a]	6.08E-01

[a] Totals may not sum due to rounding.

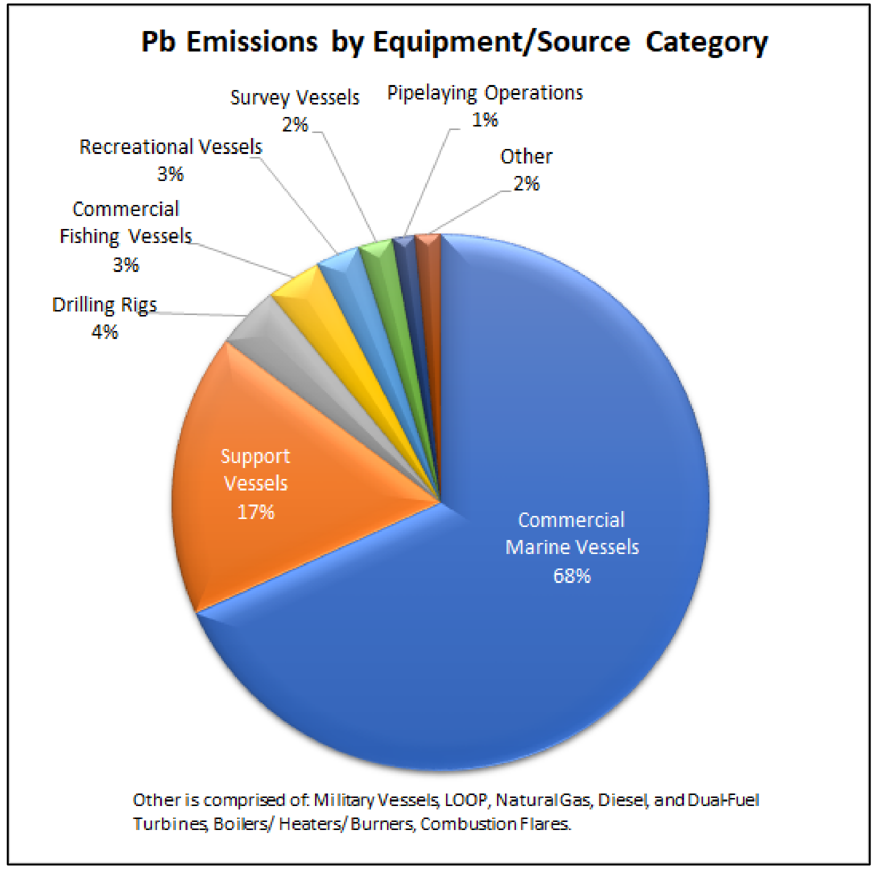


Figure 6-15. Pb 2017 Emissions by Source Type

Table 6-6. NO_x 2017 Emission Estimates for All Sources

Equipment and Source Category	NO_x Emissions (tpy)
Commercial marine vessels	149,704
Natural gas engines	32,945
Support vessels	21,651
Natural gas, diesel, and dual-fuel turbines	11,178
Commercial fishing vessels	9,061
Drilling rigs	6,418
Diesel engines	4,791
Recreational vessels	3,817
Survey vessels	3,163
Pipelaying operations	2,924
Military vessels	1,163
LOOP	936
Drilling equipment	501
Combustion flares	303
Boilers, heaters, and burners	243
Support helicopters	149
Total Emissions[a]	248,948

[a] Totals may not sum due to rounding.

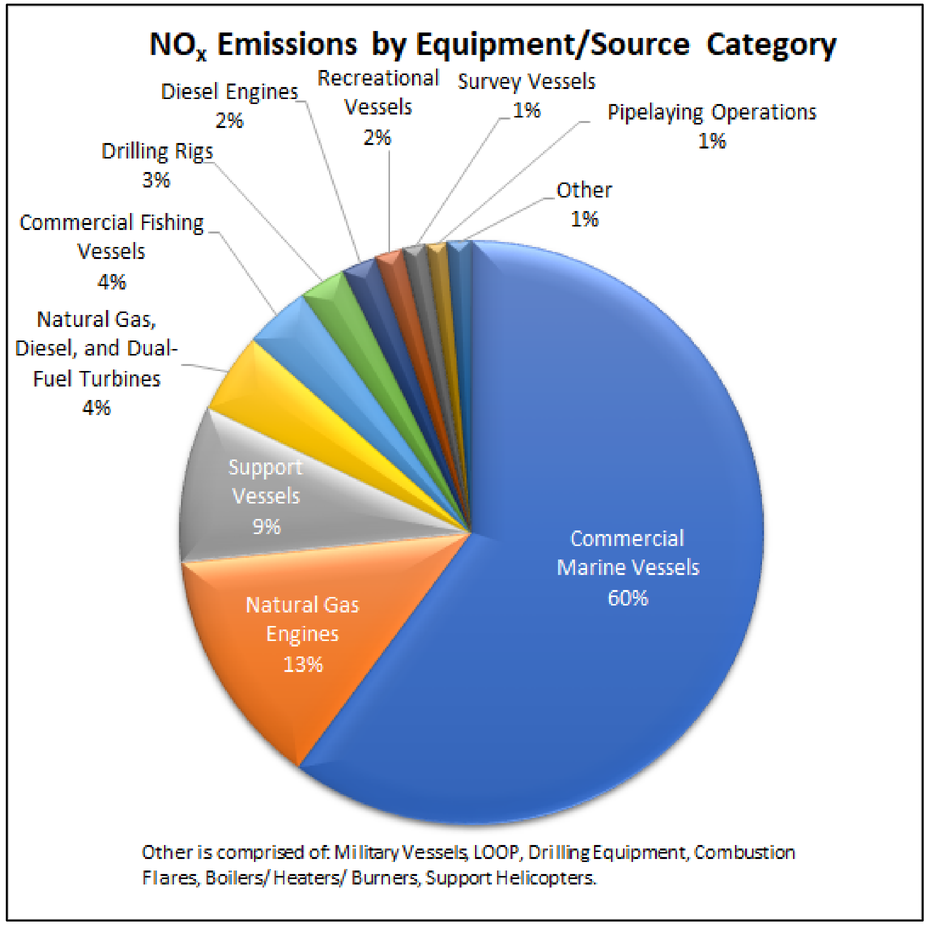


Figure 6-16. NO_x 2017 Emissions by Source Type

Table 6-7. $PM_{2.5}$-PRI 2017 Emission Estimates for All Sources[a]

Equipment and Source Category	$PM_{2.5}$-PRI Emissions (tpy)
Commercial marine vessels	2,516
Support vessels	731
Natural gas engines	281
Commercial fishing vessels	212
Diesel engines	211
Drilling rigs	141
Natural gas, diesel, and dual-fuel turbines	121
Survey vessels	94
Recreational vessels	80
Pipelaying operations	51
LOOP	33
Military vessels	27
Boilers, heaters, and burners	12
Drilling equipment	9
Support helicopters	4
Combustion flares	0.36
Total Emissions[b]	4,523

[a] Annual $PM_{2.5}$ emission estimates follow a similar pattern.
[b] Totals may not sum due to rounding.

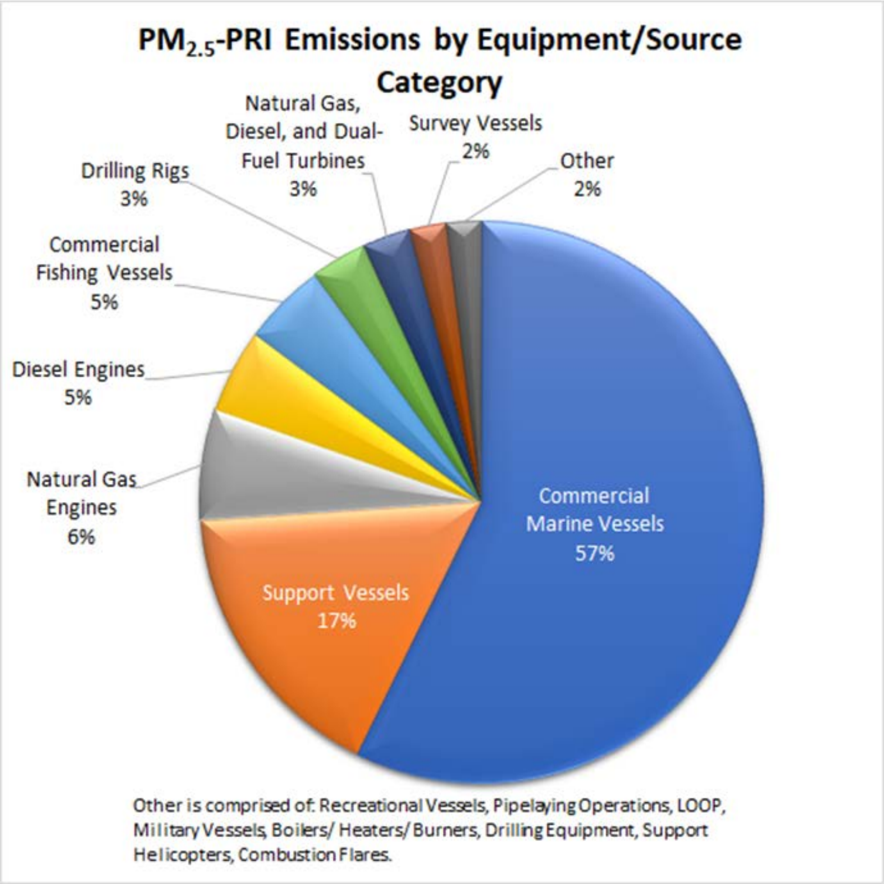


Figure 6-17. $PM_{2.5}$-PRI 2017 Emissions by Source Type

Table 6-8. NH_3 2017 Emission Estimates for All Sources

Equipment and Source Category	NH_3 Emissions (tpy)
Commercial marine vessels	43
Boilers, heaters, and burners	8
Support vessels	6
Drilling rigs	3
Commercial fishing vessels	2
Recreational vessels	2
Pipelaying operations	1
Survey vessels	1
LOOP	1
Combustion flares	1
Military vessels	0.40
Total Emissions[a]	68

[a] Totals may not sum due to rounding.

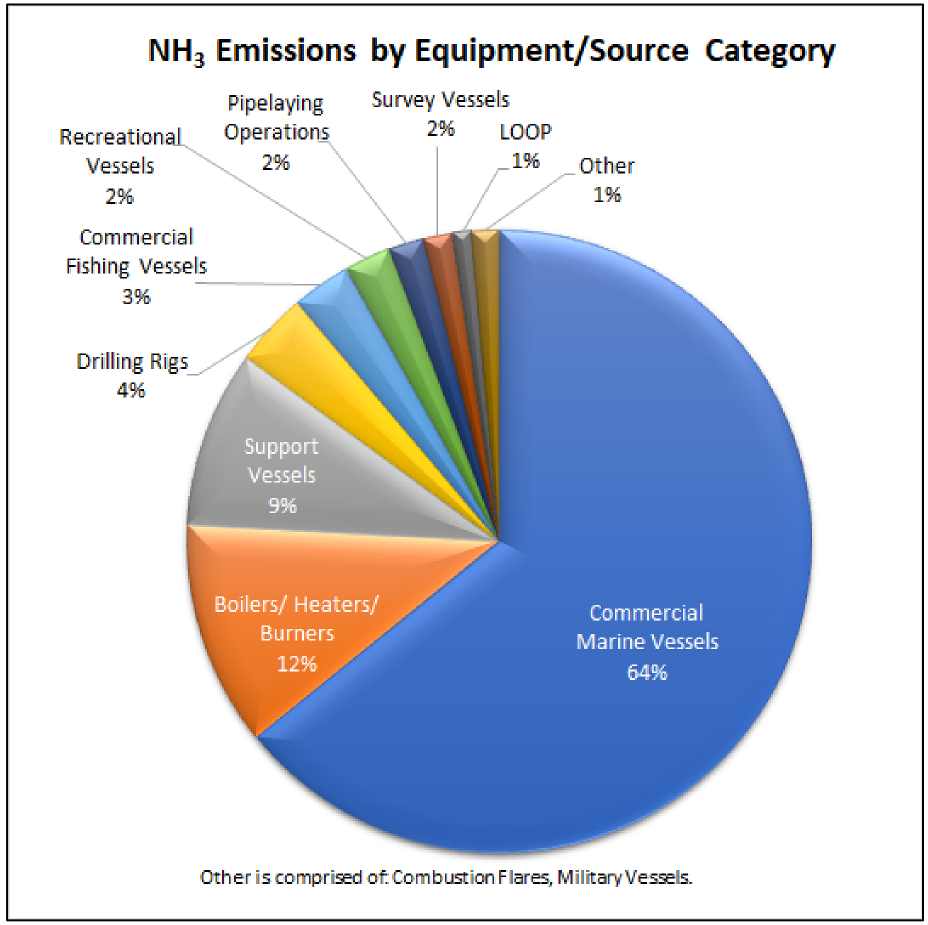


Figure 6-18. NH_3 2017 Emissions by Source Type

Table 6-9. SO_2 2017 Emission Estimates for All Sources

Equipment and Source Category	SO_2 Emissions (tpy)
Commercial marine vessels	5,261
Support vessels	594
Diesel engines	381
Drilling rigs	142
Pipelaying operations	117
Survey vessels	79
Natural gas, diesel, and dual-fuel turbines	44
Amine units	23
Support helicopters	17
LOOP	12
Natural gas engines	11
Commercial fishing vessels	4
Boilers, heaters, and burners	4
Recreational vessels	4
Military vessels	1
Drilling equipment	0.24
Combustion flares	0.07
Total Emissions[a]	6,691

[a] Totals may not sum due to rounding.

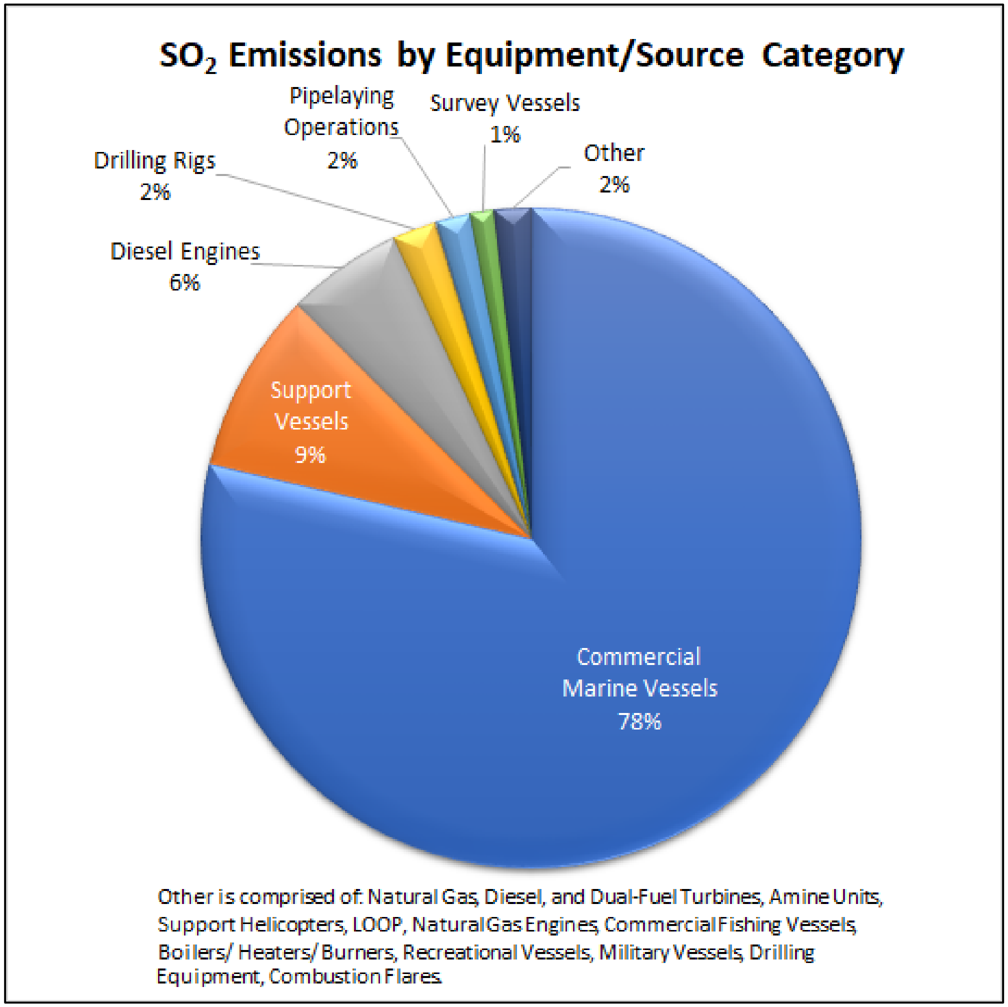


Figure 6-19. SO_2 2017 Emissions by Source Type

Table 6-10. VOC 2017 Emission Estimates for All Sources

Equipment and Source Category	VOC Emissions (tpy)
Cold vents	15,732
Biogenic and geogenic sources	13,561
Fugitive sources	13,408
Commercial marine vessels	8,859
Vessel lightering	4,603
Pneumatic pumps	3,370
Pneumatic controllers	2,222
Natural gas engines	1,074
Combustion flares	994
Glycol dehydrators	851
Storage tanks	556
Support vessels	503
LOOP	281
Diesel engines	241
Drilling rigs	213
Recreational vessels	200
Losses from flashing	181
Pipelaying operations	169
Commercial fishing vessels	96
Survey vessels	89
Support helicopters	79
Natural gas, diesel, and dual-fuel turbines	73
Loading operations	70
Mud degassing	36
Boilers, heaters, and burners	13
Drilling equipment	13
Military vessels	12
Amine units	6.47E-02
Total Emissions[a]	67,498

[a] Totals may not sum due to rounding.

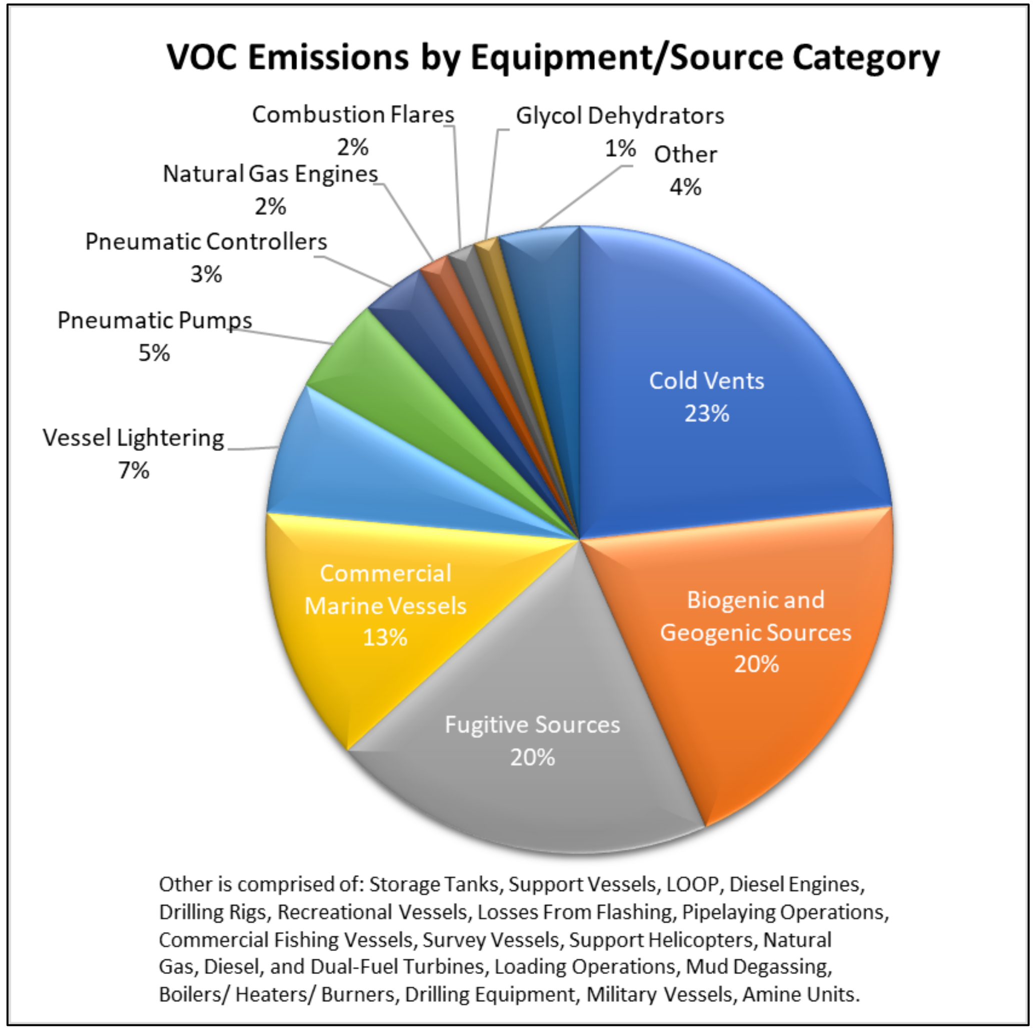


Figure 6-20. VOC 2017 Emissions by Source Type

Tables 6-11 through 6-13 present the GHG emission estimates for 2017, with the highest emission sources shown in bold in Tables 6-11 and 6-12. The inventory includes the three major GHGs (CO_2, CH_4, and N_2O), as well as a total GHG emission estimate in carbon dioxide equivalents (CO_2e). Because GHGs differ in their warming influence due to their different radiative properties and lifetimes in the atmosphere, the CO_2 equivalent was developed to express the warming influences in a common metric. The common metric is called the CO_2-equivalent emission, which is the amount of CO_2 emission that would cause the same warming influence as an emitted amount of a long-lived GHG or a mixture of GHGs. The equivalent CO_2 emissions are obtained by multiplying the GHG emissions by its global warming potential (GWP). For a mix of GHGs it is obtained by summing the equivalent CO_2 emissions of each gas. Tables 6-14 through 6-17 present the present platform and non-platform emission estimates by GHG. Figures 6-21 through 6-24 graphically depict the emission sources for each GHG.

As the science surrounding climate change evolves, the GWPs have been revised. For the 2017 inventory, the GWPs reflect the 100-year GWPs presented in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC, 2007), with a GWP of 25 for CH_4, and a GWP of 298 for N_2O. The USEPA has adopted these values under the USEPA Final Mandatory Reporting of Greenhouse Gases Rule (40 CFR Parts 86, 87, 88, 89, et al.). Other studies may use the IPCC 20-year GWPs. The 100-year GWPs are based on the energy absorbed by a gas over 100 years; the 20-year GWPs are based on the energy absorbed over 20 years. The 20-year CH_4 GWP can be four times higher than the 100-year GWP. The IPCC Fifth Assessment Report (AR5) also has updated GWPs; the GWP for CH_4 is approximately 20% higher than AR4 (28 vs. 25). The CO_2e emission estimates shown in these tables represent the number of tons of CO_2 emissions with the same GWP as one ton of another GHG as shown in the following equation:

$$CO_2e = \sum GHG_i \times GWP_i$$

Where:

CO_2e = Carbon dioxide equivalent (tpy)
GHG_i = Mass emissions of each GHG (tpy)
GWP_i = Global warming potential for each GHG in the inventory

Table 6-11. Total GHG 2017 Emission Estimates for Platform Sources

Equipment Types	CO_2 Emissions (tpy)	CH_4 Emissions (tpy)	N_2O Emissions (tpy)	CO_2e Emissions (tpy)[a]
Amine units	140	3	-	224
Boilers, heaters, and burners	291,729	5	5	293,435
Diesel engines	212,150	6	-	212,297
Drilling equipment	25,844	1	-	25,875
Combustion flares	506,262	3,184	9	588,494
Fugitive sources	-	54,239	-	1,355,971
Glycol dehydrators	-	557	-	13,914
Loading operations	-	-	-	-
Losses from flashing	94	4,033	-	100,922
Mud degassing	1	86	-	2,147
Natural gas engines	1,978,765	10,414	-	2,239,107
Natural gas, diesel, and dual-fuel turbines	**3,839,648**	298	**104**	**3,878,122**
Pneumatic pumps	537	28,559	-	714,508
Pneumatic controllers	377	15,470	-	387,138
Storage tanks	-	551	-	13,784
Cold vents	1,813	**70,488**	-	1,764,004
Total emissions[b]	6,857,360	187,894	118	11,589,943

[a] GWP = 25 for CH_4 and 298 for N_2O.
[b] Totals may not sum due to rounding.

Note: Highest emission source shown in bold.

Table 6-12. Total GHG 2017 Emission Estimates for Non-platform Sources

Source Category	CO_2 Emissions (tpy)	CH_4 Emissions (tpy)	N_2O Emissions (tpy)	CO_2e Emissions (tpy)[a]
Drilling rigs	508,797	3	26	516,469
Pipelaying operations	191,132	1	9	193,824
Support helicopters	51,921	1	2	52,459
Support vessels	2,211,718	9	134	2,251,816
Survey vessels	270,077	1	15	274,681
Total OCS oil and gas production source emissions	3,233,646	16	185	3,289,249
Biogenic and geogenic sources	2,284	**1,876**	**1,948**	629,688
Commercial fishing	439,598	3	21	445,931
Commercial marine vessels	**9,002,753**	59	476	**9,145,991**
LOOP	60,139	0.35	2	60,680
Military vessels	56,400	0.35	3	57,212
Recreational vessels	382,631	2	17	387,642
Total Non-OCS oil and gas production source emissions	9,943,805	1,940	2,466	10,727,145
Total emissions[b]	13,177,451	1,957	2,651	14,016,393

[a] GWP = 25 for CH_4 and 298 for N_2O.
[b] Totals may not sum due to rounding.
Note: Highest emission sources shown in bold.

Table 6-13. Total Platform and Non-platform 2017 Emission Estimates for GHGs

Source Category	CO_2 Emissions (tpy)	CH_4 Emissions (tpy)	N_2O Emissions (tpy)	CO_2e Emissions (tpy)[a]
Total platform emissions	6,857,360	187,894	118	11,589,943
Drilling rigs	508,797	3	26	516,469
Pipelaying operations	191,132	1	9	193,824
Support helicopters	51,921	1	2	52,459
Support vessels	2,211,718	9	134	2,251,816
Survey vessels	270,077	1	15	274,681
Total OCS oil and gas production source emissions	10,091,005	187,910	303	14,879,192
Total Non-OCS oil and gas production source emissions	9,943,805	1,940	2,466	10,727,145
Total emissions[b]	20,034,810	189,851	2,769	25,606,336

[a] GWP = 25 for CH_4 and 298 for N_2O.
[b] Totals may not sum due to rounding.
Note: Highest emission sources shown in bold.

Table 6-14. CO_2 2017 Emission Estimates for All Sources

Equipment and Source Category	CO_2 Emissions (tpy)
Commercial marine vessels	9,002,753
Natural gas, diesel, and dual-fuel turbines	3,839,648
Support vessels	2,211,718
Natural gas engines	1,978,765
Drilling rigs	508,797
Combustion flares	506,262
Commercial fishing vessels	439,598
Recreational Vessels	382,631
Boilers, heaters, and burners	291,729
Survey vessels	270,077
Diesel engines	212,150
Pipelaying operations	191,132
LOOP	60,139
Military vessels	56,400
Support helicopters	51,921
Drilling equipment	25,844
Biogenic and geogenic sources	2,284
Cold Vents	1,813
Pneumatic Pumps	537
Pneumatic Controllers	377
Amine Units	140
Losses from Flashing	94
Mud Degassing	1
Total Emissions[a]	20,034,810

[a] Totals may not sum due to rounding.

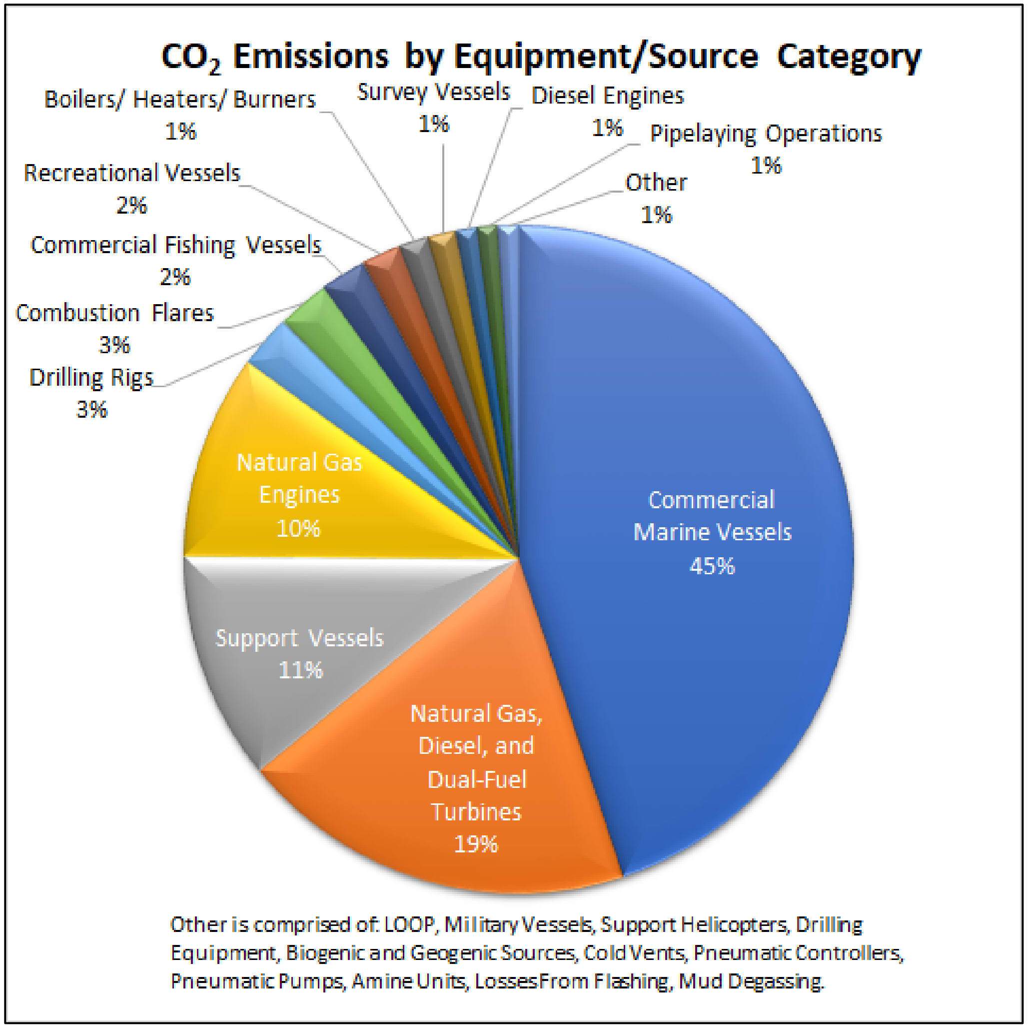


Figure 6-21. CO_2 2017 Emissions by Source Type

Table 6-15. CH_4 2017 Emission Estimates for All Sources

Equipment and Source Category	CH_4 Emissions (tpy)
Cold vents	70,488
Fugitive sources	54,239
Pneumatic pumps	28,559
Pneumatic controllers	15,470
Natural gas engines	10,414
Losses from flashing	4,033
Combustion flares	3,184
Biogenic and geogenic sources	1,876
Glycol dehydrators	557
Storage tanks	551
Natural gas, diesel, and dual-fuel turbines	298
Mud degassing	86
Commercial marine vessels	59
Support vessels	9
Diesel engines	6
Boilers, heaters, and burners	5
Amine units	3
Drilling rigs	3
Commercial fishing vessels	3
Recreational vessels	2
Support helicopters	1
Survey vessels	1
Drilling equipment	1
Pipelaying operations	1
Military vessels	0.35
LOOP	0.35
Total Emissions[a]	189,851

[a] Totals may not sum due to rounding.

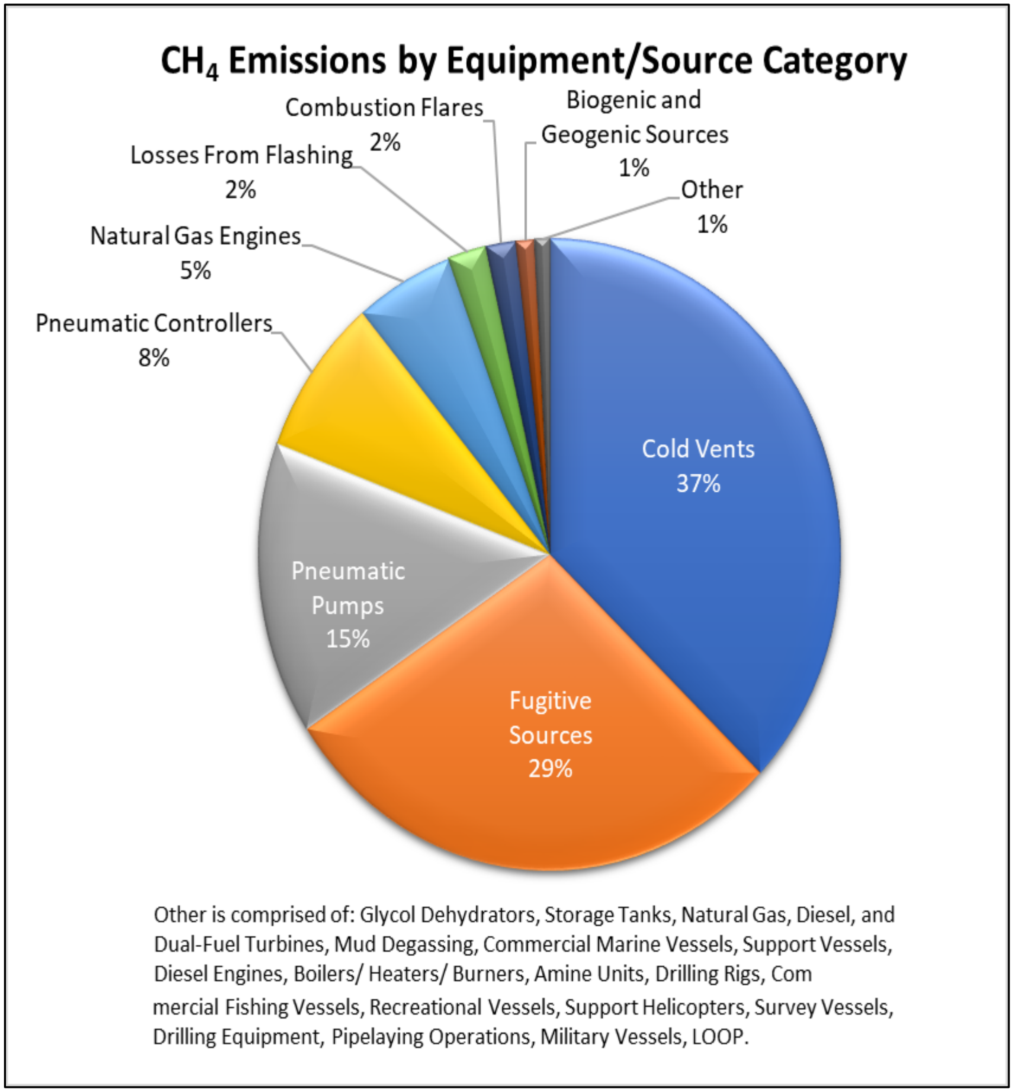


Figure 6-22. CH_4 2017 Emissions by Source Type

Table 6-16. N_2O 2017 Emission Estimates for All Sources

Equipment and Source Category	N_2O Emissions (tpy)
Biogenic and geogenic sources	1,948
Commercial marine vessels	476
Support vessels	134
Natural gas, diesel, and dual-fuel turbines	104
Drilling rigs	26
Commercial fishing vessels	21
Recreational vessels	17
Survey vessels	15
Pipelaying operations	9
Combustion flares	9
Boilers, heaters, and burners	5
Military vessels	3
LOOP	2
Support helicopters	2
Total Emissions[a]	2,769

[a] Totals may not sum due to rounding.

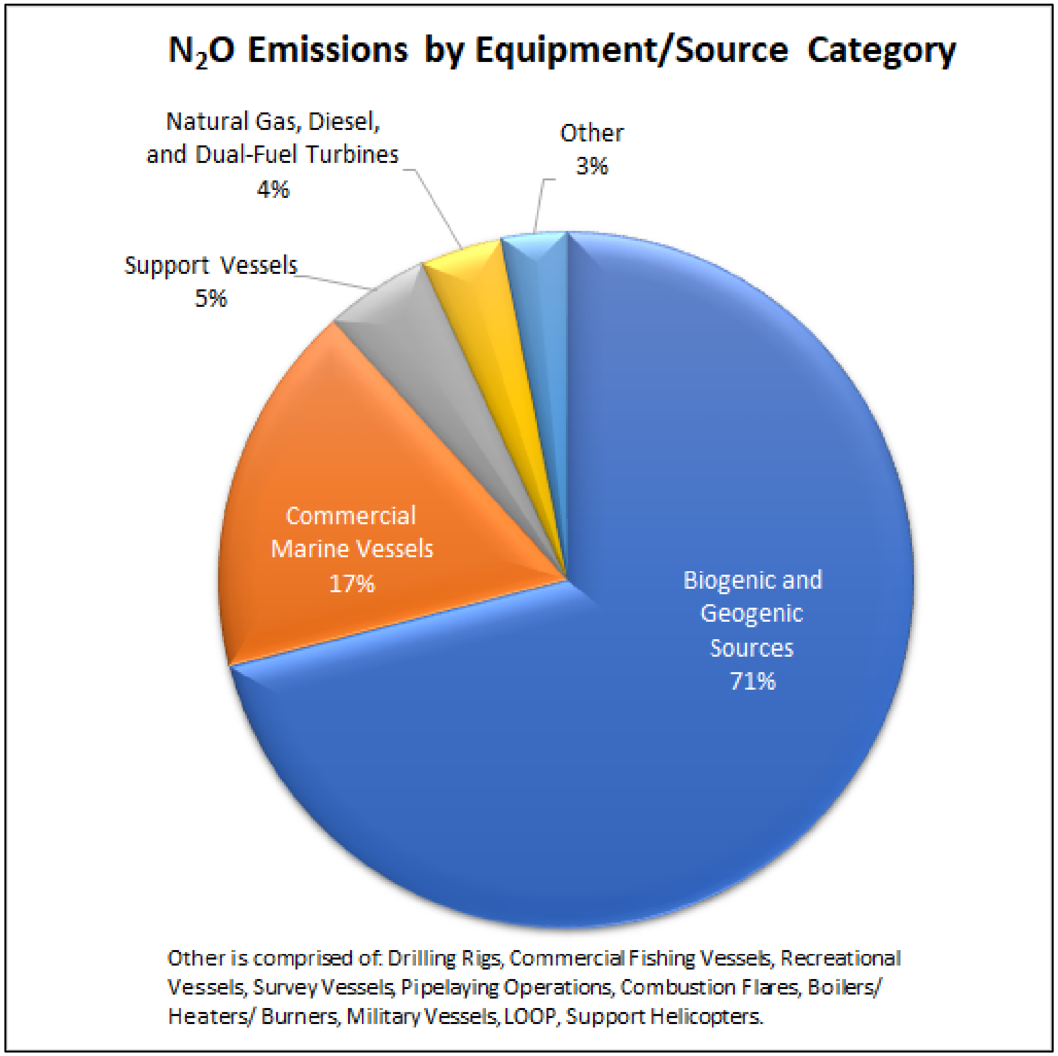


Figure 6-23. N_2O 2017 Emissions by Source Type

Table 6-17. CO_2e 2017 Emission Estimates for All Sources

Equipment and Source Category	CO_2e Emissions (tpy)[a]
Commercial marine vessels	9,145,991
Natural gas, diesel, and dual-fuel turbines	3,878,122
Support vessels	2,251,816
Natural gas engines	2,239,107
Cold vents	1,764,004
Fugitive sources	1,355,971
Pneumatic pumps	714,508
Biogenic and geogenic sources	629,688
Combustion flares	588,494
Drilling rigs	516,469
Commercial fishing	445,931
Recreational vessels	387,642
Pneumatic controllers	387,138
Boilers, heaters, and burners	293,435
Survey vessels	274,681
Diesel engines	212,297
Pipelaying operations	193,824
Losses from flashing	100,922
LOOP	60,680
Military vessels	57,212
Support helicopters	52,459
Drilling equipment	25,875
Glycol dehydrators	13,914
Storage tanks	13,784
Mud degassing	2,147
Amine units	224
Total Emissions[b]	25,606,336

[a] GWP = 25 for CH_4 and 298 for N_2O.
[b] Totals may not sum due to rounding.

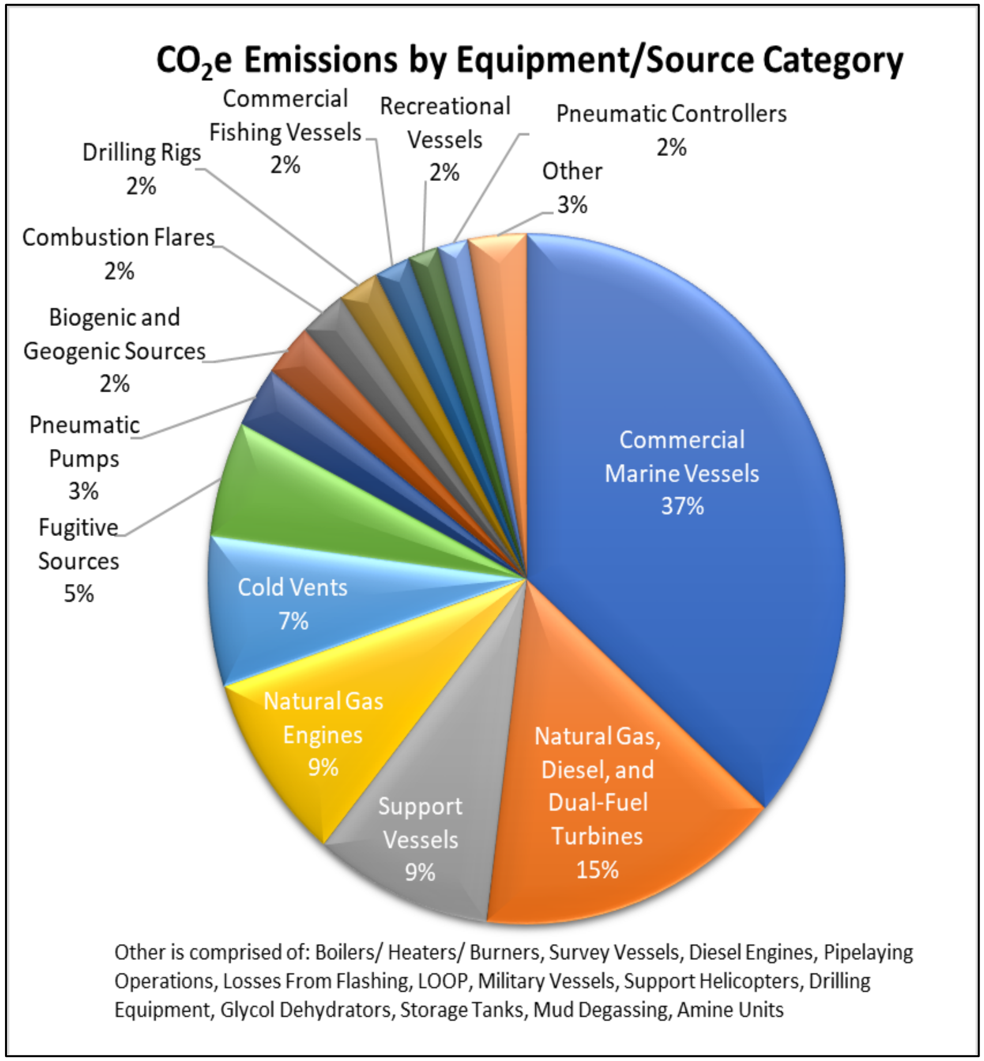


Figure 6-24. CO_2e 2017 Emissions by Source Type

6.2 Limitations

As with previous BOEM emission inventory studies, one key limitation of the 2017 OCS platform emission estimates lies in the compilation of the GOADS-2017 activity datasets. BOEM often must interpret inconsistently reported data as discussed in Section 3 of this report. For example, operators may flag a platform as inactive for a given month, yet populate fuel usage and other data fields during that month. Although these inconsistencies are handled in the same manner for all platforms, it still limits the confidence of the resulting emission estimates. After the draft 2017 emissions estimates were prepared, BOEM provided the draft version of the inventory to the operators for review. At that time, operators could review the activity data used and the resulting emissions estimates and provide corrections. Although revisions provided were incorporated into the final inventory, not all companies provided responses; therefore, accuracy limitations likely still exist due to the way the reported data were interpreted.

For fugitive sources, the current estimation method discussed in Section 4 is based on out-of-date estimation methods and surrogate component counts in many cases, which could result in an overestimate of emissions. BOEM recently initiated a study to update the out-of-date default fugitive component counts and stream composition used in this study and prior Gulfwide emissions inventory studies, conduct testing at offshore production platforms, assess preventative maintenance practices and procedures, and develop updated emission factors. However, this study was not completed.

Limitations also exist for some of the non-platform emission estimates based on the quality of the emission factors and the availability of activity data. The increased use of digital tracking data for marine vessels and helicopters provides emission estimates based on actual data rather than using assumptions about activity. These systems continue to evolve, both in terms of the number of vessels and helicopters that transmit tracking signals, as well as the geographic area these systems cover. BOEM evaluates the coverage of these sources to ensure that the data used are complete. For example, AIS coverage is very good for most vessel types with the exception of fishing and military vessels. For the 2017 inventory, commercial fishing data were evaluated to determine if the AIS data set was sufficiently complete compared to alternative data provided by NOAA. It was decided that at this time the AIS commercial fishing vessel data were not comprehensive enough for inclusion, but there was enough data to spatially allocate emissions using traffic patterns derived from the AIS data.

The AIS vessel data used in the GOM inventories are hourly observations, which are considered appropriate given the lengthy travel distances and types of operations occurring in Federal waters. More refined sampling times would provide more details about ship movements but would increase data storage requirements and processing times. To confirm that the sampling frequency is appropriate, future versions of this inventory could include a sensitivity analysis using more temporally refined data (e.g., 5-minute observations) to determine the difference in the emission estimates that the more detailed data would provide.

A known issue with matching vessels identified in the AIS data to their vessel attributes is that smaller vessels are not as well represented in classification society datasets (e.g., IHS) as the larger vessels. Much of the oil and gas related vessels operating in the GOM are small to medium sized ships equipped with smaller Category 1 and 2 engines. BOEM continues to compile information about these smaller vessels from alternative data sources (e.g., trade associations, web searches, and U.S. Waterborne Commerce data).

For the 2017 inventory, the FAA's NextGen aircraft tracking data were used to quantify helicopter operations in Federal waters. This is the first known application of these data for air quality assessment purposes, and, as such, further validation may prove to be informative. Although the dataset was not well organized and data fields not fully populated, it still represents a significant improvement over previous approaches, which were based on assumptions about where helicopters operate. As with the vessel AIS data, it is anticipated that the NextGen data will continue to evolve through improvements to the aircraft identification codes and aircraft make and model data fields. This will allow for more accurate matching of helicopters to their attributes (e.g., helicopter type, model of turboshaft engine, and maximum speed) and implementation of quality checks on the reported speed of the helicopter. It is also important that transit codes be standardized to better identify an individual trip. Such information could facilitate the development of datasets of typical helicopter trips to deepwater vs. shallow water locations, quantifying the distance traveled for a complete trip, number of stops per trip, and time-in-mode evaluations (climb out, cruise, approach, and time spent on a platform). It would also be informative to compare the NextGen data to helicopter landing logs on platforms to validate the completeness of the data.

The 2017 inventory used satellite images of surface water oil slicks to better understand the distribution of these releases. These monthly images were not sufficient to assess the flux of an individual slick needed to quantify weathering and emissions but were useful in identifying lease blocks where slicks were occurring.

It should be noted that despite repeated attempts, BOEM did not obtain any information from the LOOP to help quantify their 2017 operations. This issue may become more pressing for future inventories as the LOOP is becoming involved in crude exports (in addition to imports) such that activity on the platform is likely to increase, particularly for very large-capacity crude oil tankers that cannot navigate passage through the Houston Ship Channel.

As with the previous BOEM emission inventories, this inventory provides emission estimates for directly emitted pollutants; it does not take into account changes of the emissions due to in-plume chemistry. These changes are based on the reactivity of the individual pollutant species and transformation rates to secondary pollutants. For example, the inventory does not quantify how the NO_x and VOC emissions affect the chemical composition of the marine boundary layer, particularly in the formation of ozone and hydroxyl radicals. The transformation of pollutants needs to be modeled to account for all factors that impact the transformation rate. These considerations come into play when the inventories are modeled to assess impacts.

6.3 Comparison with Other Studies

In past BOEM emission inventory study reports, BOEM compared the results of the most recent inventory to the previous one. For example, in the *Year 2014 Gulfwide Emissions Inventory Study* (Wilson et al., 2017), the calendar year 2014 emission estimates were directly compared with those of the 2011 emissions inventory. The comparisons between all previous inventories are not presented here but discussed in Section 7, Emissions Trends Analysis. The remainder of this section compares the emissions estimates developed for calendar year 2014 and the 2017 emissions estimates by equipment type, source category, and pollutant. Similarities and differences between the two inventories are discussed.

Overall comparisons of pollutant-specific emissions estimates for platforms and non-platform (oil and gas production-related sources only) are presented in Table 6-18 and Figure 6-25 (for criteria pollutants) and Table 6-19 and Figure 6-26 (for GHGs). For criteria pollutants, the overall annual emission estimates decrease in 2017 from the 2014 estimates, most significantly an 80% decrease in the SO_2 emission estimates, a 43% decrease in the PM_{10} estimates, and a 33% decrease in the NO_x estimates. Emissions of VOC decreased 23% and CO 9%. The most significant decrease from 2014 to 2017 seen in the GHG estimates was 17% for CH_4. There was a slight decrease of 0.44% seen for CO_2 and a slight increase of 1% for N_2O due to the addition of boilers as an emission source for CMVs. All comparisons with previous inventories (such as the decreases seen in Tables 6-18 and 6-19) must take into account that the differences may be due to calculation methodologies, or real changes in activity data, equipment, and emissions (e.g., due to regulatory drivers in the case of marine vessels). The following sections examine these differences for the platform and non-platform emission estimates.

Table 6-18. Comparison of Total Platform and Non-platform Oil and Gas Production-related Sources Criteria Pollutant Emission Estimates for Years 2014 and 2017

Calendar Year	CO Emissions (tpy)	NO_x Emissions (tpy)	PM_{10}-PRI Emissions (tpy)	SO_2 Emissions (tpy)	VOC Emissions (tpy)
2014	65,511	126,445	2,997	7,151	51,577
2017	59,435	84,266	1,707	1,410	39,886
Percent difference	-9%	-33%	-43%	-80%	-23%

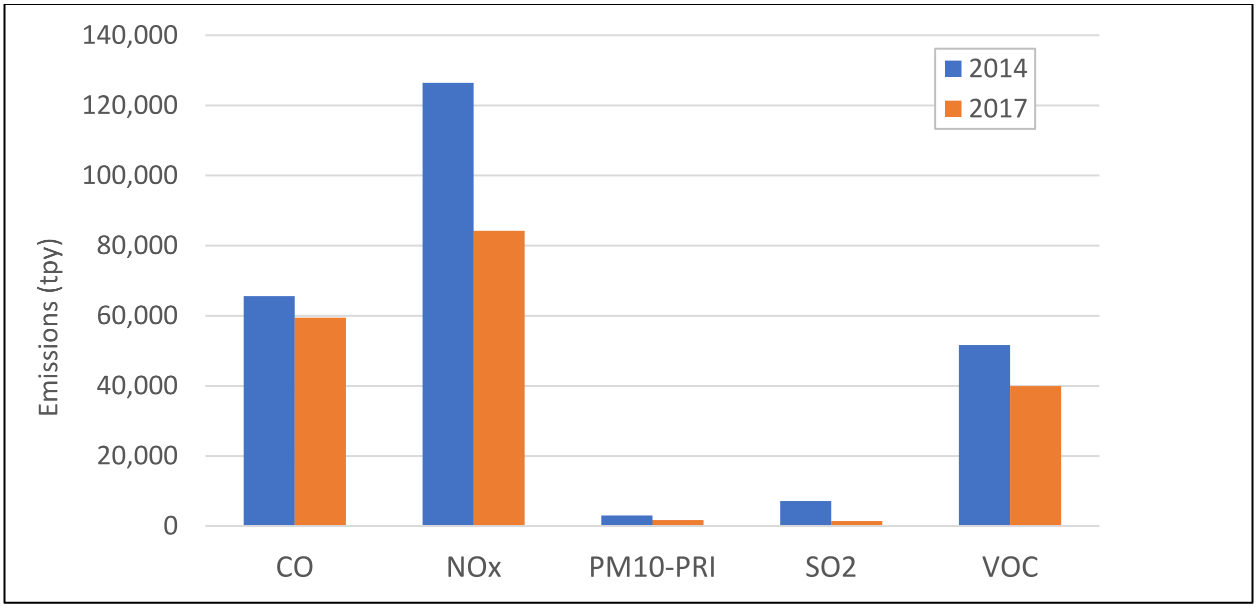


Figure 6-25. Comparison of Total Criteria Pollutant Emissions from Platform and Non-platform Oil and Gas Production-related Sources

Table 6-19. Comparison of Total Platform and Non-platform Oil and Gas Production-related Sources Greenhouse Gas Emission Estimates for Years 2017 and 2014

Calendar Year	CO_2 Emissions (tpy)	CH_4 Emissions (tpy)	N_2O Emissions (tpy)	CO_2e Emissions (tpy)[a]
2014	10,135,309	225,704	300	15,867,318
2017	10,091,005	187,910	303	14,879,192
Percent difference	-0.44%	-17%	1%	-6%

[a] GWP = 25 for CH_4 and 298 for N_2O.

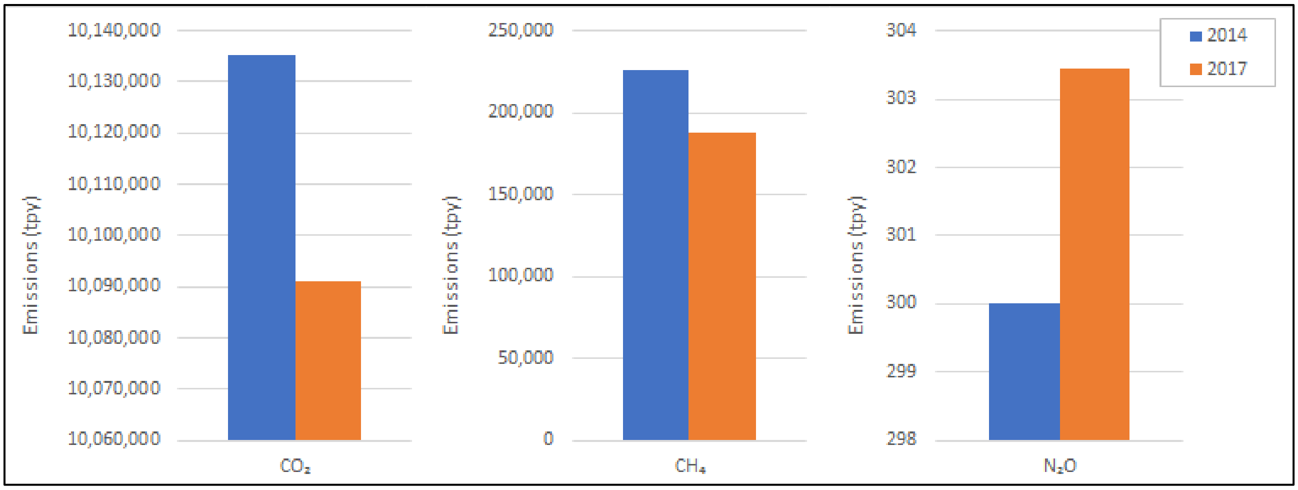


Figure 6-26. Comparison of Total GHG Emissions from Platform and Non-platform Oil and Gas Production-related Sources

6.3.1 OCS Oil and Gas Production Platforms

As noted previously, there were changes in the reporting requirements for pneumatic pumps and pneumatic controllers and changes in the emission estimation methods for glycol dehydrators and combustion flares. Changes in emission levels for 2017 are also due to the number of platforms included in the inventory, increases or decreases in activity levels, and how well the operators interpreted and completed the requested fields in the GOADS activity data collection software. In 2014, 75 companies submitted data for 1,651 active platforms, including minor sources. In 2017, 57 companies submitted data for 1,195 active platforms, including minor sources. The decline in the number of reporting companies between 2014 and 2017 reflects fewer companies that are operating in the GOM. Since the 2014 inventory, sales have consolidated lease ownership to fewer companies. As noted in Section 3.1, a portion of the decrease is also explained by nine companies who did not submit GOADS data, who, under further research, are suspected to be in some stage of bankruptcy/reorganization. The decline in number of active GOM platforms between 2014 and 2017 primarily reflects production declines on the gas-prone shelf as more platforms are idled and decommissioned.

As shown in Table 6-20 and Figure 6-27, for platform sources, there was little change overall from 2014 to 2017 for pollutants that are mainly associated with combustion equipment: CO, NO_X, PM_{10}-PRI, and SO_2. These pollutants show slight increases or decreases (all less than 10%) in the overall totals. VOC emissions decreased by about 19% from 2014 to 2017.

Table 6-20. Comparison of OCS Platform Criteria Pollutant Emission Estimates for Years 2014 and 2017 (in tons per year)

Source Category	CO 2014	CO 2017	NO_x 2014	NO_x 2017	PM_{10}-PRI 2014	PM_{10}-PRI 2017	SO_2 2014	SO_2 2017	VOC 2014	VOC 2017
Amine units	-	-	-	-	-	-	13	23	7.68E-03	0.06
Boilers, heaters, and burners	177	200	208	243	10	12	1	4	12	13
Diesel engines	1,173	1,151	4,984	4,791	246	213	425	381	275	241
Drilling equipment	397	133	1,495	501	27	9	24	0.24	37	13
Combustion flares	821	1,362	184	303	1	0.36	2	0.07	16	994
Fugitive sources	-	-	-	-	-	-	-	-	18,531	13,413
Glycol dehydrators	-	-	-	-	-	-	-	-	275	851
Loading operations	-	-	-	-	-	-	-	-	206	70
Losses from flashing	-	-	-	-	-	-	-	-	317	181
Minor sources	-	-	-	-	-	-	-	-	10	-
Mud degassing	-	-	-	-	-	-	-	-	72	36
Natural gas engines	45,070	46,190	32,355	32,945	283	281	10	11	915	1,074
Natural gas, diesel, and dual-fuel turbines	2,413	2,836	9,463	11,178	101	121	27	44	61	73
Pneumatic pumps	-	-	-	-	-	-	-	-	5,511	3,370
Pneumatic controllers	-	-	-	-	-	-	-	-	1,143	2,222
Storage tanks	-	-	-	-	-	-	-	-	677	556
Cold vents	-	-	-	-	-	-	-	-	20,152	15,732
Total emissions[a]	50,052	51,872	48,691	49,962	668	636	502	462	48,210	38,838

[a] Totals may not sum due to rounding.

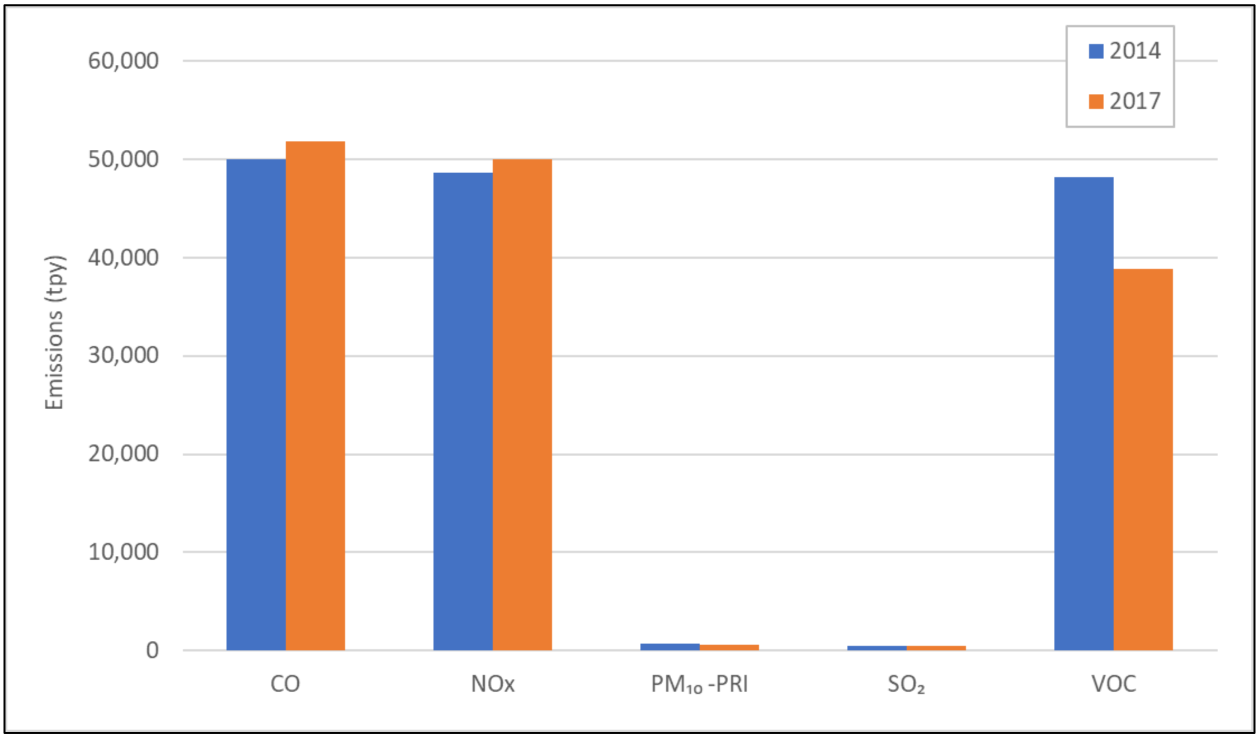


Figure 6-27. Comparison of Criteria Pollutant Emissions for Oil and Natural Gas Production Platforms

Diesel engines and drilling equipment had a decrease in the reported activity levels consistent with the reduction in the estimated emissions for these combustion equipment types. Boilers, turbines, and natural gas engines had an increase in the reported activity levels consistent with increased emissions for these equipment types. Although there were fewer active natural gas-fired boilers, natural gas engines, and natural gas-fired turbines reported for 2017, there was an overall increase in the reported fuel use. The overall fuel use reported for diesel-fired boilers and turbines also increased for 2017. The slight decrease in the PM_{10} emissions from natural gas engines can be attributed to differences in reported activity levels for the types of natural gas-fired engines (e.g., decreased activity for 4-stroke, rich burn engines and increased activity for 4-stroke, clean burn engines).

The decrease in the 2017 emission estimates for VOC are driven by fugitive, cold vent, and pneumatic pump emissions estimates. The decrease in fugitive VOC emissions estimates is due to fewer fugitives reported for 2017 than in 2014. The decrease in VOC emissions estimates for cold vents is due to fewer vents being reported for 2017 along with an overall decrease in the reported volume vented. Although the number of pneumatic pumps reported increased for 2017, the decrease in VOC emissions estimates is consistent with an overall decrease in throughput for pneumatic pumps. As mentioned in Section 4.2.13, operators were required to report fuel use rate for pneumatic pumps for 2017 rather than relying on surrogate fuel use rates. A change in pneumatic pump emissions estimates is expected as the accuracy of the activity data improves. The decreases in VOC emissions estimates were offset somewhat by increases to VOC estimates for pneumatic controllers, combustion flares, and glycol dehydrators. The number of pneumatic controllers reported increased slightly for 2017, but the emissions increase was largely driven by increased throughput. Similar to pneumatic pumps, operators were required to report fuel use rate for pneumatic controllers rather than relying on surrogates. Although the number of active flares reported for 2017 was similar to the number of flares reported for 2014, and there was a slight increase in the reported volume flared, the VOC emissions increase for combustion flares is largely due to the change in the method used for estimating these emissions. The increase in VOC estimates for glycol dehydrators is due to an increased throughput and the revised emissions estimation method. The revised emissions estimation method used the reported sales gas components for each platform rather than a surrogate gas profile. Most platforms with an active glycol dehydrator reported VOC sales gas components that were greater than the surrogate gas profile VOC components.

Table 6-21 compares emission estimates for greenhouse gases between the 2014 inventory and the 2017 inventory. Overall, the CO_2e emission estimate shows a 0.2% decrease, as the CO_2 and N_2O emission estimates increased by 15% and 20%, respectively, and CH_4 emissions estimates decreased by 17%. The increase in CO_2 emissions estimates is largely driven by the increased activity reported for turbines and natural gas-fired engines, while estimates also increased for boilers and flares. The increase in N_2O emissions estimates is driven by the increased activity reported for turbines. Similar to VOC, the CH_4 estimates for fugitive sources, vents, and pneumatic pumps showed a decrease from 2014 to 2017, which is slightly offset by an increase in CH_4 estimates for pneumatic controllers and flares.

Table 6-21. Comparison of OCS Platform Greenhouse Gas Emission Estimates for Years 2014 and 2017 (in tons per year)

Source Category	2014 CO_2	2017 CO_2	2014 CH_4	2017 CH_4	2014 N_2O	2017 N_2O	2014 CO_2e[a]	2017 CO_2e[a]
Amine units	9	140	1.04E-01	3	0	-	12	224
Boilers, heaters, and burners	253,096	291,729	5	5	5	5	254,574	293,435
Diesel engines	213,850	212,150	5	6	-	-	213,973	212,297
Drilling equipment	77,098	25,844	-	1	-	-	77,098	25,875
Combustion flares	307,392	506,262	332	3,184	5	9	317,293	588,494
Fugitive sources	-	-	74,386	54,264	-	-	1,859,640	1,356,596
Glycol dehydrators	0.19	-	2,073	557	-	-	51,827	13,914
Losses from flashing	163	94	7,040	4,033	-	-	176,156	100,922
Minor sources	-	-	32	-	-	-	795	-
Mud degassing	2	1	175	86	-	-	4,367	2,147
Natural gas engines	1,839,744	1,978,765	8,769	10,414	-	-	2,058,959	2,239,107
Natural gas, diesel, and dual-fuel turbines	3,245,409	3,839,648	253	298	88	104	3,278,047	3,878,122
Pneumatic pumps	1,430	537	36,686	28,559	-	-	918,582	714,508
Pressure and level controllers	562	377	8,453	15,470	-	-	211,878	387,138
Storage tanks	-	-	671	551	-	-	16,782	13,784
Cold vents	1,575	1,813	86,789	70,488	-	-	2,171,289	1,764,004
Total emissions[b]	5,940,330	6,857,360	225,667	187,919	98	118	11,611,272	11,590,568

[a] GWP = 25 for CH_4 and 298 for N_2O.
[b] Totals may not sum due to rounding.

6.3.2 Non-Platform Sources

As shown in Table 6-22 and Figure 6-28, comparing 2017 and 2014 emission estimates for non-platform sources shows a significant decrease in all criteria pollutant emission estimates for OCS oil and gas production-related vessels. This is largely due to the reduction in offshore oil and gas activity in 2017 quantified by use of AIS data that provide accurate estimates of the vessels operating in the GOM. This reduction in activity is noted in spite of the fact that more smaller vessels are using less expensive AIS transmitters and are now included in the GOM inventory.

The offshore oil and gas fleet is undergoing changes that also lead to lower emissions; for example, power ratings for drilling equipment were similar or less than those in the 2014 fleet. Average total power for submersibles in 2014 was 4,190 kw, whereas the 2017 average was 2,810 kw.

Another factor that impacts emissions in 2017 is the use of low sulfur ECA-compliant fuels, which reduce SO_2 emissions as well as sulfate particulate matter. This mostly impacts large Category 3 vessels; the smaller Category 1 and 2 vessels that compose most of the support vessel fleet that are fueled at U.S. ports are dispensed ultra-low sulfur content fuels (15 ppm) that comply with a USEPA fuel regulation.

For larger Category 3 vessels, the 2017 inventory was able to differentiate between the different regulatory tiers based on the year a U.S. registered vessel was built, which allowed for a more accurate assessment of regulatory compliance of the fleet. For the 2014 inventory, a single set of uncontrolled emission factors was used.

In previous inventories, data to quantify U.S. Navy operations were not available, so estimates from the 1990 inventory were adjusted to account for future years. For the 2017 inventory, the Navy was able to quantify that only a small number of training operations occurred in the GOM, specifically in the Eastern area, which was outside the geographic scope of the inventory. Removal of Navy emission sources from the inventory reduced military emissions significantly.

The 2017 inventory also included a significant improvement in the helicopter methodology. The new approach used FAA NextGen GPS satellite tracking data similar to the use of AIS for vessels emission estimates. The NextGen data notes the actual location, speed, and elevation of individual helicopters in the area of interest every 5 minutes. For earlier inventories, total trip counts were provided by the Helicopter Safety Advisory Conference, and it was assumed that all of the trips were to platforms in Federal waters of the GOM. Analysis of the FAA data showed that only approximately 10 percent of these trips are to platforms in Federal waters, which significantly reduced helicopter emissions in 2017. It should be noted that not all support helicopters were equipped with transmitters in 2017. Although it is anticipated that this process will be completed by 2020, it is acknowledged that some helicopters may be missing in the 2017 inventory.

As shown in Table 6-24, the changes described above for vessels and helicopters also affected the 2017 CO_2 emissions estimates. There was very little change in CH_4 and N_2O emissions estimates in 2017, because these pollutants are driven by biogenic sources emissions estimates, which show very little change from year to year.

Table 6-22. Comparison of OCS Non-platform Criteria Pollutant Emission Estimates for Years 2017 and 2014 (in tons per year)

Source Category	CO 2014	CO 2017	NO_x 2014	NO_x 2017	PM_{10} 2014	PM_{10} 2017	SO_2 2014	SO_2 2017	VOC 2014	VOC 2017
Drilling rigs	6,236	1,320	40,837	6,418	1,262	148	5,354	142	859	213
Pipelaying operations	239	319	2,406	2,924	86	55	669	117	98	169
Support helicopters	1,978	84	979	149	28	4	126	17	1,632	79
Support vessels	6,194	5,221	30,256	21,651	799	765	122	594	399	503
Survey vessels	812	618	3,276	3,163	154	98	378	79	379	89
Total OCS oil and gas production sources	15,459	7,563	77,754	34,304	2,329	1,070	6,648	948	3,367	1,053
Biogenic and geogenic sources	0	0	0	0	0	0	0	0	14,357	13,561
Commercial fishing vessels	1,934	1,682	9,435	9,061	219	217	5	4	102	96
Commercial marine vessels	20,655	17,555	200,258	149,704	6,409	2,725	48,215	5,261	8,802	8,859
LOOP	224	210	1,001	936	37	35	12	12	300	281
Military vessels	988	216	9,432	1,163	283	28	2,121	1	379	12
Vessel lightering[a]	0	0	0	0	0	0	0	0	17,113	4,603
Recreational vessels	1,585	755	7,732	3,817	180	83	4	4	83	200
Total Non-OCS oil and gas production sources	25,387	20,418	227,858	164,681	7,127	3,087	50,358	5,281	41,137	27,612
Total non-platform emissions[b]	40,846	27,980	305,612	198,986	9,456	4,157	57,006	6,228	44,503	28,665

[a] Vessel estimates for 2017 are reflected in commercial marine vessels.
[b] Totals may not sum due to rounding.

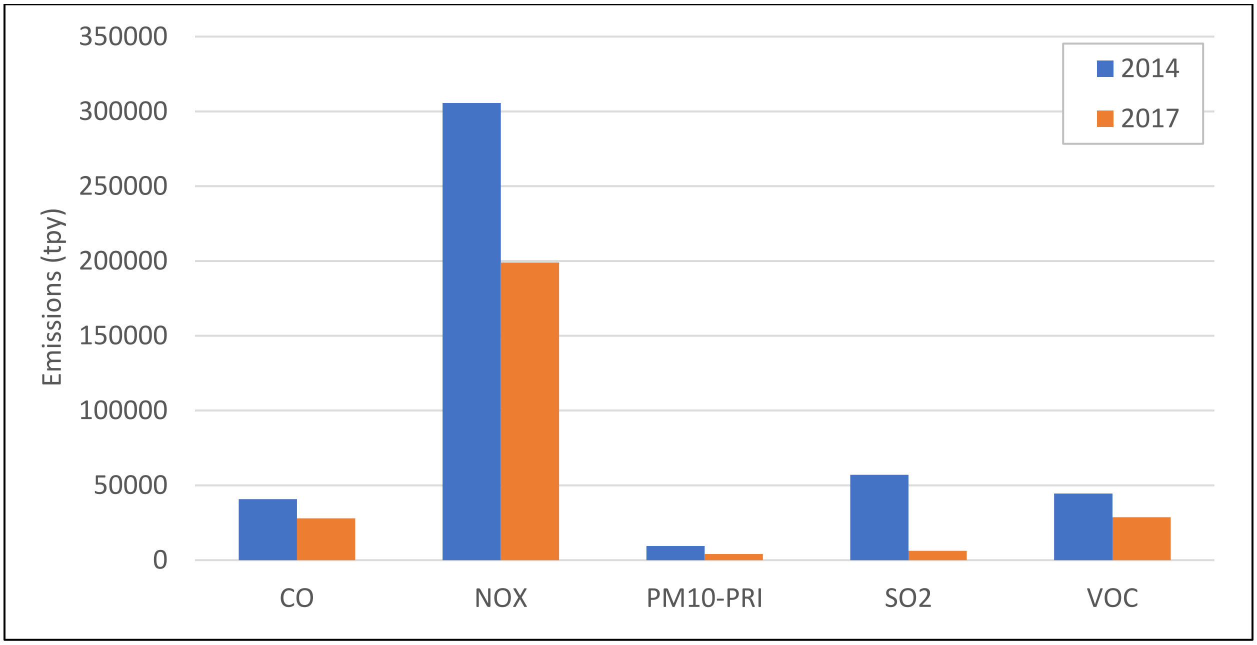


Figure 6-28. Comparison of Criteria Pollutant Emissions for Non-platform Emission Sources

Table 6-23. Comparison of OCS Non-platform Greenhouse Gas Emission Estimates for Years 2014 and 2017 (in tons per year)

Source Category	CO_2[a] 2014	CO_2 2017	CH_4 2014	CH_4 2017	N_2O 2014	N_2O 2017	CO_2e[b] 2014	CO_2e[b] 2017
Drilling rigs	2,151,121	508,797	15	3	104	26	2,182,406	516,469
Pipelaying vessels	113,755	191,132	1	1	6	9	115,447	193,824
Support helicopters	179,707	51,921	11	1	13	2	183,811	52,459
Support vessels	1,637,455	2,211,718	10	9	77	134	1,660,741	2,251,816
Survey vessels	112,941	270,077	-	1	2	15	113,641	274,681
Total OCS oil and gas production sources	4,194,979	3,233,646	37	16	202	185	4,256,046	3,289,249
Biogenic and geogenic sources	2,284	2,284	1,876	1,876	1,948	1,948	629,688	629,688
Commercial fishing vessels	531,190	439,598	3	3	25	21	538,842	445,931
Commercial marine vessels	8,398,693	9,002,753	75	59	427	476	8,527,905	9,145,991
LOOP	64,320	60,139	-	0	2	2	64,898	60,680
Military vessels	391,169	56,400	4	0	20	3	397,328	57,212
Vessel lightering[c]	0	0	-	-	0	0	-	-
Recreational vessels	435,327	382,631	3	2	21	17	441,599	387,642
Total non-OCS oil and gas production sources	9,289,509	9,943,805	82	1,940	2,443	2,466	9,431,731	10,727,145
Total non-platform emissions[d]	14,017,962	13,177,451	1,999	1,957	2,646	2,651	14,856,307	14,016,393

[a] Emissions reported in short tons.
[b] GWP = 25 for CH_4 and 298 for N_2O.
[c] Vessel estimates for 2017 are reflected in commercial marine vessels.
[d] Totals may not sum due to rounding.

6.4 Recommendations

As discussed in Section 6.2, a key limitation for the 2017 OCS platform emissions inventory is that BOEM must interpret inconsistently reported data and make assumptions about the status of monthly equipment operations. The use of a more refined activity data reporting tool, with built-in QA/QC checks, should greatly eliminate reporting inconsistencies if refined QA/QC checks are implemented before data are submitted to BOEM. For example, the GOADS-2017 software flags exit gas velocities for combustion flares that are not within the range of 0 to 1,100 feet per second as potential errors. When operators submit combustion flare exit gas velocities greater than 400 feet per second, the emissions estimates are adjusted (increased) as described in Section 4.2.5. In the 2017 inventory effort, BOEM observed that several of the higher exit gas velocities reported were carried forward unchanged by the operator in the descriptive data from the 2014 inventory effort. An additional QA/QC flag for combustion flare exit gas velocities could remind operators to confirm whether the high velocities are still accurate. The GOADS-2017 and earlier versions of the reporting software required operators to select a vent or flare ID from a dropdown list for equipment that is vented or flared remotely. This ensures that the vent or flare record exists on the platform. However, an additional QA/QC check could confirm that the remote vent or flare is actually active with a volume vented or flared greater than zero for the same months that the equipment routed to the vent or flare was active. This will prevent active equipment records being reported as routed to an inactive vent or inactive flare.

BOEM should continue to make use of the most recent emission factors, data, and research results in developing the emission estimates for platform equipment. For example, reporting of fuel usage rates for pneumatic pumps and pneumatic controllers was no longer optional for 2017; the reported rates can be assessed to determine whether operators collected data on actual fuel use or used emission factors as a surrogate for fuel use. It is important to note, however, that use of updated emission factors and methodologies complicates comparisons to previous emissions inventories as discussed Section 7, Emissions Trends Analysis, but ensures the emissions are as accurate as possible at the time the inventory is developed.

In addition, studies are needed for the offshore platform sources whose emission estimates are most uncertain. For fugitive sources, BOEM initiated a study to update the out-of-date default component counts and stream composition used in this study and prior Gulfwide emissions inventory studies, conduct testing at offshore production platforms, assess preventative maintenance practices and procedures, and develop updated emission factors. If this study is revisited, the results could be used to improve emissions estimates in future emissions inventories. For pneumatic devices, a sensitivity analysis could be conducted to evaluate the impacts of alternative assumptions regarding device population and bleed rates to determine the need for more in-depth study. GOADS-2017 was revised to solicit more specific information on the bleed rates (i.e., high-bleed, intermittent, low-bleed, or no-bleed) of the reported pneumatic controllers. However, more information is needed on the accuracy of the number of pneumatic devices (both pneumatic pumps and controllers) reported by operators, as well as the actual operating bleed rates rather than manufacturer data.

In addition to GOADS reporting requirements, BOEM also collects monthly volume vented and flared data from production operators through Oil and Gas Operations Report (OGOR) forms. Oil and Gas and Sulphur Operations in the Outer Continental Shelf-Oil and Gas Production Requirements (30 CFR Part 250) include requirements that operators meter flared and vented gas volumes (on facilities that process more than 2,000 barrels of oil per day) and report flared gas separately from vented gas on the OGOR forms. In developing the 2011 Gulfwide inventory, BOEM conducted an in-depth comparison of GOADS venting and flaring data and OGOR reported volumes. Although such an effort was not implemented for the 2014 or 2017 inventories, in part because BOEM provided operators a chance to review their draft emissions inventory activity data and emission estimates, future inventory development efforts could again use these reported data, at the least when an operator has just one platform in a single lease.

Historically, BOEM has provided descriptive data for OCS oil and gas production platforms from the previous inventory year for operators to use as a starting point for the current reporting year. Operators can edit the descriptive data as needed. For the 2014 and 2017 inventories, BOEM observed that some operators reported diesel fuel sulfur contents that were significantly higher than the surrogate sulfur content for ultra-low sulfur fuel (0.0015% by weight for the 2017 inventory). Some of these values have been carried forward unchanged from previous inventories. If most operators are using ultra-low sulfur diesel fuel, then the SO_2 emissions for platform sources could be overestimated in the inventory. For future studies, BOEM could require operators to enter diesel fuel sulfur contents without providing values reported for the previous inventory year or revise the QA/QC check in the reporting system to flag these values for review.

As discussed in Section 3.1, not all OCS oil and gas production platforms expected to be reported for 2017 were included in GOADS submittals. To improve the completeness of future inventories, BOEM could provide the expected structures from TIMS with the descriptive data that operators use as a starting point, even if the platform was not included in the previous inventory. Operators would then be able to add equipment and include the platform in their next submittal, or they could indicate why the platform is not reported (e.g., the platform was removed prior to the inventory year and the removal date needs to be updated in TIMS).

For non-platform sources, the USEPA is updating the marine vessel emission factors and HAP speciation profiles used in the USEPA's NEI for C1and C2 engines. It is recommended that future versions of this inventory use these updated factors and profiles. For the 2017 inventory, the 2014 version of IHS's ROS was used to obtain kW ratings for specific vessels. Given the typical age of marine vessels and the recent downturn in the marine vessel service market, use of these older vessel characteristics data is acceptable; however, it is recommended that an updated version be used for the next inventory.

Possible enhancements to the marine vessel AIS component of future versions of this inventory include identifying and quantifying activity and emissions from support vessels involved in platform construction and removal. These vessels are currently included in the inventory, but the individual activities are not differentiated.

Lastly, in previous Gulfwide inventory reports, BOEM recommended that detailed and comprehensive expanded comparisons and deviations (trends analysis) be performed, including analysis of the differences between deepwater and shallow water platforms, and missing or non-reported equipment types from year to year. In addition, for large changes, it is important to have a sense of how much of the change is due to differences in activity (such as for drilling vessels) and how much might be due to the changes in estimation methodologies. BOEM may want to consider recalculating some key inventory categories that show large changes in the emissions estimates. While it would be particularly challenging to normalize the oil and gas production-related marine vessel emission estimates to be more comparable, moving forward BOEM could focus on just the 2014, 2017, and future inventories for marine vessels. Overall, a detailed trends analysis will benefit BOEM in a number of ways, including preparing NEPA documents and predicting future emission trends in spatial terms. As discussed in Section 7.0 of this report, BOEM has prepared a detailed emissions trends analysis and recommendations regarding future efforts to analyze emission trends seen are provided.

7 Emissions Trends Analysis

7.1 Summary and Recommendations

BOEM conducted a detailed and comprehensive emissions trends analysis using data covering 2000–2014 to assess the long-term emissions trends in the GOM OCS emissions in the *Year 2014 Gulfwide Emissions Inventory* Study (Wilson et al., 2017). The emissions trends analysis presented in this report now includes the 2017 emissions inventory. Based on the results of the previous trends analysis, the 2000 inventory is not included. This is because the 2000 inventory qualitatively appeared to be an outlier that can shift a regression to produce a lower correlation. This is likely due to the evolved inventory calculation methods and improved operator understanding and reporting of platform activity data since the 2000 inventory. Given these changes and how the inventory compares to the subsequent inventories (and equipment added to the GOADS reporting such as diesel and dual-fuel turbines), it was advisable to drop the year 2000 inventory. Furthermore, as newer inventories become available for incorporation into a forecast model, older inventories should be reviewed with each cycle to determine if they are still representative of industry practices. Those that are not representative should no longer be considered in regression model development for trends analysis.

As the science for estimating air pollutant emissions has evolved, the methods used to estimate emissions in the BOEM inventories have also evolved. Changes in emission factors, models, and activity data sources have created artificial trends in the data (i.e., emission decreases or increases are seen due to improved method and activity quantification). For example, the increased resolution in the marine vessel identification and better quantification of activity makes it appear as if emissions from BOEM sources have decreased recently. In reality, the revisions to the methods, primarily the improved data sources, are better at identifying vessel categories and quantifying their propulsion operations.

Only OCS oil and gas platforms and the vessels and aircraft that support oil and gas production are addressed in this analysis. Overall, emissions are largely affected by not only changes in inventory methodologies and improvements in available emission factors, but also activity/production levels in the GOM by water depth and planning area. There was qualitative agreement to the spatial distribution of total production; however, there are factors that sometimes mask this trend at a total inventory level, including emission estimation methods and the uneven spatial distribution of production. The non-platform emissions inventories have changed the most over the inventory years, especially the sources associated with OCS oil- and gas-related activities. Platform equipment level trends can frequently compensate for one another, making total platform emissions appear stable in most instances, while the equipment level contribution may vary widely. Figures 7-1 and 7-2 present high-level comparisons of criteria pollutant and GHG emission estimates (in million tons per year) for OCS oil and gas platform and non-platform sources.

Moving forward, BOEM recommends that the improvements to the estimation methods be closely tracked, with discussion of noted impacts to trends (i.e., did the method change produce higher or lower estimates? Is this trend negated by activity trends?). This will ensure that future analyses, especially long-term trend analyses, take these factors into consideration when drawing conclusions on overall trends. Tracking the changes and potential impacts can also serve as a QA/QC step for the inventory development. That is, if an emission factor was higher than the previous inventory and anticipated increased emissions are not seen in the updated inventory, then further analysis of the estimates would be warranted. Another recommendation is that emissions trends analyses should continue to be prepared in the future BOEM inventory cycles. These analyses have benefits in both QA/QC and assessing the impacts of emission controls (e.g., low sulfur fuel) or identifying equipment categories for potential controls.

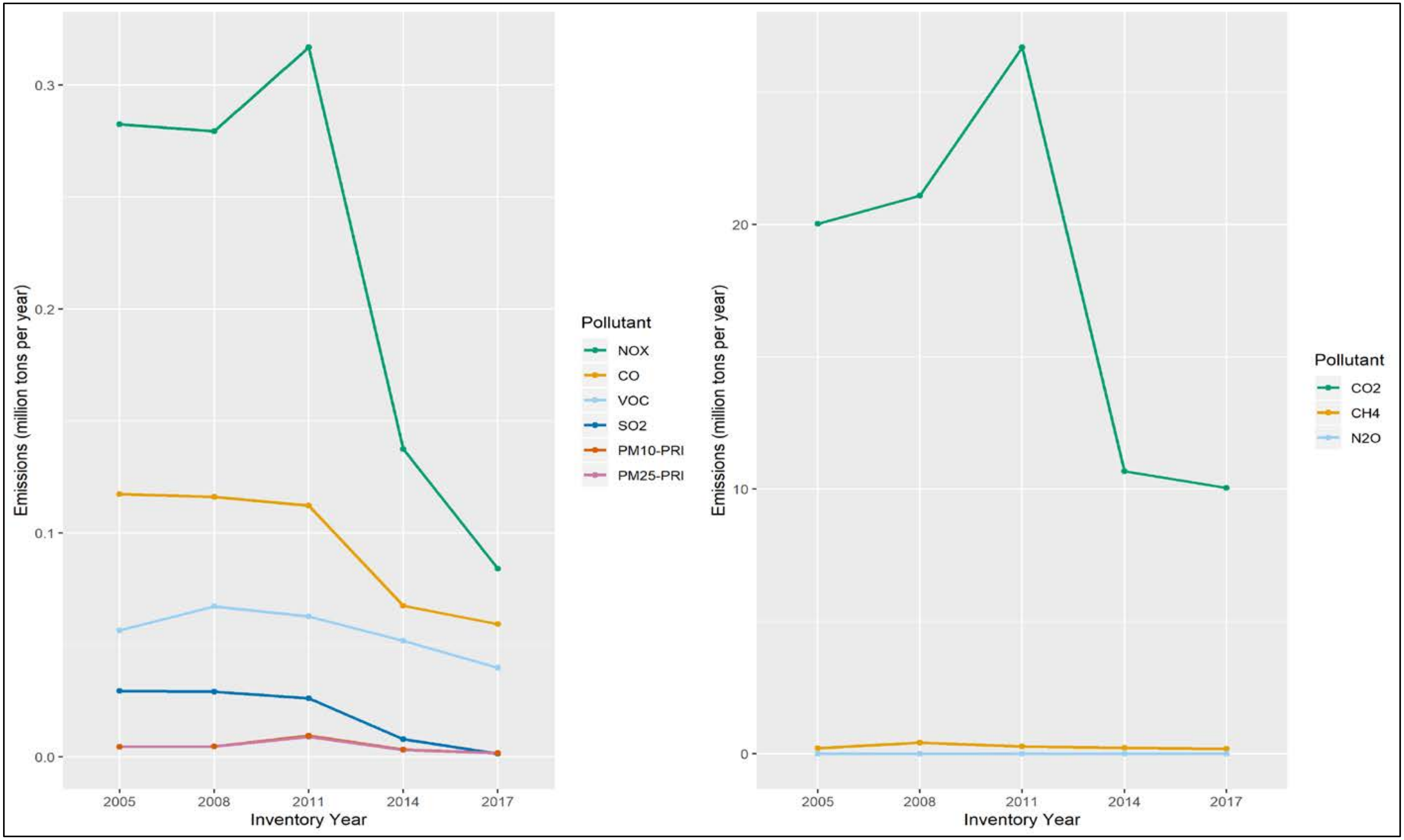


Figure 7-1. Total Emissions by Inventory Year
(left: criteria pollutants; right: GHGs)

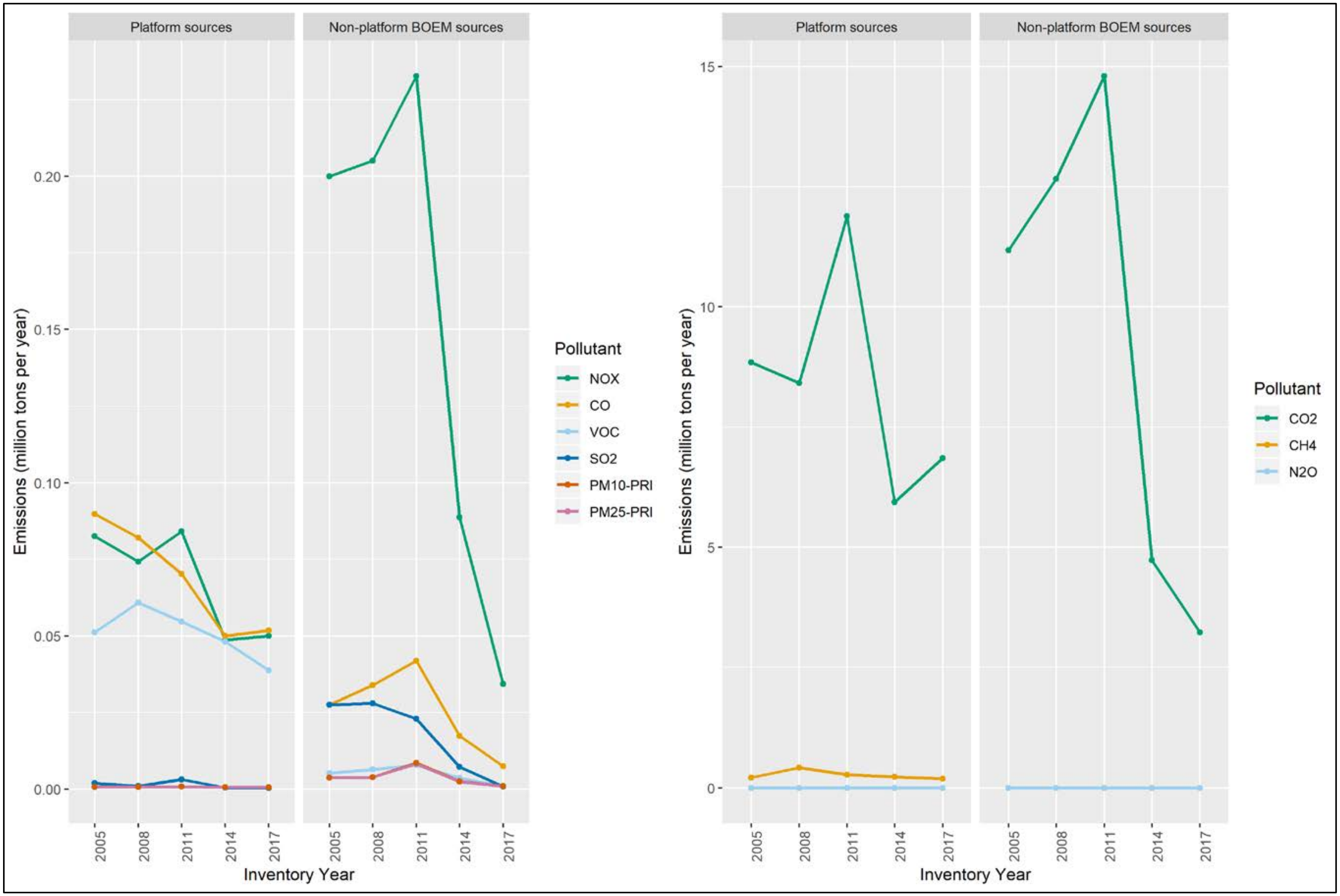


Figure 7-2. Platform and Non-platform Emissions by Inventory Year
(left: criteria pollutants; right: GHGs)

Furthermore, a trends analysis should be revisited periodically to incorporate new analysis techniques that better discern true trends in emissions data. As noted in Section 6.4, BOEM should consider recalculating only select inventory categories that show large changes in the emissions estimates, as the recalculation of the non-platform inventory in particular, whose estimation methods have benefited greatly from advancements in technology and availability of AIS data, is not feasible.

7.2 Inventory Summary

The BOEM GOM OCS Region office manages the responsible development of oil and gas and mineral resources for the 430 million acres in the Central and Western Planning Areas of the OCS that constitute the GOM Region (Figure 7-3). The inventories represent active platforms that fall outside the Congressional Moratoria area. The current extent of the Congressional Moratoria area is noted in yellow in Figure 7-3. The eastern extent of inventory data, particularly the non-platform inventory, has varied due to changes in the planning areas boundaries and availability of data.

As noted above, all the inventories include the three major GHGs (CO_2, CH_4, and N_2O). Beginning with the 2008 inventory, a total GHG emission estimate in CO_2e was included. Because GHGs differ in their warming influence due to their different radiative properties and lifetimes in the atmosphere, the CO_2 equivalent was developed to express the warming influences in a common metric, CO_2e (IPCC, 2007).

As the science surrounding climate change evolves, the GWPs are revised. For the 2008 inventory, the GWPs used were those required under the USEPA Final Mandatory Reporting of Greenhouse Gases Rule (40 CFR 98 Subpart A, Table A-1). This required a GWP of 21 for CH_4 and a global warming potential of 310 for N_2O. For the 2014 inventory, the GWPs were updated to reflect changes presented in the Fourth Assessment Report (AR4) of the IPCC (2017), with a GWP of 25 for CH_4 and a global warming potential of 298 for N_2O. For this analysis, CO_2e has been recalculated for all years with the AR4 GWPs.

Another change to the pollutant list occurred with the 2008 inventory when PM condensable (PM-CON), PM_{10} filterable (PM_{10}-FIL), and $PM_{2.5}$ filterable ($PM_{2.5}$-FIL) were added alongside PM_{10} primary (PM_{10}-PRI) and $PM_{2.5}$ primary ($PM_{2.5}$-PRI) for platform equipment. The relationships between these PM species are:

$$PM_{10}\text{-PRI} = PM_{10}\text{-FIL} + \text{PM-CON}$$

$$PM_{2.5}\text{-PRI} = PM_{2.5}\text{-FIL} + \text{PM-CON}$$

For simplicity, the balance of this report will focus on the primary components of PM_{10} and $PM_{2.5}$.

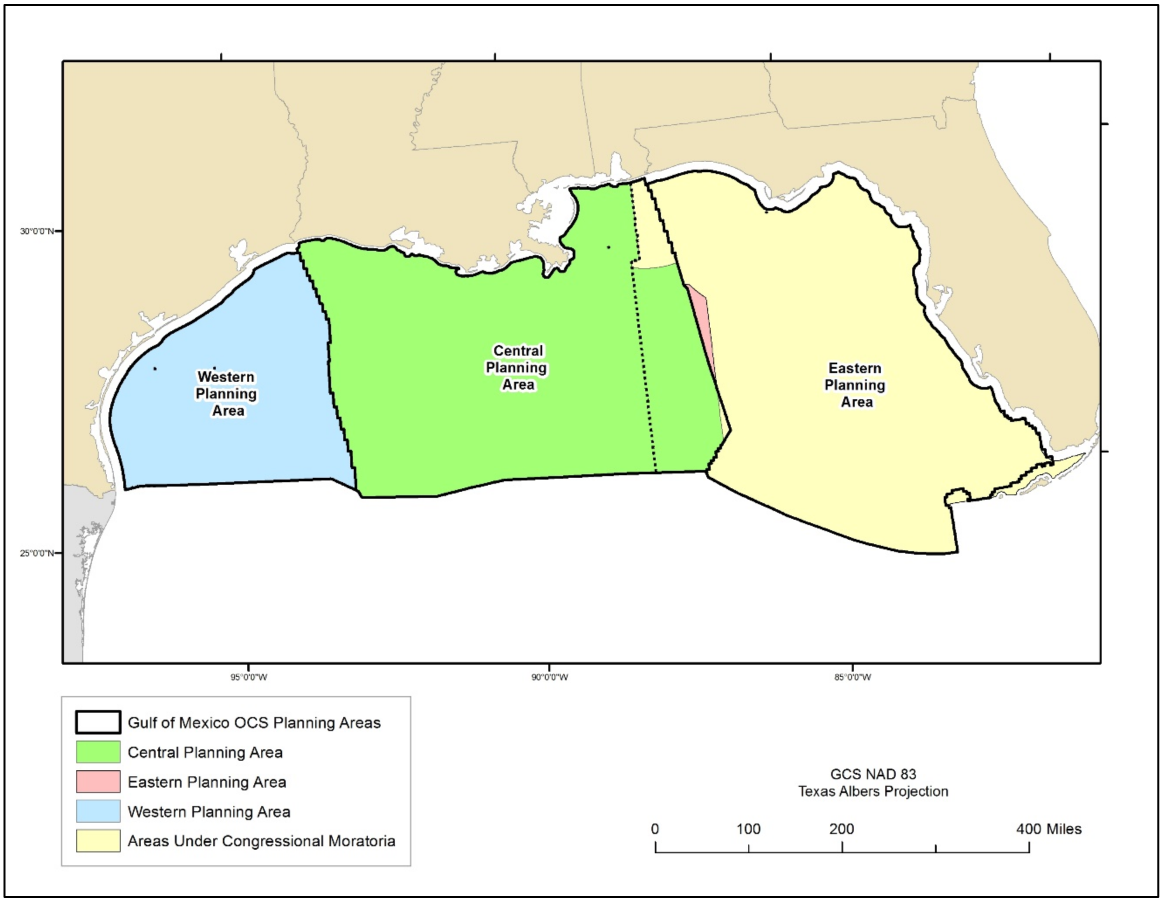


Figure 7-3. GOM Region Planning Areas and 2017 Active Leases

7.2.1 Production Platform Inventory Changes

One area of change in the platform inventory has been the reporting of minor sources such as caissons, wellhead protectors, and living quarters. For the 2005 inventory, minor sources were excluded entirely from reporting. For the 2008 and 2011 inventories, BOEM required minor sources to report minimal data via the GOADS software, and emissions were estimated using surrogate values. Operators also had the option to report individual equipment records and activity data for minor sources. Equipment and activity data were required to be reported for all minor sources in the 2014 and 2017 inventories. Because of the inconsistency in reporting over the years and the negligible emissions from these sources, minor sources will be omitted from this trends analysis.

The only other change in platform equipment reported has been the inclusion of emissions from loading operations. Loading was dropped in GOADS-2008 and GOADS-2011 but required once again in GOADS-2014 and GOADS-2017 in order to capture FPSO vessels.

Table 7-1 summarizes the platform equipment types included in each inventory year. An x ("X") denotes the equipment type was not included, and a check ("✓") notes where it was included.

The calculation methods for the platform inventories have remained consistent over the years, with a few exceptions to update emission factors and speciation profiles. In 2008, the VOC speciation profile for storage tanks was revised, and a profile for CH_4 was added. In 2011, adjustments were made to the emission estimation equations for losses from flashing and cold vents. Also, USEPA emission factors were updated for several equipment types in the 2011 inventory and for CO from combustion flares in the 2014 inventory. Updates for the 2017 inventory included requiring operators to report pneumatic pump and controller fuel use rates, a new calculation method for glycol dehydrators, and a new emission calculation method for VOC and CH_4 from flares.

Table 7-1. Platform Equipment Types Included in the Gulfwide Inventories by Year

Platform Equipment Type	Emission Trends Type Analyzed	2005	2008	2011	2014	2017
Amine units	Non-combustion	✓	✓	✓	✓	✓
Boilers	Combustion	✓	✓	✓	✓	✓
Caissons (minor source)	N/A[a]	X	✓	✓	✓	✓
Diesel engines	Combustion	✓	✓	✓	✓	✓
Drill equipment	Combustion	✓	✓	✓	✓	✓
Combustion flares	Vent/flare	✓	✓	✓	✓	✓
Fugitives	Non-combustion	✓	✓	✓	✓	✓
Glycol dehydrators	Non-combustion	✓	✓	✓	✓	✓
Loading	Non-combustion	✓	X	X	✓	✓
Losses from flashing	Non-combustion	✓	✓	✓	✓	✓
Living quarters (minor source)	N/A	X	✓	✓	✓	✓
Mud degassing	Non-combustion	✓	✓	✓	✓	✓
Natural gas engines	Combustion	✓	✓	✓	✓	✓
Natural gas, diesel, and dual-fuel turbines	Combustion	✓	✓	✓	✓	✓
Other (minor source)	N/A	X	✓	✓	✓	✓
Pneumatic pumps	Non-combustion	✓	✓	✓	✓	✓
Pneumatic controllers	Non-combustion	✓	✓	✓	✓	✓
Storage tanks	Non-combustion	✓	✓	✓	✓	✓
Cold vents	Vent/flare	✓	✓	✓	✓	✓
Wellhead protectors (minor source)	N/A	X	✓	✓	✓	✓

[a] Not applicable. Minor source emissions trends not analyzed.

7.2.2 Oil and Gas Production Non-Platform Inventory Changes

The source categories within the non-platform inventory have changed between inventories. Table 7-2 summarizes the non-platform equipment included in the inventory years. Note that emergency generators associated with drilling rigs were added to the 2008 inventory as part of total drill rig emissions.

Table 7-2. Non-platform Source Types Delineated in the Gulfwide Inventories by Year

Non-platform Source Type	2005	2008	2011	2014	2017
Drilling rigs	✓	✓	✓	✓	✓
Helicopters	✓	✓	✓	✓	✓
Pipelaying	✓	✓	✓	✓	✓
Support vessels	✓	✓	✓	X	X
FPSO	X	X	X	X	✓
Offshore oil and gas support	X	X	X	✓	✓
Tug	X	X	X	✓	✓
Well stimulation vessels	X	X	X	X	✓
Survey vessels	✓	✓	✓	✓	✓

Of the BOEM Gulfwide inventories, the non-platform portion has undergone the most changes across the inventory years. There have been several changes to emission factors and calculation methods, especially starting with the 2014 inventory with the use of AIS data to track individual vessels and linking these vessels to IHS Register of Ships data to obtain detailed information on vessel engine and operating characteristics (IHS, 2015). AIS used again in the 2017 inventory.

Drilling rigs received an enhancement to their activity data starting with the 2008 inventory. The drilling rig data was obtained from BOEM and matched to vessel characteristics data in RigZone. Propulsion operations for self-propelled drill ships and semisubmersibles were more accurately estimated in the inventories for individual rigs based on the departure and arrival times reported.

Helicopter activity were derived from the 2005, 2008, 2011, and 2014 Helicopter Safety Advisory Conference (HSAC) data (HSAC, 2006, 2009, 2012, 2015). This data set was supplemented with the FAA helicopter population data for the 2005 inventory. Unfortunately, updates to the FAA data set were not available for the 2008, 2011 or 2014 inventories. Helicopter emission factors were updated for the 2011 and 2014 inventories using Swiss Federal Office of Civil Aviation (FOCA) data that allowed for better differentiation between medium and heavy-duty twin-engine helicopters. For the 2017 inventory (FOCA, 2015), the FAA's NextGen flight management data were used to quantify individual helicopter movements derived from speed, location and elevation data averaged to five-minute intervals. To estimate emissions, these five-minute interval data were linked to helicopter emission rates developed for the fleet of helicopters that provide services to offshore oil and gas operations. Emissions were allocated to the lease blocks where the activity occurred based on the NextGen latitude/longitude coordinates.

For the 2005 inventory, the offshore support vessel population data were obtained from the Offshore Marine Service Association (OSMA, 2006). For 2008, some additional data were provided by one survey vessel company that allowed for more accurate estimates of emissions by updating the fleet compositions and day-at-sea assumptions. Spatial allocation of support vessels was improved in the 2011 inventory, when AIS data were used to spatial allocate calculated emissions (at that time, the AIS data seemed to under-represent the support vessel fleet, so the data could not be used to estimate emissions but were sufficiently representative to indicate typical traffic patterns). These data were used to develop vessel traffic contours for each vessel that were used to spatially allocate emissions. This information was coupled with the U.S. Army Corps of Engineers Entrance and Clearance data.

For 2014, the AIS data provided more comprehensive estimate of the vessels operating in the GOM, allowing a more detailed breakdown of the vessels included in the inventory, which was further improved for the 2017 inventory efforts (PortVision, 2018). Specifically, it was determined that tugs operating in Federal waters of the GOM were primarily supporting oil and gas production platforms. As a result, tug emissions estimates are now included in the support vessel non-platform trends type, not CMVs. To prevent an artificial trend in the data, the previous inventory year emissions were re-categorized to match this change. Table 7-3 provides a crosswalk from the 2017 categories to the categories used in previous inventories and this report.

Table 7-3. 2017 Non-platform Source Categories

2017 Non-platform Source Type	Non-platform Trends Type
Drilling rigs	Drilling rigs
Helicopters	Helicopters
Pipelaying vessels	Pipelaying
FPSOs	Support vessels
Offshore oil and gas support vessels	Support vessels
Tugs	Support vessels
Well stimulation vessels	Support vessels
Survey vessels	Survey vessels

7.3 Platform Trends

The following section describes the changes seen in platform emission inventories. Section 7.3.1 discusses how the spatial distribution of platforms has changed over the years with respect to counts by planning areas and water depth. Section 7.3.2 examines the total platform emission estimates for each pollutant, with more in-depth discussions for each equipment category following in Sections 7.3.3, 7.3.4, and 7.3.5.

7.3.1 Spatial Distribution

The number of active platforms reported in each inventory year has varied. Figure 7-4 shows the variability in the reported number of active platforms across all five inventory years. The 2005 inventory contained 1,619 active or inactive platforms (combination of Complex ID and Structure ID).

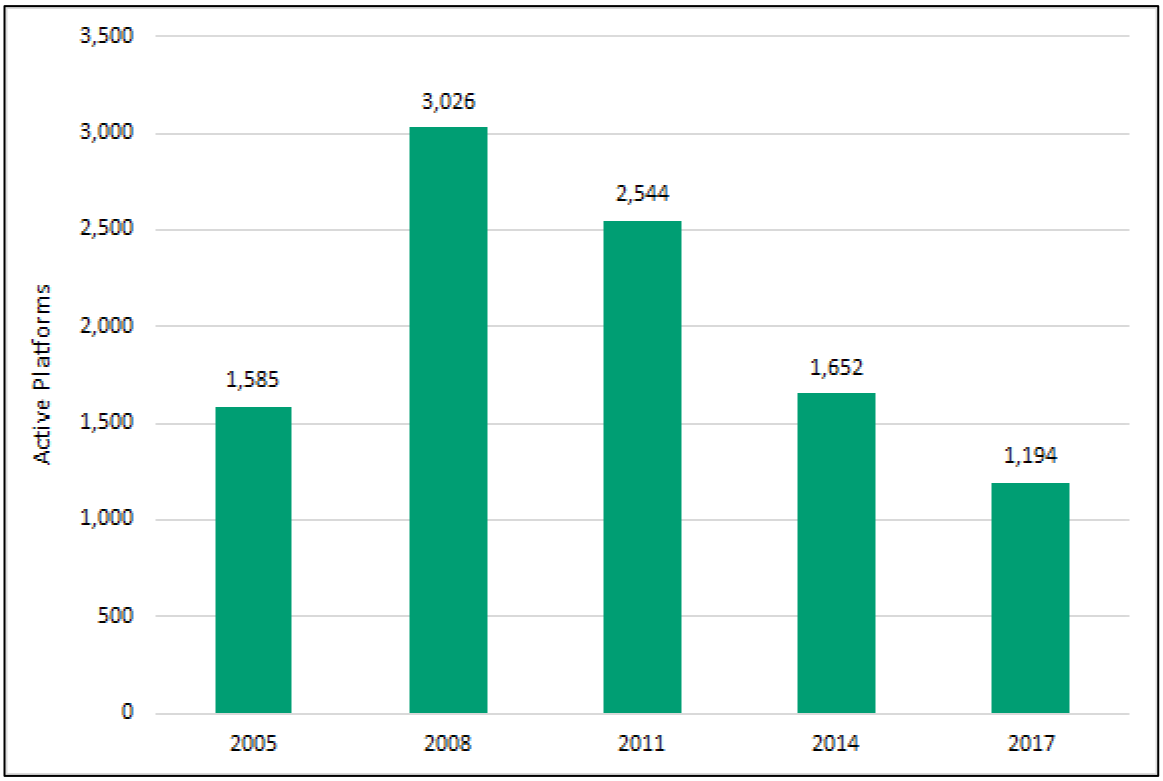


Figure 7-4. Active Platforms Reported in GOADS by Inventory Year

Unfortunately, 2005 was an atypical inventory year due to widespread hurricane damage. BOEM's TIMS database indicated at least 159 platforms were damaged or destroyed by hurricanes in 2005. As a result, many operators were likely focused on damage assessment and repairs, and 2005 GOADS data were not submitted for all major platforms. In addition, minor sources were permitted to be excluded from reporting via GOADS.

For 2008, 103 (out of 161 with leases) companies submitted data for 3,304 active or inactive platforms (about 85% of OCS platforms) including minor sources; 3,026 structures were active (at least one month). Of these, 1,538 were flagged as minor sources. For the 2008 inventory, BOEM allowed minor sources to report minimal data via GOADS. Thus, many more platforms were included in the 2008 inventory.

For the 2011 inventory, 96 companies submitted data for 3,051 active or inactive platforms (about 85% of OCS platforms) including minor sources; 2,544 structures were active (at least one month). Of these, 1,366 were flagged as minor sources.

For the 2014 inventory, 75 companies submitted data for 1,856 active or inactive platforms and identified 525 platforms as being decommissioned. This accounts for about 90% of OCS platforms, including approximately 700 minor sources.

For the 2017 inventory, 57 companies submitted data for 1,842 active or inactive platforms, including approximately 433 minor sources. An additional 193 platforms were reported as being decommissioned. The decline in the number of reporting companies between 2014 and 2017 reflects fewer companies are operating in the GOM. Since the 2014 inventory, sales have continued to consolidate lease ownership to fewer companies. The decline in number of active GOM platforms between 2014 and 2017 reflects production declines on the gas-prone shelf as more platforms are idled and decommissioned.

Table 7-4 summarizes these counts, and Figure 7-5 provides a visual representation. Section 3.1 of this report presents details on the number of expected active platforms in the GOM OCS in 2017 and possible reasons for their exclusion from GOADS reporting.

Table 7-4. Summary of Possible Reasons for Non-reporters

Reason for omission	Count	Percentage of total non-reporters (%)
Possible bankruptcy	17	6.8
Possible bankruptcy and/or sale	9	3.6
TIMs indicated terminated lease, Possible bankruptcy	4	1.6
TIMs indicated terminated lease	34	13.6
Previous non-reported	31	12.4
Installed in 2017	1	0.4
Removed after 2017	37	14.8
Removed during 2017	25	10.0
Possible removal (decommissioned with no removal date)	19	7.6
Possible sale	1	0.4
Destroyed by hurricane (no decommission or removal date)	1	0.4
Reported with another structure	11	4.4
ROW	36	14.4
RUE	6	2.4
State lease	10	4.0
SOP	1	0.4
Undetermined	7	2.8

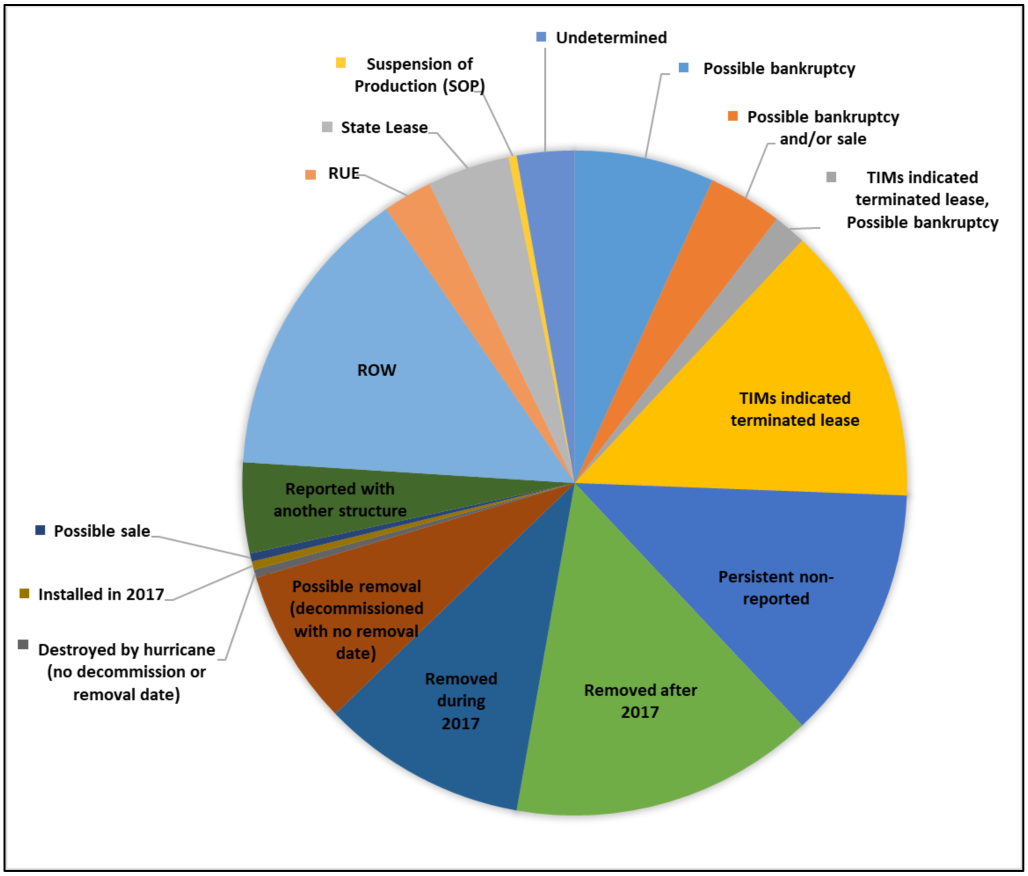


Figure 7-5. Summary of Non-reporters in 2017 Inventory

As shown in Figure 7-3, the GOM is divided into three planning areas. As seen in Figure 7-6, the CPA contains between 84 and 92% of the active platforms, depending on the inventory year. The portion of the Eastern Planning Area not under Congressional Moratorium has no production platforms that report to BOEM. Also, the USEPA has air quality jurisdiction east of the longitude 87.5º, and any platforms in this region would not be in the BOEM inventory.

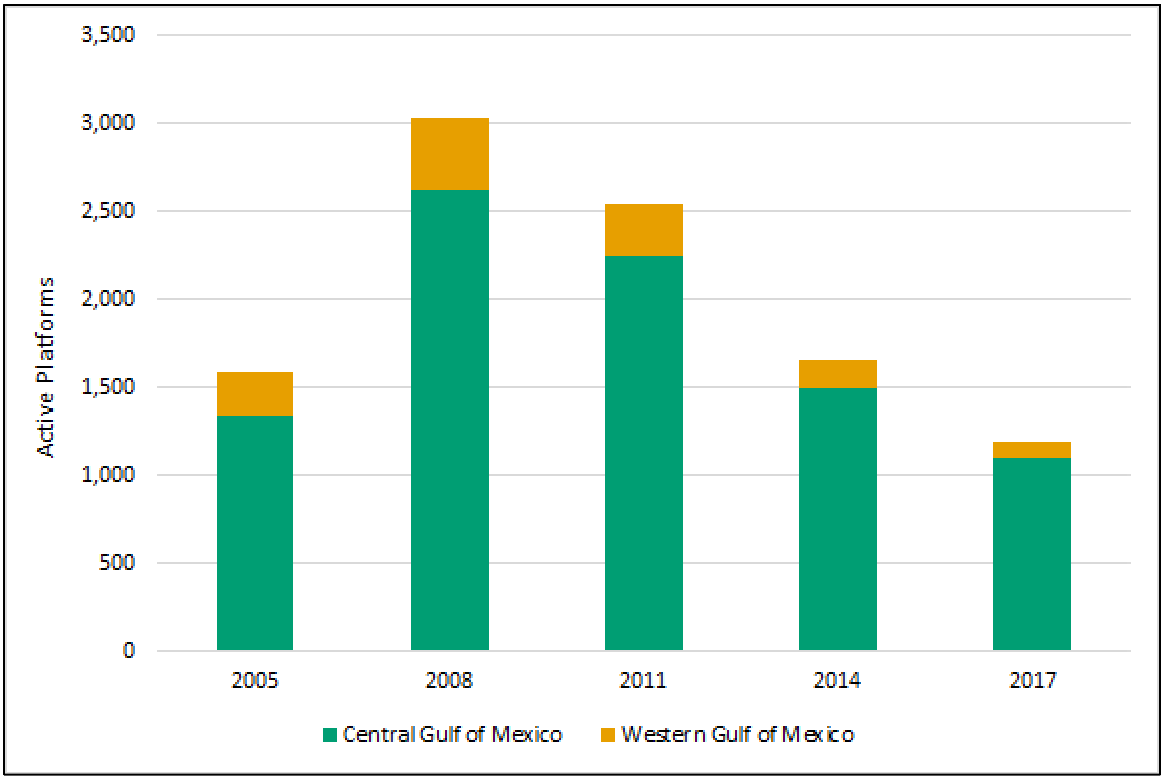


Figure 7-6. Active Platforms Reported in GOADS by Planning Area

BOEM considers development within certain water depth categories. The typical breaks used for water depth categories are 60, 200, 800, 1,600, and 2,400 meters (m). Figure 7-7 shows these water depth boundaries compared to the current active lease blocks. The less than 60-m water depth range is wider than other depth categories. As Figure 7-8 and Table 7-5 show, this water depth range contains the most active platforms. Across all inventory years more than 95% of the platforms are in water depths below 200 m.

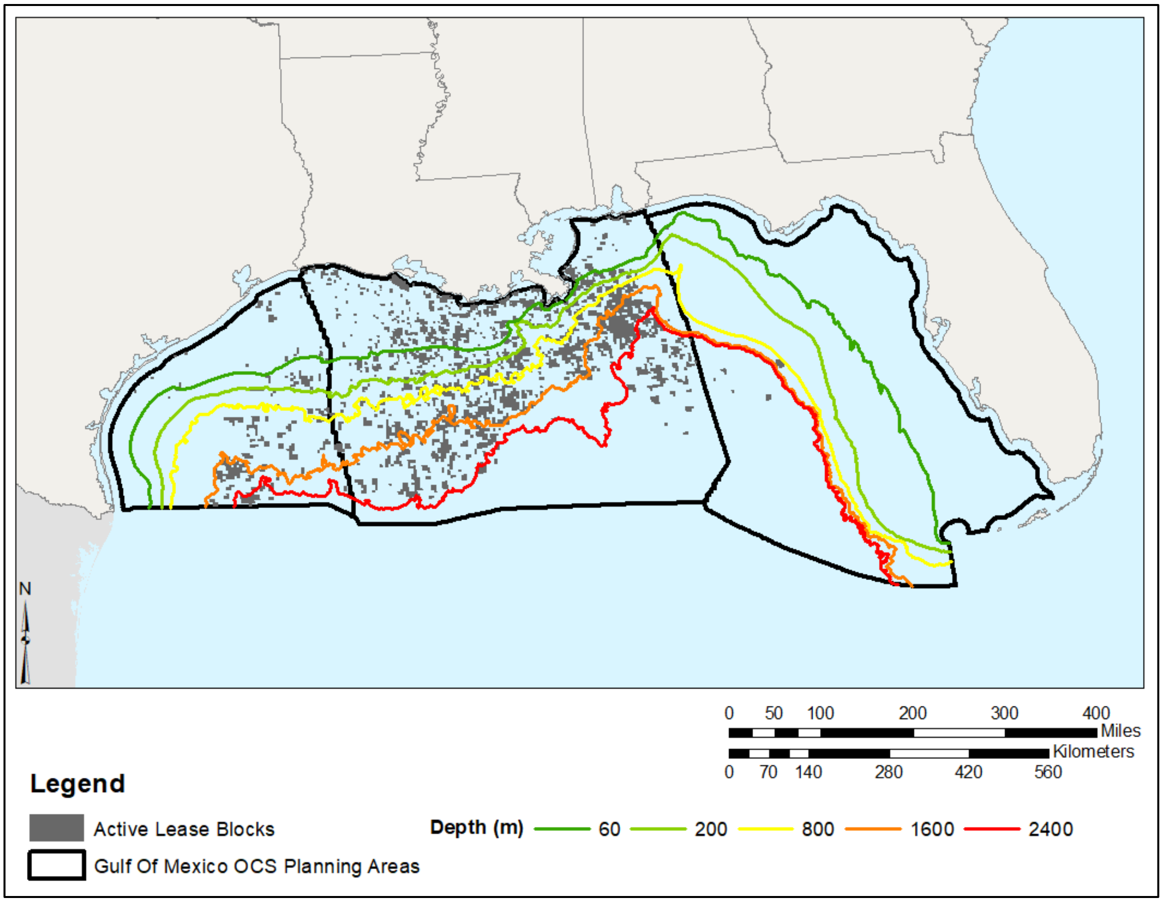


Figure 7-7. 2017 Active Leases and Water Depth Boundaries

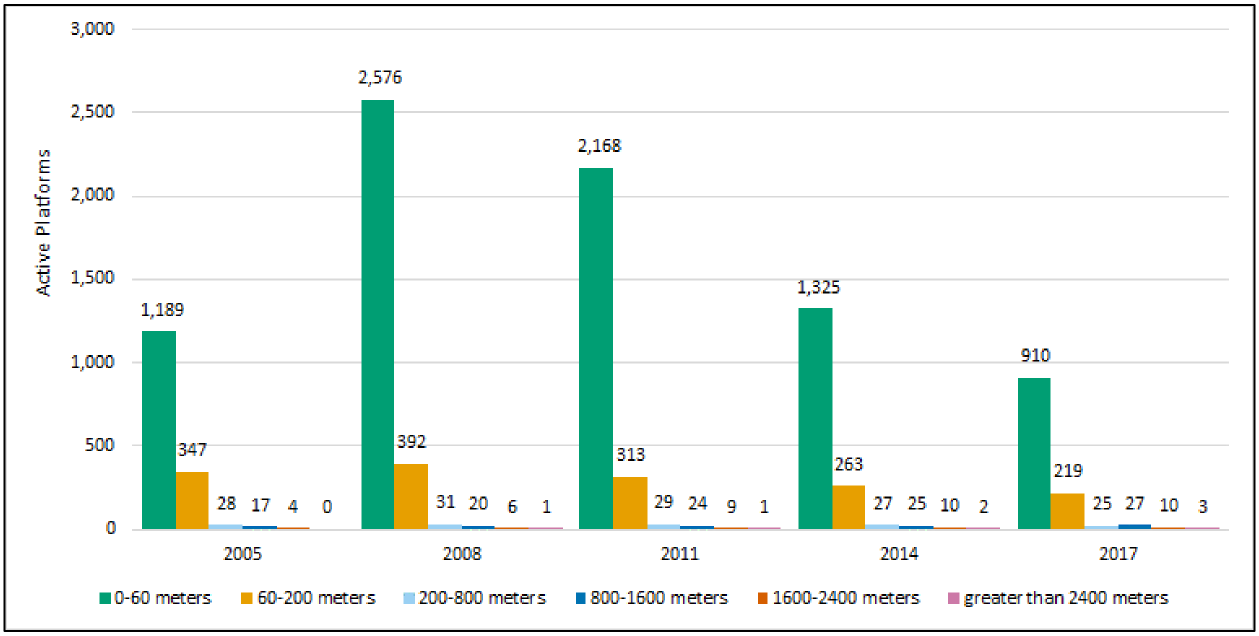


Figure 7-8. Count of Active Platforms Reported in GOADS by Water Depth (Meters)

Table 7-5. GOADS Platform Counts by Water Depth

Platform Water Depth (m)	2005	2008	2011	2014	2017
0–60	1,189	2,576	2,168	1,325	910
60–200	347	392	313	263	219
200–800	28	31	29	27	25
800–1,600	17	20	24	25	27
1,600–2,400	4	6	9	10	10
Greater than 2,400	0	1	1	2	3
Total	1,585	3,026	2,544	1,652	1,194

Figure 7-9 shows the total platform NO_x from the platform inventory for these same water depth bins. For each inventory, the highest NO_x emissions occur in the shallowest water and decrease with increasing depth. This occurs until the fourth bin, water depth between 800 and 1,600 m, is reached. The emissions in this bin increase sharply, with decreased emissions from this level for the final two bins. Even though more than 95% of the platforms are in water depth below 200 m, the platforms only account for 50 to 80% of the NO_x emissions from the inventory. This trend needs to be tempered with the fact that some discoveries in deepwater areas are too small to be developed on their own. In these cases, operators will use a subsea technology to control and produce the well while "tying back" the well to existing production facilities that can be miles away (Nixon et al., 2016). These tie backs can cross water depth bins, so their emissions are shifted across the bins as well.

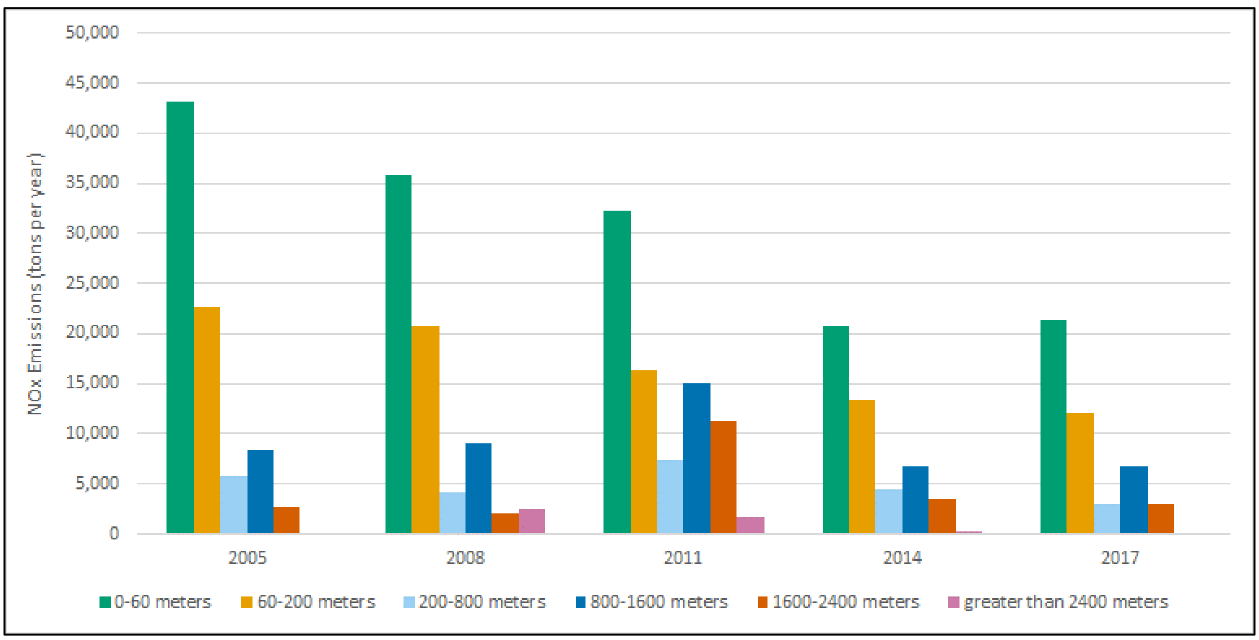


Figure 7-9. Active Platform NO_x Emissions by Water Depth (Meters)

Based on the water depth category, BOEM makes the distinction of shallow versus deepwater platforms. Deepwater is considered any areas with water depths greater than 1,000 feet (305 m). Most active platforms are in shallow waters (Figure 7-10 and Table 7-6). The absolute number of deepwater platforms shows a decrease across the five inventory years but were a larger percentage in the most recent inventories. This does not necessarily reflect of the trends across all years in the 2005 to 2017 period, however. The *Deepwater Gulf of Mexico Report* (Nixon et al., 2016) shows a little less variability in the number of active leases in deepwater. The discrepancy in the total number between the Nixon et al. (2016) *Deepwater Gulf of Mexico Report* and the GOADS counts is likely due, at least in part, to tying back subsea structures to other platforms that report to GOADS. That is, there may be more than one active lease tying back to the same active platform. The lease count in the *Deepwater Gulf of Mexico Report* (Nixon et al., 2016) also consider active blocks where exploration is occurring, and active platforms might not be established.

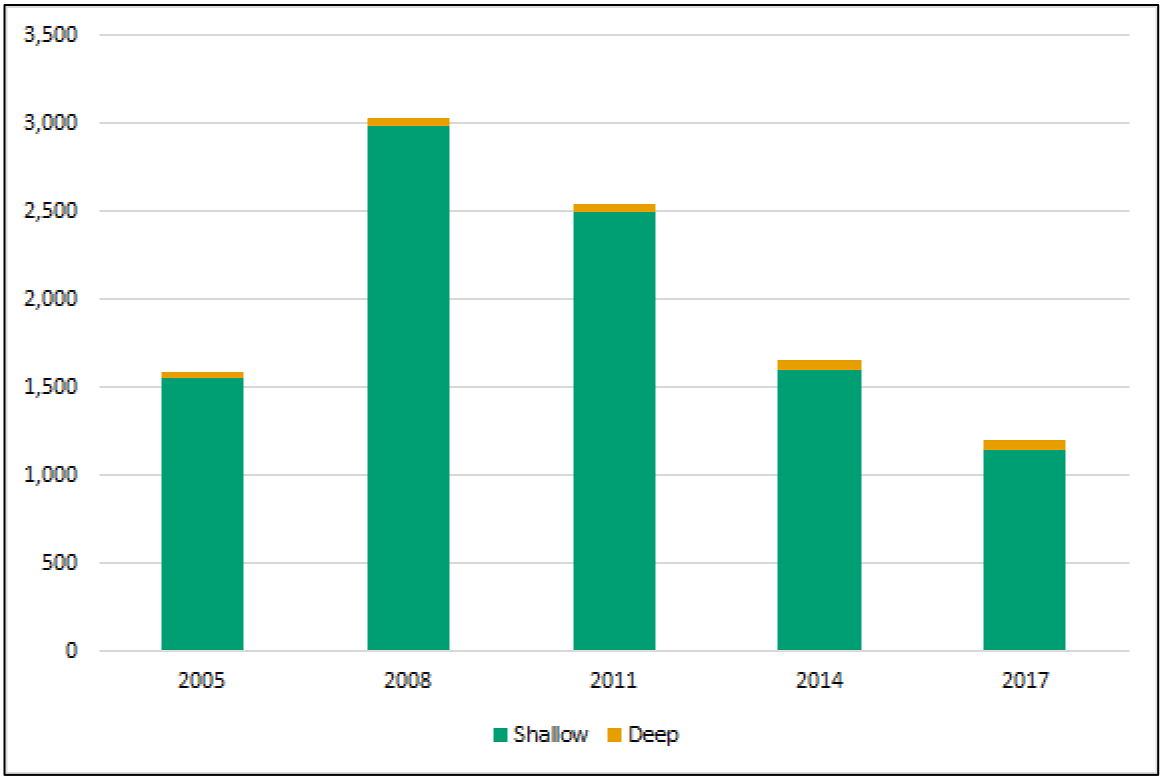


Figure 7-10. Active Platforms Reported in GOADS by Shallow/Deepwater

Table 7-6. Counts of Active Platforms in GOADS by Shallow/Deep Water Distinction

Water Depth	2005	2008	2011	2014	2017
Deep	36	43	49	53	56
Shallow	1,549	2,983	2,495	1,599	1,138
Total	1,585	3,026	2,544	1,652	1,195

Looking back at Figure 7-6, there are fewer active leases in shallow waters of the Western Planning Area. An analysis of the active platforms (Figure 7-11) shows the Western Planning Area (W GOM) platforms and the CPA (C GOM) platforms as split similarly to the overall total. Thus, 5% or less of the active platforms are in deepwater. Similar to the overall percentage, the percentage of deepwater platforms in both planning areas has increased since the 2011 inventory.

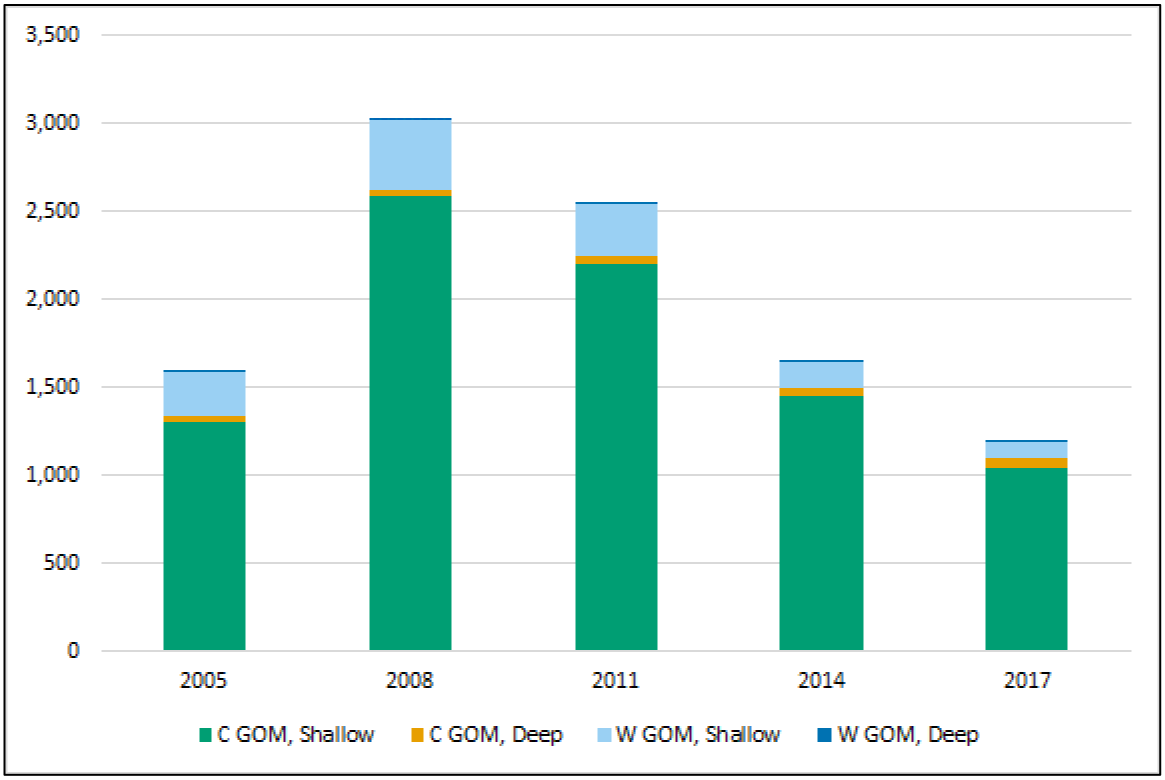


Figure 7-11. Active Platforms Reported in GOADS by Planning Area and Water Depth

These trends in platform distribution can also be seen in the spatial plots of the locations. The maps shown in Figure 7-12 show an expansion into deeper water with the progressive inventory years. The figure also shows the decline in shallow water platforms in the western GOM, particularly off the southern coast of Texas. The emissions of all pollutants tend to be higher for the newer platforms, which can be seen in the spatial progression of total platform NO_x emissions in Figure 7-13. The spatial plots of the other pollutants follow a similar pattern.

The spatial pattern of emissions also correlates with platform oil and gas production values, which is discussed further in Section 7.5.4.

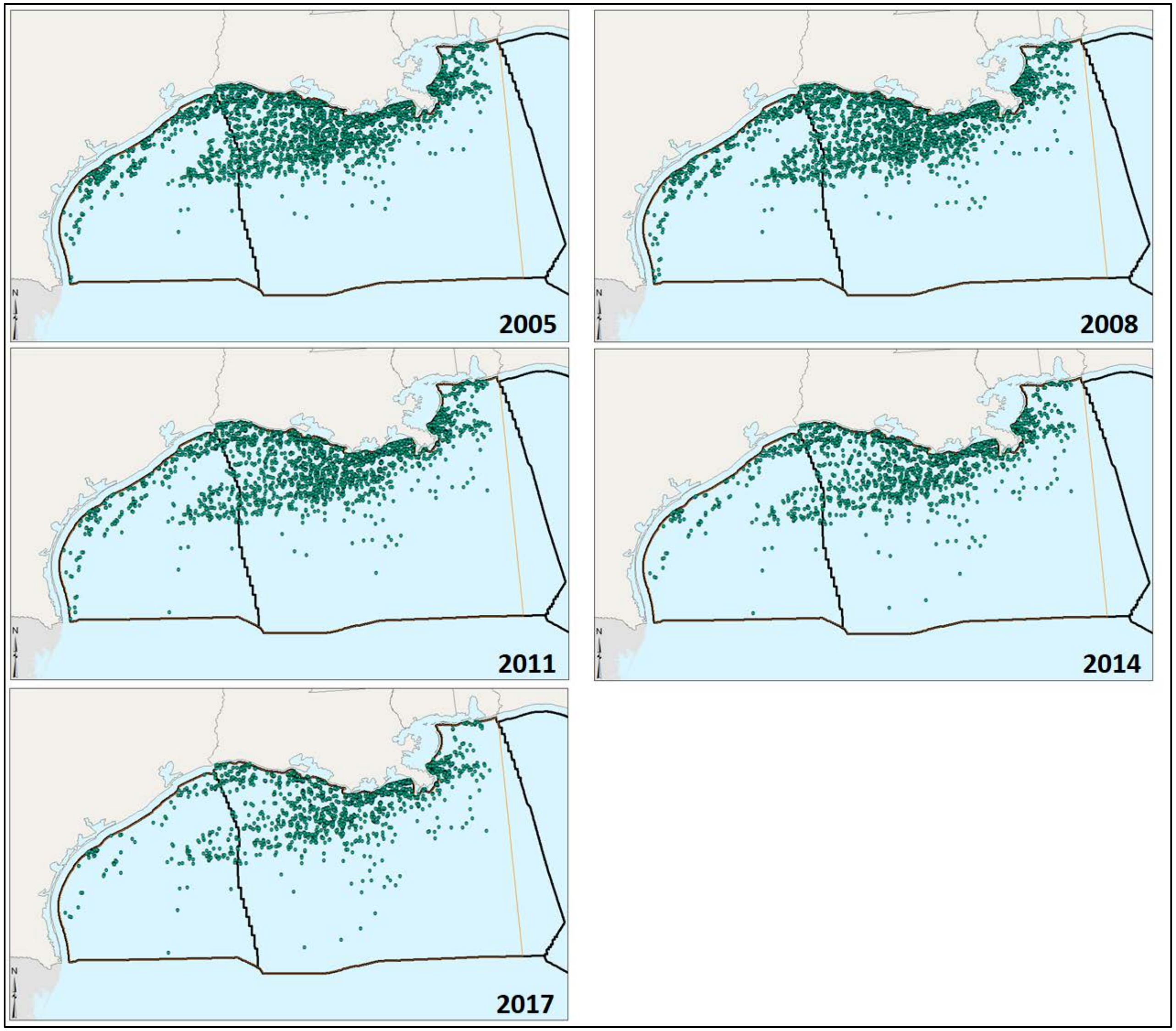


Figure 7-12. Active Platform Locations Reported in GOADS by Inventory Year

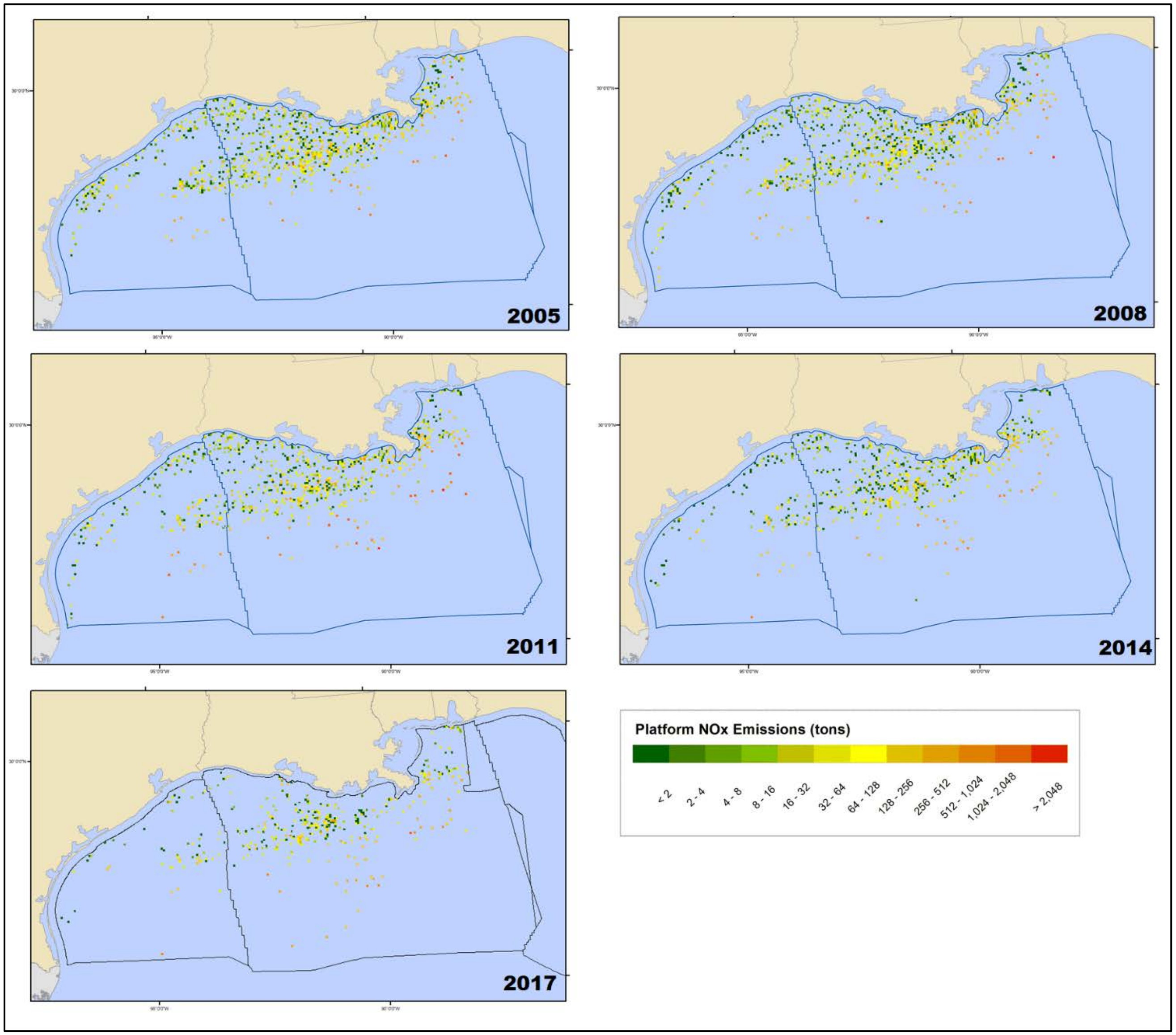


Figure 7-13. Total Platform NO_x Emissions by Year

7.3.2 Total Platform Emissions Trends

Total platform emissions, which do not include support vessel emissions, only those emissions associated with platform equipment, are summarized in Table 7-7 and shown graphically in Figures 7-14 and 7-15. On average, CO_2 emissions make up the largest portion of the inventories, followed by CH_4, CO, and NO_x. These pollutants also have high variability in their values from inventory year to inventory year. This is due in part to the annual variability in the number of active platforms, activity levels, and changes in the emission factors and calculation methods. The pollutants with lower emission rates (i.e., PM_{10}, $PM_{2.5}$, and VOC), have far less variability. Figure 7-15 also emphasizes the relative constant level in both PM_{10} and $PM_{2.5}$ emissions across all the inventories.

The bar chart in Figure 7-14 shows inventory years that stand out by breaking apparent trends. Examining the emission by equipment category sheds some light on what is driving these sudden shifts in emissions.

Figure 7-14 shows a noticeable increase in CH_4 emissions in the 2008 inventory. Looking at the emissions by broad equipment categories (Figure 7-16), this increase is due to emissions from vents and flares.

The bar charts in Figure 7-15 indicate NO_x emissions holding steady around 80,000 tons per year until 2014, when emissions dropped sharply. The decrease in emissions is due to a drop in the combustion equipment emissions, which will be explored in Section 7.3.3.

The figure also shows that SO_2 emissions have been steadily decreasing, with the exception of an increase in the 2011 inventory. By looking at the breakdown of emissions by equipment category in Figure 7-17, the trend is due both to an almost complete curtailment of SO_2 emissions from non-combustion sources in 2008 and a significant increase in SO_2 from combustion sources in 2011. Sections 7.3.3, 7.3.4, and 7.3.5 examine all the equipment trends in combustion, vent and flare, and non-combustion categories.

Table 7-7. Summary of Platform Emissions by Year

Pollutant		Emissions (tpy)				
		2005	2008	2011	2014	2017
GHGs	CO_2	8,848,779	8,417,165	11,882,029	5,940,330	6,857,360
	CH_4	214,499	422,707	271,355	225,667	187,894
	N_2O	130	125	167	98	118
	CO_2e	14,250,099	19,022,140	18,715,529	11,611,272	11,589,943
Criteria Pollutant	CO	89,813	82,146	70,339	50,052	51,872
	NO_X	82,581	74,286	84,128	48,691	49,962
	PM_{10}-PRI	746	780	838	668	636
	$PM_{2.5}$-PRI	743	769	835	667	635
	SO_2	1,961	1,021	3,197	502	462
	VOC	51,241	60,824	54,724	48,210	38,833

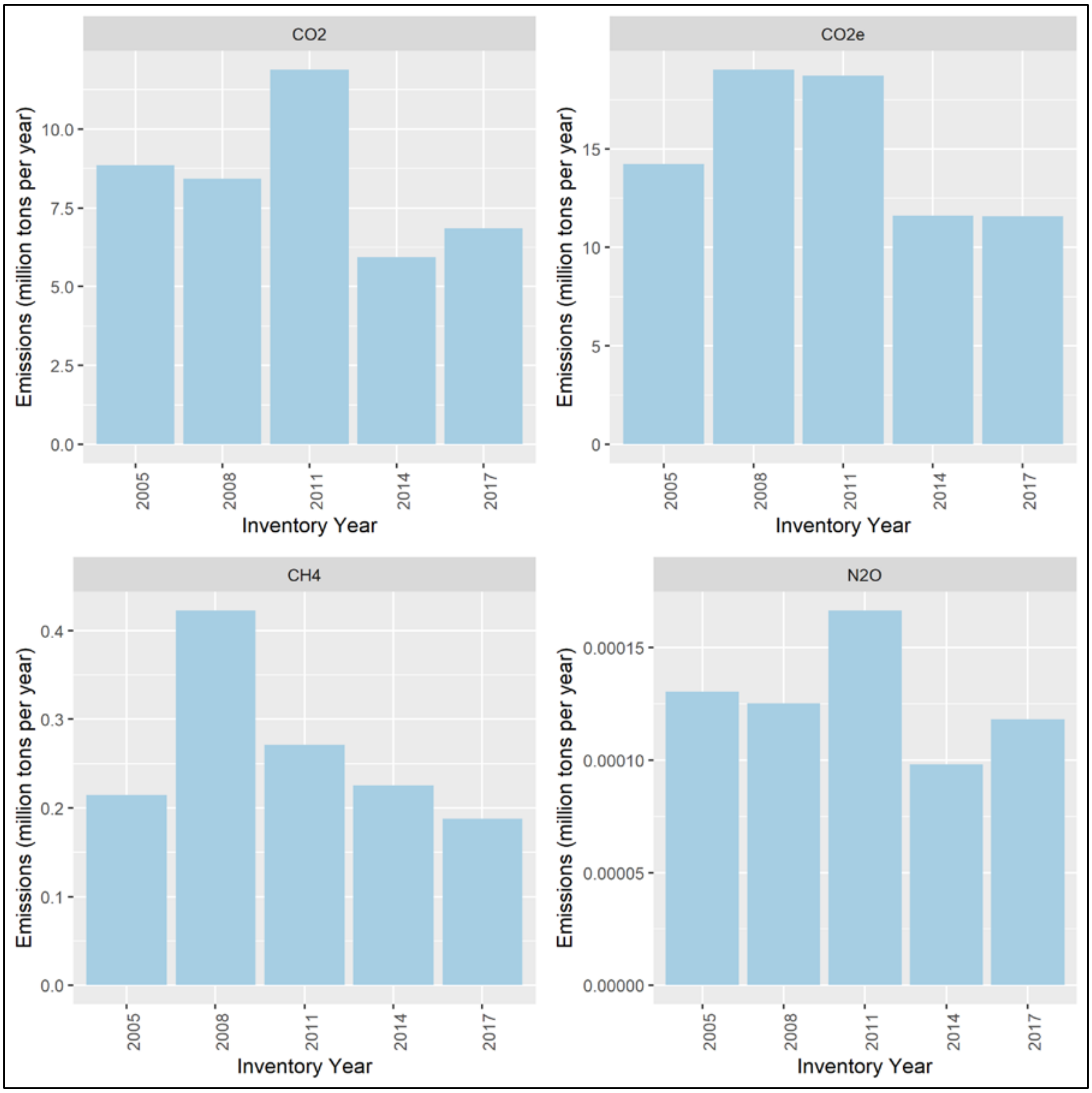


Figure 7-14. Total Platform GHG Emissions Estimates by Inventory Year

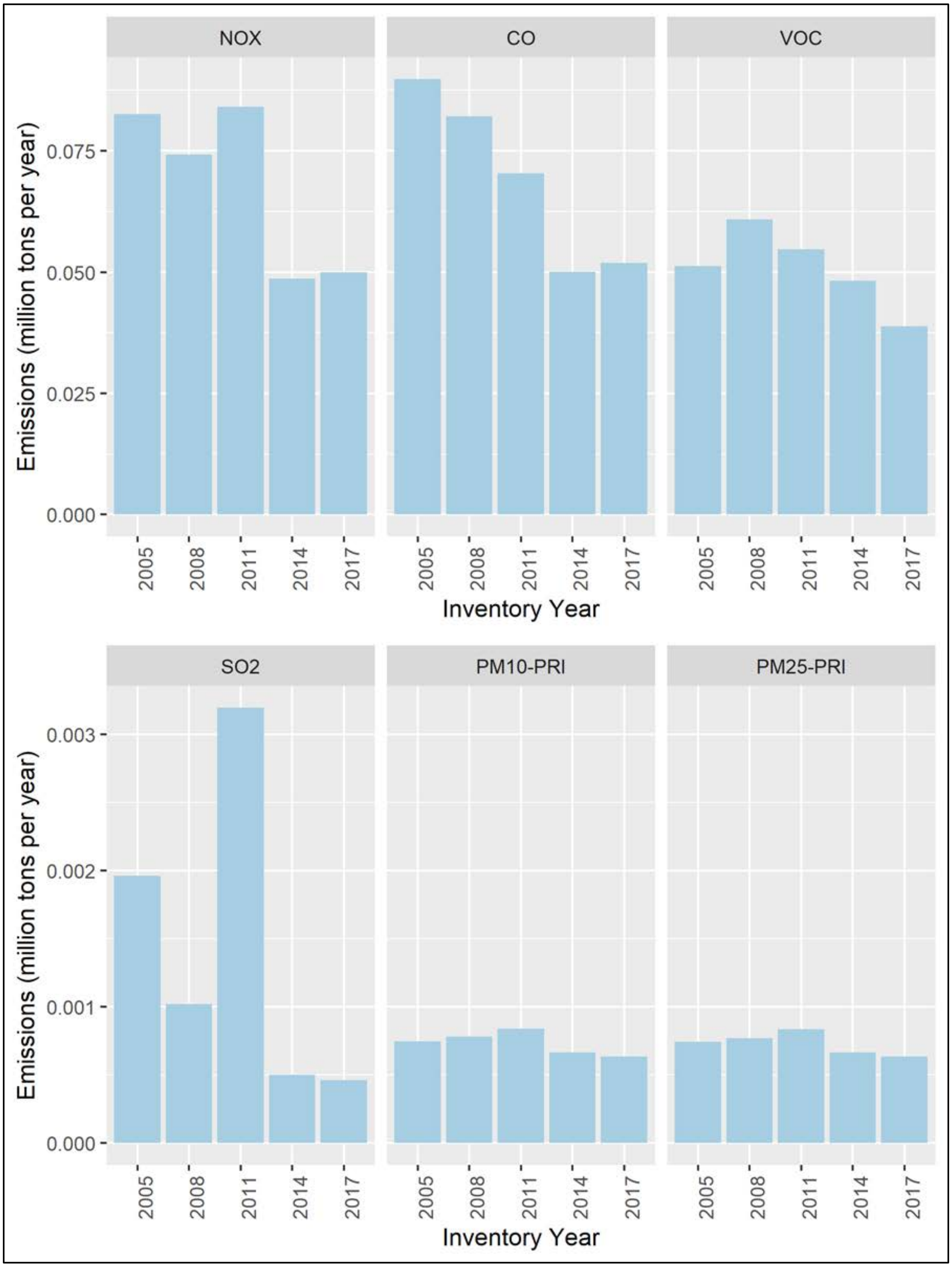


Figure 7-15. Total Platform Criteria Pollutant Emissions Estimates by Inventory Year

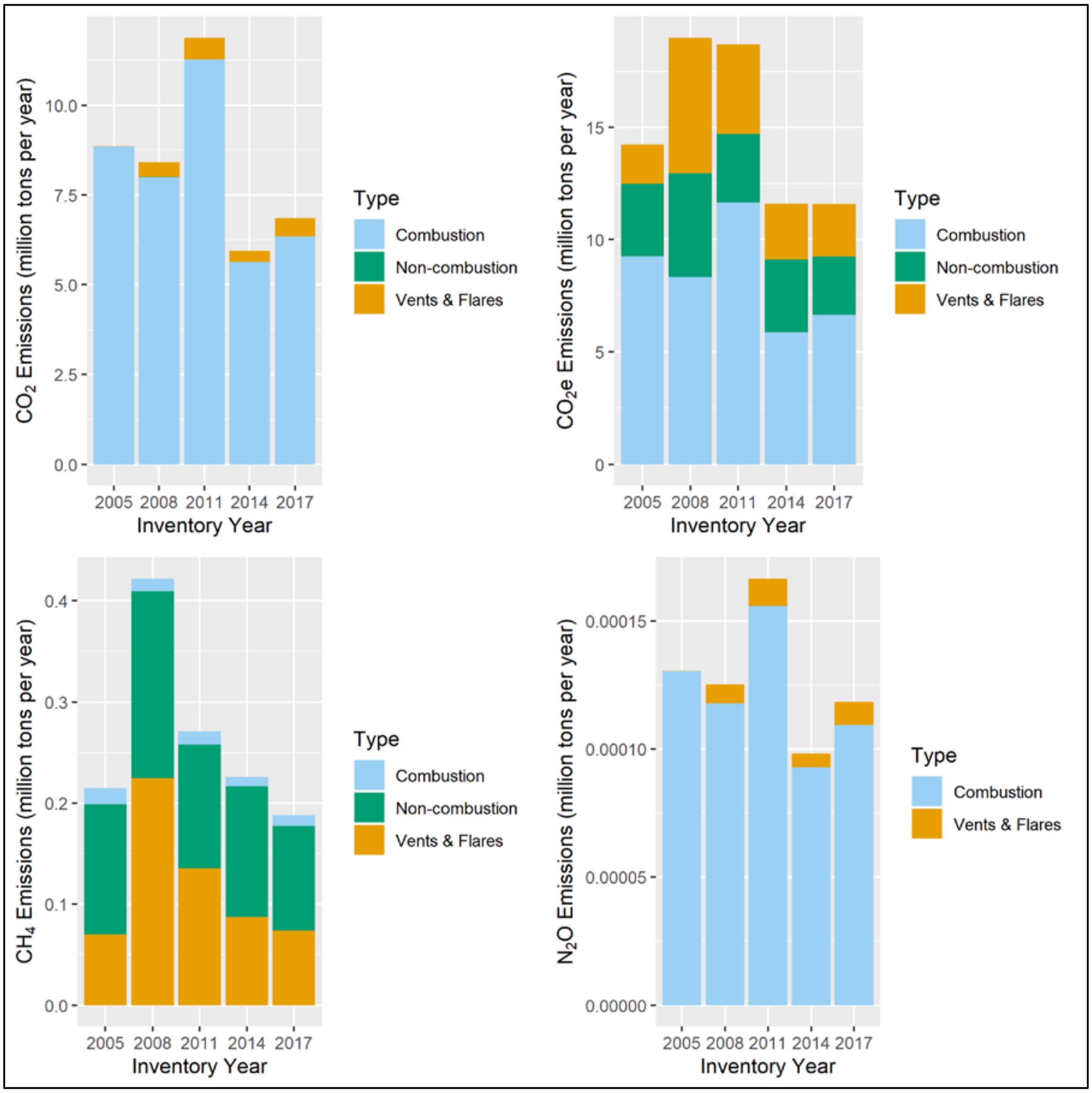


Figure 7-16. Platform GHG Emissions Estimates by Equipment Type

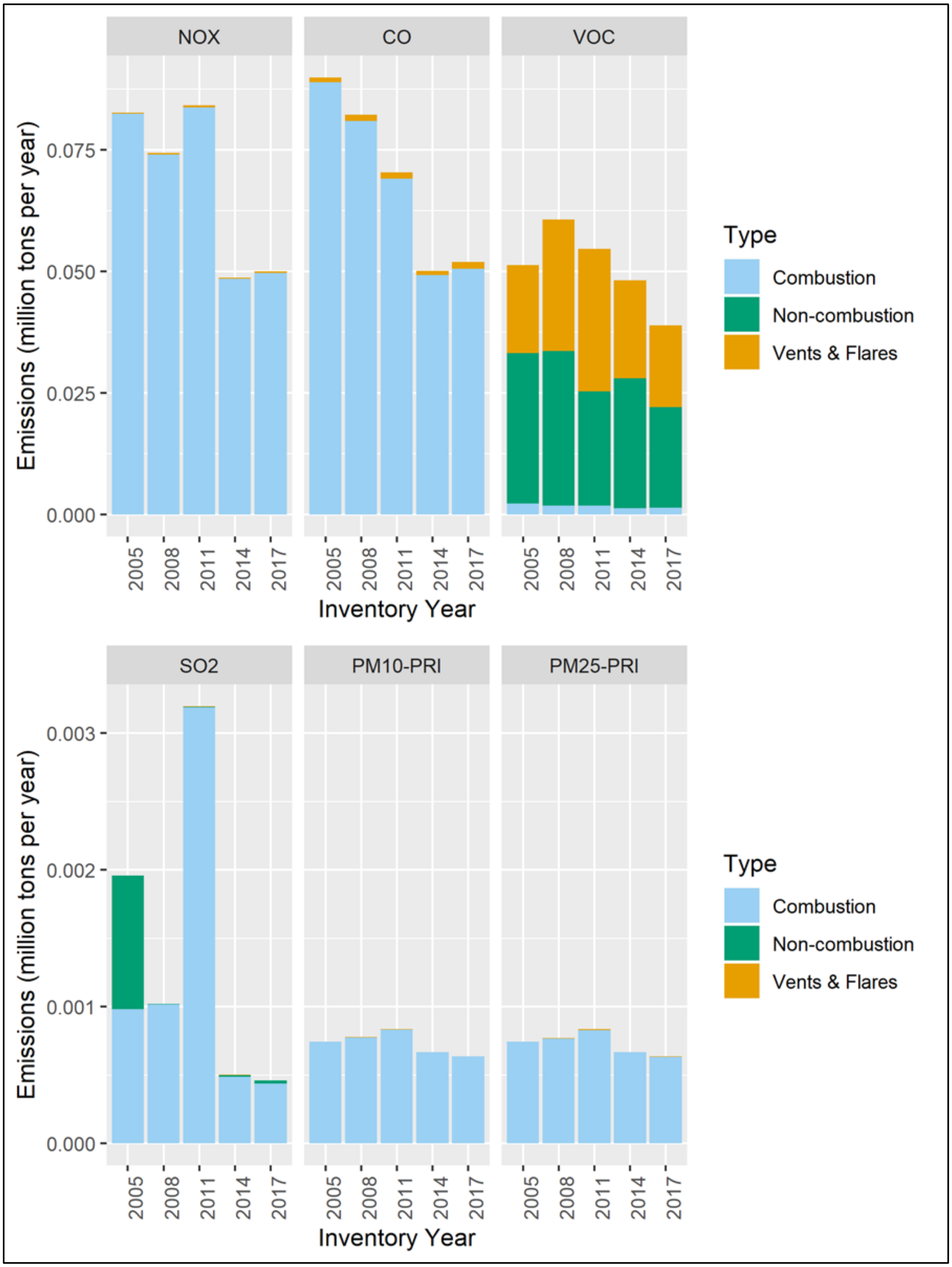


Figure 7-17. Platform Criteria Pollutant Emissions Estimates by Equipment Type

7.3.3 Combustion Equipment

The combustion equipment subcategory consists of boilers (BOI), diesel engines (DIE), drilling equipment (DRI), natural gas engines (NGE), and natural gas, diesel, and dual-fuel turbines (NGT). These equipment types burn a fuel, either gasoline, diesel, or natural gas, which is the source of their emissions.

Total combustion equipment emission estimates have been relatively stable, with any large swing in emissions correlated with changes in activity levels (Figures 7-18 and 7-19). The most notable exception is the SO_2 emissions for 2011 (Figure 7-19). Starting in 2011, diesel and dual-fuel turbines were added to the inventory falling under the heading of natural gas turbines. The increased reporting of turbines caused an initial spike in SO_2 estimates due to inaccurate reporting (e.g., dual-fuel reported as two separate turbines). The emissions dropped off again in 2014 due to decreased activity and better reporting due to outreach and familiarity with the added subcategories. Starting with the 2014 inventory, there was assumed to be a switch to ultra-low sulfur diesel fuels, which also contributed to decreases in SO_2 emissions.

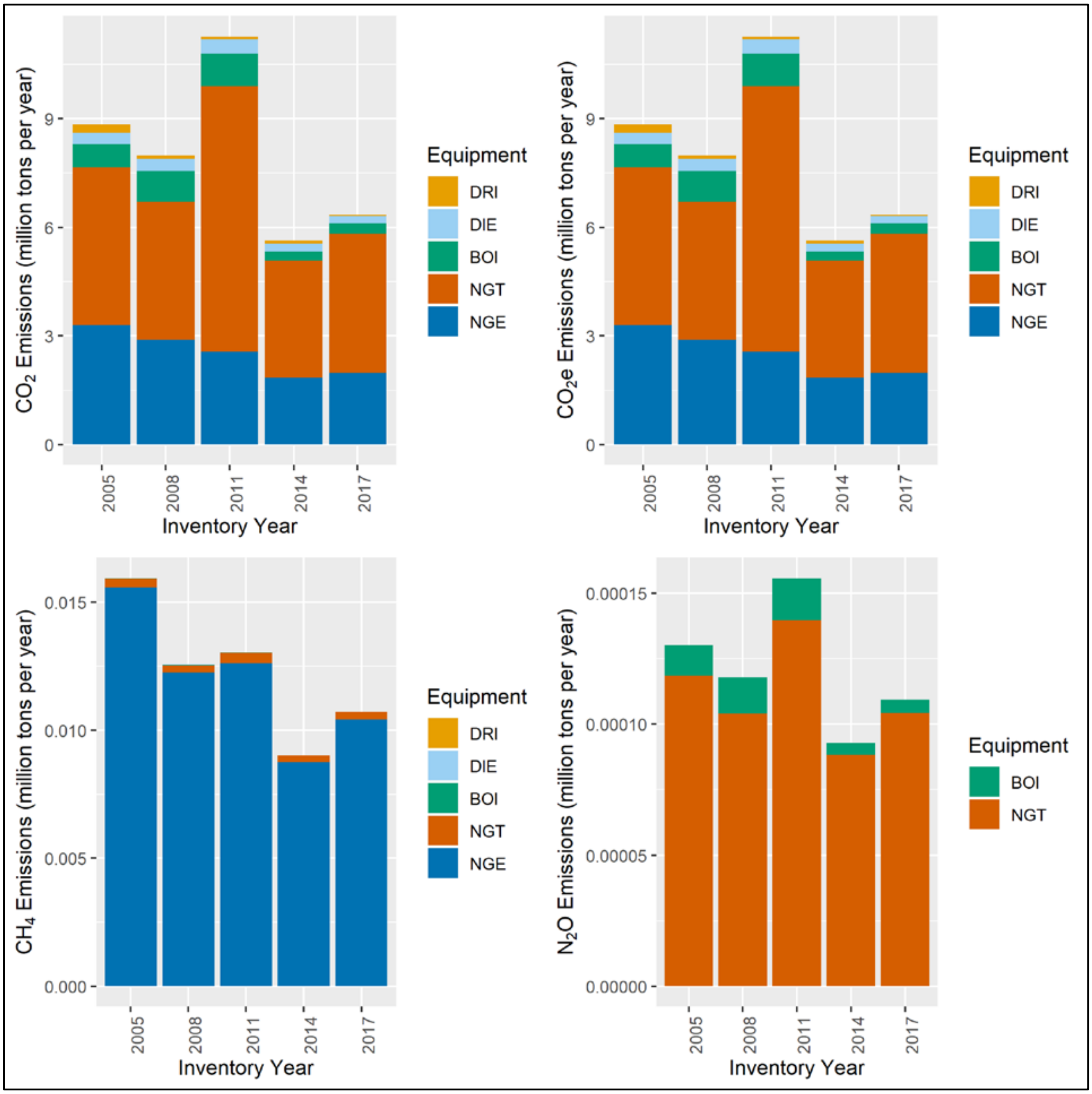


Figure 7-18. Platform GHG Emissions Estimates for Combustion Equipment
BOI = boilers, DIE = diesel engines, DRI = drilling equipment, NGE = natural gas engines, NGT = natural gas, diesel, and dual-fuel turbines

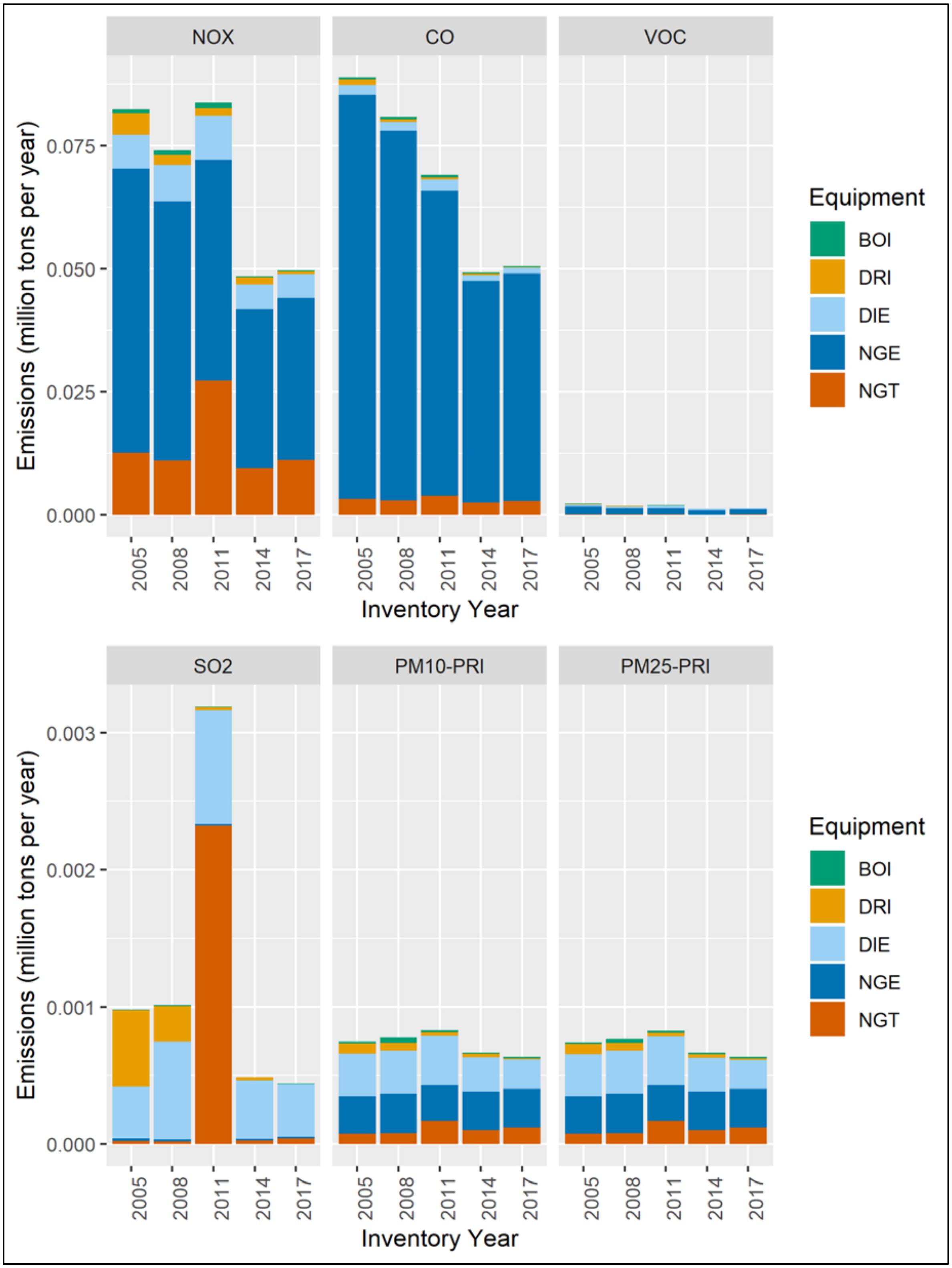


Figure 7-19. Platform Criteria Pollutant Emissions Estimates for Combustion Equipment
BOI = boilers, DIE = diesel engines, DRI = drilling equipment, NGE = natural gas engines, NGT = natural gas, diesel, and dual-fuel turbines

7.3.4 Vents and Flares

Both vents and flares are used to handle excess gas and emissions from various platform sources including storage tanks, glycol dehydration units, vent collection systems, and amine units. Vents simply release exhaust streams to the atmosphere, while flares use a burning stack to dispose of the vapors. Due to the nature of the emissions handling, flares emit combustion by-products (i.e., CO_2, CO, NO_x, SO_2, PM_{10}, and $PM_{2.5}$), while vents emit pollutants associated with raw gas (i.e., CH_4 and VOC). Bar charts of the emissions by pollutant for vents and flares (Figure 7-20 and Figure 7-21) illustrate the difference in pollutants emitted. Emission estimates for $PM_{2.5}$ are missing for 2005 in Figure 7-21, as estimates were only developed for PM_{10} in this inventory. It is expected that the $PM_{2.5}$ emissions would be consistent with PM_{10} emissions from the same period. The vent and flare portions of the emissions inventory have seen some abrupt changes in emissions estimates. For example, there is a large CO_2 increase in 2008 (Figure 7-20) despite a relatively consistent number of flares (Table 7-8). This is possibly due to misclassification of vents and flares in the early inventories by GOADS submitters due to terminology used in the offshore oil and gas production community. This led to additional outreach by BOEM to operators and changing the language to “cold vents” and “combustion flares” to reinforce that vents are passive exhausting systems and flares have combusted exhaust. As the inventory process matured, the application of the terms vent and flare became more consistent and the overall emission profile became more consistent and accurate.

After 2008, changes in emission levels are due to increased activity levels, combined with more accurate and complete reporting by the operators. There was also a change in the vent calculation method in 2011 that reduced CH_4 estimates.

Emissions from vents and flares decreased in 2014 for all pollutants. This is likely due to the decrease in the number of active vents and flares reported (Table 7-8). Additionally, the USEPA emission factor for CO emitted from combustion flares was updated in 2014. The emission factor was reduced slightly (from 0.37 to 0.31 lb/MMBtu), which accounts for some of the reduction in emissions. During the review process for the 2014 inventory, it was discovered that some operators included the flare pilot volume in their reported total volumes flared. In previous inventories, the pilot flare volume and emissions were calculated separately. Overall, the emissions from the pilot volume represent a very small fraction of the total volume flared and therefore of the total emissions. Corrections were made in the 2014 inventory, which, when combined with the emission factor change and slightly reduced activity, further contributed to a slight reduction in total emissions from flares.

For the 2017 inventory, efforts were made to clarify the reporting and calculation for flares in the 2017 inventory effort. Although the number of flares reported for 2017 was similar to the number reported for 2014, the overall volume flared increased by approximately 23% in 2017 (Figure 7-22). This resulted in an increase in emissions of CO_2 and N_2O and a slight increase in NO_x and CO from flares. Furthermore, in the 2017 inventory the methodology used to estimate CH_4 and VOC emissions from flares was revised, which led to a noticeable increase in emissions estimates. The 2017 inventory saw the number of vents and volume vented continue to decline, resulting in decreased in emissions from vents.

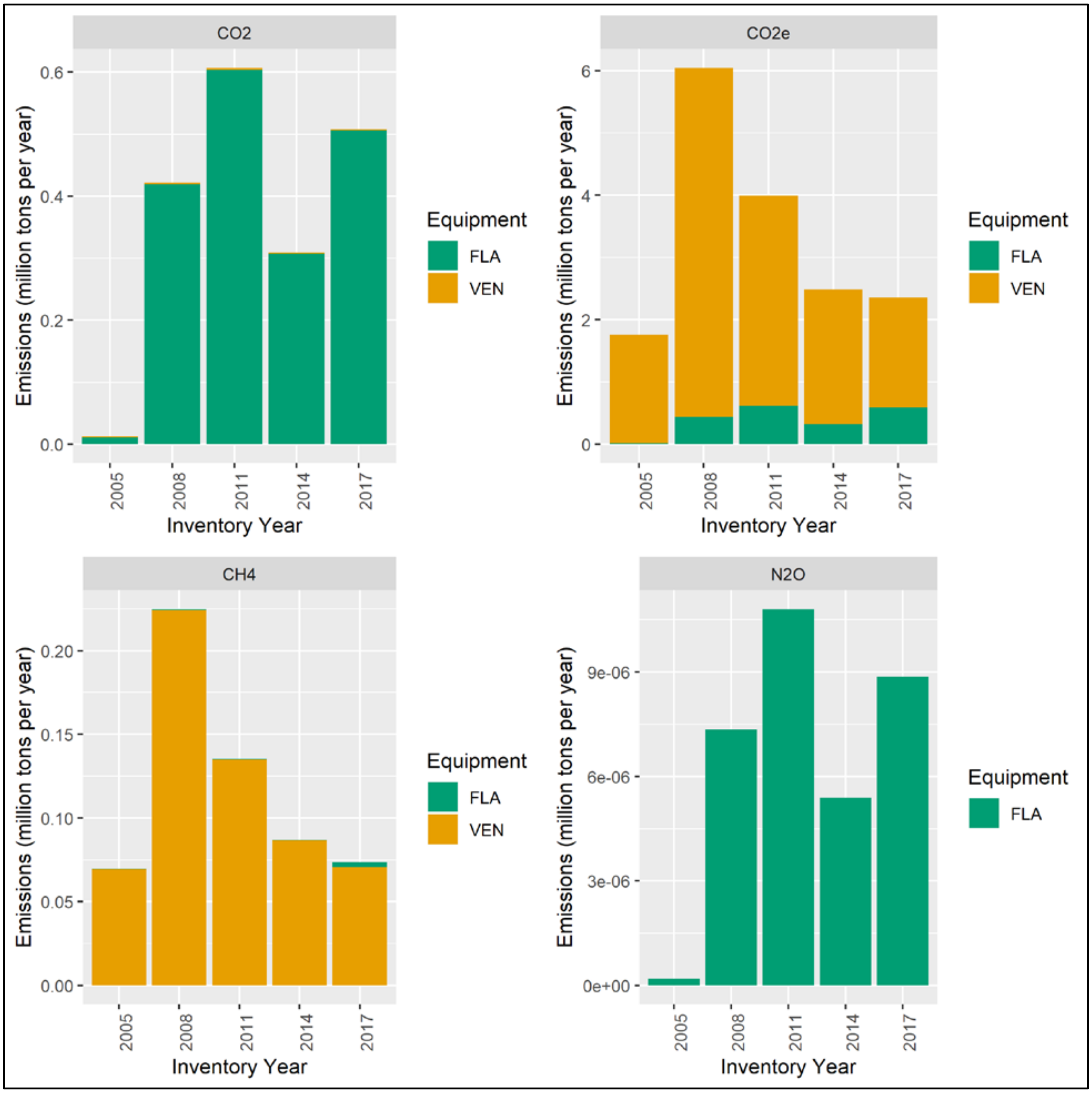


Figure 7-20. GHG Emissions Estimates for Flares (FLA) and Vents (VEN) by Inventory Year
VEN = vents, FL = flares

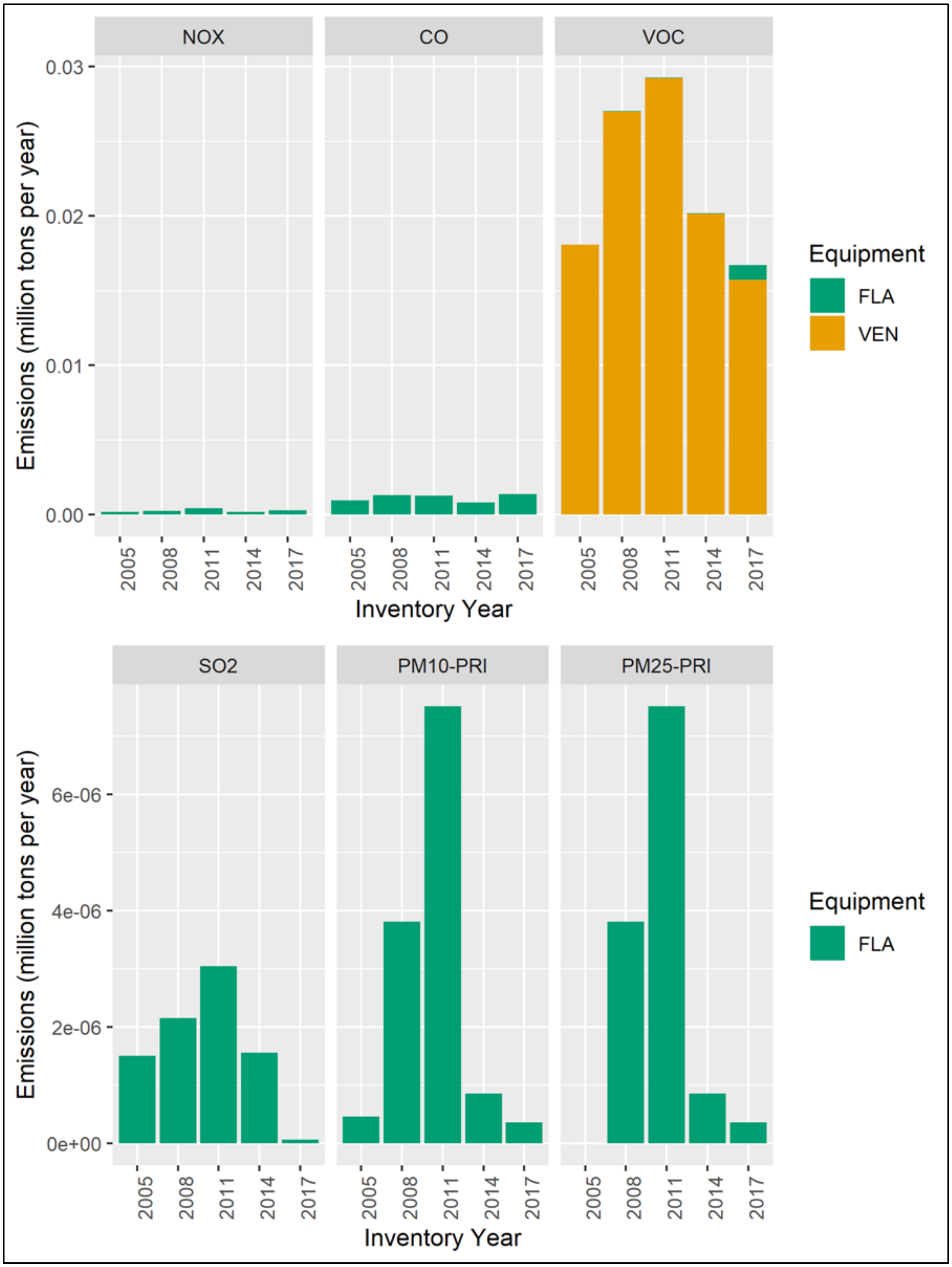


Figure 7-21. Criteria Pollutant Emissions Estimates for Flares (FLA) and Vents (VEN) by Inventory Year
VEN = vents, FL = flares

Table 7-8. Active Vent and Flare Equipment Counts Across the Inventories

Equipment	2005	2008	2011	2014	2017
Flare	110	130	144	88	90
Vent	791	881	1,169	640	540

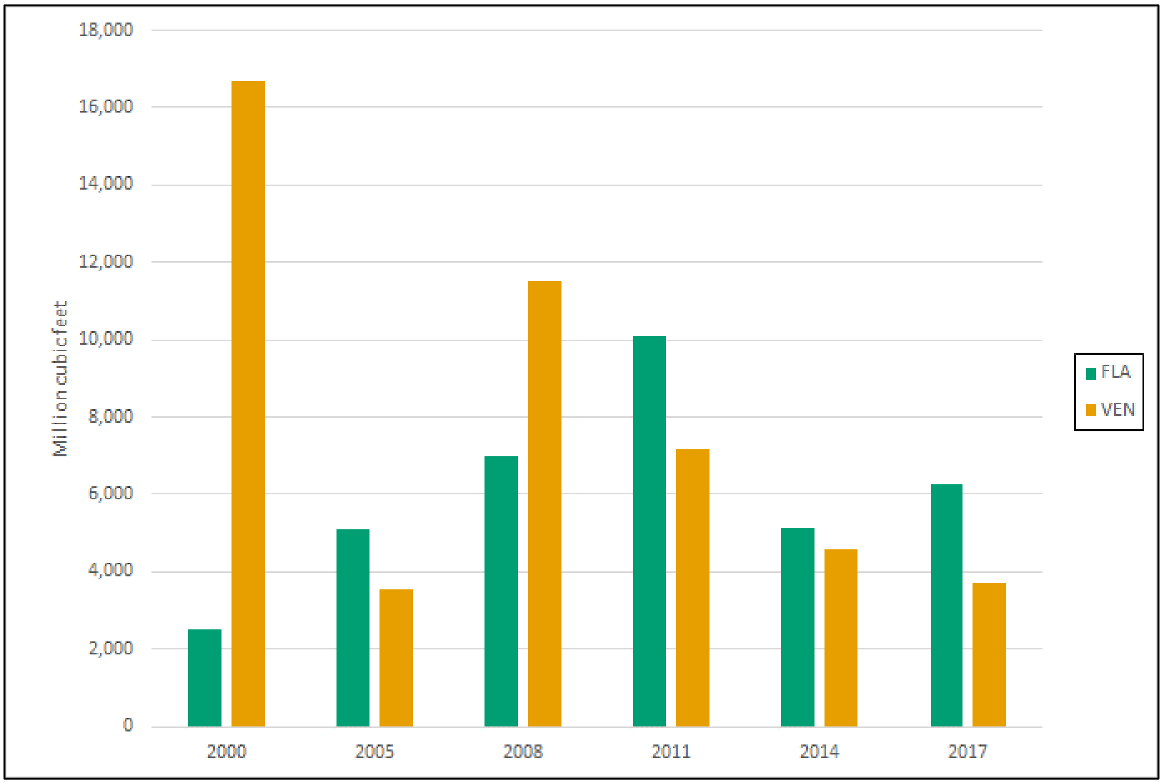


Figure 7-22. Volumes Flared (FLA) and Vented (VEN) by Inventory Year

7.3.5 Miscellaneous Non-Combustion Equipment

The remaining platform equipment not discussed in previous sections consists of:

- Fugitives (FUG)
- Storage tanks (STO)
- Loading (LOS)
- Losses from flashing (LOS)
- Pneumatic pumps (PNE)
- Pneumatic controllers (PRE)
- Glycol dehydrators (GLY)
- Amine units (AMI).
- Mud degassing (MUD)

The miscellaneous non-combustion sources only contribute to CO_2, CH_4, SO_2, and VOC emissions in the inventories. Figure 7-23 shows the contribution of each of the non-combustion equipment category to the total emissions. Table 7-9 displays the counts of active units in the inventory. As with the counts of other equipment in the inventories, as operators became more accustomed to the GOADS reporting and data definitions in each successive inventory of the inventories resulting in a more accurate and consistent reporting.

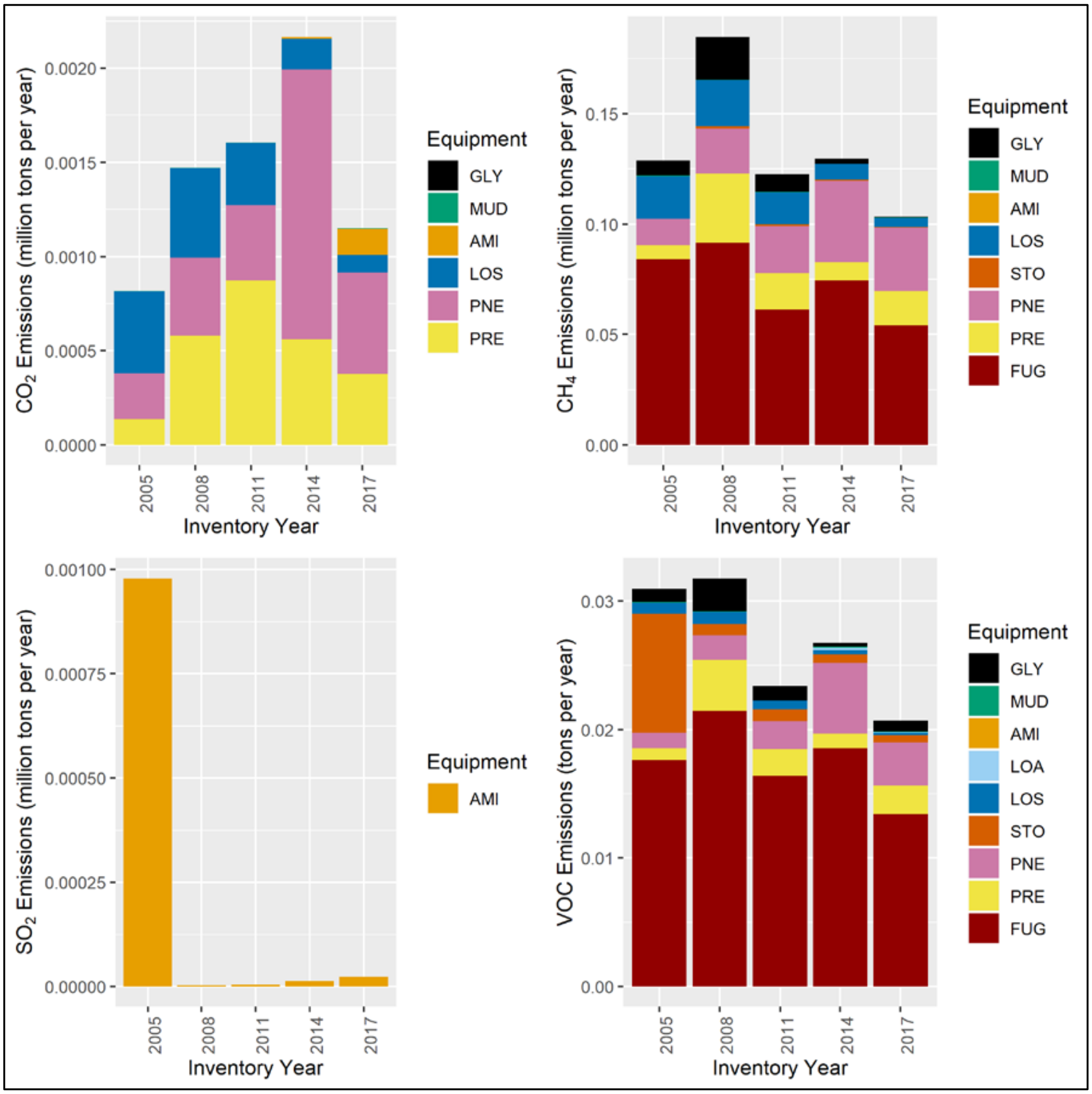


Figure 7-23. Emissions Estimates for Non-combustion Equipment

Table 7-9. Active Non-combustion Unit Count by Inventory Year

Equipment	2005	2008	2011	2014	2017
Amine units	4	4	5	6	4
Fugitives	4,097	3,971	3,079	4,090	3,199
Glycol dehydrators	189	159	108	98	174
Loading	--	--	--	1	1
Losses from flashing	70	275	148	212	400
Mud degassing	79	43	22	17	7
Pneumatic pumps	3,198	2,961	2,141	2,512	1,703
Pressure and level controllers[a]	3,502	3,187	1,834	1,654	2,757
Storage tanks	629	357	370	217	336

[a] Referred to as pneumatic controllers in 2017 inventory.

Following 2005, CO_2 emissions estimates slowly increased due to increasing pneumatic pump and pneumatic controller emissions. The increase in pneumatic pump emissions might be due to an increase in venting or flaring emissions locally as opposed to remotely or routed to system. The increase for pneumatic pumps and pneumatic controllers up until the 2014 inventory may be due to an increasing number of units using default gas usage rate (59% in 2011 compared to 77% in 2014). This default is a conservative estimate, which may be pushing the emission estimates higher. Submitting the gas usage rates for both pneumatic pumps and pneumatic controllers was optional through the 2014 inventory; however, it was made mandatory in the 2017 inventory to better quantify emissions from these sources. The CO_2 emissions for pneumatic pumps dropped substantially from 2014 to 2017, which is either the result of the reported gas rate and/or a decrease of approximately 800 units. The emissions level for pneumatic controllers remained constant despite this change, which is probably due to over 1,000 additional units being reported in 2017. CO_2 emissions from amine units were negligible for the 2005 through 2014 inventories; however, 2017 had a noticeable increase in emissions. This is mainly due to increased emissions from one amine unit, where emissions for both the regenerator and flash gas were reported as "routed to the system" in the 2014 inventory, and therefore had zero tons of CO_2 emissions in 2014. The flash gas was reported as flared locally for the 2017 inventory, which resulted in increased emissions. Other amine units had smaller increases of CO_2 emissions in the 2017 inventory.

As shown in Figure 7-23 (top right), unlike the CO_2 trend, CH_4 does not see the steady growth of pneumatic pump and pneumatic controller emissions in the 2011 and 2014 inventories, but there is a drop in total emission for 2017, similar to CO_2.

Amine unit SO_2 emissions estimates have changed greatly over the inventory years (Figure 7-23, bottom left). The estimates in the emission inventories are due to decreases in reported activity. In 2008, one unit that was operating in 2005 (and equipped with a flare) ceased operation and effectively reduced SO_2 emissions from amine units to zero for all subsequent inventory years, despite the addition of a new unit each year. Most of the remaining units are routed to the system, which results in increased emissions at other equipment, not the amine unit. The 2014 inventory had an additional unit reported, with locally flared emissions, causing the slight uptick in emissions. The 2017 inventory had a continued growth in emissions, despite a decrease in the number of units reported. This is likely due to the increase in the number of units reporting flash tanks as being flared locally (three out of the four units) as opposed to routed back to the system.

For VOC (Figure 7-23, bottom right), emission estimates for storage tanks have a significant reduction in the inventories after 2005. This is due to a revision in the VOC speciation profile for 2008 that reduced the estimated emissions. The 2008 VOC emission estimates also increased for fugitive sources, glycol dehydrators, pneumatic pumps, and pneumatic controllers. These increases are likely due to increased activity levels, combined with more complete reporting by the operators. The 2011 fugitive, glycol dehydrator, and pneumatic controller decreases are correlated with a drop in active units. There is an increase in pneumatic pump emission estimates in the 2014 inventory, despite decreasing count. This increase could be the result of increased use of local venting; however, the use of defaults for activity data make this difficult to assess. With the revised data required by GOADS for the 2017 inventory, we see an increase in pneumatic controller and pneumatic pump emissions. The 2017 fugitive and glycol dehydrator emission changes correspond with changes in unit counts. Additionally, the GRI-GLYCalc version 4.0 program (GTI, 2000) was run for each individual glycol dehydrator for the 2017 inventory rather than using regression equations that were based on GLYCalc that were used for previous inventory years.

7.4 Non-Platform Trends

As noted in Section 5 of this report, the non-platform inventory consists of OCS oil and gas production-related sources (i.e., drilling rigs, helicopters, pipelaying vessels, support vessels, and survey vessels), and non-production sources (e.g., geogenic emissions, military operations, commercial and recreational fishing, and other commercial marine vessels). For certain pollutants, like CH_4 (Figure 7-24) and VOC (Figure 7-25), the bulk of the emissions in the inventory are from non-production sources. For other pollutants, the production and non-production emissions ratios are relatively consistent across the inventory, with a few exceptions. The most pronounced exception is in the 2014 inventory, which saw an increase in the portion of emissions attributable to non-production sources. As noted in Section 7.2.2., the activity data used in emission calculations provided more detail on vessel categories starting with the 2014 inventory. This additional detail allowed for a more rigorous differentiation of vessel types (and uses), power ratings and engine classifications of these vessels, and vessel-specific propulsion operating loads for 2014. For example, AIS identified approximately twice the number of support vessels than in the 2011 inventory, while the average propulsion engine power rating for these vessels was half of that assumed in the 2011 inventory. Furthermore, even though more vessels were included, the 2014 AIS data noted that these vessels tend to idle at sea more than assumed in the earlier inventories, yielding significantly lower average engine operating loads. Collectively, the increased number of vessels, reduced engine ratings, and increased idle time resulted in lower total vessel emission estimates.

The balance of this analysis will focus on the non-platform emissions attributable to oil and gas production-related sources. Trends in GHGs will be discussed in Section 7.4.1, and trends in the criteria pollutants will be discussed in Section 7.4.2.

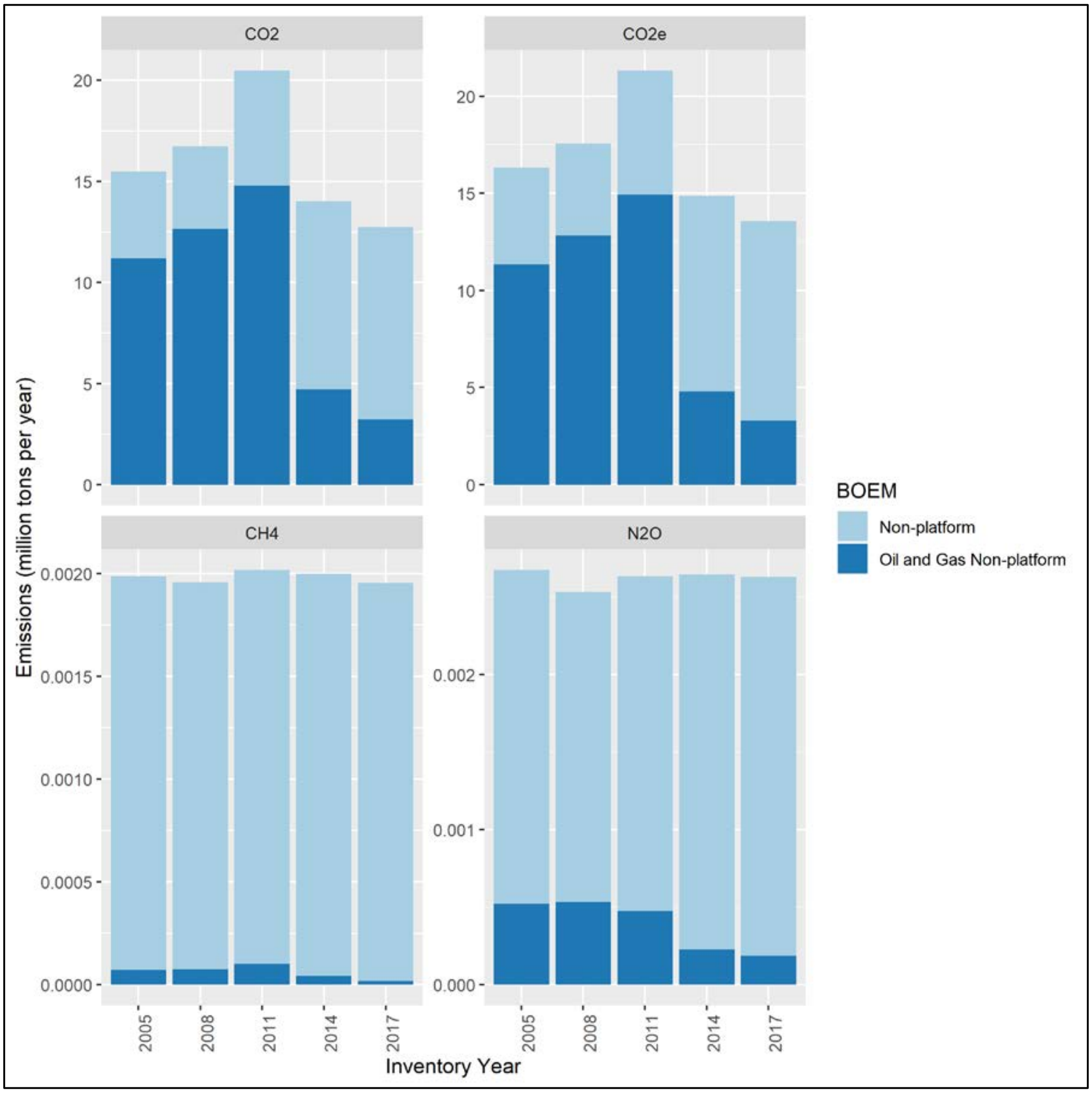


Figure 7-24. Contribution to Total Non-platform GHG Emissions Estimates for Sources Related to Oil and Gas Production

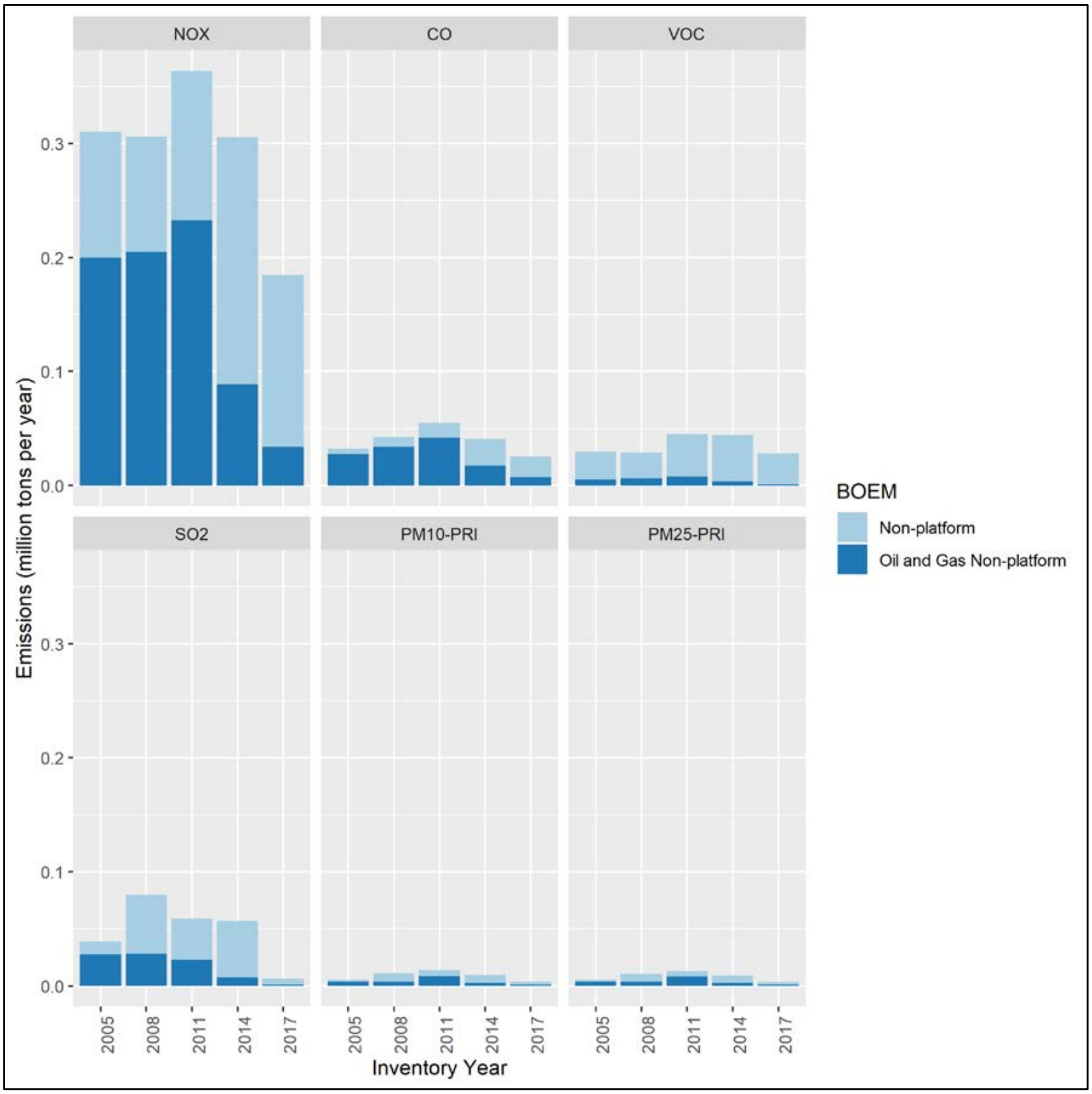


Figure 7-25. Contribution to Total Non-platform Criteria Pollutant Emissions Estimates for Sources Related to Oil and Gas Production

The spatial distribution of non-platform oil and gas production-related emissions has evolved to become more refined over time as the use of GPS location data have become more prevalent. Figure 7-26 shows the spatial evolution of non-platform production emissions estimates across the inventories. The images for each inventory year suggest traffic patterns that correlate to the routes linked to major ports along the Gulf Coast to production platforms. In progressive inventories, these traffic patterns become more refined, and, starting in 2014, traffic patterns correspond to common vessel corridors due to GPS-derived position data.

There are several hotspots corresponding to activity surrounding platforms and at pipeline segments, where construction or maintenance activities were implemented. Again, these placements become more refined starting in 2014. This enhanced placement leads to less generalized Gulfwide estimates (i.e., broad areas of less than 2 tpy [dark green]) and emission estimates directly corresponding to actual vessel traffic patterns. The spatial plots for the other pollutants are similar to the NO_x spatial plots.

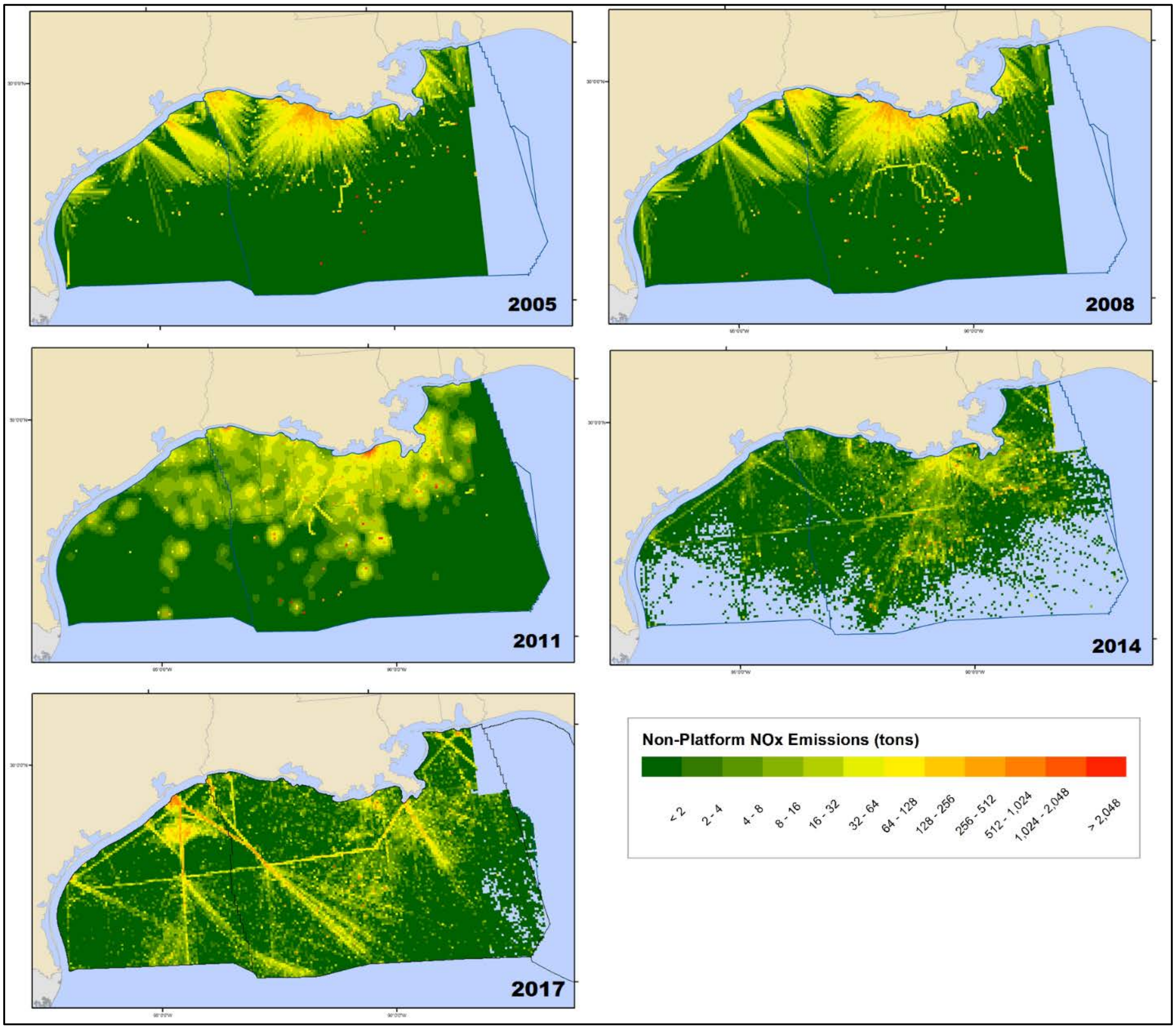


Figure 7-26. Non-platform NO_x Emissions

7.4.1 Greenhouse Gases

Since 2005, CH_4 and CO_2 emissions estimates have increased and decreased consistently. As shown in Figure C-27, constant levels in N_2O are seen across the 2005, 2008, and 2011 inventories. Values dropped significantly for 2014, which is correlated with the decrease in activity as AIS allowed for better vessel classification and improved vessel count and characteristics data. The 2017 inventory was at a consistent level to the 2014 inventory.

Looking by source category (Figure 7-28), support vessels are the largest contributor to the three major GHGs. For all non-platform sources, the updated emission factors and activity data yield an overall increase in GHG emissions between 2005 and 2008. All non-platform sources had higher GHG emissions estimates in 2008 than in 2005, except for support vessels, which is indicative of an increase in activity in 2008.

In 2011, the emission factors for vessels were updated to account for replacement of older vessels with newer vessels equipped with cleaner burning and more efficient engines and implementation of new engine and fuel standards. Similarly, helicopter emission factors obtained from FOCA's Guidance on Determination of Helicopter Emissions were revised to be more reflective of the longer landing and takeoff (LTO) cycles in the Gulf. These emission factor updates, along with increased activity, yielded an overall increase in GHG emissions for 2011.

Helicopters saw an increase in CH_4 and N_2O emissions estimates in 2011 and 2014 because more detailed emission factors allowed for better differentiation between medium- and heavy-duty twin-engine helicopters. The number dropped off again in 2017 due to a methodology change; instead of assuming all helicopter trips reported to the HSAC operate in Federal waters, FAA NextGen data were used that showed the actual location of helicopter traffic, noting a larger number of helicopter trips in state waters. This quantified a significant reduction in helicopter emissions in Federal waters.

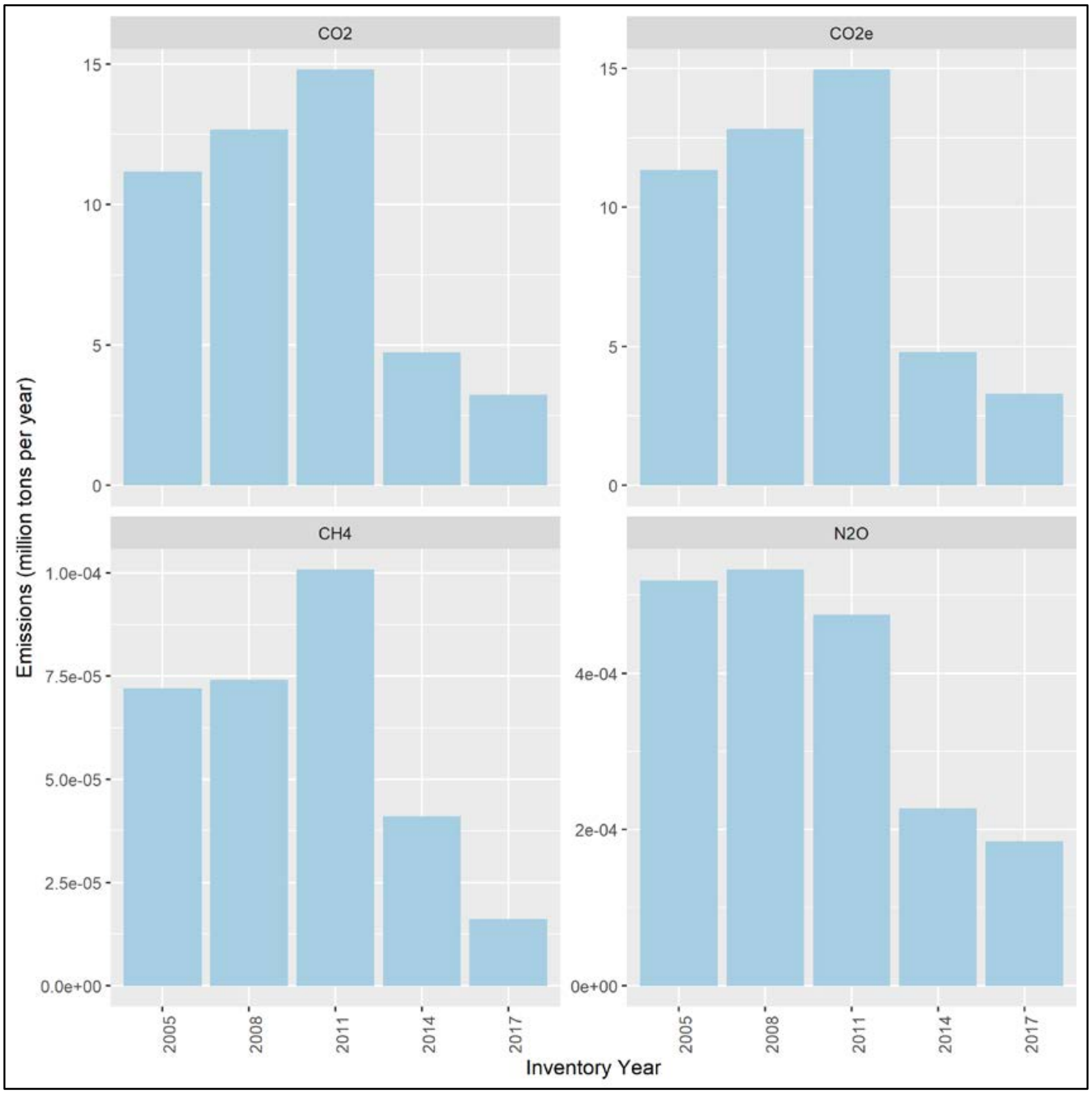


Figure 7-27. GHG Emissions Estimates for Oil and Gas Non-platform Sources Related to Oil and Gas Production

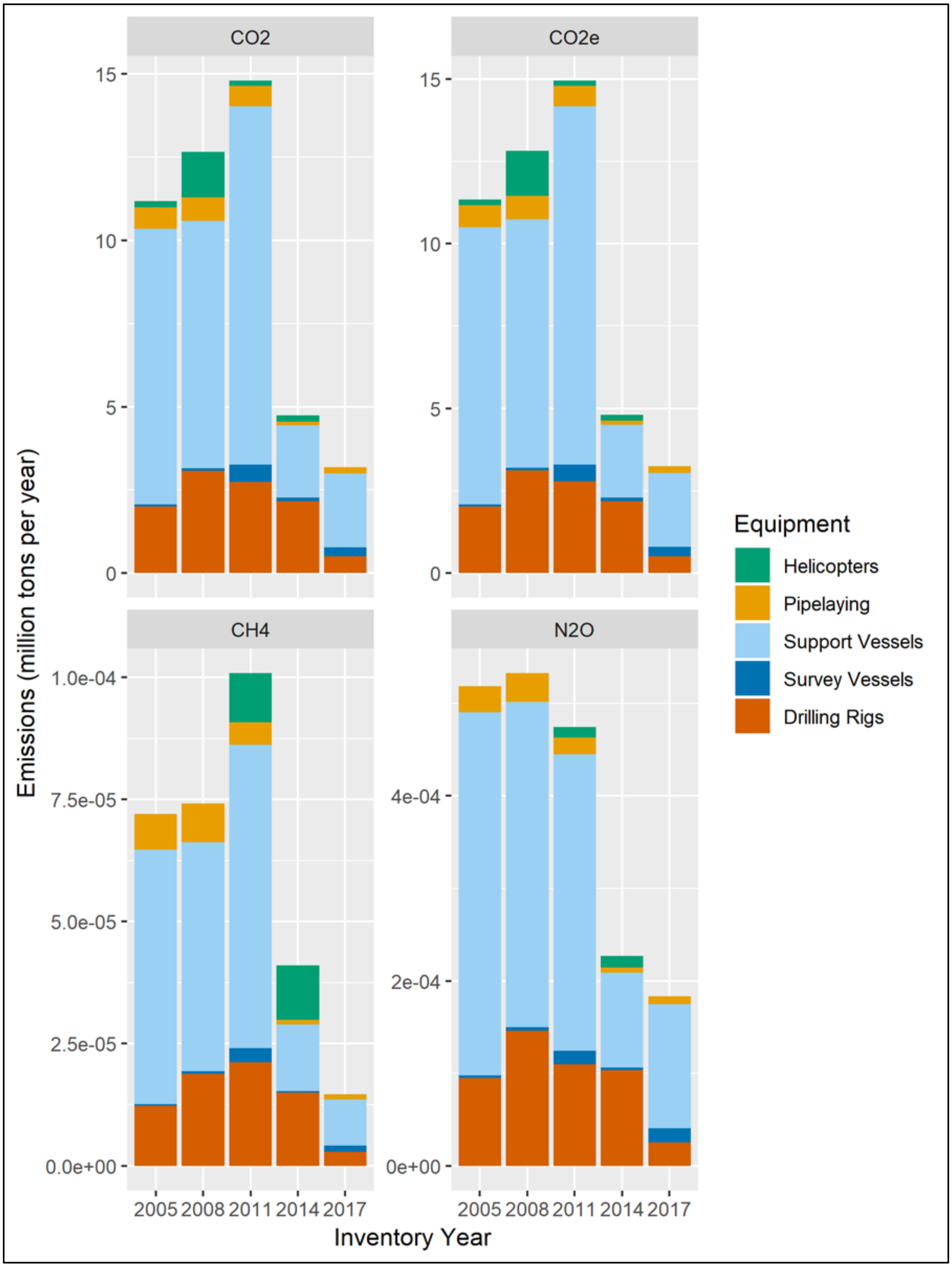


Figure 7-28. Non-platform GHG Emissions Estimates by Source Category

7.4.2 Criteria Pollutants

A review of the non-platform production-related total emissions of each criteria pollutant (Figure 7-29) shows that the total emissions for each criteria pollutant held fairly constant between 2005 and 2008. Most pollutants reached peak levels in the 2011 inventory, except for SO_2. The SO_2 emission estimates started to decline in 2011 and continued to decline for 2014 and 2017. This is primarily due to the requirement that vessels equipped with Category 1 and 2 engines (C1 and C2), which is most of the GOM oil and gas vessel fleet, use ultra-low sulfur diesel (reduced from 500 ppm to 15 ppm), and larger vessels equipped with larger, Category 3 (C3) engines use fuels that meet North American Emission Control Area (ECA) fuel sulfur standards (reduced from 50,000 ppm to 10,000 ppm). The breakdown of emissions by source category supports this reasoning, as the drop in total SO_2 emissions coincides with the significant drop in SO_2 emissions from support vessels (Figure 7-30).

The increased CO, NO_x, PM, and VOC estimates for 2011 are primarily due to the use of updated USEPA emission factors. Most notable in Figure C-29 is the increase in drilling emissions from 2008. This occurred despite a reduction in drilling activity (2008 had 39,805 days of drilling, while 2011 had 19,863 days of drilling). The drilling rig emission factors were revised significantly for the 2011 inventory, leading to the higher emission estimates despite reduced activity.

The decline following 2011 for criteria pollutants other than SO_2 is likely due to decreased activity and more detailed data for vessels and better quantification of their operations in later inventory years.

Looking at the various source categories for the other criteria pollutants (Figure 7-30), support vessels are typically the largest contributor to emissions; the exception is VOCs, where helicopters are often the largest contributor. This is due to the VOC content of jet fuel used in helicopters versus the residual-blend diesel fuel used in marine vessels. The helicopter emission factors were revised in 2008, 2011, and 2014 and are higher than the previous factors for CO, VOC, and CO_2. They were also higher for NO_x and SO_2 for single engine helicopters, but lower for light- and medium-duty helicopters. Similar to the GHG emissions, helicopter emissions dropped off in the 2017 inventory related to the use of more accurate FAA helicopter NextGen data.

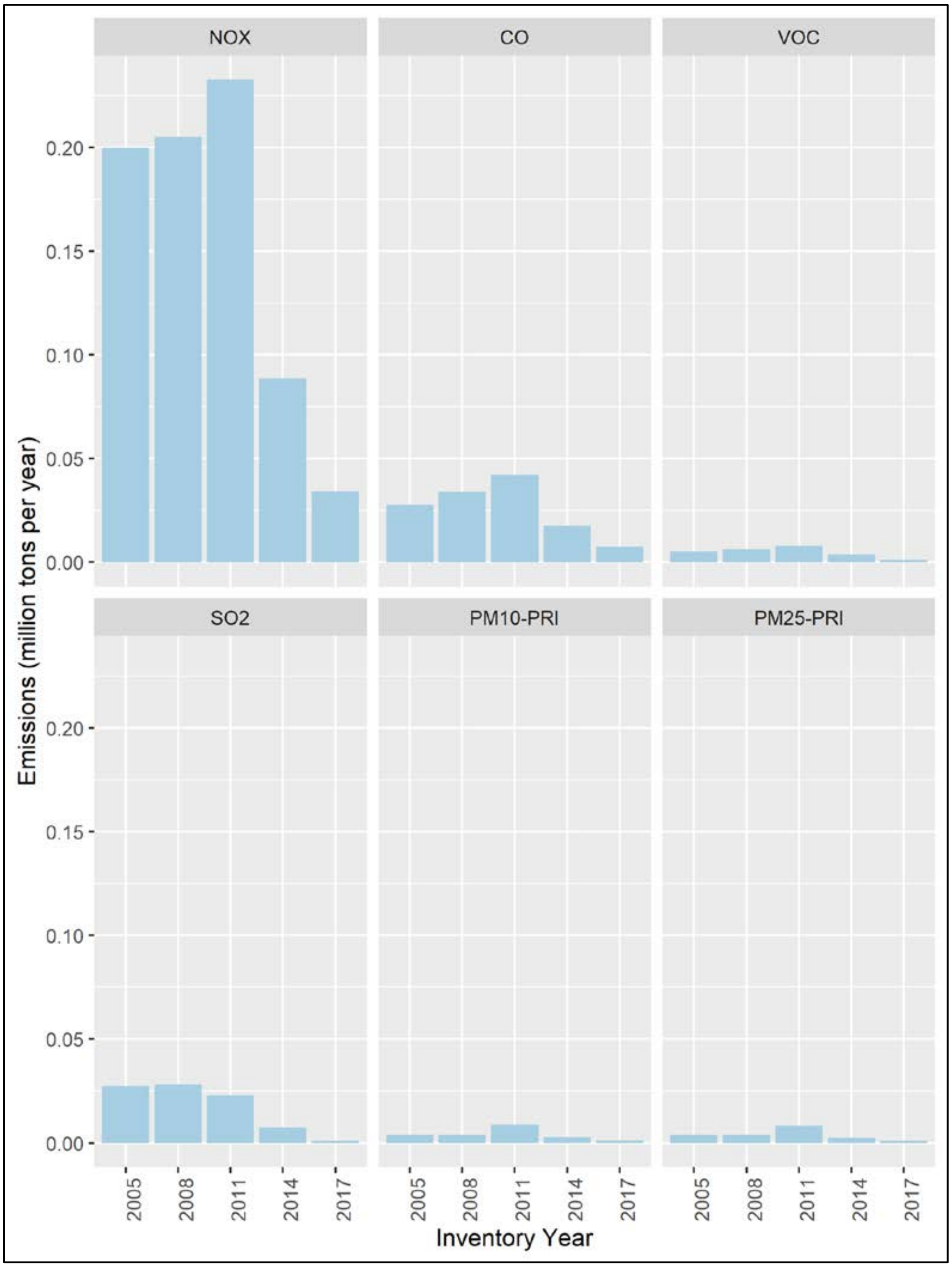


Figure 7-29. Oil and Gas Non-platform Criteria Pollutant Emissions Estimates by Year

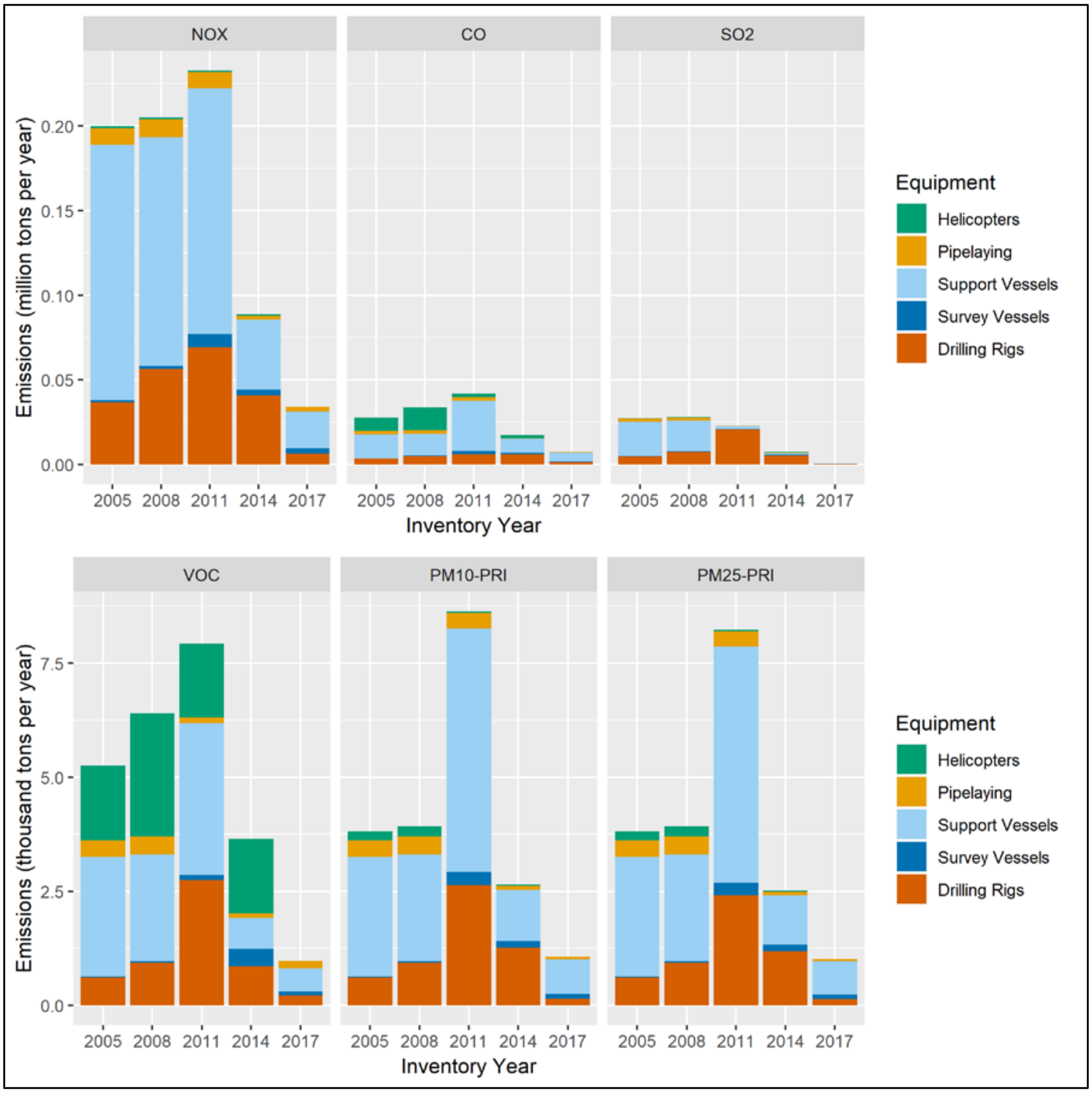


Figure 7-30. BOEM Non-platform Criteria Pollutant Emissions Estimates by Source Category

7.5 Overall Emissions Trends

Sections 7.3 and 7.4 discussed the emission trends in the platform and non-platform production-related data, respectively. The overall emissions data warrants additional review to determine if there are factors other than activity and calculation method changes that might affect emissions trends. This section compares the platform and non-platform inventories, and their contributions to overall emissions levels. A discussion of other factors with an effect on emissions trends follows.

Looking at the contribution of platforms and non-platform sources to the total GHG emissions, platform and non-platform sources roughly contribute equally to CO_2 emissions (Figure 7-31, top left). Non-platform sources contribute more to N_2O emissions (Figure 7-31, top right), and almost all CH_4 emissions are from platform sources (Figure 7-31, bottom left). Because of the higher GWP for N_2O, non-platform sources contribute more to the overall CO_2e emissions (Figure 7-31, bottom right, recalculated with AR4 GWPs).

Looking at overall trends in the criteria pollutant emission estimates (Figure 7-32), the non-platform sources contribute the most to NO_x, SO_2, and PM emissions across all inventory years. Platform sources contribute more to the overall CO and VOC emission estimates.

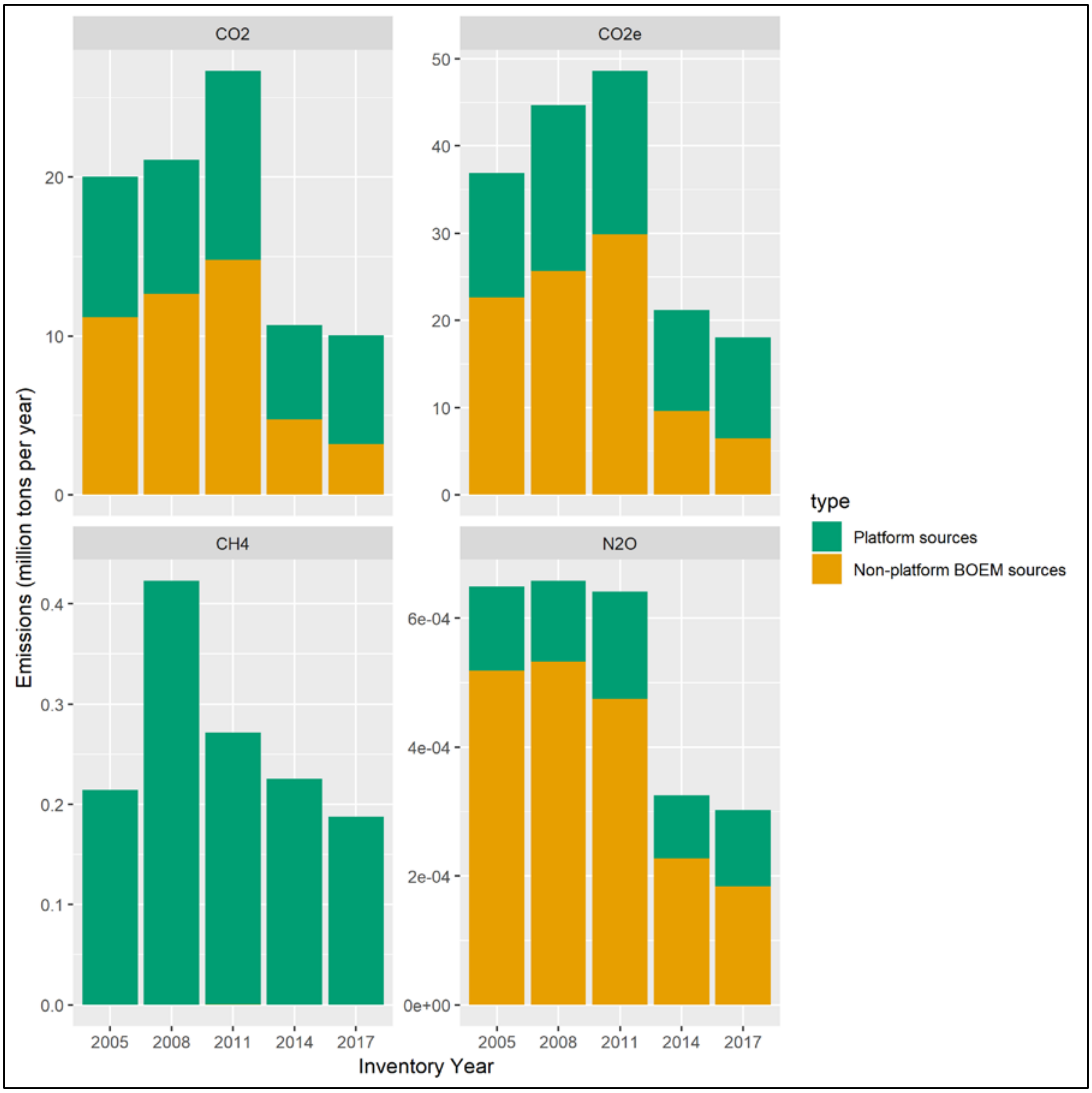


Figure 7-31. Total GHG Emissions by Inventory Category

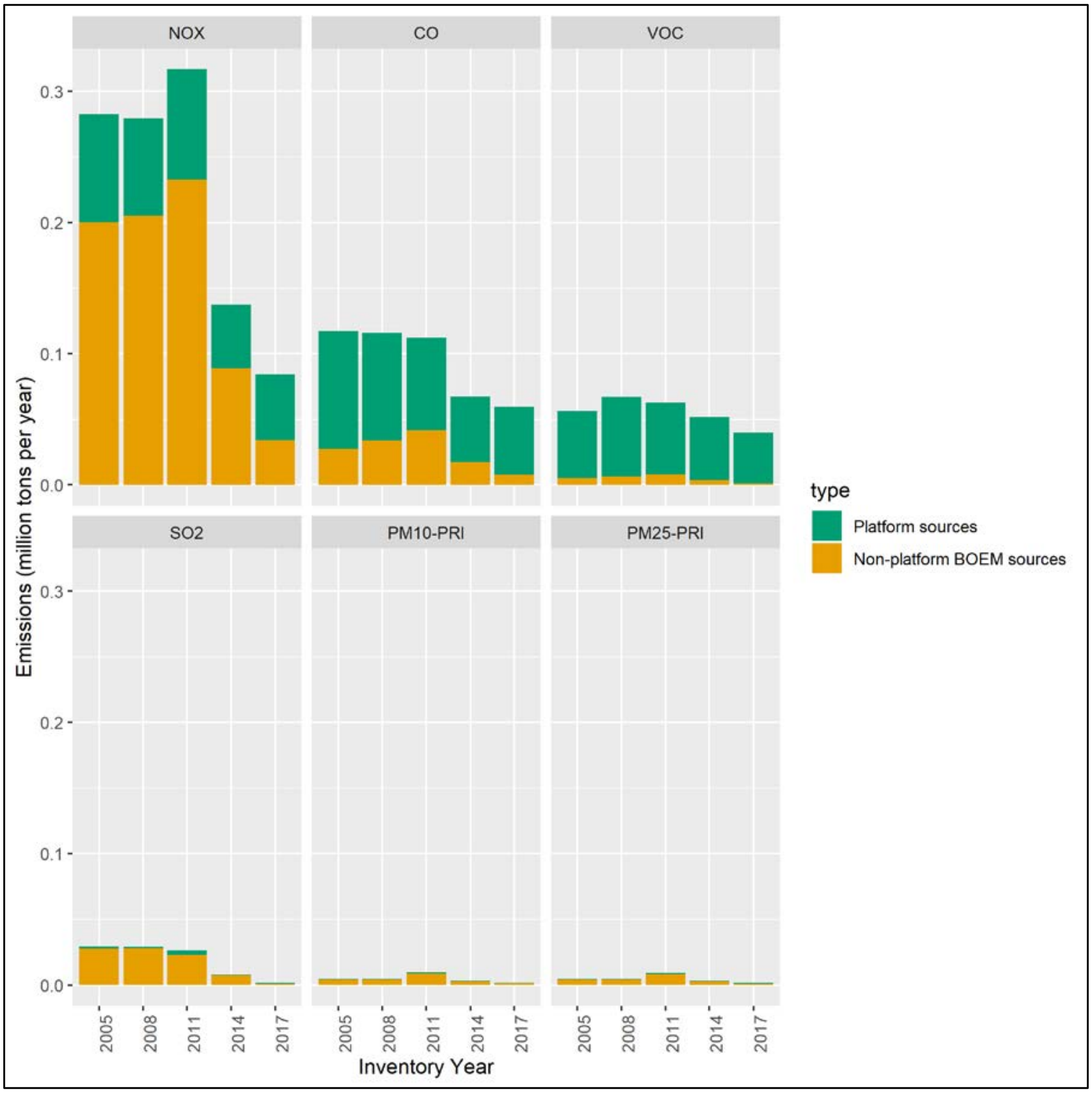


Figure 7-32. Total Criteria Pollutant Emissions Estimates by Inventory Type

7.5.1 Production Trends

Entering this analysis, an assumption to be tested was that total production of oil and gas would trend with emissions, as the amount produced would impact the activity data and in turn affect the emissions. Therefore, determining causes of variability in the production levels and their spatial distribution should provide insight into the variability of emission values.

Annual total oil (in million barrels) and natural gas (in billion cubic feet) production data since 2000 were obtained from the BOEM website (USDOI, BOEM 2019a). Total oil production has oscillated over the emission inventory years (Figure 7-33). The 2014 and 2017 inventory years represent years with increasing oil production, compared to the previous year. 2008 and 2011 are years with decreasing production trends for oil. Natural gas production has been steadily decreasing since 2000. 2014 production levels of natural gas were less than half the levels seen in 2005, with 2017 levels falling to almost a third of 2005 production levels. The following section attempts to explain these overall trends and assess if there is in fact a relationship between activity and emissions.

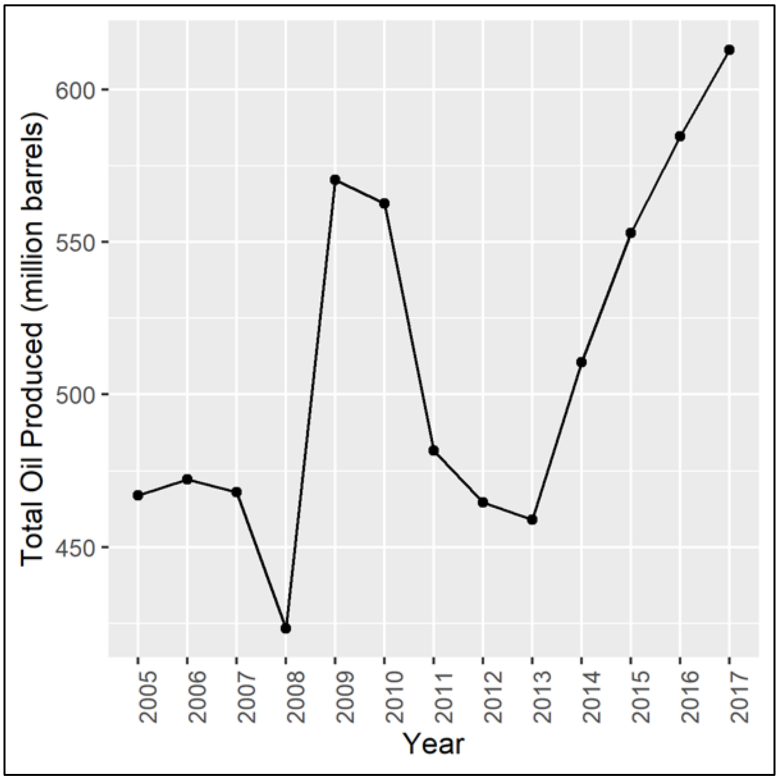


Figure 7-33. Total Annual Oil Production for the GOM

7.5.2 Tropical Activity

To explain the decreases in production in 2005 and 2008, monthly oil production trends were examined (Figure 7-34). This revealed sharp dips in production levels in September 2005 and September 2008. Both 2005 and 2008 were active years for tropical storm activity, with noteworthy systems passing through the GOM in September of each year.

2005 was a record-breaking hurricane season in the GOM (CPC, 2016), with a record number of tropical storms and hurricanes. There was also a record four Category 5 hurricanes that year: Dennis, Emily, Katrina, and Maria. Tropical storm Arlene and hurricanes Cindy, Dennis, Katrina, and Rita cut through the heart of the GOM in 2005 (Figure 7-35). Two of these hurricanes, Katrina and Rita, crossed the Gulf in late August through mid-September, which likely caused the decrease in production. Hurricane Katrina moved through major production areas in late August (August 26–29), reaching Category 5 strength during a significant portion of its transit of the Gulf. Katrina was quickly followed by Rita in mid-September (approximately September 20–24). Rita was another major hurricane that peaked at a Category 5, although it was a Category 3 or 4 for most of the transect through the oil producing region of the Gulf. The precautions taken in advance of these two hurricanes explain the rapid drop in production in September 2005. The reduced production in the following months is likely due to numerous platforms being damaged in the wake of the storms. In total 144 platforms were destroyed or damaged by these hurricanes in 2005. Production would have slowly ramped up through the end of the year as repairs were made to platform and pipelines.

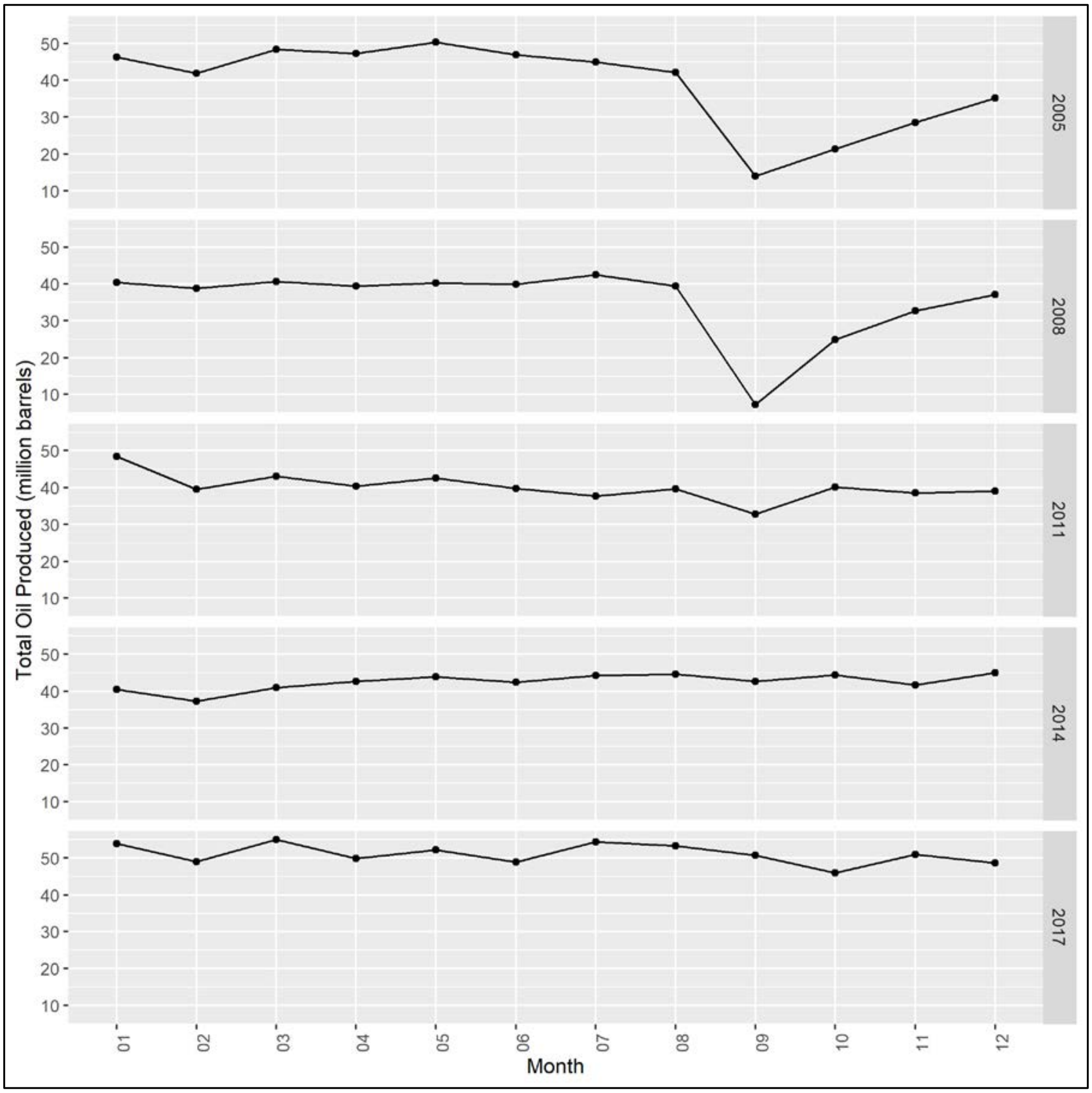


Figure 7-34. Total Monthly Oil Production for Inventory Years

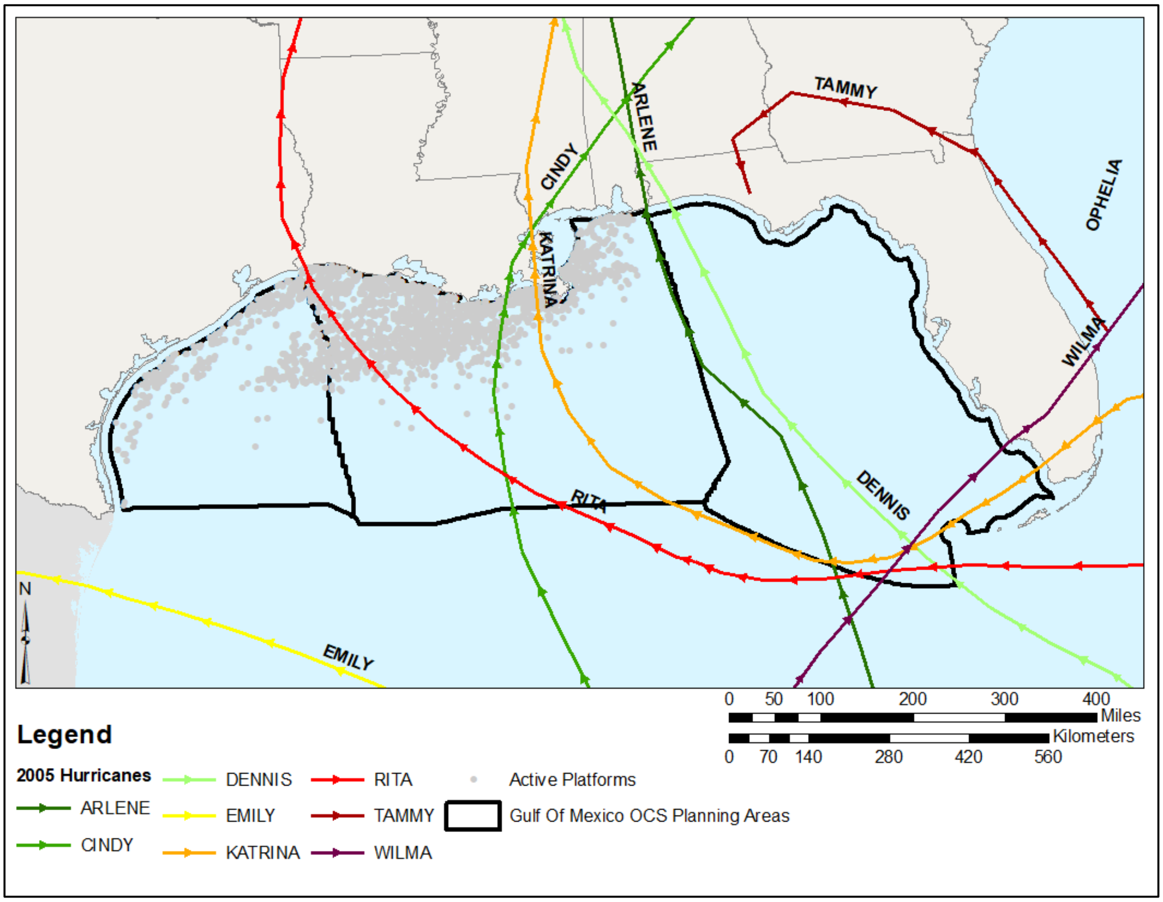


Figure 7-35. 2005 Hurricane Tracks with Active Platforms

2008 was another above average hurricane season (CPC, 2016) with three systems cutting through the GOM (Figure 7-36). The dip in production is likely due to two major hurricanes that crossed the Gulf in the late August to September timeframe. The first hurricane, Gustav, swept through the Gulf from August 31–September 1. Gustav was a Category 3 or below for most of the track through the Gulf. Gustav was promptly followed by Hurricane Ike (September 10–13). Hurricane Ike maintained Category 2 levels through the oil production regions of the Gulf. Similar to 2005, the precautions taken in advance of these two hurricanes explains the rapid drop in production in September seen in Figure 7-34. The reduced production in the following months is likely due to platforms being damaged in the wake of the storms. In total, 11 platforms were destroyed or damaged by these hurricanes. The reduced number of damaged and destroyed platforms would explain the larger increase in production in October than seen in 2005.

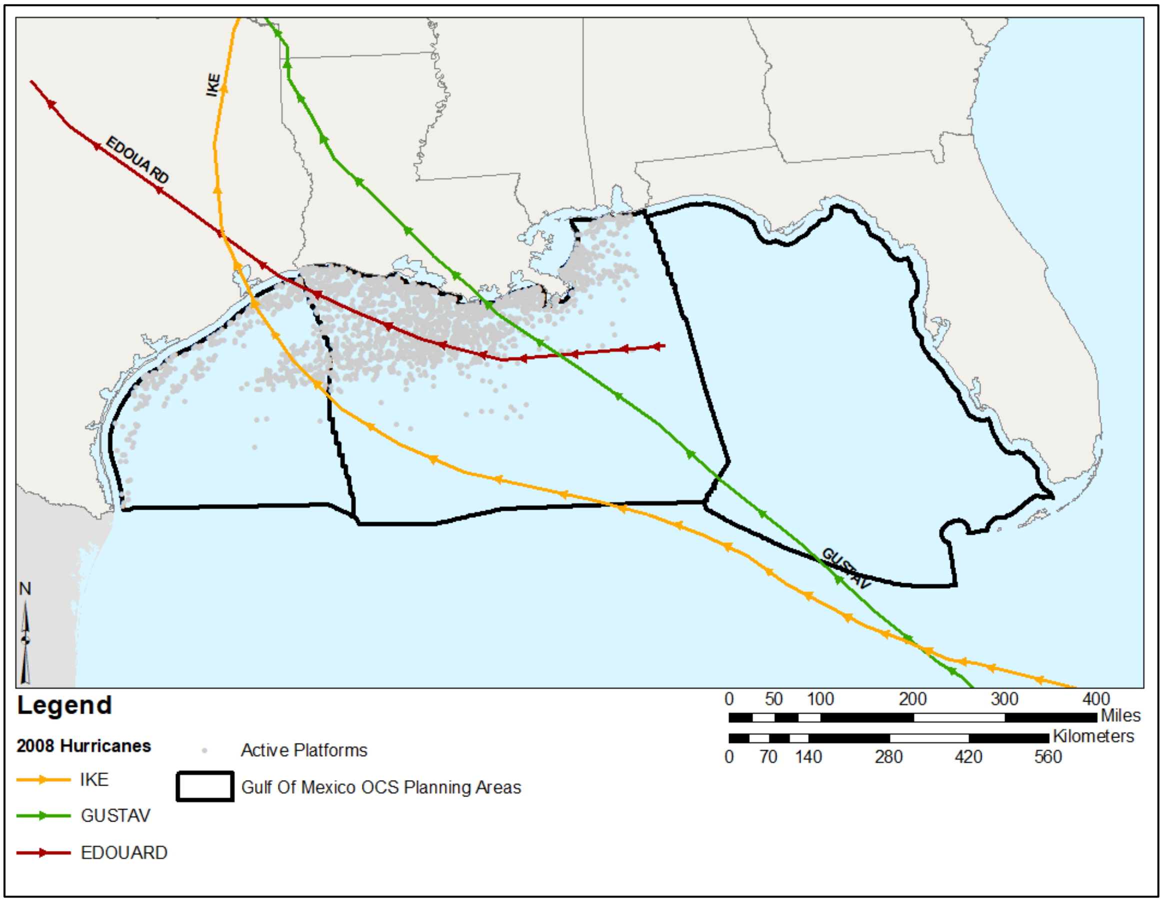


Figure 7-36. 2008 Hurricane Tracks with Active Platforms

In 2011, there were two tropical storms, Don (July 27–30) and Lee (September 2–6), that cut through the GOM Region (GOMR) planning areas. The 2014 hurricane season saw no tropical activity in the BOEM GOMR and only two tropical storms on the Yucatan peninsula. For both years, the minimal tropical storm activity across the GOM contributed to the consistency in production in these years.

In 2017, tropical activity in the Gulf picked up, as two tropical storms and three hurricanes (Figure 7-37) passed through the region. The first hurricane to move through the Gulf was Hurricane Harvey (August 17–September 1), which entered the western Gulf as a Category 2 hurricane and reached Category 4 status prior to landfall. Hurricane Irma (August 30–September 12) followed Harvey, entering the eastern GOM as a Category 4 storm before racing up the west coast of Florida. Toward the end of the hurricane season, Hurricane Nate (October 4–8) charged through the central Gulf as a Category 1 storm. Although Harvey brought staggering rainfall to the Houston area and Irma brought prolific damage to the Caribbean and Florida Coast, there was minimal disruption to total production for September. This is likely due to both Harvey and Irma cutting through the Gulf in areas with few active platforms. There was a slight dip in production in October as Nate cut through the central Gulf. However, it was low intensity and quick transit only caused a minimal disruption.

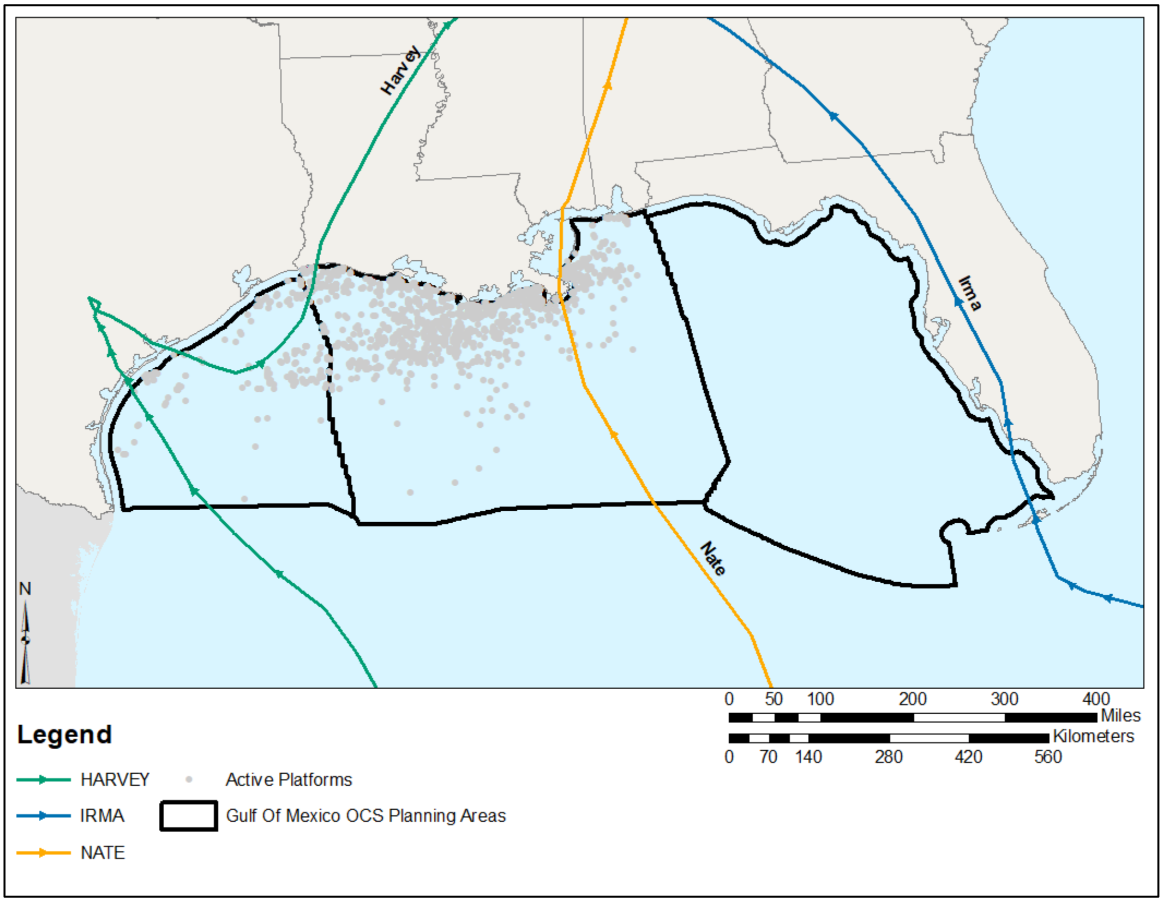


Figure 7-37. 2017 Hurricane Tracks with Active Platforms

7.5.3 Oil and Natural Gas Production Versus Prices

Analysis shows that the production of oil in the GOM has been inversely proportional to the price of oil since 2000. Figure 7-37 shows the annual average spot prices (EIA, 2019) per barrel lined up with the annual total oil production. Production reached a peak in 2002, when prices were near their lowest levels. As prices climbed through 2008, Gulf production decreased. The steepest drops were for 2005 and 2008, which corresponds to significant hurricane activity and increasing prices. Production rebounded to peak levels in 2009, while oil prices took a tumble. For 2010 through 2013 prices climbed while production fell in the GOM. 2014 proved to be an inflection point where price was on par with 2011 values, but increased production was seen. Oil production climbed after 2014 as prices dropped and continued through 2017.

This trend was expected, as it follows economic principles and cycles typical of commodities. That is, as the commodity becomes scarce (e.g., low production due to hurricanes or other factors) the price will increase. With increasing prices, production will often start to increase (when possible) to take advantage of the high prices for profit. As production increases, the price will start to fall again later leading to decrease production. Despite this strong correlation, previous efforts have found that the price of oil and gas during inventory periods are not good predictors of emissions.

Natural gas production (USDOI, BOEM, 2019a) in the Gulf has been on a steady decline since 2000 (Figure 7-38). Prices of natural gas have fluctuated through this period but seem to have no correlation to production levels. Previous trends efforts corroborated that natural gas prices are not a good predictor for emissions.

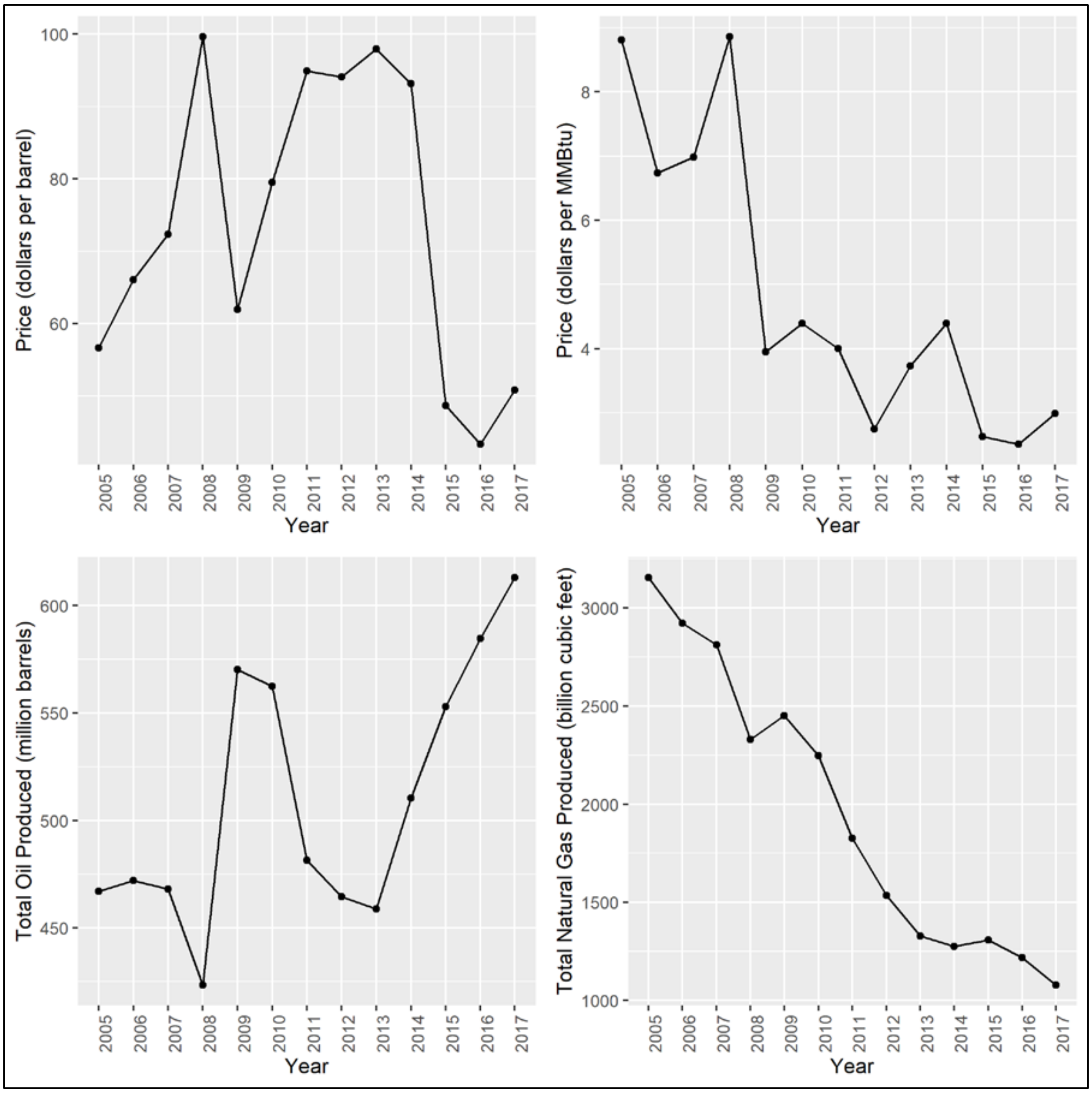


Figure 7-38. Average Production of Oil (Left) and Natural Gas (Right)

7.5.4 Spatial Distribution of Production

The spatial distribution of oil (Figure 7-39) and natural gas (Figure 7-40) production (USDOI, BOEM, 2019b) follows a similar spatial pattern to platform locations shown in Figure 7-12—that is, a general southern expansion into deeper waters with a declining trend in shallow water platforms in the Western Planning Area. When compared to the spatial pattern of platform NO_x emissions shown in Figure 7-13, the highest emissions coincide with the highest production areas. These higher emissions and higher production areas generally correspond to the newer platforms on the leading southern edge of active platforms. Looking at oil production in million barrels (Figure 7-41) and natural gas production (Figure 7-42) in billion cubic feet (BCF) further confirms this trend of increasing production at greater depths and a decrease in production at platforms in shallower depths. Of note is the steep increase in oil production in areas with depths greater than 800 m (Figure 7-40).

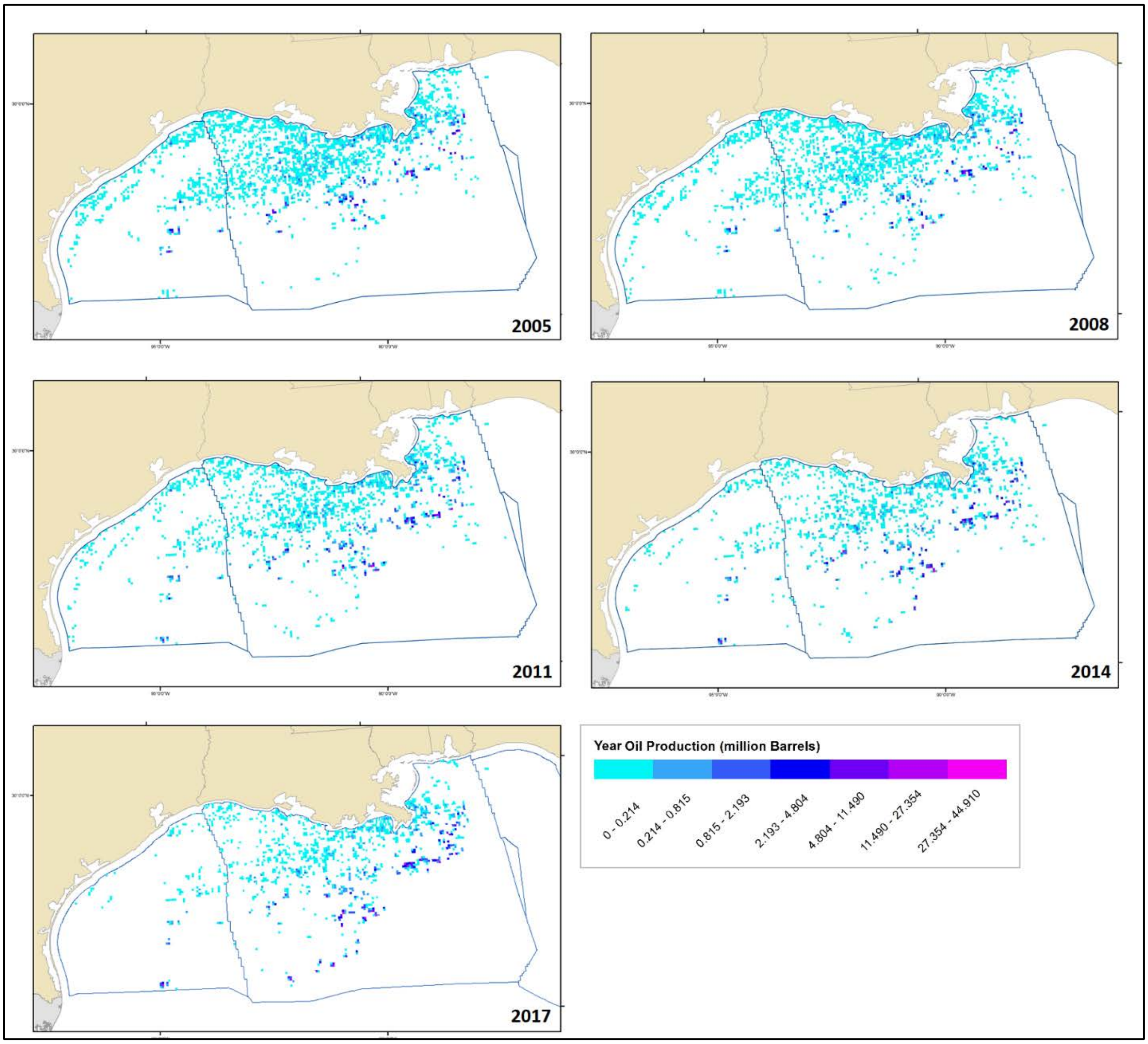


Figure 7-39. Spatial Distribution of Oil Production (in million barrels) for the Inventory Years

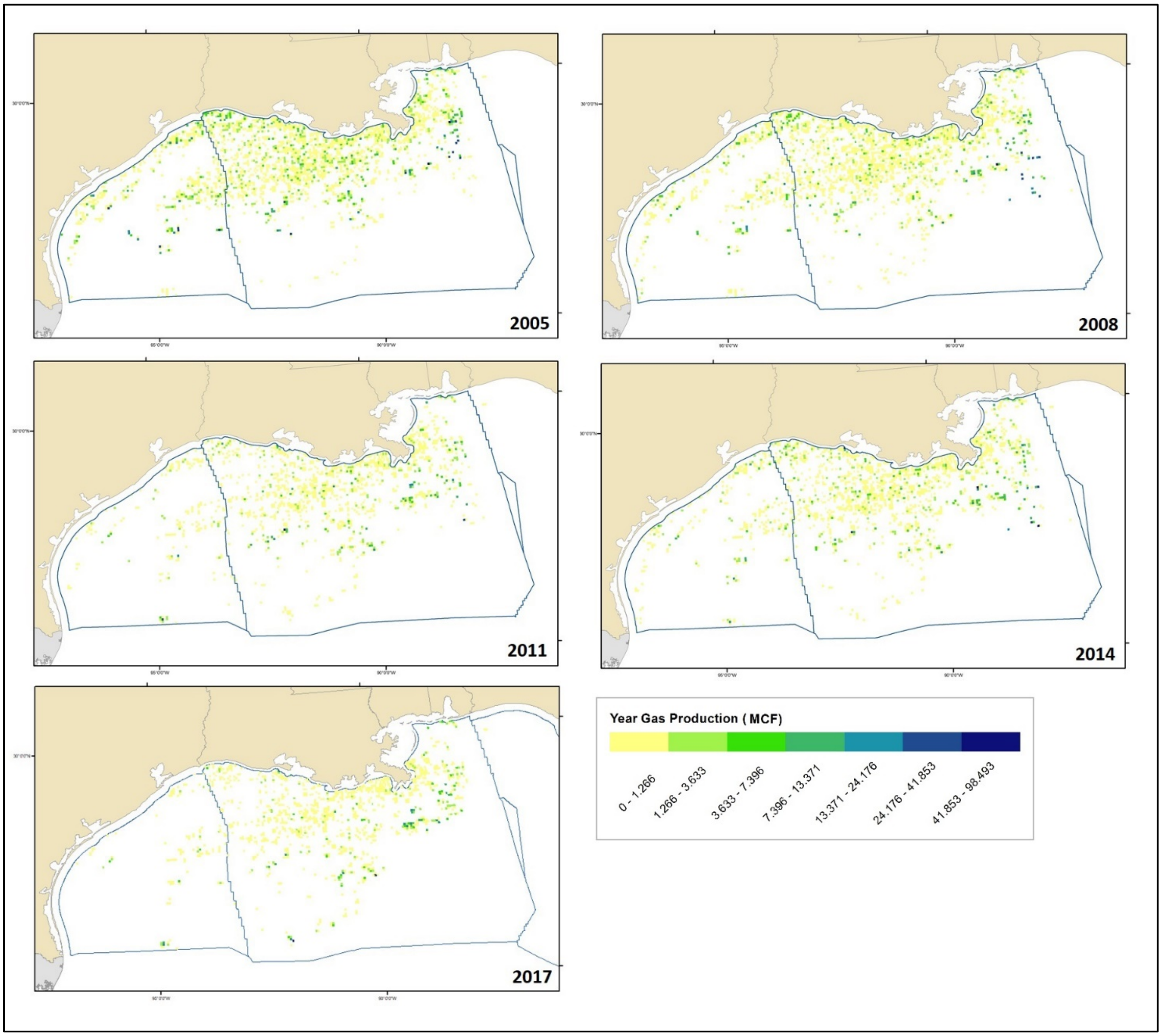


Figure 7-40. Spatial Distribution of Natural Gas Production (in BCF) for the Inventory Years

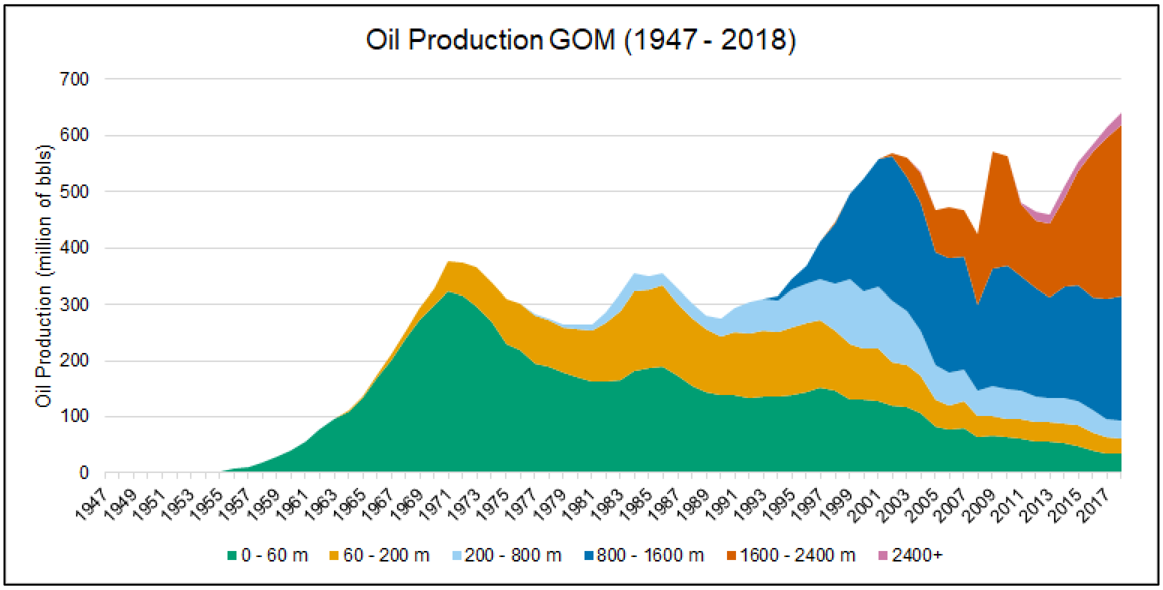


Figure 7-41. Oil Production by Water Depth

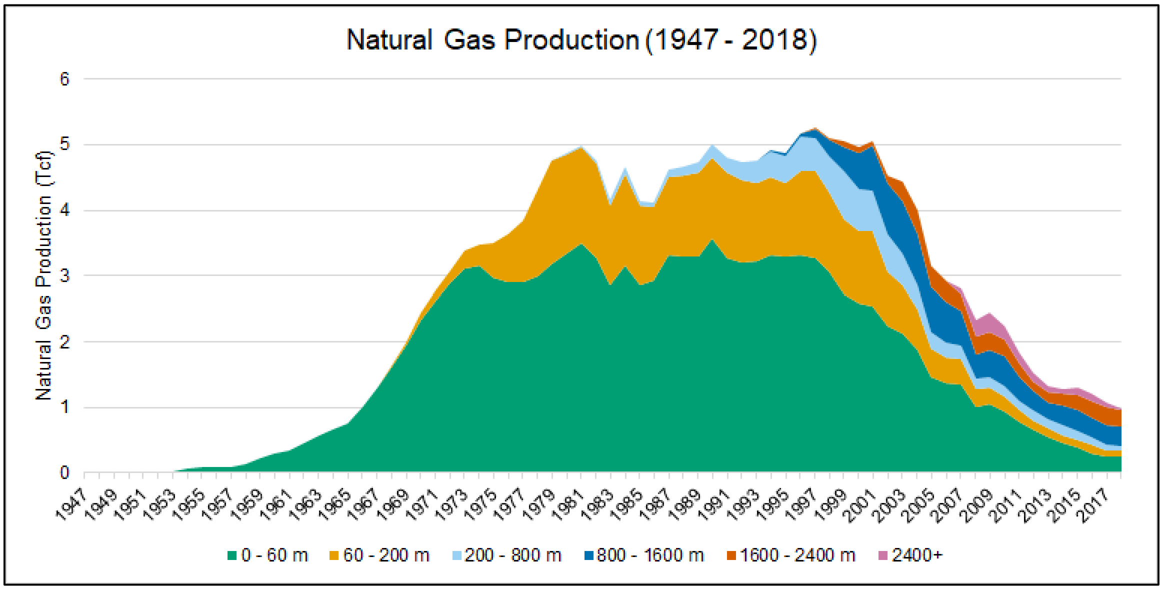


Figure 7-42. Natural Gas Production by Water Depth

8 References

API. 1993. Fugitive hydrocarbon emissions from oil and gas production operations. Health and Environmental Sciences Department, American Petroleum Institute (API) Publication Number 4589.

API. 1996. Calculation workbook for oil and gas production equipment fugitive emissions. Health and Environmental Sciences Department. American Petroleum Institute (API) Publication Number 4638.

API. 1999. AMINECalc software program, version 1.0. Amine unit air emissions model. American Petroleum Institute (API) Publication Number 4679.

Babin BL, Rabalais NN. 2009. Trends in oxygen variability in the northern Gulf of Mexico hypoxic zone. [accessed 2009 Aug 14]. https://www.researchgate.net/publication/251920174_Trends_in_oxygen_variability_in_the_northern_Gulf_of_Mexico_hypoxic_zone)

Billings R, Wilson D. 2004. Data quality control and emissions inventories of OCS oil and gas production activities in the Breton area of the Gulf of Mexico: final report. New Orleans (LA): U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region. OCS Study MMS 2004-071.

Bouwman AF, VanderHoek KW, Oliver JG. 1995. Uncertainties in the global source distribution of nitrous oxide. Journal of Geophysical Research 100(D2): 2785-2800.

Boyer B, Brodnax DK. 1996. Emission estimation methods for oil and gas operations. In: The emission inventory: key to planning, permits, compliance, and reporting. Air and Waste Management Association Specialty Conference; 1996 Oct 4–6, New Orleans, LA.

Brinkman R. 2002. Telephone conversation with Jaime Hauser, Eastern Research Group, Inc. U.S. Department of Interior, Minerals Management Service, Gulf of Mexico OCS Region.

[CARB] California Air Resource Board. 1993. Emission inventory methods, area sources; Section 9.2, Geogenic sources-petroleum seeps. Sacramento (CA): California Air Resources Board.

Climate Prediction Center (CPC). 2016. Atlantic Hurricane Outlook and Summary Archive. [accessed 2016 Aug 01]. http://www.cpc.ncep.noaa.gov/products/outlooks/hurricane-archive.shtml.

ClipperData. 2018. A sneak peek at ClipperView. [accessed 2018 Jun 08]. http://blog.clipperdata.com/sneak-peak-at-clipperview

Dimitrov LI. 2003. Mud volcanoes–a significant source of atmospheric methane. Geo-Marine Letters. 23:155–161.

Dobbins-Noble L. 2017. Atlantic Fleet Training and Testing (AFTT) EIS/OEIS air quality data for the Gulf of Mexico, email to Richard Billings from the U.S. Navy NAVFAC LANT. September 21, 2017.

Dudley J. 2018. Commercial fishing–request for information. Email to Jennifer Sellers, Eastern Research Group, Inc., from the National Oceanic & Atmospheric Administration.

Earth Institute at Columbia University. 2016. In Gulf of Mexico, microbes thrive above natural oil seeps: new insight into how plankton and oil interaction. ScienceDaily. January 25, 2016.

[EIA] U.S. Energy Information Administration. 2012. Voluntary reporting of Greenhouse Gases Program Fuel Emission Coefficients. [accessed 2016 Jul 11].and http://www.eia.gov/oiaf/1605/coefficients.html#tbl7

EIA. U.S. Gulf Coast Port limitations impose additional costs on rising U.S. crude oil exports, May 16, 2018. [accessed 2019 Jun 25]. https://www.eia.gov/todayinenergy/detail.php?id=36232

[EIIP] Emission Inventory Improvement Program. 1999. Preferred and alternative methods for estimating air emissions from oil and gas field production and processing operations; Volume II: Point sources; Chapter 10: Oil and gas field production and processing operations. [accessed 2019 Jun 25]. https://www.epa.gov/sites/production/files/2015-08/documents/ii10.pdf

[ERG] Eastern Research Group, Inc. 2017. Memorandum from Mike Pring and Regi Oommen, ERG, to Jennifer Snyder, EPA. "Summary of Revisions to the Nonpoint Oil and Gas Emissions Estimation Tool - 2014 NEI Version 2." February 9, 2017.

Federal Register. 2009. U.S. Environmental Protection Agency (USEPA) Final Mandatory Reporting of Greenhouse Gases Rule. CFR reference: Table A-1 to Subpart A of Part 98—Global Warming Potentials, 40 CFR §98 Subpart A. [accessed 2018 May 18]. https://www.ecfr.gov/cgi-bin/text-idx?SID=48e9ad376f3fdc25589d85120f877405&mc=true&node=ap40.23.98_19.1&rgn=div9

Fielden S. 2018. The future of LLS- Louisiana benchmark should move to Gulf Coast LOOP. [accessed 2019 Jun 25]. http://research-reports.morningstarcommodity.com/reportpdf/the-future-of-lls-FINAL.pdf

[FOCA] Federal Office of Civil Aviation (Switzerland). 2015. Guidance on the determination of helicopter emissions. Edition 1. Reference: 0 / 3/33/33-05-20. [accessed 2017 Aug]. http://www.bazl.admin.ch/experten/regulation/03312/03419/03532/index.html?lang=en

Gabric A, Murray N, Stone L, Kohl M. 1993. Modelling the production of dimethylsulfide during a phytoplankton bloom. Journal of Geophysical Research, 98(C12): 22,805–22,816.

[GTI] Gas Technology Institute. 2000. GRI-GLYCalc, version 4.0. Chicago (IL): GTI-00/0102. [accessed 2018 Sep 18]. http://www.gastechnology.org

Hart R. 2018. Shrimp vessel information request. Email to Jennifer Sellers, Eastern Research Group, Inc., from the National Oceanic & Atmospheric Administration.

[HSAC] Helicopter Safety Advisory Conference. 2006. Gulf of Mexico offshore helicopter operations and safety review. [accessed 2006 Mar]. http://www.hsac.org/stats.html.

HSAC. 2009. Gulf of Mexico offshore helicopter operations and safety review. [accessed 2009 Apr]. http://www.hsac.org.

HSAC. 2012. Gulf of Mexico offshore helicopter operations and safety review. [accessed 2012 Jun]. http://www.hsac.org.

HSAC. 2014. Gulf of Mexico offshore helicopter operations and safety review. [accessed 2014 Oct]. http://www.hsac.org.

HSAC. 2018. 2017 Gulf of Mexico (GoM) offshore helicopter operations and safety review. Lafayette, LA. [accessed 2019 Jun 25]. http://www.hsac.org/siteDocs/Library/Statistics/HSAC%202017%20Statistics.pdf

[IHS] Information Handling Services. 2015. Register of ships, 2014. [accessed 2015 Mar]. http://www.ihs.com/products/maritime-information/ships/register.aspx

[IPCC] Intergovernmental Panel on Climate Change. 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change. Core writing team, R.K. Pachauri and L.A. Meyer (Eds.) IPCC, Geneva, Switzerland, 151 pp. [accessed 2019 Sep 11]. https://www.ipcc.ch/report/ar5/syr/.

IPCC. 2007. Fourth Assessment Report: Climate Change 2007. Contribution of working groups I, II and III to the fourth assessment report of the Intergovernmental Panel on Climate Change. Core writing team, Pachauri, R.K. and Reisinger, A. (Eds.) IPCC, Geneva, Switzerland. pp 104. [accessed 2016 May 27]. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html.

[ITOPF] International Tanker Owners Pollution Federation. 2017. Weathering. [accessed 2017 Jan 9]. http://www.itopf.com/knowledge-resources/documents-guides/fate-of-oil-spills/weathering/

Joye, S. 2015. Deepwater Horizon, 5 years on. Science. 349(6248):592–593.

Kim IN, Lee K, Bange HW, Macdonald AM. 2013. Interannual variation in summer N_2O concentration in the hypoxic region of the northern Gulf of Mexico, 1985–2007. Biogeosciences. 10: 6783-6792.

Kohl B. Roberts HH. 1994. Fossil foraminifer from four active mud volcanoes in the Gulf of Mexico. Geo-Marine Letters. 14(2):126–134.

Larkin N. 2018. Reef fish vessel information request. Email to Jennifer Sellers, Eastern Research Group, Inc., from the National Oceanic & Atmospheric Administration.

Maiello M. 2018. Non-confidential pelagic logbook set data request. Email to Jennifer Sellers, Eastern Research Group, Inc., from the National Oceanic & Atmospheric Administration.

MarineTraffic. 2018. Vessel movement status changes. [accessed 2018 Sep 09]. https://help.marinetraffic.com/hc/en-us/articles/204214918-Vessel-Movement-Status-Changes

Mathews J. 2018. 2017 Drill rig data. Email to R. Chang, Eastern Research Group, Inc., from the Department of Interior (DOI) Bureau of Safety and Environmental Enforcement (BSEE).

McDonald IR, Garcia-Pineda O, Beet A, Daneshgar-Asi S, Feng L, Graettinger G, French-McCay D, Holmes J, Hu C, Huffer F, Leifer I, Muller-Karger F, Solow A, Silva M, Swayze G. 2015. Natural and unnatural oil slicks in the Gulf of Mexico. Journal of Geophysical Research: Oceans. 120(12):8364–8380.

Mitchell R, MacDonald IR, Kvenvolden K. 1999. Estimates of total hydrocarbon seepage into the Gulf of Mexico based on satellite remote sensing images. Presented at the 2000 Ocean Sciences Meeting, American Geophysical Union. Paper OS411-02.

[NCDC] National Climatic Data Center. 2018. National Data Buoy Center, Western Gulf of Mexico Historical Marine Data. Stennis Space Center (MS): U.S. Department of Commerce, National Weather Service. [accessed 2018 May]. https://www.ndbc.noaa.gov/

[NOAA] National Oceanic and Atmospheric Administration. 2017a. Gulf of Mexico 'dead zone' is the largest ever measured. [accessed 2017 Aug 02]. http://www.noaa.gov/media-release/gulf-of-mexico-dead-zone-is-largest-ever-measured

NOAA. 2017b. Gulf of Mexico hypoxia watch. [accessed 2018 Aug 02]. https://www.ncddc.noaa.gov/hypoxia/products/

NOAA. 2018. Recreational fisheries statistics. [accessed 2018 May]. http://www.st.nmfs.noaa.gov/recreational-fisheries/index.

Nevison R, Weiss RF, Erickson DJ 3rd. 1995. Global oceanic emissions of nitrous oxide. Journal of Geophysical Research. 100(C8):15,809–15,820.

Nixon L, Kazanis E, Alanzo S. 2016. Deepwater Gulf of Mexico December 31, 2014. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study BOEM 2016-057.

[OSMA] Offshore Marine Service Association. 2006. *2005 Offshore Vessel Population and Activities.* Harahan, LA.

PortVision. 2018. 2017 AIS data set for central and western federal water areas. Houston, TX

RB Energy. 2017. We can work it out – moving Bakken and other US Crude on VLCC from the Gulf to Asia. [accessed 2017 May 16]. https://rbnenergy.com/we-can-work-it-out-moving-bakken-and-other-light-sweet-crude-from-the-gulf-to-asia https://www.iadd-intl.org/articles/we-can-work-it-out-moving-bakken-and-other-us-crude-on-vlccs-from-the-gulf-to-asia/

RigZone Data Center. 2016. Offshore rig search. [accessed 2018 Apr]. http://www.rigzone.com/

SEAMAP. 2017. Gulf of Mexico hypoxia watch bottom dissolved oxygen contours cruise of 2001-2016. [accessed 2018 Jun]. https://catalog.data.gov/dataset?tags=dead+zone

Systems Applications International, Sonoma Technology, Inc., Earth Tech, Alpine Geophysics, Kearney AT. 1995. Gulf of Mexico Air Quality Study: Final Report, Volumes I-III. New Orleans (LA): U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region. OCS Study MMS 95-0038, 95-0039, and 95-0040.

[TCEQ] Texas Commission on Environmental Quality. 2011. 2010 Emissions inventory guidelines, Appendix A, Technical Supplement 4: Flares. Austin (TX): Texas Commission on Environmental Quality, Emissions Assessment Section, Air Quality Division. RG-360A/10. [accessed 2016 Jul 13] https://www.tceq.texas.gov/assets/public/comm_exec/pubs/rg/rg360/rg36010/rg-360a.pdf

U.S. Coast Guard. 2018. Updated fleet spreadsheet, September 18, 2018. U.S. Coast Guard, External Coordination Division (CG-823).

[USDOI, BOEM] U.S. Department of the Interior, Bureau of Ocean Energy Management. 2016. Seismic water bottom anomalies map gallery. [accessed 2016 Oct 05]. http://www.boem.gov/Oil-and-Gas-Energy-Program/Mapping-and-Data/Map-Gallery/Seismic-Water-Bottom-Anomalies-Map-Gallery.aspx

[BOEM, NOAA] Bureau of Ocean Energy Management/National Oceanic and Atmospheric Administration. 2013. AIS data handler: installation and application walk-through. [accessed 2013 Jan]. https://marinecadastre.gov/ais/AIS%20Documents/AISDataHandlerTutorial_Jan2013.pdf

[USDOI, BOEM]. 2019a. Deepwater Production Summary by Year. [accessed 2019 Mar 06]. https://www.data.boem.gov/homepg/data_center/production/production/summary.asp

[USDOI, BOEM]. 2019b. Oil and Gas Operations Reports - Part A (OGOR-A), Well Production 1996 - 2016. [accessed 2019 Mar 06]. https://www.data.boem.gov/homepg/data_center/production/production.asp

[USEPA] U.S. Environmental Protection Agency. 1977. Atmospheric emissions from offshore oil and gas development and production. Research Triangle Park (NC): U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. PB272268.

USEPA. 1995. Memorandum from Director John S. Seitz: Calculating potential to emit (PTE) for emergency generators. Research Triangle Park (NC): U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards.

USEPA. 2000. Environmental assessment of final effluent limitations guidelines and standards for synthetic-based drilling fluids and other non-aqueous drilling fluids in the oil and gas extraction point source category. Washington (DC): U.S. Environmental Protection Agency, Office of Water. EPA – 821-B-00-014.

U.S. Environmental Protection Agency (USEPA). 2008. SPECIATE. Research Triangle Park (NC): U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. [accessed 2008 Sep]. http://www.epa.gov/ttn/chief/software/speciate/

USEPA. 2009. Current methodologies in preparing mobile source port-related emission inventories: final report. U.S. Environmental Protection Agency, Office of Policy, Economics and Innovation.

USEPA. 2011. Composition of natural gas for use in the oil and natural gas sector rulemaking. Memorandum from Heather P. Brown, EC/R Inc., to Bruce Moore, USEPA. July 28, 2011.

USEPA. 2014a. Compilation of air pollutant emission factors; Volume I: Stationary point and area sources. AP-42. Research Triangle Park (NC): U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. [accessed 2018 May]. http://www.epa.gov/ttn/chief/ap42/index.html

USEPA. 2014b. SPECIATE version 4.4. Research Triangle Park (NC): U.S. Environmental Protection Agency. [accessed 2018 May]. http://www.epa.gov/ttn/chief/software/speciate/

USEPA. 2015. WebFIRE. Research Triangle Park (NC): U.S. Environmental Protection Agency. [accessed 2018 May]. http://epa.gov/ttn/chief/webfire/index.html

USEPA. 2016a. 2014 National emissions inventory, version 1, draft technical support document. Research Triangle Park (NC): U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. [accessed 2018 May]. https://www.epa.gov/sites/production/files/2016-12/documents/nei2014v1_tsd.pdf

USEPA. 2016b. PM calculator. Research Triangle Park (NC): U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. [accessed 2019 Jan]. https://www.epa.gov/air-emissions-inventories/pm-augmentation

USEPA. 2018. MOVES2014b: latest version of the motor vehicle emission simulator. Ann Arbor (MI): U.S. Environmental Protection Agency, Office of Transportation and Air Quality.

USEPA. 2019. 2017 National emissions inventory, technical support document. Research Triangle Park (NC): U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards.

U.S. Navy. 2018. Atlantic fleet training and testing final environmental impact statement/overseas environmental impact statement. [accessed 2018 Sep]. https://www.public.navy.mil/usff/environmental/Documents/aftt/AFTT-Final-EIS_OEIS-VolumeI.pdf.

[UNEP] United Nations Environment Programme. 2012 – aviation and the global atmosphere - 7.8.3. historical trends and forecasts for sulfur content. [accessed 2016 Jun 08]. http://www.grida.no/publications/other/ipcc_sr/?src=/climate/ipcc/aviation/111.htm

UNEP. 2017. What happens to oil in the water? [accessed 2017 Jan 11]. http://oils.gpa.unep.org/facts/fate.htm

Walker J, Stow C, Geron C. 2010. Nitrous oxide emissions from the Gulf of Mexico hypoxic zone. Environmental Science and Technology. 44(5): 1617–1623.

Wilson D, Fanjoy J, Billings R. 2004. Gulfwide emission inventory study for the regional haze and ozone modeling effort: final report. New Orleans (LA): U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region. OCS Study MMS 2004-072.

Wilson D, Billings R, Chang R, Sellers J, Perez H. 2017. Year 2014 Gulfwide emission inventory study. New Orleans (LA): U.S. Department of the Interior, Bureau of Ocean Energy Management, Gulf of Mexico OCS Region. OCS Study BOEM 2017-044.

Wilson, D, Billings R, Oommen R, Chang R. 2007. Year 2005 Gulfwide emission inventory study: final report. New Orleans (LA): U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region. OCS Study MMS 2007-067.

Wilson D, Billings R, Oommen R, Lange B, Marik J, McClutchey S, Perez H. 2010. Year 2008 Gulfwide emission inventory study: final report. New Orleans (LA): U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region. OCS Study BOEM 2010-045.

Wilson D, Billings R, Chang R, Perez H, Sellers J. 2014. Year 2011 Gulfwide Emissions Inventory Study. US Dept. of the Interior, Bureau of Ocean Energy Management, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study BOEM 2014-666.

Wilson D, Enoch S, Mendenhall S, Oommen R. 2018. User's guide for the 2017 Gulfwide Offshore Activities Data System (GOADS-2017). New Orleans (LA): U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Gulf of Mexico OCS Region. OCS Study BOEM 2018-038.

Zhan J, Ji Y, Chu X, Wang Y. 2016. Vessel target detection using zero doppler spectra of radar echo for high frequency surface wave radar. IET Radar Sonar Navigation. 10(7).

Zhang CL, Noakes JE. 2006. Sea-floor observatory in the Gulf of Mexico: tracing the carbon flow in gas-hydrate environments. Offshore Technology Conference.

Appendix A

Hazardous Air Pollutants from Platform Sources

Contents

List of Tables

A.1 Introduction

The Bureau of Ocean Energy Management (BOEM) Gulf of Mexico Region sponsored the *Year 2017 Emissions Inventory Study* (BOEM Contract No. M16PC00012) to develop a base year 2017 air pollution emissions inventory for all oil and gas production-related sources in the Gulf of Mexico on the OCS, along with other non-oil and gas production-related sources. Pollutants covered in the inventory include criteria pollutants: carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter (PM), sulfur dioxide (SO_2), lead (Pb); criteria pollutant precursors: volatile organic compounds (VOC) and ammonia; and greenhouse gases (GHGs): carbon dioxide (CO_2), methane (CH_4), and nitrous oxides (N_2O). BOEM's *Year 2014 Gulfwide Emissions Inventory Study* included a hazardous air pollutant (HAP) scoping task, in which HAP emission estimates were developed for select oil and natural gas production emission sources for 10 platforms that were covered in the 2014 Gulfwide inventory (Wilson et al., 2017). As a result of the scoping study, BOEM is including HAP estimates for all platforms that reported activity via the Gulfwide Offshore Activities Data System (GOADS) and non-platform sources in the 2017 inventory. Details on the development of HAP emission estimates for non-platform sources are provided in Appendix B of this report.

A.2 Development of the HAP Emissions Estimates

A.2.1 HAPS to Include

Section 112 of the 1990 Clean Air Act Amendments lists 189 HAPs identified by the U.S. Environmental Protection Agency (USEPA) as known to cause adverse human health impacts. Eastern Research Group, Inc. (ERG), under contract to BOEM, conducted a detailed literature search to identify HAPs emitted from both offshore platform non-combustion sources (i.e., fugitives, glycol dehydrators, losses from flashing, pneumatic pumps, storage tanks, and cold vents) and combustion sources (i.e., boilers, engines, and turbines). For the purposes of the 2014 scoping study, ERG determined that the HAPs presented in Table A-1 represent the key HAPs emitted from offshore oil and gas production non-combustion and combustion sources. BOEM estimated HAPs for these key HAPs for all platforms in the 2017 inventory.

Table A-1. Selected Key HAPs Emitted by Offshore Platforms

HAP	Non-combustion Sources	Combustion Sources
Acetaldehyde	-	✓
Arsenic	-	✓
Benzene	✓	✓
Beryllium	-	✓
Cadmium	-	✓
Chromium	-	✓
Ethylbenzene	✓	✓
Formaldehyde	-	✓
Hexane	✓	✓
Mercury	-	✓
Polycyclic aromatic hydrocarbons (PAH)	-	✓
Toluene	✓	✓
2,2,4 Trimethylpentane	✓	✓
Xylenes	✓	✓

A.2.2 HAP Emission Estimation Approach

HAP emission estimates are often developed using emission factors, particularly for combustion sources. This approach uses the same activity data (e.g., amount of fuel combusted) that is used to estimate criteria pollutant emissions, combined with HAP-specific emission factors, as shown in the following equation.

$$H = EF \times A$$

Where:
H = HAP emission estimate (lbs/yr)
EF = HAP emission factor (lbs/gallon)
A = Activity data (gallon)

HAP emission estimates can also be developed using speciation profiles, particularly for non-combustion sources. Speciation profiles are simply an estimate of the fraction that each individual HAP contributes to the total VOC or total hydrocarbon (TOC) emissions estimates, as shown in the following equation.

$$H = SP \times CAP$$

Where:
H = HAP emission estimate (lbs/yr)
SP = HAP speciation profile (%)
CAP = Criteria pollutant emission estimate (lbs/yr)

Table A-2 shows the HAP estimation approach used. The methodology, emission factors, and speciation profile are presented in Section 4 of this report.

Table A-2. Summary of HAP Estimation Methods for Platform Equipment

Equipment	Estimation Method	Basis
Amine Units	Speciation profile	Calculated using AMINECalc[a]
Boilers, heaters, and burners	Emission factors	Fuel use (10^3 gal, MMscf)
Diesel engines	Emission factors	Fuel use (MMBtu)
Drilling equipment	Emission factors	Fuel use (MMBtu)
Combustion flares – flaring	Emission factors	Volume flared (MMBtu)
Combustion flares - pilot	Emission factors	Fuel use (MMscf)
Fugitives	Speciation profile	VOC estimate (tons)
Glycol dehydrators	Speciation profile	Calculated using GLYCalc[b]
Losses from flashing	Speciation profile	VOC estimate (tons)
Natural gas engines	Emission factors	Fuel use (MMBtu)
Natural gas, diesel, and dual-fuel turbines	Emission factors	Fuel use (MMBtu)
Pneumatic pumps	Speciation profile	VOC estimate (tons)
Pneumatic controllers	Speciation profile	VOC estimate (tons)
Storage tanks	Speciation profile	VOC estimate (tons)
Cold vents	Speciation profile	VOC estimate (tons)

[a] AMINECalc is released by the American Petroleum Institute (API 1999).
[b] GLYCalc™ is released by the Gas Technology Institute, formerly the Gas Research Institute (GRI) (GTI 2000).

A.3 Summary of Results

The HAP emission estimates developed in this study are presented in Tables A-3 and A-4. For an overview of the results, Table A-3 summarizes the total HAP emission estimates. To facilitate more detailed review, Table A-4 presents emission estimates by pollutant and equipment type.

As shown in Table A-4, the highest HAP emissions from platform sources for the pollutants included in this study are hexane driven by cold vents, followed by formaldehyde driven by natural gas engines and combustion flares. Acetaldehyde, benzene, toluene, and xylene also contributed a significant amount to the HAP emissions estimated in this study. The metal HAPs (arsenic, beryllium, cadmium, chromium, and mercury) are driven by combustion equipment. The organic HAPs are driven in large part by the cold vents, which is consistent with the cold vent contribution to the VOC emissions estimates in the 2017 Gulfwide Inventory.

BOEM estimated HAP emissions for all platforms that reported to GOADS, and all non-platform sources and non-oil and gas related marine vessels. BOEM may consider expanding the scope to include additional HAPs in future inventory years.

Recommended improvements include re-evaluating the speciation profile used to estimate non-combustion HAP emissions. The profile used was developed based on information from onshore sources. BOEM should research the available information in order to refine the profiles to be more specific to offshore sources. In addition, it is important to continue to research the combustion equipment emission factors in order to use the latest available emission factors for all equipment types and pollutants.

Table A-3. Total 2017 HAP Emissions for Platform Sources

Pollutant	Emissions (tpy)[a]
2,2,4-Trimethylpentane	9.62
Acetaldehyde	155.00
Arsenic	2.62E-03
Benzene	225.43
Beryllium	8.66E-05
Cadmium	0.24
Chromium	0.47
Ethylbenzene	17.91
Formaldehyde	705.17
Hexane	765.51
Mercury	0.23
PAH, total	2.28
Toluene	226.23
Xylenes (Mixed Isomers)	101.58

[a] Emissions reported in short tons.

Table A-4. 2017 HAP Emissions Estimates by Equipment Type for Platform Sources

Equipment Type	2,2,4-Trimethylpentane (tpy)	Acetaldehyde (tpy)	Arsenic (tpy)	Benzene (tpy)	Beryllium (tpy)	Cadmium (tpy)	Chromium (tpy)
Amine units	-	-	-	0.01	-	-	-
Boilers, heaters, and burners	-	-	9.40E-04	0.01	3.82E-05	2.74E-03	3.61E-03
Diesel engines	-	0.44	-	1.09	-	-	-
Drilling equipment	-	3.95E-03	-	0.12	-	-	-
Combustion flares	3.18	**83.10**	3.38E-05	2.40	2.03E-06	1.86E-04	2.37E-04
Fugitives	0.55	-	-	14.45	-	-	-
Glycol dehydrators	**3.21**	-	-	**159.39**	-	-	-
Losses from flashing	0.01	-	-	0.20	-	-	-
Natural gas engines	1.78	70.07	-	23.77	-	-	-
Natural gas, diesel, and dual-fuel turbines	-	1.39	**1.64E-03**	0.42	**4.63E-05**	**0.24**	**0.46**
Pneumatic pumps	0.14	-	-	3.63	-	-	-
Pneumatic controllers	0.09	-	-	2.40	-	-	-
Storage tanks	0.02	-	-	0.60	-	-	-
Cold vents	0.64	-	-	16.96	-	-	-
Total (tpy)[a]	**9.62**	**155.00**	**2.62E-03**	**208.48**	**8.66E-05**	**0.24**	**0.47**

Table A-4. 2017 HAP Emissions Estimates by Equipment Type for Platform Sources (Cont.)

Equipment Type	Ethylbenzene (tpy)[a]	Formaldehyde (tpy)	Hexane (tpy)	Mercury (tpy)	PAH, Total (tpy)	Toluene (tpy)	Xylenes (Mixed Isomers) (tpy)
Amine units	-	-	2.00E-09	-	-	0.01	-
Boilers, heaters, and burners	2.25E-05	0.19	4.26	6.55E-04	-	0.01	3.85E-05
Diesel engines	-	0.71	-	-	0.25	0.43	0.30
Drilling equipment	-	0.01	-	-	0.03	0.04	0.03
Combustion flares	0.14	125.02	11.35	4.40E-05	-	2.14	0.61
Fugitives	0.90	-	274.20	-	-	2.19	3.74
Glycol dehydrators	**13.67**	-	19.90	-	-	**203.28**	**85.02**
Losses from flashing	0.01	-	3.71	-	-	0.03	0.05
Natural gas engines	0.62	**554.56**	4.64	-	**1.91**	10.03	3.50
Natural gas, diesel, and dual-fuel turbines	1.11	24.67	-	**0.23**	0.08	4.51	2.22
Pneumatic pumps	0.23	-	68.91	-	-	0.55	0.94
Pneumatic controllers	0.15	-	45.45	-	-	0.36	0.62
Storage tanks	0.04	-	11.37	-	-	0.09	0.16
Cold vents	1.05	-	**321.72**	-	-	2.56	4.39
Total (tpy)[a]	**16.86**	**705.17**	**443.79**	**0.23**	**2.28**	**223.67**	**97.19**

[a] Totals may not sum due to rounding.

A.4 References

API. 1999. AMINECalc software program, version 1.0. Amine unit air emissions model. American Petroleum Institute (API) Publication Number 4679.

[GTI] Gas Technology Institute. 2000. GRI-GLYCalc, version 4.0. Chicago (IL): GTI-00/0102. [accessed 2018 Sep 18]. http://www.gastechnology.org

Wilson D, Billings R, Chang R, Sellers J, Perez H. 2017. Year 2014 Gulfwide emission inventory study. New Orleans (LA): U.S. Department of the Interior, Bureau of Ocean Energy Management, Gulf of Mexico OCS Region. OCS Study BOEM 2017-044.

Appendix B

Marine Fuel HAP Speciation Fractions and Helicopter Emission Factors and Fractions

As noted in Section 5, this appendix provides the speciation profiles applied to develop the non-platform HAP emissions inventory for marine vessels (Table B-1), and the criteria pollutant emission factors (Table B-2) and HAP speciation profiles used to develop emission estimates for helicopters (Table B-3).

Table B-1. Distillate Marine Fuel HAP Speciation Fractions

Category	Engine	Pollutant	Associated Basis for Speciation	Cruising	Hotelling	Maneuvering
1	AUX	2,2,4-trimethylpentane	VOC	0.0003	0.0003	-
1	AUX	Acenaphthene	$PM_{2.5}$-PRI	0.000018	0.000018	-
1	AUX	Acenaphthylene	$PM_{2.5}$-PRI	0.00002775	0.00002775	-
1	AUX	Acetaldehyde	VOC	0.0557235	0.0557235	-
1	AUX	Anthracene	$PM_{2.5}$-PRI	0.00002775	0.00002775	-
1	AUX	Arsenic	PM_{10}-PRI	0.0000175	0.0000175	-
1	AUX	Benz[a]Anthracene	$PM_{2.5}$-PRI	0.00003	0.00003	-
1	AUX	Benzene	VOC	0.015258	0.015258	-
1	AUX	Benzo[a]Pyrene	PM_{10}-PRI	0.0000025	0.0000025	-
1	AUX	Benzo[b]Fluoranthene	PM_{10}-PRI	0.000005	0.000005	-
1	AUX	Benzo[g,h,I,]Perylene	$PM_{2.5}$-PRI	0.00000675	0.00000675	-
1	AUX	Benzo[k]Fluoranthene	PM_{10}-PRI	0.0000025	0.0000025	-
1	AUX	Cadmium	PM_{10}-PRI	0.00000283	0.00000283	-
1	AUX	Chromium III	PM_{10}-PRI	0.0000165	0.0000165	-
1	AUX	Chromium VI	PM_{10}-PRI	0.0000085	0.0000085	-
1	AUX	Chrysene	$PM_{2.5}$-PRI	0.00000525	0.00000525	-
1	AUX	Ethylbenzene	VOC	0.0015	0.0015	-
1	AUX	Fluoranthene	$PM_{2.5}$-PRI	0.0000165	0.0000165	-
1	AUX	Fluorene	$PM_{2.5}$-PRI	0.00003675	0.00003675	-
1	AUX	Formaldehyde	VOC	0.1122	0.1122	-
1	AUX	Indeno[1,2,3-c,d]Pyrene	PM_{10}-PRI	0.000005	0.000005	-
1	AUX	Mercury	PM_{10}-PRI	2.5E-08	2.5E-08	-
1	AUX	Naphthalene	$PM_{2.5}$-PRI	0.00105075	0.00105075	-
1	AUX	n-Hexane	VOC	0.004125	0.004125	-
1	AUX	Phenanthrene	$PM_{2.5}$-PRI	0.000042	0.000042	-

Category	Engine	Pollutant	Associated Basis for Speciation	Cruising	Hotelling	Maneuvering
1	AUX	Pyrene	$PM_{2.5}$-PRI	0.00002925	0.00002925	-
1	AUX	Toluene	VOC	0.0024	0.0024	-
1	AUX	Xylene	VOC	0.0036	0.0036	-
1	Main	2,2,4-trimethylpentane	VOC	0.00025	-	0.0003
1	Main	Acenaphthene	$PM_{2.5}$-PRI	0.000015	-	0.000018
1	Main	Acenaphthylene	$PM_{2.5}$-PRI	2.3125E-05	-	0.00002775
1	Main	Acetaldehyde	VOC	0.04643625	-	0.0557235
1	Main	Anthracene	$PM_{2.5}$-PRI	2.3125E-05	-	0.00002775
1	Main	Arsenic	PM_{10}-PRI	0.00003	-	0.0000175
1	Main	Benz[a]Anthracene	$PM_{2.5}$-PRI	0.000025	-	0.00003
1	Main	Benzene	VOC	0.012715	-	0.015258
1	Main	Benzo[a]Pyrene	PM_{10}-PRI	0.000005	-	0.0000025
1	Main	Benzo[b]Fluoranthene	PM_{10}-PRI	0.00001	-	0.000005
1	Main	Benzo[g,h,I,]Perylene	$PM_{2.5}$-PRI	5.625E-06	-	0.00000675
1	Main	Benzo[k]Fluoranthene	PM_{10}-PRI	0.000005	-	0.0000025
1	Main	Cadmium	PM_{10}-PRI	0.00000515	-	0.00000283
1	Main	Chromium III	PM_{10}-PRI	0.000033	-	0.0000165
1	Main	Chromium VI	PM_{10}-PRI	0.000017	-	0.0000085
1	Main	Chrysene	$PM_{2.5}$-PRI	4.375E-06	-	0.00000525
1	Main	Ethylbenzene	VOC	0.00125	-	0.0015
1	Main	Fluoranthene	$PM_{2.5}$-PRI	0.00001375	-	0.0000165
1	Main	Fluorene	$PM_{2.5}$-PRI	3.0625E-05	-	0.00003675
1	Main	Formaldehyde	VOC	0.0935	-	0.1122
1	Main	Indeno[1,2,3-c,d]Pyrene	PM_{10}-PRI	0.00001	-	0.000005
1	Main	Mercury	PM_{10}-PRI	0.00000005	-	0.000000025
1	Main	Naphthalene	$PM_{2.5}$-PRI	0.00087563	-	0.00105075
1	Main	n-Hexane	VOC	0.0034375	-	0.004125

Category	Engine	Pollutant	Associated Basis for Speciation	Cruising	Hotelling	Maneuvering
1	Main	Phenanthrene	$PM_{2.5}$-PRI	0.000035	-	0.000042
1	Main	Pyrene	$PM_{2.5}$-PRI	2.4375E-05	-	0.00002925
1	Main	Toluene	VOC	0.002	-	0.0024
1	Main	Xylene	VOC	0.003	-	0.0036
2	AUX	2,2,4-trimethylpentane	VOC	0.0003	0.0003	-
2	AUX	Acenaphthene	$PM_{2.5}$-PRI	0.000018	0.000018	-
2	AUX	Acenaphthylene	$PM_{2.5}$-PRI	0.00002775	0.00002775	-
2	AUX	Acetaldehyde	VOC	0.0557235	0.0557235	-
2	AUX	Anthracene	$PM_{2.5}$-PRI	0.00002775	0.00002775	-
2	AUX	Arsenic	PM_{10}-PRI	0.0000175	0.0000175	-
2	AUX	Benz[a]Anthracene	$PM_{2.5}$-PRI	0.00003	0.00003	-
2	AUX	Benzene	VOC	0.015258	0.015258	-
2	AUX	Benzo[a]Pyrene	PM_{10}-PRI	0.0000025	0.0000025	-
2	AUX	Benzo[b]Fluoranthene	PM_{10}-PRI	0.000005	0.000005	-
2	AUX	Benzo[g,h,I,]Perylene	$PM_{2.5}$-PRI	0.00000675	0.00000675	-
2	AUX	Benzo[k]Fluoranthene	PM_{10}-PRI	0.0000025	0.0000025	-
2	AUX	Cadmium	PM_{10}-PRI	0.00000283	0.00000283	-
2	AUX	Chromium III	PM_{10}-PRI	0.0000165	0.0000165	-
2	AUX	Chromium VI	PM_{10}-PRI	0.0000085	0.0000085	-
2	AUX	Chrysene	$PM_{2.5}$-PRI	0.00000525	0.00000525	-
2	AUX	Ethylbenzene	VOC	0.0015	0.0015	-
2	AUX	Fluoranthene	$PM_{2.5}$-PRI	0.0000165	0.0000165	-
2	AUX	Fluorene	$PM_{2.5}$-PRI	0.00003675	0.00003675	-
2	AUX	Formaldehyde	VOC	0.1122	0.1122	-
2	AUX	Indeno[1,2,3-c,d]Pyrene	PM_{10}-PRI	0.000005	0.000005	-
2	AUX	Mercury	PM_{10}-PRI	2.5E-08	2.5E-08	-
2	AUX	Naphthalene	$PM_{2.5}$-PRI	0.00105075	0.00105075	-

Category	Engine	Pollutant	Associated Basis for Speciation	Cruising	Hotelling	Maneuvering
2	AUX	n-Hexane	VOC	0.004125	0.004125	-
2	AUX	Phenanthrene	$PM_{2.5}$-PRI	0.000042	0.000042	-
2	AUX	Pyrene	$PM_{2.5}$-PRI	0.00002925	0.00002925	-
2	AUX	Toluene	VOC	0.0024	0.0024	-
2	AUX	Xylene	VOC	0.0036	0.0036	-
2	Main	2,2,4-trimethylpentane	VOC	0.00025	-	0.0003
2	Main	Acenaphthene	$PM_{2.5}$-PRI	0.000015	-	0.000018
2	Main	Acenaphthylene	$PM_{2.5}$-PRI	2.3125E-05	-	0.00002775
2	Main	Acetaldehyde	VOC	0.04643625	-	0.0557235
2	Main	Anthracene	$PM_{2.5}$-PRI	2.3125E-05	-	0.00002775
2	Main	Arsenic	PM_{10}-PRI	0.00003	-	0.0000175
2	Main	Benz[a]Anthracene	$PM_{2.5}$-PRI	0.000025	-	0.00003
2	Main	Benzene	VOC	0.012715	-	0.015258
2	Main	Benzo[a]Pyrene	PM_{10}-PRI	0.000005	-	0.0000025
2	Main	Benzo[b]Fluoranthene	PM_{10}-PRI	0.00001	-	0.000005
2	Main	Benzo[g,h,I,]Perylene	$PM_{2.5}$-PRI	5.625E-06	-	0.00000675
2	Main	Benzo[k]Fluoranthene	PM_{10}-PRI	0.000005	-	0.0000025
2	Main	Cadmium	PM_{10}-PRI	0.00000515	-	0.00000283
2	Main	Chromium III	PM_{10}-PRI	0.000033	-	0.0000165
2	Main	Chromium VI	PM_{10}-PRI	0.000017	-	0.0000085
2	Main	Chrysene	$PM_{2.5}$-PRI	4.375E-06	-	0.00000525
2	Main	Ethylbenzene	VOC	0.00125	-	0.0015
2	Main	Fluoranthene	$PM_{2.5}$-PRI	0.00001375	-	0.0000165
2	Main	Fluorene	$PM_{2.5}$-PRI	3.0625E-05	-	0.00003675
2	Main	Formaldehyde	VOC	0.0935	-	0.1122
2	Main	Indeno[1,2,3-c,d]Pyrene	PM_{10}-PRI	0.00001	-	0.000005
2	Main	Mercury	PM_{10}-PRI	0.00000005	-	0.000000025

Category	Engine	Pollutant	Associated Basis for Speciation	Cruising	Hotelling	Maneuvering
2	Main	Naphthalene	$PM_{2.5}$-PRI	0.00087563	-	0.00105075
2	Main	n-Hexane	VOC	0.0034375	-	0.004125
2	Main	Phenanthrene	$PM_{2.5}$-PRI	0.000035	-	0.000042
2	Main	Pyrene	$PM_{2.5}$-PRI	2.4375E-05	-	0.00002925
2	Main	Toluene	VOC	0.002	-	0.0024
2	Main	Xylene	VOC	0.003	-	0.0036
3	AUX	2,2,4-trimethylpentane	VOC	0.0003	0.0003	-
3	AUX	Acenaphthene	$PM_{2.5}$-PRI	0.000018	0.00000034	-
3	AUX	Acenaphthylene	$PM_{2.5}$-PRI	0.00002775	5.25E-07	-
3	AUX	Acetaldehyde	VOC	0.0557235	0.000229	-
3	AUX	Anthracene	$PM_{2.5}$-PRI	0.00002775	5.25E-07	-
3	AUX	Arsenic	PM_{10}-PRI	0.0000175	0.0004	-
3	AUX	Benz[a]Anthracene	$PM_{2.5}$-PRI	0.00003	5.67E-07	-
3	AUX	Benzene	VOC	0.015258	0.0000098	-
3	AUX	Benzo[a]Pyrene	PM_{10}-PRI	0.0000025	0.000002	-
3	AUX	Benzo[b]Fluoranthene	PM_{10}-PRI	0.000005	0.000004	-
3	AUX	Benzo[g,h,I,]Perylene	$PM_{2.5}$-PRI	0.00000675	1.28E-07	-
3	AUX	Benzo[k]Fluoranthene	PM_{10}-PRI	0.0000025	0.000002	-
3	AUX	Beryllium	PM_{10}-PRI	5.46E-07	5.46E-07	-
3	AUX	Cadmium	PM_{10}-PRI	0.00000283	0.0000059	-
3	AUX	Chromium III	PM_{10}-PRI	0.0000165	0.000396	-
3	AUX	Chromium VI	PM_{10}-PRI	0.0000085	0.000204	-
3	AUX	Chrysene	$PM_{2.5}$-PRI	0.00000525	9.93E-08	-
3	AUX	Ethylbenzene	VOC	0.0015	0.0015	-
3	AUX	Fluoranthene	$PM_{2.5}$-PRI	0.0000165	3.12E-07	-
3	AUX	Fluorene	$PM_{2.5}$-PRI	0.00003675	6.95E-07	-
3	AUX	Formaldehyde	VOC	0.1122	0.00157	-

Category	Engine	Pollutant	Associated Basis for Speciation	Cruising	Hotelling	Maneuvering
3	AUX	Indeno[1,2,3-c,d]Pyrene	PM_{10}-PRI	0.000005	0.000004	-
3	AUX	Mercury	PM_{10}-PRI	2.5E-08	0.0000014	-
3	AUX	Naphthalene	$PM_{2.5}$-PRI	0.00105075	0.0000199	-
3	AUX	n-Hexane	VOC	0.004125	0.004125	-
3	AUX	Phenanthrene	$PM_{2.5}$-PRI	0.000042	7.94E-07	-
3	AUX	Pyrene	$PM_{2.5}$-PRI	0.00002925	5.53E-07	-
3	AUX	Toluene	VOC	0.0024	0.0024	-
3	AUX	Xylene	VOC	0.0036	0.0036	-
3	Main	2,2,4-trimethylpentane	VOC	0.00025	-	0.0003
3	Main	Acenaphthene	$PM_{2.5}$-PRI	0.00000767	-	0.00000034
3	Main	Acenaphthylene	$PM_{2.5}$-PRI	1.1825E-05	-	0.000000525
3	Main	Acetaldehyde	VOC	0.02333263	-	0.000229
3	Main	Anthracene	$PM_{2.5}$-PRI	1.1825E-05	-	0.000000525
3	Main	Arsenic	PM_{10}-PRI	0.00010241	-	8.74126E-05
3	Main	Benz[a]Anthracene	$PM_{2.5}$-PRI	1.2784E-05	-	0.000000567
3	Main	Benzene	VOC	0.0063624	-	0.0000098
3	Main	Benzo[a]Pyrene	PM_{10}-PRI	2.9371E-06	-	4.37063E-07
3	Main	Benzo[b]Fluoranthene	PM_{10}-PRI	5.8741E-06	-	8.74126E-07
3	Main	Benzo[g,h,I,]Perylene	$PM_{2.5}$-PRI	2.8765E-06	-	0.000000128
3	Main	Benzo[k]Fluoranthene	PM_{10}-PRI	2.9371E-06	-	4.37063E-07
3	Main	Beryllium	PM_{10}-PRI	5.46E-07	-	0.000000546
3	Main	Cadmium	PM_{10}-PRI	1.3875E-05	-	0.0000226
3	Main	Chromium III	PM_{10}-PRI	0.00007986	-	0.00012672
3	Main	Chromium VI	PM_{10}-PRI	0.00004114	-	0.00006528
3	Main	Chrysene	$PM_{2.5}$-PRI	2.2372E-06	-	9.93E-08
3	Main	Ethylbenzene	VOC	0.00125	-	0.0015
3	Main	Fluoranthene	$PM_{2.5}$-PRI	7.031E-06	-	0.000000312

Category	Engine	Pollutant	Associated Basis for Speciation	Cruising	Hotelling	Maneuvering
3	Main	Fluorene	$PM_{2.5}$-PRI	0.00001566	-	0.000000695
3	Main	Formaldehyde	VOC	0.047535	-	0.00157
3	Main	Indeno[1,2,3-c,d]Pyrene	PM_{10}-PRI	5.8741E-06	-	8.74126E-07
3	Main	Mercury	PM_{10}-PRI	2.8724E-07	-	2.7076E-07
3	Main	Naphthalene	$PM_{2.5}$-PRI	0.00044776	-	0.0000199
3	Main	n-Hexane	VOC	0.0034375	-	0.004125
3	Main	Phenanthrene	$PM_{2.5}$-PRI	1.7897E-05	-	0.000000794
3	Main	Pyrene	$PM_{2.5}$-PRI	1.2464E-05	-	0.000000553
3	Main	Toluene	VOC	0.002	-	0.0024
3	Main	Xylene	VOC	0.003	-	0.0036

Table B-2. Helicopter Emission Factors

Aircraft ICAO Code[a]	Aircraft Model	Duty Type	Engine Name	Max SHP[b] Per Engine	Engine Type	Number of Engines	Emission Rate Kilogram Per Hour						
							Fuel Consumption	NO_X	HC	VOC	CO	PM_{10}	$PM_{2.5}$
A109	AGUSTA A109	Light	DDA250-C20R/1	450	Turboshaft	2	209.694	1.113	1.737	1.998	2.173	0.036	0.035
A109	AGUSTA A109	Light	PW207C	650	Turboshaft	2	236.679	1.548	1.318	1.516	1.630	0.047	0.046
A109	AGUSTA A109A II	Light	DDA250-C20B	420	Turboshaft	2	203.540	1.039	1.817	2.089	2.277	0.034	0.033
A109	AGUSTA A109C	Light	DDA250-C20R	450	Turboshaft	2	209.694	1.113	1.737	1.998	2.173	0.036	0.035
A109	AGUSTA A109E	Light	PW206C	550	Turboshaft	2	209.231	1.245	1.396	1.605	1.735	0.039	0.038
A109	AGUSTA A109 Power	Light	ARRIUS 2K	670	Turboshaft	2	240.697	1.601	1.297	1.492	1.603	0.048	0.047
A109	AGUSTA A109 K2	Light	ARRIEL1K1	738	Turboshaft	2	255.013	1.792	1.238	1.424	1.526	0.053	0.052
A119	AGUSTA A119	Light	PT6B-37	900	Turboshaft	1	191.530	1.695	0.600	0.690	0.730	0.048	0.047
A139	AGUSTA A139	Light	PT6C-67C	1,100	Turboshaft	2	412.218	3.538	1.369	1.574	1.669	0.101	0.098
ALO2	ALOUETTE II	Light	ARTOUSTE IIC5	402	Turboshaft	1	109.728	0.615	0.821	0.944	1.023	0.019	0.019
ALO2	ALOUETTE II	Light	ARTOUSTE IIC6	402	Turboshaft	1	109.728	0.615	0.821	0.944	1.023	0.019	0.019
ALO3	SA316B ALOUETTE III	Light	ARTOUSTE IIIB	563	Turboshaft	1	134.881	0.915	0.701	0.806	0.866	0.027	0.027
ALO3	SA316B ALOUETTE III	Light	ASTAZOU XIVB	590	Turboshaft	1	139.375	0.971	0.689	0.792	0.849	0.029	0.028
AS32	SUPER PUMA	Heavy	MAKILA 1A1	1,820	Turboshaft	2	490.660	5.605	0.946	1.088	1.136	0.153	0.149
AS35	AS 350 ECUREUIL	Light	ARRIEL 1B	641	Turboshaft	1	133.191	0.972	0.602	0.692	0.740	0.029	0.028
AS35	AS 350B ECUREUIL	Light	ARRIEL 1D1	732	Turboshaft	1	146.504	1.153	0.573	0.659	0.702	0.033	0.033
AS35	AS 350 B3	Light	ARRIEL 2B	848	Turboshaft	1	151.575	1.297	0.506	0.582	0.617	0.037	0.036
AS35	AS 350 B3	Light	ARRIEL 2B1	848	Turboshaft	1	151.575	1.297	0.506	0.582	0.617	0.037	0.036
AS50	AS 550 FENNEC	Light	ARRIEL 1D1	732	Turboshaft	1	146.504	1.153	0.573	0.659	0.702	0.033	0.033
AS55	AS 355	Light	DDA250-C20F	420	Turboshaft	2	203.540	1.039	1.817	2.089	2.277	0.034	0.033
AS55	AS 355 N	Light	ARRIUS 1A	480	Turboshaft	2	216.156	1.190	1.670	1.921	2.085	0.038	0.037
AS55	AS 555 FENNEC	Light	ARRIEL 1D1	712	Turboshaft	2	277.133	1.909	1.399	1.609	1.726	0.057	0.055
AS65	AS 365 C1 DAUPHIN	Medium	ARRIEL 1A1	641	Turboshaft	2	260.998	1.693	1.476	1.697	1.826	0.051	0.050

Aircraft ICAO Code[a]	Aircraft Model	Duty Type	Engine Name	Max SHP[b] Per Engine	Engine Type	Number of Engines	Emission Rate Kilogram Per Hour						
							Fuel Consumption	NO_X	HC	VOC	CO	PM_{10}	$PM_{2.5}$
AS65	AS 365 C2 DAUPHIN	Medium	ARRIEL 1A2	641	Turboshaft	2	260.998	1.693	1.476	1.697	1.826	0.051	0.050
AS65	AS 365 N DAUPHIN	Medium	ARRIEL 1C	660	Turboshaft	2	265.197	1.749	1.453	1.671	1.796	0.053	0.051
AS65	AS 365 N1 DAUPHIN	Medium	ARRIEL 1C1	700	Turboshaft	2	274.320	1.871	1.410	1.622	1.741	0.056	0.054
AS65	AS 365 N3 DAUPHIN	Medium	ARRIEL 2C	839	Turboshaft	2	308.940	2.336	1.306	1.502	1.603	0.068	0.066
B06	BELL 206B	Light	DDA250-C20	400	Turboshaft	1	109.450	0.611	0.823	0.946	1.026	0.019	0.019
B06	BELL 206B	Light	DDA250-C20B	420	Turboshaft	1	101.049	0.580	0.721	0.829	0.898	0.018	0.018
B06	BELL 206B	Light	DDA250-C20J	420	Turboshaft	1	101.049	0.580	0.721	0.829	0.898	0.018	0.018
B06	BELL 206B	Light	DDA250-C20R	450	Turboshaft	1	105.041	0.627	0.695	0.800	0.864	0.019	0.019
B06	BELL 206B	Light	DDA250-C20R/4	450	Turboshaft	1	105.041	0.627	0.695	0.800	0.864	0.019	0.019
B06	BELL 206L	Light	DDA250-C20R	450	Turboshaft	1	116.712	0.697	0.773	0.889	0.960	0.022	0.021
B06	BELL 206L	Light	DDA250-C30	650	Turboshaft	1	149.402	1.099	0.665	0.765	0.817	0.032	0.031
B06	BELL 206L	Light	DDA250-C30P	650	Turboshaft	1	149.402	1.099	0.665	0.765	0.817	0.032	0.031
B06T	Bell TWIN RANGER	Light	DDA250-C20R	450	Turboshaft	2	209.694	1.113	1.737	1.998	2.173	0.036	0.035
B105	BO 105	Light	DDA250-C20	400	Turboshaft	2	199.584	0.991	1.878	2.160	2.357	0.033	0.032
B105	BO 105	Light	DDA250-C20B	420	Turboshaft	2	203.540	1.039	1.817	2.089	2.277	0.034	0.033
B222	BELL 222	Medium	DDA250-C40B	715	Turboshaft	2	277.841	1.918	1.396	1.605	1.722	0.057	0.056
B222	BELL 222	Medium	LTS101-750C.1	735	Turboshaft	2	282.622	1.982	1.378	1.585	1.699	0.059	0.057
B407	Bell 407	Light	DDA250-C47B	650	Turboshaft	1	149.402	1.099	0.665	0.765	0.817	0.032	0.031
B412	Bell 412	Medium	PT6T-3	1,800	Turboshaft	2	541.323	6.145	1.056	1.214	1.269	0.168	0.164
B430	Bell 430	Medium	DDA250-C40B	715	Turboshaft	2	277.841	1.918	1.396	1.605	1.722	0.057	0.056
B47G	Bell 47G-3B	Light	LYC VO-435-A1D	220	Piston	1	49.935	0.100	0.628	0.722	49.935	0.003	0.003
B47G	Bell 47G	Light	LYC TVO-435-B1A	270	Piston	1	64.615	0.129	0.756	0.869	64.615	0.005	0.004
BK17	BK117B	Medium	LTS101-750B.1	727	Turboshaft	2	280.698	1.956	1.385	1.593	1.708	0.058	0.057
BK17	BK117	Medium	ARRIEL 1E2	738	Turboshaft	2	283.348	1.992	1.376	1.582	1.695	0.059	0.058
BK17	BK117 C-2	Medium	ARRIEL 1E2	738	Turboshaft	2	283.348	1.992	1.376	1.582	1.695	0.059	0.058

Aircraft ICAO Code[a]	Aircraft Model	Duty Type	Engine Name	Max SHP[b] Per Engine	Engine Type	Number of Engines	Emission Rate Kilogram Per Hour						
							Fuel Consumption	NO_X	HC	VOC	CO	PM_{10}	$PM_{2.5}$
EC20	EC 120	Light	ARRIUS 2F	432	Turboshaft	1	114.024	0.665	0.789	0.907	0.982	0.021	0.020
EC30	EC 130 B4	Light	ARRIEL 2B1	848	Turboshaft	1	182.621	1.563	0.610	0.701	0.744	0.045	0.043
EC35	EC 135	Light	ARRIUS 2B1	633	Turboshaft	2	259.256	1.670	1.486	1.709	1.839	0.051	0.049
EC35	EC 135	Light	ARRIUS 2B2	633	Turboshaft	2	259.256	1.670	1.486	1.709	1.839	0.051	0.049
EC55	EC 155 B	Medium	ARRIEL 2C1	839	Turboshaft	2	308.940	2.336	1.306	1.502	1.603	0.068	0.066
EC55	EC 155 B1	Medium	ARRIEL 2C2	944	Turboshaft	2	337.414	2.727	1.256	1.444	1.536	0.079	0.077
EN28	ENSTROM 280C	Light	HIO-360	190	Piston	1	42.001	0.084	0.556	0.639	42.001	0.003	0.003
EN48	ENSTROM 480	Light	DDA250-C20W	420	Turboshaft	1	112.277	0.645	0.801	0.921	0.997	0.020	0.020
EXEC	ROTORWAY EXEC 90	Light	ROTORWAY RI-162	150	Piston	1	32.073	0.064	0.461	0.530	32.073	0.002	0.002
EXPL	MD 900	Light	PW206A	621	Turboshaft	2	256.669	1.636	1.502	1.727	1.860	0.050	0.048
GAZL	SA342 GAZELLE	Light	ASTAZOU XIVG	590	Turboshaft	1	139.375	0.971	0.689	0.792	0.849	0.029	0.028
GAZL	SA342 GAZELLE	Light	ASTAZOU XIVH	590	Turboshaft	1	139.375	0.971	0.689	0.792	0.849	0.029	0.028
GAZL	SA341 GAZELLE	Light	ASTAZOU IIIA	644	Turboshaft	1	148.459	1.087	0.667	0.767	0.821	0.032	0.031
GAZL	SA341 GAZELLE	Light	ASTAZOU IIIN2	644	Turboshaft	1	148.459	1.087	0.667	0.767	0.821	0.032	0.031
H269	SCHWEIZER 269C	Light	HIO-360	190	Piston	1	42.001	0.084	0.556	0.639	42.001	0.003	0.003
H500	HUGHES 500	Light	DDA250-C18	317	Turboshaft	1	98.836	0.484	0.955	1.099	1.200	0.016	0.016
H500	HUGHES 501	Light	DDA250-C20B	420	Turboshaft	1	112.277	0.645	0.801	0.921	0.997	0.020	0.020
H500	MD 500N	Light	DDA250-C20R	450	Turboshaft	1	116.712	0.697	0.773	0.889	0.960	0.022	0.021
H53	SIKORSKY CH-53G (S-65)	Heavy	T 64-GE-7	3,925	Turboshaft	2	977.455	17.273	0.821	0.945	0.964	0.388	0.379
H53S	SIKORSKY SUPER STALLION	Heavy	T 64-GE-7	3,925	Turboshaft	3	1,332.250	21.994	1.274	1.465	1.501	0.523	0.511
H60	SIKORSKY BLACK HAWK	Heavy	T700-GE-700	1,622	Turboshaft	2	507.645	5.432	1.108	1.274	1.336	0.150	0.146
HU30	HUGHES 300	Light	HIO-360	190	Piston	1	42.001	0.084	0.556	0.639	42.001	0.003	0.003
KA27	KA-32A12	Heavy	TV3-117VMA	2,200	Turboshaft	2	621.193	7.902	0.976	1.122	1.165	0.211	0.206
KMAX	K-1200	Light	T53 17A-1	1,500	Turboshaft	1	283.866	3.358	0.512	0.589	0.614	0.091	0.089

Aircraft ICAO Code[a]	Aircraft Model	Duty Type	Engine Name	Max SHP[b] Per Engine	Engine Type	Number of Engines	Emission Rate Kilogram Per Hour						
							Fuel Consumption	NO_X	HC	VOC	CO	PM_{10}	$PM_{2.5}$
LAMA	SA315B LAMA	Light	ARTOUSTE IIIB	563	Turboshaft	1	159.160	1.079	0.827	0.951	1.021	0.032	0.031
MD52	MD 520N	Light	DDA250-C20	400	Turboshaft	1	109.450	0.611	0.823	0.946	1.026	0.019	0.019
MD60	MD 600N	Light	DDA250-C47M	650	Turboshaft	1	149.402	1.099	0.665	0.765	0.817	0.032	0.031
MI8	MIL MI-8	Heavy	TV2-117	1,500	Turboshaft	2	485.135	4.966	1.152	1.325	1.392	0.138	0.135
R22	R22 BETA	Light	HO-360	180	Piston	1	39.458	0.079	0.532	0.612	39.458	0.003	0.003
R44	R44 RAVEN	Light	HIO-540	245	Piston	1	56.995	0.114	0.690	0.793	56.995	0.004	0.004
S76	SIKORSKY S76	Medium	DDA250-C30S	650	Turboshaft	2	262.976	1.720	1.465	1.684	1.812	0.052	0.051
S76	SIKORSKY S-76 C+	Medium	ARRIEL 2S1	856	Turboshaft	2	313.445	2.397	1.297	1.491	1.591	0.070	0.068
S76	SIKORSKY S76	Medium	PT6B-36A	981	Turboshaft	2	347.707	2.873	1.241	1.428	1.517	0.082	0.080
S92	SIKORSKY S92A	Heavy	GE CT7-8A	2,740	Turboshaft	2	735.079	10.592	0.911	1.047	1.081	0.271	0.265
SCOR	ROTORWAY SCORPION	Light	ROTORWAY RW 133	133	Piston	1	28.038	0.056	0.420	0.483	28.038	0.002	0.002
SYCA	BRISTOL SYCAMORE	Light	ALVIS LEONIDES	550	Piston	1	276.804	0.554	2.524	2.903	276.804	0.019	0.019
UH1	BELL UH-1H	Medium	T53 L13	1,400	Turboshaft	1	271.282	3.086	0.527	0.606	0.633	0.084	0.082
UH12	HILLER UH-12A	Light	VO-540-1B	320	Piston	1	82.328	0.165	0.908	1.044	82.328	0.006	0.006

[a] International Civil Aviation Organization

[b] SHP—shaft horsepower

Table B-3. Helicopter HAP Speciation Fractions (Turboshaft)

Pollutant	Basis for Speciation	Speciation Fraction
Acetaldehyde	VOC	0.04309058
Anthracene	PM_{10}	4.4116E-07
Benzene	VOC	0.01695582
Benzo[a]anthracene	PM_{10}	6.6777E-08
Benzo[a]pyrene	PM_{10}	3.6563E-08
Benzo[g,h,i]perylene	PM_{10}	6.0646E-09
Chrysene	PM_{10}	6.2179E-08
Ethylbenzene	VOC	0.001755068
Fluoranthene	PM_{10}	9.2283E-07
Formaldehyde	VOC	0.12416784
Naphthalene	VOC	0.00545693
Phenanthrene	PM_{10}	0.00000410513
Toluene	VOC	0.00647569
2,2,4-Trimethylpentane	VOC	0.00038077
Xylene	VOC	0.0046772

Department of the Interior (DOI)

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

Bureau of Ocean Energy Management (BOEM)

The mission of the Bureau of Ocean Energy Management is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way.

BOEM Environmental Studies Program

The mission of the Environmental Studies Program is to provide the information needed to predict, assess, and manage impacts from offshore energy and marine mineral exploration, development, and production activities on human, marine, and coastal environments. The proposal, selection, research, review, collaboration, production, and dissemination of each of BOEM's Environmental Studies follows the DOI Code of Scientific and Scholarly Conduct, in support of a culture of scientific and professional integrity, as set out in the DOI Departmental Manual (305 DM 3).