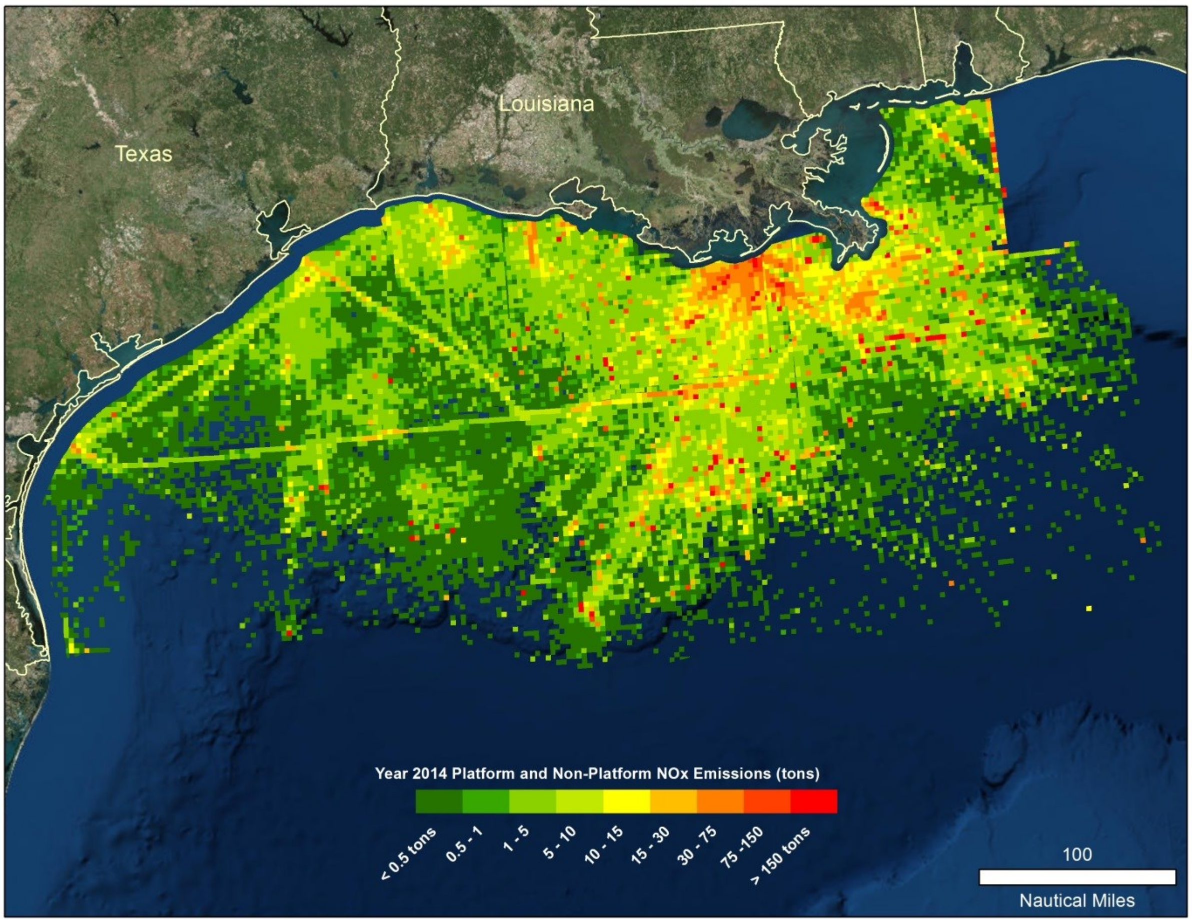
OCS Study
BOEM 2017-044

Year 2014 Gulfwide Emissions Inventory Study



U.S. Department of the Interior
Bureau of Ocean Energy Management
Gulf of Mexico OCS Region

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BOEM 2017-044

Year 2014 Gulfwide Emissions Inventory Study

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ABOUT THE COVER

The graphic on the cover depicts the calendar year 2014 estimated oxides of nitrogen (NO_x) emissions for all sources in the Gulf of Mexico region, including all platform and non-platform sources, oil and gas related and otherwise.

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ABSTRACT

This report presents the results of a calendar year 2014 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-10 (PM_{10}), particulate matter-2.5 ($PM_{2.5}$), PM precursor ammonia (NH_3), ozone precursor volatile organic compounds, and major GHGs—carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). This is the first inventory cycle to include Pb and NH_3. Details are provided on the emission estimation methods for all sources.

This report is the fifth 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, and 2011.

The 2014 inventory results indicate that OCS oil and gas production platforms and production-related vessels and helicopters account for 99% of total methane emissions, 72% of carbon monoxide emissions, 56% of volatile organic compound emissions, 36% of nitrogen oxide emissions, 30% of particulate matter emissions, and 12% of sulfur dioxide emissions in the GOM inventory.

Comparisons of the emission estimates between the BOEM calendar year 2011 inventory and the 2014 inventory show a decrease in all emission estimates for 2014. The emission estimates for some sources that are not associated with oil and gas production increased, particularly commercial marine vessels. This is due to a more complete assessment of the vessels transiting the GOM using the automatic identification system (AIS). The 2014 emission estimates for oil and natural gas production platform and non-platform oil and gas- related sources show a decrease in all emission estimates between 2011 and 2014 with a 73% decrease in SO_2, a 68% decrease in PM, a 60% decrease in NO_x, and a 17% decrease in CH_4 emissions.

This report also presents the results of a detailed emission trends analysis that analyzed BOEM inventories prepared for calendar years 2000 through 2014. The findings indicate that overall, emissions are largely affected by three factors: activity and production levels, changes in inventory methodologies, and improvements in the emission factors used to estimate emissions. The total production trend to emissions does not hold true for 2014, as higher production was paired with decreased emissions and number of platforms. Deepwater platforms account for an increasing portion of the emissions, despite only minor changes in the number of these platforms.

At the conclusion of this report, the limitations associated with the development of the 2014 inventory, and recommendations for future improvements are presented.

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ABBREVIATIONS AND ACRONYMS

AET	American Eagle Tankers
AIS	automatic identification system
API	American Petroleum Institute
BOEM	Bureau of Ocean Energy Management
CAAA	Clean Air Act Amendments
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CMV	commercial marine vessels
DBMS	database management system
ECA	Emission Control Area
EIIP	Emission Inventory Improvement Program
EIS	Environmental Impact Statement
FAA	Federal Aviation Administration
FOCA	Swiss Federal Office of Civil Aviation
GHG	greenhouse gas
GIS	geographic information system
GOR	gas-to-oil ratio
GTI	Gas Technology Institute
GOADS	Gulfwide Offshore Activities Data System
GOM	Gulf of Mexico
GOMESA	Gulf of Mexico Energy Security Act
HAP	hazardous air pollutant
HSAC	Helicopter Safety Advisory Conference
ICR	information collection request
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
LF	load factor
LOOP	Louisiana Offshore Oil Port
LTO	landing and takeoff
MRIP	Marine Recreational Information Program
NAAQS	National Ambient Air Quality Standards
NEI	National Emissions Inventory
NEPA	National Environmental Policy Act
NH_3	ammonia
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
N_2O	nitrous oxide
NO_x	total oxides of nitrogen
NTL	Notice to Lessees and Operators
NWS	National Weather Service

O_3	ozone
OCS	Outer Continental Shelf
OCSLA	OCS Lands Act
OGOR	Oil and Gas Operations Report
OMB	Office of Management and Budget
OSGL	OSG Lightering
Pb	lead
PM	particulate matter
PM-CON	particulate matter condensable
$PM_{2.5}$	particulate matter with an aerodynamic diameter of 2.5 microns and smaller
PM_{10}	particulate matter with an aerodynamic diameter of 10 microns and smaller
PM-FIL	particulate matter filterable
PM-PRI	particulate matter primary
QA/QC	quality assurance/quality control
ROM	Regional Oxidant Model
ROS	register of ships
SCC	source classification code
SFSC	Southeast Fisheries Science Center
SIP	State Implementation Plan
SO_2	sulfur dioxide
SPT	Skaugen Petrotrans
TEG	triethylene glycol
THC	total hydrocarbon
TIMS	Technical Information Management System
TOC	total organic compounds
3-D	three dimensional
2-D	two dimensional
USEPA	United States Environmental Protection Agency
VHS	very high frequency
VOC	volatile organic compounds

EQUATION UNIT DEFINITIONS

Unit	**Definition**
avg	average
bbl	barrel
Btu	British thermal unit
CF	conversion factor
°F	degrees Fahrenheit
fps	foot per second
ft	feet
ft^3	cubic feet
gal	gallon
g	gram
GOR	gas-to-oil ratio
H_2S	hydrogen sulfide
hp	horsepower
hr	hour
kW	kilowatt
kWh	kilowatt-hour
lb	pound
LF	load factor
LTO	landing and takeoff
m^2	meter squared
MMBtu	million British thermal units
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
tpy	tons per year
μmol	micromole
wt	weight

OVERVIEW

The U.S. Department of the Interior (USDOI) 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 offshore oil and gas exploration, development, and production sources do not significantly affect the air quality of any state. The Gulf of Mexico 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 87°30'W. longitude and the U.S. Environmental Protection Agency (USEPA) air quality jurisdiction eastward of 87°30'W. longitude. In addition, the CAAA requires BOEM to coordinate air pollution control activities with the state regulatory agencies. Therefore, to perform air quality impact assessments under OCSLA and to coordinate with states under the CAAA, there will be a continuing need for emission inventories and modeling.

To assess the emissions of offshore oil and gas platforms and their associated emissions, BOEM conducted limited emission inventories in the Gulf of Mexico (GOM) OCS in the 1980s. BOEM has since completed the following emission inventories: the Gulf of Mexico Air Quality Study (Systems Applications International et al. 1995) in 1995; the Gulfwide Emission Inventory Study for the Regional Haze and Ozone Modeling Effort (Wilson et al. 2004) and the Data Quality Control and Emissions Inventories of OCS Oil and Gas Production Activities in the Breton Area of the Gulf of Mexico Study (Billings and Wilson 2004) in 2004; the Year 2005 Gulfwide Emission Inventory Study (Wilson et al. 2007) in 2007; the Year 2008 Gulfwide Emission Inventory Study (Wilson et al. 2010) in 2010; and the Year 2011 Gulfwide Emission Inventory Study (Wilson et al. 2014) in 2014. As the offshore sources are changing due to new technology and drilling in deep waters and because of the continuing need for impacts assessments as required under OCSLA, BOEM continues to update the emissions inventories every three years to coincide with the USEPA and state agency onshore inventory process.

The BOEM Gulf of Mexico OCS Region office sponsored this project, the Year 2014 Gulfwide Emissions Inventory Study (BOEM Contract No. M13PC00005), which builds on the previous inventory studies and has the goal of developing a calendar year 2014 air pollution emissions inventory for all OCS oil and gas production-related sources in the GOM west of 87.5 degrees longitude, as well as sources that are not associated with oil and gas production. Pollutants covered in this inventory are the criteria pollutants—carbon monoxide (CO), lead (Pb), nitrogen oxides (NO_x), sulfur dioxide (SO_2), particulate matter-10 (PM_{10}), particulate matter-2.5 ($PM_{2.5}$); along with PM precursor ammonia (NH_3), and ozone precursor volatile organic compounds (VOC), as well as major greenhouse gases (GHGs)—carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). This is the first inventory cycle to include Pb and NH_3. The platform and non-platform emission inventory files are provided in Microsoft® Access® format. Documentation of the structure of these files is provided in the ReadMe Microsoft® Word files.

Like the previous emission inventory studies, the 2014 Gulfwide Offshore Activities Data System (GOADS-2014) software was created to collect monthly activity data from platform sources from operators. The activity data from the platform sources were combined with the most recent emission factors published by the USEPA and Emission Inventory Improvement Program (EIIP) emission estimation methods to develop a comprehensive criteria pollutant and GHG emissions inventory. Non-platform emission estimates were developed for sources such as drilling rigs, marine vessels, and helicopters that support oil and gas production, and other sources including marine vessels that do not support oil and gas production and the Louisiana Offshore Oil Port (LOOP) based on activity data obtained from numerous sources combined with the most accurate emission factors available. Ultimately, state agencies and Regional Planning Organizations will use these offshore oil and gas platform and non-platform inventories to perform modeling for ozone and regional haze for use in their State Implementation Plans (SIPs), and BOEM will use the emission inventory for the cumulative impact analysis in pre-lease National Environmental Policy Act (NEPA) Environmental Impact Statement (EIS) documents.

Figure 0-1 shows the overall contribution of OCS oil and gas production platform and non-platform sources to all criteria pollutant emission estimates (sum of the CO, NO_x, Pb, PM_{10}, SO_2, and VOC estimates). Commercial marine vessels make up 47% of the criteria pollutant emissions, followed by platforms, which make up 24%. Specific to OCS oil and gas production platform and non-platform source emissions combined, they account for 72% of the total CO emissions, 36% of NO_x emissions, 30% of PM_{10} emissions, 12% of SO_2 emissions, and 56% of VOC emissions. However, the OCS oil and gas production platform and non-platform sources combined emit 60% of the GHG emissions based on carbon dioxide equivalents[1] (CO_2e), and 99% of the CH_4. Natural gas engines on platforms represented the largest CO emission source, accounting for 49% of the total estimated CO emissions.

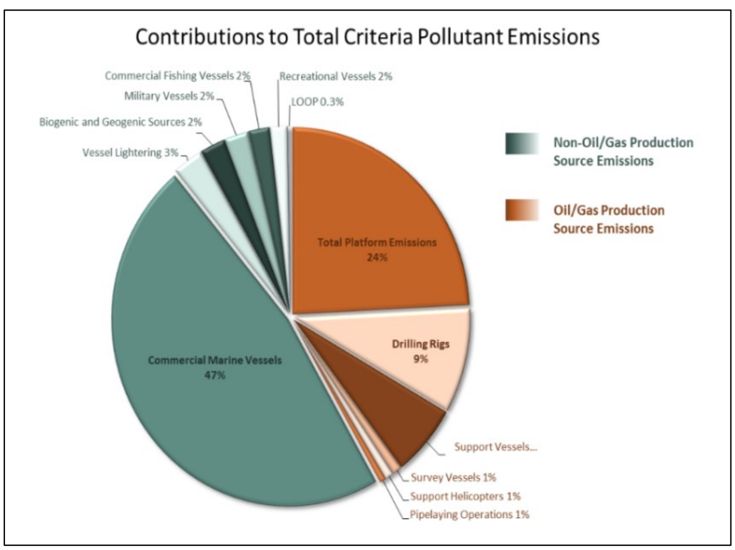


Figure 0-1. Contributions to total criteria pollutant emissions

[1] Based on Global Warming Potentials of 25 for CH_4 and 298 for N_2O.

Commercial marine vessels (not OCS oil and gas production-related sources) were the highest emitters of NO_x, PM_{10}, and SO_2, emitting 57% of the total NO_x emissions, 63% of total PM emissions, and 84% of total SO_2 emissions in the GOM.

Oil and natural gas production platform vents and fugitive sources account for the highest percentages (22% and 20%, respectively) of the VOC emissions. Production platform natural gas, diesel, and dual-fuel turbines (12% of total CO_2e emissions), and commercial marine vessels (32% of total CO_2e emissions) emit the majority of the GHG emissions. Production platform vents and fugitive sources are by far the largest sources of CH_4 in the 2014 inventory, emitting a combined 71% of total emissions for that pollutant.

Comparisons of pollutant-specific emission estimates for all sources in the inventory between 2011 and 2014 show a decrease in the overall annual emission estimates for 2014. The emission estimates for oil and natural gas production platform and non-platform oil and gas production-related sources drive this decrease, which is offset somewhat by an increase in the estimated emissions for commercial marine vessels. The most significant decreases for the oil and natural gas production sources (platforms and non-platform production-related sources) are in the SO_2 (73% decrease), PM (68% decrease), and NO_x (60% decrease) annual emission estimates. CH_4 emissions decreased 17% from 2011 to 2014.

For oil and natural gas production platforms, all emission estimates show significant annual decreases (Figure 0-2). Although the emission estimation methods and emission factors for platform sources included in this study are similar to those used in the Year 2011 Gulfwide Emission Inventory Study (Wilson et al. 2014), fewer active platforms were included in the 2014 inventory. BOEM determined that approximately 250 platforms (10% of active OCS platforms) were unaccounted for in the 2014 inventory. Approximately 29 were reported as removed according to the USDOI Bureau of Safety and Environmental Enforcement (BSEE) Technical Information Management System (TIMS), a repository of information on BOEM offshore oil and gas production leases, but either a partial year of GOADS data was still expected or no confirmed removal date had been reported. Another 107 missing platforms were reported in previous inventories, but were not included in the GOADS-2014 submittals to BOEM. A review of the companies associated with the non-reported platforms found indication that three companies were sold since the 2011 inventory (11 platforms). Previous inventory reporting compliance reviews have shown that a change in ownership can result in overlooked GOADS reporting (i.e., the neither owner provides GOADS data) or can cause confusion over who should report if purchased mid-inventory year. Another reason previously-reported platforms might have been omitted is due to the decline in oil and gas prices; some companies have, or are in the process of, declaring bankruptcy. Nine companies (accounting for 70 platforms) were found to be in some level of bankruptcy or reorganization. During bankruptcy/reorganization, staff turnover may hinder GOADS reporting. Another 23 of the previously-reported platforms had removal dates after 2014 reported in TIMS. It is possible the operators failed to submit these platforms since they were offline or poised to be offline by the GOADS submission deadline.

The TIMS data also indicated 107 that did not report in 2014, and had not reported in 2011 either. The TIMS installation date indicates data should been submitted for 105 of these platforms in 2011, and most of the previous inventories. Additionally, 17 have removal dates after 2014. Given these platforms have failed to respond in multiple inventories suggests these platform as persistent non-reporters. Of these 107 persistent non-reporters, 38 are flagged in TIMS as major (i.e., non-minor) platforms.

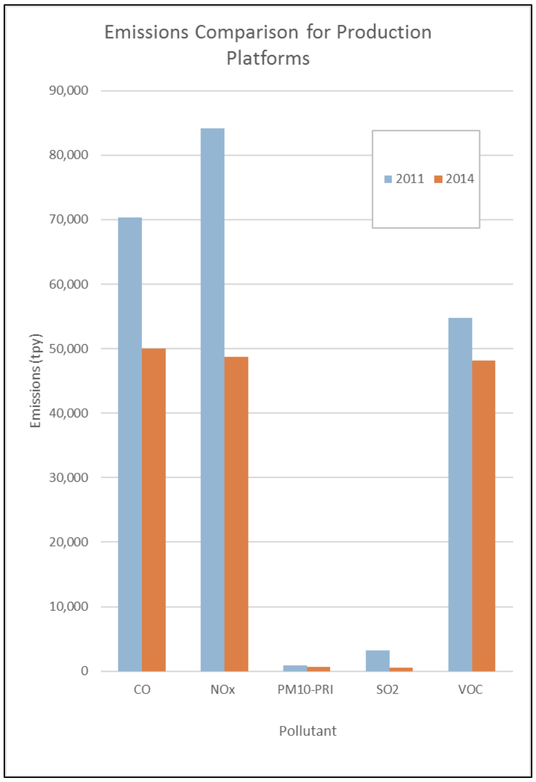


Figure 0-2. Emissions comparison for production platforms

The most notable annual decrease in the platform emission estimates from 2011 to 2014 is the 84% decrease in SO_2 emissions (2,700 tons). This reduction is driven for the most part by natural gas, diesel, and dual fuel turbines due to decreased fuel use and reduced diesel fuel sulfur content. NO_x emissions decreased by 42% (35,400 tons), with all combustion source emission estimates decreasing. VOC and PM_{10} emissions decreased less drastically, but the 2014 emission estimates still show a 12% decrease in VOC emissions (6,500 tons) and a 20% decrease in PM_{10} emissions (170 tons). The VOC emissions associated with pneumatic pumps is the only equipment category where emissions increased from 2011 to 2014. As noted in this report, there are significant limitations associated with these emission estimates, because of uncertainty in not only the number of pneumatic pumps that were reported, but the fuel usage rates used to estimate these emissions as well. The decrease in PM_{10} emissions is again associated primarily with combustion sources. The GHG emission estimates show a similar change from 2011 to 2014, with CH_4 emissions decreasing by 17% (45,700 tons). Only fugitive sources and pneumatic pumps show higher 2014 estimates for CH_4. The limitations in the activity data collected for both fugitive sources and pneumatic pumps, along with the out-of-date fugitive source emission factors, call into question the validity of these emission estimates, however.

A comparison of the 2011 and 2014 emission estimates for all non-platform sources indicates a less significant annual decrease in emission estimates, because non-OCS production-related source emissions increased substantially for almost all pollutants (Figure 0-3). The emission estimates for commercial marine vessels drive this increase. Emissions associated with non-platform OCS oil and gas production-related vessels decreased largely due to the use of AIS data, which provides more accurate estimates of the vessels operating in the GOM, their power ratings, and propulsion engine load estimates. Most significantly, the NO_x emission estimate for OCS oil and gas production-related vessels, driven predominantly by support vessels, decreased by 67% (155,000 tons), and the SO_2 emission estimate, driven by drilling rigs, decreased by 71% (16,000 tons). There were, however, increases in SO_2 emissions for pipelaying (550 tons) and survey vessels (280 tons) due to the inclusion of USEPA engine Category 3 vessels not previously identified in the GOM inventories. These Category 3 vessels use higher sulfur fuels than the Category 1 and 2 vessels. Survey vessels also had higher VOC emissions (275 tons) due to the inclusion of Category 3 vessels. A similar increase is not seen for pipelaying vessels because the speed at which they move impacts the engine operating loads. The emission estimates for non-OCS oil and gas production vessels, especially commercial marine vessels, were significantly higher in 2014 than 2011 for all pollutants. This is due to a more complete assessment of the vessels transiting the GOM in 2014, specifically the inclusion of cruise ships and dredging vessels that are not included in the previously used U.S. Army Corps of Engineers Entrance and Clearance data as they do not carry foreign cargo. These vessels were included in the 2014 AIS dataset, however. The GHG emissions essentially stayed constant compared to the 2011 inventory, as emissions associated with these pollutants are dominated by geogenic vents that are assumed to remain constant from year-to-year.

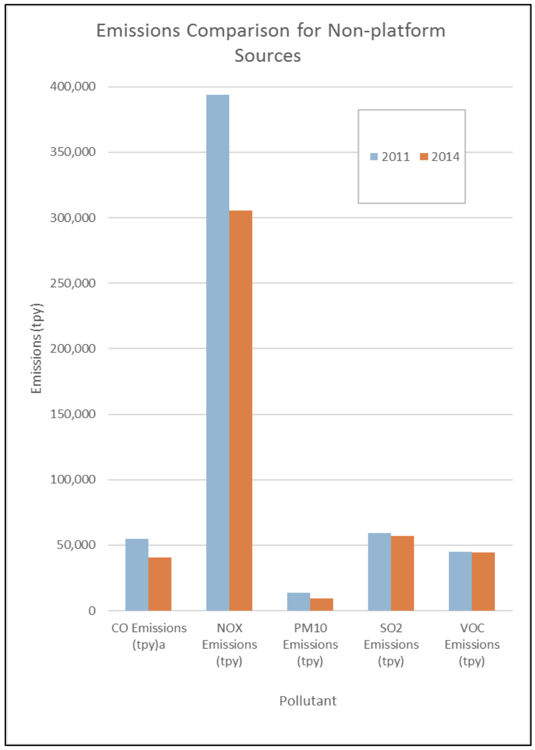


Figure 0-3. Emissions comparison for non-platform sources

The emission factors used to estimate emissions for the non-platform mobile source categories differ from those used in previous GOM inventories, as USEPA emission factors specifically representative of 2014 were used in this study. These updated emission factors include adjustments to account for compliance with the Annex VI North American Emission Control Area (ECA) fuel oil sulfur standards, which apply to both domestic and foreign-flagged vessels that traverse U.S. waters. The USEPA marine vessel emission factors vary by year because the data take into account changes in the implementation of marine fuel and engine exhaust standards and changes in the marine fleet due to the addition of new vessels and the retirement of older vessels. Including these elements within the emission factors allowed them to be used for all vessels regardless of vessel age, International Maritime Organization (IMO) emission standards by Tier, or if they are foreign-flagged. Additionally, automatic identification system (AIS) data were used to better assess vessels operating in the GOM. The AIS data provided a more comprehensive assessment of the actual vessel populations, often increasing the vessel count. When these vessels were matched to their specific engine characteristics in the IHS Register of Ships (ROS), the actual engine power data could be used; in many cases, the vessels' power rating was significantly less than the default power value used in earlier emission inventories. Furthermore, using AIS data allowed for quantification of the vessel's actual speed, which could be compared with the ROS design speed for each vessel. This allowed for calculation of the propulsion engine operating load, which was often less than the USEPA default value used in previous emission inventories. All of these updates to the marine vessel emissions calculations led to decreased overall vessel emission estimates.

In addition to evaluating the differences in the platform and non-platform emission estimates from 2011 to 2014, detailed analyses were conducted to assess the trends in the emission estimates for GOM OCS oil and gas production sources for all BOEM inventories between 2000 and 2014. Overall, emissions were found to be largely affected by three factors: 1) activity and production levels in the Gulf of Mexico by water depth and planning area, 2) changes in inventory methodologies, and 3) improvements in available emission factors. The total production trend to the emission estimates did not hold true for 2014, as higher production was paired with decreased emissions and number of platforms. It appears that the deepwater platforms account for an increasing portion of the emissions, despite only minor changes in the number of these platforms. It is possible that the disproportionate emissions at these larger platforms are affecting the overall correlation to production. That is, the production-to-emission ratio of these deepwater platforms is likely drastically different from the ratio for other water depths. It also possible that with the increased application of well stimulation and installation of subsea production systems, oil production was increased without installation of additional production platforms. Of the platforms thought to be missing from the 2014 inventory, the TIMS database has 56 flagged as major, fixed structures in deepwater (water depth greater than 250 feet). In addition, with the increased use of AIS data to track vessel movements and more detailed vessel attribute data, the non-platform emissions inventories have changed significantly over the inventory years, especially for sources associated with OCS oil and gas production activities. The increased resolution in the marine vessel identification and better quantification of activity makes it appear as if emissions from BOEM sources have decreased. In reality, the revisions to the methods are better at identifying vessel categories and quantifying their propulsion operations.

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 offshore 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 87°30'W. longitude and the U.S. Environmental Protection Agency (USEPA) air quality jurisdiction eastward of 87°30'W. longitude. Texas and Louisiana have coastal areas that are designated as nonattainment for the 2008 eight-hour ozone standard. Ozone forms in the presence of sunlight from the reaction of volatile organic compounds (VOC) and oxides of nitrogen (NO_x). Louisiana also has an area that is designated as nonattainment for sulfur dioxide (SO_2); Florida has two areas designated as nonattainment for SO_2. Alabama, Florida, and Texas each have an area that is designated as nonattainment for lead (Pb). The GOM region, along with air quality jurisdiction, nonattainment, and Class I areas are displayed in Figure 1-1.

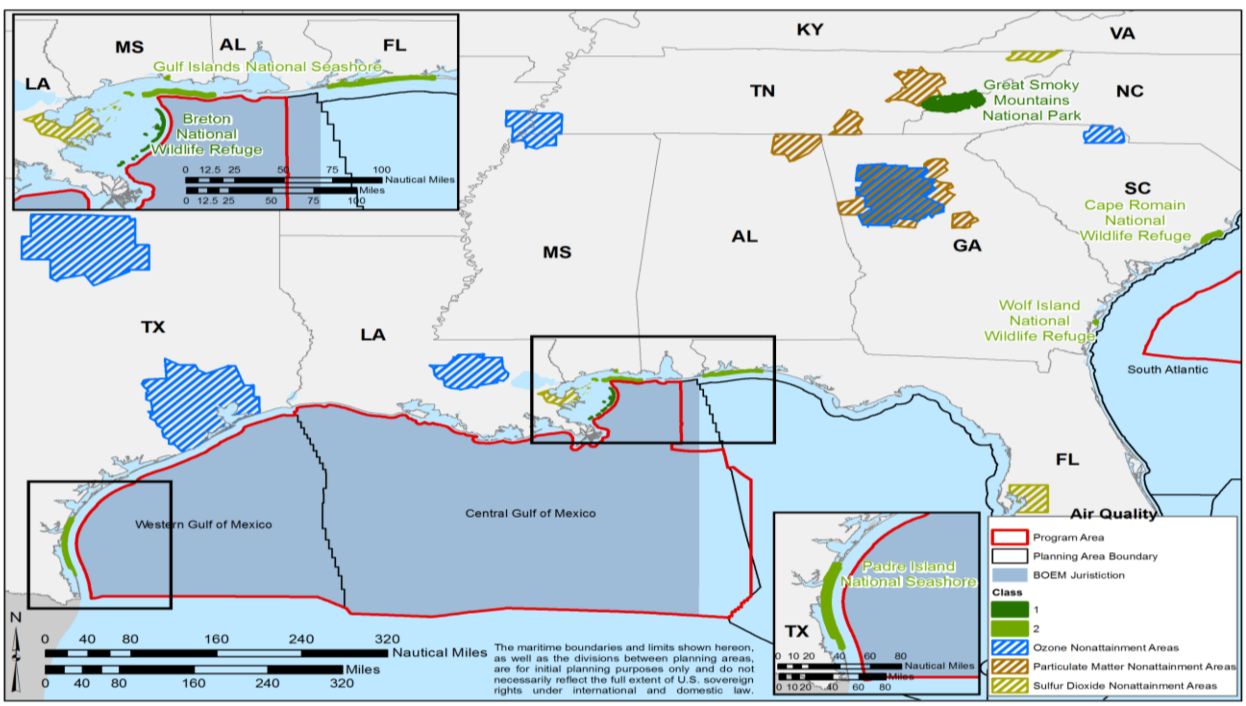


Figure 1-1. Gulf of Mexico region with the planning areas, nonattainment areas, air quality jurisdiction, and Class I (dark green) and Sensitive Class II (light green) areas

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 offshore 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 in the central and western GOM. BOEM launched a series of studies, beginning in the 1980s, to assess the emissions of offshore 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 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; it 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, and 2011 Gulfwide Emission Inventory Studies covered the same sources, pollutants, and geographic area as the 2000 inventory (Wilson et al. 2007; 2010; 2014). Updates were made to the GOADS-2005, GOADS-2008, GOADS-2011, and GOADS-2014 programs as needed.

The BOEM GOM OCS region office sponsored this project, the Year 2014 Gulfwide Emissions Inventory Study (BOEM Contract No. M13PC00005), with the goal of developing a calendar year 2014 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 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 VOC, as well as major greenhouse gases (GHGs)—carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

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 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 2014 is imperative, in that it not only provides the BOEM the essential tools to comply with the Congressional mandate to coordinate air pollution control regulations between OCS offshore and states onshore sources, but also provides BOEM the essential tools needed to assess offshore oil and gas activities impacts to the states as mandated by the OCSLA and provides the states the essential tools needed to perform their State Implementation Plan (SIP) demonstrations to the USEPA.

The goal of this project is to develop a calendar year 2014 air pollutant emissions inventory for all OCS oil and gas production-related sources in the GOM, including non-platform sources, 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 2014. The activity data were collected based on BOEM Notice to Lessees and Operators (NTL) No. 2014-G01, "2014 Gulfwide OCS Emissions Inventory (Western Gulf of Mexico)."

BOEM updated and distributed a Microsoft® Visual Basic® program (GOADS-2014) for platform operators to use to collect activity data for a number of 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, and N_2O. The Gulfwide Oracle® DBMS calculates and archives the activity data and the resulting emissions estimates. Users can query the final platform emissions database 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, and 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 database by pollutant, month, source, etc.

1.3 STUDY OBJECTIVES

The objectives of this study were to:

- Review, modify, and provide support services for GOADS-2014 and the 2014 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 one (1) calendar year (2014). Activity data from platform sources were collected using GOADS-2014.
- Calculate and archive a calendar year 2014 total emissions inventory using the most current emission factors and the 2014 Gulfwide DBMS for all specified platform sources.
- Collect activity data for non-platform sources and develop emission estimates using the most recent emission factors.
- Conduct a scoping study of the most predominant hazardous air pollutants (HAPs) emitted from combustion and non-combustion platform sources.
- Conduct emissions trends analyses to compare the 2014 emissions inventory with previous BOEM emission inventories.
- Provide the 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).

1.4 REPORT ORGANIZATION

Following this introduction, the Year 2014 Gulfwide 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, as well as the approach used to fill in data gaps in the platform data.
- Section 4 presents calculation methods for each piece of platform equipment. 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 2011 Gulfwide Emission Inventory Study Report (Wilson et al. 2014).
- Section 7 presents a summary of the detailed and comprehensive Emissions Trends Analysis conducted using the past five consecutive inventory studies from 2000-2014 to assess the long-term emissions trends in the GOM OCS emissions.
- Section 8 presents literature cited throughout the report.
- Appendix A presents the methods and results of the HAPs scoping task.
- Appendix B presents details on the methods and results of an in-depth emissions trends analysis.
- Appendices C.1, C.2, and C.3 provide details on the development of the non-platform emissions inventory for vessels and helicopters.

2. DATA COLLECTION FOR PLATFORM SOURCES

2.1 INTRODUCTION

To develop a calendar year 2014 inventory of criteria pollutants, criteria precursor pollutants, and GHG emissions for all OCS oil and gas production-related platform sources in the GOM, BOEM collected monthly activity data for 2014 from platform operators using the GOADS-2014 software. On October 15, 2013, NTL 2014-G01 was published to introduce the "2014 Gulfwide OCS Emissions Inventory (Western Gulf of Mexico)" and inform operators about the mandatory data collection. Affected operators were lessees and operators of federal oil, gas, and sulfur leases in the GOM OCS region west of 87° 30' longitude. The USEPA has air quality jurisdiction east of 87° 30' longitude.

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 2014 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, and 2011 platform activity data was revised for this study to address several issues uncovered during its use for preparing previous inventories. The largest improvements to the new version, GOADS-2014, was the addition of loading operations and the requirement that data be provided for all platforms, including minor sources. Previously, operators were able to simply flag minor sources and BOEM developed surrogate emission estimates.

2.3 WORKING WITH USERS

The User's Guide for the 2014 Gulfwide Offshore Activities Data System (GOADS-2014) (Wilson and Boyer 2014) (User's Guide) was the primary source of information for operators. The guide contains instructions on installing, starting, and exiting the GOADS program, creating and editing data, quality control, and saving and backing up files. For details on the GOADS-2014 program, refer to the User's Guide (Wilson and Boyer 2014). The guide was made available to all users on the BOEM website, where it could be downloaded and printed. GOADS Installation Instructions and a Frequently Asked Questions (FAQs) document were also provided.

2.4 GOADS QUALITY ASSURANCE/QUALITY CONTROL

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 a printout 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 runs a series of QC checks (discussed in Section 4) on the data when the operator saves the data. If the operator leaves a field blank, provides data that are out of range, or enters a value that is not consistent on a month-to-month basis, an error message will appear. The operator may 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 offshore industry averages and through discussions within BOEM.

3. QUALITY ASSURANCE/QUALITY CONTROL

3.1 INTRODUCTION

Platform operators submitted data files and QA Summary Forms generated by the GOADS-2014 software. Seventy-five companies submitted data for 1,856 active or inactive platforms (combination of complex ID and structure ID) and identified an additional 525 platforms as being decommissioned. This accounts for about 90% of OCS platforms, including minor sources. Active structures (at least one month) numbered 1,651. Thus, approximately 250 platforms are unaccounted for in the year 2014 inventory. It should be noted that surrogate emission estimates were not assigned to the missing platforms. Because operators previously reported minor source platforms without equipment data for the 2008 and 2011 inventories, the number of platforms reported was not expected to increase significantly due to the requirement to report equipment activity for minor sources for the 2014 inventory.

Further inspection of these 250 missing platforms suggests possible reasons for the missing platforms. Approximately 29 were reported as removed in the Bureau of Safety and Environmental Enforcement (BSEE) Technical Information Management System (TIMS), but either a partial year was still expected (27 platforms) or no confirmed removal date had been reported (2 platforms).

A review of the companies associated with the non-reported platforms found indication that 3 companies were sold since the 2011 inventory (17 platforms). Previous inventory reporting compliance reviews have shown 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. TIMS further indicated that some of these platforms were removed prior to (7 platforms), during (1 platform), or after (7 platforms) 2014. It is possible the operator failed to submit these platforms since they were offline or poised to be offline by the GOADS submission deadline.

Another reason a previously reported platform may be omitted is because of the decline in oil and gas prices; some companies have or are in the process of declaring bankruptcy. Reviewing each of the remaining platforms, nine companies (accounting for 87 platforms) were found to be in middle of some level of bankruptcy or reorganization. During bankruptcy or reorganization, staff turnover typically increases and regular reporting can fall through the cracks.

The TIMS data also indicated 74 that did not report in 2014, and had not reported in 2011 either. The TIMS installation date indicates data should been submitted for these platforms in 2011, and most of the previous inventories. Given these platforms have failed to respond in multiple inventories suggests these platform as persistent non-reporters. Finally, 7 of the 250 platforms did have their 2011 information requested by their operators, but no 2014 data were returned. 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
Possible bankruptcy	87	35%
Previous non-reporter	74	30%
Installed in 2014	2	1%
Removed after 2014	18	7%
Removed during 2014	27	11%
Possible removal (no date)	2	1%
Possible sale	2	1%
Possible sale; removal during 2014	1	0%
Possible sale; removal prior to 2014	7	3%
Possible sale; removal after 2014	7	3%
Operator requested, no data returned	3	1%
Undetermined	20	8%

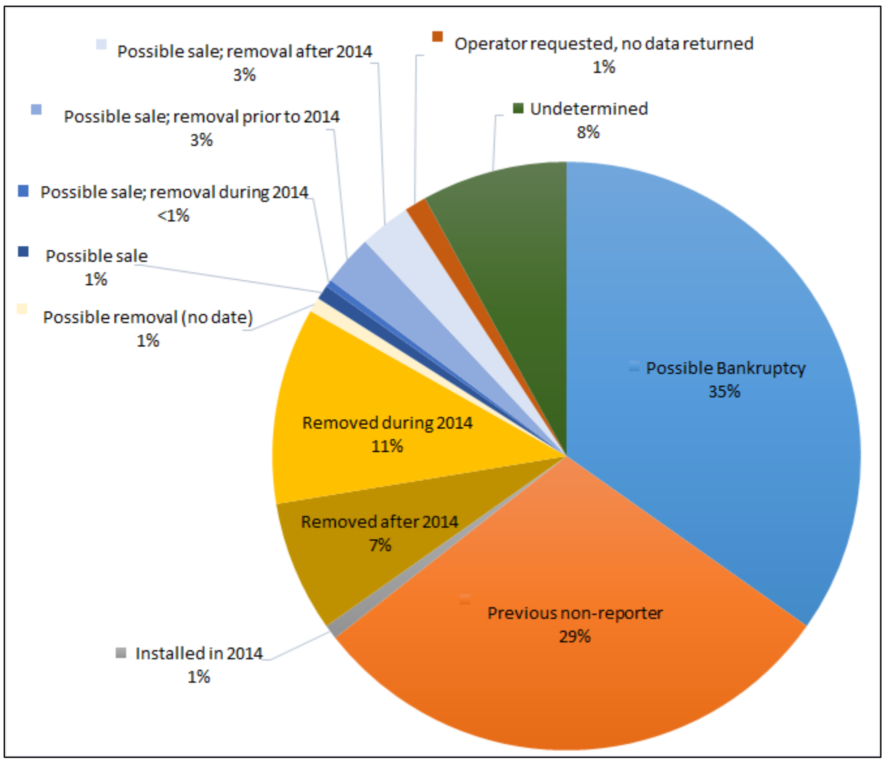


Figure 3-1. Summary of non-reporters

This section summarizes the data received, the steps BOEM took to review the GOADS-2014 descriptive and monthly activity data for completeness and accuracy, and the types of errors encountered. Also discussed in this section are the procedures used to correct and gap-fill missing data, including stack parameter data provided by the operators. When operators failed to enter data or entered data that were atypical or suspect, BOEM attempted to reconcile the data by reviewing the comments, contacting the operators, or developing surrogate data. Operators were also given an opportunity to review the draft platform emission inventory files, and BOEM incorporated suggested revisions provided prior to release of the final emissions inventory.

Information on the QA/QC of the non-platform marine vessels emission estimates can be found in Section 5.4 and Appendix C.1, which focuses on differences in the emission estimates developed using automatic identification system (AIS) data rather than previously-used assumptions about the vessel characteristics and usage.

3.2 Checking File Integrity

BOEM received 85 unique data files for the 1,651 active platforms. All electronic data were in the prescribed Microsoft® Access® database format that was created by the GOADS-2014 software. For comparison, 101 unique data files were submitted for the calendar year 2011 inventory for 2,544 active platforms. More information on this reporting discrepancy is provided in Section 6. Unlike the calendar year 2011 inventory, BOEM required minor sources to report actual equipment data through GOADS-2014. It was not anticipated that this would directly impact the number of minor sources included in the inventory, but would eliminate the need to use surrogate emission estimates for these sources.

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-2014 submittal contained templates for up to 38 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 nine platforms' structure and/or complex IDs and corrections were made to the locational data for 78 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 29,432 records were submitted, and 18,971 were considered active (64.5%). For comparison, 29,887 active records were submitted for calendar year 2011.

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 229,754 equipment surveys, of which 168,559 were active (73%).

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 reported sales gas composistions were totaled. The sum of compositions that deviated from 100% were evaluated and corrected. Questionable sales gas compositions were replaced with a default set of compositions. Less than 2% of the monthly equipment 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 83 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 values application; and 6) post-processing of surrogates. After performing these QA/QC checks and the developing draft emissions estimates, BOEM sent 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 3.4.8.

3.4.1 Pre-Processing

BOEM performed three pre-processing steps before beginning the rigorous 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, if a drilling rig engine was flagged "No Emissions to Report" but hours of operation were reported, there was diesel use reported at the platform-level for that month, 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, then the drilling rig engine was considered to be active for the month.

Platform/ and equipment surveys were also considered active based on the following: 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 47% 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 GOADS program does not populate the activity status for the fugitive equipment type; therefore, the activity status needed to be populated for almost all fugitive records. The activity status field was populated for a small number of fugitive records in the GOADS submittals that were received, because some operators made updates directly in the Microsoft® Access® database file instead of using the GOADS program. Fugitive records accounted for about half of the equipment activity status updates. For other equipment types, GOADS-2014 automatically flags a record as active when a monthly record is created, but its status is actually inactive when zero values are entered for throughput or fuel use. Changing these records to inactive status accounts for the majority of the remaining 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 3% 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 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. Approximately 2% of the monthly fuel usage records required corrections in this process.

3.4.2 Equipment Survey Consistency

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 was examined. For example, 11 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 missing or different value was populated to match the other platform equipment surveys if it was believed that a data entry error occurred. Less than 1% of the monthly equipment records required corrections in this process.

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. For example, some operators mistakenly entered incorrect gas throughput for glycol dehydrators. The processed gas throughput for a glycol dehydrator is not expected to exceed 15,500 million standard cubic feet (MMscf) per month. However, some equipment surveys had omitted a decimal or reported incorrect units of Mscf/month resulting in values greater than 50,000 MMscf/month. To correct this specific error, the glycol dehydrator throughputs were compared to the platform-level natural gas throughput to confirm the correct order of magnitude. Other types of out-of-range values included out-of-range stack parameters and weight percent VOC being reported as a fraction (e.g., 0.296 instead of 29.6). Approximately 3.5% of the monthly equipment records required corrections in this process.

The GOADS-2014 QC checks flag these incorrect data, as indicated by the limited number of corrections needed. Unfortunately, there was clear evidence that some databases were not populated with the GOADS software as they contained invalid equipment type codes, mismatching equipment type codes, and database relational integrity errors.

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 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 cold vent or combustion flare ID was populated in these tables, then a downstream analysis was performed on the cold vent or combustion flare equipment tables to verify their existence. 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

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 could be calculated for exit velocity and exhaust volume flow rate from the submitted data. Other surrogate data were developed from industry averages. Approximately 10% of the monthly equipment records required corrections in this process.

3.4.6 Post-Processing of Surrogates

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.

Table 3-3. Surrogate stack parameters used to supplement GOADS-2011 data

Unit	Field	Default Value
Amine Unit	Elevation (above sea level)	50 feet
Amine unit–ventilation system for acid gas from reboiler	Exit velocity (ft/sec)	Calculated with AMINECalc[a]
Amine unit–ventilation system for acid gas from reboiler	Exit temperature	110 ^{o}F
Amine unit–ventilation system for acid gas from reboiler	Combustion temperature	1832 ^{o}F
Boiler, heater, and burner	Elevation (above sea level)	50 feet
Boiler, heater, and burner – exhaust system	Exit temperature	400 ^{o}F
Boiler, heater, and burner – exhaust system	Outlet orientation	0 degrees
Boiler, heater, and burner – exhaust system	Outlet diameter	12 inches
Boiler, heater, and burner – exhaust system	Exit velocity	Calculated
Diesel or gasoline engine	Elevation (above sea level)	50 feet
Diesel or gasoline engine	Maximum rated fuel use	7,000 British thermal units (Btu)/horsepower per hour (hp-hr)
Diesel or gasoline engine	Average fuel use	7,000 Btu/hp-hr
Diesel or gasoline engine–exhaust system	Outlet height	7 feet above engine
Diesel or gasoline engine–exhaust system	Exit velocity	Calculated
Diesel or gasoline engine–exhaust system	Exit temperature	900 ^{o}F
Diesel or gasoline engine–exhaust system	Outlet orientation	0 degrees
Diesel or gasoline engine–exhaust system	Outlet diameter	12 inches
Combustion flare	Combustion temperature (excluding upsets)	1,832 ^{o}F
Combustion flare	Stack orientation	0 degrees
Combustion flare	Outlet diameter	12 inches
Combustion flare	Pilot feed rate	2.28 Mscf/day
Combustion flare	H_2S concentration	3.38 ppm
Glycol dehydrator	Elevation (above sea level)	50 feet

Unit	Field	Default Value
Glycol dehydrator–flash tank	Temperature	120 ^{o}F
Glycol dehydrator–flash tank	Pressure	60 pounds per square inch (psig)
Glycol dehydrator–ventilation system	Exit temperature	GLYCalc™ default (usually 212 ^{o}F)[b]
Glycol dehydrator–ventilation system	Outlet orientation	0 degrees
Glycol dehydrator–ventilation system	Flare feed rate (standard cubic feet (scf)/hr)	Calculated with GLYCalc™ [b]
Glycol dehydrator–ventilation system	Combustion temperature	1832 ^{o}F
Glycol dehydrator–ventilation system	Condenser temperature	110 ^{o}F (or calculated with GLYCalc™)[b]
Glycol dehydrator–ventilation system	Condenser pressure	14.8 pounds per square inch absolute (psia)
Losses from flashing–ventilation system	Exhaust volume flow rate	Calculated
Losses from flashing–ventilation system	Exit velocity	Calculated
Losses from flashing–ventilation system	Exit temperature	70 ^{o}F
Losses from flashing–ventilation system	Outlet diameter	Use tank vent outlet diameter
Natural gas engine	Max rated fuel usage	7,500 Btu/hp-hr
Natural gas engine	Average fuel usage	7,500 Btu/hp-hr
Natural gas engine–exhaust system	Exit velocity	Calculated
Natural gas engine–exhaust system	Exit temperature	4-cycle rich burn: 1,100 ^{o}F
Natural gas engine–exhaust system	Exit temperature	2-cycle lean burn: 700 ^{o}F
Natural gas engine–exhaust system	Outlet diameter	12 inches
Natural gas turbine	Max rated fuel use	10,000 Btu/hp-hr
Natural gas turbine	Average fuel use	10,000 Btu/hp-hr
Natural gas turbine–exhaust system	Exit velocity	Calculated
Natural gas turbine–exhaust system	Outlet diameter	12 inches
Natural gas turbine–exhaust system	Exit temperature	1,000 ^{o}F
Pneumatic pumps	Elevation (above sea level)	50 feet

Unit	Field	Default Value
Pneumatic pumps–ventilation system	Exit velocity	Calculated
Pneumatic pumps–ventilation system	Exit temperature	70 ^{o}F
Pressure and level controllers	Elevation (above sea level)	50 feet
Storage tank–general Information	Roof height above shell (feet)	0.0625*(Tank Diameter ÷2), feet
Storage tank–ventilation system	Exit velocity	Calculated
Storage tank–ventilation system	Exit temperature	70 ^{o}F
Storage tank–ventilation system	Outlet orientation	0 degrees
Storage tank–ventilation system	Flare feed rate	Calculated (or use the calculated storage tank exhaust volume flow rate)
Cold vent	Outlet elevation (above sea level)	50 feet
Cold vent	Outlet diameter	Calculated (average of submitted data)
Cold vent	Exit temperature	70 ^{o}F
Cold vent	Outlet orientation	0 degrees

[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).

3.4.7 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 drescribed above for operating hours, fuel usage, survey consistency, range checks, stream analysis, and application of surrogate values. There were six active amine units reported for the 2014 inventory, and four out of six were revised during the QA/QC process to correct operating hours and/or missing exit gas temperature. The majority of revisions for combustion equipment were due to corrections to fuel usage and operating hours. Most revisions to cold vents and combustion flares were to correct operating hours reported as 0 where the reported volume vented or flared was greater than 0. Most revisions for fugitive records were to correct out of range weight percent VOC where the operator reported a weight fraction rather than a weight percent. 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 loading operations or mud degassing data. Most of the revisions for pressure and level controllers and pneumatic pumps were due to the application of surrogate fuel use rates where those values were not reported. The fuel use rate field was optional for pneumatic pumps and pressure and level controllers for the 2014 inventory, but will be a required field for the 2017 inventory. Revisions to storage tanks were based on the survey consistency, application of surrogate values, stream analysis, and range check QA steps.

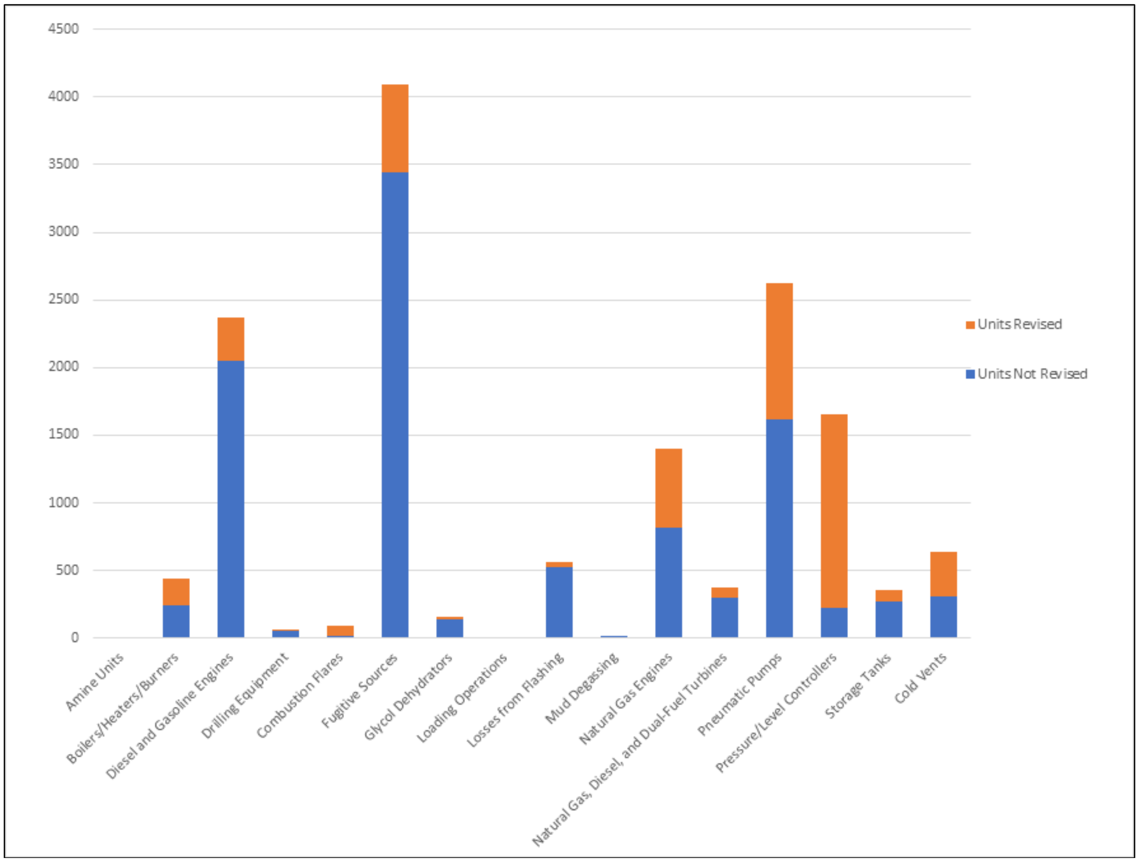


Figure 3-2. Revisions by equipment type

3.4.8 Incorporation of Draft Inventory Revisions

In February 2016, BOEM afforded platform operators the opportunity to review the draft 2014 Gulfwide emissions inventory files. Of the 71 companies that submitted GOADS-2014 files, 31 companies provided either revisions or confirmation that the activity data used to develop the emissions estimates were correct and no revisions were needed. The majority of revisions received were for diesel engines, followed by flares. BOEM incorporated the revisions provided into the final emissions inventory.

4. DEVELOPMENT OF THE PLATFORM EMISSION INVENTORY

4.1 INTRODUCTION

The goal of this study is to develop criteria pollutants, including criteria precursor pollutants, and GHG emission inventories for all oil and gas production-related sources in the GOM OCS. To achieve this goal, BOEM revised the 2011 Gulfwide Oracle® DBMS to create the 2014 Gulfwide Oracle® DBMS. The 2014 Gulfwide DBMS imports the activity data provided by platform operators through the use of the GOADS-2014 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, and N_2O.

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 BOEM recommended values. For example, the diesel fuel sulfur content is consistent with BOEM "Spreadsheet for Exploration Plans."

Natural gas H_2S content	= 3.38 parts per million volume (ppmv)
Diesel fuel sulfur content	= 0.05 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	= 95%
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 2011 Gulfwide DBMS (Wilson et al. 2014). The exceptions are the default diesel fuel sulfur content used for diesel engines, turbines, and drilling equipment (the default was revised to 0.05% to represent the use of low-sulfur fuel), the uncontrolled NO_x emission factor for natural gas boilers, the PM_{10} emission factor for diesel boilers, and the emission factors for CO and NO_x for combustion flares. Adjustments were also made to the speciation profiles used for VOC and CH_4 for mud degassing, and CO_2 emission estimates were added for amine units and glycol dehydrators. The following sections present the methods used to calculate criteria pollutant and GHG emissions from platform sources in the study.

4.2.1 Amine Units

Some platforms produce natural gas containing unacceptable amounts of hydrogen sulfide. While 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 six amine units. Operators were required to use the "Model Inputs" tab. CH_4, CO_2, and VOC emissions are 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, or a sulfur recovery unit, and 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).

$$E_{SO_2,control} = E_{H2S}\left(\frac{lb \cdot mol_{H_2S}}{34\,lb_{H_2S}}\right) \times \left(\frac{64\,lb_{SO_2}}{lb \cdot mol_{SO_2}}\right) \times \left(\frac{Eff_{SO_2}}{100}\right)$$

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 recover unit was present, it was assumed that the Claus sulfur recovery process was used, in which one third of the H_2S emissions are burned to produce SO_2 and water (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 441 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 4-1 through 4-3). These factors come from *AP-42*, Sections 1.3 and 1.4 (USEPA 2014). 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 4-1. Emission factors for liquid-fueled units – diesel

Pollutant	Emission Factors ($lb/10^3$ gal)
VOC	0.20
Pb	1.22×10^{-3}
SO_2[a]	$142 \times S$
NO_x[b, c]	24.00
$PM_{2.5}$	0.25
PM_{10}	1.00
NH_3	0.80
CO	5.00

Pollutant	Emission Factors (lb/10^3 gal)
N_2O	0.26
CH_4	0.05
CO_2	22,300.00

[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.

Table 4-2. 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	1.51×10^{-3}
SO_2 [a]	$157 \times S$
NO_x [b, c]	47.00
$PM_{2.5}$	$5.23 \times S + 1.73$
PM_{10}	$9.19 \times S + 3.22$
NH_3	0.80
CO	5.00
N_2O	0.53
CH_4	1.00
CO_2	24,400.00

[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.

Table 4-3. Emission factors for gas-fueled units–natural gas or process gas where max rated heat input ≥ 100 MMBtu/hr

Pollutant	Emission Factors (lb/MMscf)
VOC	5.50
Pb	5.00×10^{-4}
SO_2	0.60
NO_x [a, b]	280.00
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

[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 $PM_{2.5}$.

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 2014). Activity data were submitted for 2,369 engines. 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, was used to estimate emissions. The surrogate fuel consumption rate was not applied to any of the active units during the QA/QC process; however, some operators reported a fuel use rate equal to the surrogate fuel consumption rate.

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 4-4 through 4-6). These factors come from *AP-42*, Sections 3.3 and 3.4 (USEPA 2014).

Table 4-4. 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

Table 4-5. 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

Table 4-6. Emission factors for diesel engines where max HP ≥ 600

Pollutant	EF_{fu} (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
CO	0.850
CH_4	0.008
CO_2	165.000

[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 60 drilling units, all of which reported only diesel fuel usage.

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

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

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):

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

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 4-7 through 4-9). These factors come from *AP-42*, Sections 3.2, 3.3 and 3.4 (USEPA 2014). 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 4-7. 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 4-8. 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

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

Table 4-9. 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

[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 88 combustion flares.

Flare emissions for THC, VOC, NO_x, PM_{10}, and CO 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)

If the user indicated there was a continuous flare pilot, 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 were used to estimate emissions (Tables 4-10 and 4-11). Other than VOC and CH_4 for combustion flares, the emission factors come from *AP-42*, Sections 13.5 and 1.4 (USEPA 2014). The VOC and CH_4 emission factors were derived from the default sales gas composition shown in Table 4-26 of this report based on the weight fraction of the volatile components.

Table 4-10. Emission factors for combustion flares[a]

Pollutant	EF (lb/MMBtu)
VOC	0.006
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
CH_4	0.126
CO_2	114.285

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

Table 4-11. Emission factors for pilots

Pollutant	EF (lb/MMscf)
VOC	5.5
Pb	5.0×10^{-3}
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

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

If the corresponding fields were null, the following surrogate values (based on industry defaults) 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 were not assigned to any active units for the 2014 Inventory. The emission factors shown in Table 4-13 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 the Year 2005 Gulfwide Emission Inventory Study that platforms may not all be operating under stable conditions, however, BOEM reviewed the flare velocities to ensure that all were less than 400 foot per second (fps), reflective of stable conditions (TCEQ 2011). No flares had reported exit gas velocities greater than 400 fps; therefore, the emission factors for VOC and CH_4 did not need to be adjusted for any flares.

During their review of the draft inventory, several platform operators noted that they included the pilot volume in the reported total volume flared, and that pilot emissions should not be calculated separately for those flares. Pilot emissions were removed from the inventory for 55 flares reported by 12 companies.

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 provide an equipment inventory (number of components). Fugitive records were submitted for 86% of the active platforms.

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 4-12)
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 4-12. 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 2014 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 2014 inventory, which were resubmitted without revisions for 2014. 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 2014 inventory, possibly due to stream type being carried forward without revision from previous inventories. The default values in Table 4-13 were assigned if the average VOC weight percent field was blank.

Table 4-13. 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.

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). Surrogate VOC glycol dehydrator still column vent emission estimates were calculated based on regression equations from GRI-GLYCalc™ Version 4.0 (GTI 2000) computer program runs for varying combinations of wet gas pressure and wet gas temperature. Surrogate glycol dehydrator flash tank vent emissions were also calculated based on regression equations from GRI-GLYCalc™ Version 4.0 computer program runs for varying combinations of flash tank pressure and flash tank temperature. Activity data were submitted for 155 glycol dehydrators. Table 4-14 presents the surrogate gas analysis (based on industry averages) used in the runs.

The VOC emission rate in pounds per hour is directly proportional to the volume of gas dehydrated if all other variables are held constant. Thus, emission factors from the GRI-GLYCalc™ runs were developed to express VOC emissions in pounds per hour (lbs/hr) per MMscfd processed. For still column vents, VOC emission factors were developed for over 60 combinations of wet gas pressure and temperature. The emission factors range from 0.0126 lb VOC/hr-MMscfd at a pressure of 1,200 psig and temperature of 50°F to 0.3357 lb VOC/hr-MMscfd at a pressure of 600 psig and temperature of 130°F.

For glycol dehydrator flash tanks, VOC emission factors were developed for over 120 combinations of wet gas pressure and temperature, and flash tank pressure and temperature. The lowest emission factor is 0.03457 lb VOC/hr-MMscfd at a wet gas pressure of 1,100 psig and temperature of 70°F and flash tank pressure of 100 psig and temperature of 75°F. The highest emission factor is 0.09282 lb VOC/hr-MMscfd at a wet gas pressure of 800 psig and temperature of 90°F and flash tank pressure of 50 psig and temperature of 125°F.

BOEM used the following assumptions based on industry standards to estimate emissions:

- The wet gas is saturated.
- The volume of dry gas is constant at 10 MMscfd. The dry gas water content is 7 lbs water per MMscf gas.
- The triethylene glycol (TEG) circulation rate is 3 gallons/lb water removed.

- A gas injection pump is used to recirculate the TEG.
- If a flash tank is present, the flash tank is vented to the atmosphere.
- No stripping gas is used.

Table 4-14. Surrogate gas analysis for GLYCalc™ runs

Component	Mole Percent (%)
H_2S	0.000
Nitrogen	0.100
CO_2	0.800
CH_4	94.500
Ethane	3.330
Propane	0.750
n-Butane	0.150
Iso-Butane	0.150
N-Pentane	0.050
Iso-Pentane	0.050
Iso-Hexanes	0.077
N-Hexane	0.018
Benzene	0.004
Toluene	0.003
Ethylbenzene	0.000
Xylenes	0.001
Trimethylpentane	0.003
Heptanes	0.008
Octanes	0.006
Nonanes	0.000
Decanes +	0.000

Because the GRI-GLYCalc™ emissions output does not provide CO_2 emissions estimates, emission estimates for CO_2 were developed using an emission factor of 372.2 lbs CO_2 per year. This is based on the emission factor used in the USEPA's Greenhouse Gas Reporting Program for petroleum and natural gas systems (Subpart W) (Federal Register 2009). The annual factor was adjusted to represent monthly values for months the unit was active. The ratio of the monthly gas throughput to total annual gas throughput for each dehydrator was used to allocate the emissions to monthly values.

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 uncleaned, 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 2014):

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

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 4-15)
a	=	Tank paint solar absorptance (Table 4-16)
I	=	Daily solar insulation factor ($Btu/ft^2 \cdot day$) = 1,437 $Btu/ft^2 \cdot day$[a]

Table 4-15. Monthly 2014 average ambient temperature

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
F	52	55	60	69	74	81	82	83	81	76	61	61
R	512	515	520	529	534	541	542	543	541	536	521	521

Source: U.S. DOC, National Climatic Data Center 2015.

Table 4-16. Tank paint solar absorptance

Paint Color	Solar Absorptance by Paint Color and Condition	
	Paint Condition	
	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). Only 317 platforms provided activity data for losses from flashing.

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:

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

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)

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:

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

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.

The following surrogate values were used for the corrected specific gravity of gas.

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

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 17 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 on 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 follows (USEPA 1977):

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, was applied.

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 2014). Activity data were submitted for 1,402 natural gas engines.

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, was used to estimate emissions. The surrogate fuel consumption rate was not applied to any of the active units during the QA/QC process; however, some operators reported a fuel use rate equal to the surrogate fuel consumption rate.

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 4-17 through 4-20 present the emission factors used to estimate natural gas engine emissions. These factors come from *AP-42*, Section 3.2 (USEPA 2014).

Table 4-17. 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	5.88×10^{-4}
NO_x (<90% load)	1.94
PM_{10}[a]	3.84×10^{-2}
CO (<90% load)	0.353
CH_4	1.45
CO_2	110.00

Table 4-18. 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	5.88×10^{-4}
NO_x (<90% load)	0.85
PM_{10}[a]	7.71×10^{-5}
CO (<90% load)	0.56
CH_4	1.25
CO_2	110.00

Table 4-19. 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	5.88×10^{-4}
NO_x (<90% load	2.27
PM_{10}[a]	9.50×10^{-3}
CO (<90 % load)	3.51
CH_4	0.23
CO_2	110.00

Table 4-20. Emission factors for natural gas engines where engine burn type = clean

Pollutant	EF_{fu} (lb/MMBtu)
VOC	0.12
SO_2	5.88×10^{-4}
NO_x	0.59
PM_{10}[a]	7.71×10^{-5}
CO	0.88
CH_4	1.25
CO_2	110.00

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 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 2014). Activity data were submitted for 375 turbines. Of these, 335 reported only natural gas use, 34 reported both natural gas and diesel fuel use, and six reported only diesel fuel use.

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, was used to estimate emissions. 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 4-21). These factors come from *AP-42* Section 3.1 (USEPA 2014) and WebFIRE (USEPA 2015).

Table 4-21. Emission factors for natural gas turbines

Pollutant	EF (lb/MMBtu)[a]
VOC	2.10×10^{-3}
SO_2[a]	$0.94 \times S$
NO_x	0.32
PM_{10}[b]	1.90×10^{-3}
CO	8.20×10^{-2}
N_2O	0.003
CH_4	8.60×10^{-3}
CO_2	110.00

[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 4-22). These factors come from *AP-42* Section 3.1 (USEPA 2014).

Table 4-22. Emission factors for diesel turbines

Pollutant	EF (lb/MMBtu)
VOC	4.10×10^{-4}
Pb	1.40×10^{-5}
SO_2[a]	$1.01 \times S$
NO_x	0.88
PM_{10}[b]	4.30×10^{-3}
CO	3.30×10^{-3}
CO_2	157.00

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

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 2,626 pneumatic pumps on 728 platforms.

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

- Manufacturer and model.
- Amount of natural gas consumed in scf/hr (optional).

- Hours of operation in the reporting period.
- Whether it is vented to a manifold, a flare, or the atmosphere.

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 4-23 presents the default gas composition if not provided (applied for 21 units on six platforms). Table 4-23 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.

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 was applied. Information provided by the Offshore Operators Committee listing manufacturer and field data for select pneumatic devices was also used in the development of surrogates (Frederick 2011). Surrogates were applied for 719 units on 219 platforms.

Table 4-23. 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 historical average of sales gas weight percents for OCS platforms.

4.2.14 Pressure and Level 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 1,654 pressure and level controllers on 495 platforms.

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

- Service type (pressure control vs. level control).
- Manufacturer and model.
- Amount of natural gas consumed in scf/hr (optional).
- Hours of operation in the reporting period.

Similar to pneumatic pumps, CO_2, CH_4, THC, and VOC emissions estimates (in pounds) for pressure and level 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 4-23 presents the default gas composition if not provided (applied for one unit). Table 4-23 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 1,271 units on 389 platforms.

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 356 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) =

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

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 = $12.82 - 0.9672 \times \ln(\text{ReidVP})$
B = Empirical constant = $7261 - 1216 \times \ln(\text{ReidVP})$
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 4-15)
a = Tank paint solar absorptance (See Table 4-16)
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:

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

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) = $\begin{cases} 1; \text{for } N \leq 36 \\ \frac{180+N}{6N}; \text{for } N > 36 \end{cases}$
N = Number of turnovers per month = 5.614 × 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 2014): 0.467 for VOC and 0.463 for CH_4.

The following surrogates were assigned or estimated if the corresponding fields are null:

Product Type = Crude Oil
Paint Color = Grey
Condition = Good
Roof Type = Fixed
Roof Shape = Cone
API $Gravity_{default}$ = 37
Reid $VP_{default} = -1.699 + 0.179 \times$ API Gravity (or 5, if no other information is available)
$T_{b,default} = T_{aa} + 6 \times a - 1$ (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 $Hgt_{default} = 0.5 \times$ Tank Shell Hgt

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, (not including volume from equipment that are vented locally), including periods of upset venting in the total, and the chemical composition of the gas. Activity data were submitted for 640 cold vents.

Vent emissions of VOC were estimated using the following equation:

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

where:

$E_{vent,\,VOC}$	=	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:

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

where:

$E_{vent,\,CH_4}$ = 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:

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

where:

$E_{vent,\,CO_2}$ = CO_2 emissions in pounds

W_{CO_2} = Weight percent CO_2 (default = 2.04796139)

V = Volume of gas vented from miscellaneous sources (Mscf)

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-2014 activity data files submit GOADS-2014 monthly activity records for minor sources, such as caissons, wellhead protectors, and living quarters, and provide information for the Structure and Complex ID, Area, Block, Lease No., and locational coordinates. Previously, BOEM simply asked operators to identify these platforms as minor sources and BOEM assigned surrogate emission estimates. For the 2014 inventory effort, platform operators were instead asked to provide information needed to develop emission estimates. If platform structure data were submitted but no equipment records were populated, BBSEE's TIMS database was reviewed to confirm the platform type. If TIMS identified the platform as a minor source, surrogate emission estimates were used. Surrogate emission estimates based on common minor source equipment were used for 134 minor platforms. These surrogates were not applied if TIMS did not identify the source as a minor platform. These platforms were reported for the 2014 inventory without any equipment records, but are not platforms that are considered to be "missing" for the 2014 inventory.

The following surrogate emission estimates were assigned for caissons, wellhead protectors, and other minor sources if equipment activity was not provided: VOC: 7.034 tons/year, CH_4: 2.536 tons/year. The surrogate emission estimates are based on a worst-case scenario assuming all sources that would have previously qualified for a minor source exemption are present on the platform. Because the sources actually present on these platforms were not reported, BOEM used a conservative approach by applying these worst-case surrogate emissions estimates.

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 National Emissions Inventory (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:

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

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

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 1.1 (USEPA 2014). 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 2014).

4.3 HAZARDOUS AIR POLLUTANT SCOPING TASK

In addition to developing emission estimates for criteria pollutants, criteria pollutant precursors, and GHGs, BOEM also conducted a HAP scoping task. HAP emission estimates were developed for select oil and natural gas production platform emission sources using the GOADS-2014 activity data combined with available HAP emission factors and speciation profiles. Details on the HAP emission estimation methods and results of the scoping task 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, and GHGs for non-platform OCS sources operating in federal waters of the GOM (i.e., west of latitude 87.5°) for the 2014 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.
- 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).
- LOOP.
- Military vessels (U.S. Coast Guard/U.S. Navy).
- Recreational fishing vessels.

BOEM developed the 2014 Gulfwide non-platform emission estimates by building upon or enhancing work previously performed in the Year 2011 Gulfwide Emission Inventory Study (Wilson et al. 2014). The biggest change to the 2104 Gulfwide inventory was the use of AIS data. AIS tracks vessel movements within range of very high frequency (VHF) transmitting stations. The vessel transmitters send a signal every couple of seconds that documents the vessel identification codes, radio call signs, location, direction, speed, and final destination. PortVision was commissioned to compile these AIS data elements for this 2014 inventory. Less refined AIS data were used in the previous 2011 inventory to develop vessel traffic contours for each vessel type (e.g., tanker, containership, support vessel) that were used to spatially distribute emissions. For the 2014 inventory, AIS hourly snapshots were taken of the Central and Western OCS Planning Areas, and the portion of the Eastern Planning Area available for leasing in the 2006 Gulf of Mexico Energy Security Act (GOMESA). Each vessel was handled as a vector with a known location, speed, and direction. Nearly 9,000 vessels included in the snapshots were linked to their vessel characteristics using classification society data from the Information Handling Service (IHS) Register of Ships (ROS) (IHS 2015). The actual vessel speed was compared to the maximum design speed of individual vessels using the propeller law to calculate propulsion engine load. Engine load was applied to each vessel's propulsion power and duration represented in the snapshot to estimate actual kilowatt-hours (kW-hrs), which were applied to USEPA emission factors to calculate emissions. For vessels maneuvering and idling with operating loads below 20%, emissions were adjusted to account for increased emissions from low operating loads. This approach not only captures the spatial elements of vessel traffic, but it uses actual vessel speed and individual vessel power rating to estimate emissions.

The compiled AIS data were compared with existing data sources and found to be more complete and provided vessel-specific operating details. This information was used in place of previous assumptions about typical vessel power, engine loads, USEPA engine categories, and hours of operation. Using the AIS time stamp data also allowed for more accurate monthly estimates of vessel activities. Additional information regarding AIS data processing can be found in Appendix C.1.

There are some notable exceptions: U.S. Navy and U.S. Coast Guard vessels appear to run their AIS transmitters intermittently, as estimated hours of operation are smaller than suggested by data previously provided to BOEM by these agencies. To estimate U.S. Coast Guard emissions, updated fleet profiles for the GOM were obtained from the USEPA's 2014 NEI. The U.S. Navy is currently updating its emission inventory of offshore training exercises, but the work has not yet been completed; therefore, BOEM's 2011 U.S. Navy emission estimates were used to represent activities in 2014. Commercial and recreational fishing appear to be undercounted in the AIS data, as these smaller vessels do not trigger mandatory participation in the AIS program. To be consistent with previous Gulfwide inventories, the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) 2014 datasets of fishing activities were obtained, while emissions for recreational fishing boats were estimated by applying USEPA recreational marine emission factors to typical vessel power ratings and estimates of total hours of operation in federal waters. Therefore, all U.S. Coast Guard, U.S. Navy, and fishing vessels were removed from the AIS dataset to avoid double counting of emissions.

Emissions were calculated for all diesel-powered vessels by applying kilowatt hours to the USEPA's latest commercial vessel emission factors used in the 2014 NEI for the year 2014 for all vessel propulsion engine categories (Categories 1, 2, and 3).

AIS data are not applicable for helicopters, biogenic and geogenic sources, and evaporative emissions from lightering and LOOP operations. Emission estimates for these sources were developed using similar approaches as those documented in the 2011 inventory.

5.1 Marine Diesel Vessel Emission Estimation Approach and Emission Factors

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

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

where:

E = Emissions (tons)
Ah = Duration (hours)
kW = Vessel power (propulsion/auxiliary engines) (kW)
LF = Engine load factor (%)
EF = Emission factor (g/kWh)
CF = Conversion factor (g = 1.10231 E-6 ton)

In general, each vessel AIS record represents one hour of operation, but approximately 20% of the AIS transmittal data are interrupted or turned off, such that vessels do not always appear in consecutive snapshots. To fill missing transmittal gaps, vessel records were arranged chronologically, and the duration was determined by comparing consecutive time stamps.

The kW rating for specific vessels was obtained for the most part from the IHS's ROS. 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 sources.

Where AIS data are available, the propulsion operating load factor was developed by applying the actual speed and the vessel's maximum design speed to the propeller rule:

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

where:

LF = Load factor (percent)
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) based on USEPA port guidance (USEPA 2009) as summarized in Table 5-1.

Table 5-1. Auxiliary operating loads (as a fraction of power)

Vessel Types	Typical Power	Cruise	Reduced Speed Zone (RSZ)	Maneuver	Hotel
Auto carrier	2,850	0.15	0.30	0.45	0.26
Bulk carrier	1,776	0.17	0.27	0.45	0.10
Buoy tender				0.45	0.22
Container	6,800	0.13	0.25	0.48	0.19
Crude oil tanker	1,985	0.24	0.28	0.33	0.26
Cruise ship	11,000	0.80	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	0.24	0.45	0.22
Icebreaker	-	-	-	0.45	0.22
Jackup	-	-	-	0.45	0.22
Liquified natural gas (LNG) tanker	1,985	0.24	0.28	0.33	0.26
Liquified petroleum gas (LPG) tanker	1,985	0.24	0.28	0.33	0.26
Miscellaneous	-	-	-	0.45	0.22
Pipelaying	-	0.15	-	0.45	0.22
Reefer	3,900	0.20	0.34	0.67	0.32
Research	-	-	-	0.45	0.22
Roll-on/roll-off (RORO)	2,850	0.15	0.30	0.45	0.26
Supply	-	-	-	0.45	0.22
Support	-	-	-	0.45	0.22
Tanker	1,985	0.24	0.28	0.33	0.26
Tug	-	0.17	0.27	0.45	0.22
Well stimulation	-	-	-	0.45	0.22

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. This inventory did not include activity or emissions associated with boilers used to generate steam or to run pumps used to transfer product at the LOOP and lightering zones.

The emission factors used in this inventory were obtained from the USEPA's 2014 NEI (USEPA 2016a). The USEPA emission factors vary depending upon the engine that the vessel uses for propulsion, and fall into two groups: Category 1 and 2 (C1 and C2) vessel engines and Category 3 (C3) vessel engines. C1 engines have a cylinder displacement less than 5 liters, C2 engines have a cylinder displacement between 5 and 30 liters, and 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. Table 5-2 shows AIS vessel count by vessel type and USEPA category.

Table 5-2. 2014 vessel count by category and type

Vessel Type	Vessel Engine Category			Vessel Count
	C1	C2	C3	
Auto carrier	0	0	130	130
Bulk carrier	0	3	2,194	2,197
Chemical tanker	0	26	1,159	1,185
Container	0	0	238	238
Crude oil tanker	0	0	640	640
Cruise	1	1	15	17
Dredging	3	4	2	9
Drilling	86	44	25	155
Ferry	0	5	0	5
FPSO	0	1	1	2
General cargo	0	33	671	704
Miscellaneous	93	6	1	100
Oil and gas support	1,132	122	23	1,277
Passenger	42	0	0	42
Pilot	26	0	0	26
Pipelaying	1	4	10	15
Reefer	0	0	26	26
Research	18	2	2	22
RORO	0	5	34	39
Survey	6	33	12	51
Tanker, LNG/LPG	0	2	187	189
Tanker, miscellaneous	0	2	29	31
Tug	116	490	26	632
Unknown	690	0	0	690
Well stimulation	2	3	1	6

The engine categories have different fuel and emission standards that go into effect at different times. 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. For this study, BOEM assumed that marine distillate was used for the C1 and C2 vessels and the sulfur content of the C1 and C2 fuel to be ultra-low (15 ppm). For C3 vessels, the low-sulfur North America Emission Control Area (ECA) compliant fuel was assumed to have a sulfur content of 1,000 ppm. BOEM assumed commercial fishing vessels were assumed to all be C1 and LOOP generators and pumps to be C2. All U.S. Navy ships and U.S. Coast Guard 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. As noted above, BOEM assumed that vessels used ECA-compliant fuels (1,000 ppm sulfur) while transiting U.S. waters and that vessels equipped with C3 propulsion engines are likely to use the same ECA-compliant fuel for their auxiliary engines.

Table 5-3. Emission factors for vessels equipped with Category 3 propulsion engines

Pollutant	NO_x	VOC[a]	PM_{10}	CO	SO_2	CO_2	$PM_{2.5}$[b]	Pb	N_2O	CH_4	NH_3
Main engines	14.7	0.6318	0.45	1.4	3.62	588.86	0.42	0.00003	0.031	0.00561	0.00545
Auxiliary engines	12.1	0.4212	0.47	1.1	3.91	636.60	0.43	0.00003	0.031	0.00517	0.005415

Source: USEPA 2008.

[a] HC was converted to VOC using a conversion factor of 1.053 as provided in the above reference.

[b] $PM_{2.5}$ was assumed to be 97% of PM $_{10}$ using the above reference.

This approach assumes that all vessels with C3 engines implemented fuel switching prior to 2014 to comply with the 1% ECA fuel sulfur standard and that the use of controls such as scrubbing of high sulfur fuels, which is also an option to meet regulations, will be minimal.

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

Table 5-4. Tier emission factors for vessels equipped with Category 1 & 2 propulsion engines

Model Year	Tier	PM_{10}	NO_x	HC	CO	VOC[a]	$PM_{2.5}$[b]	SO_2	CO_2
Prior to 2003	0	0.32	13.36	0.134	2.48	0.141102	0.3104	0.006	648.16
2004-2006	1	0.32	10.55	0.134	2.48	0.141102	0.3104	0.006	648.16
2007-2013	2	0.32	8.33	0.134	2.00	0.141102	0.3104	0.006	648.16
Newer than 2014	3	0.11	5.97	0.07	2.00	0.073710	0.1067	0.006	648.16

Source: USEPA 2008

[a] HC was converted to VOC using a conversion factor of 1.053 as provided in the above reference.

[b] $PM_{2.5}$ was assumed to be 97% of PM_{10} using the above reference.

***Example Calculation*:**

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

where:

- E = Emissions (tons)
- Ah = Duration (hours)
- kW = Vessel power (totaling individual propulsion engines) (kW)
- LF = Engine load factor (%)
- EF = Emission factor (g/kWh)
- CF = Conversion factor (g = 1.10231 E-6 ton)

For a one-hour snapshot duration of a survey vessel constructed in 2014, equipped with a C2 engine, where the kW rating is 2,039, the load factor is 0.23, and the emission factor for NO_x for a C2 Tier 2 engine is 8.33 g/kWh, emissions are estimated as:

$$E = 1\text{hr} \times 2{,}039\text{kW} \times 0.23 \text{ load factor} \times 8.33 \text{ g/kw-hr} \times 1.10231 \times 10^{-6}$$
$$E = 0.00431 \text{ tons of } NO_x$$

This example is representative of 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. Calculated 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 emissions to the correct month.

In addition to commercial marine vessel emission factors noted above, diesel marine emission factors for recreational fishing vessels were obtained from the USEPA NONROAD model (USEPA 2012) and are provided in Table 5-6.

Table 5-6. Recreational fishing vessel emission factors

CO	NO_x	PM_{10}	$PM_{2.5}$	THC	VOC	SO_2	CO_2
0.003	0.015	0.001	0.001	0.001	0.001	0.0004	1.195

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.
- Drilling vessels (exclusive of drilling directly associated with a platform).
- Pipelaying vessels.
- Support vessels that assist in construction and removal of production platforms, construction and maintenance of pipelines, development and maintenance of subsea systems (including simulation vessels), and carry supplies, equipment, and personnel to production platforms.
- Support helicopters that carry supplies and personnel to and from the platforms.

AIS data are used for all of the above source types except for non-self-propelled drilling rigs and support helicopters.

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 (Figure 5-1). 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).

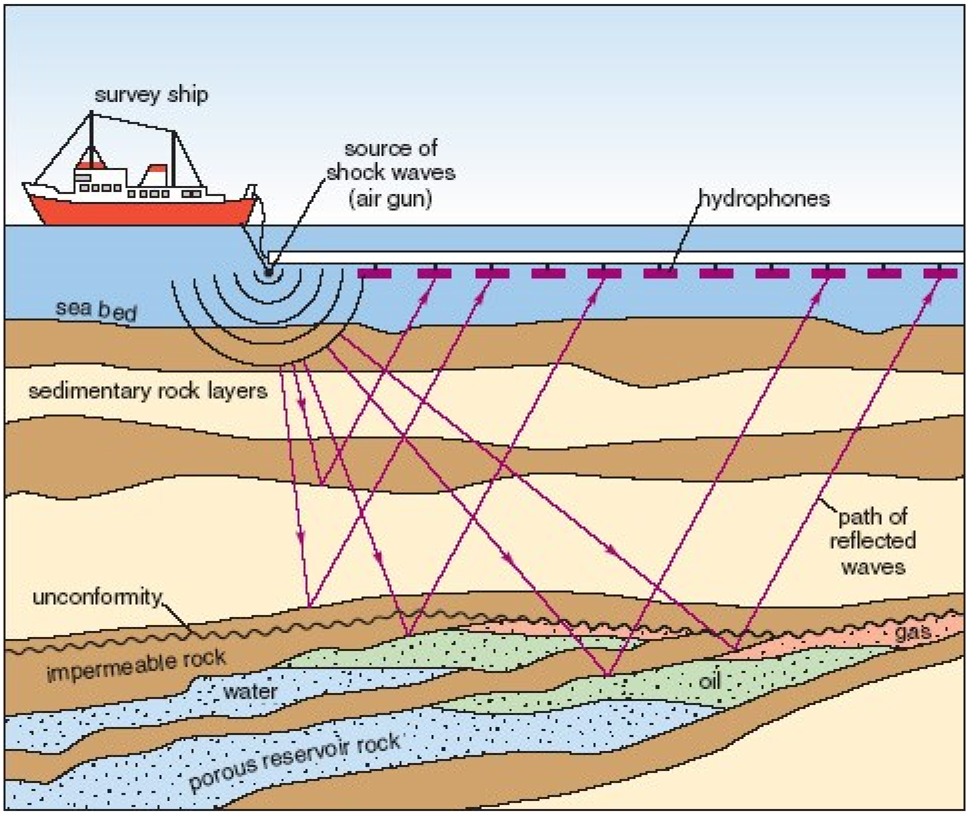


Figure 5-1. Typical geophysical survey vessel operations (USEPA 2016b)

For previous Gulfwide inventories, unsuccessful attempts were made to obtain survey vessel data from the vessel operators. Using AIS data for 2014 allowed BOEM to identify all 50 survey vessels. The AIS data included details concerning the locations where these vessels operated and the duration of their trips. Emission estimates were developed for individual vessels included in the AIS data, but to address concerns for release of confidential business information, the survey data were summed within lease blocks to ensure that individual vessel movements could not be easily identified.

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. Low-load adjustments were made for calculated propulsion operating loads based on AIS actual vessel speeds, less than 20% using the adjustment factors in Table 5-5.

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, and drill ships. Application of the appropriate drilling rig varies relative to the water depth where they operate. For example, barges tend to operate closer to shore and in inland waterways, jackups can work in water up to 375 feet deep, semisubmersibles and submersibles operate in water with depths of 300 to 2,000 feet, and drill ships operate in waters with depths greater than 2,000 feet.

The Operation and Analysis Branch of the Engineering and Operations Division of BOEM provided 2014 activity data for 154 drilling rigs by block, which included activity for drill ships, jackups, platform rigs, semisubmersibles, and submersibles (Mathews 2016). This information is provided in Appendix C.1. These drilling rigs were matched to 155 drilling rigs in the AIS data and the lease blocks where they operated were compared to their AIS locations.

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, and 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 data are shown in Table 5-7. Note that barges, jackup, platform, submersible, and semisubmersible rigs are not self-propelled (though some semisubmersibles have dynamic positioning thrusters) and so they do not appear in the AIS dataset, while tugs and support vessels that move the rig around are included in the AIS data.

Table 5-7. Equipment kW ratings by drilling rig type

Rig Type[a]	Average Total Main Power (kW)	Average Total Emergency (kW)
Inland barge	6,362	125
Jackup	3,359	559
Platform rig	8,239	[b]
Submersible	4,190	1,409

[a] Not self-propelled, relocated with support vessels.
[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 kW-hr values were applied to the emission factors provided in Tables 5-3 and 5-4 (USEPA 2016a) 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.

It should be noted that the 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. 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. Note that barges, jackups, semisubmersibles, and submersibles are typically moved to and from drilling sites by tugs or other support vessels and are captured in the AIS data for these support vessel types.

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 AIS data, as shown in Figure 5-2.

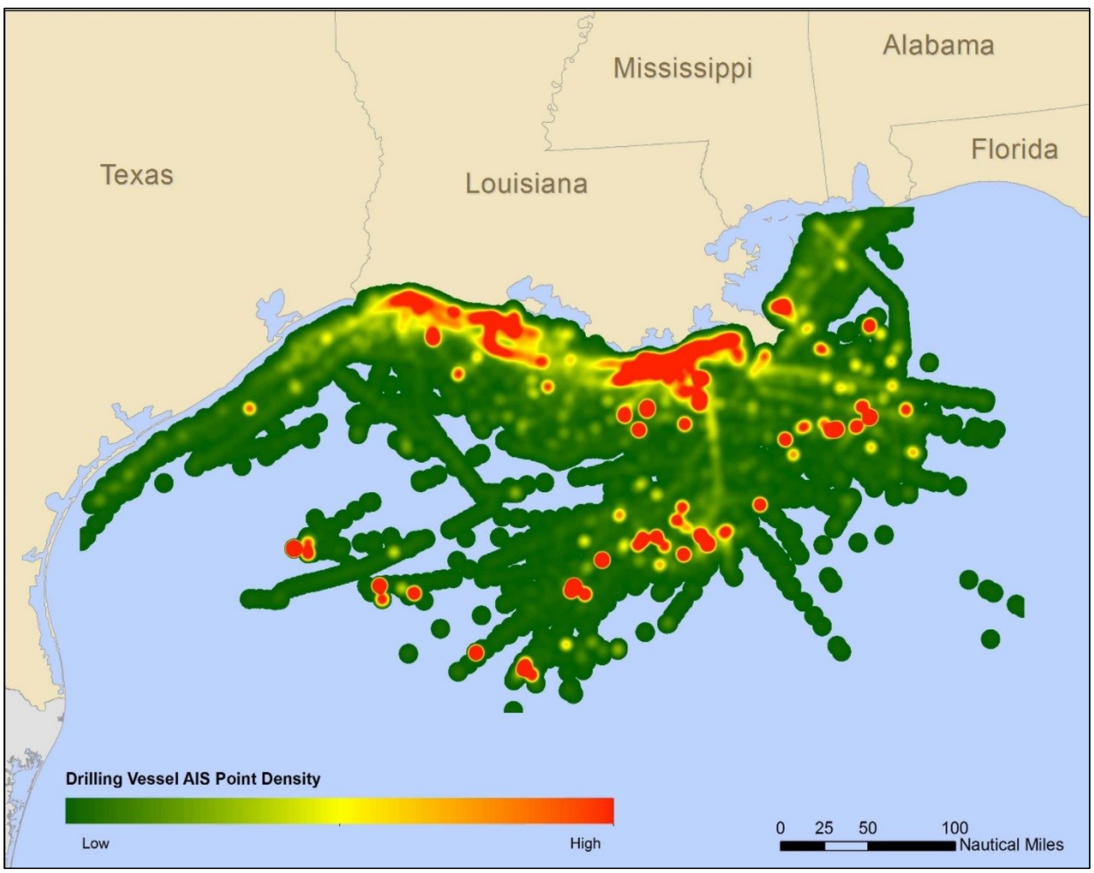


Figure 5-2. 2014 AIS point density associated with drilling vessels

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 2014 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 5-4 presents the AIS point density associated with pipelaying vessels. Note that while the 2011 inventory calculated and allocated emissions only to locations of pipeline construction and maintenance, the use of AIS data in this inventory allows emissions calculations and allocations associated both at the locations of pipeline work as well as to lease blocks where vessels are en route to and from the construction locations. Figure 5-3 shows AIS data where the vessels were not moving; Appendix C.1 gives a more in-depth analysis of the comparison between AIS and BOEM pipelaying activity.

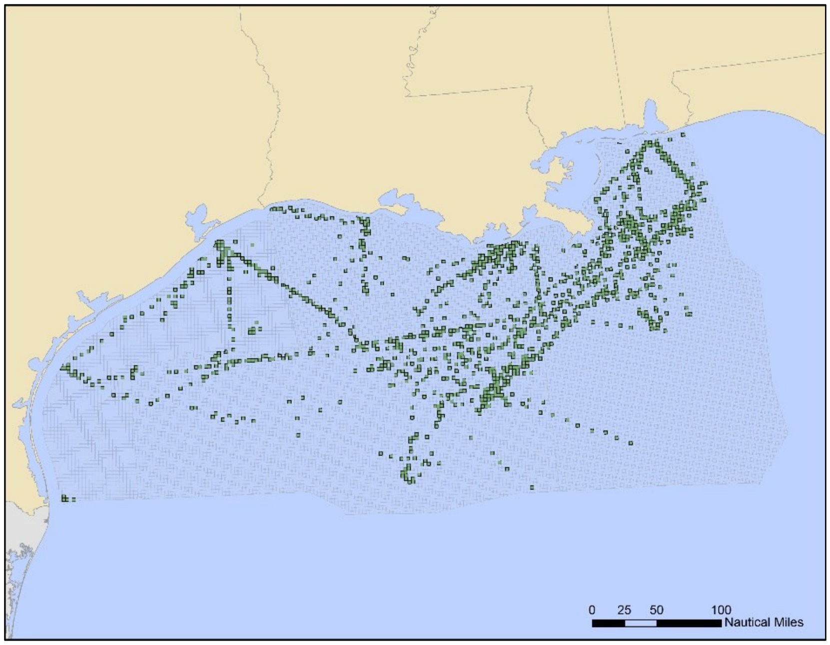


Figure 5-3. Lease blocks with pipelaying vessel activity in 2014 as determined by non-moving AIS observations

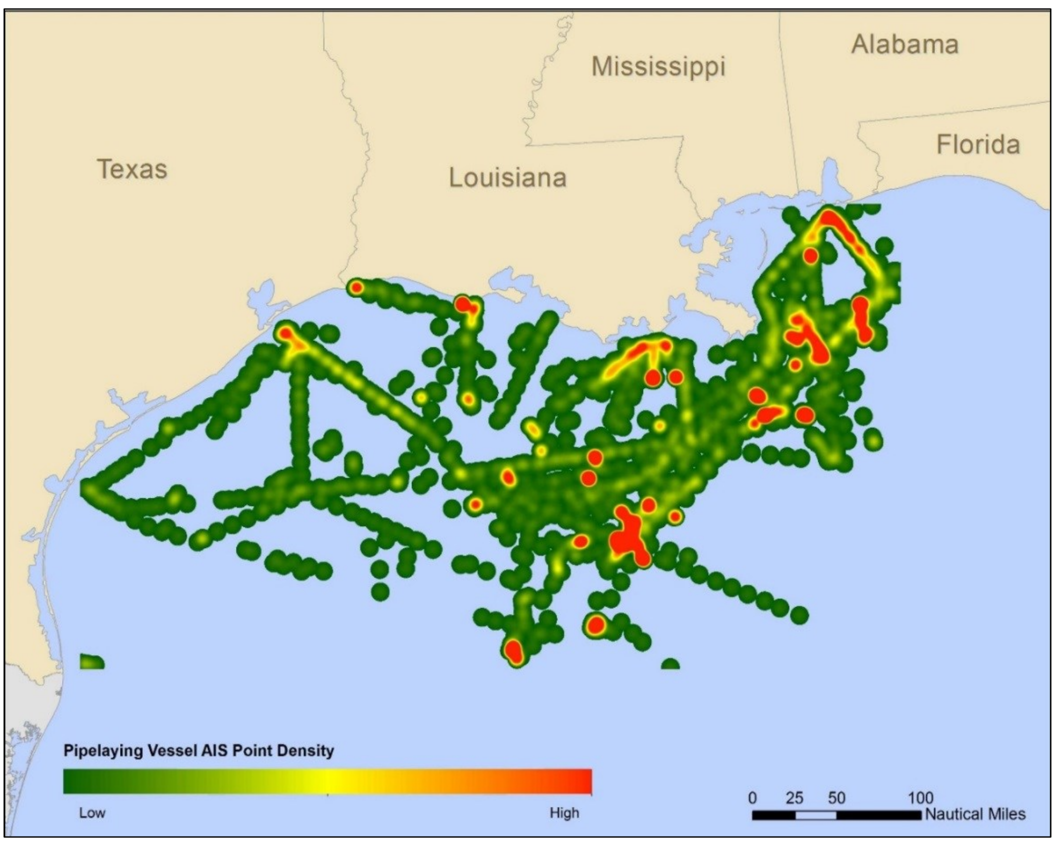


Figure 5-4. 2014 AIS point density associated with pipelaying vessels for both moving and non-moving observations

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 2014 support vessel data were derived from the AIS dataset. The AIS data included 1,276 vessels, which is nearly double the 682 offshore oil and gas platform support vessels identified in the 2011 Gulfwide inventory. 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 5-5 shows the support vessel density derived from AIS data. As anticipated, activity is highest near the coast where vessels are approaching ports that provide specialized support and supplies for offshore operations.

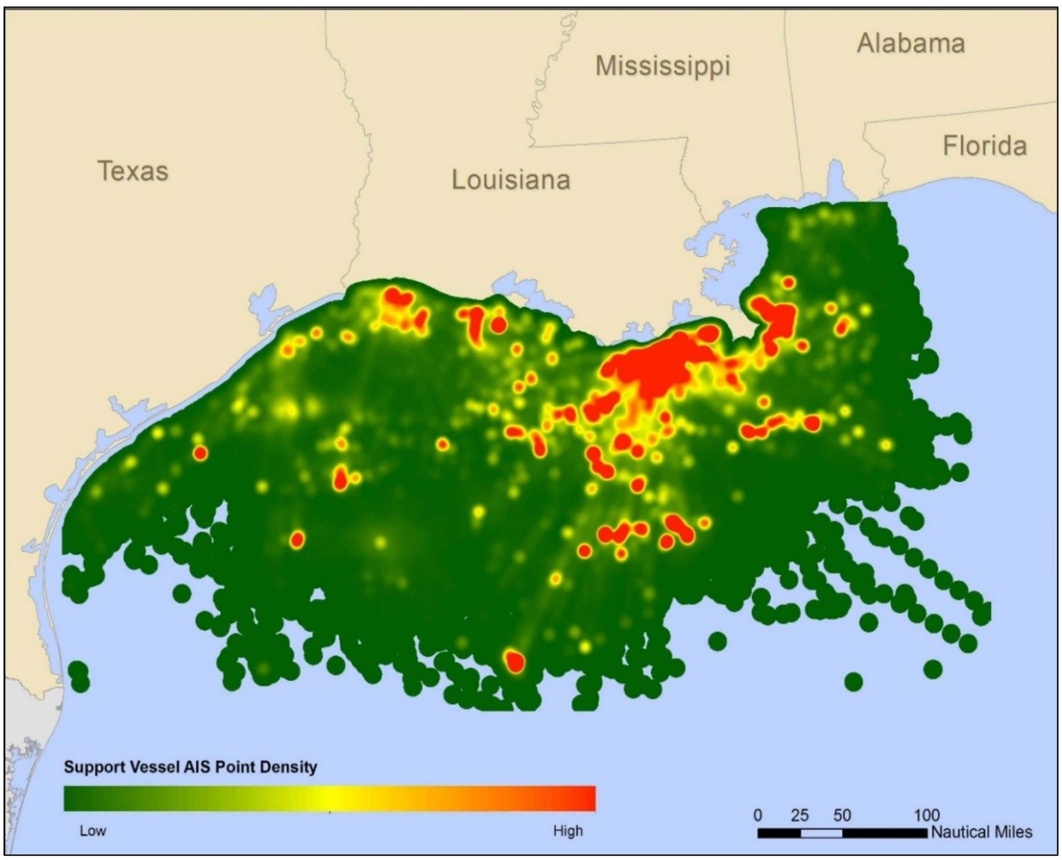


Figure 5-5. 2014 AIS point density associated with support vessels

5.2.5 Support Helicopters

Helicopters are used extensively in the GOM to move light supplies and personnel to and from platforms. The best data source for helicopter operations is the Helicopter Safety Advisory Conference (HSAC*)* annual safety report, Gulf of Mexico Offshore Helicopter Operations and Safety Review (HSAC 2015). The report contains a snapshot of all helicopter operations in the GOM as reported by participating operators. However, the report underestimates operations, as activity data are voluntarily provided by operators; based on personal communications with the government liaison committee chairman for the HSAC (Raaz 2009), approximately 70% of the offshore support helicopters provide activity data to HSAC. Therefore, the 2014 HSAC activity data were adjusted to account for the missing helicopter traffic by multiplying the landing and takeoff (LTO) data by 100/70 or 1.4286. The HSAC-compiled activity data are disaggregated into single engine, light twin engine, medium twin engine, and heavy twin engine helicopters, as noted in Table 5-8.

Table 5-8. HSAC helicopter data

Helicopter Type	2014 LTO	Adjusted 2014 LTO[a]
Single	477,117	681,596
Twin light	81,734	116,763
Twin medium	121,820	174,029
Twin heavy	60,530	86,471
Total	741,201	1,058,859

[a] Raw LTO data adjusted to account for survey bias based on personal communication with Dana Raaz, government liaison committee chairman for the HSAC

The primary helicopter emission factors were obtained from Swiss Federal Office of Civil Aviation's (FOCA's) Guidance on Determination of Helicopter Emissions (FOCA 2009). However, the LTO cycle used by FOCA was determined to be too short for typical trips taken in the GOM. The average trip length was relatively short (24 minutes) (HSAC 2015); therefore, BOEM assumed that helicopters typically hop from platform to platform. In addition to the 20-minute flight time, the helicopters were assumed to idle for an additional 15 minutes while on the platform. Therefore, the time-in-modes from the FOCA were adjusted to reflect conditions in the GOM. These values may tend to overestimate emissions, particularly during idling times on platforms. Table 5-9 shows the original FOCA time-in-mode values and the new adjusted values for the GOM.

Table 5-9. Time-in-mode values

Source	Pretake-Off Idle (Min)	Take-Off Time (Min)	Approach Time (Min)	Post-Landing Idle (Min)	Total Idling (Min)	Total Flight (Min)
FOCA	4.0	3.0	5.5	1.0	5.0	8.5
Adjusted	12.0	8.0	16.0	3.0	15.0	24.0

The FOCA emission factors were recalculated based on the new time-in-mode values. Then the LTO-based emission factors for each helicopter type were averaged to yield the emission factors used in this study. Table 5-10 lists the FOCA emission factors by helicopter and helicopter type.

The VOC helicopter emission factors were developed by converting the hydrocarbon (HC). $PM_{2.5}$ 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 GHG Program (EIA 2012). The compiled emission factors are summarized in Appendix C.2.

Table 5-10. FOCA average emission factors by helicopter type

Helicopter Type	Fuel/ LTO (kg)	Emission Factors (lbs/LTO)									
		NO_X[a]	HC[a]	VOC[b]	CO[a]	PM_{10}[a]	$PM_{2.5}$[c]	SO_2[d]	CO_2[e]	N_2O[e]	CH_4[e]
Single	65.293	0.793	2.060	2.190	2.649	0.026	0.025	0.141	201.304	0.014	0.012
Twin light	108.350	1.115	5.586	5.938	7.313	0.039	0.038	0.234	334.053	0.024	0.021
Twin medium	154.431	2.280	4.369	4.644	5.633	0.070	0.068	0.333	476.123	0.034	0.030
Twin heavy	376.379	10.294	2.935	3.120	3.648	0.259	0.252	0.811	1160.406	0.083	0.072

[a] FOCA 2009.
[b] HC to VOC = * 0.9708.
[c] $PM_{2.5}$ = 97.6% of PM_{10}.
[d] SO_2 (g/gal) = (fuel density) × (conversion factor) × (64 g SO_2/32 g S) × (S content of fuel).
[e] EIA 2012.

The emission factors developed from this project were applied to the activity data to estimate emissions using the following equation:

$$E_i = EF_i / 2000 \times LTO_i$$

where:

E_i = Helicopter emissions for helicopter type i (tons per year)
EF_i = Helicopter emission factor for helicopter type i (pounds/LTO)
LTO_i = Landing and take-off cycle for helicopter type i (cycles per year)
i = Helicopter type (i.e., single, light, medium, and heavy)
2000 = Conversion factor pounds per ton

Example Calculation:

The emission factor of NO_x for a single engine helicopter is 0.7935 pounds/LTO, and the LTOs for single engine helicopters in 2014 were 681,596.

$E_{Single} = EF_{Single} / 2000 \times LTO_{Single}$

$E = 0.7935/2000 \times 681{,}596$
$E = 270.43$ tons of NO_x

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

Helicopter emissions were assigned to lease blocks with active platforms that have heliports (Figure 5-6), as most of the emissions associated with support helicopters occur while the craft is near or at the platform (USDOI, BOEM 2013). Helicopter emissions were spatially allocated using the equation below:

$$E_{Hi} = E_H \times (P_{Hi}/P_{HT})$$

where:
E_{Hi} = Support helicopter emissions associated with lease block i (tons)
E_H = Total helicopter emissions (tons)
P_{Hi} = Number of platforms with heliports in lease block i
P_{HT} = Total number of platforms with heliports

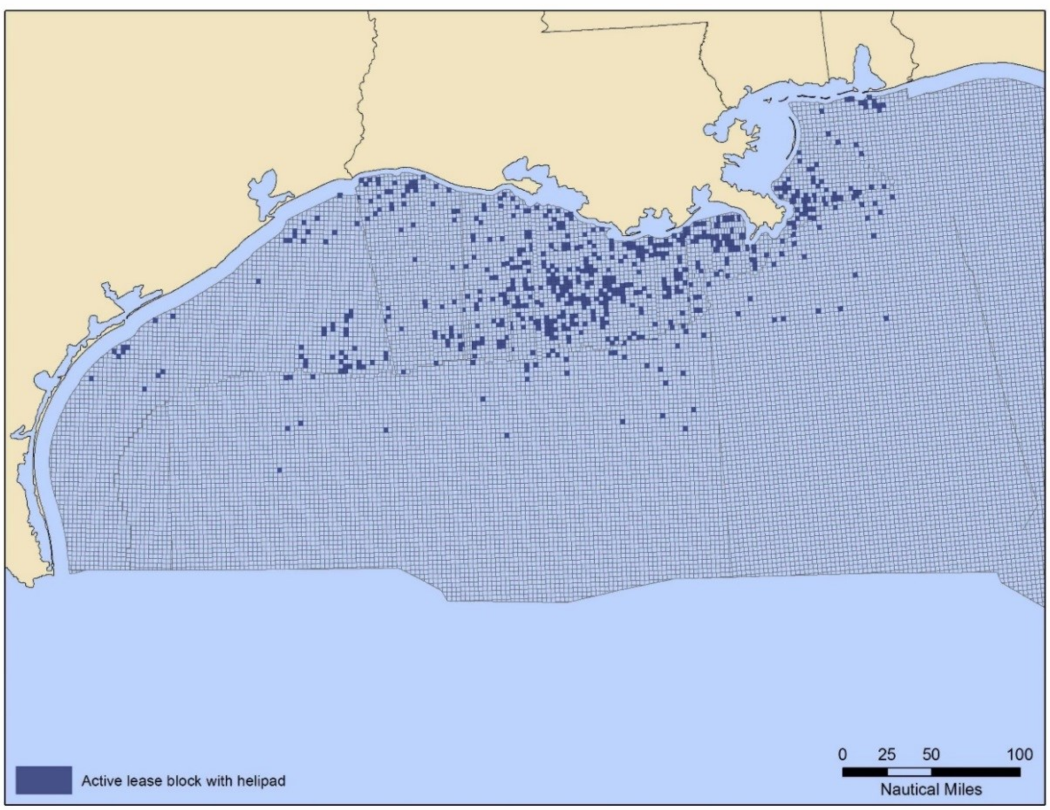


Figure 5-6. Location of active platforms with heliports

5.3 NON-OIL AND GAS PRODUCTION-RELATED SOURCES

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

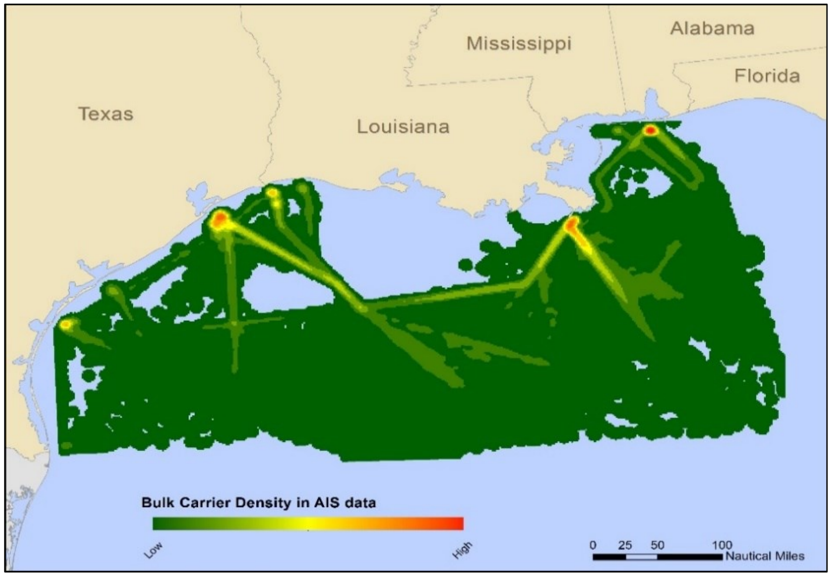
- Commercial marine vessels (CMVs) that transit the GOM carrying passengers and cargo to and from Gulf ports.
- Military vessels (U.S. Navy and U.S. Coast Guard) that operate in the area.
- LOOP.
- Lightering zone operations.
- Commercial fishing operations.
- Recreational fishing operations.
- Biogenic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

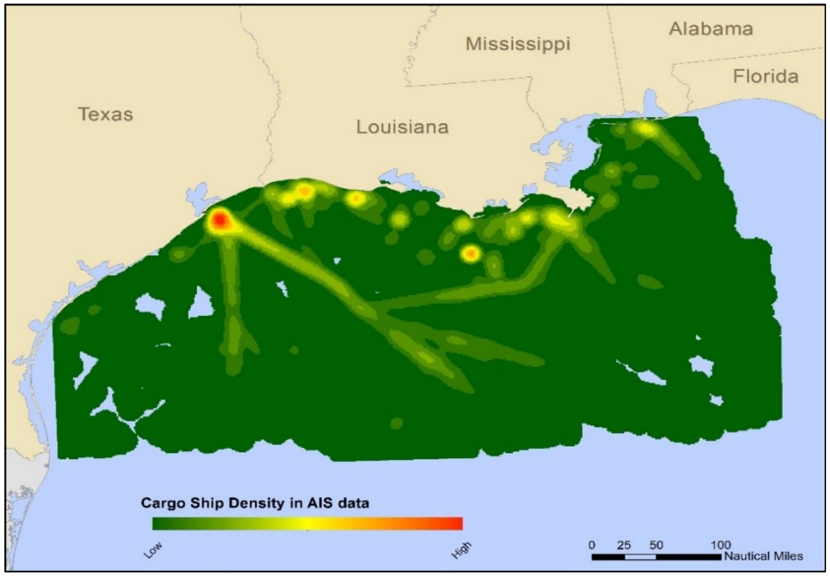
AIS data were considered appropriate for CMVs (including tankers that visit the LOOP and are involved in lightering operations). As mentioned previously, AIS coverage for commercial and recreational fishing vessels does not appear to be as complete as for other categories, and military vessels, although equipped with AIS transmitters, may not deploy them for national security reasons. Therefore, fishing and military 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 2011 inventory to ensure the data were relatively comparable. The LOOP and lightering zone sources also include non-combustion evaporative emissions sources; emissions from these sources were also developed based on approaches used in the 2011 inventory as discussed in Sections 5.3.3 and 5.3.4.

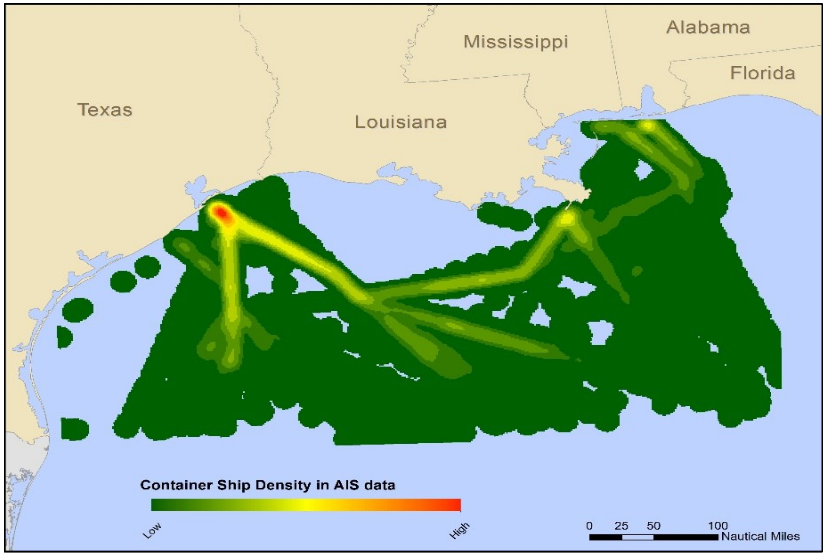
5.3.1 Commercial Marine Vessels

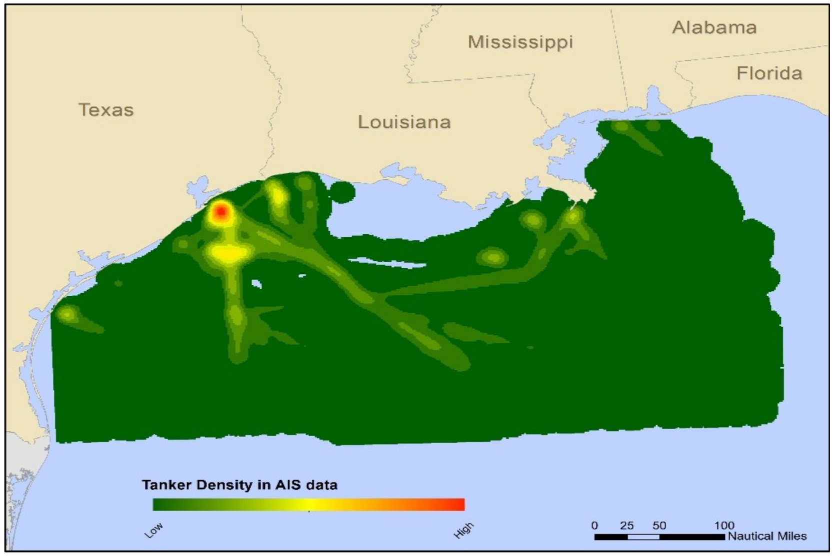
CMVs are involved in transporting a wide range of agricultural, manufacturing, and chemical products through the GOM. The majority of CMVs tend to be powered by diesel engines that combust marine diesel fuel or a blend of distillate and residual oils that are compliant with the North America ECA requirements. For the 2014 inventory, AIS data were used to estimate emissions from vessels that transit the Central and Western Planning Areas of the GOM and a portion of the Eastern Planning Area.

The AIS dataset obtained from PortVision (AIRSIS 2015) consisted of hourly “snapshot” records that included the vessel name, type, IMO identification number, Maritime Mobile Service Identity, radio call sign, vessel type, position, actual speed, and time stamp of the data transmittal. Figure 5-7 shows the 2014 AIS CMV vessel traffic for major CMV categories (bulk carriers, cargo ships, container ships, tankers, and tugs as identified in the AIS dataset.


Texas
Louisiana
Mississippi
Alabama
Florida
Bulk Carrier Density in AIS data
Low
High
0 25 50 100
Nautical Miles


Texas
Louisiana
Mississippi
Alabama
Florida
Cargo Ship Density in AIS data
Low
High
0 25 50 100
Nautical Miles


Texas
Louisiana
Mississippi
Alabama
Florida
Container Ship Density in AIS data
Low
High
0 25 50 100
Nautical Miles


Texas
Louisiana
Mississippi
Alabama
Florida
Tanker Density in AIS data
Low
High
0 25 50 100
Nautical Miles

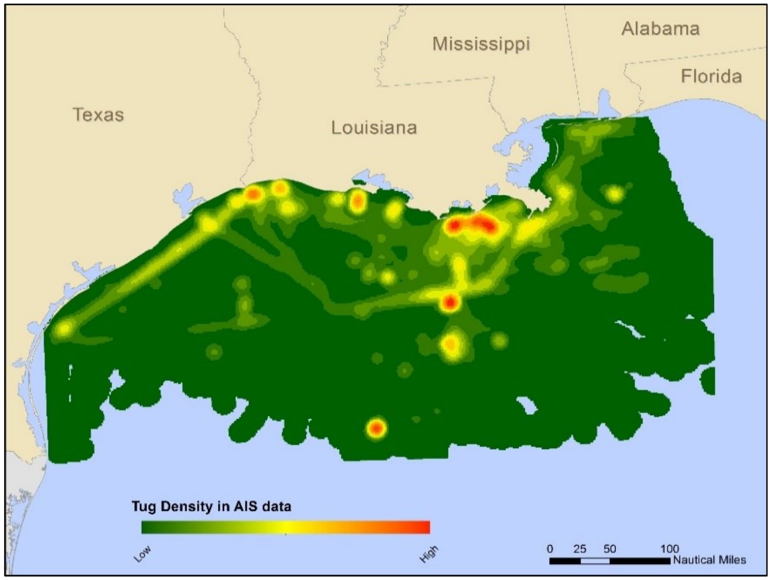


Figure 5-7. 2014 CMV AIS observation density by vessel type

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 IHS were matched using online web searches. Over 75% of vessels were matched.

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

5.3.2 Military Vessels

The U.S. Navy and U.S. Coast Guard patrol the coast and have maneuvers in the GOM. The fleet consists of vessels powered by a variety of engines, including older residual-fueled steam turbines, marine diesel engines, and high-speed diesel turbines.

BOEM contacted the U.S. Navy to obtain 2014 activity data necessary to estimate vessel emissions, but no data were provided; therefore, the emission estimates developed for the 2011 Gulfwide inventory (which were based on those in the Gulf of Mexico Air Quality Study (Systems Applications International et al. 1995)) were carried forward.

AIS was not considered to be a good data source for tracking Naval vessels as military vessels rarely send signals that would identify their location on the public AIS. For the 2014 inventory, the naval activity data reported in the Year 2011 Gulf of Mexico Emissions Inventory was applied to 2014 emission factors included in Section 5.1. To implement this approach, BOEM calculated kW-hours for each naval vessel, shown in Table 5-11.

Table 5-11. Naval diesel vessel kW hours

Vessel ID	No. Engines	Average kW Rating	Total Engine Hours	kW-hrs	Operating Load	Load Adjusted kW-hrs
PHM	2	596.56	17,520	10,451,731	0.80	8,361,385
TAG	2	1,043.98	17,520	18,290,530	0.80	14,632,424
TAG (50)	1	1,043.98	17,520	18,290,530	0.80	14,632,424
TAGS (50)	1	1,864.25	8,760	16,330,830	0.80	13,064,664
LSD	4	7,643.43	35,040	267,825,787	0.80	214,260,630
TAGS (40)	2	8,948.40	17,520	156,775,968	0.80	125,420,774
TAK (II)	2	10,066.95	17,520	176,372,964	0.80	141,098,371
Total	14	-	31,400	664,338,340	-	531,470,672

The GOM naval fleet also includes diesel turbine and steam ships; the diesel turbine factors used in this study were obtained from Swedish emissions data (SEPA 2004) while the steamship factors were obtained from USEPA guidance (Table 5-12) (USEPA 1992).

Table 5-12. Naval diesel turbine and steamship fuel consumption data and emission factors

Engine Type	Fuel Usage (liters/year)	Emission factors (lbs/1,000 liters)					
		NO_x	CO	CO_2	SO_2	VOC	PM
Diesel turbine	594,230	32.19	0.12	5,742.9	14.78	0.01	0.44
Steamship	8,918,610	14.38	0.977	6,872.3	85.9	0.33	6.816

The U.S. Coast Guard data were obtained from the USEPA 2014 NEI. This ensured consistency between the USEPA and BOEM 2014 emissions inventories. The activity data included kW-hrs of cutter vessels operating in federal waters in the Central, Western, and a portion of the Eastern Planning Area of the GOM. Data for U.S. Coast Guard vessels with home ports in Texas, Mississippi, Louisiana, and Alabama were included. Table 5-13 summarizes the average hours of operation and horsepower ratings.

Table 5-13. 2014 kW-hrs and horsepower rating by U.S. Coast Guard vessel

Vessel ID	Vessel Name	Horsepower Rating	Engine Category	Hours of Operation
WPB 87305	*Stingray*	3000	1/2	1,586
WPB 87311	*Cobia*	3000	1/2	1,427
WLIC 803	*Saginaw*	500	1/2	929
WLM 559	*Barbara Mabrity*	3400	1/2	994
WLB 210	*Cypress*	6200	1/2	1,218
WPB 87336	*Sturgeon Bay*	3000	1/2	1,547
WPB 87327	*Pelican*	3000	1/2	1,302
WLIC 800	*PAMLICO*	500	1/2	640
WPB 87332	*Razorbill*	3000	1/2	1,443
WPB 87339	*Pompano*	3000	1/2	1,603
WMEC 629	*Decisive*	5000	1/2	2,583
WPB 87348	*Brant*	3000	1/2	1,118
WPB 87363	*Manatee*	3000	1/2	609
WPB 87320	*Manta*	3000	1/2	1,229
WPB 87330	*Man-O-War*	3000	1/2	983
WPB 87353	*Skipjack*	3000	1/2	1,321
WLM 561	*Harry Claiborne*	3400	1/2	989
WMEC 624	*Dauntless*	5000	1/2	1,830
WPB 87324	*Steelhead*	3000	1/2	939
WPB 87344	*Heron*	3000	1/2	1,413

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

No monthly U.S. Navy or U.S. Coast Guard 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%).

Because it was not possible to identify where U.S. Navy vessels operate, the emissions were allocated to individual lease blocks throughout the central and western areas of the GOM. The allocations were made based on the surface area of the lease blocks using the equation below:

$$E_{MVi} = E_{MV} (S_i/S_{TNG})$$

where:

E_{MVi} = Military vessel emissions associated with lease block i (tons)
E_{MV} = Total military vessel emissions for the GOM (tons)
S_i = Surface area of lease block i (square miles)
S_{TG} = Surface area of total Gulf lease blocks (square miles)

All U.S. Coast Guard vessel emissions were allocated relative to each vessel's home port and the area where the vessels patrol (Figure 5-8).

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

where:

E_{CGi} = U.S. Coast Guard emissions associated with lease block i (tons)
E_{CG} = Total U.S. Coast Guard 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 U.S. Coast Guard district (square miles)

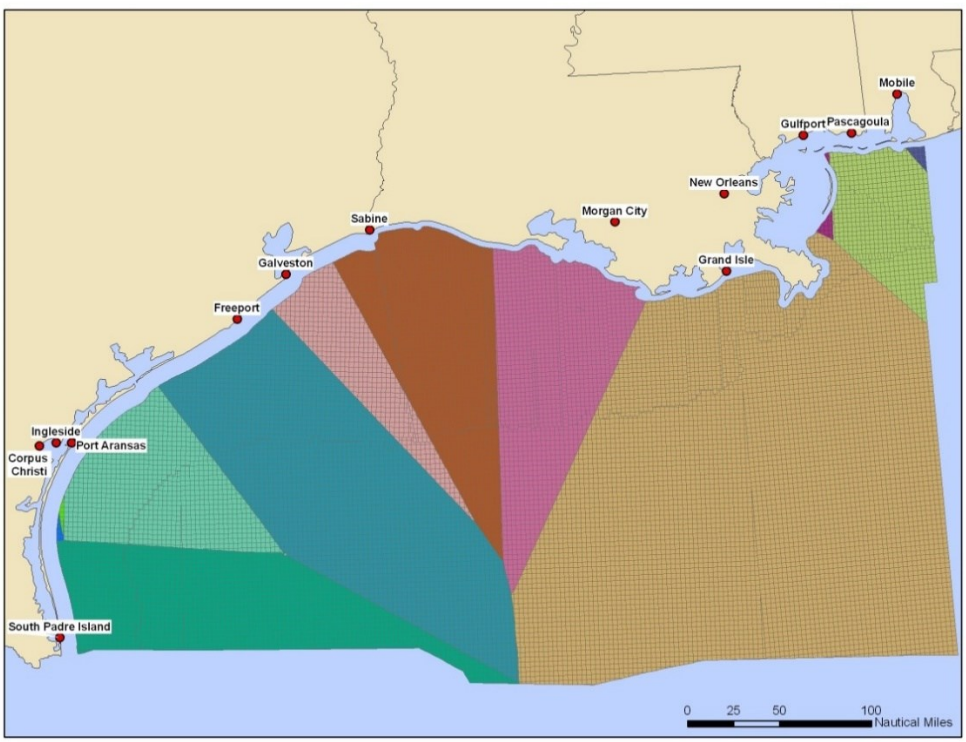


Figure 5-8. U.S. Coast Guard districts used to allocate emissions

5.3.3 Louisiana Offshore Oil Port

The LOOP is located 45 miles from shore. This offshore port allows large oil tankers to unload product without having to enter and maneuver inside urban ports. 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 5-14 summarizes the engine characteristics for combustion sources located on the LOOP platform, including kW rating, load factors, and hours of operation.

Table 5-14. 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 specifically for LOOP-related operations.

The LOOP was contacted repeatedly for data about their 2014 operations, but no data were provided. However, a 2014 study documented a decline of 50% in LOOP total crude imports from 2008 (Datamyne 2014) when the platform was operating at full capacity. Most of this decline is attributed to an increase in domestic production that has reduced the demand for imported oil. The 2011 LOOP support vessel and platform activity and emissions data and the evaporative emissions were reduced by 28.5% to more accurately represent 2014. A patrol vessel was added to the LOOP recently to address security concerns, but details concerning the patrol vessel were not publicly available, and therefore emissions from this vessel could not be included in the 2014 inventory.

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 2011 Gulfwide inventory emissions were adjusted to reflect 2014 emissions in this inventory.

5.3.4 Vessel Lightering

Lightering is the transfer of cargo to smaller ships that bring the product into port. Lightering occurs offshore in three designated areas. Emissions associated with lightering are attributed to primary propulsion engines of the vessels involved in lightering, secondary engines (e.g., pumps and winches), 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 and were not calculated specifically for lightering operations for 2014.

When large tankers transfer crude to smaller shuttle tankers, vapors in the shuttle tanker holds are displaced into the atmosphere as the crude is transferred to the smaller vessels; these evaporative emissions are known as loading losses. Ballasting emissions occur on large tankers as the ships 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. To obtain data on the volume of crude transferred, attempts were made to contact all companies that provide lightering services. Though this approach was successful in previous inventories, none of the companies contacted for the 2014 inventory provided data due to national security concerns.

In developing the lightering component of the 2011 Gulfwide inventory, data were obtained from Skaugen Petrotrans (SPT), OSG Lightering (OSGL), and American Eagle Tankers (AET); these companies are the three major ship-to-shore lightering service providers for the GOM. Therefore, the 2011 inventory is considered the most accurate lightering inventory developed for the previous Gulfwide inventories and was used to estimate 2014 evaporative emissions based on the volume of crude transferred (Table 5-15). Demand for foreign crude has been declining since 2011; therefore, the 2011 activity may be overestimating evaporative emissions from lightering in 2014.

Table 5-15. Full service lightering data for 2011

	SPT	OSGL	AET
Annual barrels	105,000,000	170,000,000	321,982,759

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:

Evaporative Loading:

$$Ev = PT \times BBL/GAL \text{ conversion factor} \times TOC \times VOC/TOC \text{ conversion factor}$$

where:

Ev	=	Evaporative loading losses (tons)
PT	=	Annual amount of product transferred (barrels)
BBL/GAL	=	Barrels to gallons conversion factor (42 gallons/barrel)
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)
VOC/TOC	=	TOC to VOC conversion factor (0.85)

Evaporative Ballasting:

$$Eb = Wat \times TOC \times VOC/TOC$$

where:

Eb	=	Ballasting emissions (tons)
Wat	=	Ratio of density of crude oil to water equivalent adjustment
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)

As with previous Gulfwide inventories, evaporative emissions were assigned to the center of the lightering zones (Figure 5-9). 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.

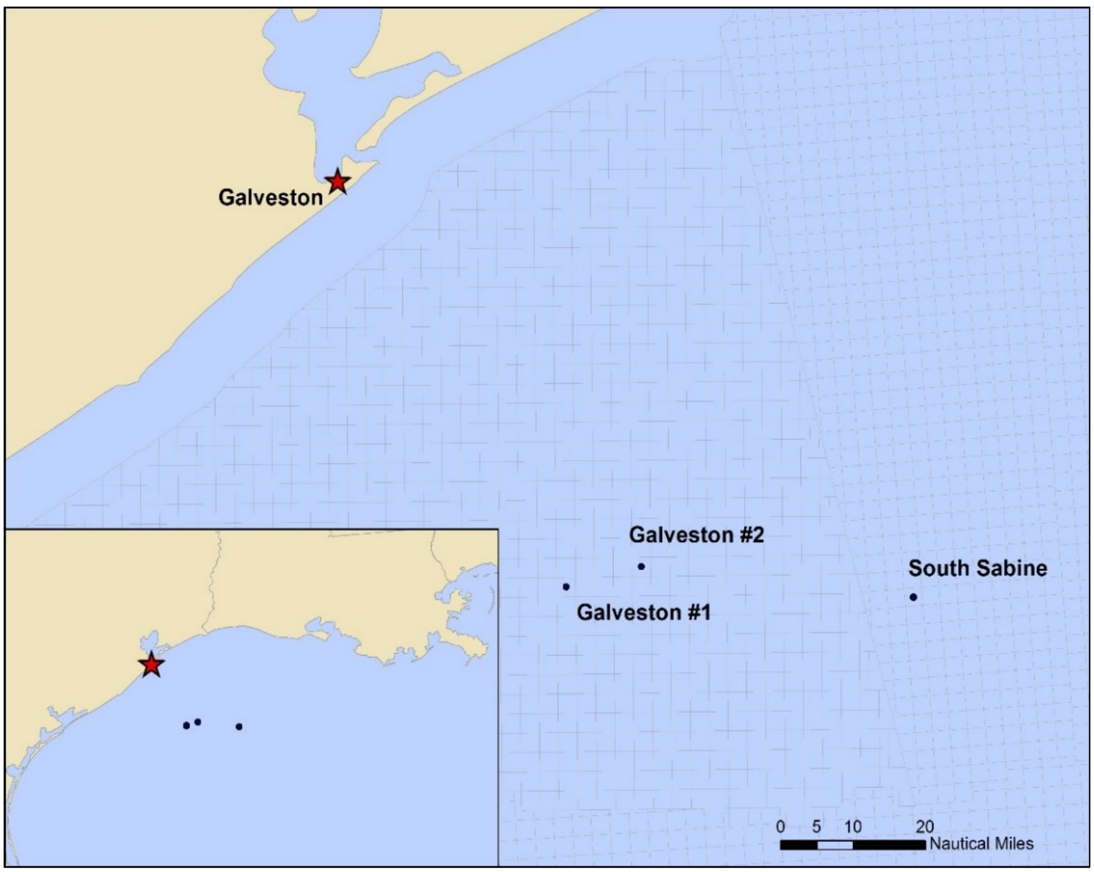


Figure 5-9. Centroid of the vessel lightering zone and shipping lane to Galveston

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 NMFS. Separate activity data were provided for the three types of offshore fishing activities that occur in the GOM: pelagic longline, reef, and shrimp operations (Maiello 2016; Farmer 2016; Hart 2016).

The activity data for these fishing operations were provided as a total for the central and western GOM plus a section of the Eastern Planning Area for pelagic longline fishing operations, and in terms of NMFS statistical zones, for reef and shrimp fishing operations. In previous inventory efforts, the activity data for pelagic longline fishing operations were provided as latitude and longitude; however, due to new confidential business procedures, the data could be provided only as a total for 2014. Table 5-16 presents the activity data for fishing operations.

Table 5-16. 2014 fishing vessel activity data

Fishing Category	NMFS Zones	2014 Fishing Vessel Hours
Shrimp	10–12	157,795
Shrimp	13–17	914,193
Shrimp	18–21	570,012
Reef	11–21	131,712
Longline	N/A	57,216

N/A – not applicable

Emissions associated with commercial fishing vessels were attributed to the operation of diesel engines used for propulsion and other smaller diesel engines that are used 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 5-3.

Average fishing vessel horsepower for longline (395 hp), reef (382 hp), and shrimp vessels (558 hp) were obtained from the average horsepower of the 2014 permitted fishing vessels (Dudley 2016). 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:

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

where:

E = Emissions (tons)
Ah = Annual hours per mode of operation (underway, maneuvering, hoteling) (hours)
kW = Average vessel kW (totaling individual propulsion engines) (kW)

EF = Emission factor (g/kWh)
CF = Conversion factor (g = 1.10231 E-6 ton)

Shrimp fishing vessels spent 1,642,000 hours at sea in 2014. The average kW is 418, the load factor is 0.80, and the emission factor for NO_x is 11.51 g/kWh.

$$E = 1,642,000 \times 418 \times 11.51 \times 1.10231 \times 10\text{-}6$$
$$E = 8,715.4 \text{ tons of } NO_x$$

Commercial fishing activities vary monthly depending on fishing season. To quantify temporal variations, monthly adjustment factors were calculated based on NOAA monthly fisheries landing data for 2014. The monthly adjustment factors were applied to the annual emission estimates to calculate the monthly emissions. Table 5-17 presents the monthly adjustment factors.

Table 5-17. Commercial fishing monthly adjustment factors

Month	2014 Monthly Adjustment Factors (%)
January	3
February	3
March	2
April	3
May	9
June	12
July	17
August	16
September	14
October	12
November	4
December	4

NMFS also provided commercial fishing locations. Reef and shrimp fishing operations are delineated by NMFS statistical zones (Figure 5-10). 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 2016) 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 87.5 degrees as part of the central and western areas of the GOM plus the Eastern Planning Area (on the right in Figure 5-10). Commercial fishing emission estimates were spatially allocated using the following formula:

$$ECFi = ECFz\ (Si/SCFz)$$

where:
ECFi = Commercial fishing emissions for lease block i (tons)
ECFz = Commercial fishing emissions for NMFS area z (tons)
Si = Surface area of lease block i (square miles)
SCFz = Total surface area of NMFS area z (square miles)

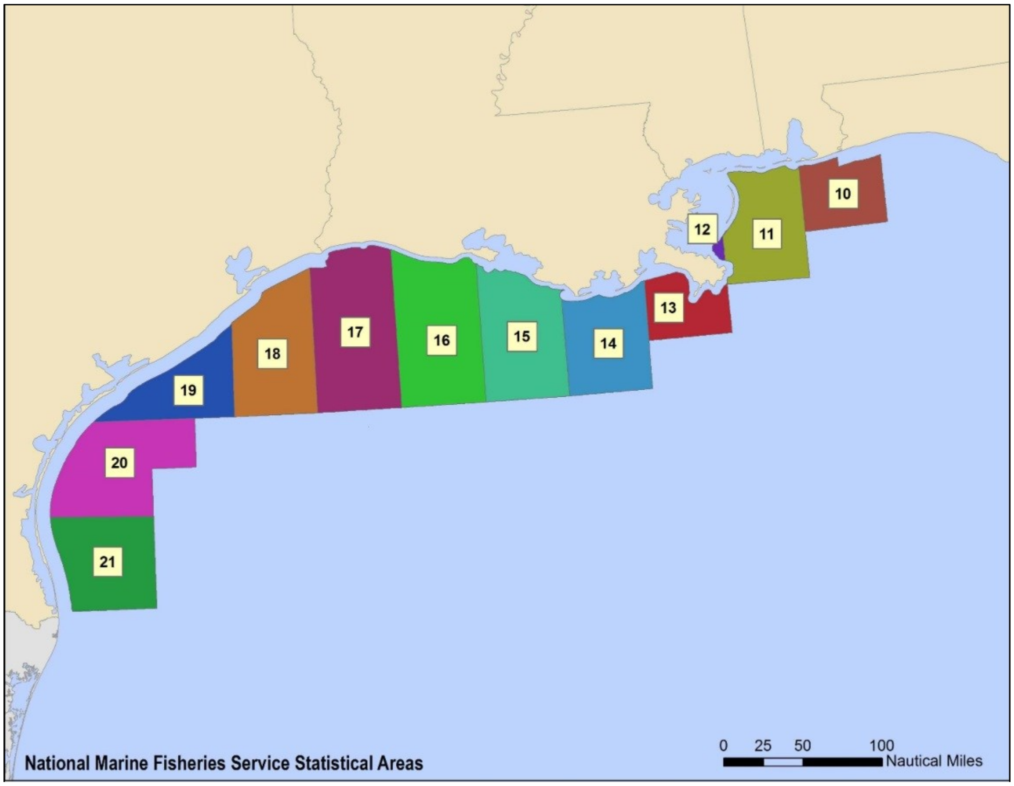


Figure 5-10. NMFS fishing zones with lease blocks

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 (Gordon 1993). Detailed recreational fishing data were obtained from the NOAA Marine Recreational Information Program (MRIP) (NOAA 2012). Aside from Texas and Louisiana, the data were disaggregated into fishing areas (inland, ocean ≤ 3 miles, and ocean > 3 miles); for this inventory of federal waters, only the ocean data were used greater than 3 miles from shore. Data for Texas and Louisiana are not disaggregated because the state, not NOAA, administered the survey. Texas and Louisiana report their data to NOAA in an aggregated form. To estimate the number of trips into federal waters, the average percent growth in trips between 2011 and 2014 were calculated for Alabama and Mississippi, and then applied to Texas and Louisiana. Table 5-18 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 5-19 presents the underway hours and maneuvering hours based on the trips.

Table 5-18. Number of trips near platforms

State	2011 Trips	2014 Trips	Percent Growth	Notes
Alabama	237,610	161,290	68%	Known
Louisiana	96,694	189,060	196%	Calculated
Mississippi	13,195	42,642	323%	Known
Texas	46,882	91,666	196%	Calculated

Table 5-19. Activity hours based on number of trips

State	Trips	Underway Hours	Maneuvering Hours
Alabama	161,290	645,159	967,739
Louisiana	189,060	756,241	1,134,362
Mississippi	42,642	170,568	255,853
Texas	91,666	366,664	549,997

The average weighted hp was estimated for diesel inboard engines from the USEPA's NONROAD (USEPA 2012) model's average hp per bin dataset and population distribution dataset shown in Table 5-20.

Table 5-20. USEPA nonroad recreational marine vessel power profile

HP Min	HP Max	HP Avg	Population	HP * Population
6	11	9.74	9,199	89,561.46
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 NONROAD model for pleasure craft diesel-fueled and 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 per mode of operation (underway, maneuvering, hoteling) hours

HP	=	Horse power
CF1	=	kW to HP conversion factors (1 HP = 0.7457 kW)
LF	=	Engine load factor for specified mode of operation (%)
EF	=	Emission factor (g/kWh)
CF	=	ton/gram conversion factor (1g = 1.10231 E-6 ton)

For example, recreational fishing vessels in Alabama spent 645,159 underway hours at sea in 2014. The average HP is 207.5, the load factor is 0.80, and the emission factor for CO_2 is 2.01 g/kW-hr.

$$E = 645{,}159 \times 207.5 \times 0.7457 \times 0.80 \times 2.01 \times 1.10231 \times 10^{-6}$$
$$E = 176.95 \text{ tons of } CO_2$$

5.3.7 Biogenic and Geogenic Emissions

The primary biogenic and geogenic sources of air pollution that were evaluated for this study are: subsurface seeps of crude oil, subsurface seeps of natural gas (including methane hydrates), and emissions from bacterial processes and ocean processes. In the previous inventory effort, credible emission estimates could be developed only for VOC subsurface seeps of oil and N_2O from bacterial processes. BOEM searched for any additional studies published or new data sources posted of the central and western areas of the GOM since the 2011 emission estimates were developed for these source categories. No additional references were uncovered that provided new data that could be used to enhance the 2011 biogenic and geogenic emission estimates. Given the nature of these emission sources, the 2011 estimates were used to represent 2014 emissions.

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 ocean waters because of cracks and vents in the sea bed. These cracks and vents open and close as the result of geological activities. The volume of oil seeping into the ocean can be relatively significant. The total quantity of oil that is released into the ocean does not, however, find its way to the surface and end up as air emissions. Some ocean-dwelling biota develop communities surrounding oil seeps that use the hydrocarbons as a source of nutrients. Other free-floating organisms in the water column consume portions of the escaping oil as the material rises to the surface. Although these processes do mitigate the amount of oil that reaches the surface for possible volatilization, the amounts of hydrocarbons consumed are unknown. After the seepage is on the surface, air pollutants, including VOC, CH_4, CO_2, and organic air toxics can be emitted through evaporation. Based on the data found in the literature, only VOC emissions can be estimated at this time.

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 and oil slicks. The total quantity of oil seeping into ocean waters has been estimated based on studies of oil slicks both at the ocean level and from satellite and space shuttle photography. These estimates have been input to models capable of 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. 1999 estimates oil seepage in the northern GOM to be 2.5–6.9 × 10^5 barrels/yr. Converting to tons, the average estimate of seepage in the northern Gulf is 73,000 tons/yr.

Using this figure, emissions can be estimated using either the oil seepage emission factor (105 lbs of VOC/barrel oil released) developed by the California Air Resources Board (CARB 1993) or the average mass volatilization from oil slicks predicted by the BOEM open ocean weathering model (USDOI, MMS 1998). One model prediction showed that after 10 days, 34% of the oil mass from a slick would have evaporated. As the surface slick ages, weathering continues to occur through the processes of photo oxidation, biodegradation, emulsification, and sedimentation; these processes are not associated with air emissions (ITOPF 2017; UNEP 2017).

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

1) 73,000 tpy × 294 gal/ton × 1 bbl/42 gal × 105 lbs/bbl = 26,827 tons/yr VOC

2) 73,000 tpy × 0.34 = 24,820 tons/yr VOC

For the purposes of this 2014 inventory, BOEM used an average of the two estimates (25,823.5 tons/yr). None of the studies provided accurate definitions of the Northern Gulf so that it was not possible to map the study area to BOEM lease blocks. In this case, these emission estimates are assumed to be for the whole Northern Gulf area. When adjusted to represent only the central and western GOM based on total surface area, the VOC emissions for the central and western areas of the Gulf were 13,561 tons per year (tpy).

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. When adjusted to represent only the western and central areas of the GOM, the N_2O estimate is 1,948 tons per year.

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 formud volcanoes were assigned equally to Garden Banks Block 382, Garden Canyon Block 143, Green Canyon Block 272, and Mississippi Canyon Block 929.

BOEM assumed that all biogenic/geogenic emissions are consistent throughout the year and therefore temporally apportioned annual emission estimates to individual months equally.

Previously, biogenic/geogenic emissions were applied to all lease blocks based on the surface area of each lease block, the exception being the mud volcanoes, whose emissions were assigned to the lease block where the volcano was located. For this 2014 inventory, biogenic/geogenic emissions were allocated based on surface area of lease blocks containing evidence of seepage or leakage activity using the equation below:

$$E_{bgi} = E_{bg} \times (S_i/S_{TNG})$$

where:

E_{bgi}	=	Biogenic/geogenic emissions associated with lease block i (tons)
E_{bg}	=	Total biogenic/geogenic emissions for GOM (tons)
S_i	=	Surface area of lease block i (square miles)
S_{TG}	=	Surface area of total GOM lease blocks (square miles)

BOEM's Gulf of Mexico Resource Studies Section has published seismic water bottom anomalies datasets (USDOI, 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 5-11). The changes in the 2016 data were relatively minor, so the 2012 data were used for the 2014 inventory. 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.

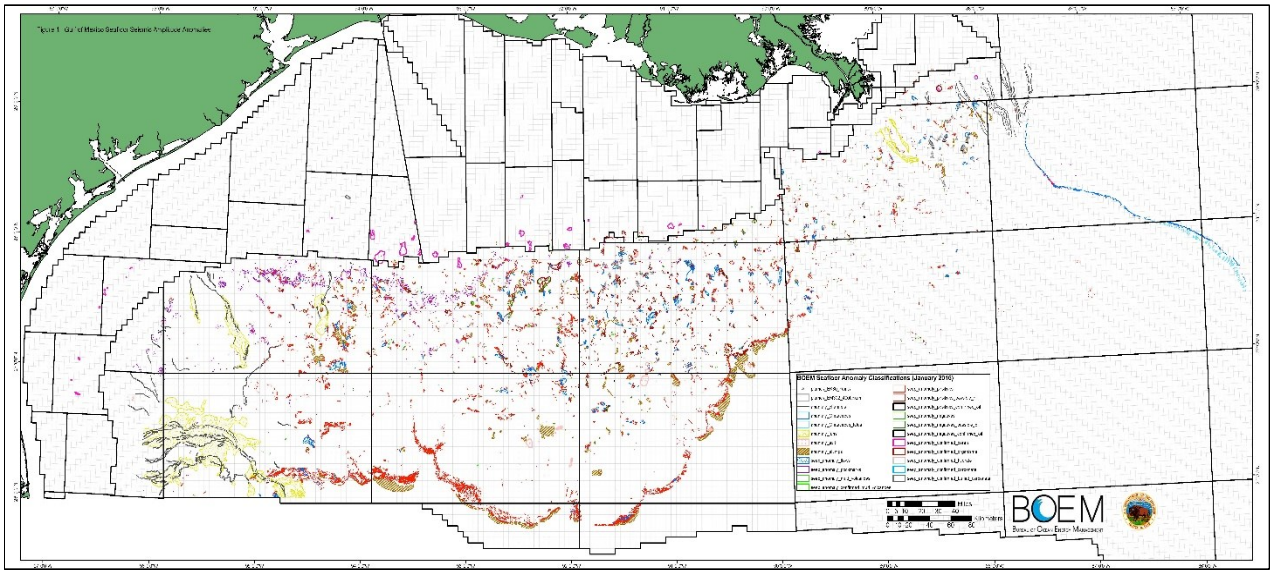


Figure 5-11. Locations of negative anomalies and pockmarks

5.4 NON-PLATFORM QUALITY ASSURANCE CHECKS

ERG implemented quality assurance 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 2014 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 vary 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 are not directly involved in the original calculations. Special attention is given to unit conversions as these can be sources of significant errors.

Details on the QA/QC activities implemented with the AIS vessel data are provided in Appendix C.1.

6. RESULTS

6.1 SUMMARY OF STUDY APPROACH

This BOEM Year 2014 Gulfwide Emissions Inventory Study includes all major oil and gas production platforms and non-platform sources in the GOM on the OCS west of 87° 30' longitude. Pollutants covered in the inventory are the criteria pollutants (CO, Pb, NO_x, PM_{10}, $PM_{2.5}$, and SO_2); criteria pollutant precursors (NH_3 and VOC); and major GHGs (CO_2, CH_4, and N_2O).

BOEM attempted to collect activity data from each active major offshore oil and gas production platform in the GOM on the OCS. Operators were provided with the GOADS-2014 Visual Basic® activity data collection software for compiling monthly data for calendar year 2014. A total of 1,651 oil and gas production platforms submitted active monthly equipment activity data files as described in Section 2. The platform equipment surveyed includes:

- Amine units.
- Boilers, heaters, and burners.
- Diesel engines.
- Drilling equipment.
- Combustion flares.
- Fugitive sources.
- 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.
- Cold vents.

Rigorous QA/QC was performed on the activity data collected from platform operators as described in Section 3. Tasks included correcting the number of operating hours provided for a given month, filling in missing monthly operating data (if the equipment was operational), verifying and correcting activity values such as fuel heating value, ensuring that the equipment shown to be vented included a vent ID and activity record, filling in missing stack parameters with surrogates, and double-checking exit velocity and fuel usage totals by recalculating the parameters. The monthly activity data collected from the platform operators were then combined with emission factors and algorithms to develop the platform production equipment emission estimates as described in Section 4. Inventory data files were compiled with the oil and gas production platform data suitable for use in air quality modeling applications. In addition to monthly emission estimates by pollutant and individual piece of equipment, the files include the company, structure and complex ID, lease number, block and area number, and latitude/longitude. For each piece of equipment, stack parameter information such as outlet height, exit velocity, and exhaust gas temperature is also presented.

Emission estimates were also developed for criteria air pollutants and GHGs for non-platform sources operating in the GOM on the OCS for the 2014 calendar year as described in Section 5. The non-platform sources included in this study are noted below.

Non-platform oil and gas production sources:

- Drilling rigs.
- Pipelaying operations.
- Support helicopters.
- Support vessels.
- Survey vessels.

Non-platform non-oil and gas production sources:

- Biogenic and geogenic sources.
- Commercial fishing vessels.
- Commercial marine vessels.
- LOOP.
- Military vessels (U.S. Coast Guard, U.S. Navy).
- Vessel lightering.
- Recreational fishing vessels.

After intensive research and data gathering of activity data specific to each source category, the compiled activity data underwent detailed QA/QC. For most marine vessel source categories, the emission factors were obtained from the USEPA 2014 NEI (USEPA 2015) specifically to represent 2014 engine and fuel standards as well as vessel turnover. These 2014 emission factors were applied to AIS vessel traffic data to estimate emissions. The resulting non-platform emission estimates were then disaggregated into BOEM lease blocks, suitable for use in air quality modeling applications. Diurnal emission curves needed for air quality modeling are presented in Year 2008 Gulfwide Emissions Inventory Study (Wilson et al. 2010).

6.2 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. Figure 6-1 depicts the locations of active platforms in 2014 included in this inventory. Figures 6-2 through 6-5 indicate the spatial locations of the PM_{10}, NO_x, SO_2, and VOC platform emission estimates for 2014.

Table 6-1. Total platform 2014 emission estimates for criteria pollutants and precursors

Equipment	CO Emissions (tpy)[a]	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	-	-	-	-	-	-	13	7.68E-3
Boilers, heaters, and burners	177	1.06E-3	208	10	10	**7**	1	12
Diesel engines	1,173	-	4,984	246	246	-	**425**	275
Drilling equipment	397	-	1,495	27	26	-	24	37
Combustion flares	821	**1.28E-3**	184	1	1	8	2	16
Fugitive sources	-	-	-	-	-	-	-	18,531
Glycol dehydrators	-	-	-	-	-	-	-	275
Loading operations	-	-	-	-	-	-	-	206
Losses from flashing	-	-	-	-	-	-	-	317
Minor sources	-	-	-	-	-	-	-	10
Mud degassing	-	-	-	-	-	-	-	72
Natural gas engines	**45,070**	-	**32,355**	**283**	**283**	-	10	915
Natural gas, diesel, and dual-fuel turbines	2,413	7.29E-4	9,463	101	101	N/A	27	61
Pneumatic pumps	-	-	-	-	-	-	-	5,511
Pressure and level controllers	-	-	-	-	-	-	-	1,143
Storage tanks	-	-	-	-	-	-	-	677
Cold vents	-	-	-	-	-	-	-	**20,152**
Total emissions[b]	50,052	3.07E-3	48,691	668	667	15	502	48,210

[a] Emissions reported in short tons.

[b] Totals may not sum due to rounding.

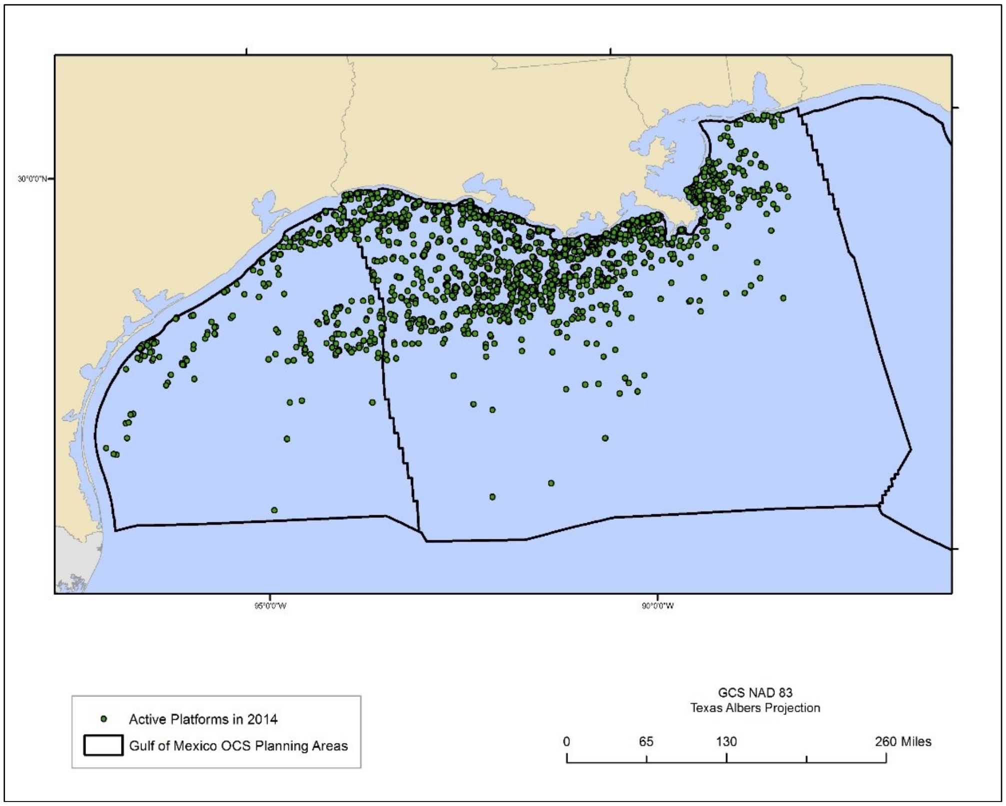


Figure 6-1. Active production platform locations in 2014

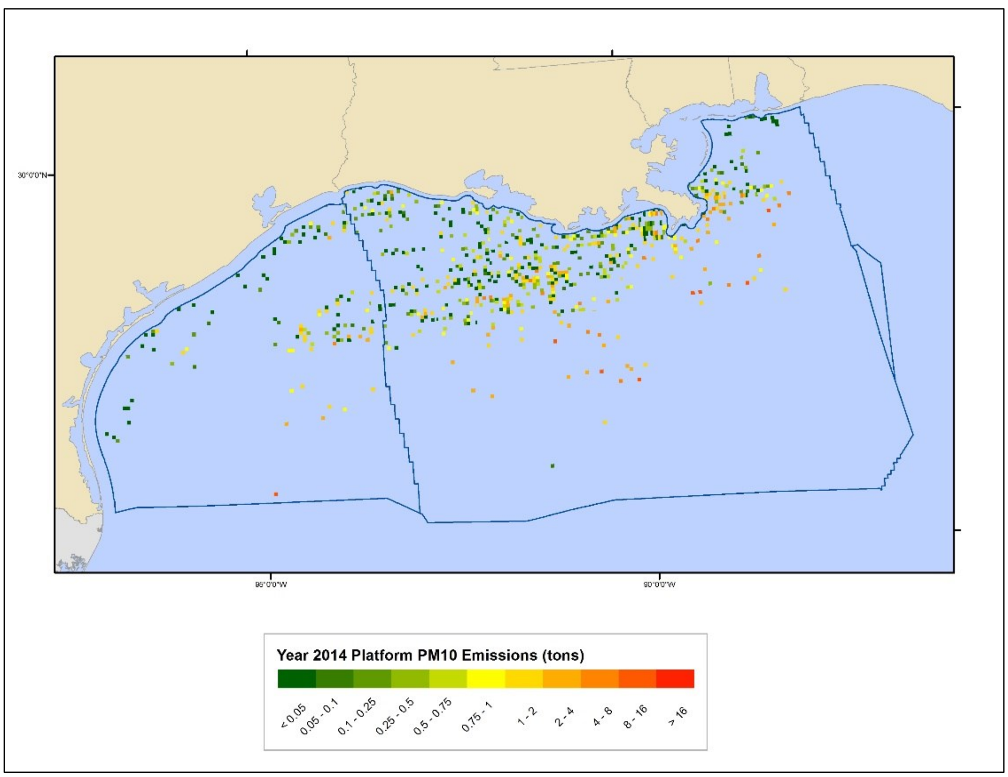


Figure 6-2. Platform PM_{10} 2014 emission estimates

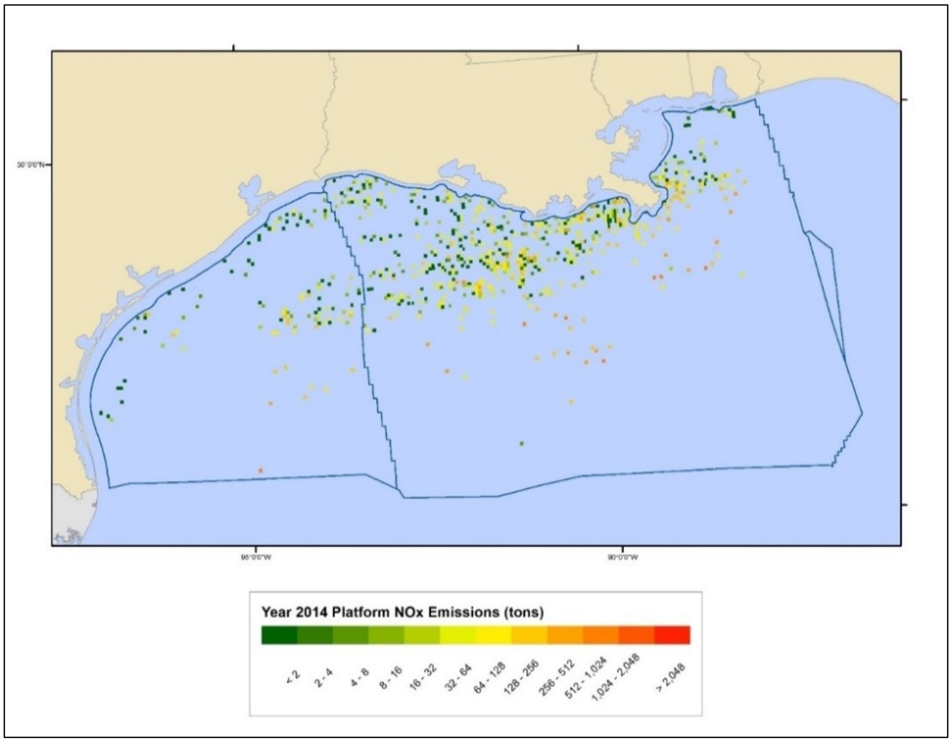


Figure 6-3. Platform NO_x 2014 emission estimates

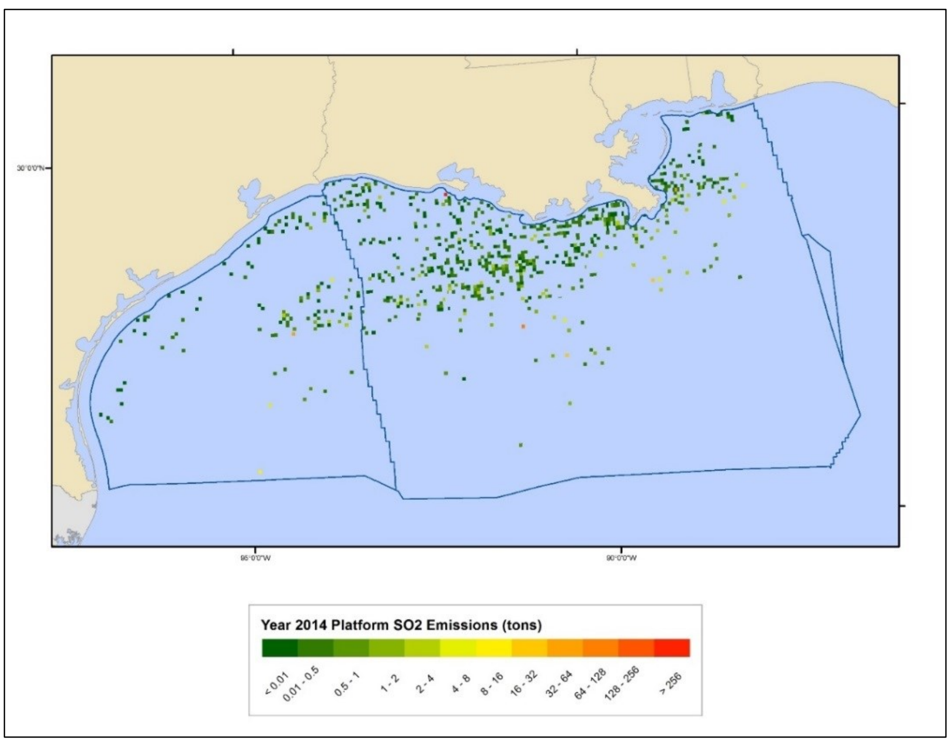


Figure 6-4. Platform SO_2 2014 emission estimates

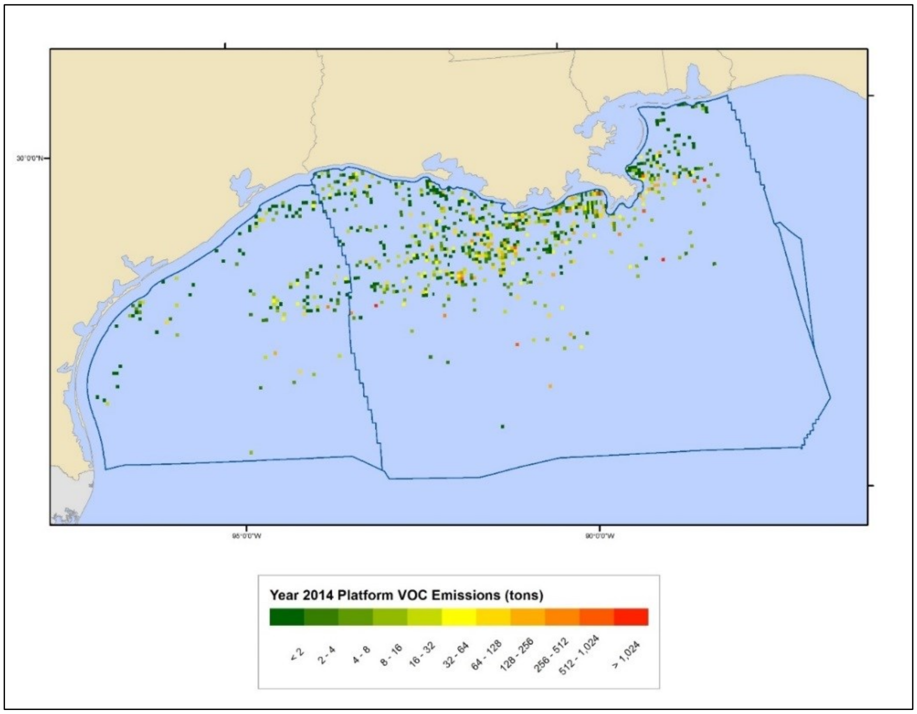


Figure 6-5. Platform VOC 2014 emission estimates

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_{10}, NO_x, SO_2, and VOC non-platform oil and gas production-related emission estimates for 2014.

Table 6-2. Total non-platform 2014 emission estimates for criteria pollutants and precursors

Source Category	CO Emissions (tpy)[a]	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	6,236	1.00E-01	40,837	1,262	1,189	17	5,354	859
Pipelaying operations	239	-	2,406	86	79	1	669	98
Support helicopters	1,978	-	979	28	28	-	126	1,632
Support vessels	6,194	7.48E-02	30,256	799	774	12	122	399
Survey *vessels*	812	2.25E-03	3,276	154	144	-	378	379
Total OCS oil and gas production sources (tpy)	15,459	1.77E-01	77,754	2,329	2,214	29	6,648	3,367
Biogenic and geogenic sources	-	-	-	-	-	-	-	14,357

Source Category	CO Emissions (tpy)[a]	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)
Commercial fishing vessels	1,934	2.46E-02	9,435	219	213	4	5	102
Commercial marine vessels	**20,655**	**4.14E-01**	**200,258**	**6,409**	**5,971**	**74**	**48,215**	8,802
LOOP	224	2.77E-03	1,001	37	36	1	12	300
Military vessels	988	1.97E-02	9,432	283	265	4	2,121	379
Vessel lightering[b]	-	-	-	-	-	-	-	**17,113**
Recreational vessels	1,585	2.01E-02	7,732	180	174	3	4	83
Total Non-OCS oil and gas production sources	25,387	4.81E-01	227,858	7,127	6,658	85	50,358	41,137
Total non-platform emissions[c]	40,846	6.61E-01	305,612	9,456	8,872	115	57,006	44,504

[a] Emissions reported in short tons.
[b] Vessel estimates are reflected in commercial marine vessels.
[c] Totals may not sum due to rounding.

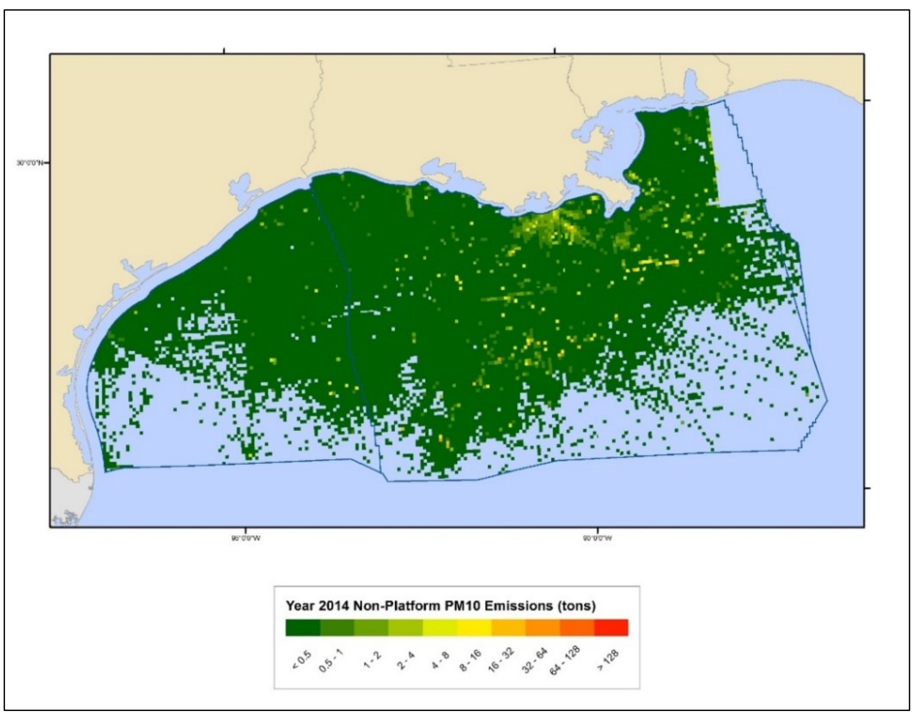


Figure 6-6. Non-platform oil and gas production-related PM_{10} 2014 emission estimates

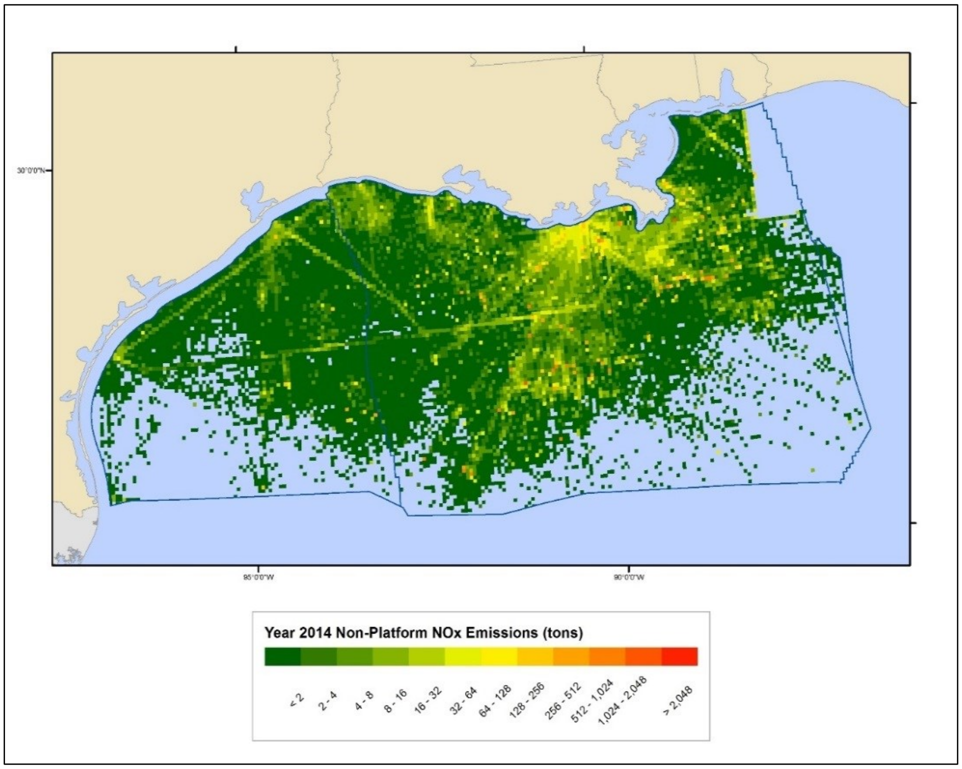


Figure 6-7. Non-platform oil and gas production-related NO_x 2014 emission estimates

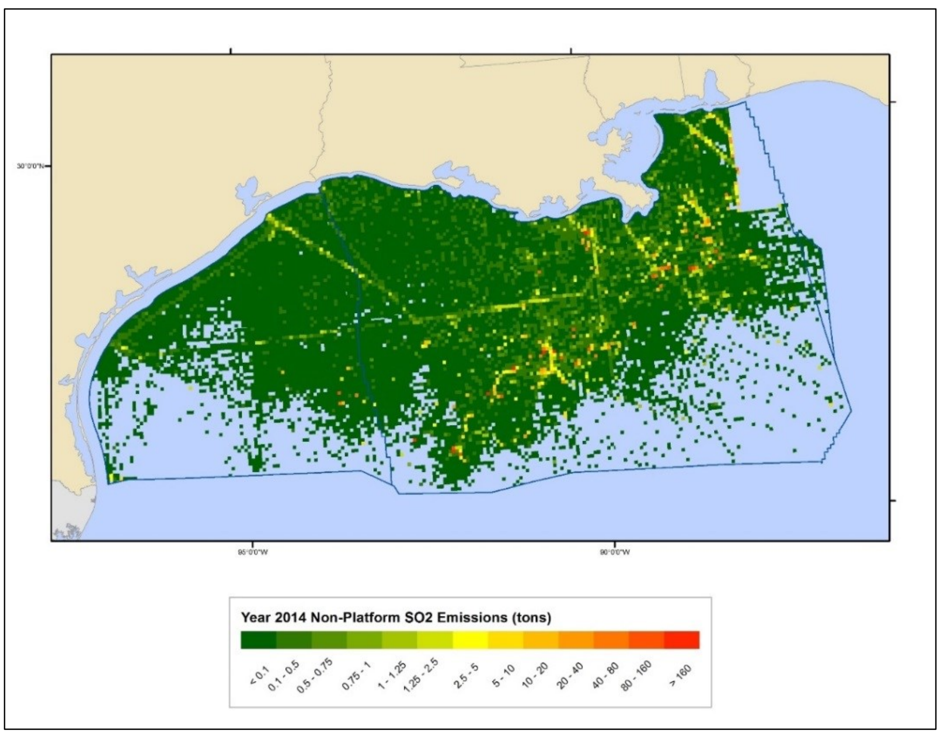


Figure 6-8. Non-platform oil and gas production-related SO_2 2014 emission estimates

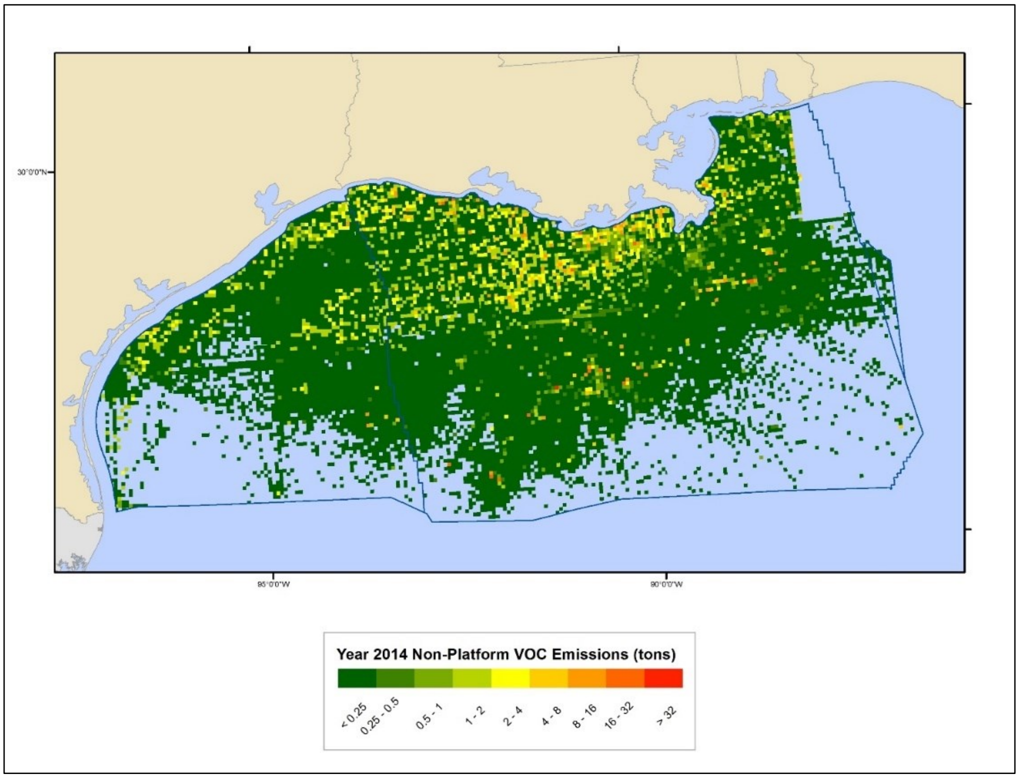


Figure 6-9. Non-platform oil and gas production-related VOC 2014 emission estimates

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_{10}, NO_x, SO_2, and VOC total platform and non-platform (oil and gas production related-sources) emission estimates for 2014. 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 2014 emission estimates for criteria pollutants and precursors

Source Category	CO (tpy)[a]	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	50,052	3.07E-3	48,691	668	667	15	502	48,210
Drilling rigs	6,236	1.00E-01	40,837	1,262	1,189	17	5,354	859
Pipelaying operations	239	-	2,406	86	79	1	669	98
Support helicopters	1,978	-	979	28	28	-	126	1,632
Support vessels	6,194	7.48E-02	30,256	799	774	12	122	399
Survey vessels	812	2.25E-03	3,276	154	144	-	378	379

Source Category	CO (tpy)[a]	Pb (tpy)	NO_x (tpy)	PM_{10}-PRI (tpy)	$PM_{2.5}$-PRI (tpy)	NH_3 (tpy)	SO_2 (tpy)	VOC (tpy)
Total OCS oil and gas production source emissions	65,511	1.80E-01	126,445	2,997	2,881	45	7,151	51,577
Total non-OCS oil and gas production source emissions	25,387	4.81E-01	227,858	7,127	6,658	85	50,358	41,137
Total emissions[b]	90,898	6.61E-01	354,303	10,124	9,539	130	57,509	92,714

[a] Emissions reported in short tons.

[b] Totals may not sum due to rounding.

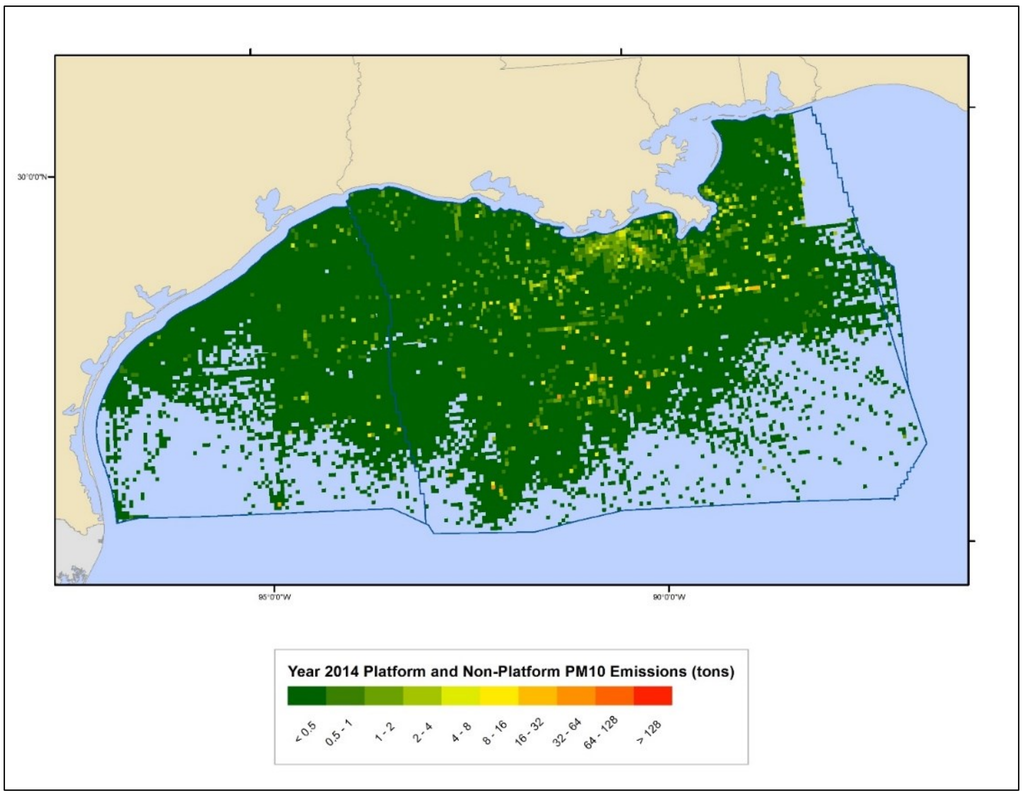


Figure 6-10. Total platform and non-platform (oil and gas production related-sources) PM_{10} 2014 emission estimates

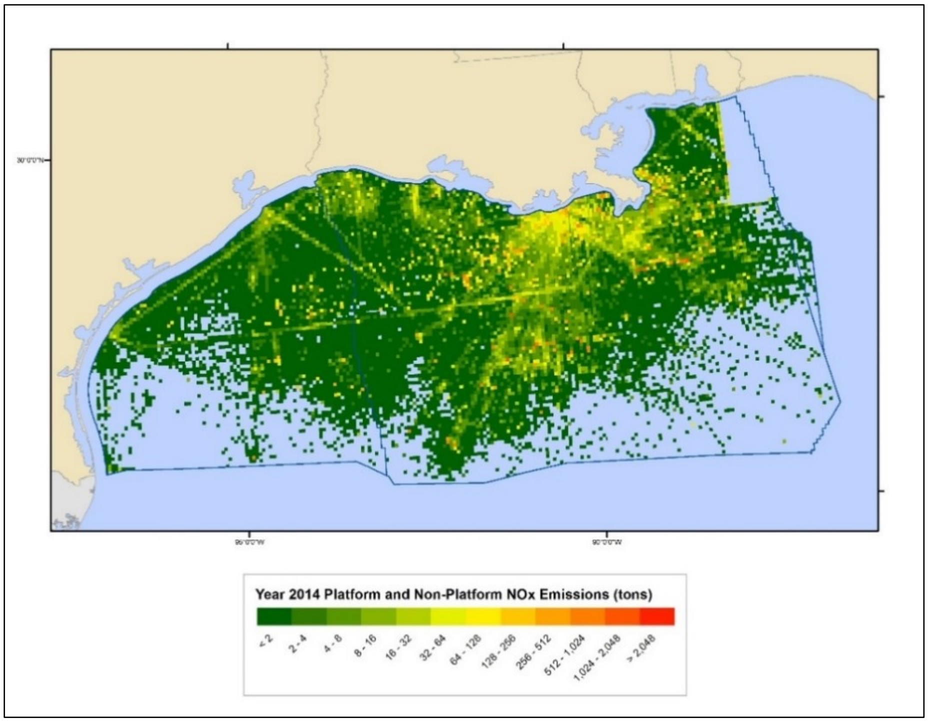


Figure 6-11. Total platform and non-platform (oil and gas production related-sources) NO_x 2014 emission estimates

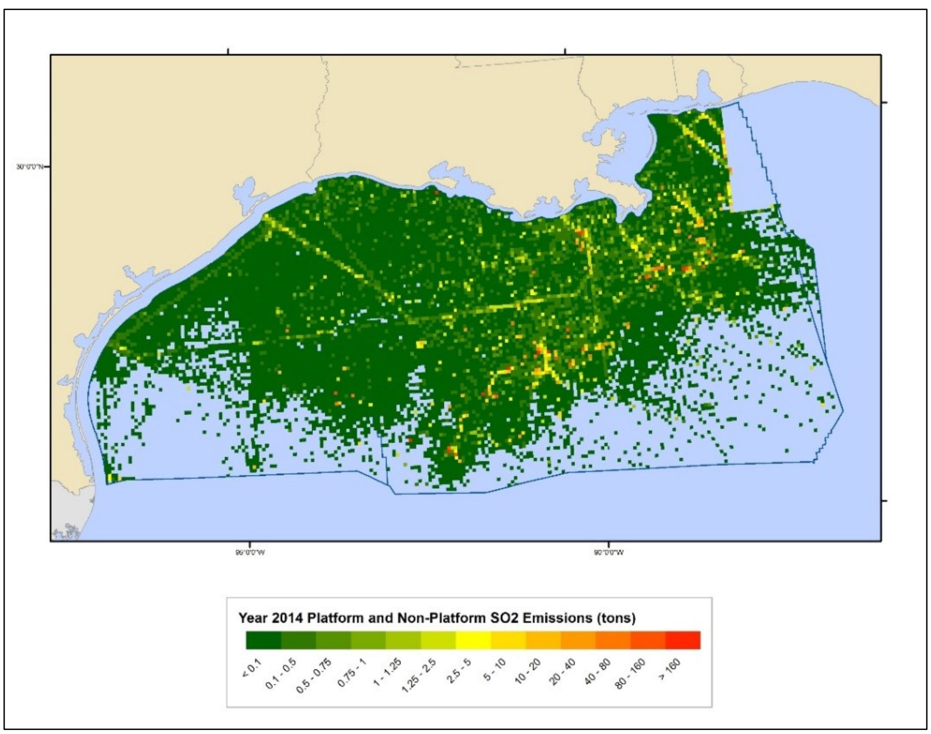


Figure 6-12. Total platform and non-platform (oil and gas production related-sources) SO_2 2014 emission estimates

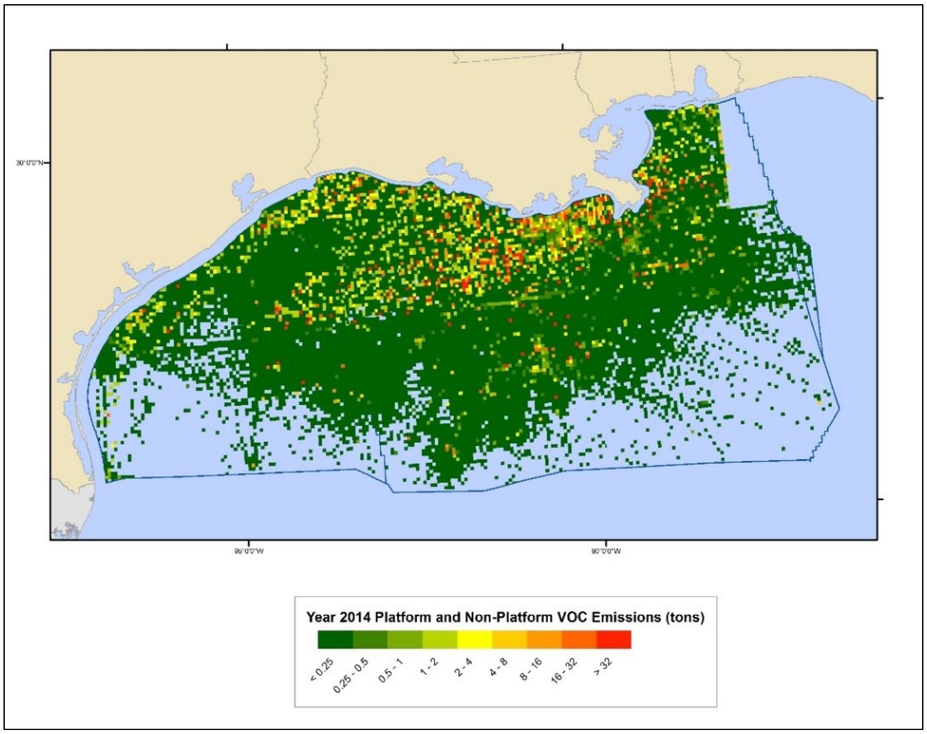


Figure 6-13. Total platform and non-platform (oil and gas production related-sources) VOC 2014 emission estimates

Table 6-4. Annual CO 2014 emission estimates for all sources

Equipment and Source Category	CO Emissions (tpy)[a]
Natural gas engines	45,070
Commercial marine vessels	20,655
Drilling rigs	6,236
Support vessels	6,194
Natural gas, diesel, and dual-fuel turbines	2,413
Support helicopters	1,978
Commercial fishing vessels	1,934
Recreational vessels	1,585
Diesel engines	1,173
Military vessels	988
Survey vessels	812
Combustion flares	821
Drilling equipment	397
Pipelaying operations	239
LOOP	224
Boilers, heaters, and burners	177
Total emissions[b]	90,898

[a] Emissions reported in short tons.

[b] Totals may not sum due to rounding.

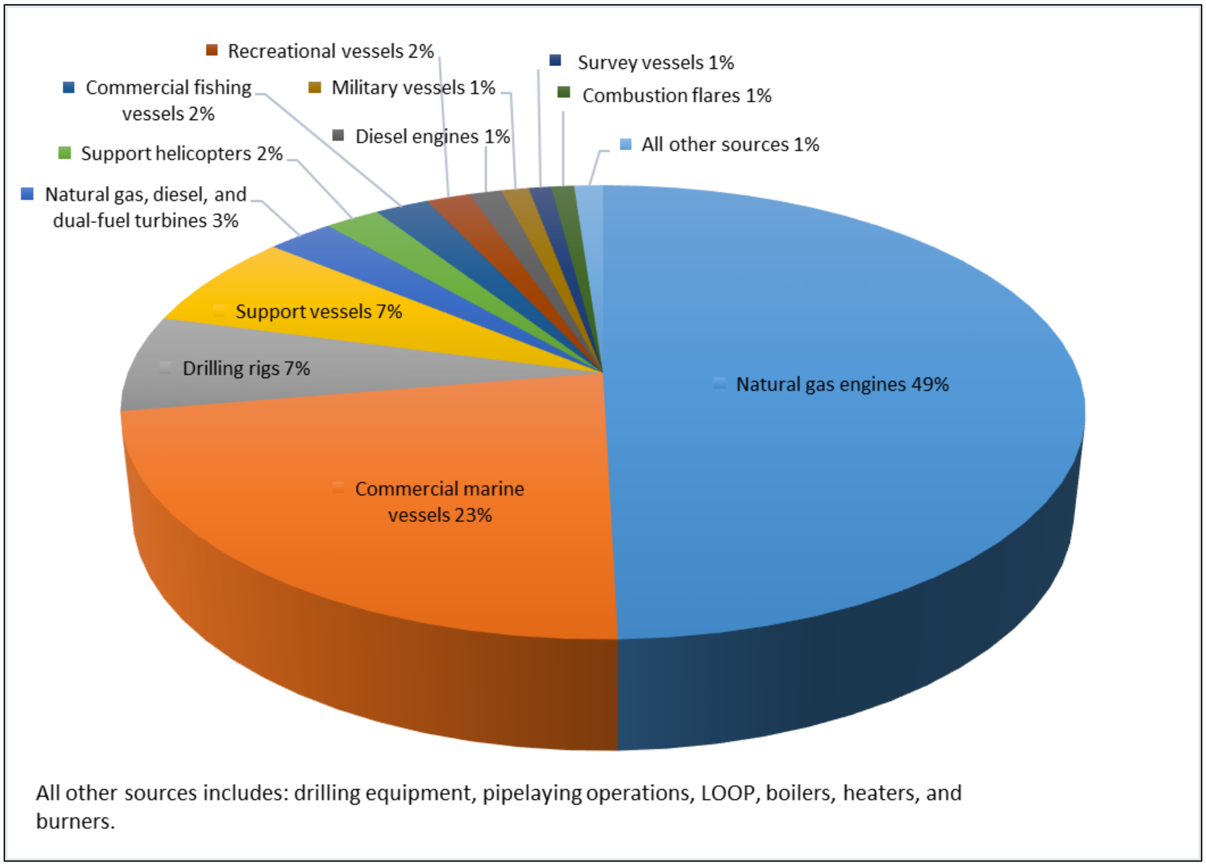


Figure 6-14. Annual CO 2014 emissions by source type

Table 6-5. Annual Pb 2014 emission estimates for all sources

Equipment and Source Category	Pb Emissions (tpy)[a]
Support vessels	7.48E-02
Commercial marine vessels	4.14E-01
Drilling rigs	1.00E-01
Natural gas, diesel, and dual-fuel turbines	7.29E-04
Survey vessels	2.25E-03
Combustion flares	1.28E-03
Commercial fishing vessels	2.46E-02
Military vessels	1.97E-02
Recreational vessels	2.01E-02
Boilers, heaters, and burners	1.06E-03
LOOP	2.77E-03
Pipelaying operations	-
Support helicopters	-
Total emissions[b]	6.61E-01

[a] Emissions reported in short tons.
[b] Totals may not sum due to rounding.

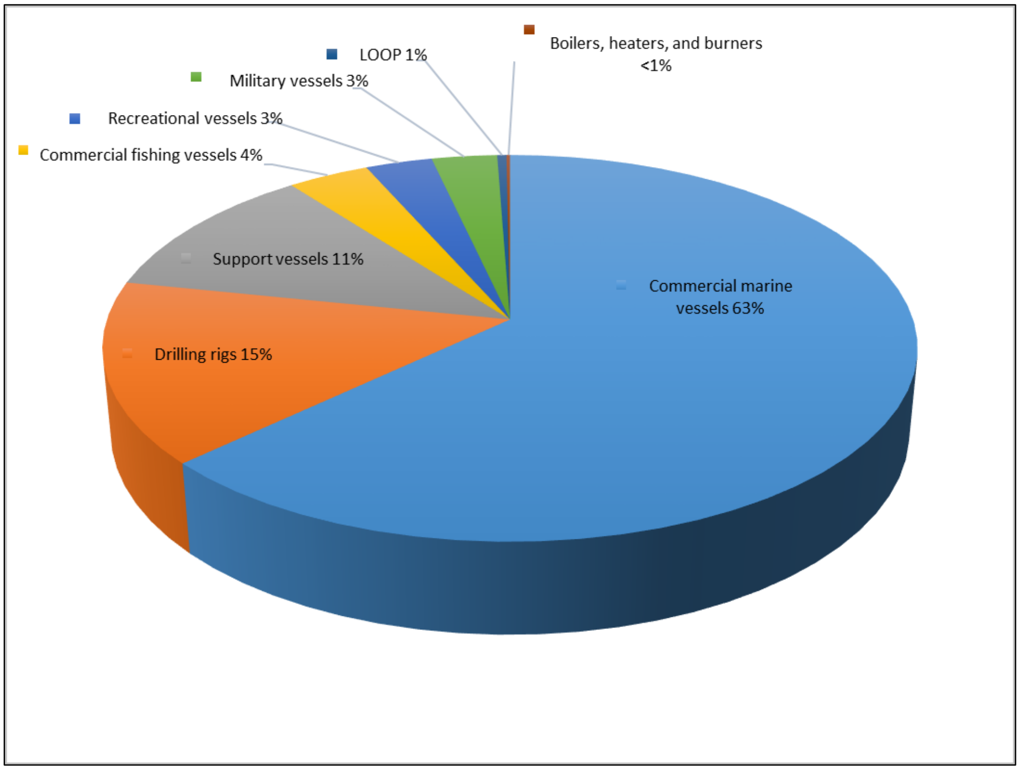
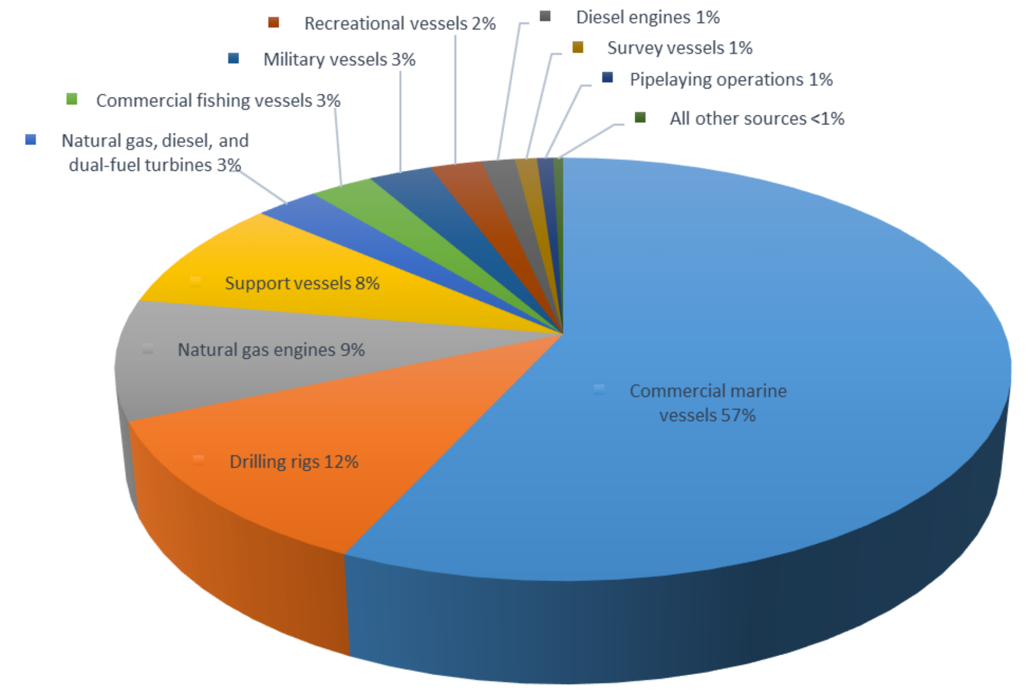


Figure 6-15. Annual Pb 2014 emissions by source type

Table 6-6. Annual NO_x 2014 emission estimates for all sources

Equipment and Source Category	NO_x Emissions (tpy)[a]
Commercial marine vessels	200,258
Drilling rigs	40,837
Natural gas engines	32,355
Support vessels	30,256
Natural gas, diesel, and dual-fuel turbines	9,463
Commercial fishing vessels	9,435
Military vessels	9,432
Recreational vessels	7,732
Diesel engines	4,984
Survey vessels	3,276
Pipelaying operations	2,406
Drilling equipment	1,495
LOOP	1,001
Support helicopters	979
Boilers, heaters, and burners	208
Combustion flares	184
Total emissions[b]	354,303

[a] Emissions reported in short tons.
[b] Totals may not sum due to rounding.



All other sources includes: LOOP, support helicopters, boilers, heaters, and burners, combustion flares.

Figure 6-16. Annual NO_x 2014 emissions by source type

Table 6-7. Annual PM_{10}-PRI 2014 emission estimates for all sources[a]

Equipment and Source Category	PM_{10}-PRI Emissions (tpy)[a, b]
Commercial marine vessels	6,409
Drilling rigs	1,262
Support vessels	799
Military vessels	283
Natural gas engines	283
Diesel engines	246
Commercial fishing vessels	219
Recreational vessels	180
Survey vessels	154
Natural gas, diesel, and dual-fuel turbines	101
Pipelaying operations	86
LOOP	37
Support helicopters	28

Equipment and Source Category	PM_{10}-PRI Emissions (tpy)[a, b]
Drilling equipment	27
Boilers, heaters, and burners	10
Combustion flares	1
Total emissions[c]	10,124

[a] Emissions reported in short tons.
[b] Annual $PM_{2.5}$ emission estimates follow a similar pattern.
[c] Totals may not sum due to rounding.

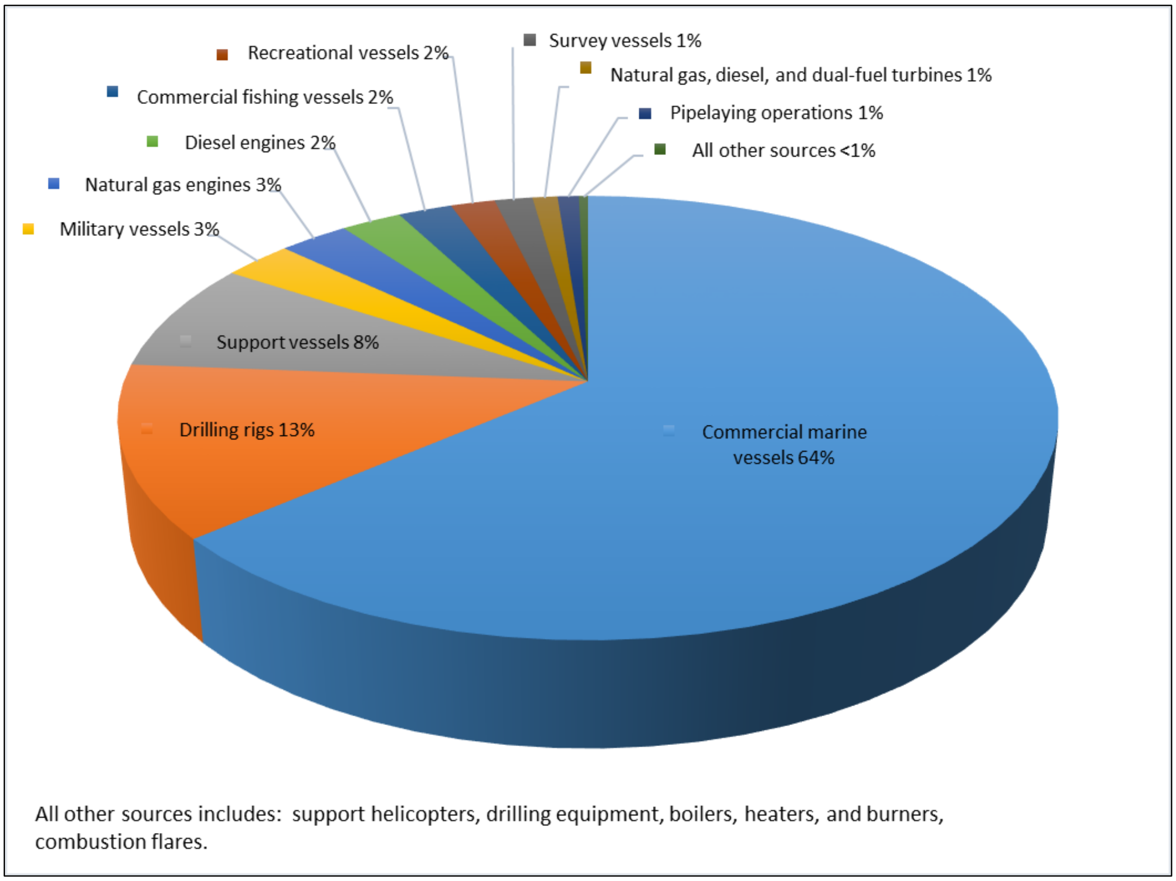


Figure 6-17. Annual PM_{10}-PRI 2014 emissions by source type

Table 6-8. Annual NH_3 2014 emission estimates for all sources[a]

Equipment and Source Category	NH_3 Emissions (tpy)[a]
Commercial marine vessels	74
Drilling rigs	17
Support vessels	12
Combustion flares	8
Boilers, heaters, and burners	7
Commercial fishing vessels	4
Military vessels	4
Recreational vessels	3
Pipelaying operations	1
LOOP	1
Support helicopters	0
Survey vessels	0
Total emissions[b]	130

[a] Emissions reported in short tons.
[b] Totals may not sum due to rounding.

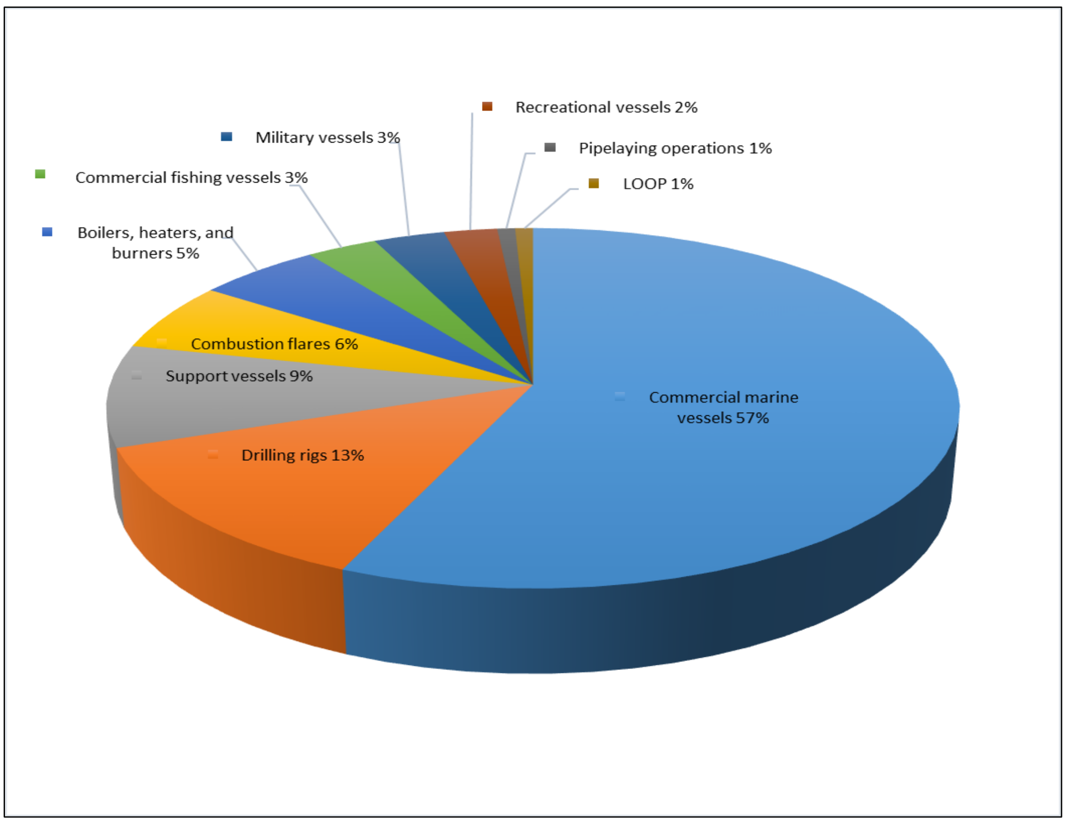


Figure 6-18. Annual NH_3 2014 emissions by source type

Table 6-9. Annual SO_2 2014 emission estimates for all sources

Equipment and Source Category	SO_2 Emissions (tpy)[a]
Commercial marine vessels	48,215
Drilling rigs	5,354
Military vessels	2,121
Pipelaying operations	669
Diesel engines	425
Survey vessels	378
Support helicopters	126
Support vessels	122
Natural gas, diesel, and dual-fuel turbines	27
Drilling equipment	24
Amine units	13
LOOP	12
Natural gas engines	10
Commercial fishing vessels	5
Recreational vessels	4
Combustion flares	2
Boilers, heaters, and burners	1
Total emissions[b]	57,509

[a] Emissions reported in short tons.
[b] Totals may not sum due to rounding.

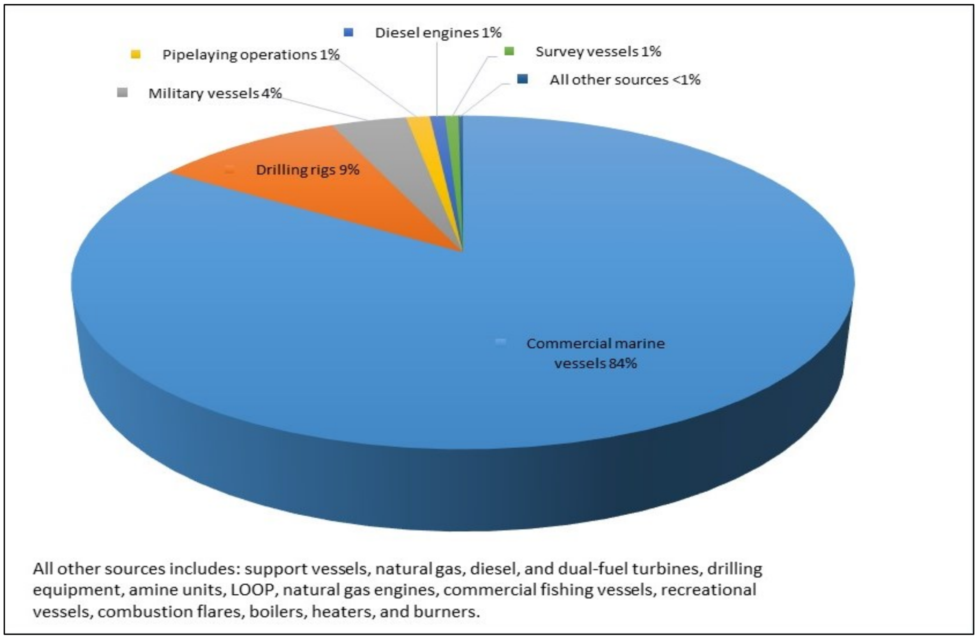


Figure 6-19. Annual SO_2 2014 emissions by source type

Table 6-10. Annual VOC 2014 emission estimates for all sources

Equipment and Source Category	VOC Emissions (tpy)[a]
Cold vents	20,152
Fugitive sources	18,531
Vessel lightering	17,113
Biogenic and geogenic sources	14,357
Commercial marine vessels	8,802
Pneumatic pumps	5,511
Pressure and level controllers	1,143
Support helicopters	1,632
Natural gas engines	915
Drilling rigs	859
Storage tanks	677
Support vessels	399
Military vessels	379
Survey vessels	379
Losses from flashing	317
LOOP	300
Glycol dehydrators	275
Diesel engines	275
Loading operations	206
Commercial fishing vessels	102
Pipelaying operations	98
Recreational vessels	83
Mud degassing	72
Natural gas, diesel, and dual-fuel turbines	61
Drilling equipment	37
Combustion flares	16
Boilers, heaters, and burners	12
Minor sources	10
Amine units	7.68E-03
Total emissions[b]	92,714

[a] Emissions reported in short tons.
[b] Totals may not sum due to rounding.

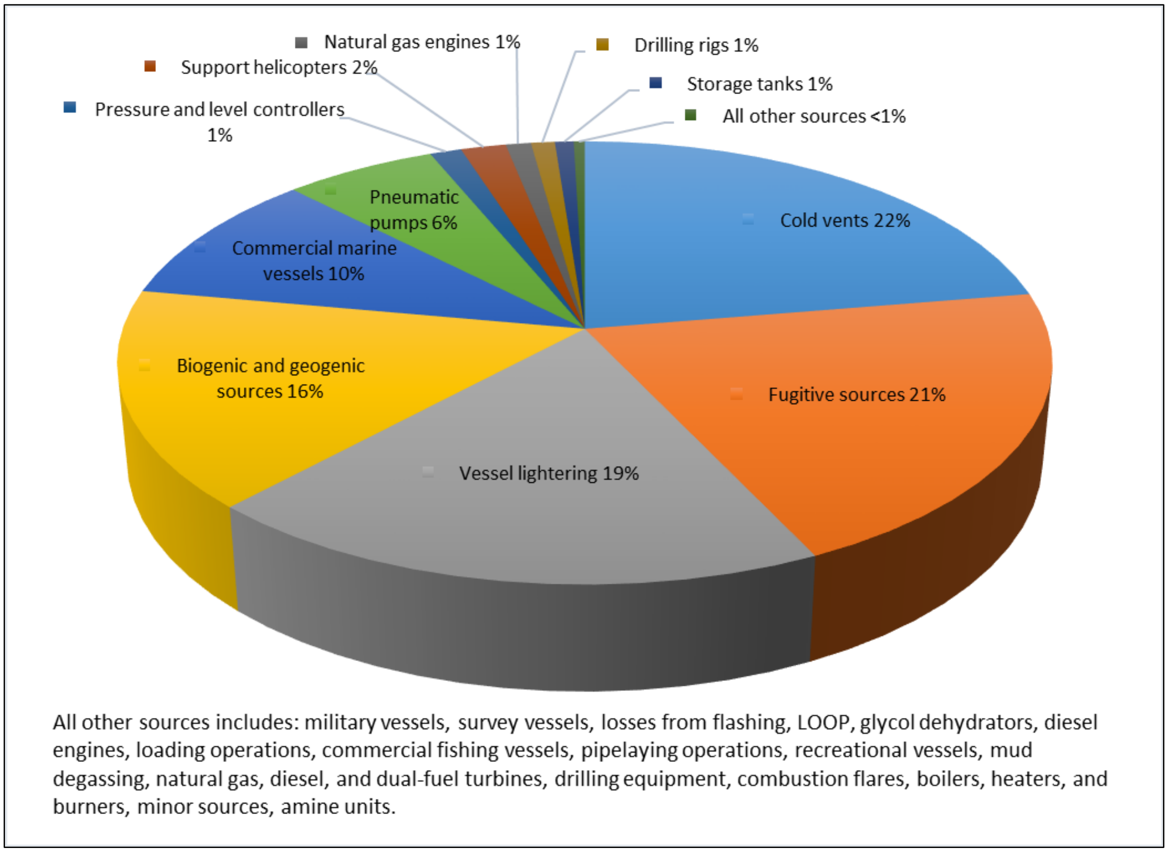


Figure 6-20. Annual VOC 2014 emissions by source type

Tables 6-11 through 6-13 present the GHG emission estimates for 2014, 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). Since 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 2014 inventory, the GWPs reflect changes presented in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC 2007), with a global warming potential of 25 for CH_4, and a global warming potential of 298 for N_2O. The USEPA has also adopted these values under the USEPA Final Mandatory Reporting of Greenhouse Gases Rule (Federal Register 2009). The CO_2e emission estimates shown in these tables represent the number of tons of CO_2 emissions with the same global warming potential 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 2014 emission estimates for platform sources

Equipment Types	CO_2 Emissions (tpy)[a]	CH_4 Emissions (tpy)	N_2O Emissions (tpy)	CO_2e Emissions (tpy)[b]
Amine units	9	1.04E-01	-	12
Boilers, heaters, and burners	253,096	5	5	254,574
Diesel engines	213,850	5	-	213,973
Drilling equipment	77,098	-	-	77,098
Combustion flares	307,392	332	5	317,293
Fugitive sources	-	74,386	-	1,859,640
Glycol dehydrators	1.86E-01	2,073	-	51,827
Loading operations	-	-	-	-
Losses from flashing	163	7,040	-	176,156
Minor sources	-	32	-	795
Mud degassing	2	175	-	4,367
Natural gas engines	1,839,744	8,769	-	2,058,959
Natural gas, diesel, and dual-fuel turbines	**3,245,409**	253	**88**	**3,278,047**
Pneumatic pumps	1,430	36,686	-	918,582
Pressure and level controllers	562	8,453	-	211,878
Storage tanks	-	671	-	16,782
Cold vents	1,575	**86,789**	-	2,171,289
Total emissions[c]	5,940,330	225,667	98	11,611,272

[a] Emissions reported in short tons.
[b] GWP = 25 for CH_4 and 298 for N_2O.
[c] Totals may not sum due to rounding.

Table 6-12. Total GHG 2014 emission estimates for non-platform sources

Source Category	CO_2 Emissions (tpy)[a]	CH_4 Emissions (tpy)	N_2O Emissions (tpy)	CO_2e Emissions (tpy)[b]
Drilling rigs	2,151,121	15	104	2,182,406
Pipelaying operations	113,755	1	6	115,447
Support helicopters	179,707	11	13	183,811
Support vessels	1,637,455	10	77	1,660,741
Survey vessels	112,941	0	2	113,641
Total OCS oil and gas production sources (tpy)	4,194,979	37	202	4,256,046
Biogenic and geogenic sources	2,284	**1,876**	**1,948**	629,688
Commercial fishing	531,190	3	25	538,842
Commercial marine vessels	**8,398,693**	75	427	**8,527,905**
LOOP	64,320	0	2	64,898
Military vessels	391,169	4	20	397,328
Vessel lightering[c]				0
Recreational vessels	435,327	3	21	441,599
Total Non-OCS oil and gas production source emissions	9,822,983	1,961	2,443	10,600,260
Total emissions[d]	14,017,962	1,999	2,646	14,856,307

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

Table 6-13. Total platform and non-platform 2014 emission estimates for GHGs

Source Category	CO_2 Emissions (tpy)[a]	CH_4 Emissions (tpy)	N_2O Emissions (tpy)	CO_2e Emissions (tpy)[b]
Total platform emissions	5,940,330	225,667	98	11,611,272
Drilling rigs	2,151,121	15	104	2,182,406
Pipelaying operations	113,755	1	6	115,447
Support helicopters	179,707	11	13	183,811
Support vessels	1,637,455	10	77	1,660,741
Survey vessels	112,941	0	2	113,641
Total OCS oil and gas production source emissions	10,135,309	225,704	300	15,867,318
Total Non-OCS oil and gas production source emissions	9,822,983	1,961	2,443	10,600,260
Total emissions[c]	19,958,292	227,665	2,743	26,467,578

[a] Emissions reported in short tons.
[b] GWP = 25 for CH_4 and 298 for N_2O.
[c] Totals may not sum due to rounding.

Table 6-14. Annual CO_2 2014 emission estimates for all sources

Equipment and Source Category	CO_2 Emissions (tpy)[a]
Commercial marine vessels	8,398,693
Natural gas, diesel, and dual-fuel turbines	3,245,409
Drilling rigs	2,151,121
Natural gas engines	1,839,744
Support vessels	1,637,455
Commercial fishing vessels	531,190
Recreational vessels	435,327
Military vessels	391,169
Combustion flares	307,392
Boilers, heaters, and burners	253,096
Diesel engines	213,850
Support helicopters	179,707
Pipelaying operations	113,755
Survey vessels	112,941
Drilling equipment	77,098
LOOP	64,320
Biogenic and geogenic sources	2,284
Cold vents	1,575
Pneumatic pumps	1,430
Pressure and level controllers	562
Losses from flashing	163
Amine units	9
Mud degassing	2
Glycol dehydrators	1.86E-01
Total emissions[b]	19,958,292

[a] Emissions reported in short tons.

[b] Totals may not sum due to rounding.

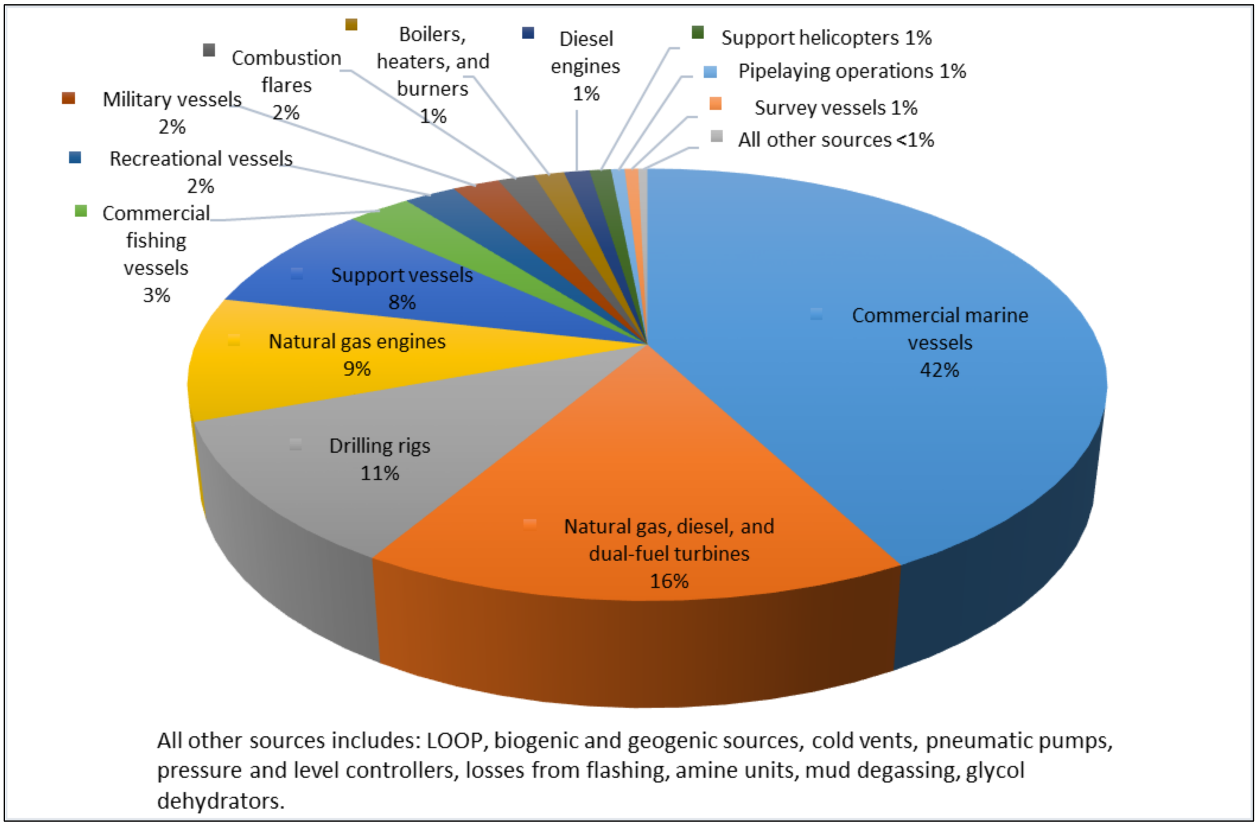


Figure 6-21. Annual CO_2 2014 emissions by source type

Table 6-15. Annual CH_4 2014 emission estimates for all sources

Equipment and Source Category	CH_4 Emissions (tpy)[a]
Cold vents	86,789
Fugitive sources	74,386
Pneumatic pumps	36,686
Natural gas engines	8,769
Pressure and level controllers	8,453
Losses from flashing	7,040
Glycol dehydrators	2,073
Biogenic and geogenic sources	1,876
Storage tanks	671
Combustion flares	332
Natural gas, diesel, and dual-fuel turbines	253
Mud degassing	175
Commercial marine vessels	75
Minor sources	32
Drilling rigs	15

Equipment and Source Category	CH_4 Emissions (tpy)[a]
Support helicopters	11
Support vessels	10
Boilers, heaters, and burners	5
Diesel engines	5
Military vessels	4
Commercial fishing vessels	3
Pipelaying operations	1
LOOP	0.4
Survey vessels	0.3
Amine units	1.04E-01
Total emissions[b]	227,665

[a] Emissions reported in short tons.
[b] Totals may not sum due to rounding.

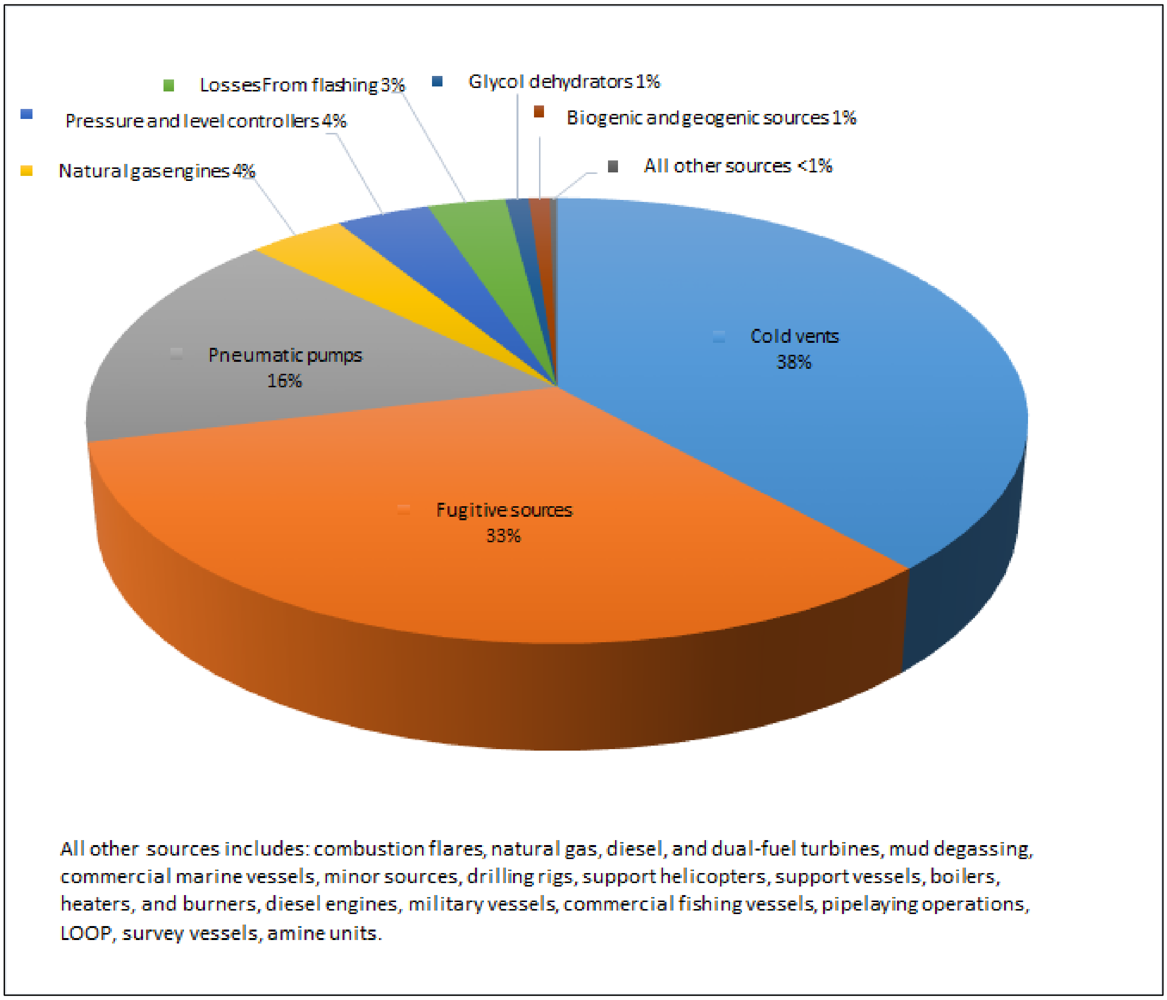


Figure 6-22. Annual CH_4 2014 emissions by source type

Table 6-16. Annual N_2O 2014 emission estimates for all sources

Equipment and Source Category	N_2O Emissions (tpy)[a]
Biogenic and geogenic sources	1,948
Commercial marine vessels	427
Drilling rigs	104
Natural gas, diesel, and dual-fuel turbines	88
Support vessels	77
Support helicopters	77
Commercial fishing vessels	25
Military vessels	20
Pipelaying operations	6
Boilers, heaters, and burners	5
Combustion flares	5
Survey vessels	2
LOOP	2
Total emissions[b]	2,743

[a] Emissions reported in short tons.

[b] Totals may not sum due to rounding.

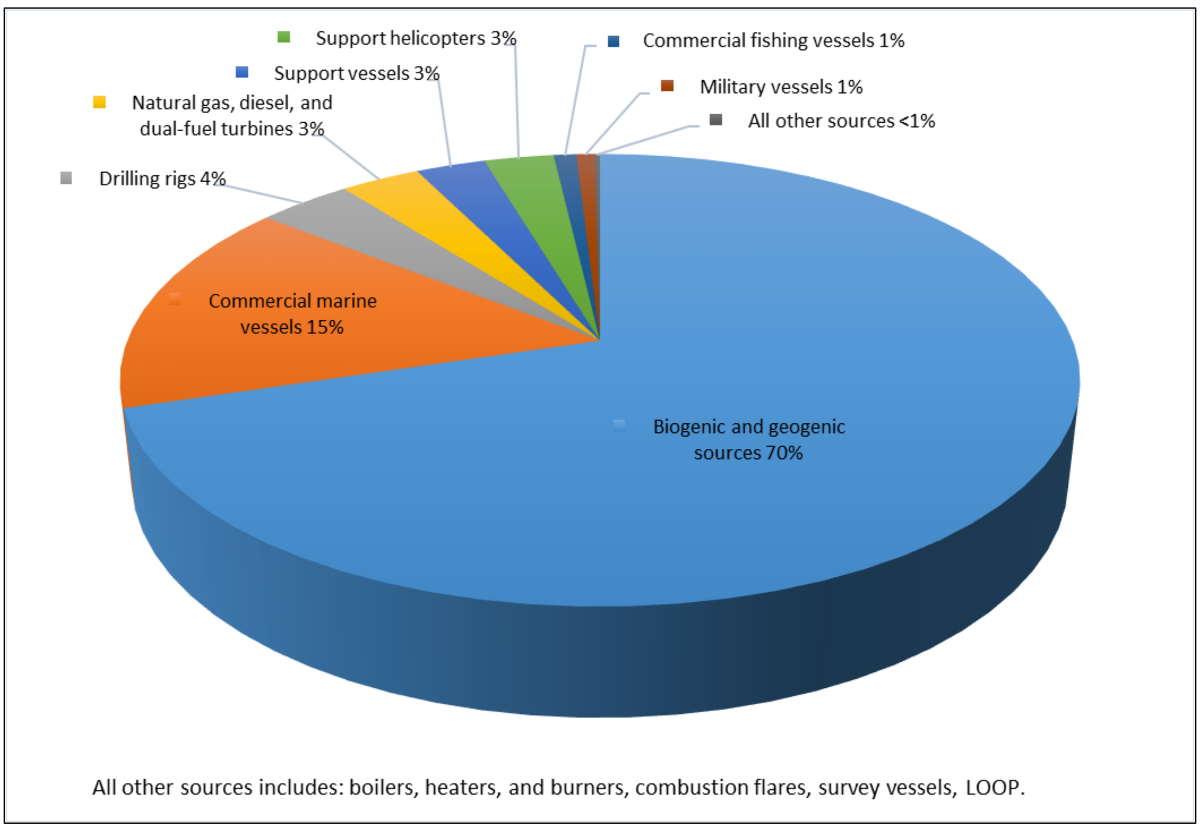


Figure 6-23. Annual N_2O 2014 emissions by source type

Table 6-17. Annual CO_2e 2014 emission estimates for all sources

Equipment and Source Category	CO_2e Emissions (tpy)[a, b]
Commercial marine vessels	8,527,905
Natural gas, diesel, and dual-fuel turbines	3,278,047
Drilling rigs	2,182,406
Cold vents	2,171,289
Natural gas engines	2,058,959
Fugitive sources	1,859,640
Support vessels	1,660,741
Pneumatic pumps	918,582
Biogenic and geogenic sources	629,688
Commercial fishing vessels	538,842
Recreational vessels	441,599
Military vessels	397,328
Combustion flares	317,293
Boilers, heaters, and burners	254,574
Diesel engines	213,973
Pressure and level controllers	211,878
Support helicopters	183,811
Losses from flashing	176,156
Pipelaying operations	115,447
Survey vessels	113,641
Drilling equipment	77,098
LOOP	64,898
Glycol dehydrators	51,827
Storage tanks	16,782
Mud degassing	4,367
Minor sources	795
Amine units	12
Vessel lightering[c]	0
Total emissions[d]	26,467,578

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

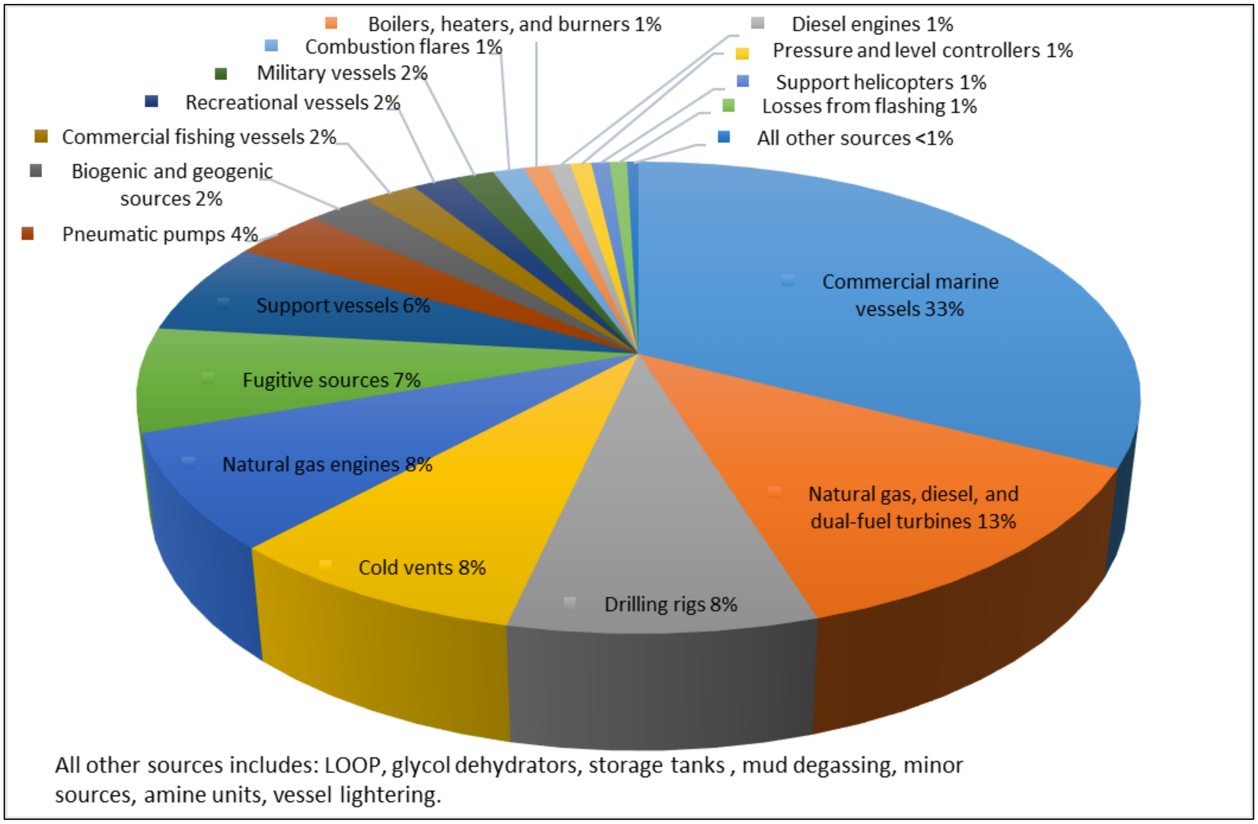


Figure 6-24. Annual CO_2e 2014 emissions by source type

6.3 LIMITATIONS

As with previous BOEM Gulfwide emission inventory studies, one key limitation of the 2014 OCS platform emission estimates is primarily the lack of direct source test data provided by the operators and therefore the need to use surrogate data to calculate emission estimates. BOEM requires that platform operators provide only activity data for platform sources and then BOEM applies emission factors to the activity data to yield emission estimates. Requiring platform operators to submit source test data, calculated emission estimates based on source-specific emission factors, or calculated emission estimates based on industry-developed software would reduce the uncertainty in the emissions estimates but greatly increase the inventory cost.

In addition, when compiling the GOADS-2014 activity datasets, BOEM often must interpret inconsistently reported data as discussed in Section 3. 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 2014 emissions estimates were prepared, BOEM provided a draft version of the inventory to the Offshore Operators Committee 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. There is also uncertainty in the pneumatic pump and pressure and level controller emission estimates because operators were not required to enter the fuel usage rate for each piece of equipment. Surrogate fuel usage rates were applied to gap-fill missing values. Over 75% of the pressure and level controllers required the application of surrogate fuel usage rates. The need to use these surrogate fuel usage rates is unfortunate, given recent studies of onshore pneumatic controllers. In a study by Allen et al. (2015), 95% of the emissions from pneumatic controllers were estimated to be from just 20% of the controller population, likely due to equipment malfunctions. A study by the Prasino Group (2013) of onshore pneumatic devices in British Columbia indicated that manufacturer data may also underestimate emissions. In addition, Allen et al. (2015) found that the number of controllers per well onshore could be under estimated by a factor of 2-3. For glycol dehydrators, the emission estimates were developed using regression equations from GLYCalc™ Version 4.0 (GTI 2000) computer runs, and would be improved if operators provided direct estimates and documentation.

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. As discussed in Section 5, emission estimates for all marine diesel engines were developed using USEPA emission factors that specifically represent 2014, accounting for compliance with appropriate C1, C2, and C3 engine and fuel regulations. Although these emission factors represent an improvement over those used in previous inventories, their accuracy is limited as they are based on regulatory standards that do not account for use of engines that exceed the manufacturer's compliance standard, nor do they account for in-use engine deterioration. Actual engine test data would provide a stronger basis for developing more accurate non-platform emission estimates.

In addition, using the USEPA emission factors requires that the engine category and Tier level are known. For vessels that could be matched to the IHS ROS, cylinder diameter and piston stroke length were used to calculate the actual cylinder volume, and the engine could to be assigned to the correct USEPA engine category. The year of manufacture was then used to determine the correct Tier level. For vessels that could not be matched to the IHS data, BOEM had to make assumptions about the engine category associated with each vessel type included in the GOM inventory. This was particularly problematic for auxiliary engines. More detailed information about auxiliary engines would improve the emission estimates by allowing for better matching of engines to appropriate emission factors.

AIS data were used to estimate and spatially allocate activity and emissions for commercial marine vessels (bulk, cargo, tankers, containerships, and tugs), LOOP tanker traffic, lightering traffic, support vessels, drilling rigs, and seismic survey vessels, as described in Section 5. Although it provides very detailed data about vessel location, speed, and propulsion engine load and transit durations, AIS does not provide information about the operation of auxiliary engines. Auxiliary engine operating loads are based on available USEPA default values and durations, and assumed to match the propulsion operating mode (i.e., underway, reduced speed, maneuvering, and hoteling at sea). More accurate data on auxiliary operations would provide more accurate estimates, particularly when vessels are stationary and most of the power is derived from auxiliary engines.

For the LOOP and offshore lightering operations, activity data that were previously available to the public are no longer available due to security issues. The tankers and support vessels involved in LOOP and lightering operations would trigger AIS reporting requirements and would therefore be included in the AIS dataset. However, evaporative emissions, which are calculated based on the volume of crude transferred, are not included in AIS. Instead, 2008 estimates for the LOOP were adjusted based on information about the reduction in LOOP oil transfers related to recent decline in crude oil importation. Similar data were not available for lightering operations; therefore, BOEM assumed that 2014 operations were similar to or less than 2011 operations and used the 2011 evaporative emissions to represent 2014. This assumption provided an estimate that is probably larger than actual emissions. Better crude transfer data would allow for a more accurate estimate of LOOP and lightering evaporative emissions.

The unavailability of up-to-date vessel data for the U.S. Navy, especially where Naval and possibly some U.S. Coast Guard vessels have been moved away from the GOM to support actions in foreign countries, makes it difficult to accurately assess emissions from these vessels as discussed in Section 5. Based the U.S. Navy's Atlantic Fleet Training and Testing Environmental Impact Statement (EIS)/Oversees Environmental Impact Statement (OEIS) (August 2013), it is likely that the 2014 estimates of Naval emissions overestimate actual emissions. Unfortunately, the emissions presented in the U.S. Navy's EIS seemed remarkably small and the information in the report was insufficient to assess how the estimates were calculated. Currently, the U.S. Navy is updating its emission inventory and BOEM is in regular contact with the staff involved in the update. The new data are anticipated to be more complete, providing more accurate emission estimates of the U.S. Navy's operations in the GOM.

BOEM updated the compilation of helicopter emission factors using Swiss helicopter data that allowed for differentiation between medium and heavy duty twin engine helicopters as described in Section 5. It should be noted, however, that the compiled emission factors still represent available data and not the complete universe of helicopters that operate in the GOM. The updated helicopter factors are grouped relative to size and engine configuration, but there is large variance in the emission factor values within each helicopter group. As more helicopter emission factor data are published and included in the GOM helicopter database, it will be possible to more accurately match helicopters and their emission factors, providing more accurate emission estimates. Another limitation to the helicopter data is the activity data. For 2011 and earlier inventories, the primary data source for helicopter activity is HSAC data, which is voluntarily provided by the helicopter service companies. These data are adjusted to include helicopter activity from companies that do not provide data, but more accurate helicopter fleet and activity data would significantly improve emission estimates for this source category. Currently, the Federal Aviation Administration (FAA) is developing NexGen real time aircraft tracking data (similar to marine vessel AIS data) that will allow for better quantification of helicopter operations including their flight paths.

One other limitation is, as with the previous GOM 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.

6.4 COMPARISON WITH OTHER STUDIES

Over the last five inventory studies, BOEM has compared the results of the most recent inventory to the previous one. For example, in the Year 2011 Gulfwide Emission Inventory report, the calendar year 2011 emission estimates were directly compared with those of the 2008 emission inventory, Similarly, the Year 2008 Gulfwide Emission Inventory report compared the emission estimates to those in the 2005 inventory. The comparisons between the previous inventories are not presented here but discussed in Section 8, Emissions Trends Analyses with details provided in Appendix B. The reminder of this section compares the emission estimates developed for calendar year 2014 and the 2011 emission estimates by equipment type, source category, and pollutant. Similarities and differences between the two inventories are discussed.

It should be noted that during QA/QC of the 2011 BOEM Gulfwide estimates, BOEM found and corrected an error in the vessel power rating for a number of smaller vessels. This correction is reflected in the 2011 emissions totals presented in this section.

Overall comparisons of pollutant-specific emission 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 2014 from the 2011 estimates, most significantly a 73% decrease in the SO_2 emission estimates, a 68% decrease in the PM_{10} estimates, and a 60% decrease in the NO_x estimates. Emissions of CO decreased 42%, and VOC 18%. A significant decrease from 2011 to 2014 is also seen in all GHG estimates as well: 65% for CO_2, and 17% for CH_4, and 68% for N_2O. 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 2011

Calendar Year	CO Emissions (tpy)[a]	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
2011	112,219	316,893	9,390	26,174	62,661
Percent difference	-42%	-60%	-68%	-73%	-18%

[a] Emissions reported in short tons.

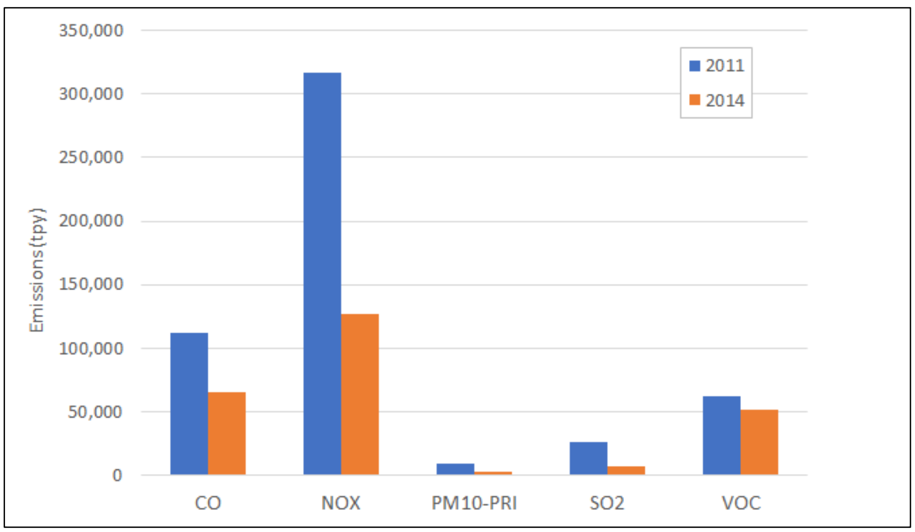


Figure 6-25. Comparison of total criteria pollutant emissions from platform and non-platform oil and gas production-related sources

Table 6-19. Comparison of total platform and non-platform oil and gas production-related sources greenhouse gas emission estimates for years 2014 and 2011

Calendar Year	CO_2 Emissions (tpy)[a]	CH_4 Emissions (tpy)	N_2O Emissions (tpy)	CO_2e Emissions (tpy)[b]
2014	10,135,309	225,704	300	15,867,318
2011	28,907,412	271,469	707	35,904,823
Percent difference	-65%	-17%	-58%	-56%

[a] Emissions reported in short tons.

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

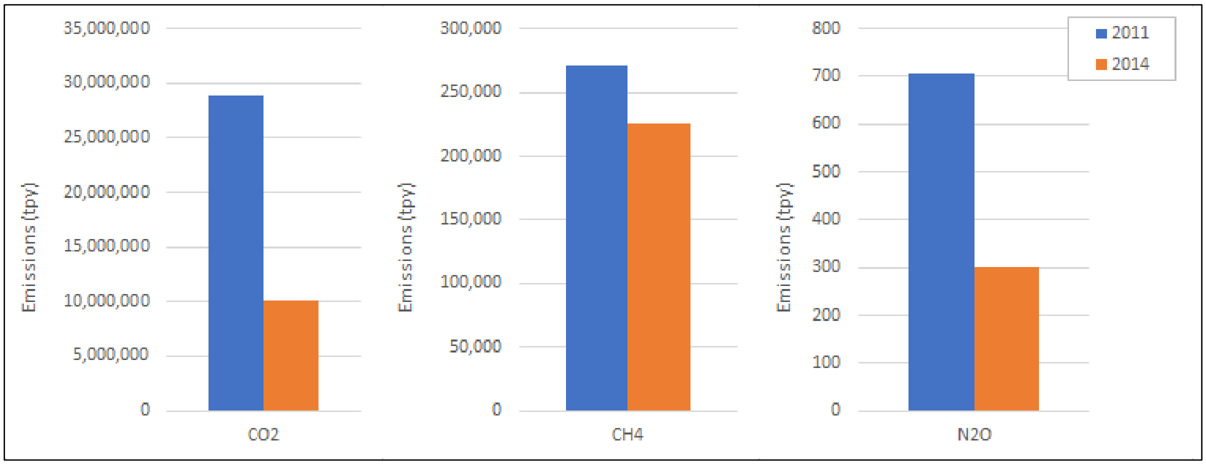


Figure 6-26. Comparison of total GHG emissions from platform and non-platform oil and gas production-related sources

6.4.1 OCS Oil and Gas Production Platforms

As noted previously, the emission estimation methods for platform sources are relatively unchanged between the 2011 and 2014 inventories. Any changes in emission levels, then, are 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 2011, 96 companies submitted data for 2,544 active platforms, including minor sources. The decline in the number of reporting companies between 2011 and 2014 reflects fewer companies that are operating in the GOM. Since the 2011 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 backruptcy/reorganization. The decline in number of active GOM platforms between 2011 and 2014 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, all pollutants show decreases in emissions from 2011 to 2014, ranging from a 12% reduction of VOC emissions to an 84% reduction of SO_2 emissions. These reductions are due in large part to the significant decrease in the number of active platforms reported from 2011 to 2014 and decreased equipment activity on remaining active platforms.

With the exception of drilling equipment, all other platform combustion equipment types had a decrease in the reported activity levels consistent with the overall reduction in the estimated emissions. Activity and estimated emissions for drilling equipment are relatively unchanged from 2011 to 2014. The 2014 natural gas engine estimates drive the overall decrease in estimated emissions for CO, indicating a decrease in reported activity levels. Natural gas engines and natural gas, diesel, and dual-fuel turbines drive the overall decrease in estimated emissions for NO_x. Turbines drive the overall decrease in SO_2 emissions due to decreased fuel use and reduced diesel fuel sulfur content. Diesel engines drive the overall decrease in PM_{10} emissions. The slight increase in the PM_{10} emissions from natural gas engines can be attributed to differences in calculations using the newer USEPA Particulate Matter Augmentation Tool for the 2014 inventory.

The decrease in the 2014 emission estimates for VOC is driven by the cold vent emission estimates, although the decrease is counterbalanced somewhat by an increase in reported activities and emissions estimates for fugitive sources and pneumatic pumps. Over half of the increase in estimated VOC emissions for fugitive sources are associated with platforms that were reported as minor source platforms without individual equipment records for the 2011 inventory. Similarly, the number of active pneumatic pumps reported for 2014 increased due to equipment records being reported for platforms that were previously reported as minor source platforms. While the requirement to report equipment activity for minor source platforms was not expected to increase the number of platforms reported, it is not unexpected to see an increase the number of equipment records reported. As discussed in section 6.3 above, the pneumatic pumps and pressure and level controller emissions are also influenced by the use of surrogate and manufacturer provided fuel use rates rather than actual fuel use rates. The fuel use rate is a required field for the 2017 inventory effort in order to improve the accuracy of emissions estimates for these two equipment types. Although the number of active pneumatic pumps reported increased for 2014, the number of active pressure and level controllers decreased for 2014. Because these pneumatic devices are similar, there may be confusion of terminology (i.e., some pressure and level controllers may have been reported as pneumatic pumps). For the 2017 inventory effort, the names have been revised to “pneumatic pump” and “pneumatic controller” to help avoid any confusion. There was also a relatively small increase in VOC emissions estimates for mud degassing due to the revised THC speciation factors presented in Section 4.

Table 6-21 compares emission estimates for greenhouse gases between the 2014 inventory and the 2011 inventory. Overall, the CO_2e emission estimate shows a 38% decrease, as the CO_2 emission estimate decreased 50%. Similar to the decrease in the SO_2 emission estimate, the overall decrease in greenhouse gas emissions is driven in large part by the CO_2 natural gas, diesel, and dual-fuel turbine estimates. The 2014 inventory includes estimates for CO_2 from amine units that are equipped with flares, which were not included in previous inventories. The CH_4 emission estimates for vents also contributed to the decrease. Similar to VOC, the CH_4 estimates for fugitive sources and pneumatic pumps showed an increase from 2011 to 2014. The CH_4 estimate for drilling equipment in the 2011 inventory was associated with natural gas-fired drilling equipment. There was no natural gas-fired drilling equipment reported for the 2014 inventory.

Table 6-20. Comparison of OCS platform criteria pollutant emission estimates for years 2014 and 2011

	2014					2011				
Source Category	CO Emissions (tpy)[a]	NO_x Emissions (tpy)	PM_{10}-PRI Emissions (tpy)	SO_2 Emissions (tpy)	VOC Emissions (tpy)	CO Emissions (tpy)	NO_x Emissions (tpy)	PM_{10}-PRI Emissions (tpy)	SO_2 Emissions (tpy)	VOC Emissions (tpy)
Amine units	-	-	-	13	7.68E-03	-	-	-	4	0.2
Boilers, heaters, and burners	177	208	10	1	12	621	1,156	17	5	41
Diesel engines	1,173	4,984	246	425	275	2,187	8,927	358	827	406
Drilling equipment	397	1,495	27	24	37	396	1,493	27	24	37
Combustion flares	821	184	1	2	16	1,252	425	8	3	30
Fugitive sources	-	-	-	-	18,531	-	-	-	-	16,403
Glycol dehydrators	-	-	-	-	275	-	-	-	-	1,158
Loading operations	-	-	-	-	206	-	-	-	-	-
Losses from flashing	-	-	-	-	317	-	-	-	-	640
Minor sources	-	-	-	-	10	-	-	-	-	157
Mud degassing	-	-	-	-	72	-	-	-	-	23
Natural gas engines	45,070	32,355	283	10	915	62,024	44,863	262	14	1,310
Natural gas, diesel, and dual-fuel turbines	2,413	9,463	101	27	61	3,859	27,264	167	2,320	103
Pneumatic pumps	-	-	-	-	5,511	-	-	-	-	2,182
Pressure and level controllers	-	-	-	-	1,143	-	-	-	-	2,064
Storage tanks	-	-	-	-	677	-	-	-	-	928
Cold vents	-	-	-	-	20,152	-	-	-	-	29,244
Total emissions[b]	50,052	48,691	668	502	48,210	70,339	84,128	838	3,197	54,724

[a] Emissions reported in short tons.

[b] Totals may not sum due to rounding.

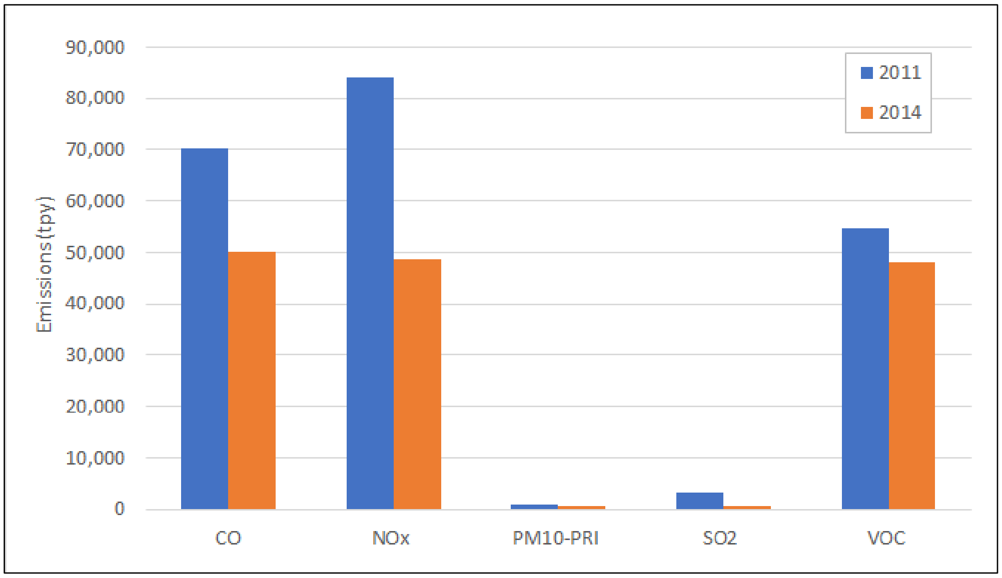


Figure 6-27. Comparison of criteria pollutant emissions for oil and natural gas production platforms

Table 6-21. Comparison of OCS platform greenhouse gas emission estimates for years 2014 and 2011

Source Category	2014				2011			
	CO_2 (tpy)[a]	CH_4 (tpy)	N_2O (tpy)	CO_2e (tpy)[b]	CO_2 (tpy)	CH_4 (tpy)	N_2O (tpy)	CO_2e (tpy)[b]
Amine units	9	1.04E-01	0	12	0	2	0	54
Boilers, heaters, and burners	253,096	5	5	254,574	891,652	17	16	896,867
Diesel engines	213,850	5	-	213,973	407,575	13	N/A[c]	407,903
Drilling equipment	77,098	-	-	77,098	76,961	1.5	N/A	76,999
Combustion flares	307,392	332	5	317,293	604,002	366	11	616,362
Fugitive sources	-	74,386	-	1,859,640	-	61,232	-	1,530,788
Glycol dehydrators	0.19	2,073	-	51,827	N/A	7,859	N/A	196,486
Losses from flashing	163	7,040	-	176,156	330	14,231	-	356,098
Minor sources	-	32	-	795	-	476	-	11,889
Mud degassing	2	175	-	4,367	2	505	-	12,637
Natural gas engines	1,839,744	8,769	-	2,058,959	2,567,943	12,619	N/A	2,883,418

Source Category	2014				2011			
	CO_2 (tpy)[a]	CH_4 (tpy)	N_2O (tpy)	CO_2e (tpy)[b]	CO_2 (tpy)	CH_4 (tpy)	N_2O (tpy)	CO_2e (tpy)[b]
Natural gas, diesel, and dual-fuel turbines	3,245,409	253	88	3,278,047	7,329,476	400	140	7,381,091
Pneumatic pumps	1,430	36,686	-	918,582	401	21,155	-	529,288
Pressure and level controllers	562	8,453	-	211,878	871	16,739	-	419,339
Storage tanks	-	671	-	16,782	-	877	-	21,921
Cold vents	1,575	86,789	-	2,171,289	2,815	134,863	-	3,374,390
Total emissions[d]	5,940,330	225,667	98	11,611,272	11,882,029	271,355	167	18,715,529

[a] Emissions reported in short tons.
[b] GWP = 25 for CH_4 and 298 for N_2O.
[c] N/A = Not available.
[d] Totals may not sum due to rounding.

6.4.2 Non-Platform Sources

As shown in Table 6-22 and Figure 6-28, comparing 2014 and 2011 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 use of AIS data that provides more accurate estimates of the vessels operating in the GOM, their power ratings, and propulsion engine load estimates. It should be noted, however, that there was an increase in SO_2 emission for pipelaying and survey vessels due to the inclusion of USEPA engine Category 3 vessels that use higher sulfur fuels than the C1 and C2 vessels. Survey vessels also had higher VOC emissions due to the inclusion of C3 vessels, not previously identified in the 2011 inventory.

Table 6-22. Comparison of OCS non-platform criteria pollutant emission estimates for years 2014 and 2011

	2014					2011				
Source Category	**CO (tpy)[a]**	**NO_x (tpy)**	**PM_{10} (tpy)**	**SO_2 (tpy)**	**VOC (tpy)**	**CO (tpy)**	**NO_x (tpy)**	**PM_{10} (tpy)**	**SO_2 (tpy)**	**VOC (tpy)**
Drilling rigs	6,236	40,837	1,262	5,354	859	6,248	69,135	2,634	20,863	2,750
Pipelaying operations	239	2,406	86	669	98	2,124	9,480	350	117	128
Support helicopters	1,978	979	28	126	1,632	2,163	753	23	112	1,624
Support vessels	6,194	30,256	799	122	399	29,585	145,546	5,335	1,789	3,330
Survey vessels	812	3,276	154	378	379	1,760	7,851	290	97	105
Total OCS oil and gas production sources (tpy)	15,459	77,754	2,329	6,648	3,367	41,880	232,765	8,631	22,977	7,937
Biogenic and geogenic sources	-	-	-	-	14,357	-	-	-	-	14,357
Commercial fishing vessels	1,934	9,435	219	5	102	1,206	6,917	245	85	218
Commercial marine vessels	20,655	200,258	6,409	48,215	8,802	9,779	108,203	4,122	32,651	4,303
LOOP	224	1,001	37	12	300	313	1,399	52	17	420
Military vessels	988	9,432	283	2,121	379	1,035	11,448	436	3,455	455
Vessel lightering[b]	-	-	-	-	17,113	-	-	-	-	17,113
Recreational vessels	1,585	7,732	180	4	83	675	3,127	118	75	197
Total Non-OCS oil and gas production sources (tpy)	25,387	227,858	7,127	50,358	41,137	13,008	131,094	4,973	36,283	37,063
Total non-platform emissions[c]	40,846	305,612	9,456	57,006	44,503	54,888	393,859	13,605	59,261	45,000

[a] Emissions reported in short tons.

[b] Vessel estimates for 2014 are reflected in commercial marine vessels.

[c] Totals may not sum due to rounding.

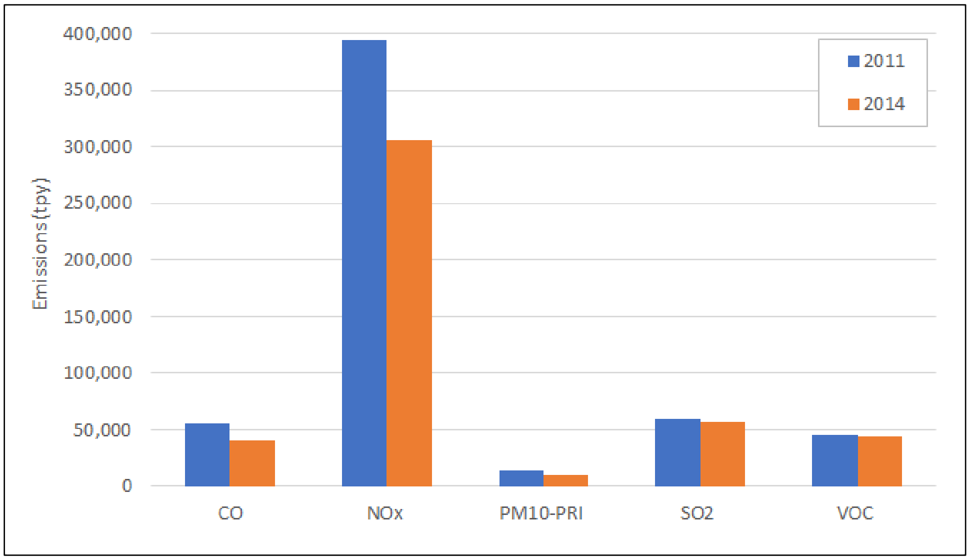


Figure 6-28. Comparison of criteria pollutant emissions for non-platform emission sources

Non-platform sources overall had a decrease in estimated emissions for all pollutants, due to the use of more accurate vessel counts, engine power data, and propulsion load estimates derived from AIS data. One exception, however, is commercial marine vessels. These estimates are significantly higher for 2014 than 2011 due to a more complete assessment of the vessels transiting the Gulf, specifically the inclusion of cruise ships and dredging vessels. These vessels were not included in the 2011 U.S. Army Corps of Engineers Entrance and Clearance data because they do not carry foreign cargo, but they are included in the AIS dataset.

The use of the AIS data was also apparent in the decline in greenhouse gas emissions from non-platform sources, specifically CO_2 emissions (38%) as noted in Table 6-23. There are exceptions–CH_4 (1% decline) and N_2O (2% decline)–that essentially stayed the same as emissions associated with these pollutants are dominated by geogenic vents, which are assumed to remain constant from year to year.

Table 6-23. Comparison of OCS non-platform greenhouse gas emission estimates for years 2014 and 2011

	2014				2011			
Source Category	CO_2 (tpy)[a]	CH_4 (tpy)	N_2O (tpy)	CO_2e (tpy)[b]	CO_2 (tpy)	CH_4 (tpy)	N_2O (tpy)	CO_2e (tpy)[b]
Drilling rigs	2,151,121	15	104	2,182,406	2,748,279	21	110	2,781,584
Pipelaying vessels	113,755	1	6	115,447	609,535	5	18	615,024
Support helicopters	179,707	11	13	183,811	160,752	10	11	164,280
Support vessels	1,637,455	10	77	1,660,741	13,002,103	75	386	13,119,006
Survey vessels	112,941	-	2	113,641	504,714	3	15	509,259
Total OCS oil and gas production sources (tpy)	4,194,979	37	202	4,256,046	17,025,383	114	540	17,189,153
Biogenic and geogenic sources	2,284	1,876	1,948	629,688	2,284	1,876	1,948	629,688
Commercial fishing vessels	531,190	3	25	538,842	585,204	2	17	590,320
Commercial marine vessels	8,398,693	75	427	8,527,905	4,301,312	33	172	4,353,393
LOOP	64,320	-	2	64,898	89,958	0.5	3	90,865
Military vessels	391,169	4	20	397,328	455,071	4	18	460,535
Vessel lightering[c]	-	-	-	-	-	-	-	-
Recreational vessels	435,327	3	21	441,599	244,483	N/A	N/A	244,483
Total non-OCS oil and gas production sources (tpy)	9,289,509	82	470	9,431,731	5,678,312	1,915	2,158	6,369,284
Total non-platform emissions[d]	14,017,962	1,999	2,646	14,856,307	22,703,695	2,029	2,698	23,558,437

[a] Emissions reported in short tons.

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

[c] Vessel estimates for 2014 are reflected in commercial marine vessels.

[d] Totals may not sum due to rounding.

6.5 RECOMMENDATIONS

As discussed in Section 6.3, a key limitation for the 2014 OCS platform emissions inventory is that emissions are not estimated using direct source test data or based on source-specific emission factors. In lieu of requiring that platform operators submit source test data or prepare and submit emission estimates, BOEM will continue to make use of the most recent emission factors and research results in developing the emission estimates for platform equipment, and make adjustments to the GOADS activity data collection program in the future to address limitations as needed. In addition, BOEM needs to conduct focused studies of the offshore platform sources whose emission estimates are most uncertain. Some of these efforts are already underway. For fugitive sources, BOEM recently 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. The results of this study will be available for use in the Year 2017 Gulfwide emissions inventory. Revisions were also made to the GOADS-2017 data collection program to solicit data specific to whether or not component counts provided are facility-specific (vs. based on a surrogate), and preventative maintenance practices and procedures.

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-, low-, intermittent, or no-bleed) of the reported pressure and level controllers. However, more information is needed on the accuracy of the number of pneumatic devices, both pneumatic pumps and pressure and level controllers, reported by operators, as well as the actual operating bleed rates rather than manufacturer data.

For glycol dehydrators, BOEM could require that operators submit emission estimates and supporting documentation developed from the Gas Technology Institute's GLYCalc™software program (BOEM's contractor runs the GTI AIRCalc™ program for amine units, using detailed data collected from the operators). Also, while the GLYCalc program does not explicitly include CO_2 in its emissions reports, operators could review the "Equipment Reports" or "Stream Reports" to determine the fate (emissions) of CO_2 present in the wet gas stream fed to the dehydrator. For losses from flashing, BOEM collects information from the platform operators and calculates emissions using the Vasquez-Beggs correlation equations. BOEM could instead require that operators collect pressurized oil samples from separators or heater treaters and perform laboratory flash analyses to obtain gas-to-oil ratio and chemical composition, or use API's E&P Tank® software and provide documentation.

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) now include requirements that operators meter flared and vented gas volumes on facilities that process more than 2,000 barrels of oil per day, and to report flared gas separately from vented gas on the OGOR forms (Federal Register 2010). In developing the 2011 Gulfwide inventory, BOEM conducted an in-depth comparison of

GOADS venting and flaring data and OGOR reported volumes. While such an effort was not implemented for the 2014 inventory, 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.

Another recommendation for future inventory efforts for OCS oil and gas production platforms is validating or updating the range check values and surrogate stack parameters given changes in offshore platform operations (e.g., the increase in deepwater platform operations).

For non-platform sources, an alternative approach to estimating helicopter activities and emissions is using the FAA NextGen tracking data. These data are similar to the AIS data used to track ship movements. Flight paths of individual helicopters can be mapped to BOEM lease blocks and hours of operation calculated. This approach would require purchasing helicopter flight data from a vendor who would distill the data into a useful format, but it would provide a more accurate assessment of helicopters, their flight paths, and an indication of monthly activity variance.

In 2013, the U.S. Navy published the Atlantic Fleet Training and Testing EIS/OEIS quantifying vessel emissions from offshore training exercises, which suggested that naval emissions may be smaller than estimated in the 2014 BOEM data. Unfortunately, the data provided were not sufficiently detailed to assess completeness or estimate what portion of the U.S. Navy emissions are attributed to federal waters of the central/eastern and western areas of the GOM. The U.S. Navy is currently developing a comprehensive inventory of emissions from Naval vessels for all offshore exercises and BOEM has been in regular contact with U.S. Navy staff about this inventory. Once these data are reviewed by the U.S. Department of Defense and posted, BOEM can used to better quantify Naval emissions in the central and western areas of the GOM.

Geogenic releases of crude oil and natural gas are a significant source of VOCs. Currently, BOEM GOM estimates are based on available studies that provide approximate release rates from undersea vents, seeps, and mud volcanoes. New satellite data are currently being developed to quantify the location and geographic distribution of surface oil slicks. These data can also be used to quantify the location and volume of geogenic releases, which can be evaluated to estimate associated VOC emissions, providing more accurate estimates and locations for these geogenic emissions.

Last, in previous Gulfwide inventory reports, BOEM recommended that detailed and comprehensive expanded comparisons and deviations (trends analyses) be performed. These analyses will benefit BOEM in a number of ways, including preparing NEPA documents and predicting future emission trends in spatial terms. At the completion of the 2014 inventory development effort, BOEM now has emission estimates for five consecutive inventory studies that span 2000 through 2014. As discussed in Section 7.0 and Appendix B of this report, BOEM has prepared detailed Emissions Trends Analyses, and recommendations regarding future efforts to analyze emission trends seen are provided.

7. EMISSIONS TRENDS ANALYSES

Now that Gulfwide emissions inventories are available for calendar years 2000, 2005, 2008, 2011, and 2014 for oil and gas production platforms and marine vessels and helicopters that support production, BOEM is assessing the possible trends in the estimates with the goal of benefitting it in predicting future emission trends in spatial terms and preparing NEPA documents. Appendix B of this report provides specific details on the emissions trends analyses conducted and the results and recommendations for future analyses.

Overall, emissions are thought to be largely affected by three factors: activity/production levels, changes in inventory methodologies, and improvements in available emission factors. There was qualitative agreement found to the spatial distribution of total production; however, there are factors that mask this trend at a total inventory level, including emission estimation methods and the increase in deepwater production. For example, with the increased use of AIS data to track marine vessel movements and more detailed vessel attribute data, the non-platform emissions inventories have changed the most over the inventory years, especially the BOEM sources.

In addition, the total production trend to the emission estimates does not hold true for 2014, as higher production was paired with decreased emissions and number of platforms. It appears that the deepwater platforms account for an increasing portion of the emissions, despite only minor changes in the number of these platforms. It is possible that the disproportionate emissions at these larger platforms are affecting the overall correlation to production. That is, the production-to-emission ratio of these deepwater platforms is likely drastically different from the ratio for other water depths. It also possible that with the increased application of well stimulation and installation of subsea production systems, oil production was increased without installation of additional production platforms. Of the 250 platforms thought to be missing from the 2014 inventory, the BSEE TIMS database has 234 as shallow water (<250 feet) and 16 in deepwater. 76 are flagged as major fixed structures in TIMS, 67 in shallow water and 9 in deepwater. Of the 67 missing shallow water major platforms, 27 are flagged in the TIMS comment field with removal dates in 2014, 2015, or 2016. One of the deepwater platforms was also flagged with a removal date in this time period. It is possible that the 16 deepwater structures missing from the 2014 inventory had an impact on the production-to-emission ratio. BOEM recommends that the production-to-emission ratio trend continue to be tracked and explored at the platform level.

Moving forward, BOEM also recommends that the improvements to the estimation methods be more closely tracked, with discussion of potential impacts on trends. This will ensure that future analyses, especially long-term trends 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 inventory development. That is, if an emission factor was revised and anticipated changes in the emission estimates aren't seen, then further analysis of the estimates is needed. Another recommendation is that BOEM should continue to prepare emissions trends analyses in future inventory cycles. These analyses have benefits in both QA/QC and assessing the impacts of emission controls (e.g., use of low sulfur fuel) or identifying platform equipment categories for potential controls.

Furthermore, BOEM should revisit a full trends analysis periodically to incorporate new analysis techniques that better identify true trends in emissions data. An option for further study would be to recalculate the emission inventories with the same emission estimation methods. This is likely only possible with the more recent inventory years, where the appropriate data exist. The most problematic inventory for recalculation is the non-platform inventory, whose estimation methods have benefited greatly from advancements in technology and availability of AIS data.

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APPENDIX A: HAZARDOUS AIR POLLUTANT SCOPING STUDY

Contents

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A.1 INTRODUCTION

The Bureau of Ocean Energy Management (BOEM) Gulf of Mexico Outer Continental Shelf (OCS) Region office sponsored the Study, the Year 2014 Gulfwide Emissions Inventory Study (BOEM Contract No. M13PC00005), to develop a base year 2014 air pollution emissions inventory for all oil and gas production-related sources in the Gulf of Mexico on the OCS. 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). This scoping study focuses on the oil and natural gas production platform hazardous air pollutant (HAP) scoping task, in which HAP emission estimates were developed for select oil and natural gas production platform emission sources that are covered in the 2014 Gulfwide inventory. The results of this scoping study, in which select HAP emission estimates were developed for 10 platforms, will be used to inform future BOEM emission inventory efforts with respect to development of HAP emission estimates.

Table A-1 of this scoping study presents the 2014 emission estimates for platform sources. The emission estimates by equipment type were assessed to prioritize the sources to include in the HAP scoping study inventory based on the VOC and PM_{10} primary (PM_{10}-PRI) emission estimates. The VOC estimates were used to select platforms to be included in this task because HAPs are often delineated as volatile gases in terms of their photochemical reactivity. The PM_{10}-PRI estimates were used because combustion sources typically emit HAPs that are metals.

Table A-1. Total 2014 platform emission estimates

Equipment	CO Emissions (tpy)[a]	NO_x Emissions (tpy)	PM_{10}-PRI Emissions (tpy)[b]	SO_2 Emissions (tpy)	VOC Emissions (tpy)
Amine units	0	0	0	13	7.68E-3
Boilers, heaters, and burners	177	208	10	1	12
Diesel engines	1,173	4,984	246	425	275
Drilling equipment	397	1,495	27	24	37
Combustion flares	821	184	1	2	16
Fugitives	0	0	0	0	18,531
Glycol dehydrators	0	0	0	0	275
Loading operations	0	0	0	0	206
Losses from flashing	0	0	0	0	317
Minor sources	0	0	0	0	10
Mud degassing	0	0	0	0	72
Natural gas engines	45,070	32,355	283	10	915
Natural gas, diesel, and dual-fuel turbines	2,413	9,463	101	27	61
Pneumatic pumps	0	0	0	0	5,511
Pressure and level controllers	0	0	0	0	1,143

Table A-1. Total 2014 platform emission estimates

Equipment	CO Emissions (tpy)[a]	NO_x Emissions (tpy)	PM_{10}-PRI Emissions (tpy)[b]	SO_2 Emissions (tpy)	VOC Emissions (tpy)
Storage tanks	0	0	0	0	677
Cold vents	0	0	0	0	20,152
Total emissions (tpy)	50,052	48,691	668	502	48,210

[a] Emissions reported in short tons.

[b] Primary (filterable +condensable) inhalable particulate matter (less than 10 microns in effective diameter).

Select HAP estimates were developed for equipment based on the contribution to total VOC and PM_{10}-PRI emissions.

This scoping study is organized as follows. After this introduction, Section A.2 summarizes the platform selection process (Section A.2.1), the HAP selection process (Section A.2.2), and the HAP emission estimation methods (Section A.2.3). The results are presented in Section A.3, and references are listed in Section A.4.

A.2 DEVELOPMENT OF THE HAP EMISSION ESTIMATES

A.2.1 PLATFORMS TO INCLUDE

The 2014 Gulfwide inventory was assessed to identify the top-emitting platforms to include in this task. HAP estimates were developed for 10 platforms, based on their VOC and PM_{10}-PRI estimated emissions. The following platforms were identified as top-emitters of VOC and PM_{10}-PRI in the 2014 emissions inventory (Tables A-2 and A-3 of this scoping study).

Table A-2. Top-emitting VOC platforms in 2014 Gulfwide inventory

Complex-Structure	2014 VOC Emissions (tpy)[a]	% of Total Platform VOC Emissions	Platform Type[b]
A	2,103	6.94%	Gas
B	1,053	3.48%	Gas
C	888	2.93%	Oil
D	724	2.39%	Oil
E	637	2.10%	Oil

Table A-3. Top-emitting PM_{10}-PRI platforms in 2014 Gulfwide inventory

Complex-Structure	2014 PM_{10} Emissions (tpy)[a]	% of Total Platform PM_{10} Emissions	Platform Type[b]
F	12.6	1.88%	Oil
G	10.4	1.55%	Oil
H	10.4	1.55%	Oil
I	9.4	1.42%	Oil
J	9.1	1.36%	Oil

A.2.2 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 this scoping study, ERG has determined that the HAPs presented in Table A-4 of this scoping study represent the key HAPs emitted from offshore oil and gas production non-combustion and combustion sources.

Table A-4. 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.2.3 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-5 of this scoping study shows the HAP estimation approach used for the selected emission sources.

Table A-5. Summary of HAP estimation methods for platform equipment

Equipment	Estimation Method	Basis
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)
Fugitives	Speciation profiles	VOC estimate (tons)
Glycol dehydrators	Emission factors	MMscf
Losses from flashing	Speciation profiles	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 profiles	VOC estimate (tons)
Storage tanks	Speciation profiles	VOC estimate (tons)
Cold vents	Speciation profiles	VOC estimate (tons)

A.2.3.1 Combustion Emission Factors

Tables A-6 through A-10 of this scoping study present the emission factors for combustion sources.

Table A-6. Emission factors for boilers, heaters, and burners

Pollutant	Emission Factor	
	Diesel Fuel[a] (lb/10^3 gal)	Natural Gas[b] (lb/MMscf)
Arsenic	1.32E-03	2.0E-04
Benzene	2.14E-04	2.1E-03
Beryllium	2.78E-05	<1.2E-05
Cadmium	3.98E-04	1.1E-03
Chromium VI	2.48E-04	1.4E-03
Ethylbenzene	6.36E-05	-
Formaldehyde	0.033	0.075
Hexane	-	1.8
Mercury	1.13E-04	2.6E-04
Toluene	6.20E-03	3.4E-03
Xylenes	1.09E-04	-

Source: USEPA 2014 (*AP-42* Sections 1.3 and 1.4)

Table A-7. Emission factors for diesel engines (lb/MMBtu)

Pollutant	Emission Factor (lb/MMBtu)	
	<600 HP	≥600 HP
Acetaldehyde	7.67E-04	2.52E-05
Benzene	9.33E-04	7.76E-04
Formaldehyde	1.18E-03	7.89E-05
Mercury	3.01E-07	3.01E-07
PAH	1.68E-04	2.12E-04
Toluene	4.09E-04	2.81E-04
Xylenes	2.85E-04	1.93E-04

Source: USEPA 2014 (*AP-42* Sections 3.3 and 3.4), USEPA 2015 (WebFIRE)

Table A-8. Emission factors for drilling equipment

Pollutant	Emission Factor (lb/MMBtu)
Natural Gas[a]	
Acetaldehyde	5.58E-03
Benzene	1.01E-03
Ethylbenzene	3.23E-05
Formaldehyde	3.67E-02
PAH	8.40E-05
Toluene	4.83E-04
Xylenes	1.90E-04
Diesel Fuel	
Acetaldehyde	2.52E-05
Benzene	7.76E-04
Formaldehyde	7.89E-05
Mercury	3.01E-07
PAH	2.12E-04
Toluene	2.81E-04
Xylenes	1.93E-04

[a] Average of four stroke lean and four stroke rich burn engines
Sources: USEPA 2014 (*AP-42* Sections 3.2 and 3.4), USEPA 2015 (WebFIRE)

Table A-9. Emission factors for natural gas-fired engines (lb/MMBtu)

Pollutant	2-stroke Lean Burn	4-stroke Rich Burn	4-stroke Lean Burn	4-stroke Clean Burn
Acetaldehyde	7.76E-03	2.79E-03	8.36E-03	3.52E-03
Benzene	1.94E-03	1.58E-03	4.40E-04	6.00E-04
Ethylbenzene	1.08E-04	2.48E-05	3.97E-05	4.19E-05
Formaldehyde	5.52E-02	2.05E-02	5.28E-02	4.95E-02
Hexane	4.45E-04	-	1.11E-03	6.48E-04
PAH	1.34E-04	1.41E-04	2.69E-05	-
Toluene	9.63E-04	5.58E-04	4.08E-04	5.05E-04
2,2,4-Trimethylpentane	8.46E-04	-	2.50E-04	1.05E-04
Xylenes	2.68E-04	1.95E-04	1.84E-04	1.71E-04

Sources: USEPA 2014 (*AP-42* Section 3.2)

Table A-10. Emission factors for natural gas- and diesel-fired turbines (lb/MMBtu)

Pollutant	Emission Factor
Natural Gas	
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
Diesel Fuel	
Arsenic	<1.10E-05
Benzene	5.50E-05
Beryllium	<3.10E-07
Cadmium	4.80E-06
Chromium	1.10E-05
Formaldehyde	2.80E-04
Mercury	1.20E-06
PAH	4.00E-05

Source: USEPA 2014 (*AP-42* Section 3.1), USEPA 2015 (WebFIRE)

A.2.3.2 Non-combustion Emission Factors and Speciation Profiles

HAP emission estimates for non-combustion sources were developed using emission factors for glycol dehydrators, and speciation profiles for fugitives, losses from flashing, pneumatic pumps, storage tanks, and cold vents. The glycol dehydrator emission factors are shown in Table A-11 of this scoping study. These factors represent the statewide (Texas) glycol dehydrator flash vessel and regenerator vent emissions (Pring et al. 2010).

Table A-11. Glycol dehydrator HAP emission factors

Pollutant	Emission Factor (lbs/MMscf)
Benzene	0.38
Ethylbenzene	0.02
Toluene	0.20
Xylene	0.75

Source: Pring et al. 2010

Table A-12 of this scoping study presents the HAP speciation profiles for other non-combustion sources. These profiles were obtained from a 2011 technical support document for the USEPA's oil and natural gas sector rulemaking (USEPA 2011). The USEPA speciation profiles distinguish natural gas production wells from oil production wells. Tables A-2 and A-3 of this scoping study reflect the type of platform based on the BOEM report: Estimated Oil and Gas Reserves, Gulf of Mexico OCS Region, December 31, 2013, in which OCS oil and gas production fields with a GOR less than 9,700 scf per barrel are classified as oil fields (Kazanis et al., 2015).

To assign these categories, the selected platforms from the 2014 Gulfwide inventory were linked by lease ID to the 2014 BOEM Oil and Gas Operations Report (OGOR) production data (USDOI, BOEM 2016).

Using the OGOR production data for oil and gas, each lease was categorized as "oil" or "gas" using the definition provided above.

Table A-12. Speciation profiles for other non-combustion sources

Pollutant	Gas Wells Weight %	Oil Wells Weight %
Benzene	0.0183	0.0188
Ethylbenzene	0.0005	0.0018
Hexane	0.6865	0.0174
Toluene	0.0159	0.0008
2,2,4-Trimethylpentane	0.0004	0.0010
Xylenes	0.0048	-
VOC	10.00	24.42

Source: USEPA 2011

Using this methodology, two of the platforms listed in Tables A-2 and A-3 of this scoping study were determined to be gas producing wells, and the remaining eight platforms were determined to be oil producing wells.

A.3 Summary of Results

The HAP emission estimates developed in this scoping study are presented in Tables A-13 and A-14 of this scoping study. For an overview of the results, Table A-13 of this scoping study summarizes the total HAP emission estimates. To facilitate more detailed review, Table A-14 of this scoping study presents emission estimates by pollutant and equipment type.

As shown in Table A-14, the highest HAP emissions for the pollutants included in this study are hexane driven by cold vents, followed by formaldehyde driven by natural gas engines and natural gas, diesel, and dual fuel turbines. 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 2014 Gulfwide Inventory.

This scoping study was limited to 10 platforms; however, BOEM plans to estimate HAP emissions for all platforms in the 2017 Gulfwide Inventory. BOEM will also estimate HAP emissions associated with non-platform sources for comparison with platform sources and non-oil and gas related marine vessels. BOEM should also consider expanding the scope to include additional HAPs.

Recommended improvements include re-evaluating the speciation profiles used to estimate non-combustion HAP emissions. The profiles used were 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, so the latest available emission factors for all equipment types and pollutants are used.

Table A-13. Total 2014 HAP emissions for selected platforms

Pollutant	Emissions (tpy)[a]
2,2,4-Trimethylpentane	0.28
Acetaldehyde	2.57
Arsenic	2.80E-04
Benzene	11.0
Beryllium	8.18E-06
Cadmium	0.04
Chromium	0.08
Ethylbenzene	0.69
Formaldehyde	22.2
Hexane	222
Mercury	0.04
PAH, total	0.13
Toluene	7.56
Xylenes (Mixture of o, m, and p Isomers)	6.63

[a] Emissions reported in short tons.

Table A-14. 2014 HAP emissions estimates by equipment type for selected platforms

Equipment Type	2,2,4-Trimethylpentane (tpy)[a]	Acetaldehyde (tpy)	Arsenic (tpy)	Benzene (tpy)	Beryllium (tpy)	Cadmium (tpy)	Chromium (tpy)
Boiler, heater, and burner	-	-	8.93E-06	9.38E-05	5.36E-07	4.91E-05	6.25E-05
Diesel or gasoline engine	-	5.24E-02	-	0.25	-	-	-
Drilling equipment	-	1.07E-03	-	3.29E-02	-	-	-
Fugitives	1.89E-02	-	-	0.42	-	-	-
Glycol dehydrator unit	-	-	-	2.29	-	-	-
Losses from flashing	7.57E-04	-	-	1.42E-02	-	-	-
Natural gas engine	4.65E-02	2.27	-	0.52	-	-	-
Natural gas, diesel, or dual fuel turbine	-	0.25	2.71E-04	7.69E-02	7.64E-06	4.37E-02	8.40E-02
Pneumatic pump	6.35E-02	-	-	1.24	-	-	-
Storage tank	3.41E-03	-	-	6.45E-02	-	-	-
Cold vent	0.15	-	-	6.14	-	-	-
Total (tpy)	0.28	2.57	2.80E-04	11.00	8.18E-06	0.04	0.08

Table A-14. 2014 HAP emissions estimates by equipment type for selected platforms (Cont.)

Equipment Type	Ethylbenzene[a] (tpy)	Formaldehyde (tpy)	Hexane (tpy)	Mercury (tpy)	PAH (tpy)	Toluene (tpy)	Xylenes (tpy)
Boiler, heater, and burner	-	3.35E-03	8.04E-02	1.16E-05	-	1.52E-04	-
Diesel or gasoline engine	-	9.05E-02	-	9.22E-05	6.23E-02	9.37E-02	6.46E-02
Drilling equipment	-	3.34E-03	-	1.27E-05	8.98E-03	1.19E-02	8.17E-03
Fugitives	3.28E-02	-	4.43	-	-	0.11	2.90E-02
Glycol dehydrator unit	0.12	-	-	-	-	1.21	4.52
Losses from flashing	1.36E-03	-	1.43E-02	-	-	6.31E-04	7.89E-06
Natural gas engine	1.60E-02	17.58	0.22	-	3.98E-02	0.25	9.25E-02
Natural gas, diesel, or dual fuel turbine	0.20	4.48	-	4.18E-02	1.48E-02	0.82	0.40
Pneumatic pump	0.11	-	3.87	-	-	0.11	1.95E-02
Storage tank	6.12E-03	-	8.85E-02	-	-	3.39E-03	2.06E-04
Cold vent	0.20	-	213.60	-	-	4.96	1.49
Total (tpy)	0.69	22.20	222	0.04	0.13	7.56	6.63

[a] Emissions reported in short tons.

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APPENDIX B: EMISSIONS TRENDS ANALYSIS DETAILS

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Summary and Recommendations

The Bureau of Ocean Energy Management (BOEM) is responsible for assessing the potential impacts of offshore oil and gas exploration, development, and production sources on the Outer Continental Shelf (OCS). To facilitate these assessments, BOEM regularly develops air pollutant emission inventories for all sources across the Gulf of Mexico (GOM) OCS. BOEM's predecessor agency, the Minerals Management Service (MMS), conducted limited emission inventories in the Gulf of Mexico in the 1980s. In 1991, the MMS sponsored a regional ozone modeling effort conducted by the U.S. Environmental Protection Agency (USEPA) using the Regional Oxidant Model (ROM). The Gulf of Mexico Air Quality Study (GMAQS) was initiated that same year, and activity data for a Gulfwide emissions inventory were collected for a one-year period in 1991-1992 (Systems Applications International et al. 1995). MMS then sponsored a study to develop an air pollutant emissions inventory for calendar year 2000 (Wilson et al. 2004). The next inventory developed was for calendar year 2005, with additional updates on a three-year cycle to match the USEPA's National Emissions Inventory (NEI) inventory years, or 2008, 2011, and 2014 (Wilson et al. 2007; 2010; 2014). The inventories include criteria pollutants—carbon monoxide (CO), nitrogen oxides (NO_X), particulate matter with an aerodynamic diameter of 10 microns and smaller (PM_{10}), particulate matter with an aerodynamic diameter of 2.5 microns and smaller ($PM_{2.5}$), sulfur dioxide (SO_2) and ozone precursor volatile organic compounds (VOCs); and the major greenhouse gases (GHGs)—carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Later inventories include ammonia and lead.

BOEM has conducted a detailed and comprehensive emissions trends analysis using data from the five most recent inventory studies covering 2000-2014 to assess the long-term emissions trends in the GOM OCS emissions. These inventories include both platform and non-platform emission sources. The platform inventories include combustion and non-combustion equipment found on oil and gas production platforms. The non-platform sources encompass marine vessels and aircraft that support OCS oil and gas production, as well as other non-platform sources such as commercial marine vessels, military vessels, fishing vessels, the Louisiana Offshore Oil Port (LOOP), vessel lightering zones, and geogenic sources, which are not addressed in this analysis since they are not part of the OCS oil and gas exploration, development, and production activity.

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.

Overall, emissions are largely affected by three factors 1) activity/production levels in the GOM by water depth and planning area, 2) changes in inventory methodologies, and 3) improvements in available emission factors. 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. With the increased use of automatic identification system (AIS) data (use of global positioning system (GPS) to track vessel movements) and more detailed vessel attribute data, 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 fairly stable in most instances, while the equipment level contribution vary widely. Figures B-1 and B-2 present high-level comparisons of criteria pollutant and GHG emission estimates (in million short tons per year) for these OCS oil and gas platform and non-platform sources. Note that all remaining figures and tables throughout this analyses with non-platform sources include only oil and gas production related sources.

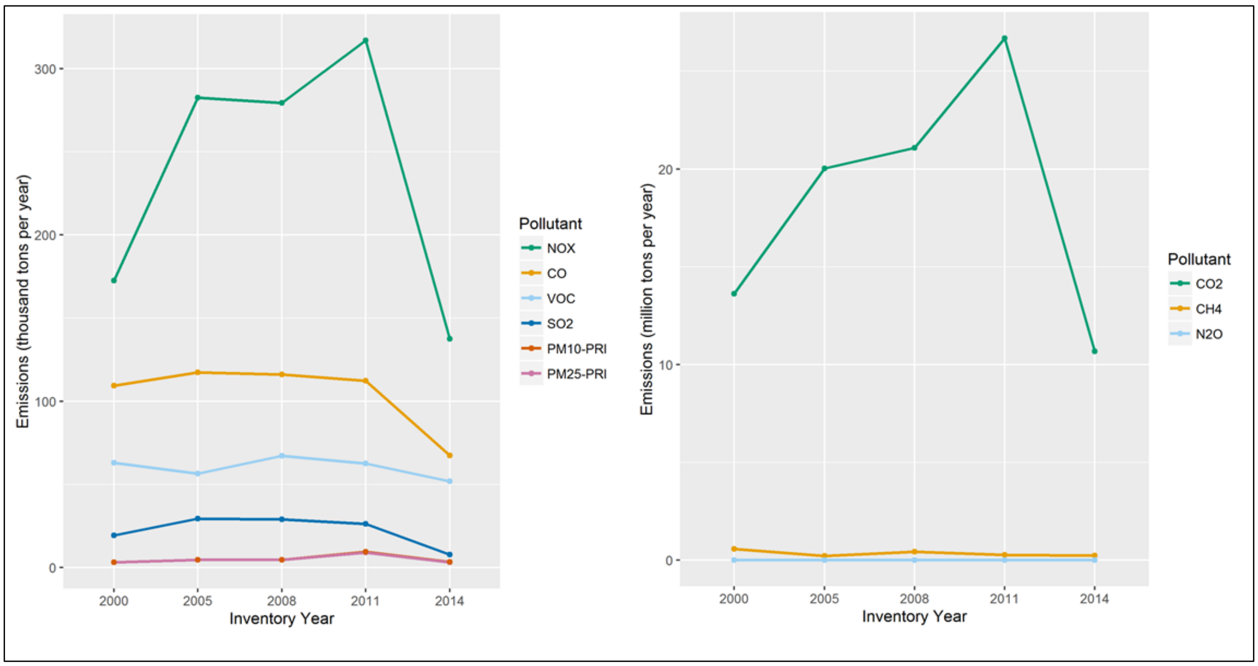

Figure B-1. Total emissions by inventory year (left: criteria pollutants; right: GHGs)

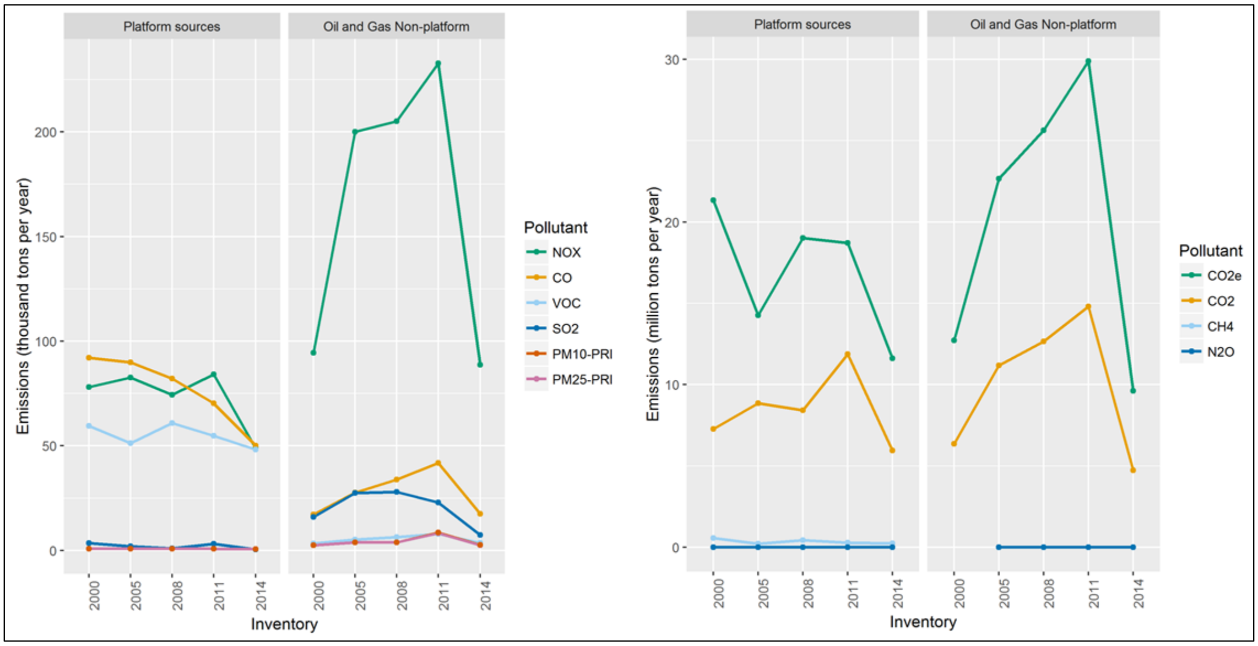

Figure B-2. Platform and non-platform emissions by inventory year (left: criteria pollutants; right: GHGs)

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 quality assurance/quality control (QA/QC) step for the inventory development. That is, if an emission factor was revised higher than the previous inventory and anticipated increased emissions aren't 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.

Furthermore, a full trends analysis should be revisited periodically to incorporate new analysis techniques that better discern true trends in emissions data. An option for further study would be to recalculate the emission inventories with the same emission estimation methods. This is likely only possible with the more recent inventory years, where the appropriate data exists. The most problematic inventory for recalculation is the non-platform inventory, whose estimation methods have benefited greatly from advancements in technology and availability of AIS data.

Based on the preliminary simple regression, the year 2000 inventory qualitatively appears 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 delivery of platform activity data, since this first inventory. Given these changes and how the inventory compares to the subsequent inventories, it may be advisable to drop the year 2000 inventory from any forecast model development. Furthermore, as newer inventories become available for incorporation into a forecast model, older inventories should be reviewed each cycle to determine if they are still representative of industry practices. Those that are not representative, should no longer be considered in model development.

B.1 INTRODUCTION

B.1.1 Background

The Bureau of Ocean Energy Management (BOEM) Gulf of Mexico Outer Continental Shelf (OCS) Region office sponsored this study, the Year 2014 Gulfwide Emissions Inventory Study (BOEM Contract No. M13PC00005), with the goal of developing a base year 2014 air pollutant emissions inventory sources in the Gulf of Mexico (GOM) OCS. Sources include those associated with OCS oil and gas exploration, development, and production activity (i.e., offshore platforms and their support vessels) as well as those emission sources unrelated to exploration, development, and production activities (i.e., commercial marine vessels). In previous reports, comparison of the emission estimates focused on comparing the two most recent BOEM inventories. At the completion of the 2014 inventory development effort, BOEM now has emission estimates for five consecutive inventory studies that span 2000-2014. For the 2014 inventory, a detailed and comprehensive emissions trends analysis of all five inventory years has been conducted to assess the long-term emission trends in Gulf of Mexico (GOM) OCS emissions across all inventory years.

Early inventories were not recalculated to account for changes in emission factors or emission estimation methods. In some cases, a recalculation of inventory elements is not possible. For example, the estimation method for the non-platform inventory has evolved to make use of automatic identification system (AIS)-tracked vessel positions for activity data. these data are not available for inventory years prior to 2002. Furthermore, as the technology was being incrementally introduced, the earlier AIS data sets may not represent the vessel fleet completely; the program has only come to maturation in the last couple years (e.g., increased number of vessels included in the AIS data and expanded geographic coverage). Additionally, it would take considerable effort to recalculate the inventories. The goal of these emissions trends analyses is to produce a consolidated record of the inventory calculation methods that would affect long-term trends analyses, determine the extent to which the methods differences affect the apparent trends, and the impact of external factors (e.g., fuel prices, hurricane activity) on emission levels.

This trends analysis includes the emissions from BOEM oil and gas production platform and non-platform sources for all pollutants covered in the inventories, including the criteria pollutants— carbon monoxide (CO), nitrogen oxides (NO_X), particulate matter with an aerodynamic diameter of 10 microns and smaller (PM_{10}), particulate matter with an aerodynamic diameter of 2.5 microns and smaller ($PM_{2.5}$), sulfur dioxide (SO_2) and ozone precursor volatile organic compounds (VOCs); and the major greenhouse gases (GHGs)—carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

Because of the size of the inventories, the first phase of the analysis was to load the inventories into a Microsoft® SQL Server database. This linked all inventory years together and allowed initial aggregation of the data. These aggregated data sets were analyzed using R, a statistical analysis program. R is free software under the GNU general public license. Since R is free and publicly available, the methods can be reviewed and run by anyone, making the analysis transparent.

B.1.2 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 B-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 B-3. The figure also includes a vertical dashed line in the eastern portion of the Central Planning Area (CPA) that represents the extent of the CPA prior to 2007. The Gulf of Mexico Energy Security Act (GOMESA) of 2006 revised the CPA to the green shaded area. As such, the 2008 and prior inventories, and any spatial plots of their data, will be limited to the initial extent of the CPA (i.e., no data in the area between the dashed line and current CPA boundary).

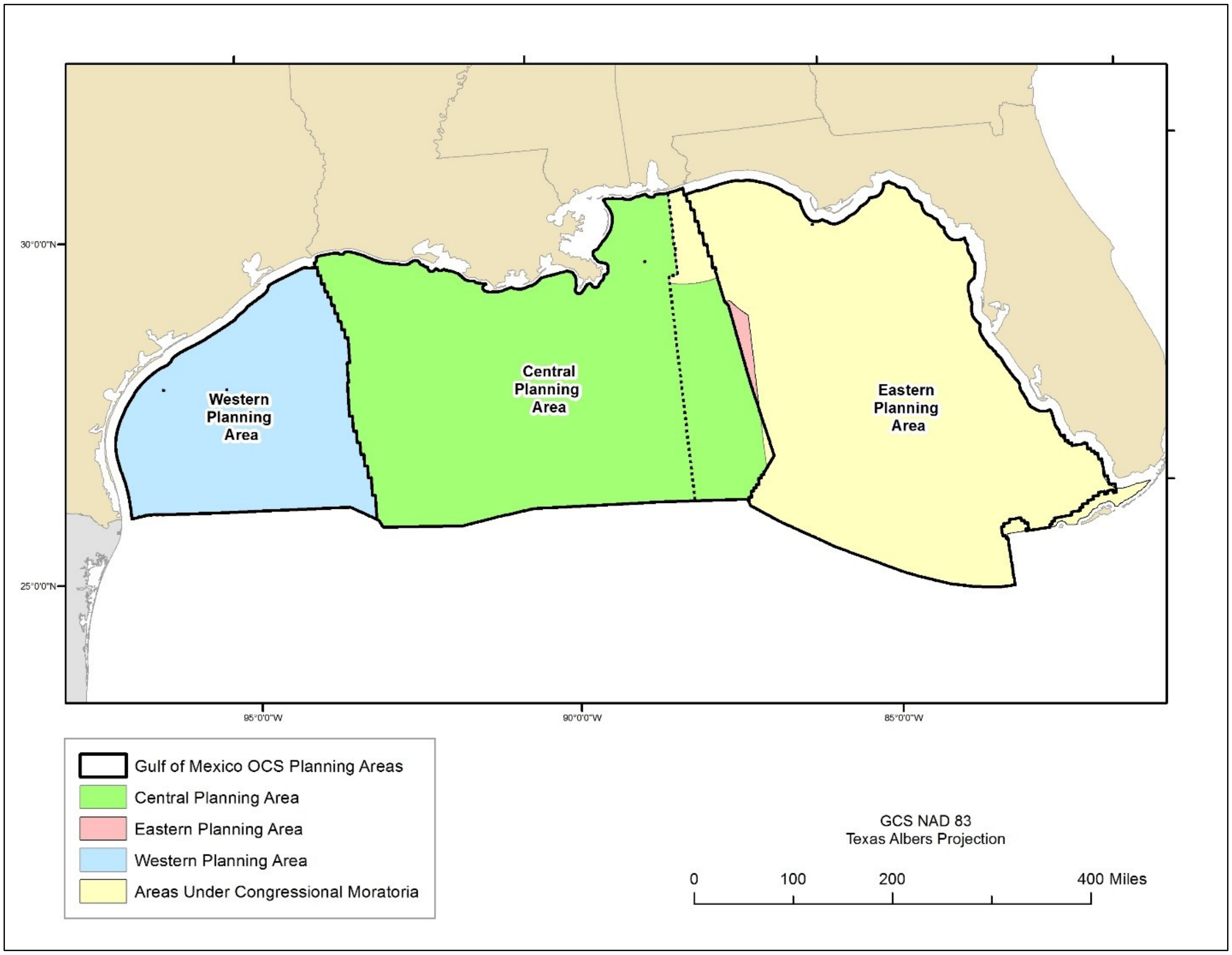

Figure B-3. Gulf of Mexico region planning areas and 2014 active lease blocks

The inventories include the processes and equipment found on oil and gas platforms, as well as the vessels and aircraft supporting the platforms. The inventories are divided into two databases: platform and non-platform.

The platform equipment surveyed include:

- Amine units;
- Boilers, heaters, and burners;
- Diesel engines;
- Drilling equipment;
- Combustion flares;
- Fugitive sources;
- Glycol dehydrators;
- Loading operations;
- Losses from flashing;
- Mud degassing;
- Natural gas engines;
- Natural gas turbines;
- Pneumatic pumps;
- Pressure and level controllers;
- Storage tanks; and
- Cold vents.

The non-platform oil and gas production sources consist of:

- Drilling vessels;
- Pipelaying operations;
- Support helicopters;
- Support vessels; and
- Survey vessels.

The non-platform non-oil and gas production sources include:

- Biogenic and geogenic sources;
- Commercial fishing vessels;
- Commercial marine vessels (e.g., tankers, containerships, and cruise ships);
- Louisiana Offshore Oil Port (LOOP);
- Military vessels (U.S. Coast Guard and U.S. Navy);
- Commercial and recreational fishing vessels; and
- Vessel lightering operations.

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 carbon dioxide equivalents (CO_2e) was included. Since 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 (IPCC 2007). 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 CO2 emissions of each gas.

As the science surrounding climate change evolves, the GWPs are revised. For the 2008 inventory, the GWPs used were those required under the U.S. Environmental Protection Agency (USEPA) Final Mandatory Reporting of Greenhouse Gases Rule (Federal Register 2009). 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 Intergovernmental Panel on Climate Change (IPCC), 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}-PRI = PM_{10}-FIL + PM-CON; and

$PM_{2.5}$-PRI = $PM_{2.5}$-FIL + PM-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. These species of PM we added to the inventory to incorporate the data into the USEPA National Emissions Inventory (NEI). For simplicity, the balance of this report will focus on the primary components of PM_{10} and $PM_{2.5}$.

B.1.2.1 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 from reporting. For the 2008 and 2011 inventories, BOEM required minor sources to report minimal data via the Gulfwide Offshore Activities Data System (GOADS) software. Minor sources were required to report equipment data starting in the 2014 inventory. 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 emission from loading operations. Emissions due to 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. Activity data required to calculate loading emission were required in both the 2000 and 2005 inventories. Loading was dropped in GOADS-2008, but required once again in GOADS-2014 in order to capture floating production storage and offloading (FPSO) vessels.

Table B-1 summarizes the platform equipment types required for reporting each inventory year. An x ("✕") denotes the equipment type was not required and a check ("✓") noted where it was required.

Table B-1. Platform equipment types included in the Gulfwide inventories by year

Platform Equipment Type	2000	2005	2008	2011	2014
Amine units	✓	✓	✓	✓	✓
Boilers	✓	✓	✓	✓	✓
Caissons (minor source)	✕	✕	✓	✓	✓
Diesel engines	✓	✓	✓	✓	✓
Drill rigs	✓	✓	✓	✓	✓
Combustion flares	✓	✓	✓	✓	✓
Fugitives	✓	✓	✓	✓	✓
Glycol dehydrators	✓	✓	✓	✓	✓
Loading	✓	✓	✕	✕	✓
Losses	✓	✓	✓	✓	✓
Living quarters (minor source)	✕	✕	✓	✓	✓
Mud degassing	✓	✓	✓	✓	✓
Natural gas engines	✓	✓	✓	✓	✓
Natural gas turbines	✓	✓	✓	✓	✓
Other (minor source)	✕	✕	✓	✓	✓
Pneumatic devices	✓	✓	✓	✓	✓
Pressure and level controllers	✓	✓	✓	✓	✓
Storage tanks	✓	✓	✓	✓	✓
Cold vents	✓	✓	✓	✓	✓
Wellhead protectors (minor source)	✕	✕	✓	✓	✓

The calculation methods for the platform inventories have remained fairly 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.

B.1.2.2 Oil and Gas Production Non-Platform Inventory Changes

The source categories within the non-platform inventory have changed between inventories. Table B-2 summarizes the non-platform equipment included in the inventory years. An x ("✕") denotes the equipment type was not required and a check ("✓") noted where it was required. As the table shows, platform construction and decommissioning was deleted as an emission category after the 2000 inventory to remove the potential for double counting of emissions from support vessels. Also of note, emergency generators associated with drilling rigs were also added to the 2008 inventory as part of total drill rig emissions.

Additionally, the 2000 inventory divide LOOP emissions into three categories, which were consolidated in later inventories. Since 2011, the fishing vessel category has been divided between commercial and recreational values as sufficient data has become available to make the distinction. These last two changes are not noted in the table, as they are not BOEM oil and gas production activities. The balance of this report will focus on the OCS oil and gas production activities: drilling rigs, helicopters, pipe laying, and support and survey vessels.

Table B-2. Non-platform sources delineated in the Gulfwide inventories by year

Non-platform Source Type[a]	2000	2005	2008	2011	2014
Biogenic & geogenic emissions	✓	✓	✓	✓	✓
Commercial marine vessels (CMV)	✓	✓	✓	✓	✓
Drilling rigs	✓	✓	✓	✓	✓
Fishing	✓	✓	✓	✓	✓
Helicopters	✓	✓	✓	✓	✓
Lightering	✓	✓	✓	✓	✓
LOOP	✓	✓	✓	✓	✓
Military vessels	✓	✓	✓	✓	✓
Pipelaying	✓	✓	✓	✓	✓
Platform construction/removal[b]	✓	✕	✕	✕	✕
Support vessels	✓	✓	✓	✓	✓
Survey vessels	✓	✓	✓	✓	✓

[a] OCS oil and gas production sources noted in bold.

[b] Included in the support vessel emission estimates for 2005 through 2014.

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 for 2014 with the use of AIS data to track individual vessels and linking these vessels to Information Handling Services (IHS) Register of Ships data to obtain detailed information on vessel engine and operating characteristics.

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 2000, 2005, 2008, 2011, and 2014 Helicopter Safety Advisory Conference's data. This data set was supplemented with the Federal Aviation Administration (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 2005 inventory, the offshore support vessel population data were obtained from the Offshore Marine Service Association, which documented a significantly higher vessel population than used in the 2000 inventory. 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). AIS tracks vessel movements within range of very high requency (VHF) transmitting stations. The vessel transmitters send a signal every two seconds that documents: vessel identification codes, radio call signs, location, direction, speed, and final destination. These data were used to develop vessel traffic contours for each vessel type (e.g., tanker, containership, support vessel) that was used to spatially allocate emissions. This information was coupled with the U.S. Army Corps of Engineers Entrance and Clearance data. The Entrance and Clearance data were used to quantify hours of operation for commercial marine vessels by mapping the length of the route in federal waters between the ports the vessels visited, divided by their design cruising speed. Hours of operation were applied to the vessels power rating to get kilowatt hours.

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. Table B-3 provides a crosswalk from the 2014 categories to the categories used in previous inventories and this report.

Table B-3. 2014 Non-platform source categories

2014 Non-platform Type	Non-Platform Type	OCS Source
Auto carrier	CMV	N
Bulk carrier	CMV	N
Chemical tanker	CMV	N
Commercial fishing	Fishing	N
Container	CMV	N
Crude oil tanker	CMV[2]	Y
Cruise ships	CMV	N
Dredging	CMV	N
Drilling	Drilling rigs	Y
Ferry	CMV	N
FPSO	Support vessels	Y
General cargo	CMV	N
Geogenic	Biogenic andgeogenic	N
Helicopters	Helicopters	Y
Lightering	Lightering	N
LOOP	LOOP	N
Military	Military vessels	N

[2] May include some OCS tankers, but they cannot be distinguished.

2014 Non-platform Type	Non-Platform Type	OCS Source
Miscellaneous	CMV	N
Offshore oil and gas support	Support vessels	Y
Passenger	CMV	N
Pilot	CMV	N
Pipelaying	Pipelaying	Y
Recreational fishing	Fishing	N
Reefer	CMV	N
Research	CMV	N
RORO	CMV	N
Survey	Survey vessels	Y
Tanker, LNG and LPG	CMV	N
Tanker, miscellaneous	CMV	N
Tug	Support vessels	Y
Unknown	Miscellaneous and unknown	N
Well stimulation vessel	Support vessels	Y

B.2 PLATFORM TRENDS

The following section describes the changes seen in platform emission inventories. Section B.2.1 discusses how the spatial distribution of platforms have changed over the years with respect to counts by planning areas and water depth. Section B.2.2 examines the total platform emission estimates for each pollutant, with more in-depth discussions for each equipment category following in Sections B.2.3, B.2.4, and B.2.5.

B.2.1 Spatial Distribution

The number of active platforms reported in each inventory year has varied. Figure B-4 shows the variability in the reported number of active platform across all five inventory years. The 2000 inventory contained 3,154 active or inactive platforms (combination of Complex ID and Structure ID), while 2005 contained 1,619 active or inactive platforms. This sharp drop in reported number of platforms was examined by reviewing the Minerals Management Service (MMS) Technical Information Management System (TIMS) database for major sources that should be reporting. This was then compared to the submitted facility list to identify non-reporters. MMS followed-up with reminders to these major sources to encourage the submittal of activity data. Unfortunately, 2005 was an atypical inventory year due to widespread hurricane damage. The 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, for the 2005 inventory minor sources were permitted to be excluded from reporting via GOADS. Therefore, the 2005 inventory had a much lower number of platforms reported.

In 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 required minor sources to report minimal data via GOADS. Thus, many more platforms are included in the 2008 inventory.

In 2011, 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.

In 2014, 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. 1,651 structures were active (at least one month). Thus, approximately 250 platforms are unaccounted for in the year 2014 inventory. The decrease in active platforms from 2011 appears to stem, at least in part, from the decrease in oil prices.

Further inspection of these 250 missing platforms suggests possible reasons for the missing platforms. Approximately 29 were reported as removed in TIMS, but either a partial year was still expected (27 platforms) or no confirmed removal date had been reported (two platforms).

A review of the companies associated with the non-reported platforms found indication that 3 companies were sold since the 2011 inventory (17 platforms). Previous inventory reporting compliance reviews have shown 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. TIMS further indicated that some of these platforms were removed prior to (seven), during (one), or after (seven) 2014. It is possible the operator failed to submit these platforms since they were offline or poised to be offline by the GOADS submission deadline.

Another reason a previously reported platform might be omitted is related to the recent decline in oil and gas prices; as some companies have or are in the process of declaring bankruptcy. Reviewing each of the remaining platforms, nine companies (accounting for 87 platforms) were found to be in middle of some level of bankruptcy or reorganization. During bankruptcy/reorganization, staff turnover typically increases and regular reporting can fall through the cracks.

The TIMS data also indicated 74 platforms that did not report in 2014, and had not reported in 2011 either. The TIMS installation date indicates data should been submitted for these platforms in 2011, and most of the previous inventories. Given these platforms have failed to respond in multiple inventories suggests these platform as persistent non-reporters. Finally, seven of the 250 platforms did have their 2011 information requested by their operators, but no 2014 data were returned. Table B-4 summarizes these counts, and Figure B-4 provides a visual representation.

Table B-4. Summary of possible reasons for non-reporters

Reason for omission	Count	Percentage of total (%)
Possible bankruptcy	87	35
Previous non-reporter	74	30
Installed in 2014	2	1
Removed after 2014	18	7
Removed during 2014	27	11
Possible removal (no date)	2	1
Possible sale	2	1
Possible sale; removal during 2014	1	0
Possible sale; removal prior to 2014	7	3
Possible sale; removal after 2014	7	3
Operator requested, no data returned	3	1
Undetermined	20	8

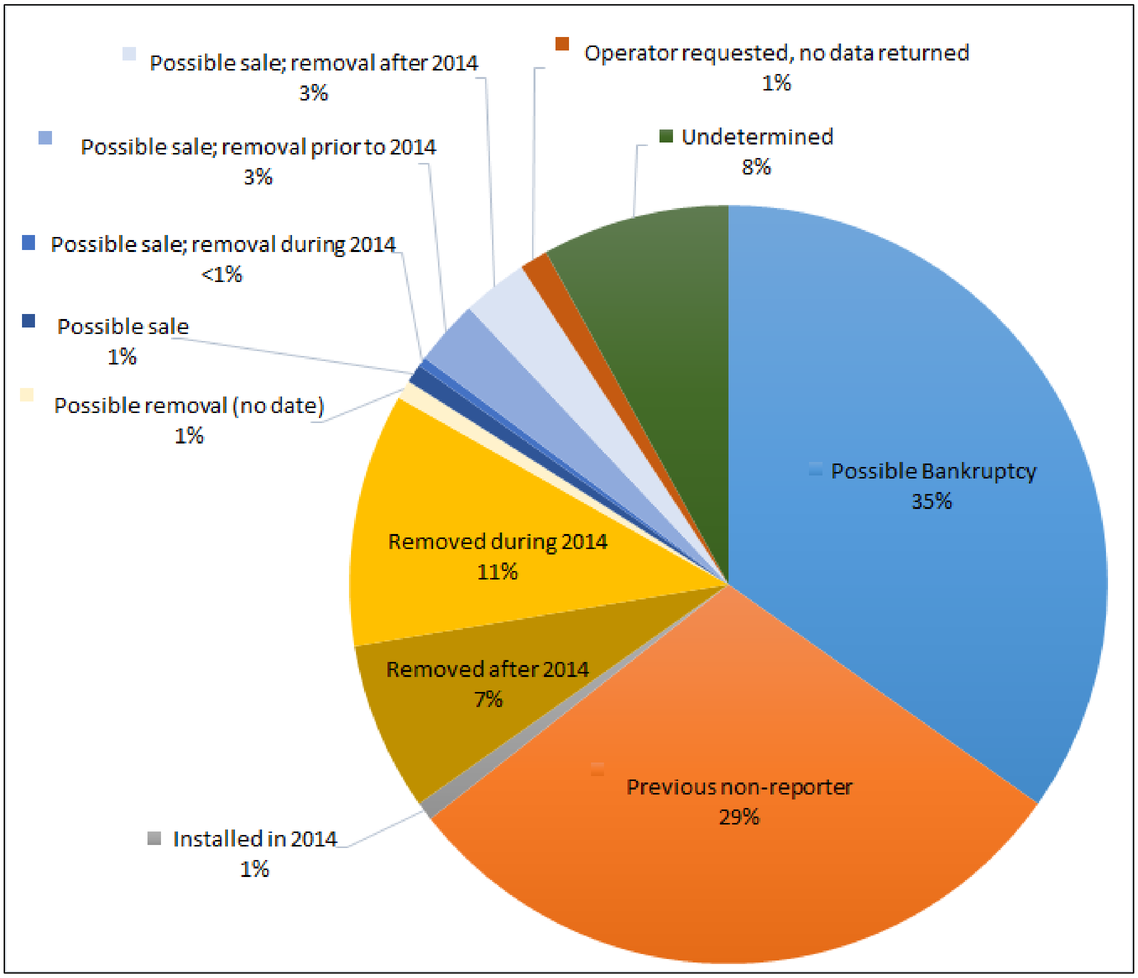

Figure B-4. Summary of non-reporters

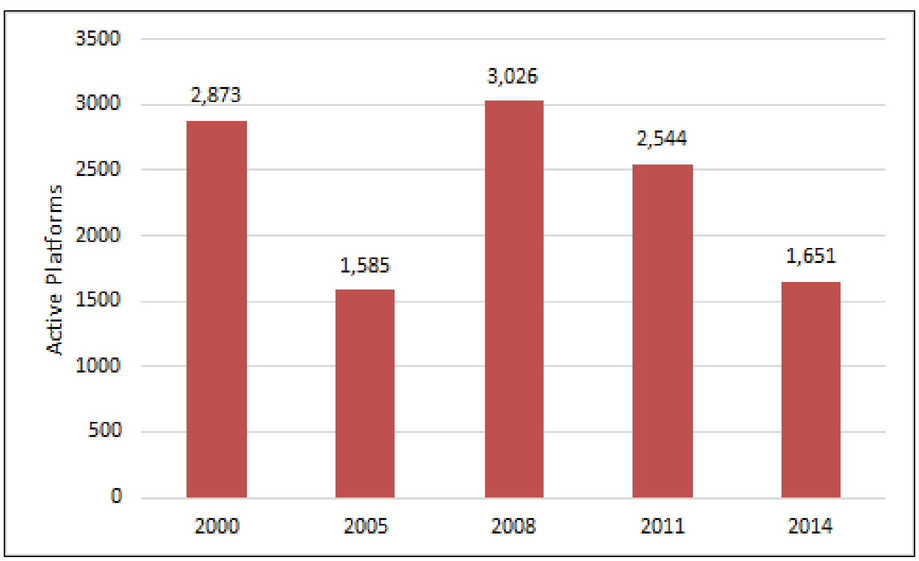

Figure B-5. Active platforms by inventory year

As mentioned in Section B.1.2, the GOM is divided into three planning areas. As shown in Figure B-6, the Central Planning Area contains between 84 and 88% of the active platforms, depending on the inventory year. The Eastern Planning Area has no production platforms to report. Also, the USEPA has air quality jurisdiction east of the 87.5^0 longitude.

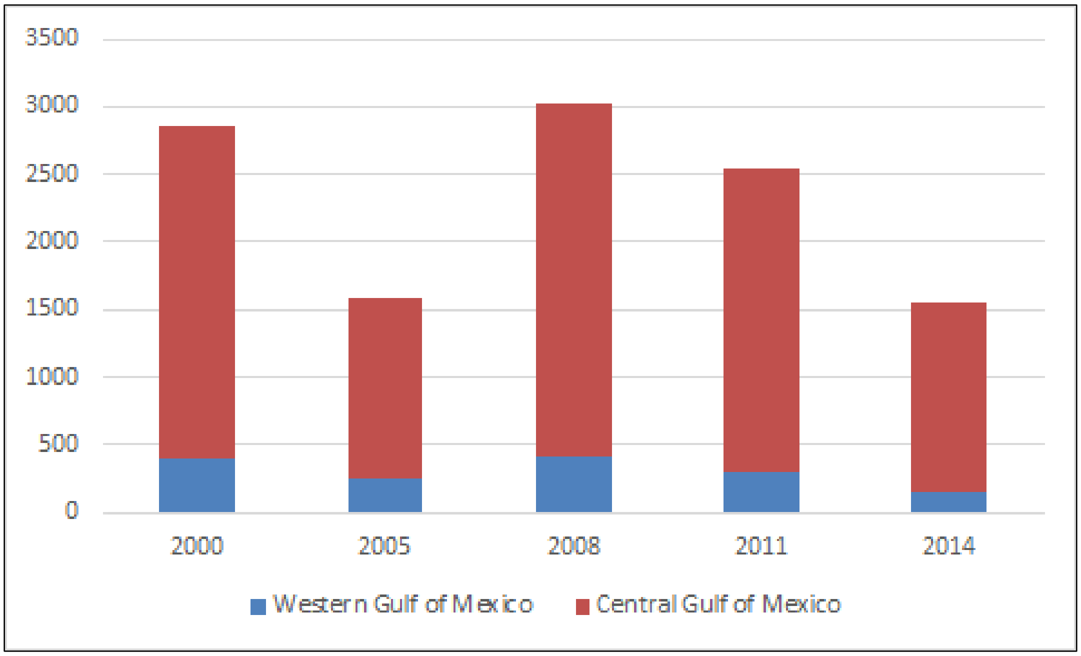

Figure B-6. Active platforms by planning area

BOEM considers development within certain water depth categories. The typical breaks for used for water depth categories are 60, 200, 800, 1,600, and 2,400 meters. Figure B-7 shows these water depth boundaries compared to the current active lease blocks. The below 60-meter water depth range is wider than other depth categories. As Figure B-8 and Table B-5 show, this water depth range contains the most active platforms. Across all inventory years more than 75% of the platforms are in water depth below 200 meters.

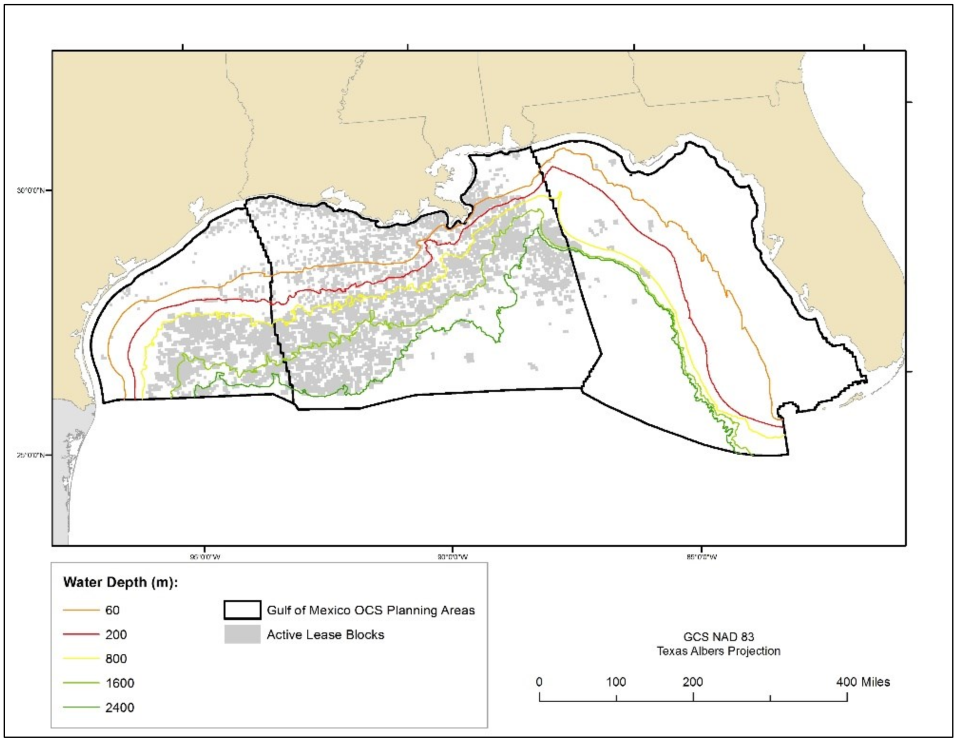

Figure B-7. 2014 Active lease blocks and water depth boundaries

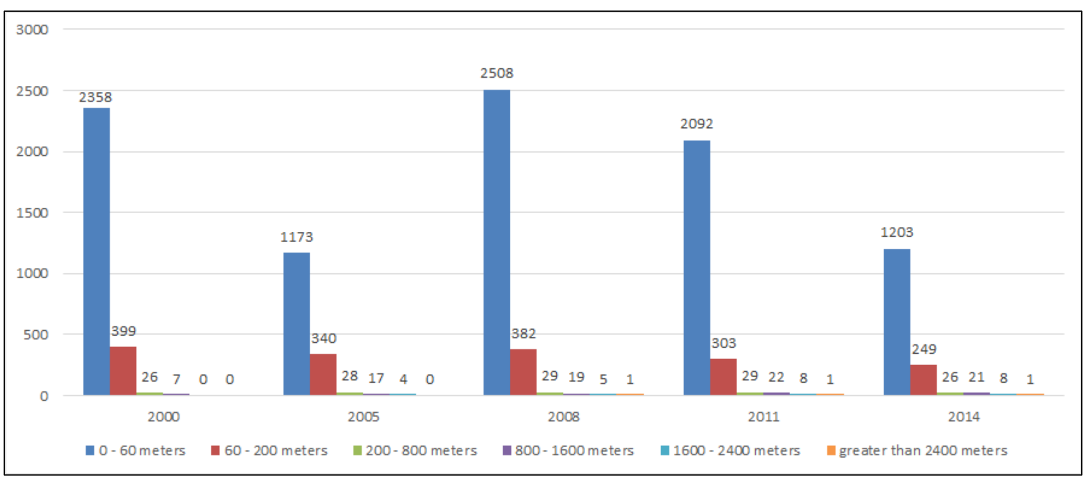

Figure B-8. Count of active platforms by water depth (feet)

Table B-5. Platform counts by water depth

Platform Water Depth	2000	2005	2008	2011	2014
0 - 60 meters	2,358	1,173	2,508	2,092	1,203
60 - 200 meters	399	340	382	303	249
200 - 800 meters	26	28	29	29	26
800 - 1600 meters	7	17	19	22	21
1,600 - 2,400 meters	0	4	5	8	8
Greater than 2,400 meters	0	0	1	1	1
Unavailable	83	23	82	89	143
Total	2,873	1,585	3,026	2,544	1,651

Figure B-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 final bin, water depth greater than 2400 meters, is reached. The emissions in this final bin increase sharply, especially in later inventory years. This trend needs to be tempered with the fact that some discoveries in deepwater areas are too small to 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 from the facility (Nixon 2016). This trend is discussed further in Section B.4.1.

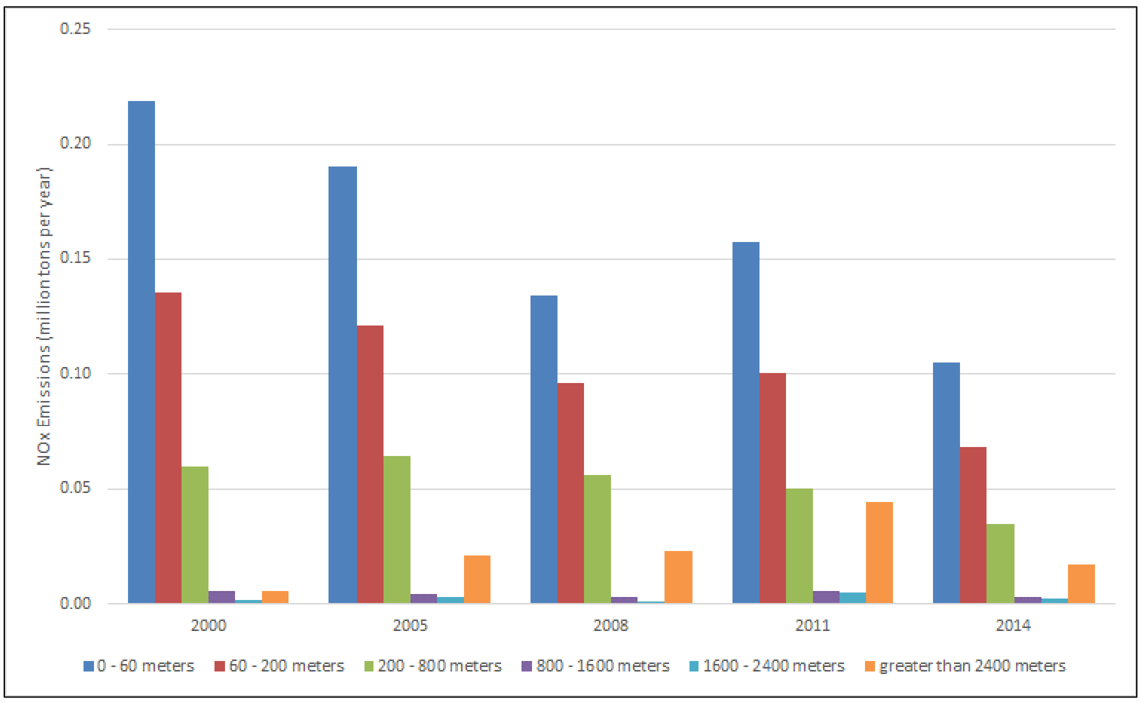

Figure B-9. Active platform NO_x emissions by water depth (meters)

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). The majority of active platforms are in shallow waters, except for the 2005 inventory (Figure B-10 and Table B-6). This is likely due to the aforementioned underreporting of minor sources for the year. The absolute number of deepwater platforms show decrease across the five inventory years, but were a larger percentage in the most recent inventory. It is worth noting this is not necessarily reflect of the trends across all years in the 2000 to 2014 period. The Deepwater Gulf of Mexico Report (Nixon 2016) shows a little less variability in the number of active leases in deepwater. The discrepancy in the total number between the Deepwater Gulf of Mexico Report and the GOADS counts likely due, at least in part, to "tying back" subsea structures to other platforms who report the emissions to GOADS.

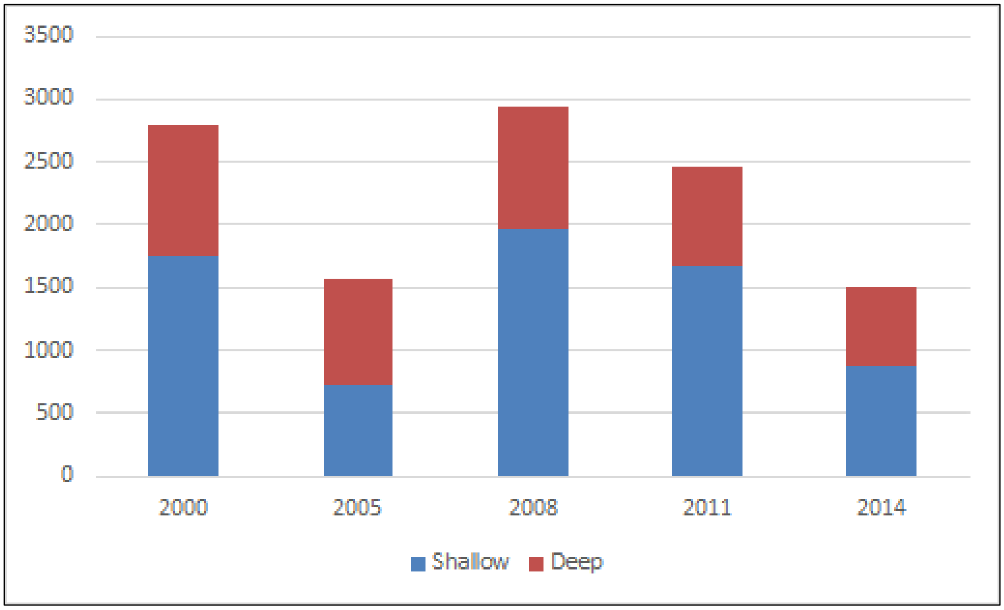

Figure B-10. Active platforms by shallow/deepwater

Table B-6. Counts of active platforms by shallow/deepwater distinction

Water depth	2000	2005	2008	2011	2014
Shallow	1,748	720	1,960	1,676	877
Deep	1,042	842	984	779	631
Unavailable	83	23	82	89	143
Total	2,873	1,585	3,026	2,544	1,651

Looking back at Figure B-6, there are fewer active leases in shallow waters of the Western Planning Area. An analysis of the active platforms (Figure B-11) shows the Western Planning Area (W GOM) platforms are roughly split evenly between shallow and deepwater. The active platforms in the Central Planning Area (C GOM) are less evenly split, with on average 60% in the shallow water category.

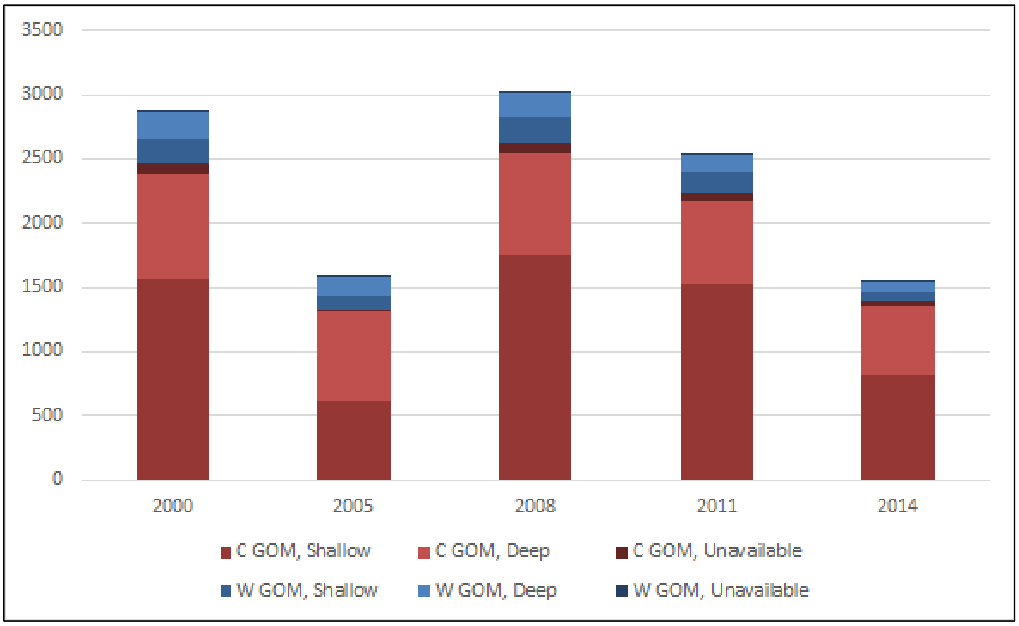

Figure B-11. Active platforms by planning area and water depth

These trends in platform distribution can also be seen in the spatial plots of the locations. The maps shown in Figure B-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 Gulf of Mexico, 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 B-13. The spatial plots of the other inventory pollutants follow a similar pattern, which are included in the attachment to this document.

The spatial pattern of emissions also correlates with platform oil and gas production values, which is discussed further in Section B.4.1.

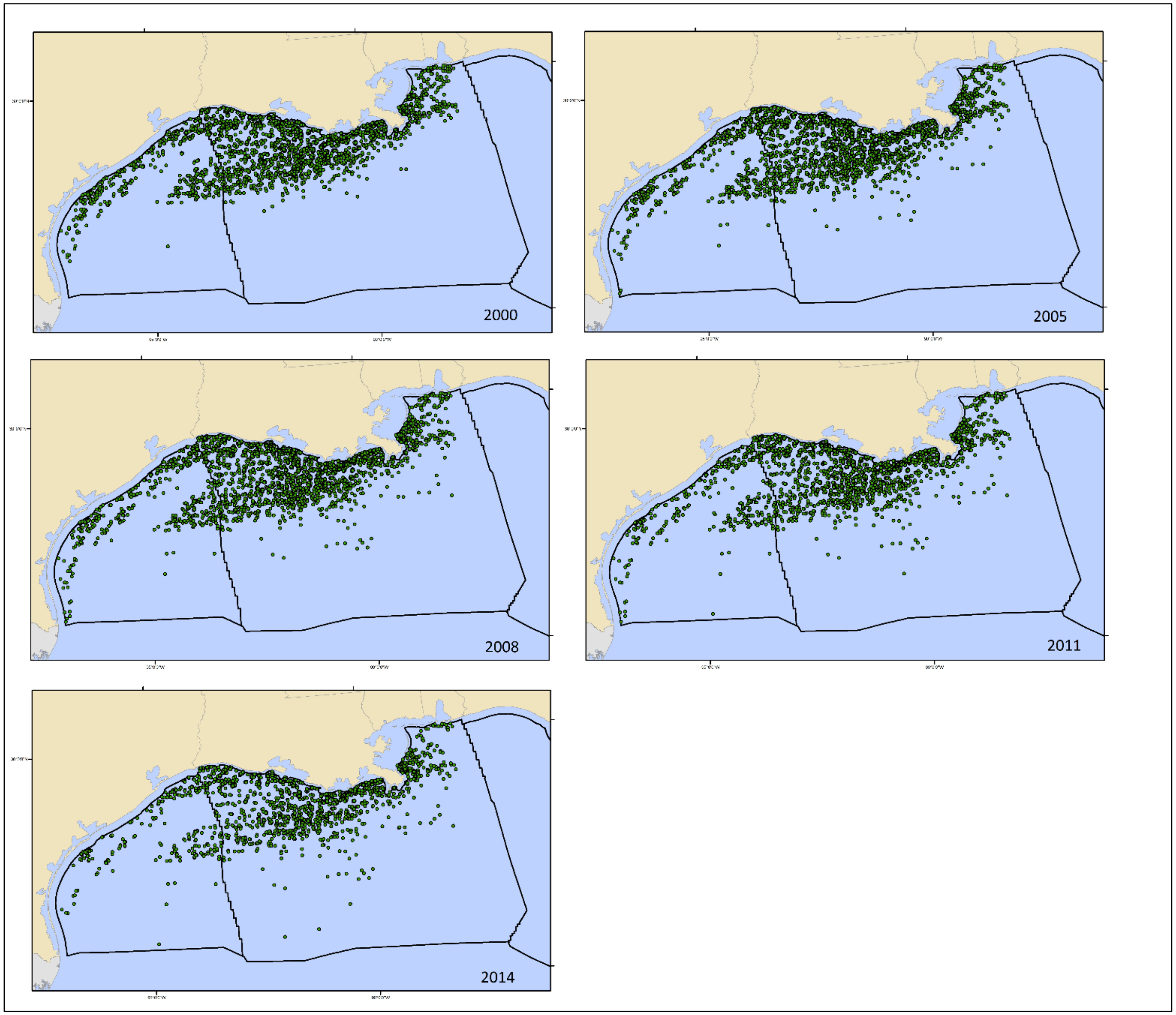

Figure B-12. Active platform location by inventory year

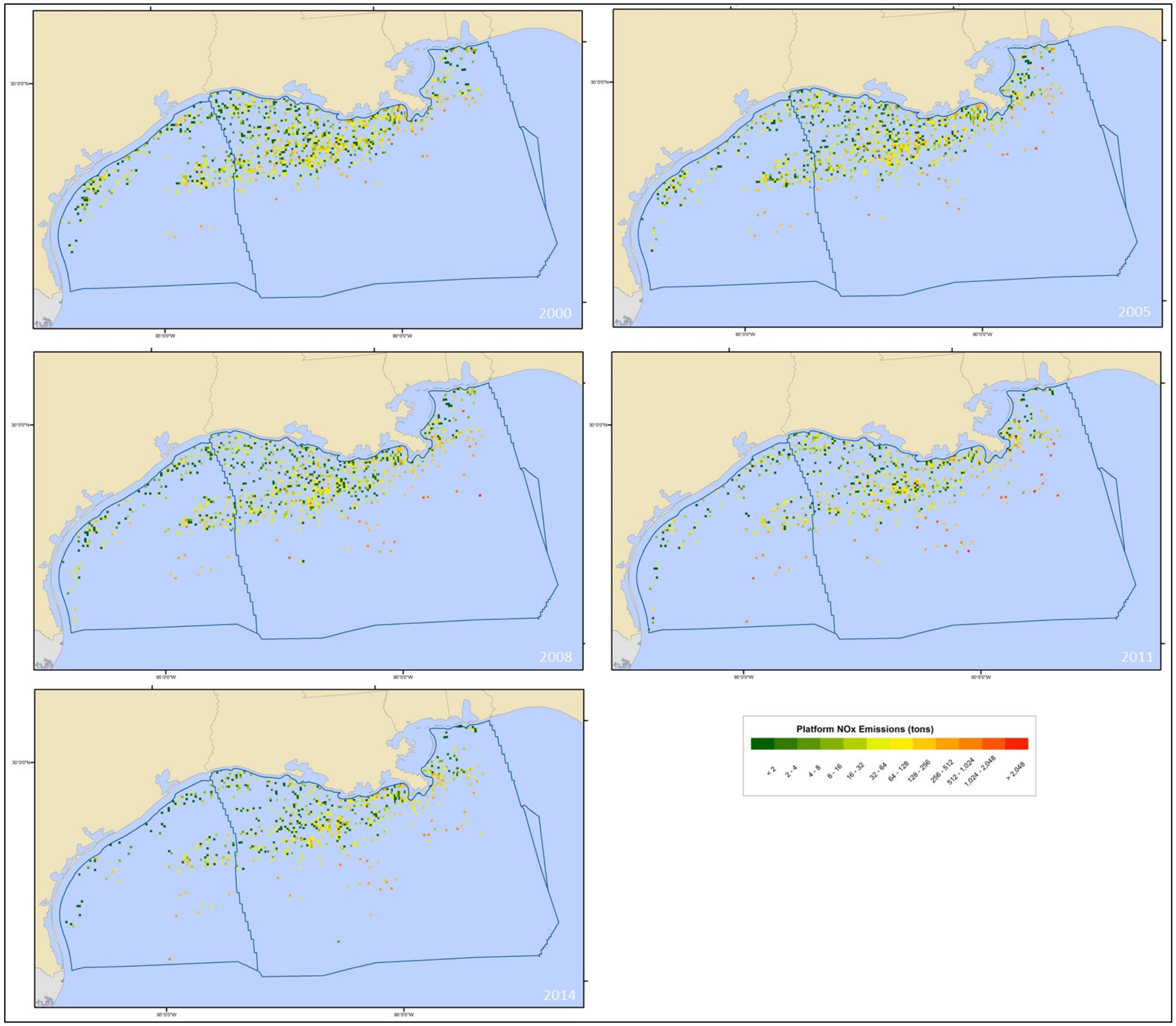

Figure B-13. Total platform NO_x emissions by year

B.2.2 Total Emission Trends

Total platform emissions, which don't include support vessel emissions, only those emissions associated with platform equipment, are summarized in Table B-7 and shown graphically in Figures B-14 and B-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 in part due to the annual variability in the number of active platforms, the 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 B-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 B-14 shows inventory years that standout by breaking apparent trends. Examining the emission by equipment category sheds some light on what is driving these sudden shifts in emissions.

Figure B-14 shows a sharp drop in CH_4 emissions in the 2005 inventory. Looking at the emissions by broad equipment categories (Figure B-16), this drop is due to a sharp drop in emissions from vents and flares.

The bar charts in Figure B-15 indicate NO_x emissions holding steady around 80,000 ton 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 B.2.3.

The figure also shows that SO_2 emissions have been fairly steadily decreasing, with the exception of an increase in the 2011 inventory. By looking at the breakdown of emission by equipment category in Figure B-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 B.2.3, B.2.4, and B.2.5 examine all the equipment trends in combustion, vent and flare, and non-combustion categories.

Table B-7. Summary of platform emissions by year

Pollutant		Emissions (short tons per year)				
		2000	2005	2008	2011	2014
GHGs	CO_2	7,260,620	8,848,779	8,417,165	11,882,029	5,940,330
	CH_4	562,194	214,499	422,707	271,355	225,667
	N_2O	75	130	125	167	98
Criteria Pollutants	CO	92,143	89,813	82,146	70,339	50,052
	NO_x	78,050	82,581	74,286	84,128	48,691
	PM_{10}-PRI	789	746	780	838	668
	$PM_{2.5}$-PRI	783	743	769	835	667
	SO_2	2,100	1,961	1,021	3,197	502
	VOC	59,536	51,241	60,824	54,724	48,210

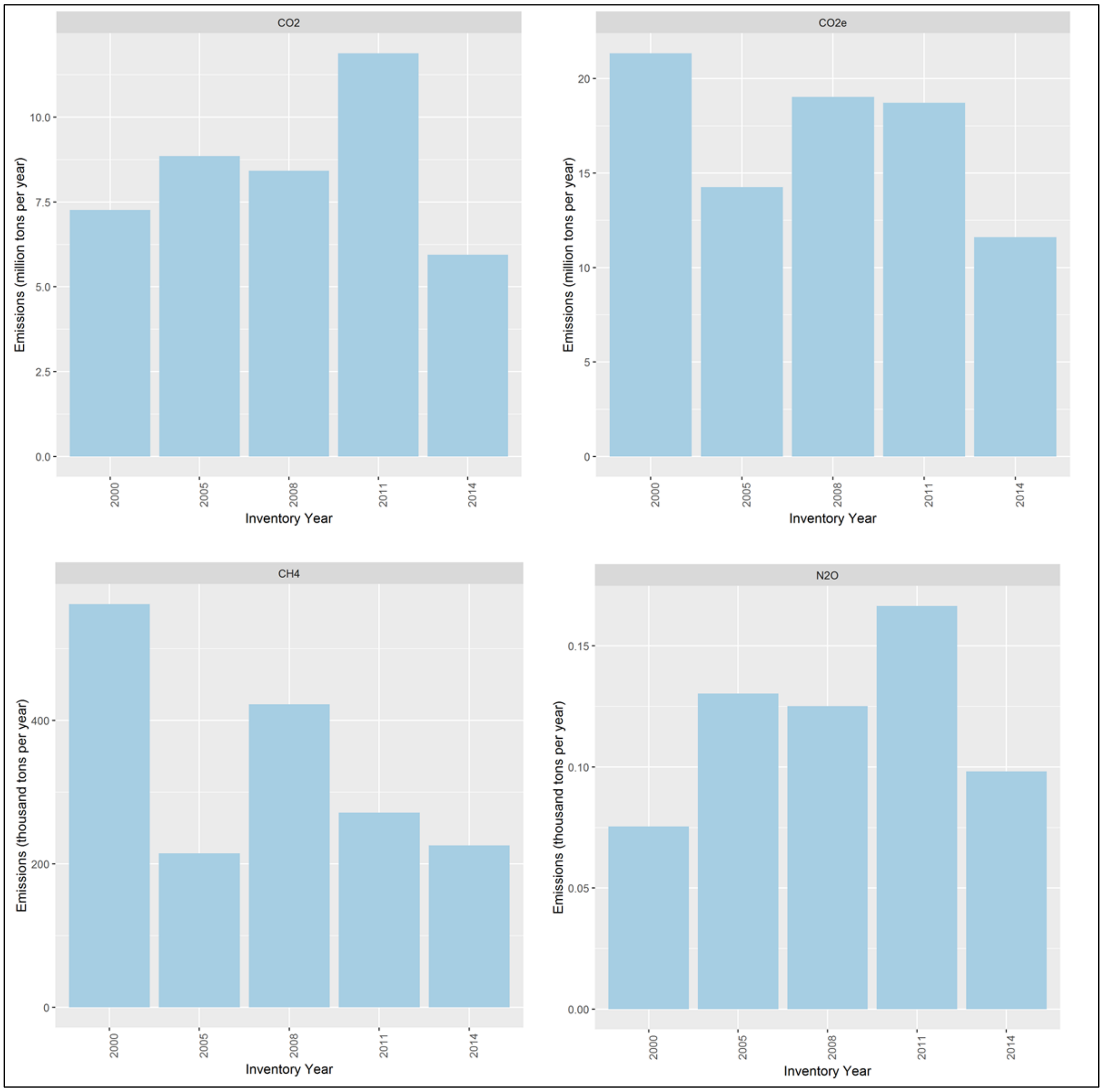

Figure B-14. Total platform GHG emissions by inventory year

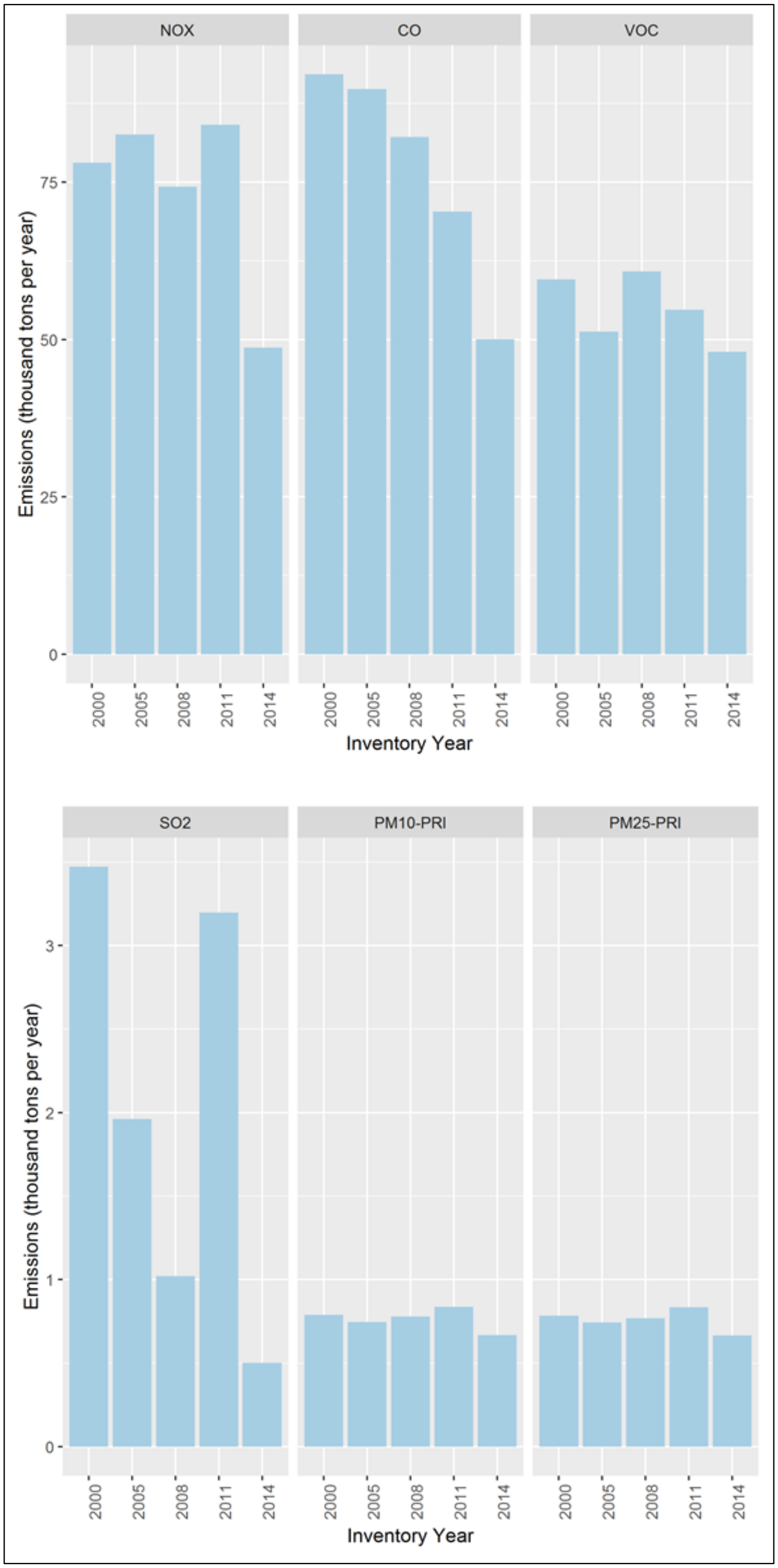

Figure B-15. Total platform criteria pollutant emissions by inventory year

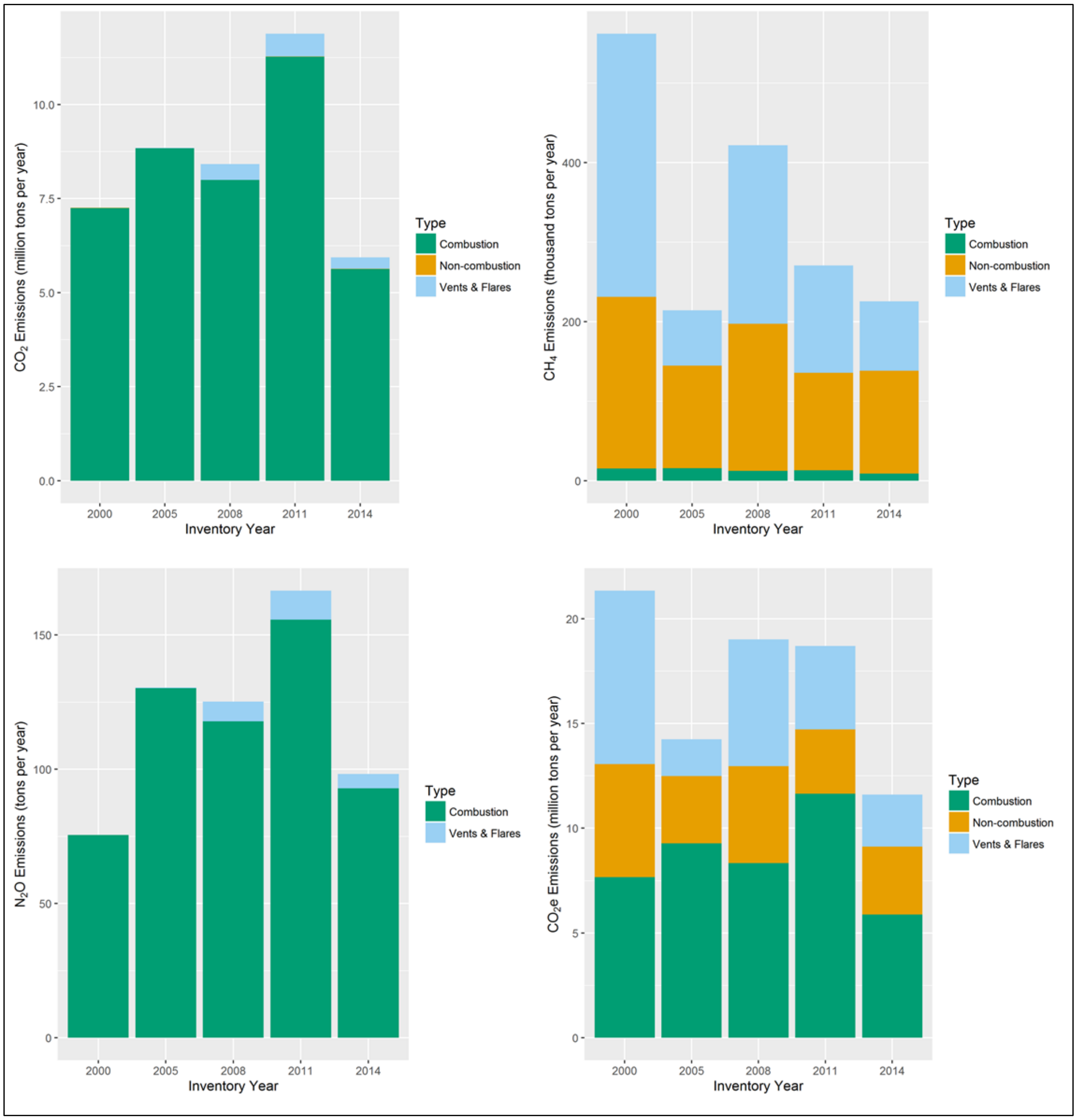

Figure B-16. Platform GHG emissions by equipment type

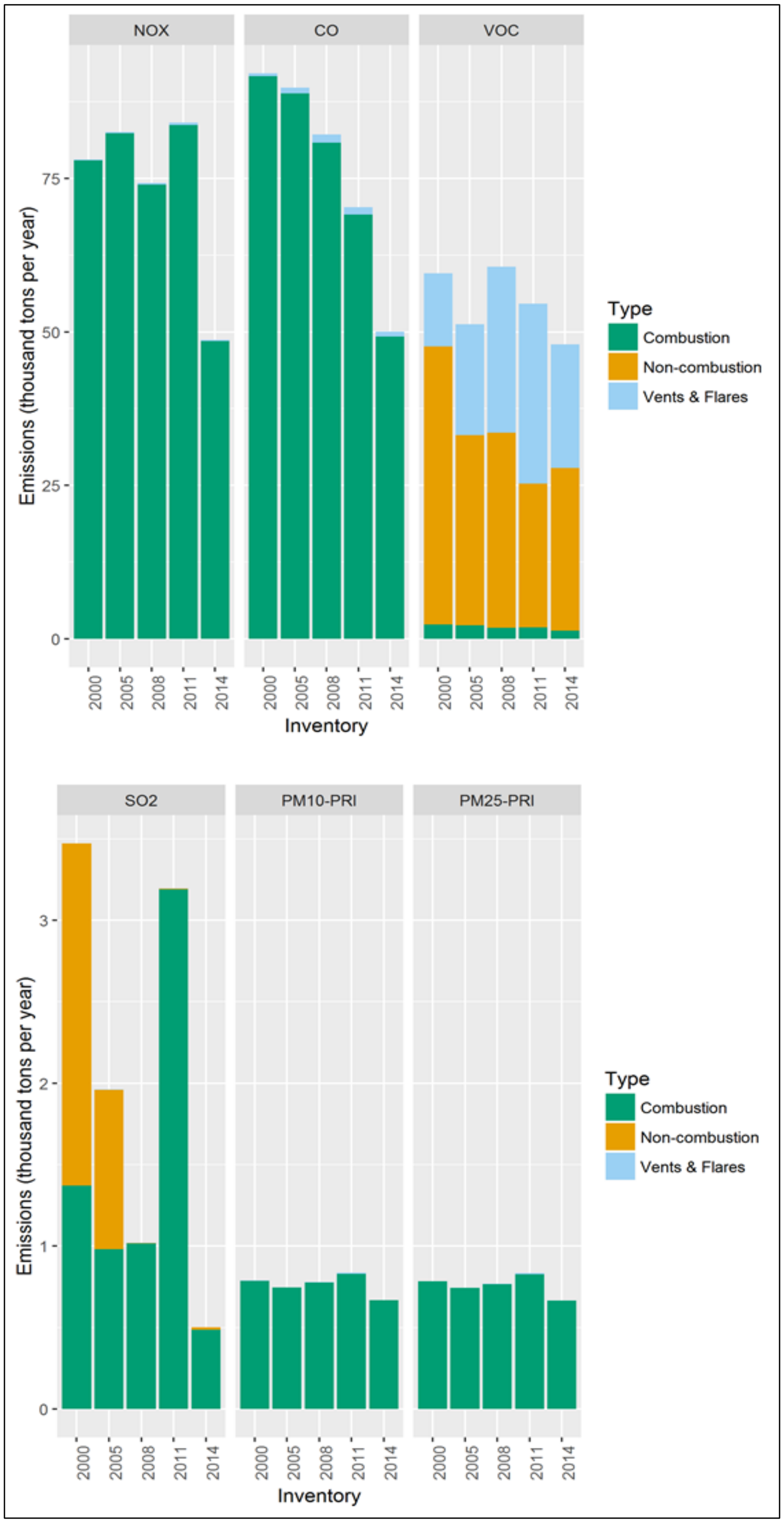

Figure B-17. Platform criteria pollutant emissions by equipment type

B.2.3 Combustion Equipment

The combustion equipment subcategory consists of boilers, diesel engines, drilling equipment, natural gas engines, and natural gas turbines. 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 B-18 and B-19). The most notable exception is the SO_2 emissions for 2011 Figure (Figure B-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 categories. The 2014 inventory also saw a complete implementation of ultra-low sulfur diesel fuels, which also contributed to decreases in SO_2 emissions.

There was also a slight decrease in PM_{10} emission estimates in the 2005 inventory for boilers, heaters, and burners and natural gas turbines, which is most likely due to updated emission factors. Any remaining trends are explained by changes in activity level.

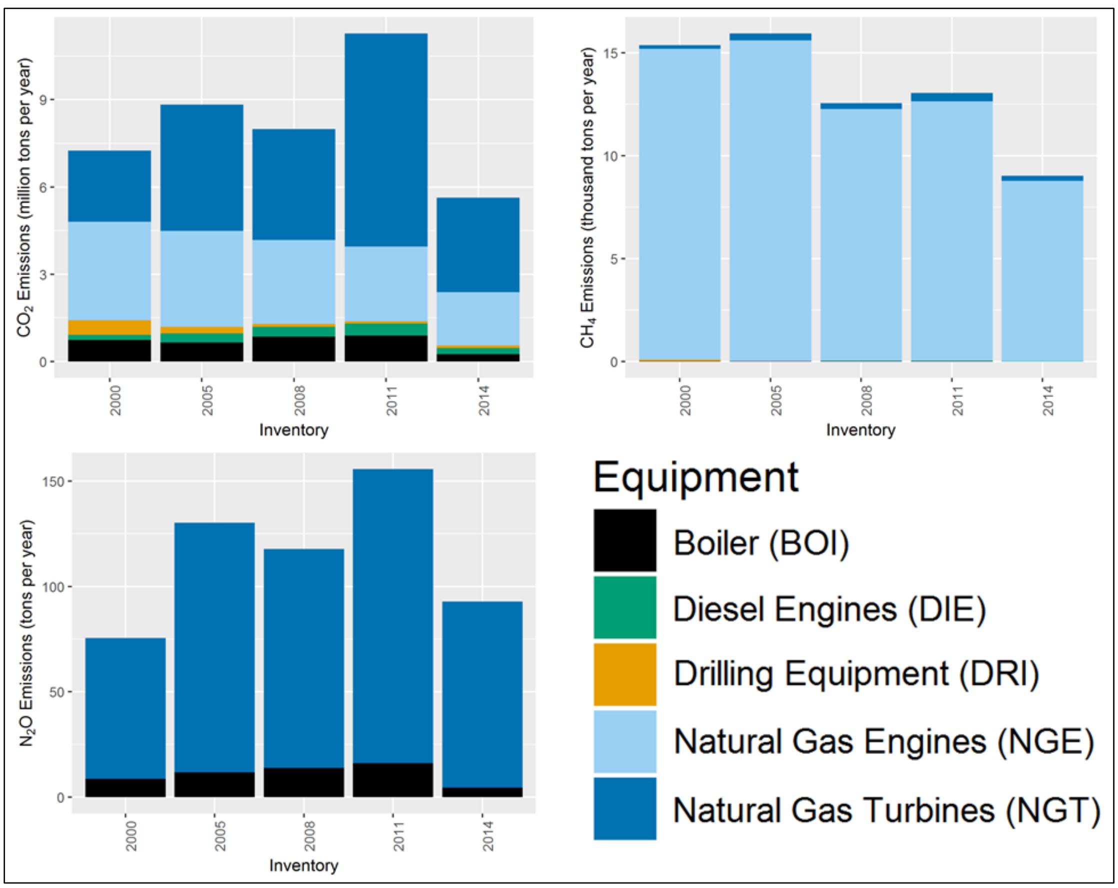

Figure B-18. Platform GHG emissions by combustion equipment

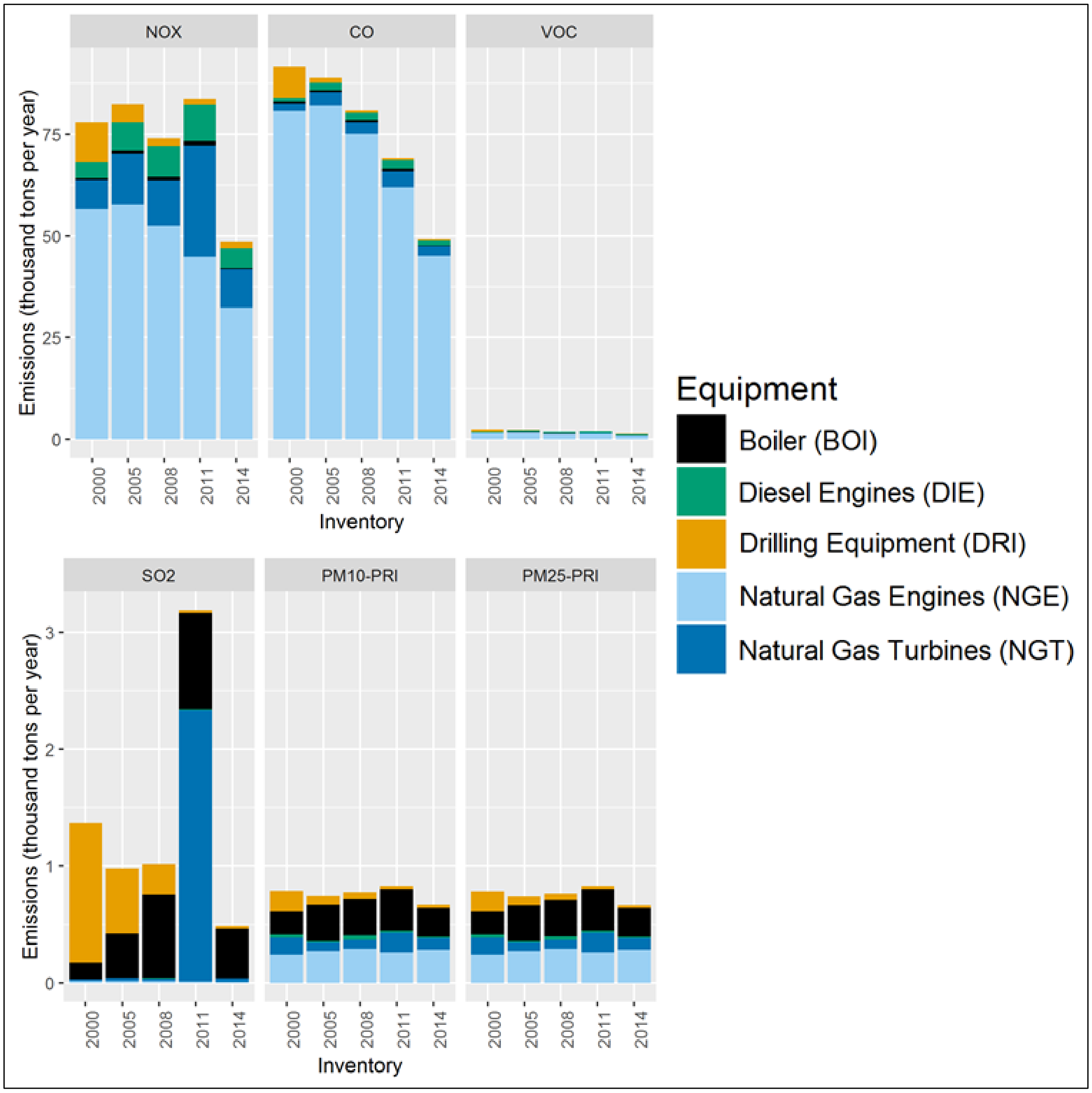

Figure B-19. Platform criteria pollutant emissions by combustion equipment

B.2.4 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}, $PM_{2.5}$), 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 B-20 and Figure B-21) illustrate the difference in pollutants emitted. Emission estimates for $PM_{2.5}$ are missing for 2000 and 2005 in Figure B-21, as estimates were only developed for PM_{10} in these inventories. 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 emission inventory have seen some abrupt changes in emission estimates between the 2000 and 2005 inventories and later years. For example, there is a large CO_2 increase in 2008 (Figure B-20) despite a relatively consistent number of flares Table B-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 the vents are passive exhausting systems and flares 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 a change to the flare pilot emission factors in 2005, which increased emission estimates slightly. There was also a change in the vent calculation method in 2011 that reduced CH_4 estimates.

Emissions from vents and flares were decreased in 2014 for all pollutants. This is likely due to the decrease in the number of active vents and flares reported (Table B-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 as well.

During the review process for the 2014 inventory, it was discovered that some operators included the pilot flare volume in their reported volumes. In previous inventories, the pilot flare volume and emissions were calculated separately from the upset volume. 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 combined with the emission factor change and slightly reduced activity, further contributed to a slight reduction in total emissions from flares. Efforts are underway to clarify the reporting and calculation for flares in the 2017 inventory effort.

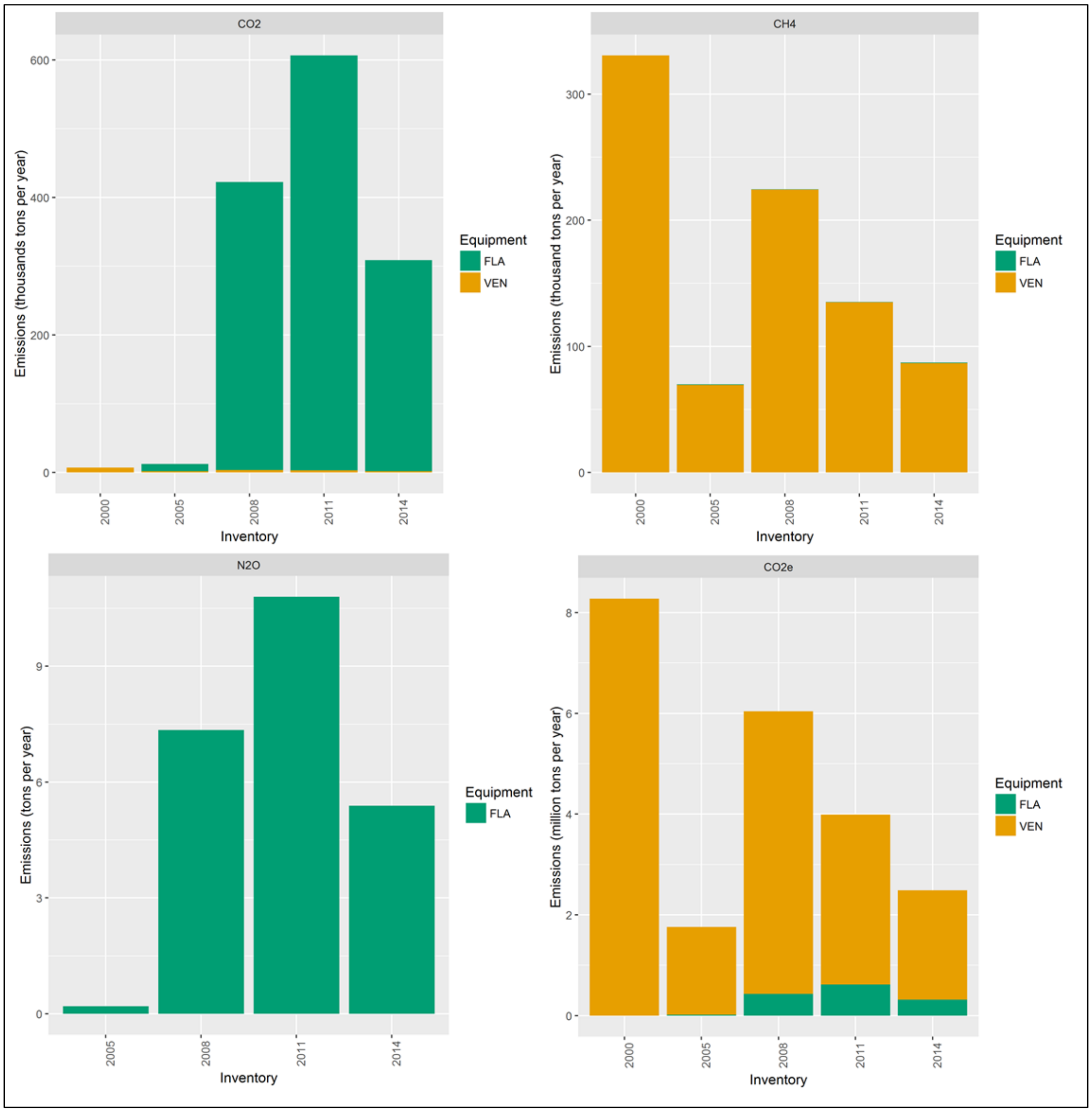

Figure B-20. GHG emissions for flares (FLA) and vents (VEN) by inventory year

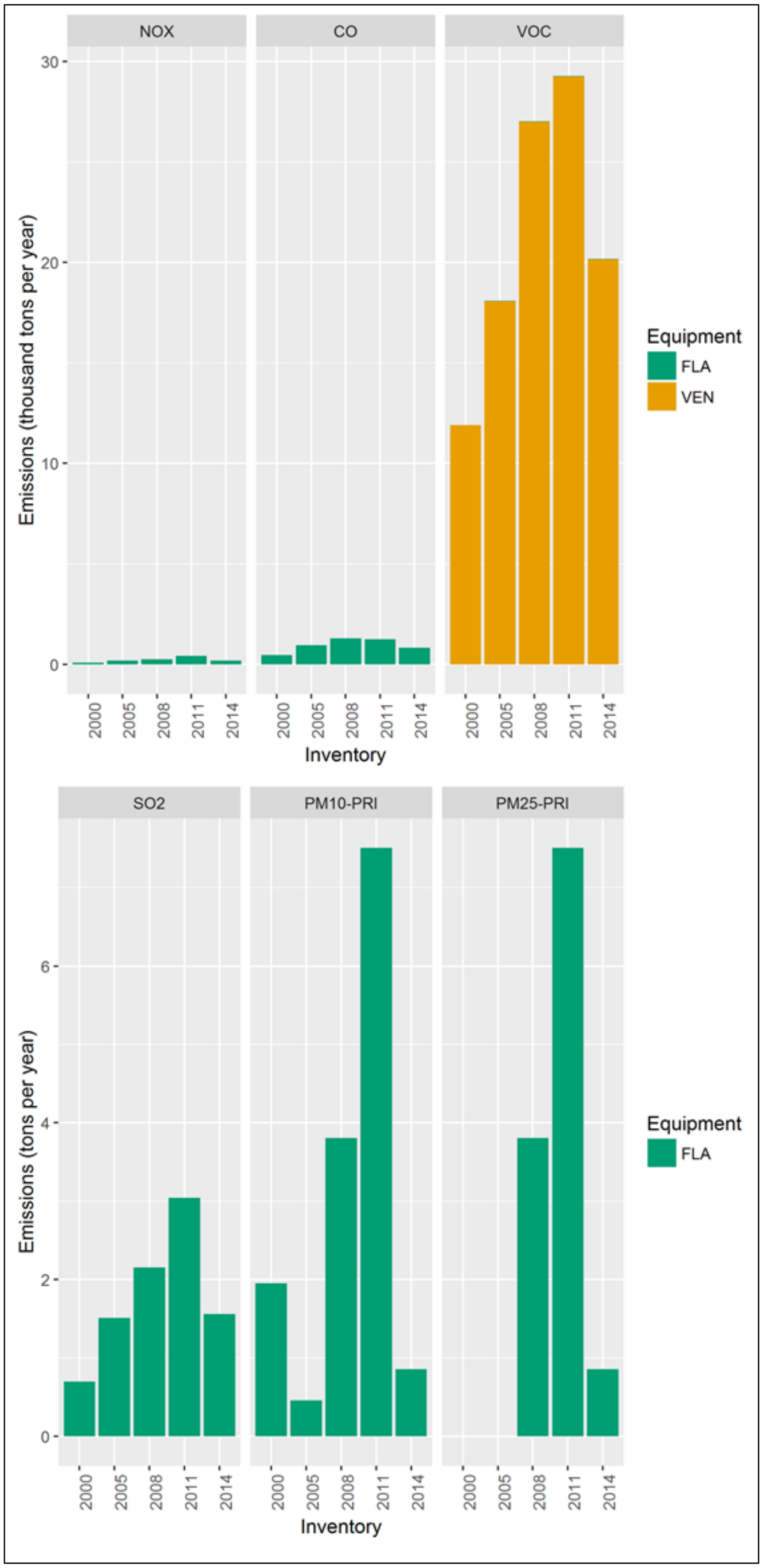

Figure B-21. Criteria pollutant emissions for flares (FLA) and vents (VEN) by inventory year

Table B-8. Active vent and flare equipment counts across the inventories

Equipment	2000	2005	2008	2011	2014
Flare	53	110	130	144	88
Vent	504	791	881	1,169	640

B.2.5 Miscellaneous Non-Combustion Equipment

The remaining platform equipment not discussed in previous sections includes:

- Fugitives,
- Storage tanks,
- Losses from flashing,
- Pneumatic pumps,
- Pressure and level controllers,
- Glycol dehydrators,
- Amine units, and
- Mud degassing

The miscellaneous non-combustion sources only contribute to CO_2, CH_4, SO_2, and VOC emissions in the inventories. Figure B-22 shows the contribution of each of the non-combustion equipment category to the total emissions. Table B-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.

Working clockwise around Figure B-22, CO_2 emissions saw a sharp drop in 2005 due to a reduction in emissions from losses from flashing. This was primarily due to activity or reporting reductions. Table B-9 shows the 2000 inventory had over 171 active losses from flashing units; the 2005 inventory only had 70 active units with most emissions reportedly as routed to system, vented remotely, or flared remotely. Emissions routed to system are not calculated and remote venting and flaring emissions are attributed to a vent or flare. In subsequent inventories, the number of units reporting losses from flashing increases significantly. However, this does not result in an increase in emissions since most of the emissions (75-80%) are routed to system, vented remotely, or flared remotely.

Following 2005, CO_2 emissions slowly increase due to increasing pneumatic pump and pressure and level 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 and pressure and level controllers 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 pressure and level controllers are currently optional; however, it will be made mandatory in the 2017 inventory to better quantify emissions from these sources.

Non-combustion CH_4 emissions (top right Figure B-22) show a decrease in 2005, which is again due to the changes in losses from flashing emissions. Unlike the CO_2 trend, CH_4 does not see the steady growth of pneumatic pump and pressure and level controller emissions in the 2011 and 2014 inventories.

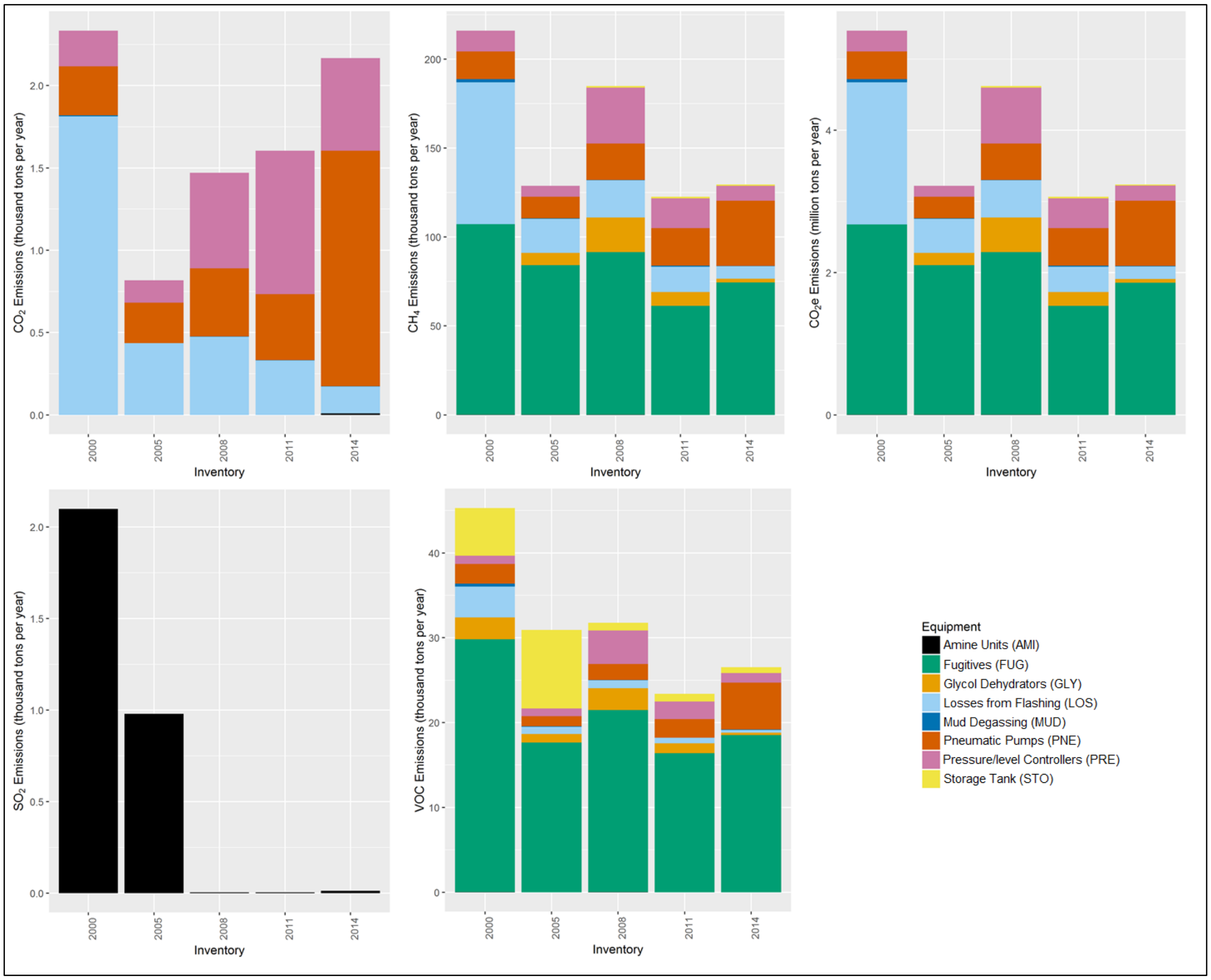

Figure B-22. Emissions by non-combustion equipment

Table B-9. Active non-combustion unit count by inventory year

Equipment	2000	2005	2008	2011	2014
Amine units	8	4	4	5	6
Fugitives	6,848	4,097	3,971	3,079	4,090
Glycol dehydrators	201	189	159	108	98
Losses from flashing	171	70	275	148	212
Mud degassing	162	79	43	22	17
Pneumatic pumps	3,222	3,198	2,961	2,141	2,512
Pressure and level controllers	4,215	3,502	3,187	1,834	1,654
Storage tanks	558	629	357	370	217

Amine unit SO_2 emissions have changed greatly over the inventory years (bottom left, Figure B-22). In the 2000 and 2005 inventory, the SO_2 estimate was independent of the number of platforms included in the inventories. The 43% decrease in 2005 emissions is explained by the hurricane activity in September and October of that year. The decreases in the remaining 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.

For VOC (bottom right, Figure B-22), the reduction in emission estimates between 2000 and 2005 is due to the fugitive sources. Part of the decrease in fugitive emissions reflects BOEM's goal to only include major platform sources in the inventory. VOC emission estimates for storage tanks had a spike in 2005, with a significant reduction in the subsequent inventories. 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 pressure and level controllers. These increases are likely due to increased activity levels, combined with more complete reporting by the operators. The 2011 fugitive, glycol dehydrator, and pressure and level 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. The data required by GOADS will be revised in the 2017 inventory, which may help illuminate trends in for pneumatic pumps.

B.3 NON-PLATFORM TRENDS

As noted in Section B.1.2.2, 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 B-23) and VOC (Figure B-24), 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 B.1.2.2., the activity data used in emission calculations provided more detail on vessel categories for 2014. 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 quantifying that 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 oila and gas production-related sources. Trends in GHGS will be discussed in Section B.3.1, and trends in the criteria pollutants will be discussed in Section B.3.2.

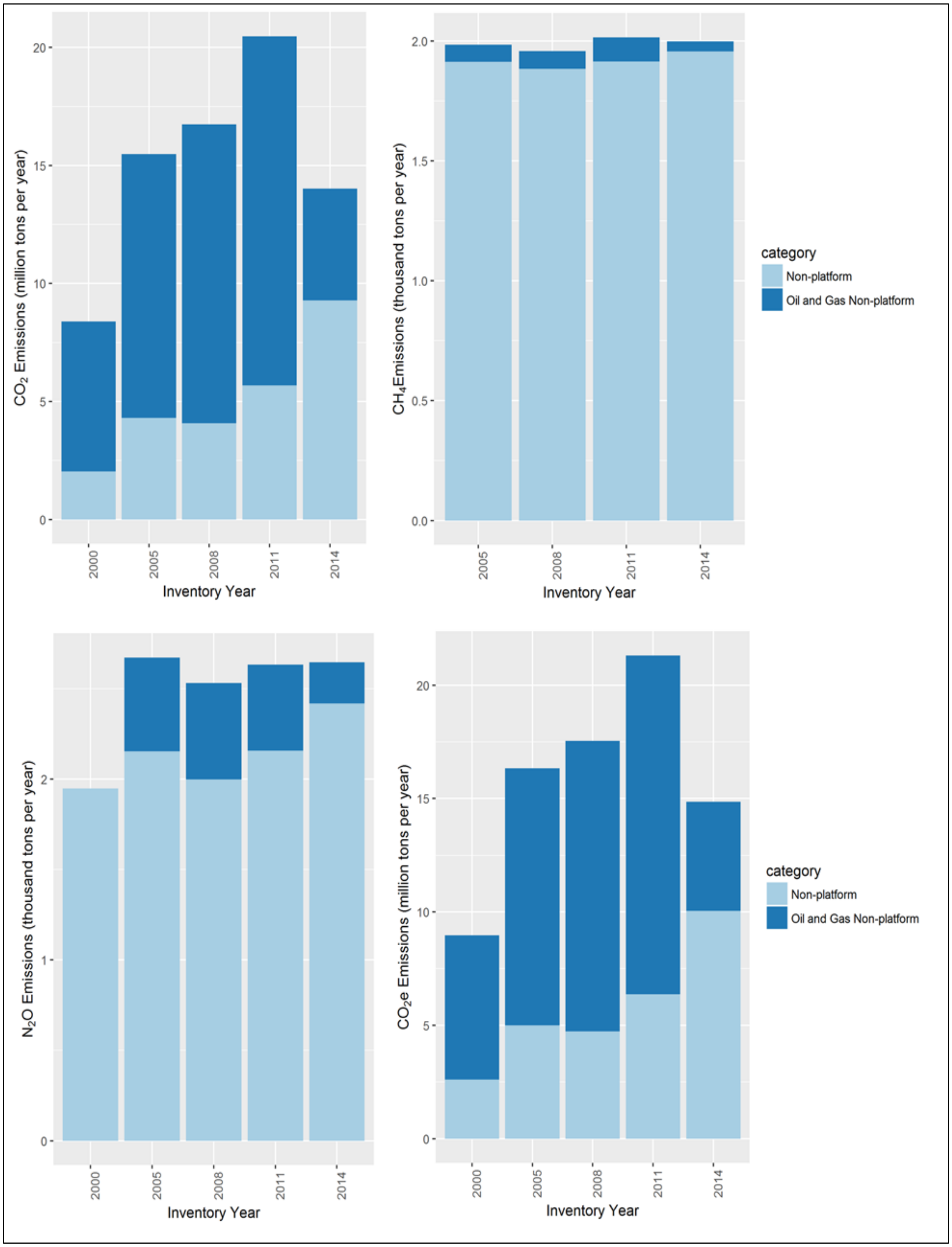

Figure B-23. Non-platform GHG emission by source category

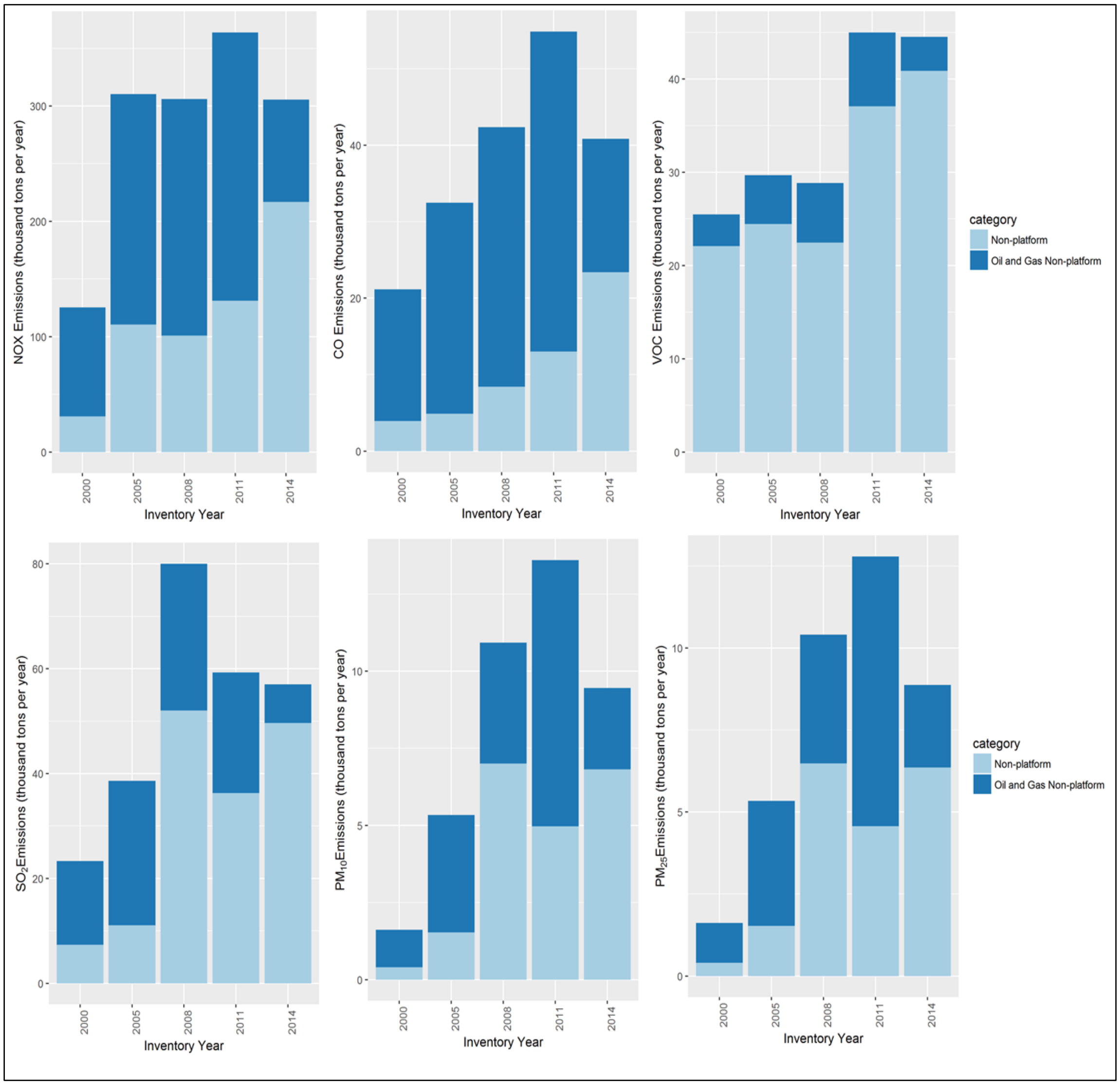

Figure B-24. Non-platform criteria pollutant emissions by category

The spatial distribution of non-platform production-related emissions has evolved to become more refined over time as the use of GPS location data have become more prevalent. Figure B-25 shows the spatial evolution of non-platform emissions across the inventories. The images for each 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 in 2014 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 are implemented. Again, these placements become more refined by 2014 due to the use of geographic information system (GIS) data. 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.

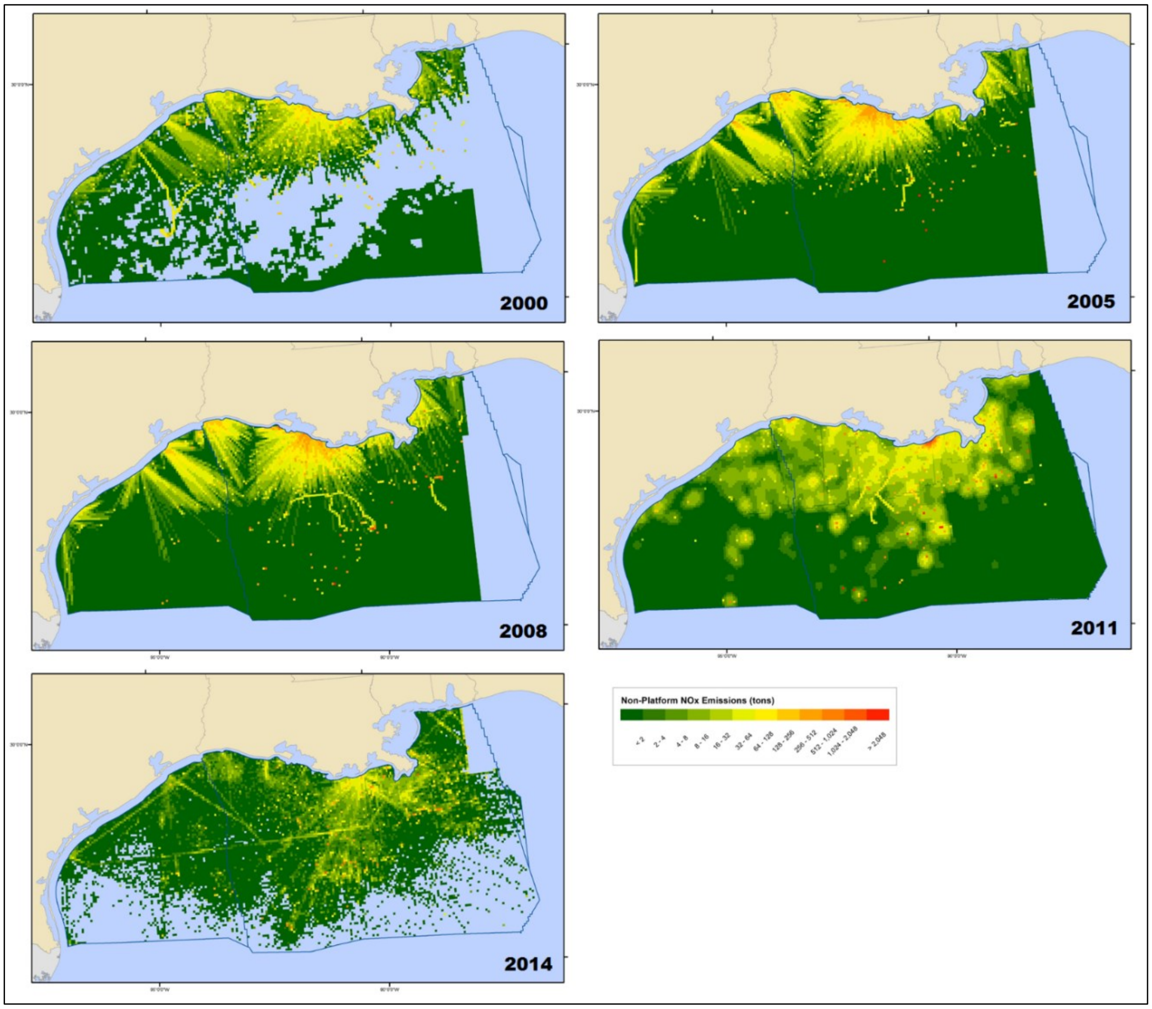

Figure B-25. Non-platform NO_x emissions

B.3.1 Greenhouse Gases

In 2000, CH_4 and N_2O were not included due to lack of vetted emission factors. Since 2005, CH_4 and CO_2 emissions increased and decreased consistently. As shown in Figure B-26, fairly 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 the improved vessel count and characteristics data.

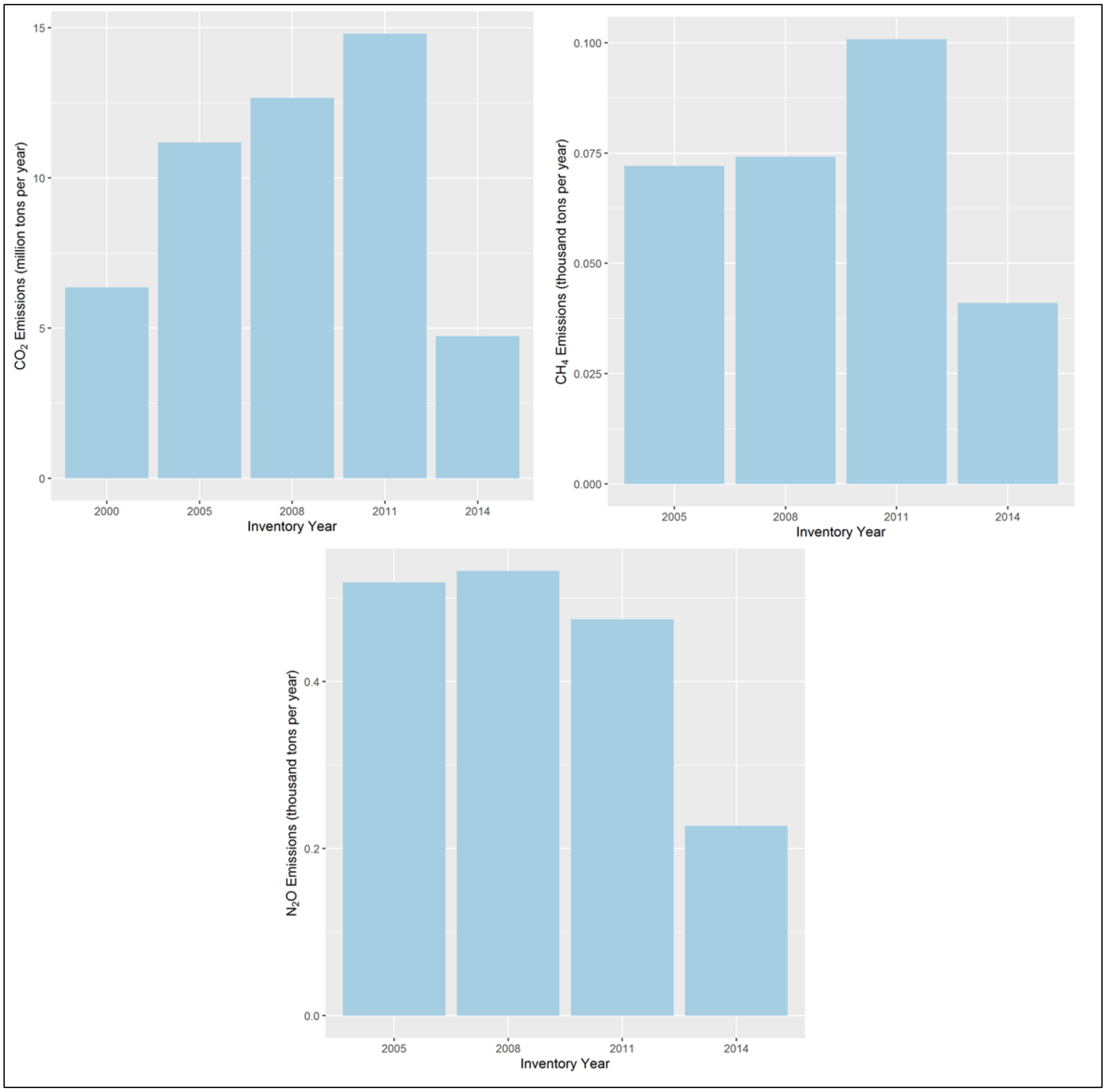

Figure B-26. GHG emissions for oil and gas non-platform sources

Looking by source category (Figure B-27), support vessels are the largest contributor to the three major GHGs. Helicopters saw an increase in CH_4 and N_2O emissions in 2011 and 2014 because more detailed emission factors allowed for better differentiation between medium and heavy duty twin engine helicopters.

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. The largest increase in GHG estimates for non-platform sources is seen in the helicopter emission estimates, which is based on the updated helicopter emission factors, and drilling rigs, which is due to the increase in drilling rig activity between 2005 and 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 take off (LTO) cycles in the Gulf. These emission factor updates, along with increased activity, yielded an overall increase in GHG emissions for 2011.

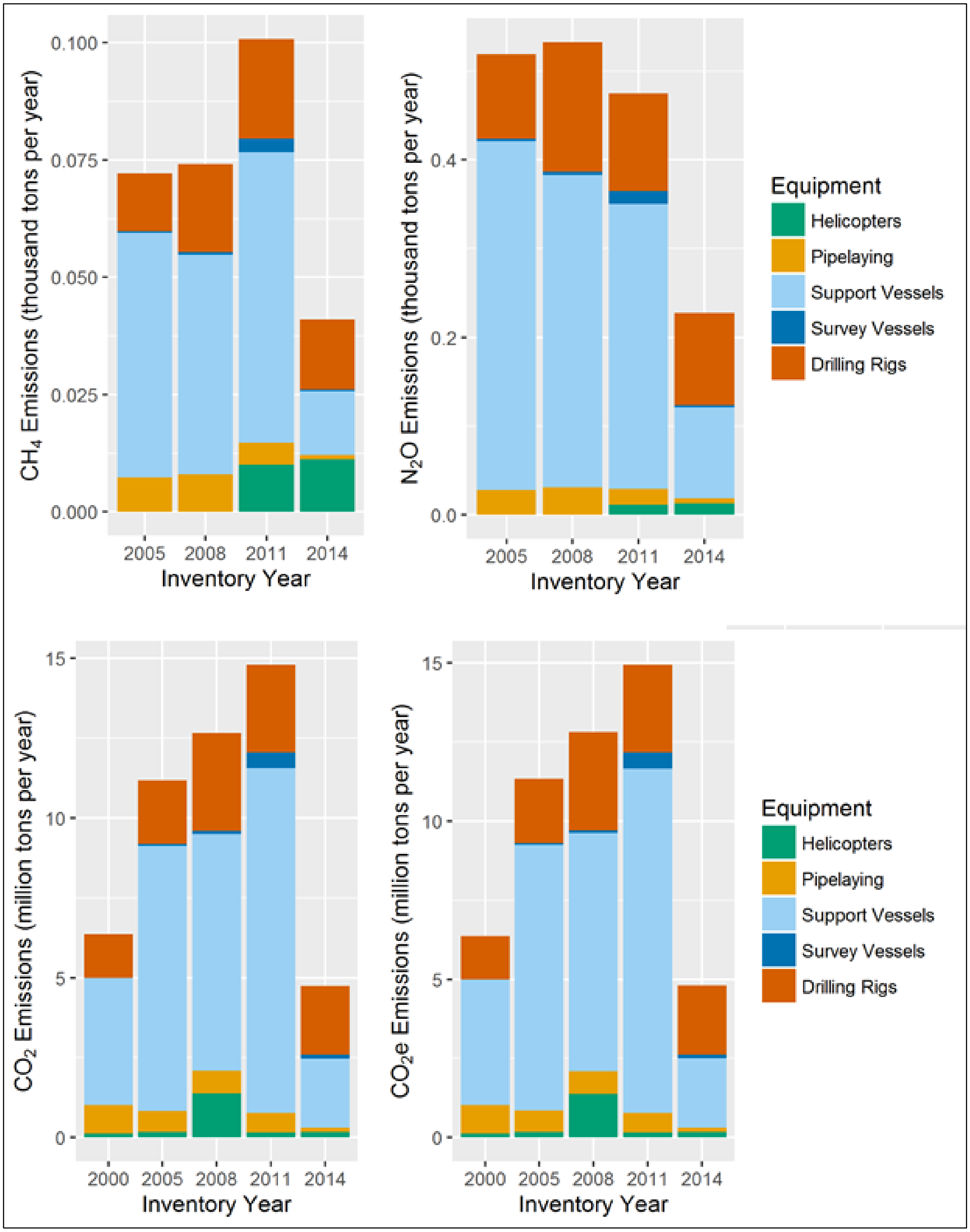

Figure B-27. Non-platform GHG emissions by source category

B.3.2 Criteria Pollutants

A review of the non-platform production-related total emissions of each criteria pollutant (Figure B-28) shows most pollutants reached peak levels in the 2011 inventory, with a dip below 2000 levels in the 2014 inventory. This is likely due to decreased activity and more detailed data for vessels and better quantification of their operations.

Emission estimates for all criteria pollutants show increases in the 2005 inventory compared to the 2000 inventory. The increase in the 2005 inventory relative to the 2000 inventory is due to two reasons: 1) for source categories with the more up-to-date marine diesel engine emission factors, the emission factors tend to be higher than the older marine vessel emission factors previously used; and 2) more accurate activity data were used in the 2005 inventory for support helicopters, support vessels, and survey vessels, which tended to be higher than the 2000 values.

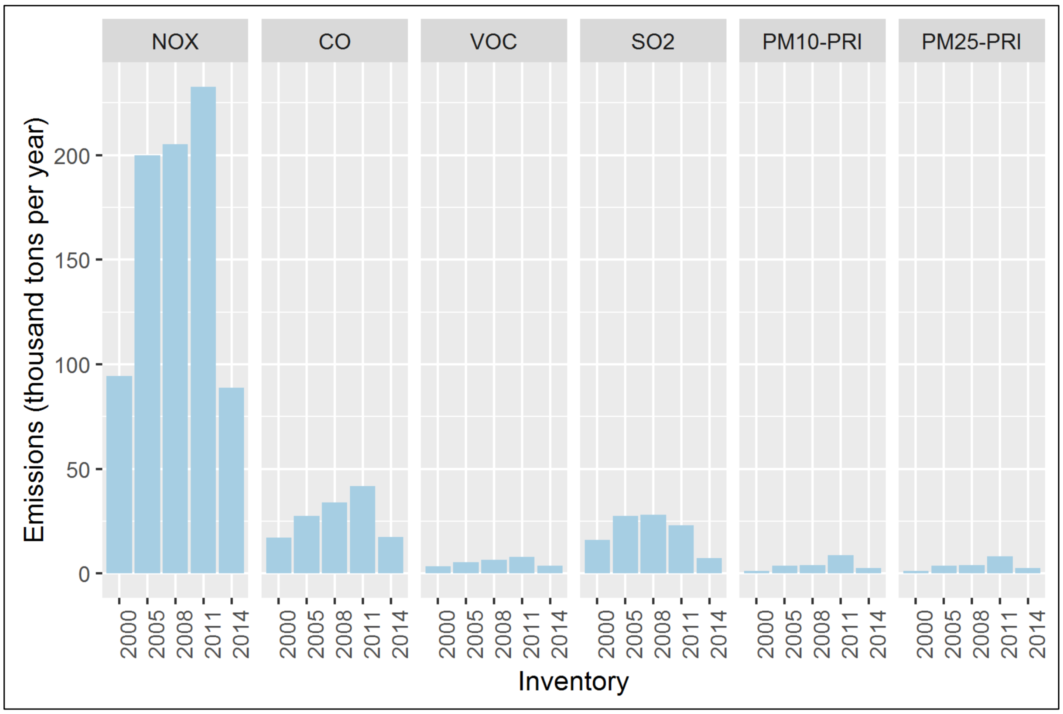

Figure B-28. Oil and gas non-platform criteria pollutant emissions by year

The exception is the SO_2 emission estimates, which started to decline in 2011 and continued to decline for 2014. 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 ultralow sulfur diesel (reduced from 500 ppm to 15 ppm) and larger vessels equipped with larger, Category 3 (C3) engines use fuels that meet 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 as the drop in total SO_2 emissions coincides with the significant drop in SO_2 emissions from support vessels (Figure B-29).

Looking at the various source categories for the other criteria pollutants (Figure B-29), support vessels are typically the largest contributor to emissions; the exception being 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.

Higher emission estimates associated with the new marine diesel engine emission factors for 2005 affected all pollutants, with most dramatic changes noted with NO_x and VOC. An evaluation was performed of the emission factors used in the 2000 inventory and the emission factors used in the 2005 inventory. Comparison between the two sets of emission factors suggest that they were similar except for NO_x, which was consistently higher in the Swedish factors for slow and medium speed diesel engines.

While pipelaying operations show an increase in emissions from 2000 to 2005, the activity level was declining due to hurricane activity and reduced development of new sites. When the reduced activity data were combined with updated emission factors, pipelaying showed an increase due to the updated (higher) emission factors.

The total emissions for each criteria pollutant held fairly constant from 2005 to 2008. Support vessels had a slight decline in emissions due to a 10% reduction in the fleet size. This was offset in the total emissions by an increase in drilling rig activity.

The 2011 inventory saw a significant increase in criteria pollutant emission estimates, except for SO_2. The SO_2 emission estimate shows a decrease from 2008 to 2011 due to reductions in vessel activities and application of the most recent USEPA emission factors that accounted for replacement of older vessel with more efficient newer vessels and use of low sulfur fuels for vessels equipped with C2 engines. These USEPA factors have lower sulfur values for smaller vessels equipped with C1 and C2 propulsion engines, such as pipelaying and support vessels, which can be seen in Figure B-29.

The increased CO, NO_x, PM, and VOC estimates are primarily due to the use of updated USEPA emission factors. Most notable in Figure B-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.

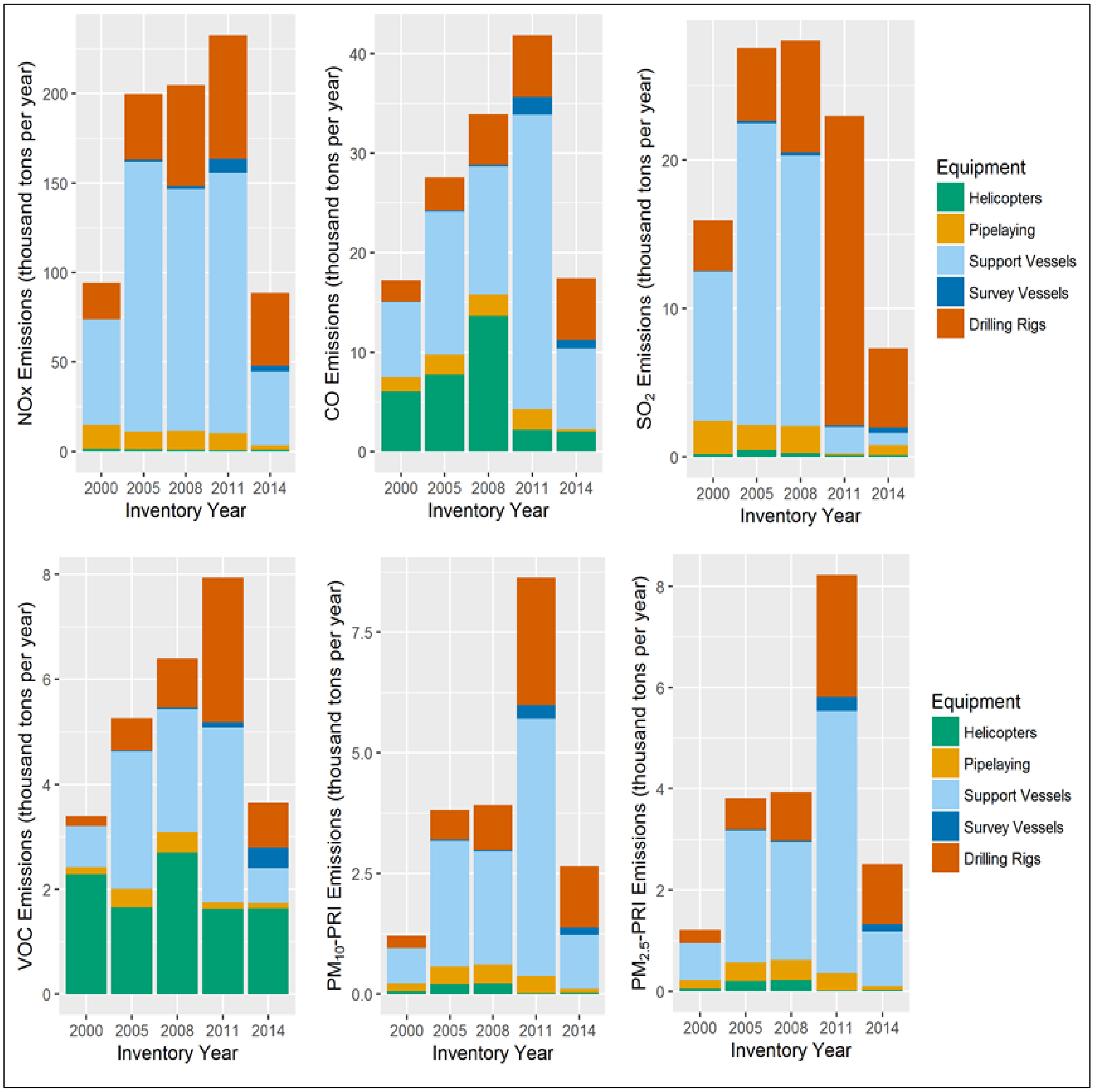

Figure B-29. BOEM non-platform criteria pollutant emissions by source category

B.4 OVERALL EMISSIONS TRENDS

Sections B.2 and B.3 provided an explanation of 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 emission 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 B-30, top left). Non-platform sources contribute more to N_2O emissions (Figure B-29, top right), and almost all CH_4 emissions are from platform sources (Figure B-30, bottom left). Because of the higher GWP for N_2O, non-platform sources contribute more to the overall CO_2e emissions (Figure B-30, bottom right, recalculated with AR4 GWPs).

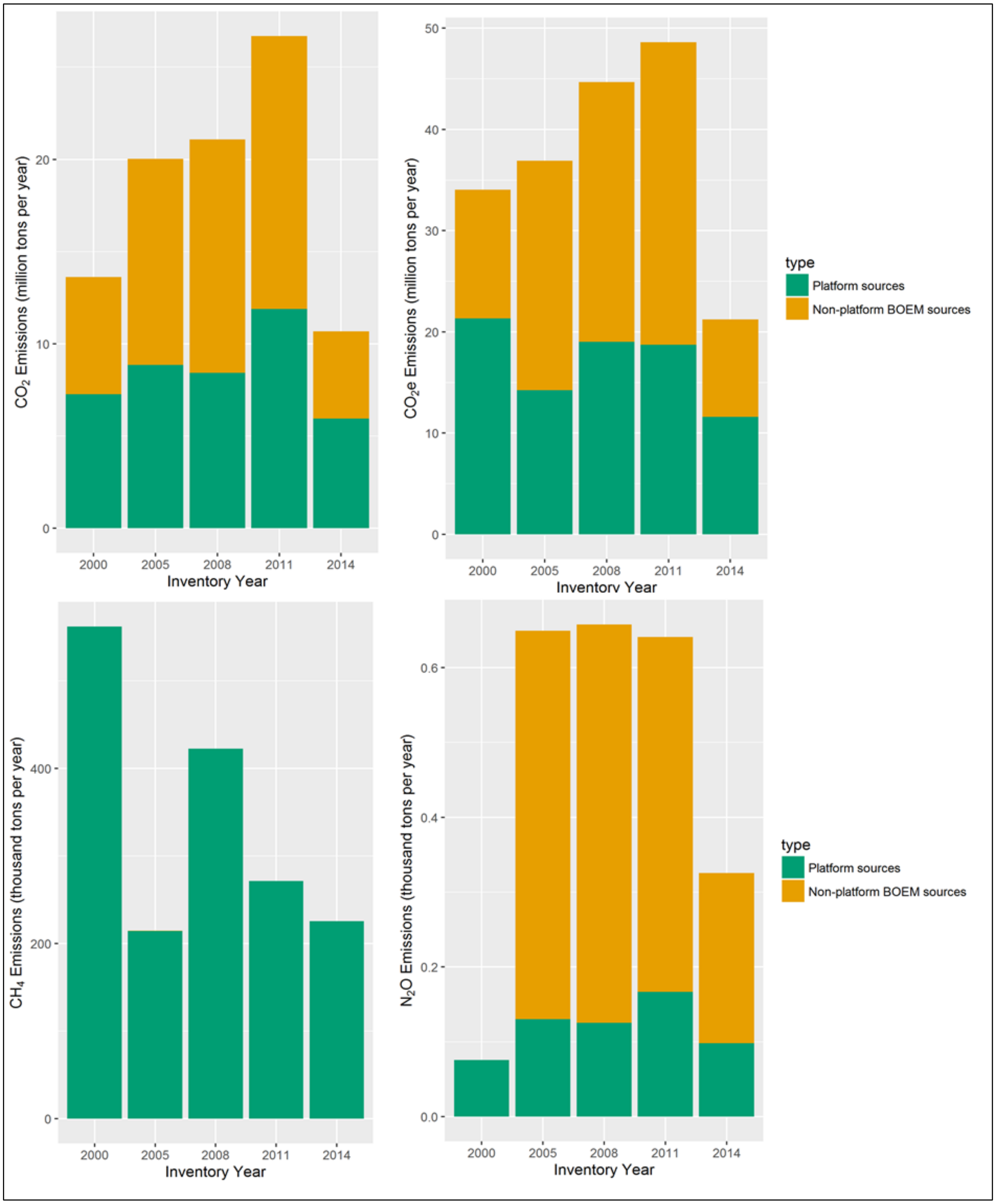

Figure B-30. Total GHG emissions by inventory category

Looking at overall trends in the criteria pollutant emission estimates (Figure B-31), 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.

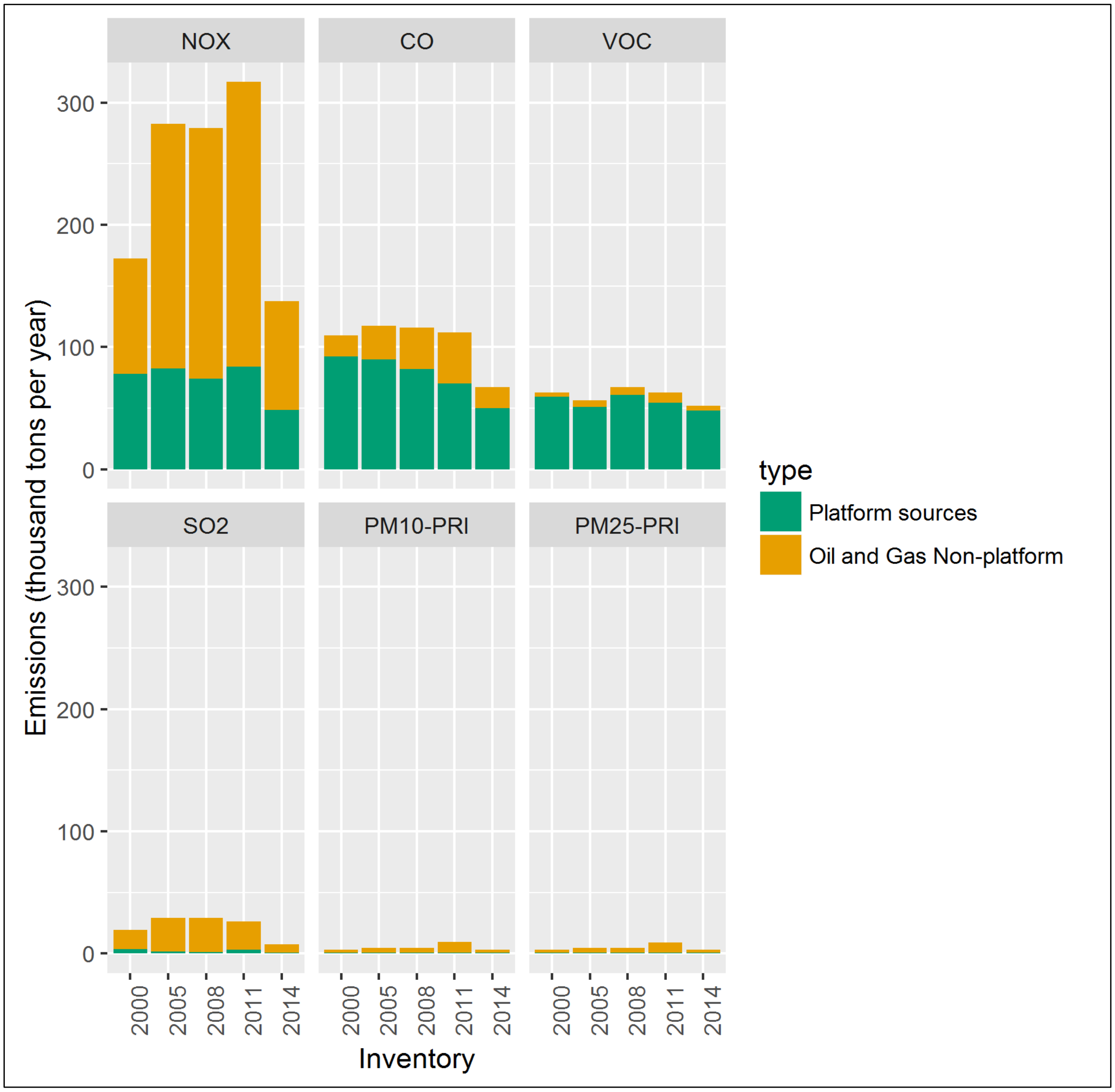

Figure B-31. Total criteria pollutant emissions by inventory type

Looking at the relationship of the total emissions of the various pollutants, some pollutants are highly correlated to one another. Table B-10 shows the Pearson product-moment correlation coefficient (R^2) for the paired emission of pollutants. Pearson product-moment correlation coefficient is a measure of the linear dependence between two variables, here the total emissions of two pollutants. The result is a value between +1 and −1 inclusive, where 1 is total positive linear correlation, 0 is no linear correlation, and −1 is total negative linear correlation. Pearson's correlation coefficient is the covariance of the two variables divided by the product of their standard deviations. Figure B-32 shows the scatter plot matrix of the emissions, with higher correlated pollutants highlighted in pink. There is a strong correlation between PM_{10} and $PM_{2.5}$, which is expected as $PM_{2.5}$ is a subset of PM_{10}. There is also a fairly strong positive correlation between NO_x and the pollutants commonly associated with combustion (i.e., CO, CO_2, PM_{10},

$PM_{2.5}$, and SO_2). The other combustion product emissions have fairly strong positive correlations with the other combustion pollutants. The exceptions are PM_{10} and $PM_{2.5}$, both of which only have high correlation with CO_2, and only moderate correlation with CO and SO_2. Looking at the GHGs, N_2O and CO_2 are positively correlated (0.78), but neither pollutant shows a strong positive correlation with CH_4. There is a slight negative correlation between N_2O and CH_4. There is a moderate positive correlation between CH_4 and VOC, which is reasonable given the overlap in sources producing both gases.

Table B-10. Correlation values for total emissions

	CH_4	**CO**	**CO_2**	**N_2O**	**NO_x**	**PM_{10}**	**$PM_{2.5}$**	**SO_2**	**VOC**
CH_4	1.000	0.342	-0.184	-0.572	-0.212	-0.300	-0.290	0.027	0.674
CO	0.342	1.000	0.704	0.409	0.776	0.365	0.397	0.928	0.748
CO_2	-0.184	0.704	1.000	0.782	0.971	0.881	0.897	0.842	0.561
N_2O	-0.572	0.409	0.782	1.000	0.848	0.584	0.601	0.719	0.189
NO_x	-0.212	0.776	0.971	0.848	1.000	0.756	0.778	0.930	0.533
PM_{10}	-0.300	0.365	0.881	0.584	0.756	1.000	0.999	0.495	0.336
$PM_{2.5}$	-0.290	0.397	0.897	0.601	0.778	0.999	1.000	0.526	0.357
SO_2	0.075	0.950	0.813	0.679	0.900	0.448	0.479	1.000	0.652
VOC	0.674	0.748	0.561	0.189	0.533	0.336	0.357	0.639	1.000

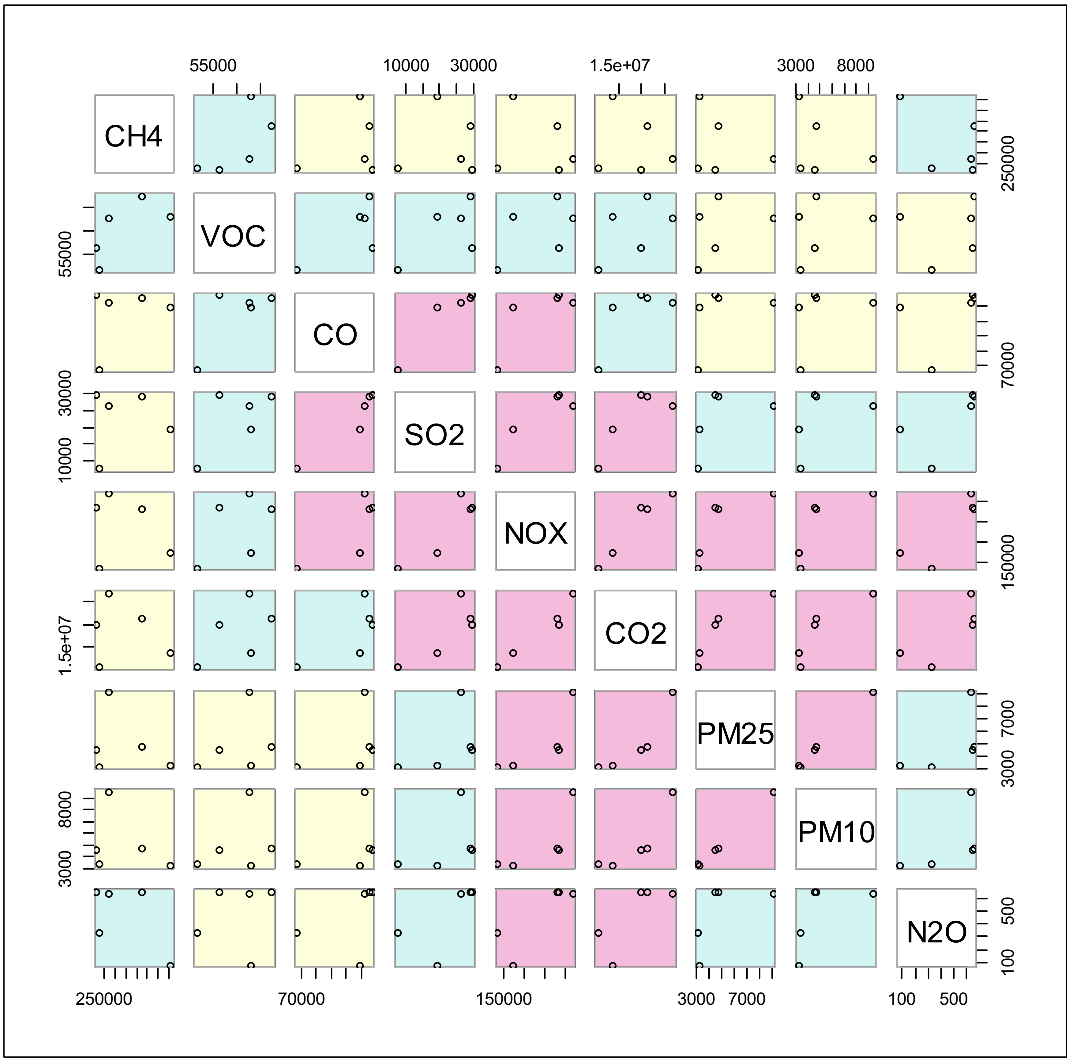

Figure B-32. Correlation matrix of pollutant emissions in tons per year

Pink shading indicates high correlation, blue moderate, and yellow little correlation (x and y axes represent emissions in tpy).

B.4.1 Production Trends

Entering this analysis, the assumption 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 trillion cubic feet) production data since 2000 was obtained from the BOEM website (USDOI, BOEM 2016a). Total oil production has oscillated since 2000 (Figure B-33). The 2000 and 2014 inventory years represent years with increasing oil production, compared to the previous year. The 2005, 2008, and 2011 are years with decreasing production trends for oil. Natural gas production has been steadily decreasing since 2000. 2014 production level were less than half the levels seen in 2000. The following section attempts to explain these overall trends and assess if there is a relationship with activity and emissions.

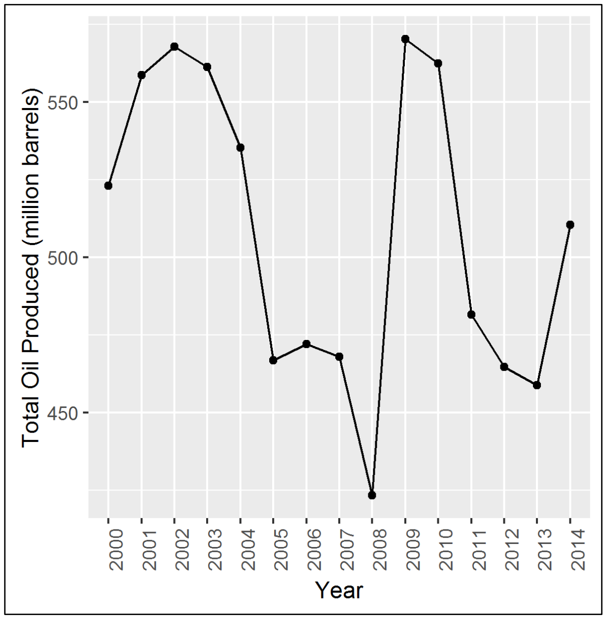

Figure B-33. Total annual oil production for the GOM

B.4.1.1 Tropical Activity

To explain the decreases in production in 2005 and 2008, monthly oil production trends were examined (Figure B-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 B-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.

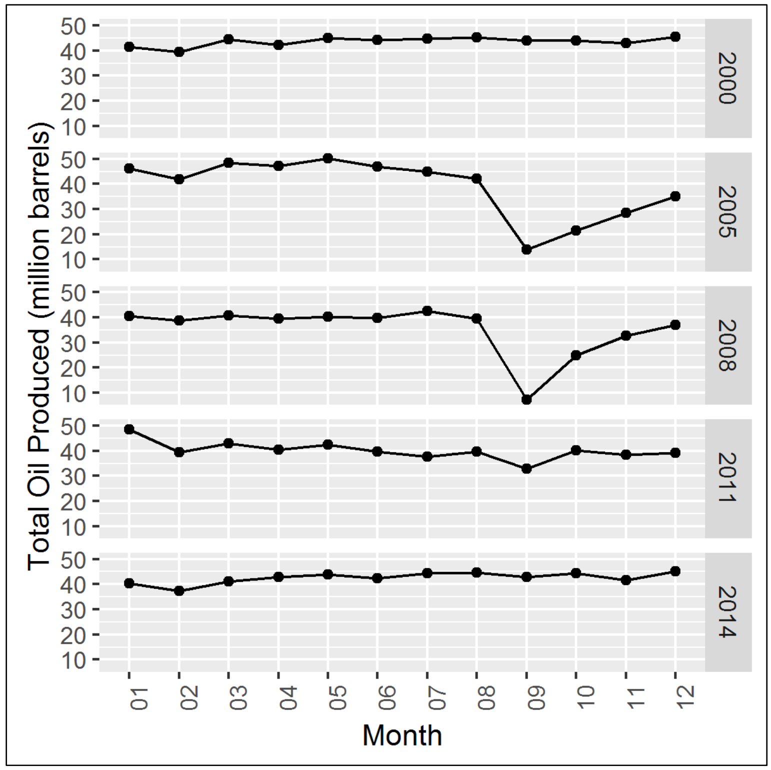

Figure B-34. Total monthly oil production for inventory years

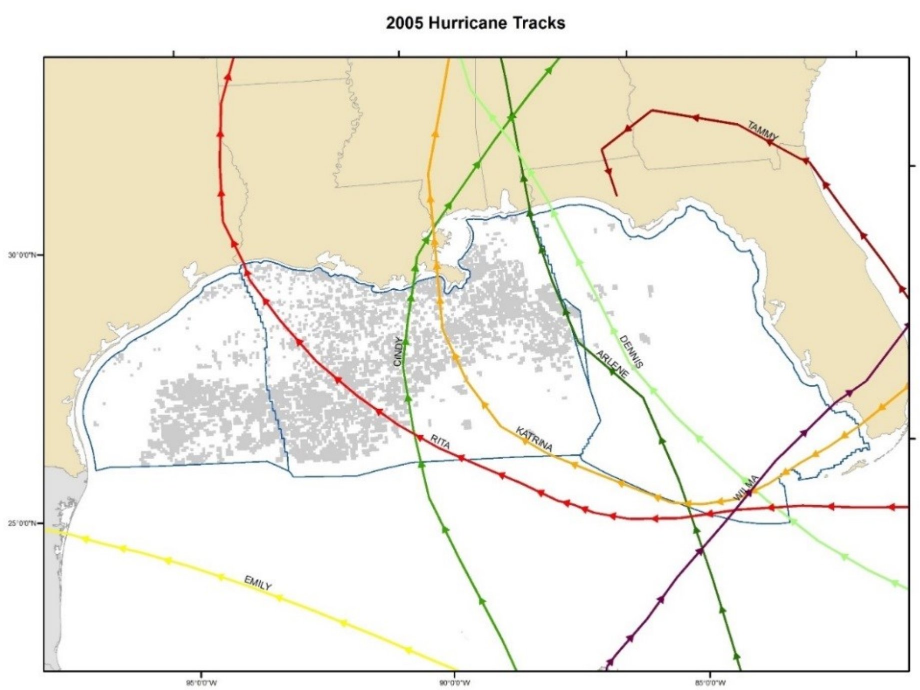

Figure B-35. 2005 Hurricane tracks with active lease blocks (gray shading)

2008 was another above average hurricane season (CPC 2016) with three systems cutting through the GOM (Figure B-36). The dip in production is likely due to two major hurricanes that crossed the Gulf in the late August to September time frame. The first hurricane, Gustav, swept through the Gulf from August 31 – September 1. Gustav was 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 B-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.

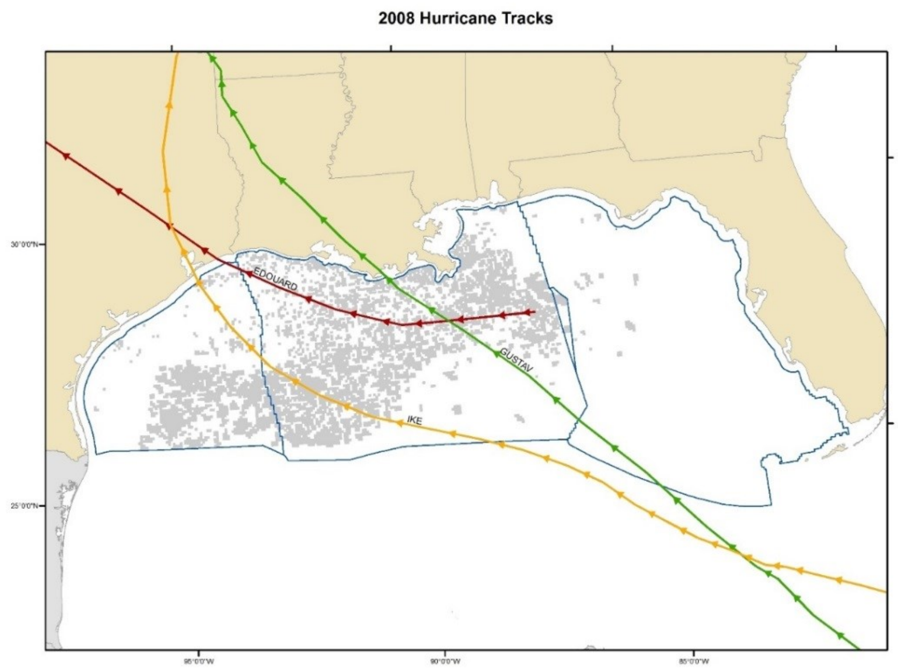

Figure B-36. 2008 Hurricane tracks with active lease blocks (gray shading)

The other inventory years had minimal tropical storm activity across the GOM, which likely contributed to the consistency in production in these years.

B.4.1.2 Oil and Natural Gas Production versus Prices

As a traded commodity, oil and natural gas prices are often projected. The assumption was tested that the price of oil and gas during inventory periods could be used to develop a predictive model of emissions. Analysis shows that the production of oil in the GOM has been inversely proportional to the price of oil since 2000. Figure B-37 shows the annual average spot prices (EIA 2016) 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. The only break in the pattern is 2014, where price was on par with 2011 values but increased production was seen. This could be due to lower oil imports for the year, which would necessitate higher U.S. production to keep with demand.

This trend was expected, as it follows economic principles and cycles typical of commodities. That is, as the commodity become 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.

Natural gas production (USDOI, BOEM 2016a) in the Gulf has been on a steady decline since 2000 (Figure B-37). Prices of natural gas have fluctuated through this period, but seem to have no correlation to production levels. Therefore, it is unlikely natural gas prices could be used as a predictor for production or emissions.

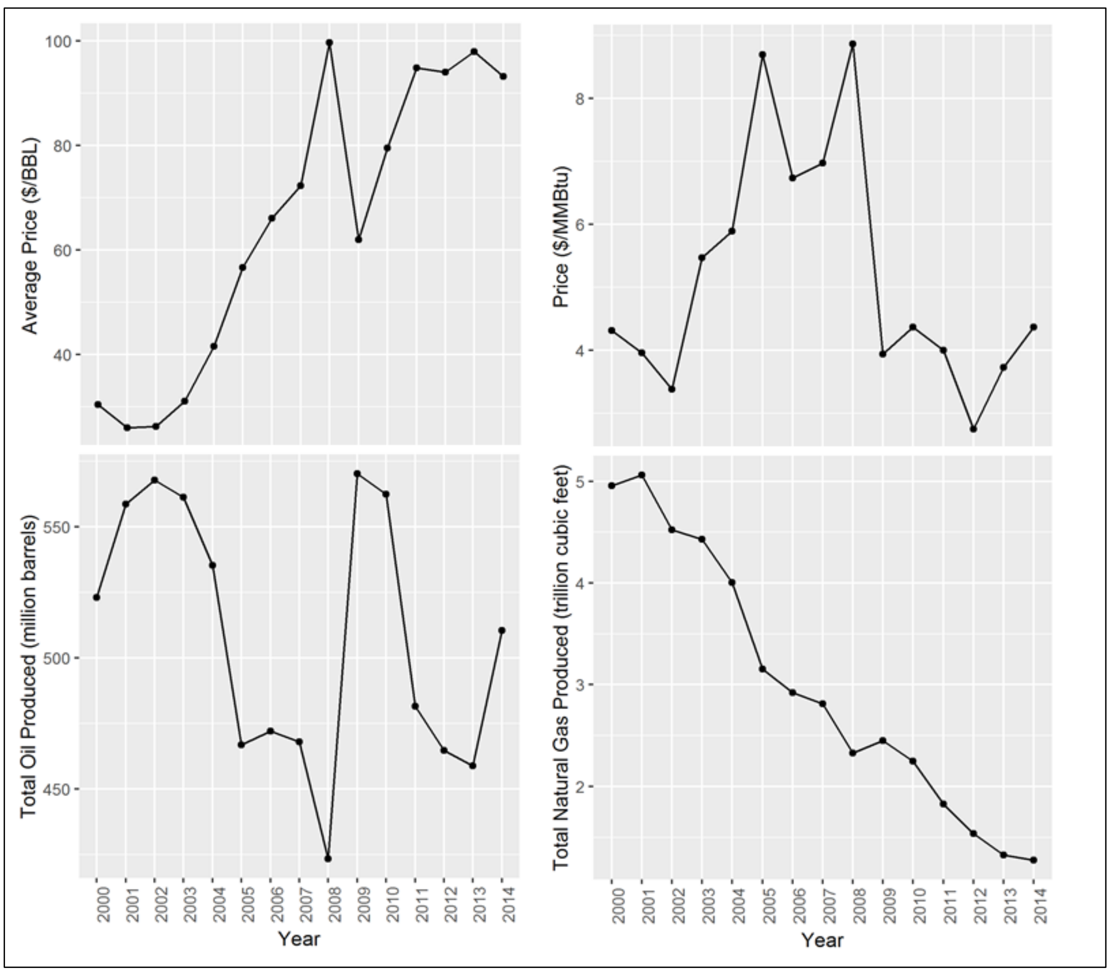

Figure B-37. Average production of oil (left) and natural gas (right)

B.4.1.3 Spatial Distribution of Production

The spatial distribution of oil (Figure B-38) and natural gas (Figure B-39) production (USDOI, BOEM 2016b) follows a similar spatial pattern to platform locations shown in Figure B-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 B-13, the highest emissions coincide with the highest production areas. These higher emissions, higher production areas generally correspond to the newer platforms on the leading southern edge of active platforms. Looking at oil production (Figure B-40) and natural gas production (Figure B-41) 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 a depth greater than 800 meters (purple section of Figure B-40).

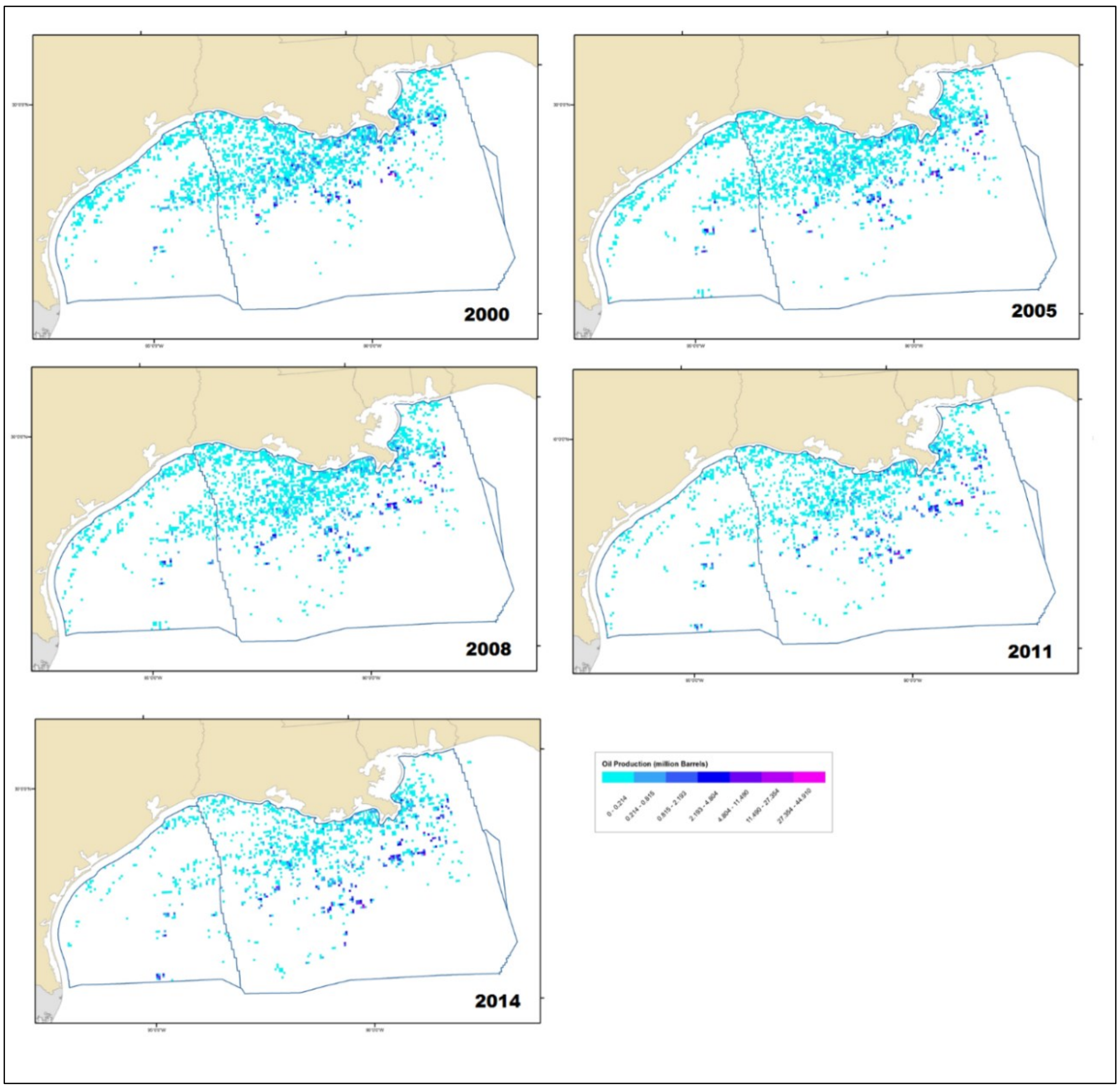

Figure B-38. Spatial distribution of oil production (in million barrels) for the inventory years

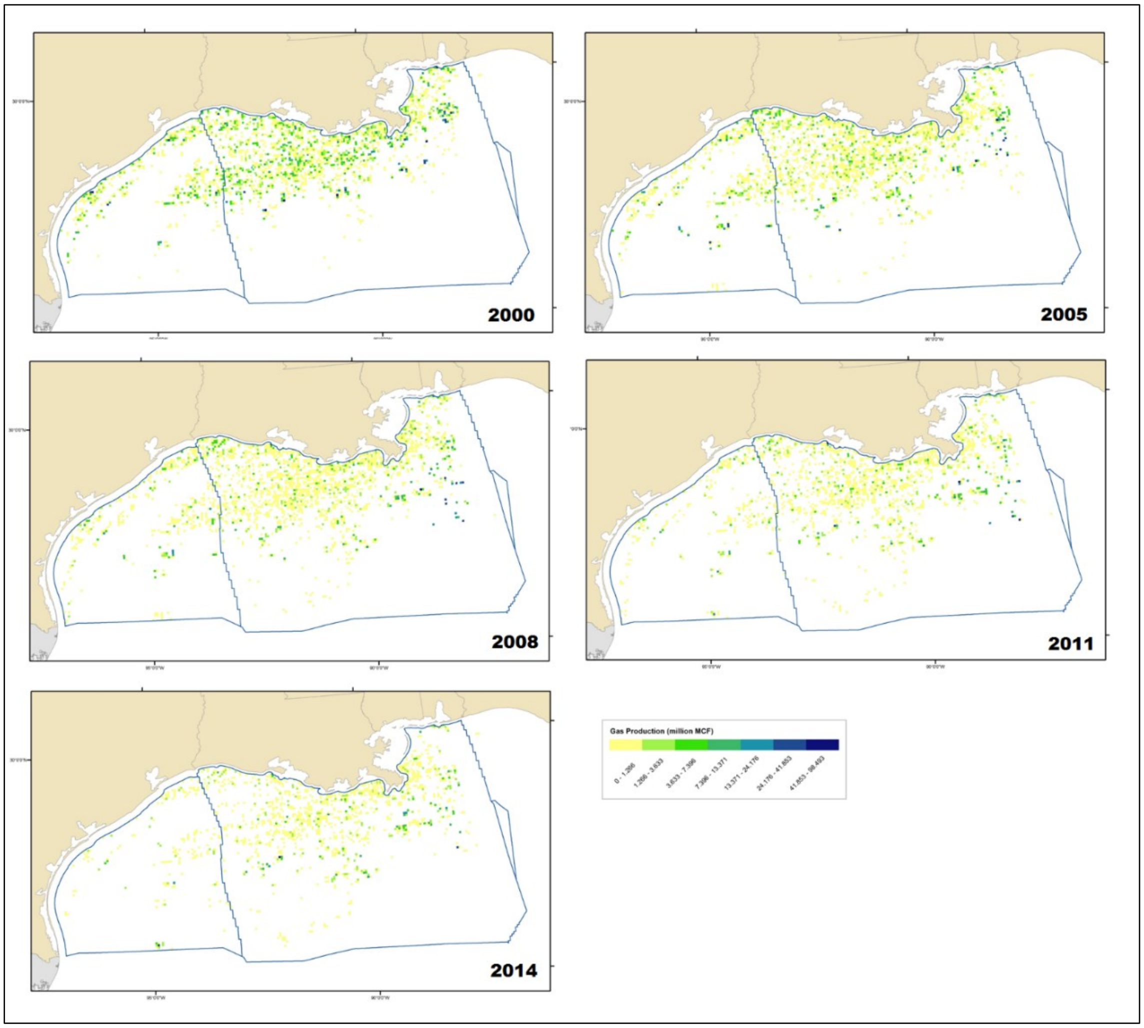

Figure B-39. Spatial distribution of natural gas production (in million MCF) for the inventory years

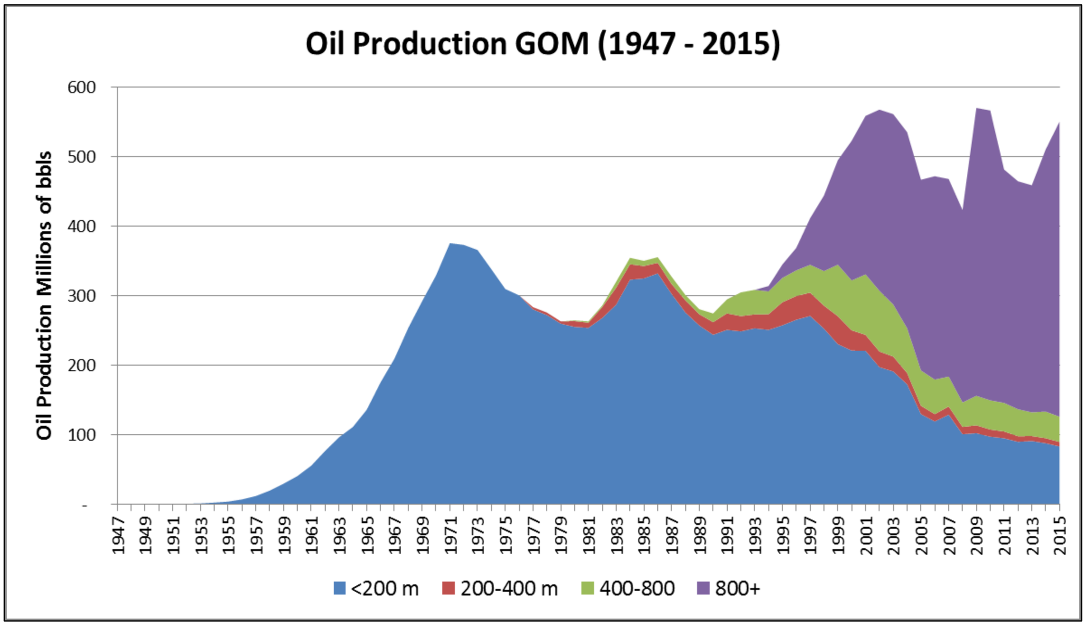

Figure B-40. Oil production by water depth

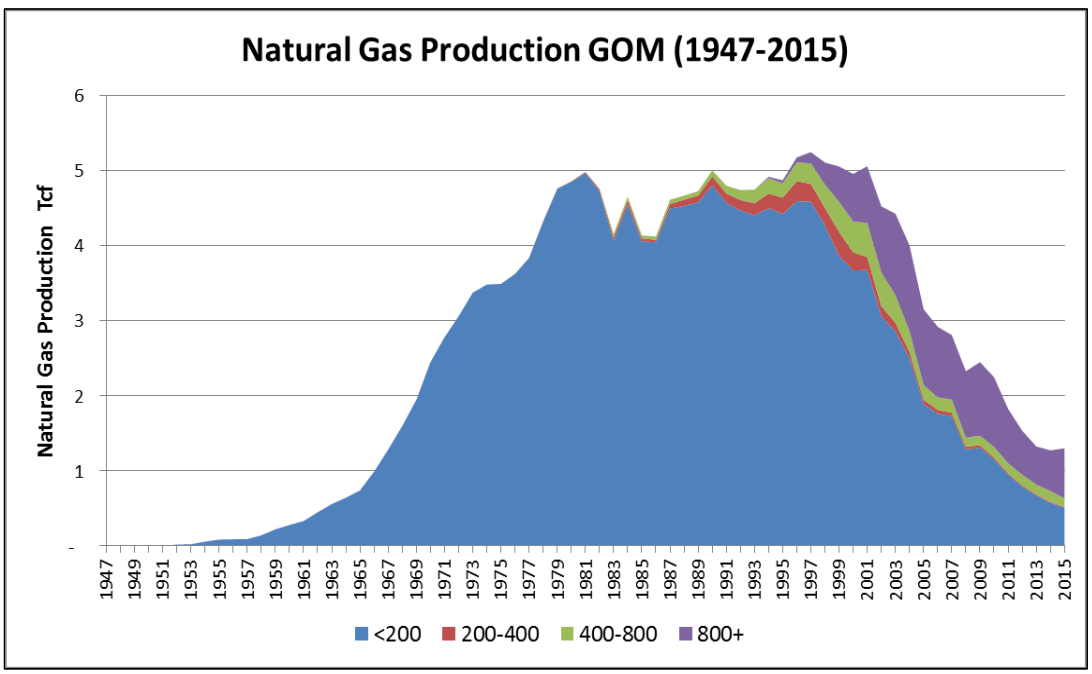

Figure B-41. Natural gas production by water depth

B.5 EMISSIONS FORECASTING

Based on the analyses discussed in the previous sections, an attempt was made to build a simple regression equation to predict emissions based on known parameters. The key was finding a parameter that could be used as a proxy for activity level. As mentioned in Section B.4.1, production or price seemed like a likely candidate as both parameters could qualitatively be related to activity and emissions level. However, neither price nor production proved to be roust indicators with simple linear regressions. Figure B-42 shows the scatter plots and linear regression equations for NO_X.

Based on the initial results of regressions based on price and oil production, the analysis was expanded to include platform count and a production per platform value (i.e., total production/number of platforms). This had mixed results, with NO_X and most other pollutants continued to have no correlation to the new parameters. The exceptions were VOC (Figure B-43) and CH_4, which did show strong correlation (R^2 >.8) to both the new factors.

One possible reason for the weak correlations could be the spatial patterns of production. As noted in Section B.2.1, new platforms are typically located in the southern edge of the GOM (Figure B-12). The emissions (Figure B-13) and production (Figure B-40) are higher for these platforms. The issue with an overall correlation seems to lie in the older platforms with lower production. It is possible these lower emissions and lower production combinations have weaker correlation that disrupts an overall correlation. Future attempts at developing emission estimation equations should explore separate trends by water depth, as it appears there are different production profiles and relationships.

It also possible that the increased application of well stimulation and installation of subsea production systems, oil production was increased without installation of additional production platforms. This would reduce the amount of vessel supports required to develop a field, and reduce overall emissions and complicate these correlations. The time series of lease use, vented and flared volume, and total natural gas production (USDOI, BOEM 2016b) is presented in Figure B-44. The volume of gas used at the platform and the volume vented or flared shows little correlation with production.

Further investigation is necessary to get at the cause of the lack of correlation between production and emissions, or to find a more suitable proxy for activity level.

Also of note in the correlations, the 2000 inventory qualitatively appears to be an outlier that can shift a regression to yield a lower correlation for the production and production per platform regressions for many pollutants. This is likely due to the evolving inventory calculation methods, and improved operator understanding of platform activity data to be submitted, since this was the first Gulfwide inventory effort to make use of the GOADS software. Given the changes in inventory methods and how the inventory compares to the subsequent inventories, it is advisable to look at a shorter-term trend (i.e., last four inventories) in addition to a longer-term trend analysis.

To a lesser extent, 2014 also seems out of line with trends set in earlier inventories. For example, in the NO_x correlation plots (Figure B-42), 2014 has low emissions paired with high values of price, production, and production per platform. Further regression analysis shows the removal of 2014 from the dataset improves correlation values in the production regression for CH_4, CO and SO_2. It is possible this is a new trend emerging in the inventories, and bears watching in the future inventories.

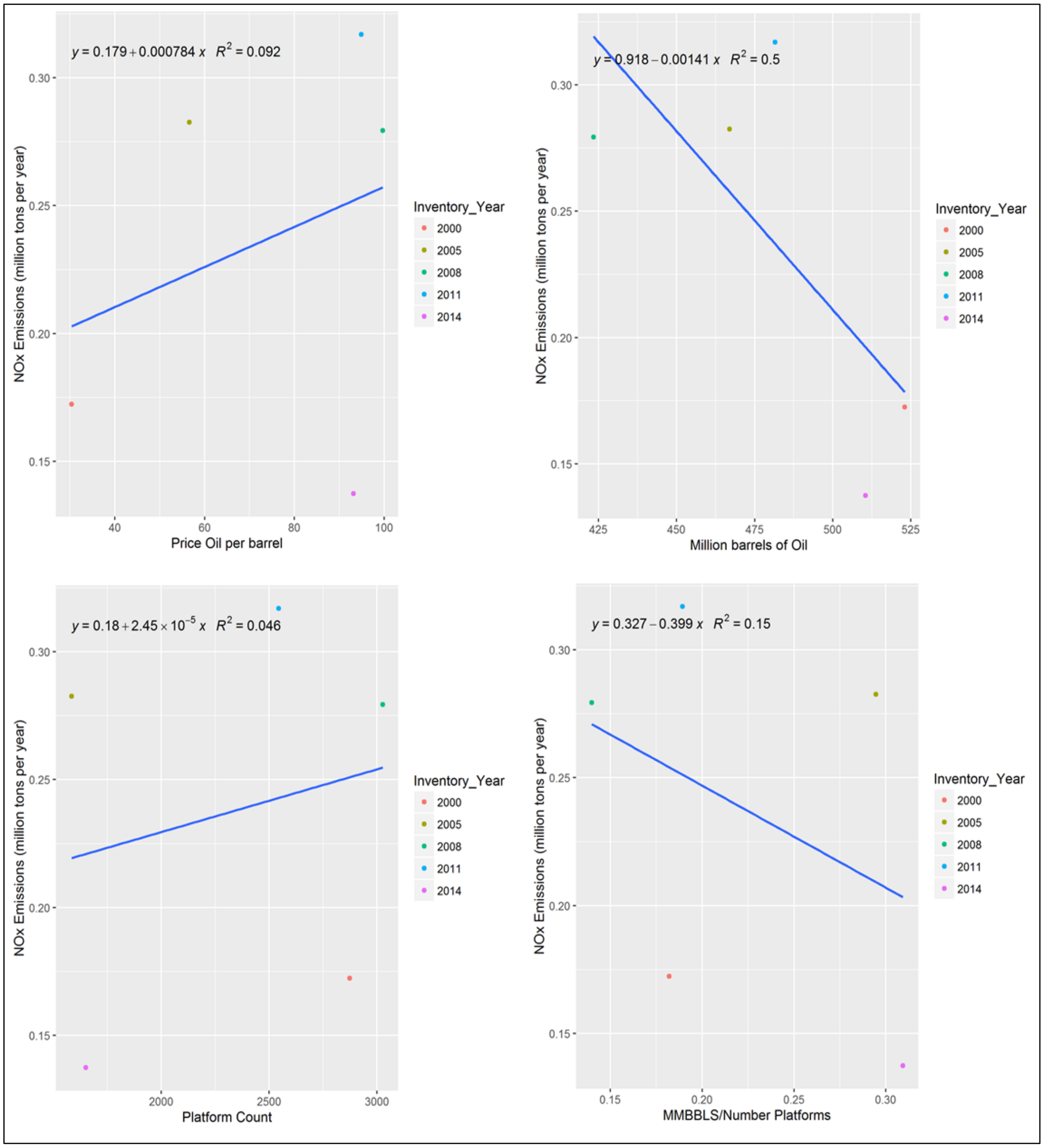

Figure B-42. Correlation of NO_x emissions to price of oil (top left), production of oil (top right), number of active platforms (bottom left), and production per platform (bottom right)

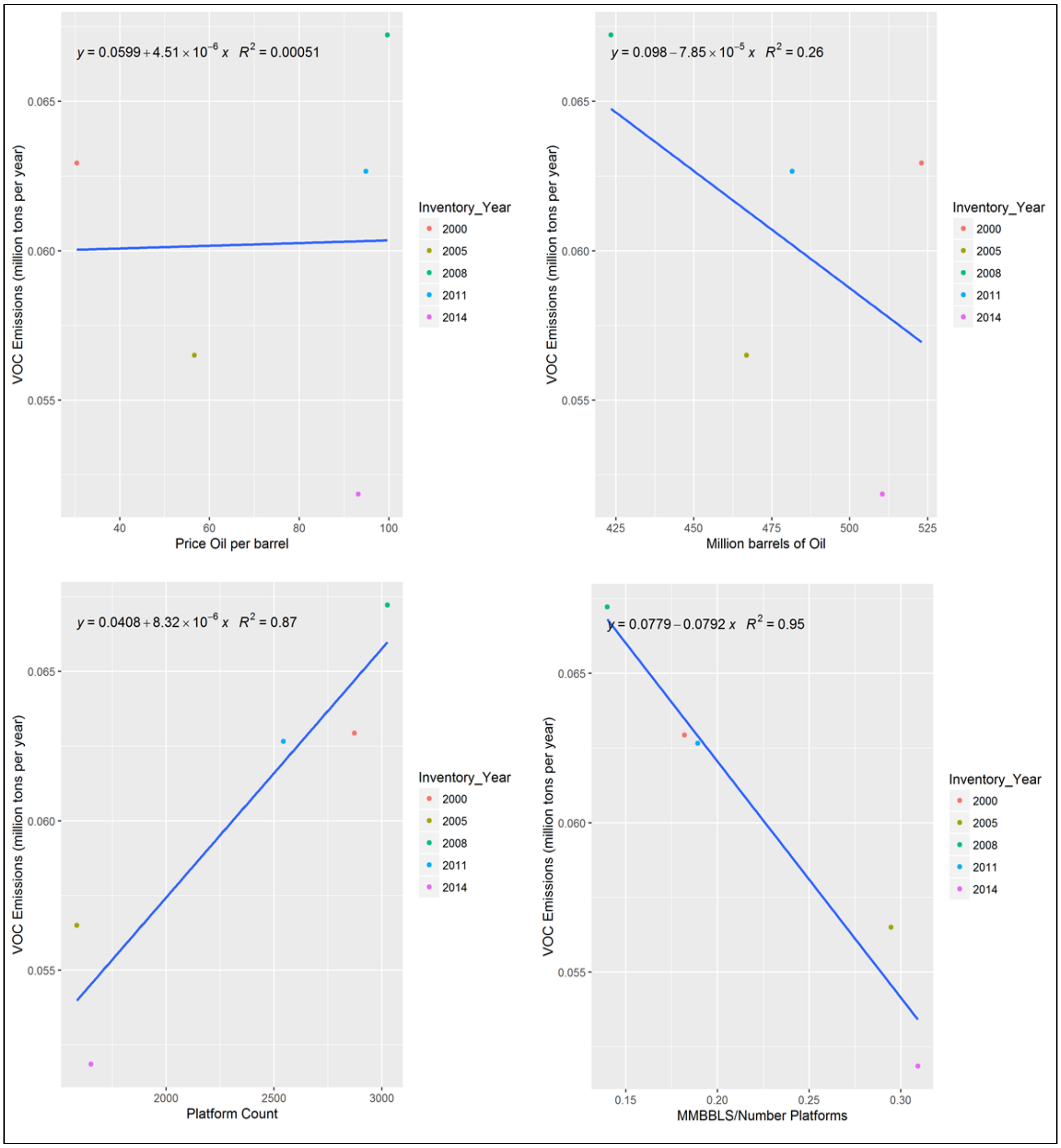

Figure B-43. Correlation of VOC emissions to price of oil (top left), production of oil (top right), number of active platform (bottom left), and production per platform (bottom right)

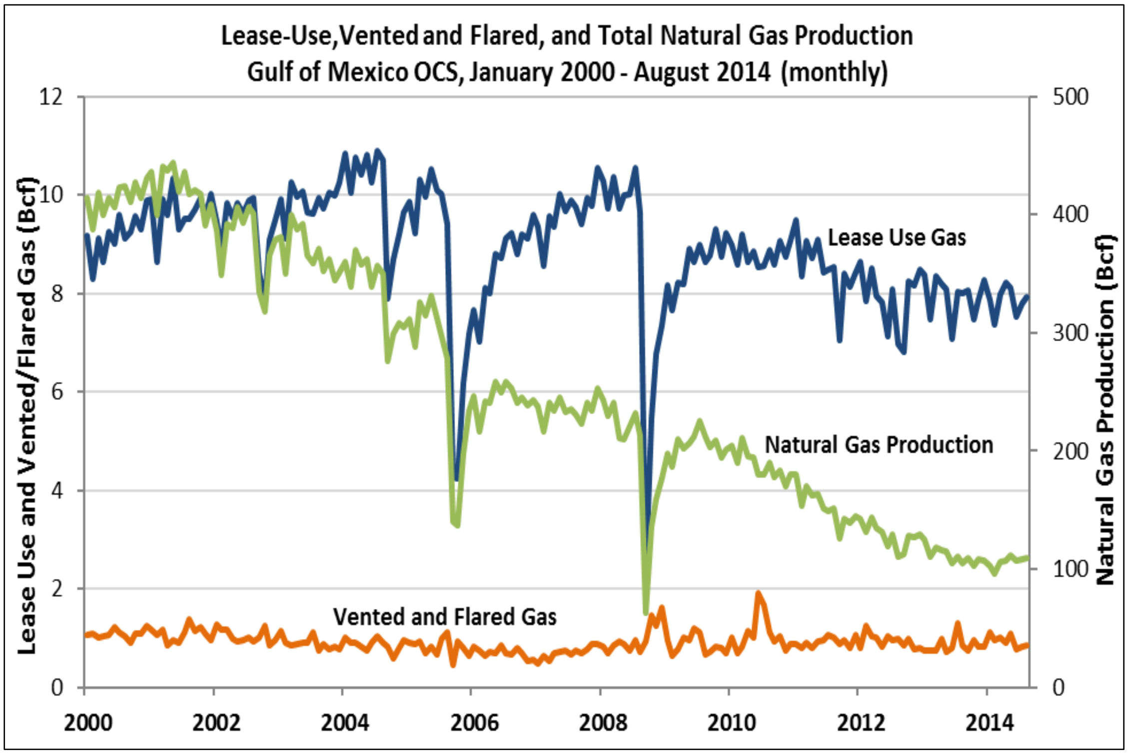

Figure B-44. Lease-use, vented and flared, and total natural gas production

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APPENDIX C.1: EVALUATION OF THE USE OF AUTOMATIC IDENTIFICATION SYSTEM DATA FOR MARINE VESSELS

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C.1 INTRODUCTION

The BOEM Year 2014 Gulfwide Emissions Inventory Study (2014 inventory) for marine vessels incorporates significant improvements compared to the BOEM Year 2011 Gulfwide Emissions Inventory Study (2011 inventory) due to the advanced use of PortVision automatic identification system (AIS) data. The detailed ship movement information included in the AIS dataset combined with vessel characteristics from Information Handling Service (IHS) Register of Ships (ROS) greatly reduces the uncertainty regarding actual vessel movements, vessel speeds, hours of operation, and engine load factors.

The replacement of the vessel operating assumptions used to develop the 2011 emission estimates with actual AIS data in 2014 has led to a significant change in the marine vessel emission estimates across vessel types and pollutants, as illustrated in Table C.1-1 of this memo. In addition, the 2014 AIS data provide a more complete assessment of commercial marine vessels (CMV), because AIS includes all vessels that transmit an AIS signal. Thus, the dataset now includes specific categories for cruise ships and dredging vessels, which were not previously accounted for in the 2011 inventory (or not specifically delineated) because they are not involved in movement of cargo, yielding expanded coverage of the CMV fleet and resulting in higher emission estimates for the source category. The AIS data also provide a more complete list of support and survey vessels. However, use of the AIS data to quantify propulsion engine categories and replacing previously-assumed propulsion engine operating loads with calculated engine loads yielded lower cumulative emission estimates. In cases where AIS seemed to underrepresent activities for specific vessel types such as military and fishing vessels, these records were removed from the AIS dataset and activity was estimated using more comprehensive dataset such as National Oceanographic and Atmospheric Administration (NOAA) commercial fishing data, U.S. Coast Guard vessel data, and regional and state recreational fishing studies.

This memorandum outlines improvements made to the marine vessel component of the 2014 inventory, and discusses how the use of AIS data affects the Gulfwide vessel activity data and emission estimates.

Table C.1-1. Aggregated marine vessel emission estimates by year

Vessel Type	Source	CH_4	CO	CO_2	N_2O	NH_3	NO_X	PM_{10}-PRI	$PM_{2.5}$-PRI	SO_2	VOC
CMV	2011	33.22	9,778.76	4,301,312.10	171.65	19.66	108,203.25	4,122.07	3,767.93	32,652.07	4,303.19
	2014	75.11	20,655.12	8,398,693.43	427.30	74.34	200,258.30	6,408.62	5,970.82	48,215.26	8,802.45
Drilling rigs	2011	21.23	6,248.04	2,748,279.25	109.68	52.68	69,135.35	2,633.76	2,407.48	20,862.71	2,749.48
	2014	15.00	6,236.46	2,151,121.33	103.73	16.53	40,837.07	1,261.84	1,188.88	5,354.07	859.10
Pipelaying	2011	4.67	2,123.51	609,535.49	18.08	7.00	9,479.96	350.03	338.36	116.68	128.34
	2014	0.95	239.27	113,755.26	5.60	0.97	2,405.64	85.90	79.24	668.86	97.61
Support	2011	74.79	35,685.79	13,002,103.10	386.41	128.71	175,558.05	6,435.38	6,242.32	2,157.34	4,016.15
	2014	10.01	6,194.42	1,637,454.57	77.30	11.52	30,256.43	798.62	774.03	121.91	398.60
Survey	2011	2.90	1,760.44	504,714.45	14.97	5.80	7,851.49	289.79	281.09	96.51	104.77
	2014	0.35	811.56	112,940.89	2.32	0.37	3,275.88	153.94	144.16	377.67	379.10

C.2 IMPROVEMENTS IN THE 2014 INVENTORY

C.2.1 Improved AIS Data Pull

For the 2011 inventory, the PortVision AIS data purchased from AIRSIS, Inc. consisted of "event" data that were driven by the proximity of a vessel to a receiver: instances where a vessel was first detected by each receiver as the vessel transited the area of interest. The intent was to connect the events for each vessel and map individual transits to calculate vessel speed and hours of operation for a bottom-up activity estimate. However, the event data contained too many inconsistencies and irresolvable errors, such as repeat events and missing data points, to be useful in estimating activity or emissions directly. At that time, use of AIS transmitters was gradually increasing. Although the fleet data were not sufficiently complete to allow for accurate estimates of operating hours, the AIS data were considered to be sufficiently representative of the Gulf fleet to be used to spatially and temporally allocate activity and emissions. The 2011 emission estimates were developed from detailed activity data sources such as the U.S Corps of Engineers' CMV Entrance and Clearance data, BOEM drilling logs and pipelaying maps, and the Offshore Marine Service Association.

For the 2014 inventory, a much larger AIS dataset was purchased containing hourly observations of all vessels regardless of proximity to receivers. These hourly data and greatly increased coverage by PortVision eliminated many of the errors encountered with the 2011 "events" dataset. While the 2014 dataset was not completely error-free, these hourly data provided sufficient detail to achieve the goal of "connecting the dots" and showing individual transits by vessel. Furthermore, it allowed reduction of the dataset to include only vessels in federal waters—a step that was not possible given the previous "event" datasets. This removed a potential confounder observed in the 2011 dataset wherein the it likely represented a significant number of vessels that spent most or all of their time in state waters, which were outside the geographic scope of the inventory.

C.2.2 Improved IHS Vessel Matching and Gap-Filling

Given the previous experience in matching AIS vessel data to IHS ROS data, a significant improvement was made in the match rate for the 2014 inventory using an updated vessel characteristics dataset from IHS and the 2011 database of previous matches. Vessels were matched using a combination of vessel name, type, category, Maritime Mobile Service Identity (MMSI) code, call sign, and International Maritime Organization (IMO) number. This effort focused on matching more than one identifier, where possible, to ensure higher quality matches. The reported AIS vessel types were updated to IHS vessel type where possible, resulting in greater distinction between types and engine categories. Although some vessel types were still aggregated to facilitate processing, the 2014 dataset has 52 different AIS/IHS-derived vessel type/engine category combinations, as illustrated in Table C.1-2, not including those that were removed for separate processing, such as military and fishing vessels. This is a big improvement over the 15 vessel type combinations that were extracted from the 2011 data (Table C.1-3). For example, in 2011, 36% of the vessels were "unknown" vessel type, whereas in 2014, the portion of vessels of "unknown" type represented only 8% of vessels. AIS coverage was also sufficiently complete to account for two new oil and gas vessel types: floating production storage and offloading (FPSO) and well stimulation vessels.

Table C.1-2. 2014 vessel count by category and type

Vessel Type	Vessel Category 1	Vessel Category 2	Vessel Category 3	Vessel Count
Auto carrier			130	130
Bulk carrier		3	2,194	2,197
Chemical tanker		26	1,159	1,185
Container			238	238
Crude oil tanker			640	640
Cruise	1	1	15	17
Dredging	3	4	2	9
Drilling	86	44	25	155
Ferry		5		5
FPSO		1	1	2
General cargo		33	671	704
Miscellaneous	93	6	1	100
Offshore oil and gas support	1,132	122	23	1,277
Passenger	42			42
Pilot	26			26
Pipelaying	1	4	10	15
Reefer			26	26
Research	18	2	2	22
Roll-on/roll-off (RORO)		5	34	39
Survey	6	33	12	51
Tanker, LNG/LPG		2	187	189
Tanker, miscellaneous		2	29	31
Tug	116	490	26	632
Unknown	690			690
Well stimulation vessel	2	3	1	6
Total vessel count	**2,216**	**786**	**5,426**	**8,428**

Table C.1-3. 2011 vessel count by type

Vessel Category	Vessel Count
Bulk	1,870
Cargo	1,379
Container	218
Drilling	26
Fishing	92
Government	167
Miscellaneous – Category 1/2	376
Miscellaneous – Category 3	589
Pipelaying	10
Recreation	431
Research	3
Support	961
Tanker	1,820
Tug	2,040
Unknown	5,612
TOTAL	**15,594**

C.2.3 Improved Spatial and Temporal Resolution

The 2011 AIS data from PortVision consisted of "snapshot" files showing the position of all vessels within the Gulf at approximately 12:00AM on the first day of each month of the year. These "snapshot" files were examined for seasonality in vessel activity throughout the year. No seasonal trends were detected either for overall marine vessel traffic or by vessel type. The snapshot files were then compiled to develop representative vessel traffic contours for each vessel type (e.g., tanker, containership, support vessel), which were used to spatially allocate emissions.

For the 2011 inventory, ERG spatially allocated emissions by using geographic information system (GIS) tools to develop density grids of the vessel point locations from the compiled snapshot files for each major vessel type. However, some vessel types had few vessels upon which the density grid was created, leading to gaps in coverage in the study area. To ensure a more robust spatial allocation, the 2011 AIS data were reprocessed to provide three activity density grids: one for Category 3 CMV, which included different tankers, cargo ship, bulkers and containerships, etc.; one for Category 1 and 2 vessels developed from tug data; and one for oil and gas offshore support vessels. As a result, emissions allocations were based on annualized vessel positions by vessel category.

The 2014 AIS data provided a more complete inventory of vessels, allowing for more accurate estimates of activity and emissions. For each vessel's position (latitude/longitude coordinates) and for each hour, activity and emissions were linked to the specific lease block where the vessel was operating relative to the vessel's date/ time stamp. With true vessel locations, there was no need to create density contours to spread out activity. Additionally, there was no consolidation among vessel types or even among vessels of the same type and category. Furthermore, a federal waters boundary was created to include only vessels and activities occurring within the boundary, a step that was not possible with the previous "event" datasets.

C.2.4 Improved Load Factors

As noted previously, the 2011 activity data did not include data elements that allowed for calculation of individual vessel propulsion load factors, and thus required the use default USEPA load factors for activity. However, with the improved 2014 AIS data and better matching with IHS, it was possible to calculate actual load factors for individual vessel locations using the following equation:

$$\text{Load Factor} = (\text{Actual Speed}/\text{Max Speed})^3$$

The average calculated load factor from AIS data for 2014 was 0.233. The default load factors used in the 2011 inventory were much higher than the actual 2014 load factors. Table C.1-4 lists the default load factors used in the 2011 inventory.

Table C.1-4. 2011 default propulsion engine operating load factors

Vessel Type	Mode	Load Factor
Pipelaying Operations		
Pipelaying	At sea	0.75
Drilling Rigs		
Drill ship	At sea	0.75
Jack-up equipment	At sea	0.75
Semisubmersible equipment	At sea	0.75
Submersible equipment	At sea	0.75
Emergency generators	At sea	0.75
Drill ship propulsion (maintain position)	Maneuvering	0.15
Semisubmersible propulsion (maintain position)	Maneuvering	0.15
Drilling propulsion (relocation)	At sea	0.75
Semisubmersible propulsion (relocation)	At sea	0.75
Survey Vessels		
Survey vessels	At sea	0.9
Support Vessels		
Supply/crew boats	At sea	0.85
	Maneuvering	0.1
Lift boats	At sea	0.85
	Maneuvering	0.1
Tugs/Towing Boats	At sea	0.85
	Maneuvering	0.1

C.3 Quality Checks on AIS Data

Because the 2014 AIS data are very different from the activity data and assumptions used in previous inventory efforts, additional quality assurance/quality checks (QA/QC) were conducted to validate the strength of the emission estimation approach and calculations. These checks included overall quality checks for completeness and outliers, as well as checks by vessel type, comparison of 2014 vessel characteristics and operation data with 2011 default values, visual examination of spatial allocations, and cross-checks against other data sources. These checks are outlined below.

C.3.1 AIS Data Vetting

AIS data have known limitations, such as incomplete or incorrect information as input by the ship's owner or operator, particularly in the case of the MMSI code and vessel type data fields, as well as technical errors during signal transmission or receipt, such as incorrect coordinates or missed transmittals (due to heavy weather conditions or AIS transmitters being turned off or experiencing technical difficulties). As a result, the AIS data were thoroughly checked, and when needed, revisions to the data were made as follows:

- Removed coordinates outside the area of interest (e.g., state waters, International waters, and eastern GOM) or clearly erroneous, such as (0, 0) coordinates or locations that plot on land.
- Updated all null or erroneous owner-input columns with data from more reliable sources such as IHS, Federal Communication Commission (FCC), or U.S. Coast Guard databases.
- Compared AIS-reported speed over ground to IHS-reported maximum speed. Replaced speed over ground with maximum speed where the reported speed over ground was larger than maximum speed. In most cases, these replacements were very minor, e.g., replacing a speed of 15.1 knots with 15.
- Verified vessel counts by type to other sources such as support vessel trade data, and previous Gulfwide inventories developed for BOEM.

C.3.1.1 Dredging

For the Gulfwide inventories prior to 2014, dredging vessels were not included because data quantifying operations were not located. Because dredging vessels transmit AIS signals, they could be easily included as new vessel category for the 2014 inventory. Dredging is an excavation activity usually carried out in shallow seas or freshwater areas with the purpose of gathering up bottom sediments and disposing of them at a different location. Dredging is frequently carried out to create a new harbor, berth, or waterway, to deepen existing facilities in order to allow larger ships access, or to assist pipelaying operations. Visual assessment of the spatial distribution of dredging activities by vessel speed confirms that the majority of dredging vessel activities are associated with transiting the Gulf to inland ports. There are a handful of locations where vessel speed is reduced, which could indicate active dredging operations in shallow waters or the vessels are awaiting their next assignment. Figure C.1-1 shows dredging vessel transit operations as well as locations where the vessels are stationary. Although dredging was not included in previous inventories, it is likely that dredging activities increased in 2014 in anticipation of the expansion of the Panama Canal, which will allow larger vessels to travel across the isthmus, requiring deeper shipping channels and port accesses.

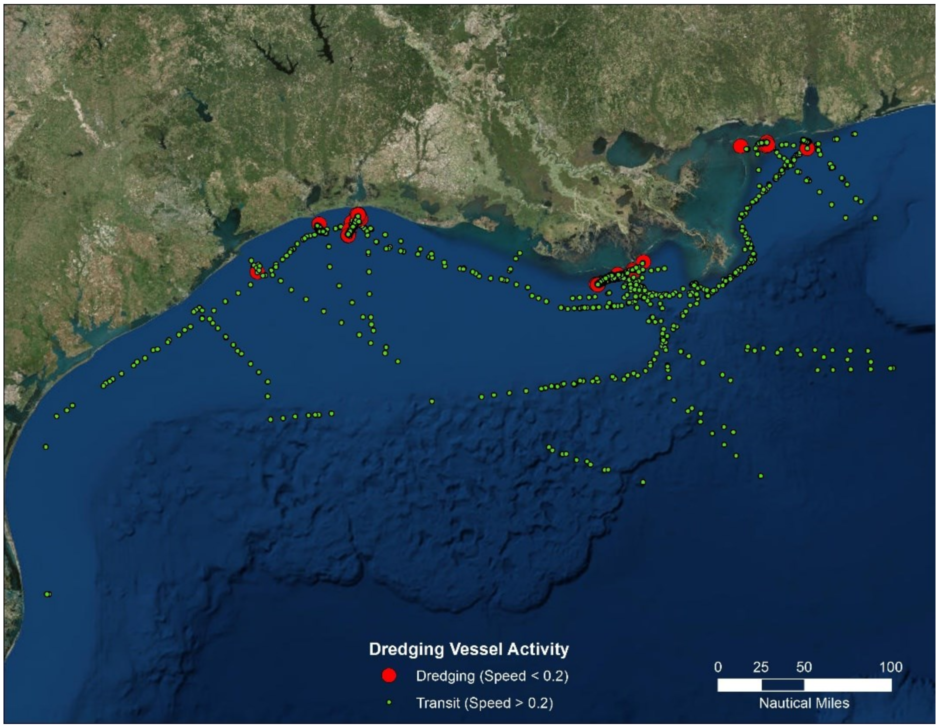

Figure C.1-1. Dredging vessel activity by speed

C.3.1.2 Cruise Ships

For the 2014 inventory, because cruise ships transmit AIS signals, they could be easily included as new vessel category. Cruise ships are passenger vessels with large propulsion/auxiliary engines that supply power to motors, pumps, heating/air conditioning, lighting, navigation, and other functions. These vessels enter and leave port quickly and spend the majority of their hours of operation at sea. In reviewing cruise activity estimates, they appeared disproportionately high compared to those of other vessel types. During review, it was found that one cruise ship had an erroneous auxiliary power rating in IHS. Once that was corrected to match another, sister cruise ship and the default auxiliary kilowatt (kW) power rating was recalculated, the revised activity sums reflected a more reasonable estimate. Further quality checks were made to review spatial allocations that appeared to correlate with typical cruise ship routes to Central American destinations such as Mexico, Belize, Honduras, Costa Rica, and Panama as shown in the final mapping of emissions and activity (Figure C.1-2).

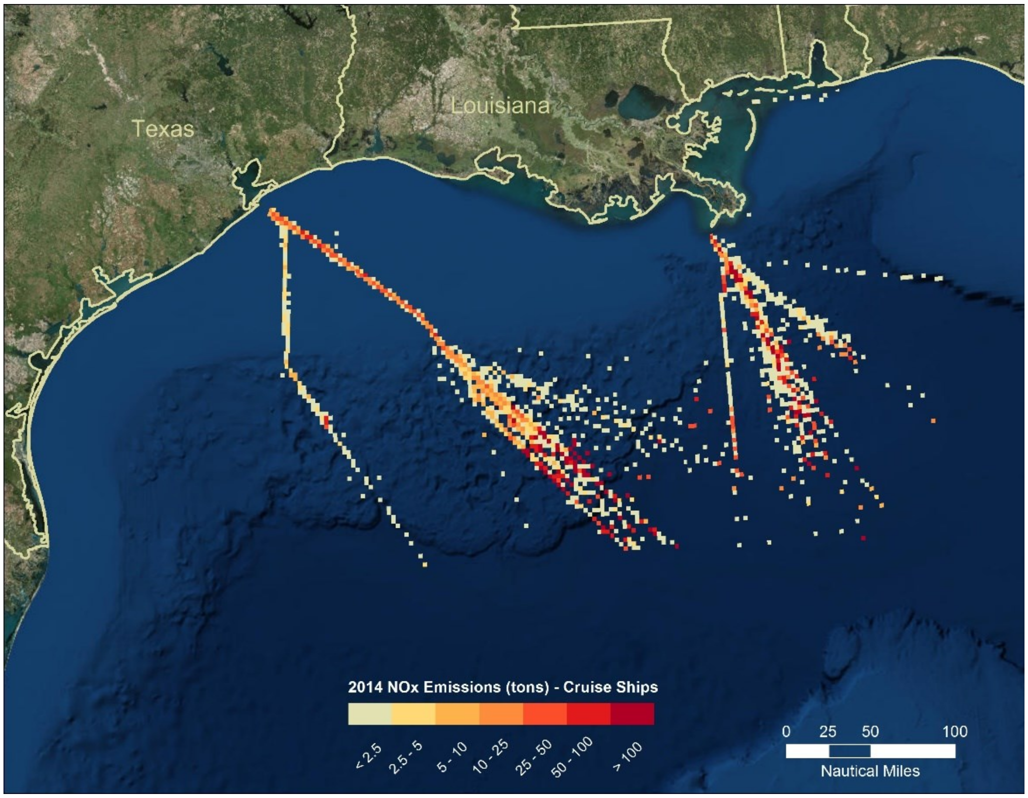

Figure C.1-2. 2014 NO_x emissions from cruise ships

C.3.1.3 Offshore Support Vessels

In the 2011 inventory, it was assumed that the offshore support vessels operated in federal waters 70% of the time. This operating assumption results in 6,132 annual hours of operation in federal waters per vessel. Of these hours spent in federal waters, it was estimated that 85% of the time is spent at sea underway and 15% of the time is spent idling adjacent to the platform. (Regulations require that support vessels cannot tie-up to platforms; instead, they idle nearby while offloading or loading cargo.)

For the 2011 inventory, typical offshore support vessel operating engine load factors were provided by the U.S. Coast Guard National Offshore Safety Advisory Committee. These load factors vary, with most of the time spent at 80% load while at-sea underway, and 10% load while idling adjacent to the platform. The 2011 vessel population, engine kW rating, average hours of operation and typical load factor for the two modes (i.e., underway and at-sea idling) were used to calculate the total annual kW-hours associated with support vessels operate in federal waters.

In the 2014 inventory, these assumptions are no longer required given the improved AIS data. Actual hours of operation in federal waters could be summed using location and time stamp data, and load factors were calculated given the vessel's speed over ground compared with the vessels' maximum speed. Analysis of the time stamp data indicate that support vessels are idling 29.8% of the time, about twice the rate assumed in the 2011 inventory. Figures C.1-3 and C.1-4 show the final mapping of emissions and activity, which appears to confirm widespread offshore support vessel activity and "hot spots" near offshore platforms where vessels are idling or managing cargo. Note how the emissions and idling locations align well with the offshore platform locations (Figure C.1-5).

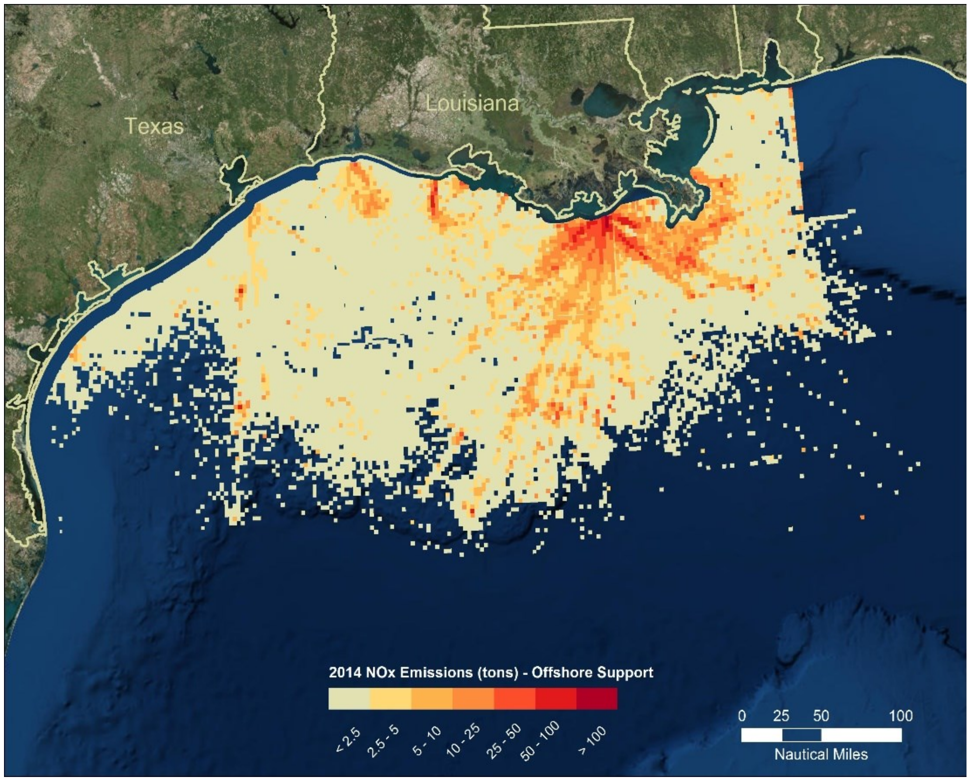

Figure C.1-3. 2014 NO_x emissions from offshore support vessels

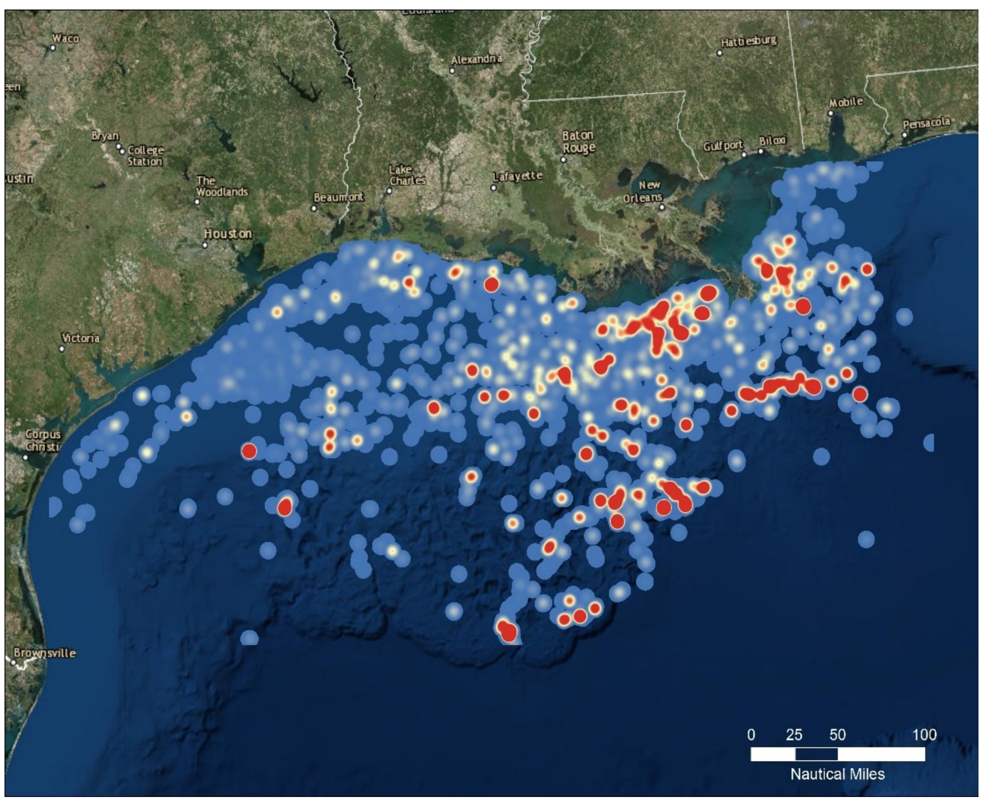

Figure C.1-4. Offshore support vessel idling hot spots

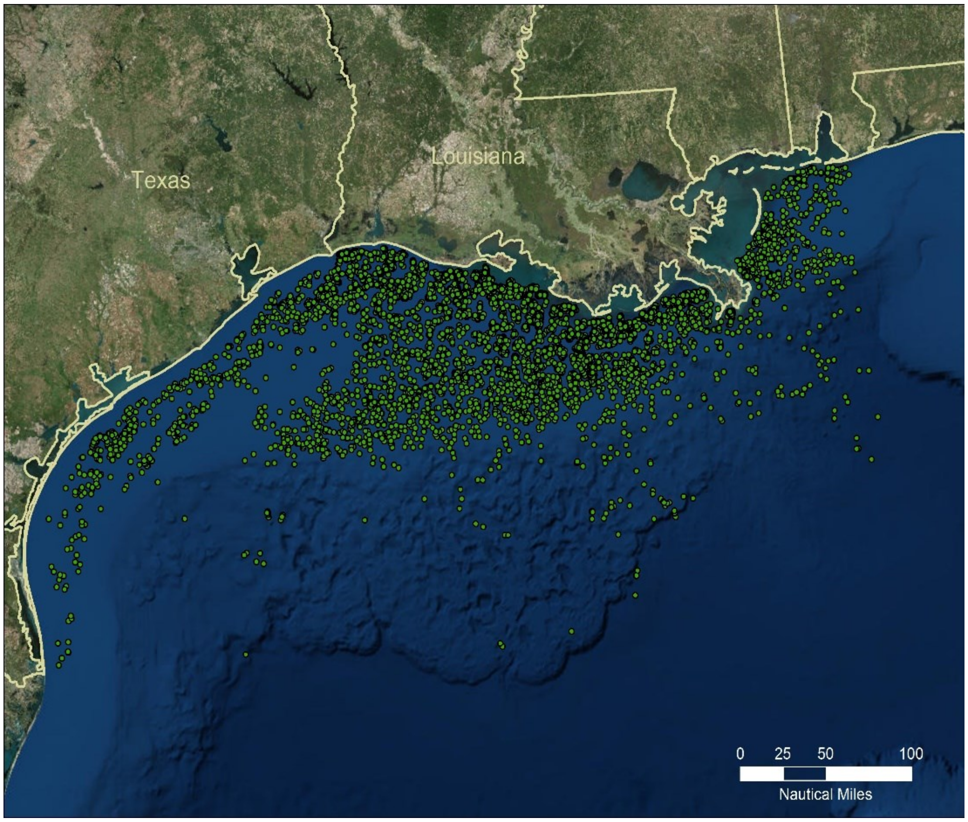

Figure C.1-5. Offshore platform locations

C.3.1.4 Drilling Vessels

BOEM's drilling database was queried to identify lease blocks where drilling operations occurred in 2014. These lease blocks were mapped against the AIS data points associated with drilling vessels. Of the 369 lease blocks with drilling activities, 305 (83%) showed drilling vessel activity in the AIS data. For drilling operations, only the drilling ship records that had speeds of 0.2 knots or less were considered, which indicated that the vessels were not in transit to or from a work site and may have been implementing drilling operations or may have been awaiting the next assignment.

To help evaluate this difference, it was noted that 269 records (73%) were clustered within the drilling lease blocks reported to BOEM as illustrated in Figure C.1-6. AIS does not capture non-propelled drill ships, which may explain why BOEM indicated drilling in areas where there is not corresponding AIS data. Drilling associated with non-propulsion rigs was calculated separately based on the BOEM drilling dataset and rig zone vessel specific power ratings. Non-propulsion drilling rigs include platform drilling rigs that are shipped to the platform, assembled on the platform, used for production drilling, and when completed, disassembled and shipped to another location. These drilling rigs are considered mobile drilling units, even though they are physically part of the stationary platform. Support vessels and tugs that move non-propulsion rigs to and from the site are included in the support vessel category.

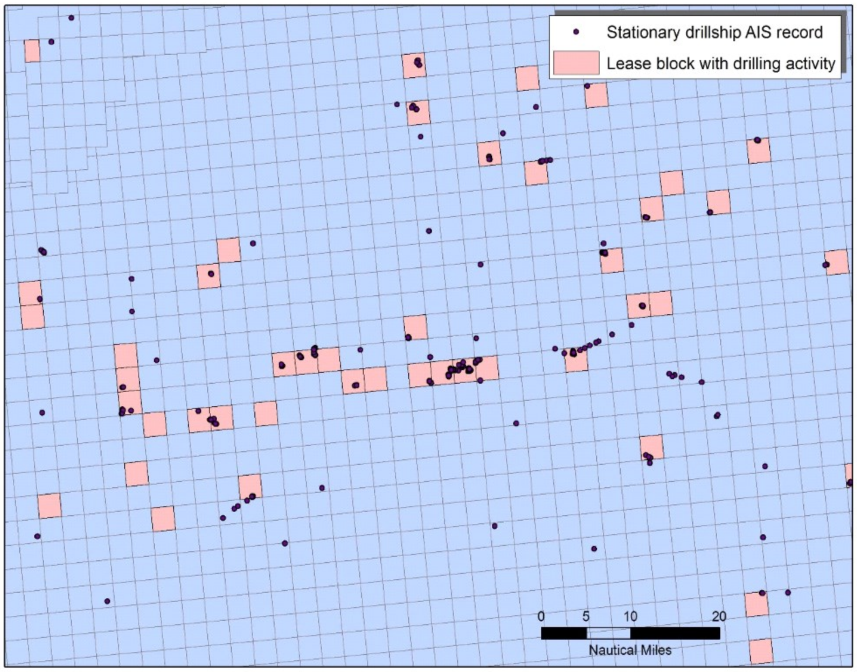

Figure C.1-6. AIS drilling vessel locations compared to BOEM drilling

C.3.1.5 Pipelaying

The AIS data points were compared to BOEM's master pipeline database and BOEM's pipeline arc shapefile to see how well the two independent data sources agreed.

For the BOEM data, in order to quantify 2014 pipelaying activities, the first step was to identify the sections of pipelines that underwent construction activities in 2014. Pipeline maintenance or repair activities were also identified as those segments in the BOEM master pipeline dataset with a pipeline construction date in the year 2014. New pipelines were identified from the BOEM master pipeline dataset as those that showed no construction date but had an initial hydrostatic test date in 2014. The segment IDs from these two datasets were linked to BOEM's pipeline arc dataset and overlaid with the pipeline vessels identified in the AIS data and mapped as points described above.

In several cases, the AIS data matched BOEM's new pipelaying construction data very well, as shown in Figures C.1-7 and C.1-8 where the yellow AIS points follow the green "new construction" pipelines from BOEM's data.

Figure C.1-7. Match of AIS data points to BOEM's new pipelines

Figure C.1-
to BOEM's

In some cases, AIS data indicate work along pipelines that were not flagged in the master pipeline database as being under construction in the year 2014, for example, the yellow AIS data points following gray pipelines in Figures C.1-9 and C.1-10.

Figure C.1-9. AIS data points along existing pipelines

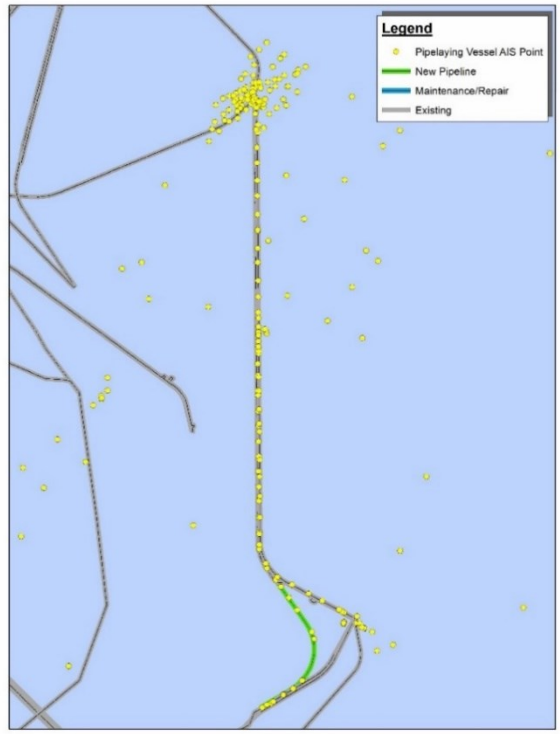

Figure C.1-10. AIS data points along existing and new pipelines

Areas that showed high presence of pipelaying vessels, as determined by AIS data points, were investigated to determine whether there were missing pipelines or pipelaying activities from BOEM's data. In most cases, these activities were found to be consolidated around known shipping lanes, indicating that the vessel(s) were travelling to or from a job site, as shown in Figure C.1-11.

Figure C.1-11. Pipelaying vessels transiting shipping lanes

Support vessels and tugs associated with pipelaying operations are included in the support vessel category.

C.4 Summary

The quality of AIS data has improved drastically over the last several years, and the use of AIS data in emission inventory efforts is significantly enhancing the accuracy of marine vessel emission estimates as seen in the 2014 inventory. The ability to identify specific vessels, documenting their location and calculating true engine load factors and hours of operation is a significant improvement over approaches that rely heavily on defaults or surrogates for vessel operations. These enhancements are a crucial step toward developing more accurate activity and emission calculations. Furthermore, analysis of AIS data is leading to important insights about vessel operations, from typical cruising and maneuvering speeds and idling operations to fleet composition and vessel-type specific movement patterns. It is anticipated that there will be even more improvements, such as better characterization of smaller miscellaneous Category 1 and 2 vessels.

As AIS coverage expands and analytical methods evolve, the necessity to carefully preprocess the data becomes increasingly critical to the use of these data; this preprocessing would include:

- Identification and hours adjustment to account for data gaps in transmittal records.
- Accurate vessel matching between the AIS vessel identification codes and IHS ROS data.
- Corrections to vessel type labels.
- Reduction in the number of vessels that are considered "unknown".
- Identification of incorrect data in the ROS data, such as inappropriate power ratings.
- Identification of data anomalies such as inconsistent used of AIS for recreational vessels.

Finally, it is important to note that although AIS and ROS data are very useful in evaluating propulsion emissions, auxiliary engine operations are currently not directly correlated to any data compiled using this AIS approach and emissions from these engines continue to be based on assumptions about power rating and operating load.

APPENDIX C.2: DRILLING VESSEL ACTIVITY DATA

Table C.2-1. BOEM 2014 drilling vessel data

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
BR	BA	502	* BARGE RIG TO BE DETERMINED	07/18/14	07/24/14	6
BR	HI	A 260	* BARGE RIG TO BE DETERMINED	08/25/14	09/16/14	22
BR	HI	A 317	*DIVE SUPPORT VESSEL (DSV)*	09/30/14	10/28/14	28
BR	HI	A 317	*DIVE SUPPORT VESSEL (DSV)*	11/15/14	12/16/14	31
BR	SM	212	*PARKER DRILLING RIG 55-B*	05/17/14	05/27/14	10
BR	SM	217	*PARKER DRILLING RIG 55-B*	07/04/14	08/20/14	47
BR	SM	217	*PARKER DRILLING RIG 55-B*	08/21/14	09/30/14	40
BR	SM	218	*PARKER DRILLING RIG 55-B*	05/28/14	06/03/14	6
BR	SM	218	*PARKER DRILLING RIG 55-B*	06/05/14	07/04/14	29
BR	SM	48	*DIVE SUPPORT VESSEL (DSV)*	10/30/14	11/08/14	9
BR	ST	301	*TETRA DB-1*	09/02/14	10/08/14	36
DS	AT	362	*ENSCO DS-4*	04/28/14	05/23/14	25
DS	AT	362	*ENSCO DS-4*	05/23/14	08/18/14	87
DS	AT	426	*HARKAND SPEARFISH*	06/29/14	07/25/14	26
DS	AT	573	*GSF C.R. LUIGS*	04/26/14	05/09/14	13
DS	AT	575	*GSF C.R. LUIGS*	05/09/14	05/23/14	14
DS	AT	617	*GSF C.R. LUIGS*	04/12/14	04/26/14	14
DS	AT	618	*T.O. DEEPWATER INVICTUS*	07/28/14	11/09/14	104
DS	DC	178	*T.O. DISCOVERER DEEP SEAS*	03/29/14	09/18/14	173
DS	DC	398	*NOBLE GLOBETROTTER*	07/12/14	12/26/14	167
DS	DC	4	*HELIX 534*	12/20/14	01/07/14	347
DS	DC	4	*T.O. DISCOVERER DEEP SEAS*	01/31/14	03/28/14	56
DS	DC	47	*T.O. DISCOVERER DEEP SEAS*	12/15/13	01/31/14	30
DS	DC	621	*HARKAND SPEARFISH*	08/15/14	08/26/14	11
DS	DC	621	*HARKAND SPEARFISH*	08/29/14	09/11/14	13
DS	DC	621	*HARKAND SPEARFISH*	11/28/14	11/27/14	1
DS	DC	843	*NOBLE GLOBETROTTER*	08/27/13	01/20/14	19
DS	EB	602	*HELIX 534*	08/30/14	09/14/14	15
DS	EB	602	*HELIX 534*	09/20/14	10/22/14	32
DS	EB	602	*HELIX 534*	09/20/14	10/26/14	36
DS	GB	668	*HARKAND SPEARFISH*	07/29/14	08/13/14	15
DS	GB	973	*PACIFIC SANTA ANA*	06/27/13	03/09/14	67
DS	GC	385	*T.O. DEEPWATER PATHFINDER*	02/10/14	05/07/14	86
DS	GC	473	*T.O. DEEPWATER PATHFINDER*	01/20/14	02/10/14	21
DS	GC	516	*T.O. DISCOVERER 534*	02/17/14	04/04/14	46
DS	GC	534	*NOBLE BOB DOUGLAS*	07/27/14	08/09/14	13
DS	GC	562	*T.O. DISCOVERER SPIRIT*	03/13/14	05/01/14	49
DS	GC	562	*T.O. DISCOVERER SPIRIT*	05/01/14	07/28/14	88
DS	GC	596	*T.O. DISCOVERER INSPIRATION*	07/12/14	11/08/14	119
DS	GC	640	*T.O. DISCOVERER INSPIRATION*	12/12/13	06/28/14	178
DS	GC	640	*T.O. DISCOVERER INSPIRATION*	11/08/14	11/29/14	21
DS	GC	640	*T.O. DISCOVERER INSPIRATION*	11/29/14	03/03/15	32
DS	GC	643	*NOBLE SAM CROFT*	07/22/14	12/09/14	140
DS	GC	643	*NOBLE SAM CROFT*	12/08/14	04/05/15	23
DS	GC	653	*GSF C.R. LUIGS*	11/21/13	03/31/14	89
DS	GC	653	*GSF C.R. LUIGS*	05/23/14	10/08/14	138
DS	GC	653	*T.O. DEEPWATER INVICTUS*	11/22/14	01/03/15	39
DS	GC	680	*NOBLE BOB DOUGLAS*	06/04/14	06/18/14	14
DS	GC	680	*NOBLE BOB DOUGLAS*	06/18/14	07/09/14	21

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
DS	GC	683	*NOBLE BOB DOUGLAS*	11/17/14	11/20/14	3
DS	GC	683	*NOBLE BOB DOUGLAS*	11/20/14	02/05/15	41
DS	GC	683	*T.O. DISCOVERER SPIRIT*	12/15/13	01/22/14	21
DS	GC	733	*T.O. DEEPWATER CHAMPION*	07/17/14	09/11/14	56
DS	GC	733	*T.O. DEEPWATER CHAMPION*	09/11/14	10/03/14	22
DS	GC	743	*SEADRILL WEST AURIGA*	11/22/14	05/12/15	39
DS	GC	767	*NOBLE BOB DOUGLAS*	07/09/14	07/27/14	18
DS	GC	807	*PACIFIC SANTA ANA*	03/11/14	08/05/14	147
DS	GC	807	*PACIFIC SANTA ANA*	08/06/14	12/30/14	146
DS	GC	825	*ENSCO DS-3*	08/14/14	12/05/14	113
DS	KC	10	*T.O. DISCOVERER INDIA*	05/29/14	12/24/14	209
DS	KC	147	*SEADRILL WEST VELA*	10/31/14	11/21/14	21
DS	KC	147	*SEADRILL WEST VELA*	12/23/14	05/14/15	8
DS	KC	292	*SEADRILL WEST VELA*	03/02/14	03/26/14	24
DS	KC	414	*T.O. DISCOVERER INDIA*	12/24/14	05/26/15	7
DS	KC	627	*T.O. DEEPWATER CHAMPION*	05/16/14	07/16/14	61
DS	KC	642	*ENSCO DS-5*	12/30/13	05/30/14	149
DS	KC	642	*ENSCO DS-5*	06/15/14	10/27/14	134
DS	KC	814	*PACIFIC SANTA ANA*	12/30/14	05/11/15	1
DS	KC	829	*T.O. DISCOVERER CLEAR LEADER*	07/09/13	10/14/14	286
DS	KC	875	*NOBLE BOB DOUGLAS*	08/09/14	11/15/14	98
DS	KC	93	*ENSCO DS-4*	09/03/14	08/05/15	119
DS	KC	964	*T.O. DEEPWATER CHAMPION*	12/27/13	03/13/14	71
DS	KC	964	*T.O. DEEPWATER CHAMPION*	03/13/14	03/19/14	6
DS	LL	317	*T.O. DISCOVERER SPIRIT*	01/23/14	03/12/14	48
DS	LL	411	*T.O. DEEPWATER PATHFINDER*	05/18/14	07/09/14	52
DS	MC	211	*T.O. DEEPWATER CHAMPION*	03/19/14	05/16/14	58
DS	MC	292	*ATWOOD ADVANTAGE*	04/04/14	05/19/14	45
DS	MC	300	*SEADRILL WEST NEPTUNE*	12/15/14	03/13/15	16
DS	MC	383	*ENSCO DS-3*	03/25/14	04/24/14	30
DS	MC	429	*ENSCO DS-3*	12/07/13	02/14/14	44
DS	MC	522	*ENSCO DS-3*	12/18/14	03/31/15	13
DS	MC	522	*SEADRILL WEST VELA*	12/07/13	01/30/14	29
DS	MC	525	*NOBLE GLOBETROTTER*	01/23/14	02/19/14	27
DS	MC	525	*NOBLE GLOBETROTTER*	02/20/14	07/08/14	138
DS	MC	525	*NOBLE GLOBETROTTER*	07/08/14	07/10/14	2
DS	MC	538	*T.O. DISCOVERER DEEP SEAS*	09/28/14	01/06/15	94
DS	MC	546	*T.O. DEEPWATER PATHFINDER*	10/02/13	01/20/14	19
DS	MC	582	*T.O. DISCOVERER DEEP SEAS*	09/20/14	09/27/14	7
DS	MC	608	*ENSCO DS-3*	05/14/14	07/09/14	56
DS	MC	608	*ENSCO DS-3*	07/15/14	07/16/14	1
DS	MC	608	*SEADRILL WEST VELA*	03/29/14	04/24/14	26
DS	MC	697	*ENSCO DS-5*	10/29/14	03/12/15	63
DS	MC	725	*STENA FORTH*	05/28/13	01/07/14	6
DS	MC	725	*STENA FORTH*	04/15/14	06/03/14	49
DS	MC	726	*STENA FORTH*	01/29/14	03/12/14	42
DS	MC	726	*STENA FORTH*	03/26/14	04/15/14	20
DS	MC	726	*STENA FORTH*	06/16/14	12/20/14	187
DS	MC	726	*STENA FORTH*	12/21/14	01/09/15	10
DS	MC	762	*NOBLE BULLY I*	11/04/13	03/07/14	65
DS	MC	762	*NOBLE BULLY I*	04/01/14	08/15/14	136

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
DS	MC	762	*NOBLE BULLY I*	06/17/14	07/23/15	197
DS	MC	762	*NOBLE BULLY I*	09/26/14	03/04/15	96
DS	MC	772	*T.O. DEEPWATER PATHFINDER*	07/10/14	07/22/14	12
DS	MC	772	*T.O. DEEPWATER PATHFINDER*	07/23/14	10/10/14	79
DS	MC	772	*T.O. DEEPWATER PATHFINDER*	10/13/14	10/15/14	2
DS	MC	776	*SEADRILL WEST AURIGA*	10/30/13	07/03/14	183
DS	MC	776	*SEADRILL WEST VELA*	05/05/14	05/22/14	17
DS	MC	776	*SEADRILL WEST VELA*	06/14/14	08/26/14	73
DS	MC	776	*SEADRILL WEST VELA*	10/18/14	10/22/14	4
DS	MC	776	*T.O. DISCOVERER ENTERPRISE*	12/29/14	03/01/15	2
DS	MC	777	*SEADRILL WEST VELA*	11/26/14	12/13/14	17
DS	MC	777	*T.O. DISCOVERER ENTERPRISE*	02/25/14	03/10/14	13
DS	MC	777	*T.O. DISCOVERER ENTERPRISE*	10/15/14	12/08/14	54
DS	MC	777	*T.O. DISCOVERER ENTERPRISE*	11/04/14	02/19/14	258
DS	MC	777	*T.O. DISCOVERER ENTERPRISE*	12/17/14	12/29/14	12
DS	MC	778	*SEADRILL WEST VELA*	01/30/14	02/16/14	17
DS	MC	778	*SEADRILL WEST VELA*	10/14/14	10/18/14	4
DS	MC	778	*T.O. DISCOVERER ENTERPRISE*	03/10/14	04/30/14	51
DS	MC	778	*T.O. DISCOVERER ENTERPRISE*	05/11/14	08/10/14	91
DS	MC	778	*T.O. DISCOVERER ENTERPRISE*	09/27/14	10/02/14	5
DS	MC	782	*ATWOOD ADVANTAGE*	05/19/14	09/12/14	116
DS	MC	782	*ATWOOD ADVANTAGE*	10/20/14	01/10/15	72
DS	MC	809	*NOBLE DON TAYLOR*	09/03/13	01/10/15	364
DS	MC	85	*NOBLE TOM MADDEN*	11/25/14	04/21/15	36
DS	MC	943	*STENA ICEMAX*	08/24/14	05/16/15	129
DS	VK	825	*HELIX 534*	04/05/14	05/19/14	44
DS	VK	825	*HELIX 534*	07/23/14	08/26/14	34
DS	VK	869	*HELIX 534*	05/19/14	07/04/14	46
DS	VK	869	*HELIX 534*	07/04/14	07/23/14	19
DS	VK	915	*T.O. DEEPWATER CHAMPION*	10/06/14	02/12/15	86
DS	WR	143	*T.O. DISCOVERER INDIA*	12/15/13	05/26/14	145
DS	WR	469	*VANTAGE TITANIUM EXPLORER*	11/30/13	01/06/14	5
DS	WR	52	*DIAMOND OCEAN BLACKHAWK*	05/25/14	01/13/15	220
DS	WR	578	*MAERSK VALIANT*	09/18/14	01/26/15	104
DS	WR	584	*MAERSK VIKING*	07/08/14	12/13/14	158
DS	WR	584	*MAERSK VIKING*	12/13/14	07/08/15	18
DS	WR	634	*PACIFIC SHARAV*	12/23/14	04/10/15	8
DS	WR	677	*T.O. DISCOVERER CLEAR LEADER*	11/10/14	02/24/15	51
DS	WR	95	*STENA DRILLMAX ICE*	01/02/14	01/15/14	13
DS	WR	95	*STENA ICEMAX*	01/15/14	08/20/14	217
JU	BM	2	*HERCULES 173*	05/14/14	05/27/14	13
JU	BM	2	*HERCULES 173*	07/10/14	07/25/14	15
JU	BM	2	*HERCULES 173*	10/14/14	11/01/14	18
JU	BM	2	*HERCULES 173*	12/02/14	12/03/14	1
JU	BM	2	*HERCULES 204*	02/03/14	02/17/14	14
JU	BM	2	*HERCULES 204*	06/04/14	07/11/14	37
JU	BS	55	*HERCULES 120*	06/16/14	07/23/14	37
JU	EC	172	*HERCULES 214*	07/10/14	08/23/14	44
JU	EI	125	*ROWAN CECIL PROVINE*	07/04/14	12/15/14	164
JU	EI	133	*ROWAN LOUISIANA*	07/24/13	01/07/14	6
JU	EI	136	*ENSCO 86*	03/07/13	02/04/14	34

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
JU	EI	158	*SPARTAN 208*	09/11/14	10/17/14	36
JU	EI	175	*SPARTAN 208*	10/17/14	12/06/14	50
JU	EI	182	*ENSCO 86*	07/22/14	08/18/14	27
JU	EI	184	*HERCULES 209*	02/17/14	03/10/14	21
JU	EI	187	*HERCULES 214*	04/17/14	07/08/14	82
JU	EI	208	*ENSCO 90*	12/25/13	03/05/14	63
JU	EI	208	*ENSCO 90*	03/05/14	03/24/14	19
JU	EI	208	*ENSCO 90*	03/24/14	03/31/14	7
JU	EI	227	*HERCULES 300*	05/04/14	05/21/14	17
JU	EI	227	*HERCULES 300*	05/21/14	07/19/14	59
JU	EI	227	*HERCULES 300*	07/19/14	08/29/14	41
JU	EI	276	*ENSCO 81*	08/09/14	09/04/14	26
JU	EI	276	*ENSCO 81*	09/04/14	10/10/14	36
JU	EI	276	*ENSCO 81*	10/10/14	11/07/14	28
JU	EI	28	*SPARTAN 208*	08/11/14	09/10/14	30
JU	EI	302	*ENSCO 75*	03/20/14	05/30/14	71
JU	EI	32	*HERCULES 150*	12/26/13	01/11/14	10
JU	EI	32	*HERCULES 150*	01/11/14	02/09/14	29
JU	EI	331	*ENSCO 75*	06/30/14	11/04/14	127
JU	EI	360	*ENSCO 68*	12/19/13	01/05/14	4
JU	EI	360	*ENSCO 68*	01/05/14	01/21/14	16
JU	EI	360	*ENSCO 68*	01/21/14	02/03/14	13
JU	EI	360	*ENSCO 68*	02/06/14	03/14/14	36
JU	EI	360	*ENSCO 68*	03/14/14	03/21/14	7
JU	EI	360	*ENSCO 68*	03/21/14	03/22/14	1
JU	EI	360	*ENSCO 68*	03/22/14	04/07/14	16
JU	EI	360	*ENSCO 68*	04/07/14	04/24/14	17
JU	EI	360	*ENSCO 68*	04/24/14	05/19/14	25
JU	EI	360	*ENSCO 68*	05/19/14	05/31/14	12
JU	EI	360	*ENSCO 68*	05/31/14	06/08/14	8
JU	EI	360	*ENSCO 68*	06/08/14	06/17/14	9
JU	EI	95	*SPARTAN 208*	12/07/14	01/12/15	24
JU	GA	209	*ENSCO 86*	05/06/14	05/28/14	22
JU	GA	209	*ENSCO 86*	05/28/14	07/20/14	53
JU	GI	21	*ENSCO 99*	02/02/14	02/16/14	14
JU	GI	22	*ENSCO 99*	01/10/14	02/02/14	23
JU	GI	54	*HERCULES 214*	03/20/14	04/16/14	27
JU	GI	82	*HERCULES 253*	08/04/14	10/03/14	60
JU	HI	110	*HERCULES 200*	08/17/14	10/16/14	60
JU	HI	131	*HERCULES 264*	07/09/14	01/24/15	175
JU	HI	A 469	*HERCULES 263*	02/10/14	06/11/14	121
JU	MI	654	*HERCULES 263*	06/13/14	07/13/14	30
JU	MI	654	*HERCULES 263*	07/13/14	08/08/14	26
JU	MI	654	*HERCULES 263*	08/08/14	11/17/14	101
JU	MI	654	*HERCULES 263*	11/18/14	11/24/14	6
JU	MP	144	*ENSCO 68*	09/29/14	11/14/14	46
JU	MP	151	*ROWAN LOUISIANA*	04/07/14	04/26/14	19
JU	MP	151	*ROWAN LOUISIANA*	04/26/14	06/09/14	44
JU	MP	153	*ENSCO 87*	04/20/14	06/16/14	57
JU	MP	153	*ENSCO 87*	12/11/14	01/06/15	20
JU	MP	244	*HERCULES 253*	10/05/14	11/02/14	28

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
JU	MP	295	*ROWAN CECIL PROVINE*	01/27/14	03/30/14	62
JU	MP	299	*ENSCO 68*	06/20/14	07/18/14	28
JU	MP	299	*ENSCO 68*	07/18/14	08/11/14	24
JU	MP	299	*ENSCO 68*	08/11/14	09/29/14	49
JU	MP	299	*ENSCO 81*	03/12/14	03/29/14	17
JU	MP	310	*ENSCO 87*	08/16/14	08/23/14	7
JU	MP	311	*ENSCO 87*	12/29/13	04/20/14	109
JU	MP	311	*ENSCO 87*	06/16/14	08/06/14	51
JU	MP	311	*ENSCO 87*	08/23/14	09/20/14	28
JU	MP	313	*ENSCO 68*	11/14/14	12/12/14	28
JU	MP	313	*ENSCO 68*	12/12/14	01/27/15	19
JU	MP	41	*HERCULES 120*	03/23/14	05/03/14	41
JU	MP	41	*HERCULES 120*	10/07/14	11/20/14	44
JU	MP	42	*HERCULES 120*	07/23/14	09/08/14	47
JU	MP	42	*HERCULES 120*	11/20/14	12/16/14	26
JU	MP	58	*HERCULES 120*	05/03/14	06/14/14	42
JU	MP	59	*HERCULES 120*	12/25/13	02/02/14	32
JU	MP	59	*HERCULES 120*	02/11/14	03/23/14	40
JU	MP	61	*ENSCO 82*	12/28/13	01/18/14	17
JU	MP	61	*ENSCO 82*	02/15/14	03/09/14	22
JU	MP	61	*ENSCO 82*	03/09/14	05/26/14	78
JU	MP	61	*ENSCO 82*	05/26/14	06/03/14	8
JU	MP	61	*ENSCO 82*	06/03/14	07/18/14	45
JU	MP	61	*ENSCO 82*	07/18/14	08/20/14	33
JU	MP	61	*ENSCO 82*	08/20/14	10/10/14	51
JU	MP	61	*ENSCO 82*	10/10/14	11/29/14	50
JU	PL	25	*HERCULES 350*	01/08/14	03/17/14	68
JU	SM	149	*ENSCO 75*	02/10/14	03/18/14	36
JU	SM	152	*ROWAN LOUISIANA*	11/20/14	12/31/14	41
JU	SM	196	*ROWAN GORILLA IV*	11/07/14	12/19/14	42
JU	SM	230	*ROWAN EXL III*	07/10/14	08/15/14	36
JU	SM	234	*ROWAN EXL III*	12/03/13	07/10/14	190
JU	SM	234	*ROWAN EXL III*	08/15/14	12/24/14	131
JU	SM	234	*ROWAN EXL III*	08/15/14	01/25/15	138
JU	SM	48	*ROWAN CECIL PROVINE*	12/28/14	04/12/15	3
JU	SM	50	*ENSCO 75*	06/05/14	06/25/14	20
JU	SM	57	*HERCULES 264*	05/02/14	07/08/14	67
JU	SM	6	*SPARTAN 202*	05/16/14	07/29/14	74
JU	SS	150	*HERCULES 214*	11/10/14	01/06/15	51
JU	SS	151	*HERCULES 209*	10/27/13	01/28/14	27
JU	SS	171	*HERCULES 253*	12/28/14	01/19/15	3
JU	SS	188	*ROWAN JOE DOUGLAS*	05/19/14	12/06/14	201
JU	SS	189	*HERCULES 200*	06/16/14	08/14/14	59
JU	SS	193	*ROWAN CECIL PROVINE*	04/03/14	05/23/14	50
JU	SS	198	*HERCULES 205*	03/21/14	04/05/14	15
JU	SS	208	*HERCULES 213*	04/17/14	04/22/14	5
JU	SS	208	*HERCULES 213*	04/22/14	05/17/14	25
JU	SS	208	*HERCULES 213*	05/17/14	10/01/14	137
JU	SS	208	*SPARTAN 303*	02/15/14	03/23/14	36
JU	SS	209	*HERCULES 202*	11/18/13	03/10/14	68
JU	SS	209	*HERCULES 202*	03/13/14	03/23/14	10

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
JU	SS	209	*HERCULES 202*	03/30/14	07/14/14	106
JU	SS	209	*HERCULES 202*	07/25/14	10/01/14	68
JU	SS	209	*HERCULES 213*	07/28/13	02/16/14	46
JU	SS	215	*HERCULES 201*	10/26/13	04/07/14	96
JU	SS	215	*HERCULES 213*	10/01/14	11/10/14	40
JU	SS	219	*HERCULES 205*	05/03/14	06/24/14	52
JU	SS	219	*HERCULES 205*	11/14/14	03/01/15	47
JU	SS	253	*ROWAN GORILLA IV*	06/27/14	09/01/14	66
JU	SS	255	*SPARTAN 202*	12/16/13	05/10/14	129
JU	SS	274	*ENSCO 87*	09/22/14	12/08/14	77
JU	SS	305	*ENSCO 75*	11/05/14	01/19/15	56
JU	ST	125	*HERCULES 253*	05/31/14	06/22/14	22
JU	ST	125	*ROWAN LOUISIANA*	06/30/14	10/16/14	108
JU	ST	128	*HERCULES 350*	06/06/14	10/05/14	121
JU	ST	131	*HERCULES 251*	12/31/13	01/07/14	6
JU	ST	131	*HERCULES 251*	01/09/14	03/24/14	74
JU	ST	151	*HERCULES 300*	01/19/14	03/12/14	52
JU	ST	151	*HERCULES 300*	03/12/14	04/28/14	47
JU	ST	152	*HERCULES 350*	10/17/14	12/18/14	62
JU	ST	23	*HERCULES 173*	11/09/13	01/04/14	3
JU	ST	23	*HERCULES 173*	03/18/14	04/03/14	16
JU	ST	23	*HERCULES 173*	04/10/14	04/19/14	9
JU	ST	23	*HERCULES 173*	06/18/14	07/10/14	22
JU	ST	23	*HERCULES 173*	12/25/14	01/23/15	6
JU	ST	232	*ROWAN JOE DOUGLAS*	02/24/14	04/05/14	40
JU	ST	232	*ROWAN JOE DOUGLAS*	04/05/14	05/09/14	34
JU	ST	232	*ROWAN JOE DOUGLAS*	05/09/14	05/17/14	8
JU	ST	24	*HERCULES 173*	01/04/14	02/07/14	34
JU	ST	24	*HERCULES 173*	07/25/14	09/03/14	40
JU	ST	26	*HERCULES 253*	01/31/14	03/13/14	41
JU	ST	285	*ROWAN GORILLA IV*	11/29/13	05/29/14	148
JU	ST	300	*ENSCO 87*	11/28/14	03/02/15	33
JU	ST	41	*HERCULES 253*	11/26/14	12/22/14	26
JU	ST	51	*HERCULES 120*	12/18/14	01/14/15	13
JU	ST	51	*HERCULES 204*	02/28/14	05/25/14	86
JU	ST	52	*HERCULES 173*	06/02/14	06/18/14	16
JU	ST	54	*ENSCO 82*	12/29/14	01/20/15	2
JU	ST	59	*ROWAN JOE DOUGLAS*	05/25/13	01/07/14	6
JU	ST	72	*HERCULES 200*	01/26/14	06/16/14	141
JU	VR	179	*ENSCO 99*	06/03/13	01/04/14	3
JU	VR	245	*ENSCO 81*	03/29/14	07/16/14	109
JU	VR	245	*ENSCO 81*	08/03/14	08/08/14	5
JU	VR	245	*ENSCO 81*	11/10/14	01/28/15	51
JU	VR	252	*HERCULES 251*	04/01/14	04/30/14	29
JU	VR	252	*HERCULES 251*	04/30/14	06/24/14	55
JU	VR	261	*HERCULES 214*	01/09/14	03/16/14	66
JU	VR	282	*DIAMOND OCEAN KING*	03/16/14	11/20/14	249
JU	VR	282	*SPARTAN 208*	12/27/13	01/19/14	18
JU	VR	284	*HERCULES 263*	11/09/13	02/10/14	40
JU	VR	342	*HERCULES 300*	09/07/14	11/20/14	74
JU	VR	356	*ROWAN LOUISIANA*	01/14/14	04/05/14	81

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
JU	VR	45	*HERCULES 200*	12/02/13	01/25/14	24
JU	WC	170	*HERCULES 212*	04/09/14	04/25/14	16
JU	WC	176	*ENSCO 81*	10/12/13	03/08/14	66
JU	WC	210	*HERCULES 214*	12/05/13	01/08/14	7
JU	WD	27	*SPARTAN 303*	12/12/13	02/15/14	45
JU	WD	28	*HERCULES 205*	04/07/14	04/21/14	14
JU	WD	28	*HERCULES 205*	04/21/14	05/02/14	11
JU	WD	28	*HERCULES 253*	03/14/14	05/30/14	77
JU	WD	29	*HERCULES 209*	04/02/14	05/25/14	53
JU	WD	29	*HERCULES 209*	05/28/14	07/22/14	55
JU	WD	29	*HERCULES 209*	07/23/14	09/05/14	44
JU	WD	29	*HERCULES 209*	09/05/14	10/11/14	36
JU	WD	29	*HERCULES 213*	02/17/14	03/24/14	35
JU	WD	30	*DIAMOND OCEAN KING*	11/22/13	02/10/14	40
JU	WD	30	*ENSCO 99*	02/16/14	03/07/14	19
JU	WD	30	*ENSCO 99*	03/08/14	04/12/14	35
JU	WD	30	*ENSCO 99*	04/12/14	05/19/14	37
JU	WD	30	*ENSCO 99*	05/19/14	06/28/14	40
JU	WD	30	*ENSCO 99*	06/28/14	07/09/14	11
JU	WD	30	*ENSCO 99*	07/09/14	07/20/14	11
JU	WD	30	*ENSCO 99*	07/20/14	09/15/14	57
JU	WD	31	*ENSCO 82*	11/30/14	12/28/14	28
JU	WD	59	*HERCULES 253*	09/30/13	01/30/14	29
JU	WD	68	*ROWAN CECIL PROVINE*	11/21/13	01/20/14	19
LB	BA	A 23	* LIFT BOAT (LAKE JACKSON)	07/09/14	07/19/14	10
LB	BA	A 23	* LIFT BOAT (LAKE JACKSON)	07/09/14	07/30/14	21
LB	EC	24	* LIFT BOAT	07/27/14	08/16/14	20
LB	EC	281	* LIFT BOAT (LAKE CHARLES DIST	12/15/14	03/30/15	16
LB	EC	299	* LIFT BOAT (LAKE CHARLES DIST	11/26/14	02/24/15	35
LB	EC	320	* LIFT BOAT	09/14/14	10/26/14	42
LB	EC	46	* LIFT BOAT (LAKE CHARLES DIST	02/06/14	02/28/14	22
LB	EC	46	* LIFT BOAT (LAKE CHARLES DIST	04/19/14	05/03/14	14
LB	EC	64	* LIFT BOAT (LAKE CHARLES DIST	05/18/14	06/17/14	30
LB	EC	82	* LIFT BOAT (LAKE CHARLES DIST	05/02/14	05/14/14	12
LB	EC	82	* LIFT BOAT (LAKE CHARLES DIST	11/26/14	12/01/14	5
LB	EC	83	* LIFT BOAT (LAKE CHARLES DIST	09/05/14	10/10/14	35
LB	EC	83	* LIFT BOAT (LAKE CHARLES DIST	12/03/14	12/18/15	28
LB	EI	105	* LIFT BOAT	03/30/14	04/17/14	18
LB	EI	105	* LIFT BOAT	04/13/14	04/25/14	12
LB	EI	105	* LIFT BOAT	04/25/14	05/12/14	17
LB	EI	105	* LIFT BOAT	05/16/14	06/12/14	27
LB	EI	107	* LIFT BOAT	06/15/14	06/30/14	15
LB	EI	119	* LIFT BOAT	01/19/14	02/01/14	13
LB	EI	120	* LIFT BOAT	02/05/14	02/24/14	19
LB	EI	172	* LIFT BOAT	05/06/14	06/01/14	26
LB	EI	182	* LIFT BOAT	05/18/14	05/30/14	12
LB	EI	193	* LIFT BOAT	03/18/14	03/30/14	12
LB	EI	193	* LIFT BOAT	09/29/14	10/25/14	26
LB	EI	208	* LIFT BOAT	10/08/14	10/30/14	22
LB	EI	208	* LIFT BOAT	10/30/14	02/26/15	62
LB	EI	208	* LIFT BOAT (LAF #2)	11/19/14	12/21/14	32

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
LB	EI	208	* LIFT BOAT (LAF #2)	12/21/14	12/31/14	10
LB	EI	211	* LIFT BOAT	04/25/14	05/06/14	11
LB	EI	214	* LIFT BOAT	09/03/14	09/16/14	13
LB	EI	238	* LIFT BOAT	04/23/14	05/17/14	24
LB	EI	24	* LIFT BOAT	11/18/13	02/24/14	54
LB	EI	27	* LIFT BOAT	02/16/14	02/20/14	4
LB	EI	30	* LIFT BOAT	07/17/14	08/10/14	24
LB	EI	32	* LIFT BOAT	12/18/13	02/24/14	54
LB	EI	32	* LIFT BOAT	09/19/14	09/24/14	5
LB	EI	32	* LIFT BOAT	09/24/14	09/25/14	1
LB	EI	38	* LIFT BOAT	06/18/14	06/25/14	7
LB	EI	39	* LIFT BOAT	03/06/14	03/07/14	1
LB	EI	47	* LIFT BOAT	02/22/14	02/28/14	6
LB	EI	47	* LIFT BOAT	03/30/14	04/04/14	5
LB	EI	48	* LIFT BOAT	11/19/14	11/30/14	11
LB	EI	57	* LIFT BOAT (LAFAYETTE DIST)	11/08/14	11/11/14	3
LB	EI	58	* LIFT BOAT	09/17/14	09/24/14	7
LB	EI	62	* LIFT BOAT	02/04/14	02/17/14	13
LB	EI	77	* LIFT BOAT	12/20/13	06/29/15	364
LB	EI	77	* LIFT BOAT	01/16/14	01/20/14	4
LB	EI	89	* LIFT BOAT	11/21/13	02/24/14	54
LB	EI	95	* LIFT BOAT	12/08/13	02/24/14	54
LB	EI	95	* LIFT BOAT	10/16/14	10/27/14	11
LB	EI	95	* LIFT BOAT (LAFAYETTE DIST)	10/27/14	11/08/14	12
LB	GA	151	* LIFT BOAT	02/08/13	03/05/14	63
LB	GA	209	* LIFT BOAT	04/24/14	05/03/14	9
LB	GA	225	* LIFT BOAT (LAKE JACKSON)	08/26/14	08/31/14	5
LB	GA	301	* LIFT BOAT (L.J. #3)	10/11/13	03/05/14	63
LB	GI	75	* LIFT BOAT (N.O. #3)	02/03/14	03/15/14	40
LB	HI	110	* LIFT BOAT (LAKE JACKSON)	01/03/14	03/13/14	69
LB	HI	110	* LIFT BOAT (LAKE JACKSON)	07/14/14	07/23/14	9
LB	HI	110	* LIFT BOAT (LAKE JACKSON)	07/23/14	08/02/14	10
LB	HI	116	* LIFT BOAT (LAKE JACKSON)	09/14/14	10/28/14	44
LB	HI	154	* LIFT BOAT (LAKE JACKSON)	10/10/14	11/04/14	25
LB	HI	176	* LIFT BOAT (LAKE JACKSON)	01/19/14	02/09/14	21
LB	HI	176	* LIFT BOAT (LAKE JACKSON)	01/22/14	02/10/14	19
LB	HI	179	* LIFT BOAT (L.J. #2))	08/01/13	03/05/14	63
LB	HI	A 171	* LIFT BOAT (LAKE JACKSON)	07/20/14	08/03/14	14
LB	HI	A 171	* LIFT BOAT (LAKE JACKSON)	12/17/14	12/28/14	11
LB	HI	A 268	* LIFT BOAT (L.J. #3)	05/16/14	06/04/14	19
LB	HI	A 334	* LIFT BOAT (L.J. #2))	09/03/14	10/12/14	39
LB	MI	519	* LIFT BOAT (LAKE JACKSON)	06/25/14	07/20/14	25
LB	MI	623	* LIFT BOAT (LAKE JACKSON)	06/14/14	06/20/14	6
LB	MI	683	* LIFT BOAT (LAKE JACKSON)	05/27/14	06/06/14	10
LB	MO	991	* LIFT BOAT (N.O. #2)	05/18/14	07/03/14	46
LB	MP	101	* LIFT BOAT (N.O. #3)	09/19/14	10/06/14	17
LB	MP	107	* LIFT BOAT (N.O. #3)	10/03/14	10/12/14	9
LB	MP	125	* LIFT BOAT (N.O. #2)	12/22/13	02/04/14	34
LB	MP	41	* LIFT BOAT (N.O. #2)	04/12/14	04/23/14	11
LB	MP	41	* LIFT BOAT (NEW ORLEANS DIST)	04/14/14	07/13/14	90
LB	MU	726	* LIFT BOAT (LAKE JACKSON)	02/13/14	02/28/14	15

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
LB	SM	10	* LIFT BOAT	03/04/14	03/30/14	26
LB	SM	212	* LIFT BOAT	03/18/14	03/19/14	1
LB	SM	212	* LIFT BOAT	03/21/14	05/02/14	42
LB	SM	212	* LIFT BOAT	06/15/14	06/20/14	5
LB	SM	212	* LIFT BOAT	10/06/14	10/18/14	12
LB	SM	217	* LIFT BOAT	02/28/14	03/13/14	13
LB	SM	217	* LIFT BOAT	03/20/14	03/27/14	7
LB	SM	217	* LIFT BOAT	04/22/14	04/27/14	5
LB	SM	217	* LIFT BOAT	11/07/14	11/12/14	5
LB	SM	234	* LIFT BOAT	10/17/14	12/15/14	59
LB	SM	236	* LIFT BOAT	06/25/13	02/24/14	54
LB	SM	237	* LIFT BOAT	03/13/14	03/19/14	6
LB	SM	237	* LIFT BOAT	09/21/14	09/27/14	6
LB	SM	238	* LIFT BOAT	02/20/14	03/04/14	12
LB	SM	238	* LIFT BOAT	07/26/14	07/29/14	3
LB	SM	239	* LIFT BOAT	05/28/14	06/02/14	5
LB	SM	240	* LIFT BOAT	05/10/14	05/18/14	8
LB	SM	265	* LIFT BOAT	05/16/14	06/06/14	21
LB	SM	288	* LIFT BOAT	06/29/14	07/05/14	6
LB	SM	34	* LIFT BOAT	05/15/14	05/25/14	10
LB	SM	34	* LIFT BOAT	11/01/14	11/15/14	14
LB	SM	39	* LIFT BOAT	02/17/14	02/27/14	10
LB	SM	40	* LIFT BOAT	02/27/14	03/30/14	31
LB	SM	48	* LIFT BOAT	05/15/13	02/24/14	54
LB	SM	48	* LIFT BOAT	01/18/14	05/21/14	123
LB	SM	48	* LIFT BOAT	05/21/14	06/08/14	18
LB	SM	99	* LIFT BOAT	04/13/14	04/28/14	15
LB	SS	149	* LIFT BOAT (HOUMA DIST)	02/02/14	03/29/14	55
LB	SS	214	* LIFT BOAT (HOUMA #2)	01/16/14	03/02/14	45
LB	SX	17	* LIFT BOAT	02/10/14	03/17/14	35
LB	VK	900	* LIFT BOAT (N.O. #3)	05/14/14	08/05/14	83
LB	VR	131	* LIFT BOAT (LAKE CHARLES DIST	02/28/14	04/19/14	50
LB	VR	200	* LIFT BOAT (LAKE CHARLES DIST	07/10/14	07/30/14	20
LB	VR	214	* LIFT BOAT (LAKE CHARLES DIST	12/05/13	01/16/14	15
LB	VR	255	* LIFT BOAT (LAKE CHARLES DIST	07/03/14	07/05/14	2
LB	VR	256	* LIFT BOAT (LAKE CHARLES DIST	04/26/14	05/03/14	7
LB	VR	256	* LIFT BOAT (LAKE CHARLES DIST	07/07/14	07/14/14	7
LB	VR	26	* LIFT BOAT	03/22/14	04/11/14	20
LB	VR	26	* LIFT BOAT (LAKE CHARLES DIST	01/19/14	02/10/14	22
LB	VR	26	* LIFT BOAT (LAKE CHARLES DIST	08/17/14	09/14/14	28
LB	VR	26	* LIFT BOAT (LAKE CHARLES DIST	11/27/14	12/17/14	20
LB	VR	26	* LIFT BOAT (LAKE CHARLES DIST	12/17/14	12/20/14	3
LB	VR	267	* LIFT BOAT (LAKE CHARLES DIST	06/30/14	07/03/14	3
LB	VR	30	* LIFT BOAT (LAKE CHARLES DIST	02/08/14	02/10/14	2
LB	VR	35	* LIFT BOAT	07/08/14	07/16/14	8
LB	VR	35	* LIFT BOAT (L.C.#3)	10/07/14	11/01/14	25
LB	VR	35	* LIFT BOAT (LAKE CHARLES DIST	11/10/14	11/26/14	16
LB	VR	38	* LIFT BOAT (LAKE CHARLES DIST	12/29/13	01/06/14	5
LB	VR	38	* LIFT BOAT (LAKE CHARLES DIST	09/29/14	10/08/14	9
LB	VR	39	* LIFT BOAT (L.C.#2)	06/02/14	06/09/14	7
LB	VR	39	* LIFT BOAT (LAKE CHARLES DIST	02/13/14	03/24/14	39

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
LB	VR	39	* LIFT BOAT (LAKE CHARLES DIST	05/18/14	05/20/14	2
LB	VR	67	* LIFT BOAT (L.C.#2)	03/01/14	03/08/14	7
LB	VR	67	* LIFT BOAT (LAKE CHARLES DIST	05/15/14	05/28/14	13
LB	VR	67	* LIFT BOAT (LAKE CHARLES DIST	10/09/14	10/16/14	7
LB	VR	96	* LIFT BOAT (LAKE CHARLES DIST	07/09/14	07/16/14	7
LB	WC	112	* LIFT BOAT (LAKE CHARLES DIST	11/02/14	11/10/14	8
LB	WC	170	* LIFT BOAT (L.C.#2)	11/08/14	12/05/14	27
LB	WC	170	* LIFT BOAT (LAKE CHARLES DIST	06/07/14	06/23/14	16
LB	WC	172	* LIFT BOAT (LAKE CHARLES DIST	04/12/14	04/22/14	10
LB	WC	173	* LIFT BOAT (LAKE CHARLES DIST	04/02/14	04/07/14	5
LB	WC	198	* LIFT BOAT (LAKE CHARLES DIST	04/07/14	04/23/14	16
LB	WC	198	* LIFT BOAT (LAKE CHARLES DIST	12/22/14	01/20/15	9
LB	WC	205	* LIFT BOAT (LAKE CHARLES DIST	08/07/14	08/17/14	10
LB	WC	205	* LIFT BOAT (LAKE CHARLES DIST	09/15/14	09/28/14	13
LB	WC	290	* LIFT BOAT	05/29/14	06/08/14	10
LB	WC	291	* LIFT BOAT (LAKE CHARLES DIST	07/01/14	07/30/14	29
LB	WC	291	* LIFT BOAT (LAKE CHARLES DIST	07/30/14	10/29/14	91
LB	WC	291	* LIFT BOAT (LAKE CHARLES DIST	11/02/14	12/04/14	32
LB	WC	39	* LIFT BOAT	04/12/14	05/06/14	24
LB	WC	575	* LIFT BOAT	05/01/14	05/22/14	21
LB	WC	575	* LIFT BOAT	05/22/14	07/01/14	40
LB	WC	62	* LIFT BOAT (LAKE CHARLES DIST	09/07/14	09/27/14	20
LB	WD	41	* LIFT BOAT (N.O. #2)	04/27/14	05/18/14	21
LB	WD	41	* LIFT BOAT (N.O. #3)	04/16/14	04/27/14	11
LB	WD	45	* LIFT BOAT (NEW ORLEANS DIST)	10/08/14	11/02/14	25
LB	WD	70	* LIFT BOAT (NEW ORLEANS DIST)	11/14/13	02/05/14	35
NR	BA	A 70	* NONE RIG PA OPERATION	02/05/14	03/05/14	28
NR	BA	A 70	* NONE RIG PA OPERATION (LJ)	09/01/12	03/05/14	63
NR	EC	81	* NONE RIG PA OPERATION (LC)	03/08/14	04/06/14	29
NR	EI	193	* NONE RIG PA OPERATION	07/08/14	07/21/14	13
NR	EI	193	* NONE RIG PA OPERATION (LAF)	02/19/14	02/24/14	5
NR	EI	273	* NONE RIG PA OPERATION	04/30/14	07/08/14	69
NR	EI	273	* NONE RIG PA OPERATION (LAF)	11/14/13	02/24/14	54
NR	EI	273	* NONE RIG PA OPERATION (LAF)	08/09/14	08/16/14	7
NR	EI	28	* NONE RIG PA OPERATION	09/22/14	09/23/14	1
NR	HI	A 350	* NONE RIG PA OPERATION (LJ)	08/01/14	11/02/14	93
NR	HI	A 467	* NONE RIG PA OPERATION (LJ)	01/12/14	03/05/14	52
NR	HI	A 472	* NONE RIG PA OPERATION (LJ)	11/25/14	11/29/14	4
NR	HI	A 571	* NONE RIG PA OPERATION (LJ)	02/09/14	02/21/14	12
NR	HI	A 571	* NONE RIG PA OPERATION (LJ)	03/09/14	05/13/14	65
NR	HI	A 571	* NONE RIG PA OPERATION (LJ)	08/21/14	08/26/14	5
NR	HI	A 582	* NONE RIG PA OPERATION (LJ)	07/01/14	09/09/14	70
NR	HI	A 596	* NONE RIG PA OPERATION (LJ)	10/12/14	03/04/15	80
NR	MC	311	* NONE RIG PA OPERATION (ALTER	07/02/14	07/10/14	8
NR	MU	A 111	* NONE RIG PA OPERATION	05/22/14	09/22/14	123
NR	SM	147	* NONE RIG PA OPERATION	09/17/14	09/23/14	6
NR	SM	147	* NONE RIG PA OPERATION (LAF)	10/28/14	10/31/14	3
NR	SM	149	* NONE RIG PA OPERATION (LAF)	05/08/14	08/09/14	93
NR	SS	293	* NONE RIG PA OPERATION (HOUMA	05/11/14	07/02/14	52
NR	VK	989	* NONE RIG PA OPERATION	12/27/14	03/19/15	4
NR	VR	287	* NONE RIG PA OPERATION (LC)	04/12/14	04/14/14	2

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
NR	WC	193	* NONE RIG PA OPERATION (LC)	09/03/14	09/12/14	9
NR	WC	22	* NONE RIG PA OPERATION (LC)	08/24/14	08/26/14	2
NR	WC	504	* NONE RIG PA OPERATION (LC)	12/09/13	01/20/14	19
NR	WC	504	* NONE RIG PA OPERATION (LC)	08/27/14	09/03/14	7
NR	WC	560	* NONE RIG PA OPERATION (LC)	02/27/14	05/11/14	73
NR	WC	575	* NONE RIG PA OPERATION (LC)	09/11/14	10/13/14	32
NR	WD	41	* NONE RIG PA OPERATION	06/04/14	08/21/14	78
PF	AC	857	*H&P 205*	12/02/13	03/13/14	71
PF	AC	857	*H&P 205*	03/13/14	06/09/14	88
PF	AC	857	*H&P 205*	06/15/14	10/23/14	130
PF	AC	857	*H&P 205*	11/22/14	12/19/14	27
PF	BA	504	* UNSPECIFIED	09/23/14	10/01/14	8
PF	EB	110	*NABORS S.D. IV*	09/18/13	02/14/14	44
PF	EB	110	*NABORS S.D. IV*	02/14/14	04/11/14	56
PF	EB	110	*NABORS S.D. IV*	04/11/14	05/30/14	49
PF	EB	110	*NABORS S.D. IV*	05/30/14	07/17/14	48
PF	EB	110	*NABORS S.D. IV*	07/17/14	08/09/14	23
PF	EB	110	*NABORS S.D. IV*	08/25/14	09/12/14	18
PF	EB	110	*NABORS S.D. IV*	09/15/14	10/13/14	28
PF	EB	110	*NABORS S.D. IV*	10/13/14	11/08/14	26
PF	EB	110	*NABORS S.D. IV*	11/08/14	01/08/15	53
PF	EC	321	*NABORS SUPER S.D. XIX*	09/20/13	08/08/14	219
PF	EI	314	*H&P 105*	12/26/13	01/26/14	25
PF	EI	314	*H&P 105*	01/26/14	02/10/14	15
PF	EI	314	*H&P 105*	02/10/14	03/31/14	49
PF	EI	314	*H&P 105*	04/01/14	04/24/14	23
PF	EI	314	*H&P 105*	04/24/14	05/03/14	9
PF	EI	314	*H&P 105*	05/03/14	06/15/14	43
PF	EI	314	*H&P 105*	06/16/14	07/16/14	30
PF	EI	314	*H&P 105*	07/24/14	08/09/14	16
PF	EI	314	*H&P 105*	08/09/14	08/12/14	3
PF	EI	314	*H&P 105*	08/13/14	08/30/14	17
PF	EI	314	*H&P 105*	09/01/14	10/26/14	55
PF	EI	314	*H&P 105*	10/26/14	11/11/14	16
PF	EI	314	*H&P 105*	11/11/14	12/20/14	39
PF	EI	314	*H&P 105*	12/21/14	01/25/15	10
PF	EI	338	*H&P 100*	12/15/13	02/11/14	41
PF	EI	338	*H&P 100*	02/11/14	03/31/14	48
PF	EI	338	*H&P 100*	04/04/14	05/26/14	52
PF	EI	338	*H&P 100*	05/29/14	05/26/14	3
PF	EI	338	*H&P 100*	05/30/14	06/26/14	27
PF	EI	338	*H&P 100*	06/26/14	08/03/14	38
PF	EI	338	*H&P 100*	08/03/14	08/15/14	12
PF	EI	338	*H&P 100*	08/17/14	09/29/14	43
PF	EI	338	*H&P 100*	10/03/14	11/13/14	41
PF	EI	338	*H&P 100*	11/21/14	01/05/15	40
PF	EW	1003	*NABORS S.D. XIV*	02/13/14	05/25/14	101
PF	EW	1003	*NABORS S.D. XIV*	12/13/14	04/01/15	18
PF	EW	826	*BLAKE 1007*	01/08/14	02/14/14	37
PF	EW	910	*H&P 203*	10/22/14	07/06/15	70
PF	GC	158	*H&P 202*	01/14/14	03/23/14	68

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
PF	GC	158	*H&P 202*	03/23/14	05/16/14	54
PF	GC	158	*H&P 202*	05/16/14	05/24/14	8
PF	GC	158	*H&P 202*	05/24/14	06/23/14	30
PF	GC	158	*H&P 202*	06/23/14	06/25/14	2
PF	GC	158	*H&P 202*	06/25/14	06/27/14	2
PF	GC	158	*H&P 202*	06/27/14	07/01/14	4
PF	GC	158	*H&P 202*	07/01/14	09/17/14	78
PF	GC	158	*H&P 202*	09/17/14	09/24/14	7
PF	GC	158	*H&P 202*	09/24/14	10/21/14	27
PF	GC	158	*H&P 202*	10/21/14	01/09/15	71
PF	GC	18	*NABORS MODS 201*	12/08/14	06/27/15	23
PF	GC	205	*NABORS 85 (MAYRONNE 162)*	01/24/14	02/16/14	23
PF	GC	205	*NABORS 85 (MAYRONNE 162)*	02/16/14	09/30/14	226
PF	GC	608	*NABORS SUPER SUNDOWNER XXI*	12/06/13	02/28/14	58
PF	GC	608	*NABORS SUPER SUNDOWNER XXI*	03/01/14	04/27/14	57
PF	GC	608	*NABORS SUPER SUNDOWNER XXI*	04/27/14	05/23/14	26
PF	GC	645	*HOLSTEIN SPAR RIG*	01/30/14	02/25/14	26
PF	GC	645	*HOLSTEIN SPAR RIG*	02/26/14	06/15/14	109
PF	GC	645	*HOLSTEIN SPAR RIG*	06/17/14	09/28/14	103
PF	GC	645	*HOLSTEIN SPAR RIG*	10/01/14	10/09/14	8
PF	GC	645	*HOLSTEIN SPAR RIG*	10/09/14	11/02/14	24
PF	GC	645	*HOLSTEIN SPAR RIG*	11/02/14	11/06/14	4
PF	GC	645	*HOLSTEIN SPAR RIG*	11/06/14	11/29/14	23
PF	GC	645	*HOLSTEIN SPAR RIG*	11/29/14	12/04/14	5
PF	GC	645	*HOLSTEIN SPAR RIG*	12/04/14	12/08/14	4
PF	GC	645	*HOLSTEIN SPAR RIG*	12/08/14	12/11/14	3
PF	GC	645	*HOLSTEIN SPAR RIG*	12/11/14	01/26/15	20
PF	GC	65	*H&P 206*	12/02/13	05/18/14	137
PF	GC	65	*H&P 206*	05/21/14	07/27/14	67
PF	GC	65	*H&P 206*	07/27/14	12/16/14	142
PF	GC	65	*H&P 206*	12/16/14	02/07/15	15
PF	GC	680	*BLAKE 1007*	03/10/14	07/06/14	118
PF	GC	782	*MAD DOG SPAR RIG*	08/17/14	08/15/15	136
PF	GC	782	*PRIDE MAD DOG SPAR RIG*	02/17/14	04/24/14	66
PF	GC	782	*PRIDE MAD DOG SPAR RIG*	07/23/14	09/23/14	62
PF	HI	A 595	*BLAKE 1505*	11/22/13	03/15/14	73
PF	MC	21	*NABORS MODS 200*	08/06/14	10/13/14	68
PF	MC	21	*NABORS MODS 200*	10/13/14	12/22/14	70
PF	MC	21	*NABORS MODS 200*	12/22/14	03/17/15	9
PF	MC	773	*NABORS POOL 140*	01/25/14	08/22/14	209
PF	MC	778	*THUNDER HORSE PDQ*	08/02/13	02/23/14	53
PF	MC	778	*THUNDER HORSE PDQ*	02/24/14	04/24/14	59
PF	MC	778	*THUNDER HORSE PDQ*	06/28/14	07/04/14	6
PF	MC	778	*THUNDER HORSE PDQ*	11/14/14	02/26/15	47
PF	MC	807	*H&P 201*	12/15/13	03/08/15	364
PF	MC	809	*H&P 204*	02/02/14	03/13/14	39
PF	MC	809	*H&P 204*	06/05/14	11/04/14	152
PF	SM	128	*BLAKE 210*	10/12/13	01/06/14	5
PF	SM	128	*BLAKE 210*	01/08/14	01/20/14	12
PF	SM	128	*BLAKE 210*	01/22/14	03/03/14	40
PF	SM	130	*NABORS S.D. XVI*	10/02/13	01/12/14	11

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
PF	SM	130	*NABORS S.D. XVI*	01/12/14	03/19/14	66
PF	SM	130	*NABORS S.D. XVI*	03/19/14	04/14/14	26
PF	SM	130	*NABORS S.D. XVI*	04/14/14	05/12/14	28
PF	SM	130	*NABORS S.D. XVI*	05/13/14	06/10/14	28
PF	SM	144	** UNSPECIFIED - DO NOT DELETE*	10/12/14	10/17/14	5
PF	SP	58	*BLAKE 210*	12/15/14	01/09/15	16
PF	SP	62	*BLAKE 14*	12/18/13	03/10/14	68
PF	SS	349	*H&P 107*	12/14/13	04/27/14	116
PF	SS	349	*H&P 107*	05/29/14	11/03/14	158
PF	SS	349	*H&P 107*	11/03/14	12/09/14	36
PF	SS	349	*H&P 107*	12/25/14	01/23/15	6
PF	VK	786	*NABORS 87*	12/24/13	01/12/14	11
PF	VK	786	*NABORS 87*	03/18/14	04/02/14	15
PF	VK	786	*NABORS 87*	12/14/14	01/03/15	17
PF	VK	956	*NABORS 202*	10/23/13	01/14/14	13
PF	VK	956	*NABORS 202*	01/14/14	06/22/14	159
PF	VK	956	*NABORS 202*	07/11/14	09/19/14	70
PF	VK	956	*NABORS 202*	09/20/14	09/22/14	2
PF	VK	956	*NABORS 202*	10/28/14	11/10/14	13
PF	VK	956	*NABORS 202*	11/10/14	11/13/14	3
PF	VK	956	*NABORS 202*	11/12/14	05/17/15	49
PF	VR	379	*BLAKE 1505*	05/24/14	11/25/14	185
PF	WD	73	*NABORS 17*	12/31/13	02/07/14	37
PF	WD	73	*NABORS MODS RIG 150*	05/08/14	07/25/14	78
PF	WD	73	*NABORS MODS RIG 150*	07/25/14	09/19/14	56
PF	WD	73	*NABORS MODS RIG 150*	09/19/14	11/07/14	49
PF	WD	73	*NABORS MODS RIG 150*	11/07/14	12/25/14	48
PF	WD	73	*NABORS MODS RIG 150*	12/25/14	03/10/15	6
PF	WD	74	*NABORS 17*	05/29/14	06/15/14	17
PF	WD	74	*NABORS 17*	06/15/14	07/09/14	24
PF	WD	74	*NABORS 17*	07/09/14	09/15/14	68
PF	WD	74	*NABORS 17*	09/15/14	10/02/14	17
PF	WD	74	*NABORS 17*	10/02/14	12/30/14	89
SD	AT	261	*CAL-DIVE Q-4000*	08/02/14	08/14/14	12
SD	AT	349	*CAL-DIVE Q-4000*	07/08/14	07/18/14	10
SD	AT	349	*CAL-DIVE Q-4000*	08/14/14	08/07/14	7
SD	AT	575	*T.O. DEVELOPMENT DRILLER I*	12/24/13	02/20/14	50
SD	DC	231	*MAERSK DEVELOPER*	09/18/14	12/20/14	93
SD	EB	645	*ENSCO 8506*	08/25/13	06/23/14	173
SD	EB	646	*ENSCO 8500*	12/10/13	03/14/14	72
SD	EW	1006	* DP SEMI RIG TO BE DETERMINED	09/21/14	09/22/14	1
SD	EW	913	* DP SEMI RIG TO BE DETERMINED	06/30/14	07/15/14	15
SD	EW	913	* DP SEMI RIG TO BE DETERMINED	07/15/14	07/28/14	13
SD	GB	515	*ENSCO 8503*	04/04/14	06/04/14	61
SD	GC	237	*ENSCO 8502*	07/16/14	07/21/14	5
SD	GC	237	*ENSCO 8502*	09/28/14	01/11/15	94
SD	GC	40	*ENSCO 8501*	03/15/14	09/15/14	184
SD	GC	452	*MAERSK DEVELOPER*	04/06/14	04/16/14	10
SD	GC	627	*SEADRILL WEST SIRIUS*	05/27/14	04/26/15	218
SD	GC	683	*ENSCO 8505*	01/05/14	03/17/14	71
SD	GC	683	*ENSCO 8505*	04/14/14	07/11/14	88

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
SD	GC	683	*ENSCO 8505*	04/14/14	08/20/14	128
SD	GC	726	*ENSCO 8505*	03/17/14	04/14/14	28
SD	GC	743	*T.O. DEVELOPMENT DRILLER II*	06/17/13	04/18/14	107
SD	GC	743	*T.O. DEVELOPMENT DRILLER III*	09/05/13	04/07/14	96
SD	GC	743	*T.O. DEVELOPMENT DRILLER III*	05/15/14	07/24/14	70
SD	GC	743	*T.O. DEVELOPMENT DRILLER III*	11/16/14	01/26/15	45
SD	GC	903	*ENSCO 8505*	07/11/14	04/14/14	88
SD	GC	903	*ENSCO 8506*	06/29/14	07/17/14	18
SD	GC	903	*ENSCO 8506*	07/17/14	12/06/14	142
SD	GC	903	*ENSCO 8506*	12/06/14	12/18/14	12
SD	GC	903	*ENSCO 8506*	12/18/14	02/17/15	13
SD	KC	57	*SEADRILL WEST SIRIUS*	07/29/13	05/18/14	137
SD	KC	875	*ENSCO 8500*	04/17/14	08/06/14	111
SD	KC	875	*ENSCO 8500*	08/13/14	11/02/14	81
SD	KC	919	*ENSCO 8500*	11/02/14	03/18/15	59
SD	LL	399	*CAL-DIVE Q-4000*	06/04/14	06/07/14	3
SD	LL	399	*CAL-DIVE Q-4000*	06/07/14	06/18/14	11
SD	LL	399	*CAL-DIVE Q-4000*	06/18/14	07/08/14	20
SD	LL	399	*CAL-DIVE Q-4000*	08/17/14	08/19/14	2
SD	LL	399	*CAL-DIVE Q-4000*	08/19/14	08/21/14	2
SD	LL	399	*CAL-DIVE Q-4000*	08/26/14	08/31/14	5
SD	LL	5	*CAL-DIVE Q-4000*	05/09/14	05/25/14	16
SD	LL	5	*CAL-DIVE Q-4000*	08/23/14	08/26/14	3
SD	LL	5	*CAL-DIVE Q-4000*	09/02/14	09/27/14	25
SD	LL	50	*CAL-DIVE Q-4000*	05/25/14	06/04/14	10
SD	LL	50	*CAL-DIVE Q-4000*	08/21/14	08/23/14	2
SD	LL	50	*CAL-DIVE Q-4000*	08/31/14	09/02/14	2
SD	LL	50	*CAL-DIVE Q-4000*	11/05/14	11/17/14	12
SD	LL	50	*CAL-DIVE Q-4000*	12/06/14	01/23/15	25
SD	MC	204	*ENSCO 8501*	12/15/13	01/08/14	7
SD	MC	215	*ENSCO 8505*	11/07/14	03/17/15	54
SD	MC	253	*ENSCO 8503*	10/15/14	02/07/15	77
SD	MC	29	*ENSCO 8502*	01/03/14	01/18/14	15
SD	MC	29	*ENSCO 8502*	01/19/14	01/25/14	6
SD	MC	29	*ENSCO 8502*	01/25/14	03/14/14	48
SD	MC	29	*ENSCO 8502*	03/14/14	05/03/14	50
SD	MC	29	*ENSCO 8502*	05/03/14	05/09/14	6
SD	MC	29	*ENSCO 8502*	05/09/14	05/12/14	3
SD	MC	29	*ENSCO 8502*	05/12/14	06/06/14	25
SD	MC	29	*ENSCO 8502*	06/06/14	07/12/14	36
SD	MC	292	** RIG TO BE DETERMINED DP SEM	05/13/14	06/06/14	24
SD	MC	300	*SEADRILL SEVAN LOUISIANA*	12/17/14	03/08/15	14
SD	MC	479	*ENSCO 8501*	10/26/14	01/14/15	66
SD	MC	503	*ENSCO 8503*	07/07/14	08/25/14	49
SD	MC	674	*ENSCO 8505*	09/08/14	10/23/14	45
SD	MC	687	*ATWOOD CONDOR*	07/09/14	11/29/14	143
SD	MC	687	*ATWOOD CONDOR*	11/29/14	12/17/14	18
SD	MC	687	*ATWOOD CONDOR*	12/17/14	01/03/15	14
SD	MC	687	*CAL-DIVE Q-4000*	02/28/14	03/19/14	19
SD	MC	687	*CAL-DIVE Q-4000*	03/19/14	03/29/14	10
SD	MC	687	*CAL-DIVE Q-4000*	03/29/14	04/11/14	13

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
SD	MC	687	*CAL-DIVE Q-4000*	04/11/14	04/16/14	5
SD	MC	687	*CAL-DIVE Q-4000*	04/12/14	04/23/14	11
SD	MC	687	*CAL-DIVE Q-4000*	04/16/14	04/21/14	5
SD	MC	687	*CAL-DIVE Q-4000*	04/23/14	04/26/14	3
SD	MC	687	*CAL-DIVE Q-4000*	04/26/14	04/28/14	2
SD	MC	698	*ENSCO 8501*	01/08/14	03/12/14	63
SD	MC	718	*MAERSK DEVELOPER*	04/18/14	09/16/14	151
SD	MC	727	*NOBLE DANNY ADKINS*	11/17/14	06/23/15	44
SD	MC	754	*SEADRILL SEVAN LOUISIANA*	11/03/14	12/16/14	43
SD	MC	775	*SEADRILL WEST CAPRICORN*	06/26/14	07/16/14	20
SD	MC	775	*SEADRILL WEST CAPRICORN*	07/25/14	07/29/14	4
SD	MC	775	*SEADRILL WEST CAPRICORN*	08/13/14	01/28/15	140
SD	MC	777	*SEADRILL WEST CAPRICORN*	01/06/14	06/22/14	167
SD	MC	79	*SEADRILL SEVAN LOUISIANA*	05/27/14	11/03/14	160
SD	MC	809	*CAL-DIVE Q-4000*	12/14/13	01/24/14	23
SD	MC	810	*CAL-DIVE Q-4000*	01/24/14	02/28/14	35
SD	MC	812	*NOBLE DANNY ADKINS*	04/28/14	09/08/14	133
SD	MC	894	*NOBLE DANNY ADKINS*	08/05/13	04/27/14	116
SD	MC	934	*ATWOOD CONDOR*	08/31/13	02/20/14	50
SD	MC	934	*ATWOOD CONDOR*	02/27/14	07/09/14	132
SD	MC	961	*MAERSK DEVELOPER*	03/01/14	04/04/14	34
SD	MC	983	*ENSCO 8505*	09/05/13	01/04/14	3
SD	WR	160	*MAERSK DEVELOPER*	12/24/14	03/18/15	7
SD	WR	508	*NOBLE JIM DAY*	11/03/13	02/13/14	43
SD	WR	508	*NOBLE JIM DAY*	02/13/14	07/23/14	160
SD	WR	508	*NOBLE JIM DAY*	07/23/14	03/19/15	161
SS	GB	169	*DIAMOND OCEAN ONYX*	01/13/14	06/06/14	144
SS	GB	427	*NOBLE JIM THOMPSON*	10/13/13	01/11/14	10
SS	GB	427	*NOBLE JIM THOMPSON*	02/13/14	06/24/14	131
SS	GB	427	*NOBLE JIM THOMPSON*	07/13/14	10/15/14	94
SS	GB	427	*NOBLE JIM THOMPSON*	10/19/14	11/25/14	37
SS	GB	427	*NOBLE JIM THOMPSON*	12/08/14	12/21/14	13
SS	GB	427	*NOBLE JIM THOMPSON*	12/29/14	01/15/15	2
SS	GC	113	*NOBLE DRILLER*	12/23/13	01/06/14	5
SS	GC	113	*NOBLE DRILLER*	12/27/13	06/26/14	176
SS	GC	113	*NOBLE DRILLER*	06/26/14	07/05/14	9
SS	GC	155	*NOBLE DRILLER*	07/05/14	11/28/14	146
SS	GC	248	*T.O. DEEPWATER NAUTILUS*	11/26/13	02/15/14	45
SS	GC	248	*T.O. DEEPWATER NAUTILUS*	02/25/14	02/17/15	309
SS	MC	26	*DIAMOND OCEAN VICTORY*	11/03/13	03/05/14	63
SS	MC	503	*NOBLE AMOS RUNNER*	12/24/13	06/09/14	159
SS	MC	546	*NOBLE AMOS RUNNER*	11/12/14	03/31/15	49
SS	MC	705	*DIAMOND OCEAN SARATOGA*	12/09/13	04/18/14	107
SS	MC	707	*DIAMOND OCEAN SARATOGA*	04/19/14	06/20/14	62
SS	MC	718	*DIAMOND OCEAN ONYX*	11/10/14	12/06/14	26
SS	MC	718	*DIAMOND OCEAN ONYX*	12/07/14	02/12/15	24

APPENDIX C.3: HELICOPTER EMISSION FACTORS

Table C.3-1. Helicopter emission factors by helicopter and helicopter type

Type	Code	Aircraft ICAO	Aircraft Name	Engine Name	LTO Fuel (kg)	LTO NO_x (g)	LTO HC (g)	LTO CO (g)	LTO PM Non Volatile (g)
Single	H001	ALO2	*ALOUETTE II*	ARTOUSTE IIC5	51.9	213	1128	1464	7.8
Single	H001	ALO2	*ALOUETTE II*	ARTOUSTE IIC6	51.9	213	1128	1464	7.8
Single	H001	ALO3	*SA316B ALOUETTE III*	ARTOUSTE IIIB	61.0	305	917	1179	10.2
Single	H001	ALO3	*SA316B ALOUETTE III*	ASTAZOU XIVB	62.4	322	892	1144	10.7
Single	H001	AS35	*AS 350 B3*	ARRIEL 2B	78.2	502	732	928	15.5
Single	H001	AS35	*AS 350 B3*	ARRIEL 2B1	78.2	502	732	928	15.5
Single	H001	AS35	*AS 350 ECUREUIL*	ARRIEL 1B	66.9	362	862	1103	11.8
Single	H001	AS35	*AS 350B ECUREUIL*	ARRIEL 1D1	71.9	422	797	1015	13.4
Single	H001	AS50	*AS 550 FENNEC*	ARRIEL 1D1	71.9	422	797	1015	13.4
Single	H001	B06	*BELL 206B*	DDA250-C20	51.8	212	1132	1469	7.8
Single	H001	B06	*BELL 206B*	DDA250-C20B	53.0	223	1098	1423	8.1
Single	H001	B06	*BELL 206B*	DDA250-C20J	53.0	223	1098	1423	8.1
Single	H001	B06	*BELL 206B*	DDA250-C20R	54.7	240	1052	1361	8.5
Single	H001	B06	*BELL 206B*	DDA250-C20R/4	54.7	240	1052	1361	8.5
Single	H001	B06	*BELL 206L*	DDA250-C20R	54.7	240	1052	1361	8.5
Single	H001	B06	*BELL 206L*	DDA250-C30	67.4	368	855	1094	11.9
Single	H001	B06	*BELL 206L*	DDA250-C30P	67.4	368	855	1094	11.9
Single	H001	B407	*Bell 407*	DDA250-C47B	67.4	368	855	1094	11.9
Single	H001	EC20	*EC 120*	ARRIUS 2F	53.6	230	1079	1397	8.3
Single	H001	EC30	*EC 130 B4*	ARRIEL 2B1	78.2	502	732	928	15.5
Single	H001	EN48	*ENSTROM 480*	DDA250-C20W	53.0	223	1098	1423	8.1
Single	H001	GAZL	*SA341 GAZELLE*	ASTAZOU IIIA	67.1	364	860	1100	11.8
Single	H001	GAZL	*SA341 GAZELLE*	ASTAZOU IIIN2	67.1	364	860	1100	11.8
Single	H001	GAZL	*SA342 GAZELLE*	ASTAZOU XIVG	62.4	322	892	1144	10.7
Single	H001	GAZL	*SA342 GAZELLE*	ASTAZOU XIVH	62.4	322	892	1144	10.7
Single	H001	H500	*HUGHES 500*	DDA250-C18	47.0	169	1310	1712	6.6
Single	H001	H500	*HUGHES 501*	DDA250-C20B	53.0	223	1098	1423	8.1
Single	H001	H500	*MD 500N*	DDA250-C20R	54.7	240	1052	1361	8.5
Single	H001	KMAX	*K-1200*	T53 17A-1	123.5	1097	616	767	31.2
Single	H001	LAMA	*SA315B LAMA*	ARTOUSTE IIIB	61.0	305	917	1179	10.2

Type	Code	Aircraft ICAO	Aircraft Name	Engine Name	LTO Fuel (kg)	LTO NO_x (g)	LTO HC (g)	LTO CO (g)	LTO PM Non Volatile (g)
Single	H001	MD52	*MD 520N*	DDA250-C20	51.8	212	1132	1469	7.8
Single	H001	MD60	*MD 600N*	DDA250-C47M	67.4	368	855	1094	11.9
Single	H002	UH1	*BELL UH-1H*	T53 L13	118.9	1013	641	800	29.1
Single	H013	A119	*AGUSTA A119*	PT6B-37	81.0	539	708	896	16.5
AVERAGE of Single					**65.3**	**360**	**935**	**1202**	**11.7**
Twin Light	H001	A109	*AGUSTA A109*	DDA250-C20R/1	96.1	389	2808	3695	14.5
Twin Light	H001	A109	*AGUSTA A109*	PW207C	118.2	594	2298	2991	20.0
Twin Light	H001	A109	*AGUSTA A109 K2*	ARRIEL1K1	126.1	684	2123	2753	22.4
Twin Light	H001	A109	*AGUSTA A109 Power*	ARRIUS 2K	119.9	614	2255	2932	20.5
Twin Light	H001	A109	*AGUSTA A109A II*	DDA250-C20B	93.3	363	2932	3866	13.8
Twin Light	H001	A109	*AGUSTA A109C*	DDA250-C20R	96.1	389	2808	3695	14.5
Twin Light	H001	AS55	*AS 355*	DDA250-C20F	93.3	363	2932	3866	13.8
Twin Light	H001	AS55	*AS 355 N*	ARRIUS 1A	98.9	416	2697	3543	15.2
Twin Light	H001	AS55	*AS 555 FENNEC*	ARRIEL 1D1	123.7	657	2171	2818	21.7
Twin Light	H001	B06T	*Bell TWIN RANGER*	DDA250-C20R	96.1	389	2808	3695	14.5
Twin Light	H001	B105	*BO 105*	DDA250-C20	91.4	346	3024	3993	13.3
Twin Light	H001	B105	*BO 105*	DDA250-C20B	93.3	363	2932	3866	13.8
Twin Light	H001	B222	*BELL 222*	DDA250-C40B	124.0	660	2165	2810	21.8
Twin Light	H001	B222	*BELL 222*	LTS101-750C.1	125.8	681	2129	2760	22.3
Twin Light	H001	EC35	*EC 135*	ARRIUS 2B1	116.6	577	2337	3044	19.6
Twin Light	H001	EC35	*EC 135*	ARRIUS 2B2	116.6	577	2337	3044	19.6
Twin Light	H019	EXPL	*MD 900*	PW206A	115.6	565	2366	3083	19.3
Twin Light	H021	A109	*AGUSTA A109E*	PW206C	105.4	480	2482	3248	16.9
AVERAGE of Twin Light					**108.4**	**506**	**2534**	**3317**	**17.6**
Twin Medium	H001	AS65	*AS 365 C1 DAUPHIN*	ARRIEL 1A1	117.4	585	2319	3019	19.8
Twin Medium	H001	AS65	*AS 365 C2 DAUPHIN*	ARRIEL 1A2	117.4	585	2319	3019	19.8
Twin Medium	H001	AS65	*AS 365 N DAUPHIN*	ARRIEL 1C	119.1	604	2276	2961	20.3
Twin Medium	H001	AS65	*AS 365 N1 DAUPHIN*	ARRIEL 1C1	122.6	644	2194	2849	21.4
Twin Medium	H001	AS65	*AS 365 N3 DAUPHIN*	ARRIEL 2C	135.2	794	1965	2538	25.3
Twin Medium	H001	B430	*Bell 430*	DDA250-C40B	124.0	660	2165	2810	21.8
Twin Medium	H001	BK17	*BK117*	ARRIEL 1E2	126.1	684	2123	2753	22.4

Type	Code	Aircraft ICAO	Aircraft Name	Engine Name	LTO Fuel (kg)	LTO NO_x (g)	LTO HC (g)	LTO CO (g)	LTO PM Non Volatile (g)
Twin Medium	H001	BK17	*BK117 C-2*	ARRIEL 1E2	126.1	684	2123	2753	22.4
Twin Medium	H001	BK17	*BK117B*	LTS101-750B.1	125.1	672	2143	2780	22.1
Twin Medium	H001	EC55	*EC 155 B*	ARRIEL 2C1	135.2	794	1965	2538	25.3
Twin Medium	H001	EC55	*EC 155 B1*	ARRIEL 2C2	144.6	913	1834	2359	28.5
Twin Medium	H001	S76	*SIKORSKY S76*	DDA250-C30S	118.2	594	2298	2991	20.0
Twin Medium	H001	S76	*SIKORSKY S-76 C+*	ARRIEL 2S1	136.7	813	1942	2506	25.8
Twin Medium	H002	A139	*AGUSTA A139*	PT6C-67C	171.2	1052	2221	2856	33.1
Twin Medium	H002	H60	*SIKORSKY BLACK HAWK*	T700-GE-700	206.8	1599	1712	2174	47.2
Twin Medium	H002	MI8	*MIL MI-8*	TV2-117	198.7	1467	1801	2293	43.8
Twin Medium	H002	S92	*SIKORSKY S92A*	GE CT7-8A	278.7	2967	1248	1559	80.5
Twin Medium	H011	S76	*SIKORSKY S76*	PT6B-36A	147.9	956	1793	2305	29.6
Twin Medium	H014	B412	*Bell 412*	PT6T-3	218.3	1798	1602	2028	52.3
Twin Medium	HF30	AS32	*SUPER PUMA*	MAKILA 1A1	219.6	1820	1591	2013	52.9
AVERAGE of Twin Medium					**154.4**	**1034**	**1982**	**2555**	**31.7**
Twin Heavy	H001	KA27	*KA-32A12*	TV3-117VMA	244.2	2271	1417	1782	64.1
Twin Heavy	H002	H53	*SIKORSKY CH-53G (S-65)*	T 64-GE-7	354.0	4695	1031	1273	115.1
Twin Heavy	H002	H53S	*SIKORSKY SUPER STALLION*	T 64-GE-7	531.0	7042	1546	1909	172.7
AVERAGE of Twin Heavy					**376.4**	**4669**	**1331**	**1655**	**117.3**

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island communities.

The Bureau of Ocean Energy Management Mission

The Bureau of Ocean Energy Management (BOEM) works to manage the exploration and development of the nation's offshore resources in a way that appropriately balances economic development, energy independence, and environmental protection through oil and gas leases, renewable energy development and environmental reviews and studies.