Baseline Emissions Inventory and Future Year Projections for the Arctic Air Quality Modeling Study

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ABSTRACT

The Bureau of Ocean Energy Management (BOEM) is assessing air quality impacts from offshore oil and gas exploration, development and production on the Alaska Outer Continental Shelf (OCS), as well as those in near-shore state waters, and related onshore activities. For this assessment, BOEM is sponsoring the Arctic Air Quality Impact Assessment Modeling Study, including developing a bottom-up emissions inventory of impacting sources located on the North Slope of Alaska, evaluating detailed meteorological data sets, and conducting far- and near-field photochemical and atmospheric dispersion modeling.

This paper provides details on the development of the baseline and projected emissions inventories for use in air quality modeling. Emissions of criteria air pollutants, greenhouse gases, and hazardous air pollutants from offshore and onshore oil/gas production, stationary sources located in North Slope communities, onroad motor vehicles, nonroad equipment, marine vessels and airports were estimated. Emissions that could reasonably be expected to occur in the future were also estimated, based on potential future levels of increased oil and gas production activities to be conducted on the North Slope. Results were vetted through BOEM and a Science Review Group to ensure emissions were estimated according to the established protocol. Results showed that the majority of criteria air pollutants and greenhouse gases are emitted by onshore oil and gas production sources in both the baseline and projected emissions inventories.

GIS data sets, including spatial surrogates, as well as temporal profiles are currently being developed to allocate emissions spatially and temporally for use in the air quality photochemical and atmospheric dispersion models.

INTRODUCTION

The Department of the Interior, Bureau of Ocean Energy Management (BOEM), Alaska Outer Continental Shelf Regional Office (AOCSR) in Anchorage, Alaska, is responsible for management of oil and gas exploration, development, and production activities on the Alaska Outer Continental Shelf (OCS) under the OCS Lands Act and for assessing the potential environmental impacts from these activities as required by the National Environmental Policy Act (NEPA). In addition, AOCSR is responsible for regulating air emission sources from activities related to offshore oil and gas exploration, development and production within the Chukchi Sea and Beaufort Sea OCS Planning Areas adjacent to the North Slope Borough (NSB) of Alaska.

To assist BOEM with assessing potential air quality impacts from oil and gas exploration, development, and production on the Alaska OCS as well as in near-shore state waters (within 3 nautical miles of the coast), and related onshore activities, BOEM is sponsoring the Arctic Air Quality Impact Assessment Modeling Study (Arctic AQ Modeling Study). The study will inform two important processes:

- **National Environmental Policy Act (NEPA) Environmental Impact Air Quality Assessments.** To date, much of the emissions and meteorological data developed for the Arctic region are project specific. The Arctic AQ Modeling Study will provide a comprehensive air quality analysis with a comprehensive emissions inventory, consistent meteorological dataset, and air dispersion analysis to support environmental impact assessments under NEPA.

- **Emission Exemption Threshold Evaluation.** The Arctic AQ Modeling Study will evaluate current methods for estimating thresholds used to assess the potential adverse effects that offshore oil and gas activities might have on onshore air quality, and recommend improvements, if necessary.

In addition, the Arctic AQ Modeling Study will provide improved and consolidated information about the emission sources in the study area, disseminate that information to the public, and inform several environmental justice initiatives.

One of the first steps in the Arctic AQ Modeling Study, and in support of subsequent air quality modeling analyses, was to develop a comprehensive air emissions inventory that accurately estimates emissions within the study area that encompasses the North Slope region and adjacent waters of the Beaufort Sea and Chukchi Sea Planning Areas (see Figure 1). This emissions inventory is the basis for the information presented in this paper.[1]

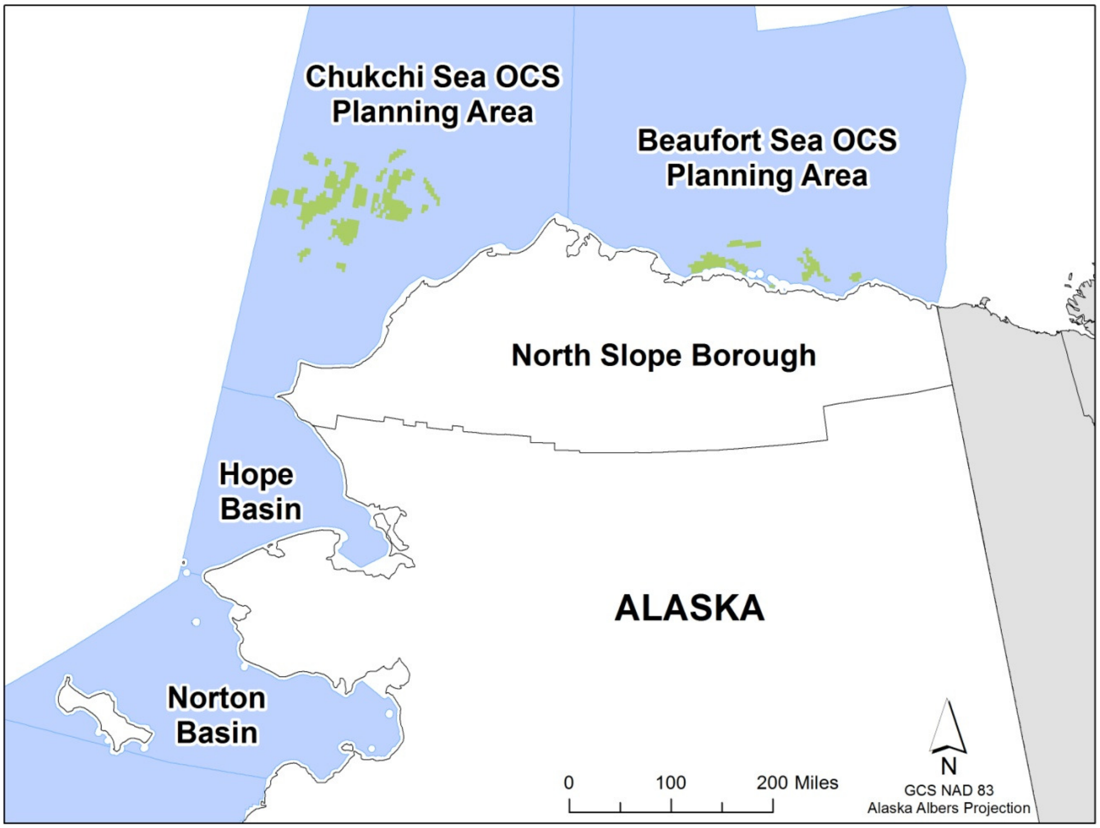
The scope of the emissions inventory was defined as follows:

- **Baseline** – the year for which the most recent, credible, reliable information was available. To the greatest extent possible, 2012 data were used, but these were sometimes augmented with data from other years (including 2011 and 2013).

- **Future scenario** – future year sources and activities that are reasonably foreseeable and expected to continue for an extended period of time. Projected (future year) emissions were estimated for use in evaluating impacts anticipated from potential future oil and gas exploration, development, and production activities on the Arctic OCS. ERG projected future emissions based on information and guidance provided by BOEM for a year in the future when projected offshore operations are "fully built out" (BOEM, 2014a). ERG estimated annual emissions (i.e., baseline and future emissions), and developed temporal profiles for use in air quality modeling.

- **Pollutants** – the air pollutants that contribute to air quality, health and visibility concerns, including: criteria air pollutants (CAPs) and precursors; hazardous air pollutants (HAPs, as defined by the Clean Air Act, Title III); greenhouse gases (GHGs, including carbon dioxide [CO_2], methane [CH_4]), nitrous oxide [N_2O], sulfur hexafluoride [SF_6], hydrofluorocarbons [HFCs], and perfluorocarbons [PFCs]); hydrogen sulfide (H_2S); and ammonia (NH_3).

Figure 1. Regional Map Depicting OCS Planning Areas, including location of Arctic Air Quality Modeling Study (Currently leased areas are indicated in green.) Data Source: Reference 2



- **Sources –** the sources operating within the inventory domain, including stationary sources located in North Slope communities and oil fields, onroad motor vehicles, nonroad equipment, marine vessels and other offshore (oil- and gas-related) sources (i.e., both OCS and near shore in state waters), the Trans Alaska Pipeline System (TAPS) and airports. Also, emissions from other sources were estimated based on their potential influence on air quality concentrations, including dust from paved and unpaved portions of the Dalton Highway and other roads located in communities and the oil fields. Table 1 lists the source groups and categories included in the Arctic AQ Modeling Study emissions inventory and the associated air pollutants. Note that emissions from biogenic sources (e.g., NO_x from soils; geogenic sources such as oil seeps and wildfires) will be estimated in a future stage in this study.

- **Domain –** the geographic area in which the emission sources reside. For the Arctic AQ Modeling Study emissions inventory, the domain encompasses the Arctic OCS, including the Chukchi and Beaufort Seas, near shore state waters (within 3 nautical miles of the coast), and the NSB.

Table 1. Sources included in the BOEM Arctic AQ Modeling Study Emissions Inventory.

Group and Category		CAPs	HAPs	GHGs	H_2S	NH_3
Offshore Oil & Gas Activities	Seismic survey and supply vessels	✓	✓	✓		✓
	Seismic support helicopters	✓	✓	✓		
	On-ice seismic survey equipment	✓	✓	✓		✓
	Exploratory drilling – drill ships, jackups	✓	✓	✓		✓
	Exploratory drilling – fleet support vessels	✓	✓	✓		✓
	Platform construction and support vessels	✓	✓	✓		✓
	Island construction and support vessels	✓	✓	✓		✓
	Production platform operation	✓	✓	✓		✓
	Platform support – supply and support vessels	✓	✓	✓		✓
	Platform support – helicopters	✓	✓	✓		
	Pipelaying and support vessels	✓	✓	✓		✓
Offshore - Other	Commercial marine vessels	✓	✓	✓		✓
	Research vessels	✓	✓	✓		✓
Onshore Oil & Gas Fields	Seismic survey equipment	✓	✓	✓		✓
	Drilling/exploration	✓	✓	✓	✓	
	Well pads		✓		✓	
	Processing plants, gathering centers, etc.	✓	✓	✓	✓	
	Support (injection, seawater treatment)	✓	✓	✓	✓	
Airports	Aircraft and helicopters	✓	✓	✓		✓
	Ground support equipment	✓	✓	✓		✓
TransAlaska Pipeline System	Pump stations (1-4)	✓	✓	✓		✓
	On-road patrol vehicles	✓	✓	✓		✓
	Aerial surveillance aircraft	✓	✓	✓		✓
	TAPS fugitives	✓	✓	✓	✓	
	Natural gas supply line fugitives	✓	✓	✓	✓	
	Pigging operations	✓	✓	✓	✓	
	Pipeline replacement, repair	✓	✓	✓		✓
Onshore Non-Oil & Gas Activities	Power plants	✓	✓	✓		✓
	Industrial/commercial/institutional/residential fuel combustion	✓	✓	✓		✓
	On-road motor vehicles	✓	✓	✓		✓
	Nonroad mobile sources	✓	✓	✓		✓
	Road dust	✓				
	Waste burning	✓	✓	✓		✓
	Wastewater treatment	✓				
	Fuel dispensing	✓	✓	✓		
	Power plants	✓	✓	✓		✓
	Industrial/commercial/institutional/residential fuel combustion	✓	✓	✓		✓
Spills	OCS pipeline spills	✓	✓	✓		✓
	Platform spills	✓	✓	✓		✓

METHOD – BASELINE EMISSIONS INVENTORY

The baseline emissions inventory represents air emissions from the sources operating in the Arctic OCS, including the Chukchi and Beaufort Seas, near shore state waters (within 3 nautical miles of the coast), and the NSB, over the course of a year. The baseline emissions inventory generally was developed using data from 2012, however because it was necessary to use data from other years in order to compile a comprehensive inventory, the initial annual inventory is also referred to as the "baseline" emissions inventory.

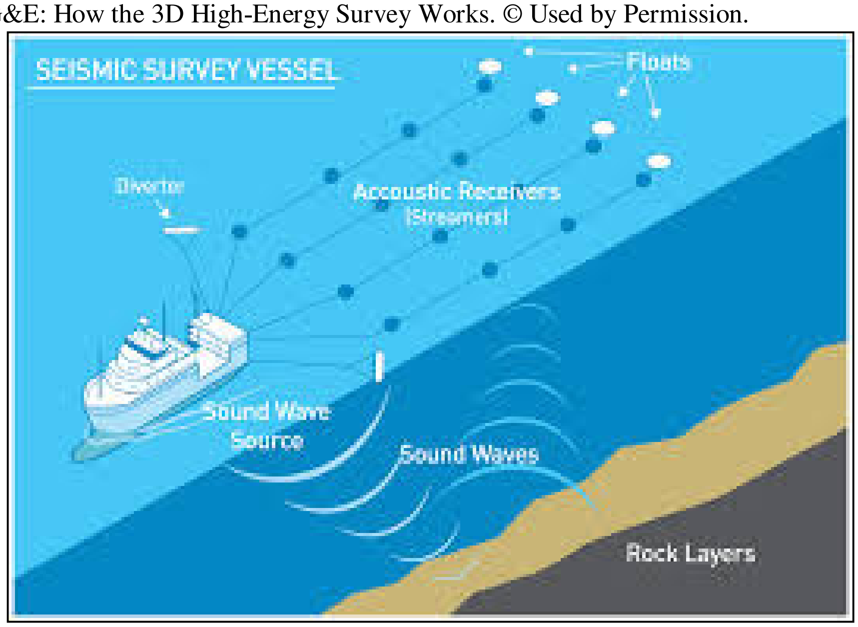
Offshore Sources

Offshore activities during 2012 included oil and gas seismic surveys, exploratory drilling, and support helicopters visiting survey vessels and exploratory drilling rigs to deliver supplies and transfer personnel. Also, commercial marine and research vessels operated in the Beaufort and Chukchi Seas during this time, although these were not directly related to oil and gas exploration. The method used to estimate vessel emissions was to apply activity data to appropriate Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model marine vessel emission factors[3] and HAP speciation profiles.[4] For estimating helicopter and aircraft landing and takeoff (LTO) emissions, ERG used the Federal Aviation Administration's (FAA's) Emissions and Dispersion Modeling Systems (EDMS).[5] The activity data used to estimate emissions is described in detail below.

Seismic Survey Operations

Seismic surveys are used in the Arctic to evaluate the possible locations of oil-bearing strata (seismic survey), assess geologic risk to constructed structures (geohazard surveys), and provide seabed data for platform design and construction (geotechnical surveys). Only seismic survey vessels are included in the baseline emissions inventory, while all three types are included in the projected inventory. Most types of survey vessels are equipped with an air gun that generates a sound wave that reflects off the seabed and is picked up by an array of acoustic receivers (hydrophones) that are pulled behind the vessel (Figure 2).[6] Results from the seismic soundings are mapped to identify density anomalies in the geologic strata that could suggest the existence of oil and possible sites for exploratory drilling.

Figure 2. Typical seismic survey**.**
Online image from PG&E: How the 3D High-Energy Survey Works. © Used by Permission.



The survey vessel emissions inventory includes estimates for associated support vessels. Support vessels are ice breakers and scout vessels. Ice breakers travel ahead of the seismic survey vessel to break up ice along the route. Scout vessels are smaller vessels, and travel ahead of the seismic survey vessel to warn of ice coverage or location of sea life, mainly whales.

Survey vessel activity was defined in terms of kilowatt hours (kW-hrs) derived from vessel power ratings, hours of operation, and appropriate load factors. Internet searches were implemented to identify seismic surveys conducted in the Arctic in 2012. Through these searches, one seismic survey project implemented in both the Chukchi and Beaufort Seas was identified, the ION Geophysical Seismic Survey.[7] The seismic survey occurred during a 76-day period in 2012 and focused on specified areas in the Beaufort Sea and a small part of the Chukchi Sea. Emissions were estimated by applying emission factors and HAP speciation profiles to activity data and load factors.

Exploratory Drilling

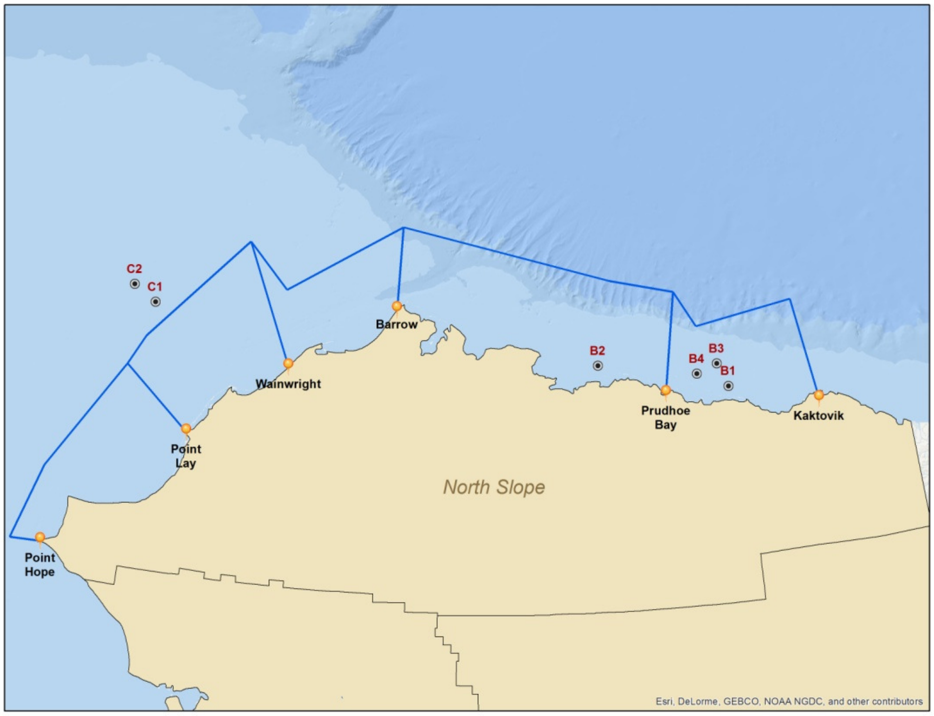
Exploratory drilling in 2012 was implemented in both seas using two teams equipped with drilling rigs, support vessels, ice breakers, oil spill response vessels, and helicopter support for a period of 53 days in the Chukchi Sea and 29 days in the Beaufort Sea. Drilling rigs typically include multiple emissions sources such as mud pumps, generators, draw works, compressors, and propulsion engines. The emissions inventory includes estimates for all emissions sources that typically operate on a drilling rig off the coast of the North Slope, based on data provided by BOEM and the exploratory drilling plans submitted to BOEM by Shell Gulf of Mexico Inc.[8,9] Based on the Exploration Plan submitted to BOEM by Shell[9] and a report submitted to DOI by Shell,[10] ERG compiled vessel and support fleet information, including engine characteristics (kW power rating) and estimated hours of operation for operations in the Beaufort and Chukchi Seas. Emissions were estimated by applying emission factors and HAP speciation profiles to activity data and load factors. As noted above, drilling operations also include helicopters for personnel and equipment transfers and airplanes for wildlife monitoring. Emissions were associated with the LTOs at the airport (in the onshore emission estimates), LTOs at the drilling vessels, and the cruise portion between the airports and drilling vessels. Emissions were calculated using the FAA's EDMS.[5]

In 2012, there were no offshore production platforms, no platform or pipeline construction activities, and no geohazard or geotechnical surveys.

Commercial Marine Vessels

The emission inventory included non-oil/gas related offshore sources in addition to seismic survey operations and exploratory drilling. Cargo and supplies that are too heavy to be shipped to the North Slope communities by aircraft are transported via commercial marine vessels (CMV). These shipments occur during the open water period when navigation is possible (generally July through October). Because ports in the North Slope are relatively shallow, the CMV fleet comprises shallow draft vessels or tugs and barges. The CMV activity data were defined in terms of kW-hrs and derived from the vessel power rating, hours of operation, and appropriate load factors. Automatic Identification System (AIS) data for July through October 2012 were obtained from the Marine Exchange of Alaska (MEA) for 7 North Slope ports for 29 vessels.[11] Vessel power ratings were obtained for most vessels from IHS Register of Ships.[12] Emissions were estimated based on GREET Category 2 Tier III marine vessel emission factors.[3] CMV emissions were spatially allocated to the closest shipping lanes noted in Figure 3, associated with the AIS location data.

Figure 3. U.S. Army Corps of Engineers shipping lanes and development sites (C1, C2, B1, B2, B3, and B4) off the North Slope.
Data Source: Reference 13



Research Vessels

Several organizations, such as the Arctic Council, U.S. Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA), operate research vessels off the North Slope coast to implement oceanographic research and monitor changes in fish and mammal populations. These vessels are equipped with Category 2 or 3 propulsion engines and Category 1 auxiliary engines. The research vessel activity data were defined in terms of kW-hrs derived from the vessel power rating, hours of operation, and appropriate load factors.[14] Internet searches were conducted to identify research projects active in 2012. The United States Coast Guard (USCG) provided the most comprehensive list of projects that occurred in the Beaufort and Chukchi Seas in 2012.[15] The USCG data included vessel names, start and end dates, and location of each project. Emissions were estimated by applying diesel marine emission factors and HAP speciation profiles to activity data for 2012.

Onshore Sources

In addition to offshore sources, the emissions inventory includes estimates for onshore emission sources within the North Slope region and adjacent waters of the Beaufort Sea and Chukchi Sea Planning Areas. These sources include the North Slope oil and gas fields, as well as onshore sources located in eight nearby villages and elsewhere on the North Slope (e.g., airports, the TransAlaska Pipeline System, non-oil and gas related stationary and mobile sources).

Seismic Survey Equipment

Emission sources within the onshore oil and gas fields on the North Slope include devices and activities associated with both oil and gas exploration and production. Prior to conducting exploratory drilling, oil and gas companies will typically conduct geological and geophysical (G&G) explorations. These companies will use seismic survey equipment if these exploratory activities occur on sea ice or on land. Information regarding land-based G&G permits could not be obtained from the Alaska Department of Oil & Gas, so it is not clear whether any land-based G&G work was conducted in 2012. Given this uncertainty, ERG assumed that one G&G project occurred in 2012 that was similar in scope and size to the most recent active G&G permit, which included both ice- and land-based activities.[16] The permit assumed operation of 12 vibroseis vehicles (i.e., “thumper trucks”), in addition to various other support equipment (e.g., long-haul fuel tractors, remote fuelers, water makers, incinerators, resupply and survival sleighs, tractors, loaders). A total of 477,000 gallons of ultra-low sulfur diesel (ULSD) fuel (4,500 gallons for 106 days) was assumed to be used. As in the BOEM G&G permit, emissions were estimated by combining the ULSD quantity of 477,000 gallons with EPA WebFIRE emission factors.[17]

Exploratory Drilling

Emissions from onshore oil and gas exploratory drilling are generated when fuel used in the drilling rig engines, heaters, and boilers used on the drill rig is combusted and from fluid flowback during well completion. Emissions from fuel combustion from onshore oil and gas exploratory drilling rigs are generated as diesel fuel is burned in drilling rig engines, heaters, and boilers. The Alaska Department of Environmental Conservation (ADEC) covers drilling rig activities in their permitting program, and air emissions data for the North Slope drilling rig fleet are available through air permit applications and permits. There are two primary permits that cover the North Slope drilling fleet: ConocoPhillips’ Kuparuk Transportable Drilling Rigs permit and BPXA’s Transportable Drilling Rigs permit. These permits list specific rigs and drilling companies permitted to operate on the North Slope, and in many cases, the same rigs are listed in both permits. In addition to data available in air permits and permit applications, GHG emissions from drilling rigs are reported under 40 CFR Part 98, subpart W of EPA’s Greenhouse Gas Reporting Program (GHGRP). Four GHGRP facilities produce nearly 99% of crude oil from the North Slope: Badami Development Facility; BP Alaska, 890 – Arctic Slope Basin; ConocoPhillips Alaska, Inc. – KRU-ALP Fields; and Nikaitchuq Development. Therefore, the GHGRP emissions from drilling rig engines, heaters, and boilers from these four facilities are considered complete estimates of emissions of GHG pollutants.

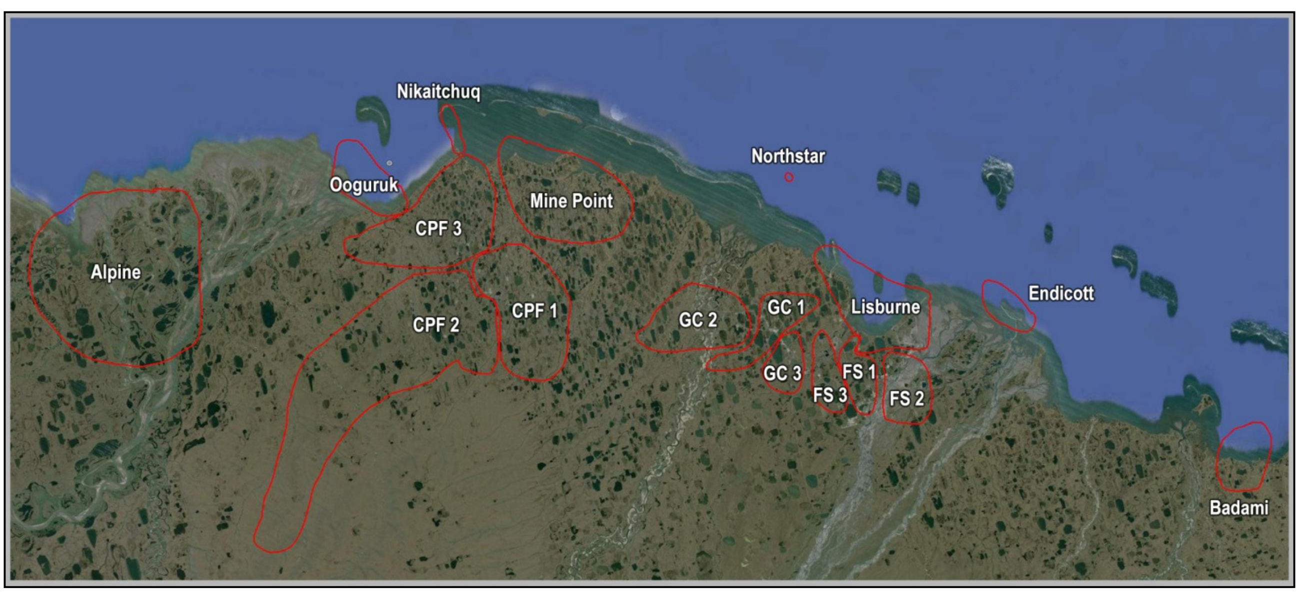
To estimate emissions of CAPs and HAPs, the ConocoPhillips Title V renewal application for the Kuparuk Transportable Drilling Rigs permit was reviewed. This permit application contains potential emissions estimates for CO_2, CH_4, N_2O, CAPs, and HAPs, allowing for a direct comparison to the reported GHGRP actual emissions data for the three GHG pollutants. This comparison showed that reported emissions of all three GHG pollutants for the entire North Slope were approximately one-half (in the case of CO_2, 51.18%) of the potential emissions listed in the Kuparuk application. Therefore, total actual emissions across the North Slope for the other pollutants listed in the application (combustion generated CAPs and 16 individual HAPs) were estimated to be 51.18% of the potential emissions of the Kuparuk permit application.

For well completions, ERG developed emission estimates using information contained in the Kuparuk Transportable Drilling Rigs permit application. This permit application contains emission estimates for 30 well completions for VOC, CO_2, CH_4, and six HAPs (2,2,4-trimethlypentane, benzene, ethylbenzene, *n*-hexane, toluene, and xylene). The estimates are based on the total amount of oil assumed to flowback during one well completion, the gas-to-oil ratio (GOR) of the oil, the flowback lift gas volume, and typical flash gas composition data. Available data indicate that in 2011, 86 wells were completed on the North Slope.[18] Therefore, total emissions of VOC, CO_2, CH_4, and HAPs from North Slope well completions were estimated by multiplying the estimates contained in the Kuparuk permit application by the ratio of total North Slope well completions to the Kuparuk well completions (86/30 = 2.87). H_2S estimates are based on an assumed H_2S concentration of 30 parts per million by volume (ppmv) in the flash gas, based on a recently proposed permit for the North Slope liquefied natural gas facility. The accuracy of the drilling rig emissions are affected by the fact that, historically, the large drilling rig engines have been treated as nonroad engines and have not been subject to annual (or triennial) emission reporting requirements. Therefore, drilling rig emissions are not typically included in the U.S. NEI. However, as described above, GHG emissions from drilling are well characterized under GHGRP subpart W and formed the basis of the CAP and HAP estimates. ADEC is in the process of renewing the Title V transportable drilling rig permits for BP and ConocoPhillips. It is expected that the Title V renewal permits will be issued in the near future and these may require annual or triennial emissions submittals. These data may be useful for updating future versions of this emissions inventory.

Oil and Gas Production

Onshore oil and gas production on the North Slope occurs along a 100-mile-by-40-mile span of coastline near Prudhoe Bay. In 2012, this area produced nearly 200,000,000 barrels of crude oil. Natural gas produced from North Slope wells is primarily reinjected back into the reservoir to maintain pressure to facilitate oil production, with some used to fuel various oil and gas exploration and production equipment such as compressor engines. Additionally, there are two small topping plants (refineries) that refine a portion of the crude oil to produce Jet-A, diesel fuels, and Arctic heating fuel (AHF) for use in the North Slope oil fields. As shown in Figure 4, 14 onshore and three offshore production facilities (located on man-made islands) service the approximately 120 well pads located on the North Slope. Each production facility receives three-phase (oil, gas, and water) production fluids from the surrounding well pads, separates the fluid into crude oil, gas, and water, and delivers the crude oil downstream to the TransAlaska Pipeline System (TAPS) Pump Station #1. As with the majority of the gas produced from these wells, the separated water is reinjected into the reservoir.

Figure 4. North Slope production facilities.
Online image from Google Maps. https://www.google.com/maps/ (Accessed September 22, 2014.)



The starting point for onshore oil and gas production emissions estimates was the point source emissions data submitted by ADEC to the EPA for the triennial 2011 U.S. NEI.[4] The 2011 NEI includes the most complete data currently available for point source emissions from facilities operating on the North Slope, and includes estimates for 26 oil and gas facilities. ADEC receives annual emissions inventory submittals directly from the operators of Title V facilities as required under their permits. Although ADEC has received 2012 emissions data from the operators of these point sources, the reporting threshold for 2012 (and 2013) is much higher than for the 2011 reporting year, making the 2012 ADEC inventory less complete. ERG considered how representative the NEI 2011 data were compared to data from operations in 2012. Given that North Slope crude oil production declined by approximately 7% between 2011 and 2012,[19] using 2011 data would provide a conservatively high estimate of emissions for 2012. In addition, a review of ADEC permit data identified all sources currently in operation, and identified nine facilities that are not included in the 2011 NEI data.

Gap-filling was also needed for facilities included in the NEI, as the NEI includes emissions data for Title V facilities, but only for the larger emission units such as the large combustion turbines found at the production facilities and not for “insignificant emissions units” (which would include smaller heaters, small emergency engines, and small VOC sources such as storage tanks) or “nonroad engines” such as portable generator or light tower engines. To address these two categories of missing units, ERG conducted an analysis using the 2011 reported NEI data and the list of emission units found in the ADEC air quality permits and permit applications for a selected subset of the North Slope sources.[20]

ERG obtained permit documents (i.e., permits and background/supporting documents) for all 35 sources identified (i.e., the 26 NEI facilities, and nine non-NEI facilities) and permit applications from ADEC for 16 of the permitted Title V facilities. A detailed, pollutant-specific analysis of the permits and permit application documents was conducted to determine the percentage of total facility assessable emissions subject to reporting to the NEI. In an ADEC permit, assessable emissions are calculated based on the source equipment’s potential to emit (PTE), operating 8,760 hours per year, or as limited by the permit. Facility permits typically provide only total facility assessable emissions, while permit applications provide disaggregated potential emission estimates for significant emission units, insignificant emission units, and nonroad engines. This information is needed to determine permit level and to assess permitting fees. In this analysis, total facility assessable emissions are assumed to be the sum of potential emissions from significant emission units, insignificant units, and nonroad engines. Actual emissions are based on actual operating time of the equipment and are typically less than the total assessable emissions of a source. However, as described above, actual emissions from insignificant emission units and nonroad engines are not reported to the NEI.

ERG estimated emissions for equipment at facilities that did not report to the NEI (non-NEI facilities) and for insignificant units and nonroad engines located at facilities that reported to the NEI by analyzing emissions and equipment data for the significant emission units located at those facilities. This analysis compared actual emissions from significant emission units with assessable emissions for significant emission units, and was used to develop estimates for insignificant emission units and nonroad engines using detailed information in permits and permit applications. This analysis showed that on average, of total facility assessable emissions, significant emission units account for between 70 and 86%, insignificant emission units account for between 1 and 6%, and nonroad engines account for between 8 and 28%. However, there are a few sources on the North Slope with numerous nonroad engines, and for these sources, the potential emissions from nonroad engines can account for well over half of the total potential emissions at any single facility, particularly for VOC. For example, at the three Kuparuk production facilities, there are over 250 nonroad engines that account for approximately 60% of the total facility potential VOC emissions. To develop actual emission estimates for the insignificant emission units and nonroad engines, the ratio of actual-to-potential emissions for the insignificant emission units and nonroad engines was assumed to be identical to the same ratio for the significant emission units at the facility. The ratio of actual-to-potential emissions for the significant emission units at the facility was developed by comparing the 2011 NEI reported emissions (actual emissions) to the potential emissions as reported in the permits or permit applications. This analysis showed that, for significant emission units subject to NEI reporting, the average actual emissions were 38, 55, 41, 19, and 52% of potential VOC, NO_x, CO, SO_2, and PM_{10} emissions, respectively.

ERG conducted this analysis at the facility level for the 16 facilities for which detailed permit application data were available. Actual emission estimates for insignificant units and nonroad engines were calculated by multiplying the estimates for potential emissions from insignificant emission units and nonroad engines, as recorded in the permit applications, by the ratio of actual-to-potential emissions for the reported significant units. ERG developed actual emission estimates of HAPs and $PM_{2.5}$ from insignificant emission units and nonroad engines using HAP and $PM_{2.5}$ data from significant emission units, as reported in the NEI. VOC and PM_{10} (estimated as described above) were used as surrogates to scale emissions of volatile organic and metal HAPs/$PM_{2.5}$, respectively.

Scaling factors for VOC and PM_{10} were derived by comparing assessable emissions to reported actual emissions in the NEI. These scaling factors were then applied to estimates of VOC and PM_{10} emissions from insignificant emission units and nonroad engines to develop estimates for HAP emissions from these same sources. For the nine permitted facilities not covered in the 2011 NEI, emissions estimates were developed based on assessable emissions estimates available in permit documentation using the methodology described above for the NEI-covered facilities. For example, assessable nonroad engine VOC emissions were assumed to equal 28% of total facility assessable VOC emissions, and 38% of those assessable nonroad engine VOC emissions were assumed to actually be emitted.

GHGRP 2012 subparts W (Petroleum and Natural Gas Systems) and C (General Stationary Fuel Combustion Sources) data were used to supplement the 2011 NEI and ADEC permit data, not only for GHG emission estimates, but also to estimate CAPs and HAPs emissions for additional sources not included in the NEI. EPA's Nonpoint Oil and Gas Emissions Estimation Tool (Tool) contains default emission estimates for oil and gas "area" sources for the North Slope.[21] These data were analyzed to supplement the NEI, ADEC permit, and GHGRP subpart W data to fill in any data gaps in source coverage or in source category coverage.

Airports, Aircraft, and Ground Support Equipment

Alaska's aviation sector is one of the largest and most active of any state. This is particularly true for the North Slope, where commercial and general aviation are used to move people, supplies, and mail, provide medical airlift, monitor pipelines for spills, and track wildlife. Airport emissions include aircraft main engines, auxiliary power units (APUs) and ground support equipment (GSEs). Airport emissions include only the LTO cycle, not the cruise portion of the flight. BOEM selected 16 airports located on the North Slope to include in the emissions inventory based on level of activity and geographic location (Figure 5). Representatives from each airport were contacted to obtain activity and operational data, including information about possible operating conditions for airports on the North Slope that could affect emission estimates due to longer idling times or shorter taxi times. Of the 16 airports, two have been closed, and three could not provide data (Airports with codes A19, AK03, 5CD, LUR, and PHO as shown in Figure 5). Some of the data from the local airports were actually passenger enplanements and not LTOs or operations. The enplanement data were very similar to the FAA's Terminal Area Forecast (TAF) data, which include both enplanement and operations data. Therefore, the TAF LTO activity data were used in place of the local enplanement data.[22]

Figure 5. North Slope airport locations and FAA codes.
Data Source: Reference 23

Ten of the 11 airports provided aircraft-specific or air-carrier-specific data, which were applied to the FAA's EDMS to estimate aircraft, APU, and GSE emissions.[5] The remaining airport, Deadhorse, provided approximate LTO data. Because the data were approximations, the detailed TAF data for Deadhorse were used. The TAF LTOs were applied to emission factors from the 2011 NEI to estimate emissions for Deadhorse.[23] Most of the aircraft used on the North Slope are smaller aircraft that do not have APUs or do not require GSE; therefore, APU and GSE emissions were included only for airports serviced by commercial aircraft that are associated with APU and GSE in the FAA's EDMS model.

<u>TransAlaska Pipeline System</u>

The TAPS pipeline has a total length of 800 miles from the North Slope to the Valdez Marine Terminal; the portion of the TAPS pipeline within the North Slope is approximately 177 miles long with four pump stations.[24] Emissions were estimated for both the actual pipeline sources as well as activities associated with pipeline operation and maintenance. Pump Stations 1 through 4 are the only pump stations located within the North Slope. Emissions from Pump Stations 1, 3, and 4 were obtained from the 2011 NEI; Pump Station 2 was ramped down on July 1, 1997 and does not have any active emission sources.[4]

ERG estimated fugitive emissions from both the TAPS pipeline and the natural gas supply line that fuels the pump stations by using national production-based emission factors from the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.[25] Calculated emissions were then scaled by the ratio of the TAPS pipeline/supply line mileage within the North Slope to national pipeline mileages.[26]

Detailed emissions information regarding TAPS pigging operations were not available; therefore, ERG assumed that pigging operations were conducted once a week. Methane emissions from pigging operations on the TAPS were estimated using guidance from the EPA's Methane to Markets program.[27]

On-road motor vehicles patrolling the TAPS also generate exhaust and evaporative emissions, as well as re-entrained road dust emissions from driving on unpaved roads. Information regarding the type and extent of patrol vehicles was not available; therefore, two trucks were assumed to patrol the length of the TAPS pipeline within the North Slope every day. ERG estimated the emissions associated with the on-road patrols as described below for non-oil/gas stationary point, area, and mobile sources.

Nonroad construction equipment involved in pipeline replace and repair projects along the TAPS generate exhaust and evaporative emissions. Since the TAPS pipeline was completed, replacement and repair construction projects are periodically conducted to maintain the integrity of the system. Information regarding the type and extent of replacement and repair projections was not available; therefore, ERG assumed that two work crews operating a dump truck, backhoe, and a bulldozer worked a 10-hour shift somewhere along the TAPS pipeline on the North Slope during the winter. ERG also assumed that 10 similar work crews worked a 10-hour shift during the summer.

Emissions from helicopters occur during aerial surveillance of the TAPS and associated feeder lines (Figure 6). The helicopters used for TAPS surveillance are based at the Fairbanks International Airport, which is outside of the North Slope area. ERG estimated emissions for aerial surveillance aircraft by applying air time for each surveillance run to take-off emission factors from EDMS for the typical helicopters used in this activity.

Figure 6. TAPS and feeder pipelines.
Source: Reference 28

Non-Oil/Gas Stationary Point, Area, and Mobile Sources

Non-oil/gas stationary point, area, and mobile sources include sources located in the eight North Slope Villages, as well as the related support activities (within the onshore oil and gas fields not directly related to oil production). Barrow is the largest village on the North Slope with an estimated population of 4,445 people in 2012; the remaining seven villages are considerably smaller with populations ranging from 196 to 668 people.[29] The onshore oil and gas fields in Prudhoe Bay do not have a permanent population, but have thousands of workers that rotate in and out on a transient basis.

The emission sources located in the villages are broadly classified as follows: fuel combustion (i.e., power plants, commercial/institutional, and residential), mobile sources (i.e., on-road motor vehicles and nonroad mobile sources), road dust, and miscellaneous (i.e., waste burning, wastewater treatment, and fuel dispensing). In general, ERG estimated emissions by multiplying the relevant activity data by EPA WebFIRE[17] emission factors; HAP emissions were estimated using speciation fractions from the SPECIATE database.[30]

<u>Power Plants</u>

Power plants are located in each of the North Slope villages; two additional plants are located in the oil and gas fields. The Barrow Power Plant is operated by the Barrow Utilities and Electric Co-op, Inc. (BUECI); the remaining village plants are run by the North Slope Borough (NSB) Department of Public Works. The two oil and gas field facilities and the village plants in Barrow and Nuiqsut use natural gas as primary fuel, while the other power plants use fuel oil as primary fuel. ERG obtained emissions for the two oil and gas field facilities and three village plants (Barrow, Point Hope, and Wainwright) from the 2011 NEI.[4] ERG estimated emissions for the remaining village plants using fuel data obtained from the Alaska Energy Authority's (AEA's) Power Cost Equalization (PCE) rural energy subsidy program.[31]

<u>Industrial and Commercial/Institutional Fuel Combustion</u>

The two primary fuels used within the North Slope (natural gas and distillate fuel oil) are combusted within industrial (not related to oil and gas production) and commercial/institutional (e.g., schools, community facilities, village corporations) settings. Two specific industrial facilities were identified that provided logistical support to the oil and gas fields. Emissions were based upon the estimated emissions or permitted fuel quantities identified in the permits.

Distillate fuel oil is consumed at each of the North Slope Borough School District (NSBSD) schools in the villages with the exception of Barrow; consumption quantities for 2012 were provided by the NSB's Department of Public Works' Fuel Division.[32] Distillate fuel oil is also consumed at four North Slope Long-Range Radar Sites (LRRS) operated by the U.S. Air Force. Fuel consumption quantities for 2012 could not be identified, so permitted quantities from the LRRS permits were used.

Unlike other North Slope villages (which almost exclusively use distillate fuel oil), Barrow meets much of its energy needs from fuel supplied by three nearby natural gas fields. Specific 2012 natural gas consumption quantities were obtained from invoices for two commercial/institutional consumers in Barrow.

In addition, there is unspecified commercial/institutional fuel combustion in the North Slope. BUECI staff provided natural gas consumption quantities in Barrow,[33] while NSB staff provided fuel oil consumption quantities.[32]

Residential Fuel Combustion

Private residences within the North Slope villages use two primary fuels (natural gas and distillate fuel oil) for space heating, water heating, backup electricity generation, cooking, etc. Most village residences (outside of Barrow and Nuiqsut) are heated using distillate fuel oil. Unlike other regions within Alaska, wood is not used in the North Slope for residential heating and cooking because there are no natural wood sources in close proximity. Minor quantities of liquefied petroleum gas (LPG) are also used on the North Slope, but mainly for hunting and camping activities, not as a primary residential fuel.

Residential fuel combusted in Barrow is strictly limited to natural gas, while the residential fuel combusted in Nuiqsut is a mix of natural gas and distillate fuel oil. Residential fuel combusted in the remaining six villages is distillate fuel oil. BUECI provided Barrow residential natural gas consumption statistics,[33] while NSB's Department of Public Works' Fuel Division provided all residential fuel consumption statistics in the other villages.[32]

On-Road Motor Vehicles

ERG developed on-road motor vehicle emissions in the North Slope using emission factors from EPA's MOVES2014 model (MOVES)[34] with local meteorological and vehicle activity data for vehicle miles traveled (VMT) and fuel consumption. The on-road emissions inventory includes six vehicle categories: on-road emissions by village for the eight villages in the North Slope, wintertime idling for the eight villages, vehicles traveling on the Dalton Highway, TAPS patrols, vehicles traveling within the Prudhoe Bay oil fields, and gasoline refueling emissions in the North Slope.

ERG ran MOVES and processed the results to produce the emission factors, and in conjunction with fleet activity data, estimated on-road emissions for each category listed above. Most of the MOVES input data specific to the North Slope were prepared by ADEC for the 2011 NEI.[35] The specific MOVES inputs that ERG used included fuel supply and formulation, fleet age, fleet diesel fractions, and VMT patterns as well as local meteorological data recorded at Deadhorse Airport (for Dalton Highway) and Barrow Airport (all other categories).[36]

On-road emissions were calculated for each North Slope village. Because Barrow is the most populous village and had the only available VMT, ERG ran MOVES specifically for Barrow and then scaled the emission results to the smaller villages based on population.[29] The Alaska Department of Transportation and Public Facilities (ADOT&PF) collected annual average daily traffic (AADT) statistics in 2012 for Barrow only.[37] Although these AADT statistics do not represent all vehicle activity in Barrow, they do represent traffic on the most heavily travelled roads, and were used to represent Barrow vehicle activity.

MOVES does not estimate wintertime idling activity by default as part of any on-road inventory. MOVES accounts for a small amount of idling as part of typical driving cycles that reflect trip patterns where vehicles stop for short periods. However, in the Arctic, vehicles are frequently left idling while parked during the wintertime, particularly during the coldest months of the year. Staff of NSB Public Works Department indicated that some of the NSB vehicles may idle more than 3,000 hours per year[38]; however, this level of idling is probably too high for the overall vehicle population. Therefore, wintertime idling was assumed to be 640 hours per vehicle per year.

ERG ran MOVES to estimate idle emission factors in grams/hour using average meteorological conditions for daytime in the four winter months. MOVES is a "modal" emissions model, meaning that it contains base emission rates for operating modes, which are defined by vehicle-specific power (VSP) and speed. To estimate the idle emission factors, ERG ran MOVES using the "Project Scale" mode and a unique operating mode distribution with 100 percent idle operation. The results of this modeling were grams/hour for each vehicle type. The grams/hour idle emission factors were multiplied by 640 hours and the population of vehicles in Barrow. Although the exact number of vehicles was not known, it was estimated by dividing the annual VMT by a fleet average annual mileage accumulation rate of approximately 10,400 miles per vehicle per year.

The Dalton Highway was modeled in MOVES as a rural highway (Rural Restricted Access) with an average speed of 50 mph (i.e., posted speed limit). VMT on the highway was dominated by heavy-duty diesel truck traffic (82 percent) with the remaining 18 percent from light-duty gasoline trucks.[39]

Trucks were assumed to patrol the length of the TAPS pipeline within the North Slope every day. The running emission factors for light commercial trucks operating on rural non-highway roads developed for the Barrow on-road analysis were used to represent patrol vehicles driving along the TAPS.

A considerable amount of on-road motor vehicle fuel (i.e., gasoline and ULSD) is transported across the Dalton Highway from Fairbanks up to Prudhoe Bay. Staff from NSB provided an estimate of the amount of motor vehicle fuel transported in 2012 (2,775,000 gallons of gasoline).[40] Due to the absence of better data, the corresponding VMT and population of trucks was estimated based on the total gasoline using the corresponding activity proportions from the Barrow analysis, but accounting for higher rates of wintertime idling (1,140 hours of idling per vehicle per year).

Nonroad Mobile Sources

Nonroad mobile source emissions in the North Slope were estimated using EPA's NONROAD2008a model to derive emission factors based on fuel consumption.[41] Custom inputs to NONROAD specific to the North Slope were used where available; otherwise, NONROAD default data were used. Village-specific monthly meteorological data were used.[36] Nonroad mobile source fuel inputs were synchronized with the MOVES inputs provided by ADEC (ADEC, 2012a). Monthly and daily activity data adjustments were made for 2-stroke gasoline snowmobiles, 4-stroke ATVs, and 4-stroke recreational marine motors based on discussions with NSB personnel.[42] Emissions were only estimated for the following types of nonroad equipment: 2-stroke gasoline snowmobiles, 4-stroke gasoline ATVs, 4-stroke recreation marine engines, and a few types of diesel-powered construction equipment.

The NONROAD model estimates emissions for CAPs, only. Emissions for HAPs were estimated using a modified version of the NONROAD reporting utility, which applies speciation factors obtained from the EPA's National Mobile Inventory Model (NMIM). Using these NONROAD outputs, ton/gallon emission factors were developed for each source classification code (SCC) and pollutant combination. The NONROAD outputs were also used to calculate the fraction of total fuel consumption for each SCC. The amount of annual gasoline and diesel fuel consumption for nonroad equipment was then allocated to each SCC based on the fuel use fraction calculated from the NONROAD outputs. The amount of nonroad gasoline and diesel fuel consumption was determined by subtracting the amount of on-road gasoline and diesel from the total gasoline and diesel quantities. Once the amount of fuel used by each piece of equipment was calculated, the tons per gallon emission factor derived from the NONROAD outputs were applied, resulting in a total emissions estimate for each SCC and pollutant combination.

Road Dust

Dust emissions are generated from vehicle and equipment travelling over unpaved roads. Although paved road dust is also typically included in regional emissions inventories, no paved areas were identified in the North Slope that had vehicle or equipment activity. ERG estimated emissions by multiplying unpaved road VMT by emission factors derived from empirical equations found in AP-42, Section 13.2.2[43]; the equation for publicly accessible roads (Equation 1b) was used for the North Slope villages, while the equation for industrial roads (Equation 1a) was used for the Dalton Highway, the Prudhoe Bay oil and gas fields, and the TAPS patrols.

Village road dust emissions were estimated for Barrow and then extrapolated to the other villages based upon population. Detailed vehicle traffic information was available for the Dalton Highway; based upon ADOT&PF data, approximately 82 percent of the daily VMT from the Atigun River to Deadhorse was from trucks.[39] Assumptions were made to estimate the VMT associated with the TAPS pipeline surveillance patrols and vehicle activity in the Prudhoe Bay oil and gas field.

Although silt content samples were not collected in this study, ERG identified a silt content value of 25 percent that was previously collected on the Dalton Highway which was used for all unpaved dust calculations.[44] An average speed of 35 mph was assumed for vehicle travel in the villages.

The emission factor equations include a correction factor that accounts for the number of days with measureable precipitation. Although there are some days during the winter when there is no measureable precipitation, residual snow and ice cover due to extremely low temperatures also prevents unpaved road dust emissions. Discussions with NSB Public Works Department staff revealed that unpaved road dust emissions primarily occur during the summer, between May and October.[45]

Other Sources

Municipal solid waste (MSW) is widely burned in the North Slope landfills to reduce the overall waste volume and to discourage scavenging by wild animals. Waste in Barrow is burned at the Barrow Thermal Oxidation System (TOS) Facility; incinerated MSW quantities were provided by NSB Department of Public Works staff.[46] In the remaining seven villages, waste is burned at the community landfills either in a burn box, burn cage, or a trench. As far as can be determined, waste is not burned in burn piles or burn barrels located at individual residences in the North Slope villages. For each village landfill, NSB Department of Public Works staff provided the quantity of waste hauled and the quantity of waste landfilled.[46] The difference of these two quantities was assumed to be the quantity of waste burned.

Wastewater treatment is conducted in each of the eight North Slope villages. The Barrow wastewater treatment plant is a bioreactor membrane filtration system with ultraviolet purification, while the other village wastewater treatment plants are simpler package plants based on an extended activated sludge process. Treated wastewater effluent quantities were provided by NSB Department of Public Works staff.[47] The NSB also operates a wastewater treatment plant in Service Area 10; however, treated wastewater effluent quantities could not be identified.

Both on-road motor vehicles and nonroad mobile sources are refueled in each of the eight North Slope villages, as well as in the oil and gas fields. Because of the relative higher volatility of gasoline compared to ULSD, ERG only estimated emissions for gasoline refueling emissions. Barrow is the only village with a “gasoline station” (i.e., ASRC SKW Eskimos); other villages have simple free-standing gasoline and ULSD pumps. In Anaktuvuk Pass, Atqasuk, Nuiqsut, Point Lay, and Wainwright, these pumps are located at the village tank farm, while in Kaktovik and Point Hope, they are located at a different location separate from the tank farm.[48] In the oil and gas fields, vehicles are primarily refueled from refueling trucks. Refueling emission factors were estimated using the MOVES model without Stage II controls.

METHOD – EMISSIONS INVENTORY PROJECTIONS

To help BOEM determine impacts on air quality from future oil and gas exploration, development and production on the Alaska OCS as well as those in near-shore state waters, ERG also developed future year emissions inventory projections. The future year emissions inventory projections covered sources and activities in Arctic OCS that are reasonably foreseeable, and expected to continue for an extended period of time. The projections reflect a future scenario as defined by BOEM.[2] The projections also include potential increases in future emissions from certain onshore sources including: operation of new production facilities; increased TAPS throughput; increased airport activities necessary to support offshore production; and construction and operation of new onshore pipelines to transport the anticipated offshore oil produced. Finally, the projections reflect decreased emissions for select stationary and area sources that are anticipated to convert to exclusive use of ULSD in the future.

Offshore Sources

The offshore projection emissions inventory represents a single future year when offshore operations are "fully built out" and includes operations such as seismic, geotechnical, geohazard, and on-ice surveys; exploratory drilling; platform construction; gravel island construction; pipelaying; active production platforms; and potential spill events.

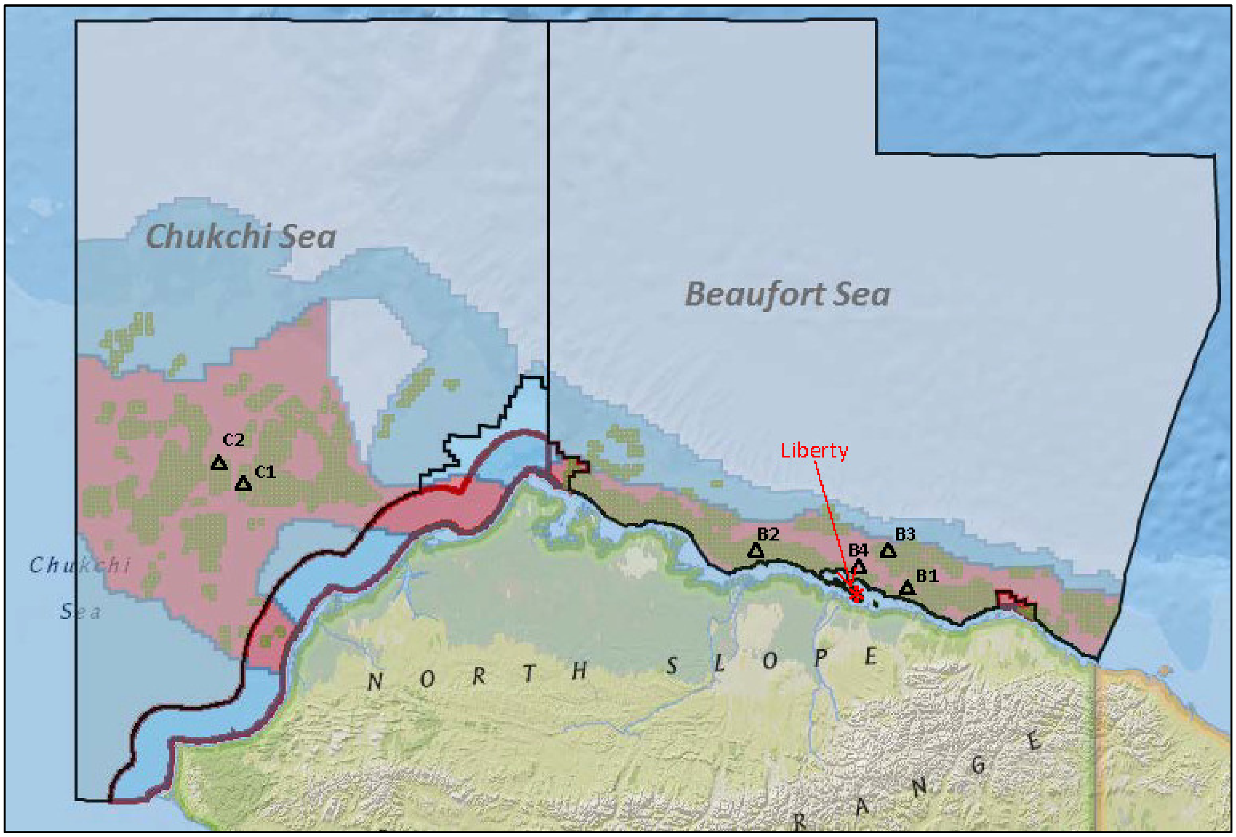
The offshore projection scenario developed by BOEM[2] includes two sites in the Chukchi Sea, and four sites in the Beaufort Sea as noted in Figure 7. (The figure also shows the anticipated location of the Liberty (gravel) Island, discussed below). Because the projection scenario does not identify specific vessels and aircraft to be used, actual periods of activities, or actual vessel traffic patterns, a number of assumptions were made.

Seismic Survey Vessels

For the future scenario, it was assumed that each seismic survey vessel will require a support vessel and an ice-breaker/scout vessel. Similar to the approach for the 2012 seismic survey vessel activity estimates, the seismic survey and support vessels are assumed to have the same characteristics as the M/V Geo Arctic and the Polar Prince. The scout vessel was assumed to have a power rating of 1,268 kW.[49] For the geohazard and geotechnical surveys, it was assumed that two survey vessels with an average power rating of 1,519 kW each and six support vessels with an average power rating of 824 kW each will be used, based on Arctic survey fleet data compiled by BOEM.[50] The emissions factors for these survey vessels are for combusting ULSD fuels (15 ppm sulfur).

In addition to survey and support vessels, support helicopters visit the survey vessels to deliver supplies and transfer personnel. It was assumed that, during the 120-day open water season when the sea ice has melted (July through October), helicopters will fly from the airport to the area where the survey vessels operate three times a week, at a cruising speed of 100 mph. The emissions from the LTOs were calculated using the FAA's EDMS for a Sikorsky SH-60 Sea Hawk.[5]

Figure 7. Offshore projected development areas.
Data Source: Reference 2



Exploratory Drilling

For the projection scenario, exploratory drilling and subsea well construction are expected to continue; both activities will require use of drilling rigs, specifically drillships and jackups. The potential drilling activity locations (B1, B2, B3, B4, C1 and C2) are noted on Figure 7. BOEM provided projected daily activity,[2] which is summarized in Table 2.

Projected drilling operations will also include helicopters and airplanes. At the Chukchi sites, the helicopters were assumed to fly 12 round trips a week from Barrow Airport to the drilling sites at three hours per trip. Airplanes were assumed to fly four times a week between Wainwright Airport and Barrow Airport to bring supplies to the helicopters at Barrow Airport.[9] Wildlife monitoring aircraft were assumed to fly seven times a week at six hours a trip. It was also assumed that when the helicopters fly to the drilling sites, they will land at more than one drilling rig; therefore, each trip will have multiple LTOs at the drilling sites but only one LTO at the airport. Helicopters and airplanes were assumed to fly for the entire 120-day open water season when the sea ice has melted (July through October). Airplane and helicopter LTO emissions were estimated using the FAA's EDMS.[5]

Table 2. Projected drilling activity.

Activity Type	Development Areas	Vessel Type	Number of Vessels	Wells per Vessel	Days per Well	Total Days
Exploratory	B3	Jackup	1	2	38	76
		Support Fleet	1	2	38	76
	B4	Jackup	1	1	38	38
		Support Fleet	1	1	38	38
	C1	Drillship	2	2	38	152
		Support Fleet	1	2	38	76
Subsea Well	B2	Jackup	2	3	38	228
		Support Fleet	1	3	38	114
	B3	Jackup	1	3	38	114
		Support Fleet	1	3	38	114
	C1	Drillship	2	3	38	228
		Jackup	1	3	38	114
		Support Fleet	1	3	38	114

Source: Reference 2

Pipelaying and Support Vessels

Pipelines link offshore platforms to onshore refineries and storage facilities and connect to other pipelines. Pipelines are constructed using special pipelaying vessels. There are two types of pipelaying vessels: vessels installing flexible pipe that is unwound from giant reels (S lay), and vessels installing ridged pipe that is welded together while at sea. Pipelaying vessels also install underwater valves and pumps, which requires using large heavy-lift cranes. Pipelaying vessels can be self-propelled ships equipped with Category 2 or 3 propulsion engines and Category 2 auxiliary engines or they can be non-self propelled barges that require tugs to tow them to the site. These barges are specifically designed to lay pipe and are equipped with large auxiliary engines. Pipelaying vessel emissions include estimates for vessels providing pipeline construction services, as well as associated support vessels and dredges.

Each pipelaying vessel was assumed to require four support vessels.[2] The pipelaying vessels and their associated support vessels were also assumed to operate 24 hours per day laying pipe at a rate of 1 mile per day.[51] The projected pipelaying activity data were derived from the vessel power rating, load factor, and hours of operation in terms of kW-hrs. The vessel power rating is assumed to be 67,200 kW based on a representative ice class pipelaying vessel,[52] and 3,820 kW for associated support vessels.[7] The hours of operation were based on total pipeline length in miles constructed in both the Beaufort and Chukchi Seas.[2]

Platform Construction

Various types of offshore platforms are used for offshore extraction. In BOEM’s scenario it is anticipated that the platforms to be constructed offshore of the North Slope will be gravity-based structures (GBS) built to withstand winter ice flows. GBS platforms are typically constructed offsite at a dry dock or adjacent to a protected harbor. The base and topside are constructed separately. The base is typically towed to a deeper water location where water is pumped into the structure allowing it to sink below the surface. Next, the topside structure is positioned above the base, and compressed air is added allowing the base to rise, connecting it to the topside structure. The combined base and topside structure are then towed to the site where the GBS will operate. Once the GBS is at the site, the platform is carefully positioned and ballast water is added to the base allowing it to slowly sink to the sea bed. Then the ballast water is displaced with denser material such as stone, sand, or concrete to provide the necessary mass needed to secure the base to floor of the sea.[53,54] The projected year emissions inventory includes vessels involved in towing the GBS to the site, positioning the platform, ballasting the base, as well as support vessel and helicopter activities necessary to complete the platform construction.

In developing emission estimates for the projected offshore platform construction, ERG identified other applications similar to those expected in the Arctic,[55] and determined the Hibernian Platform off the coast of Newfoundland, Canada, to be an appropriate model on which to base Arctic GBS activities.[56,57,58] As with other GBSs, it is assumed that the platforms in the Arctic will be constructed offsite (not on the North Slope as special dry docks or deeper water locations are needed), probably elsewhere in Alaska or the western coast of Canada and transported to offshore locations in the Beaufort and Chukchi Seas. During towing, a platform will travel at 2 mph. BOEM has developed maps of the most direct routes to the projected platform construction sites using GIS mapping tools. This mapping activity provides an estimate of the travel distances with which to calculate the period of time each GBS would be towed to the site.[2]

It was assumed that it will take 40 hours for the tugs to set the platform in place. After the platform is set, two support tugs will be needed for transporting ballast material (i.e., rock, sand, or cement) to the platforms for one month. Lastly, it is assumed that two support vessels will continue activities during the remaining open water season (2.5 months), to transfer supplies and crew changes to complete platform construction. This projected platform construction scenario also assumes three helicopter trips weekly for personnel transfers. The helicopter LTO emissions were estimated using the FAA's EDMS and the cruising emissions to the nearest port were calculated using the same approach used for the baseline inventory.[5]

Platform Operations

Constructed platforms are put into operation to drill production wells, extract crude and gas from the sea bed, re-inject gas to maintain site production rates, and pump product to shore. The process of extracting and pumping oil and gas to shore creates combustion and evaporative emissions from a number of emission units. Because there are currently no production platforms in the Chukchi or Beaufort Seas, details concerning the actual unit process configurations for Arctic platforms are unknown. Emission profiles for projected offshore production platforms were derived from available data from some of the larger offshore platforms operating in Cook Inlet, Alaska.

Emissions data for these platforms were compiled from the EPA's 2011 NEI and the GHGRP subpart C (Combustion Sources) and subpart W (Petroleum and Natural Gas Systems) data submittals for 2012. The number of wells for each platform was obtained from the Cook Inlet Facility Assessment: Report, Final Draft.[59] An emissions profile was developed for each pollutant at each production platform, then averaged to obtain an estimate of average emissions per well. This approach assumes the ratio of production versus injector wells for the Arctic offshore platforms will be similar to the Cook Inlet platforms. In addition, the NEI includes only the most important sources on the platform (i.e., minor or sources that occur occasionally are not included in the NEI data); therefore, actual emissions from production platforms may be slightly larger than the values calculated for this study.

The average Cook Inlet platform emissions per well were applied to the projected number of production wells for each development area (e.g., B1, B2, B3, B4, and C1) in BOEM's projection scenario as noted in Table 3. In addition to emission sources located on each production platform, support helicopters also visit the production platforms to drop off supplies and transfer personnel. Three helicopter trips per week were assumed to occur for personnel transfers.

Table 3. Projected number of on-platform and subsea production wells.

Location	Well Type	Development Areas	Number of Wells
Beaufort Sea	On-platform	B1	27
Beaufort Sea	On-platform	B2	81
Beaufort Sea	On-platform	B3	54
Beaufort Sea	On-platform	B4	54
Beaufort Sea	Subsea	B2	23
Beaufort Sea	Subsea	B3	11
Chukchi Sea	On-platform	C1	260
Chukchi Sea	Subsea	C1	9
Liberty Island	-	-	32

Source: Reference 2

Spills

BOEM anticipates that there may be emissions associated with spills from oil and gas exploration, development and production activities in the Chukchi and Beaufort Seas. This includes evaporation from the spill and emissions associated with operating the spill response vessels. To estimate air emissions from offshore oil spills, BOEM provided the potential volumes of crude and diesel that may be spilled.[2] It was assumed that the composition of the crude oil used in modeling emissions from spills in the Chukchi and Beaufort Seas will be equivalent to that produced on the North Slope.[60] Evaporative emissions from the volume of oil and diesel spilled were developed using evaporative emission curves that quantified the range of emissions from an offshore spill for different water temperatures. Film thickness of the spill is not considered in evaporation calculations, as both crude and diesel spread quickly on water. Evaporation curves developed based on the percentage of evaporation relative to the amount of time occurring after crude oil and diesel spills associated with winter water temperatures (-2°C) and summer water temperatures (5°C) indicate that, even in the coldest months, the majority of the volatile content of spilled crude oil and diesel will evaporate within one to two days.[60,61,62] The experience of cleanup crews in Cook Inlet also suggests that diesel spills will fully disperse within two days.[63]

In addition to evaporative emissions from the spill, combustion emissions from the spill response vessels will occur. These vessels include oil spill response vessels, tug and oil spill containment system barges (operated offshore), skimmer boats, and work boats. Oil spill response vessels vary in size and capacity; vessels operating in Arctic waters are larger and with greater spill cleanup capacity and have greater holding capacity for recovered petroleum products than similar vessels operating in less extreme environments. Skimmer boats are small, 75-foot boats with built-in oil skimmers, and are designed to be fast and maneuverable in and around ice. Six work boats were included in the oil spill emissions estimates. These smaller vessels help set booms that confine and consolidate product floating on the surface. Spill recovery fleets often include tankers to store and transport the crude oil, emulsion, and free water that may be recovered from an oil spill.

To estimate emissions from the spill response activities, power ratings of vessels currently in the fleet were compiled for propulsion and auxiliary engines. Typical operating loads were also included along with an assumption that these vessels will be at sea for three days for a 1,700-barrel pipeline leak; five days for a 5,100-barrel offshore platform crude spill; and two days for a 48-barrel diesel spill. The larger vessels were assumed to operate 24 hours per day, while the tug and other boats were assumed to operate 12 hours per day. The emissions factors used for vessels associated with the oil and gas industry were assumed to be based on ULSD fuels.

Onshore Sources

ERG estimated onshore projected emissions that represent anticipated future year emissions for sources that can reasonably be expected to be constructed and/or operated during a future year that is consistent with the offshore projection scenario. These sources are described below. Sources and activities not addressed in this future year scenario include existing onshore oil and gas production facility activities and several non-oil/gas related stationary point and mobile sources, as any prediction of future activities for these sources would be highly speculative at this time. Also, note that no future (post-2012) regulations are anticipated to reduce future emissions from the existing onshore oil and gas production facilities and the existing non-oil/gas related stationary point and mobile sources, with one exception: Tier 4 diesel manufacturer emission standards that came into effect in 2014. Although these standards will serve to reduce emissions from affected engines after 2012 as older engines are replaced, the rate of turnover is difficult to predict. Therefore, ERG did not estimate these reductions, which will provide a conservatively high estimate of these emissions for modeling.

<u>New Oil and Gas Production Facilities</u>

Projected emissions from future onshore oil and gas exploration and production facilities were estimated using a combination of available information on the planned facilities and emissions data for existing facilities. The four future production facilities of interest are Greater Moose's Tooth Unit 1, Point Thomson Production Facility, CD-5 Satellite at Alpine, and a planned Chukchi coast processing production base facility. The methodology used to estimate projected emissions from each of these facilities is based on ADEC construction permits, BLM EIS, and actual emissions estimates for similar existing facilities. Each of these facilities is discussed separately below.

The Greater Moose's Tooth Unit 1 project is being undertaken by ConocoPhillips. Unit 1 will be located in the Alpine satellite field located in the National Petroleum Reserve-Alaska (NPR-A), to the west of the current Alpine Central Processing Facility. Emissions data for the proposed project is available through the BLM.[64]

The Point Thomson project is being undertaken by ExxonMobil approximately 20 miles east of the current Badami Production Facility. Unlike the current North Slope fields, Point Thomson is primarily a natural gas play with an estimated 8 trillion cubic feet (TCF) of gas and 200 million barrels of condensate. Construction on this facility commenced in 2008 and initial condensate production into the TAPS is expected to begin in late 2015 or early 2016. ADEC issued a revised construction permit for this facility on August 7, 2014.[65] Emission estimates for the Point Thomson Production Facility are based on the PTE listed in the permit and the emission characterization profiles developed for existing sources.

The CD-5 Satellite project is being undertaken by ConocoPhillips and will consist of a new production drill site and well pad located approximately 6 miles west of the existing Alpine field in the NPR-A. First production is expected in late 2015. ADEC issued a revised construction permit for this facility on September 17, 2009.[65] Emission estimates for the Alpine Satellite CD-5 facility are based on the PTE listed in the permit and the emission characterization profiles developed for existing sources.

The new processing production base facility will be located on the western coast of the North Slope and will process fluids from offshore platforms operating in the Chukchi Sea. No permit or existing data is available for this potential facility, which is projected to have a maximum peak production of 200 million barrels per year. Construction emissions for the new processing facility were estimated based upon construction emissions associated with Greater Moose's Tooth Unit 1.[66] Construction emissions for Greater Moose's Tooth Unit 1 were scaled up based on the ratio of the proposed facility footprint divided by the Greater Moose's Tooth Unit 1 pad footprint. Only emissions from the ice roads, gravel roads and pads, and facilities installation construction activities (both on-road motor vehicle and nonroad equipment) were used for this estimate. Emission estimates from operation of this facility are based on the emissions data generated for the Alpine Central Production Facility scaled up to reflect the larger capacity of the planned Chukchi coast processing facility.

New Pipeline Construction and Operations

Construction emissions for the two new onshore pipelines to be constructed and operated to transport new offshore production to TAPS and the existing feeder pipelines were estimated based on construction emissions associated with Greater Moose's Tooth Unit 1.[66] A total of 20 miles of new pipeline is projected to be built for the Beaufort Sea. For the Chukchi Sea, a 300-mile long pipeline extending from the Chukchi Sea coast to the TAPS is projected to be built at a rate of 75 miles per year. Construction emissions for Greater Moose's Tooth Unit 1 were scaled up based on the ratio of the proposed pipeline length divided by the pipeline length associated with Greater Moose's Tooth Unit 1. Only emissions from the pipelines, power lines, fiber optics, ice roads, gravel roads, and pads, and facilities installation construction activities (both on-road motor vehicle and nonroad equipment) were used for this estimate. Operation emissions from the two new pipelines were estimated by scaling the TAPS operation emissions by the ratio of pipeline. The only TAPS operation emissions that were scaled were pipeline fugitives, pigging operation emissions, and on-road patrol vehicle emissions; emissions from other TAPS operations were not estimated as these are not expected to increase with increased throughput.

Liberty Island Construction and Drilling

Liberty Island will be a self-contained offshore drilling/production facility located on a conventional gravel island with pipelines to shore. The island will be built in Foggy Island Bay in the Beaufort Sea in approximately 21 feet of water. The future emissions expected to be emitted by Liberty Island will be due to its construction, followed by drilling and production operations. Construction emissions for Liberty Island were estimated based upon construction emissions associated with Greater Moose's Tooth Unit 1.[66] Construction emissions for Greater Moose's Tooth Unit 1 were scaled up based on the ratio of the amount of gravel to be used for Liberty Island[67] divided by the amount of gravel to be used for Greater Moose's Tooth Unit 1 pad footprint. Only emissions from the ice roads, gravel roads and pads, and facilities installation construction activities (both on-road motor vehicle and nonroad equipment) were used for this estimate. The emissions estimates for the Liberty Island drilling operation were derived from the Kuparuk River Transportable Drilling Rigs Renewal Application,[68] and the peak number of production wells to be drilled as provided in the BOEM scenario.[2]

Airports, Aircraft and Supply Boat Terminal

As offshore activities increase on the North Slope, aviation is anticipated to increase proportionally for transporting supplies and personnel. Additional local helicopter and small aircraft activities are also anticipated to increase to provide necessary support to the offshore platforms, as well as wildlife and pipeline surveillance. This section of the projection scenario includes aviation-related emissions that occur near airports.

The airport emissions were projected into the future using the FAA's Air Traffic Activity[69] from the FAA's Aerospace Forecast Fiscal Years 2012-2032. Note these activities are provided in terms of one LTO cycle comprising two separate operations, landings and takeoffs. For this study, operations were used only to develop the growth factors; to estimate aviation emissions, LTO data were used for airports and platforms. The FAA projection activity data account for changes in activity by aircraft type (commercial air carriers, air taxis, and general aviation). The projected aircraft-type growth factors were calculated by dividing year 2020 national activity data (assumed to provide a conservatively high level of growth, and commensurate to a year that could be expected for the BOEM scenario) by the year 2012 national data for each aircraft type. The projected growth factors were then applied to the 2012 emissions data for each airport based on the aircraft categories.

In support of increased aircraft activities, a number of additional facilities will need to be built, including the following: an Exploration Base, an Air Support Base, and a Search and Rescue Base. Also, a new Supply Boat Terminal will be built to support offshore production in the Chukchi Sea. ERG assumed that the Exploration Base, the Air Support Base, and the Search and Rescue Base will all be built as an expansion to an existing airport. It was also assumed that the Supply Boat Terminal was collocated with the production base processing facility, even though it is a separate and distinct facility. The exact size of these four facilities is not known. Because these facilities will be adjacent to other existing or proposed facilities, the facilities are not expected to be extremely large. The following facility sizes were assumed: Exploration Base (20 acres), Air Support Base (20 acres), Search and Rescue Base (15 acres), and Supply Boat Terminal (10 acres). Construction emissions from these four facilities were based on construction emissions for Greater Moose's Tooth Unit 1, scaled based on the ratio of the proposed facility footprint divided by the Greater Moose's Tooth Unit 1 pad footprint. Only emissions from the ice roads, gravel roads and pads, and facilities installation construction activities (both on-road motor vehicle and nonroad equipment) were used for this estimate.

TransAlaska Pipeline System

The future year increased production will affect some of the existing emissions associated with the TAPS. According to Alyeska Pipeline Service Company (APSC) statistics, the 2012 TAPS throughput was slightly over 200 million barrels,[24] so the future year increased production will effectively double the TAPS throughput. ERG assumed that the following emissions sources associated with the TAPS will increase with increased production throughput: pump stations, pipeline fugitives, and natural gas supply line fugitives. A review of pump station inventories from ADEC's on-line Point Source Emissions Inventory indicated a general trend of decreased pump station emissions with decreasing throughput.[65] Conversely, increased throughput should result in increased emissions. Future year emissions for pump stations, pipeline fugitives, and natural gas supply line fugitives were estimated by doubling the 2012 emissions. It was assumed that future year emissions did not increase for on-road patrols, aerial surveillance, pigging operations, and pipeline replacement and repair.

Non-Oil and Gas Stationary Point and Area Sources

Non-oil and gas sources include the air emissions sources (both stationary and mobile) operating in the North Slope villages, and combustion of ULSD in all equipment and vehicles (which is expected to be fully implemented by 2017). Year 2012 emissions modeling of on-road motor vehicles and nonroad mobile sources was conducted using ULSD; however, a number of point sources (i.e., seven schools, four Air Force LRRS facilities, five power plants, and the Service Area 10 incinerator) and two area source categories (i.e., commercial/institutional fuel combustion and residential fuel combustion) used heating oil with a higher sulfur content. To account for the use of ULSD in these sources, their future year SO_2 emissions will be reduced by 99.4 percent (i.e., corresponding to a shift from 2500 ppm sulfur content of heating oil to 15 ppm sulfur content of ULSD).

RESULTS

This section presents the results of the Arctic AQ Modeling Study emissions inventory for the baseline emissions and the future projections.

Baseline Emissions Inventory

Tables 4, 5 and 6 summarize the baseline emissions inventory for CAPs, GHGs, and other pollutants (i.e., HAPs, H_2S, and NH_3), respectively. In the baseline emissions inventory, offshore sources include emissions from seismic survey vessels, drilling rigs, and survey/drilling support aircraft and vessels; CMV; and, research vessels. Onshore sources include oil and gas activities (i.e., seismic surveys, exploratory drilling, and oil and gas production); airports, aircraft, and GSE; TAPS; and non-oil and gas related stationary and mobile sources. These tables show that emissions from onshore sources in the baseline inventory are much larger (i.e., by two orders of magnitude for most pollutants) than emissions from offshore sources. This result is not unexpected given that the offshore sources that operated during this time were limited to a very small number of sources as compared to the onshore sources.

Table 4. Summary of baseline emissions – criteria air pollutants (tons/yr).

Sector	Pollutant						
	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	Pb
Offshore	1,816.3	38.2	106.0	248.6	35.8	27.2	0.005
Onshore	45,733.9	1,235.2	2,886.1	14,001.9	35,643.9	4,770.8	0.325
Total	**47,550.2**	**1,273.3**	**2,992.0**	**14,250.5**	**35,679.7**	**4,798.0**	**0.330**

Table 5. Summary of baseline emissions – greenhouse gases (tons/yr).

Sector	Pollutant			
	CO_2	CH_4	N_2O	CO_2e[a]
Offshore	139,982.5	0.8	6.5	141,932.6
Onshore	13,567,667.1	8,791.9	29.1	13,796,134.6
Total	**13,707,649.6**	**8,792.7**	**35.6**	**13,938,067.2**

[a] Calculated using GWPs from Reference 70.

Table 6. Summary of baseline emissions – other pollutants (tons/yr).

Sector	Pollutant		
	HAPs	H_2S	NH_3
Offshore	18.1	0.0	0.7
Onshore	390.2	16.4	4.4
Total	**408.4**	**16.4**	**5.2**

Figures 8, 9, and 10 provide the relative contributions of various sources to the baseline emissions inventory for NO_x, PM_{10}, and HAPs. These figures show that onshore oil and gas sources are the largest contributors to the baseline emissions inventory for NO_x (i.e., two orders of magnitude larger than other sources), and the same is true for CO_2e. Unpaved road dust contributes over 96 percent of the total PM_{10} emissions, as well as about 70 percent of the total $PM_{2.5}$ emissions. A few other sources are the largest emitters of HAPs, including other nonroad vehicles/equipment and onroad gasoline trucks.

Figure 8. Baseline emissions by sources – NO_x.

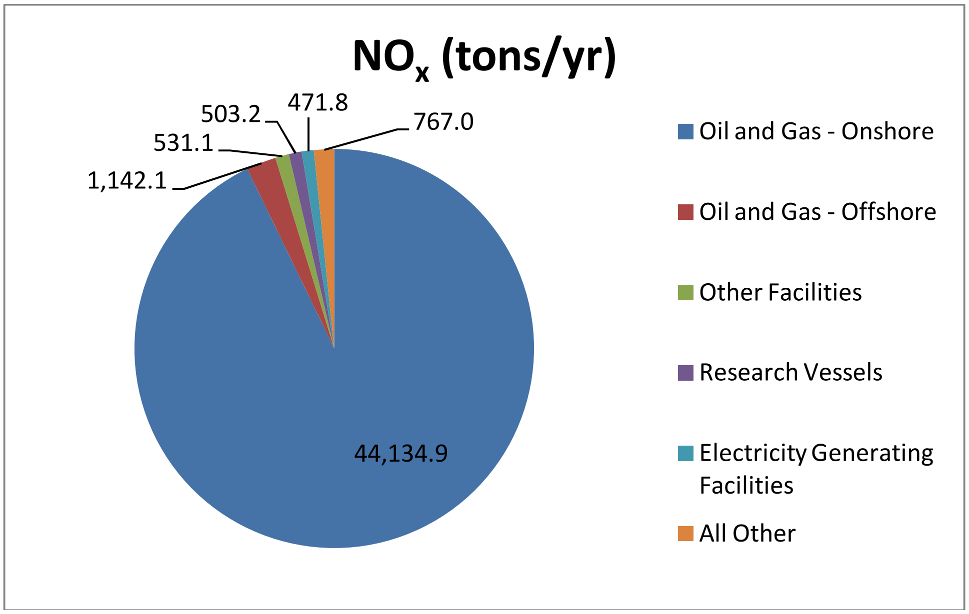


Figure 9. Baseline emissions by sources – PM_{10}.

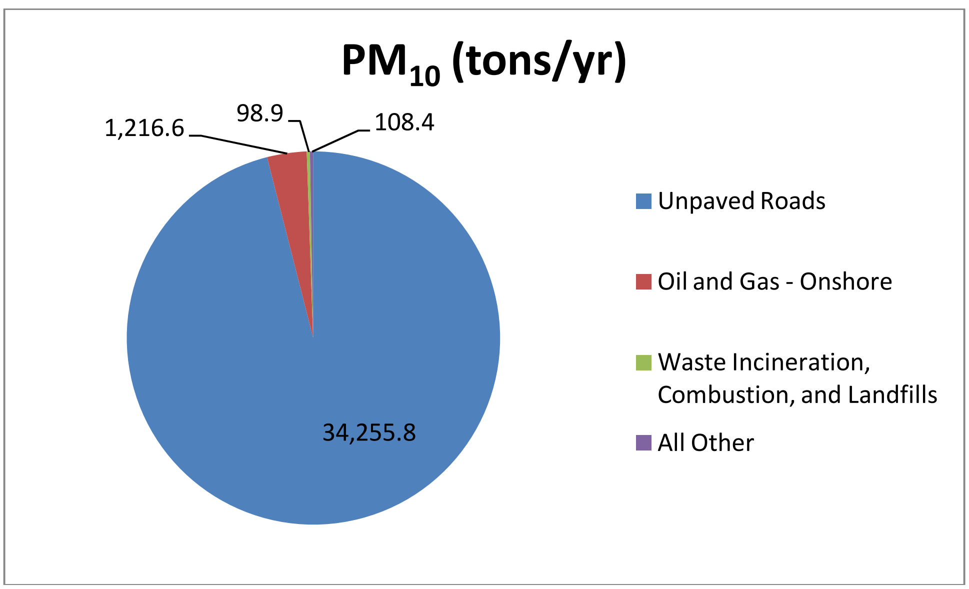


Figure 10. Baseline emissions by sources – HAPs.

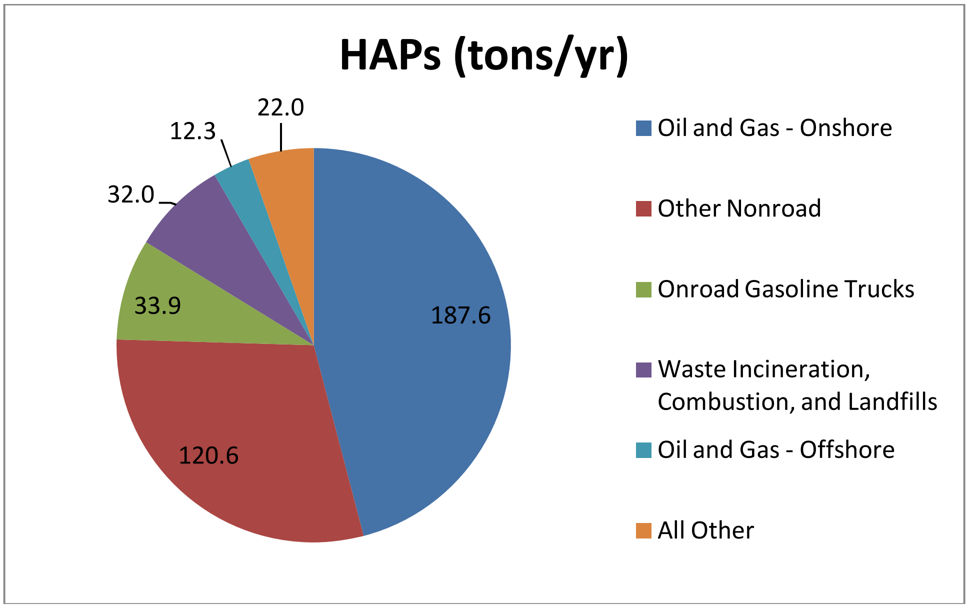


Table 7 shows the baseline emissions inventory for the onshore oil and gas sector, by source category. This table provides the total emission (tons/yr) by pollutant and source category within the onshore oil and gas sector, as well as the percentage of the total pollutant emissions contributed by each source category. As can be seen, production accounts for the majority of emissions generated within the sector.

Table 7. Selected baseline emissions from onshore oil and gas sector, by source category.

Pollutant		Exploratory Drilling	Oil and Gas Production	Seismic Survey Equipment	Total
NO_x	**Tons/yr**	**1,388.2**	**42,260.1**	**144.1**	**43,792.4**
	Percent of Total	3%	97%	<1%	100%
SO_2	**Tons/yr**	**42.1**	**1,049.0**	**9.5**	**1,100.6**
	Percent of Total	4%	95%	1%	100%
VOC	**Tons/yr**	**354.2**	**1,707.2**	**2.7**	**2,064.1**
	Percent of Total	17%	83%	<1%	100%
CO	**Tons/yr**	**318.0**	**8,967.5**	**31.0**	**9,316.5**
	Percent of Total	3%	96%	<1%	100%
PM_{10}	**Tons/yr**	**19.0**	**1,168.6**	**10.1**	**1,197.7**
	Percent of Total	2%	98%	<1%	100%
CO_2e	**Tons/yr**	**108,823.1**	**13,185,512.4**	**5,390.1**	**13,299,725.6**
	Percent of Total	<1%	99%	<1%	100%

Emissions Inventory Projections

Tables 8, 9, and 10 summarize the emissions inventory projections for the CAPs, GHGs, and other pollutants (i.e., HAPs, H_2S, and NH_3), respectively. These tables show projection emissions for the offshore sources based on BOEM's scenario,[2] and for the onshore sources reasonably expected to occur and that are affected by increased offshore production and exclusive use of ULSD fuel in selected onshore point and area sources.

Note that the projected emissions described in this section do not represent all future year projected emissions. The projected emissions include only those sources and activities that are expected to change (i.e., increase or decrease) in the future. Furthermore, the future year projected emissions should not simply be added to the 2012 emissions of the sources that are not expected to change to calculate total future year emissions because onshore oil and gas emissions from existing facilities, and emissions from construction and operation emissions from new facilities will likely not all occur during the same year. Future work by ERG to be conducted during the modeling phase of the BOEM Arctic AQ study will define which specific sources should be modeled to determine future air quality impacts; at that time, the total future year inventory will be calculated.

These tables show that the emissions projected for the offshore sources are distributed nearly equally across sources anticipated operating in the Beaufort and Chukchi Seas in the future.

Table 8. Summary of emissions projections – criteria air pollutants (tons/yr).

Sector	Pollutant						
	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	Pb
Offshore – Beaufort Sea	7,474.2	561.3	417.8	1,484.6	174.5	144.5	0.017
Offshore – Chukchi Sea	6,961.9	768.5	353.1	1,528.5	173.2	149.7	0.013
Onshore[a]	17,067.9	341.5	894.1	7,407.7	952.7	879.2	0.105
Total	**31,504.0**	**1,671.3**	**1,665.0**	**10,420.8**	**1,300.4**	**1,173.4**	**0.135**

[a] Includes only emissions from new sources and from sources expected to change under the projection scenario (i.e., future new oil and gas production facilities; new pipelines; Liberty (gravel) Island; airports, aircraft and supply boat terminal; TAPS; and certain non-oil and gas stationary point and area sources).

Table 9. Summary of emissions projections – greenhouse gases (tons/yr).

Sector	Pollutant			
	CO_2	CH_4	N_2O	CO_2e[a]
Offshore – Beaufort Sea	1,293,500.1	52,375.3	181.9	2,657,097.2
Offshore – Chukchi Sea	1,532,252.9	73,618.2	242.4	3,444,957.2
Onshore[b]	18,359,826.6	26,601.4	76.8	19,047,753.7
Total	**21,185,579.6**	**152,594.8**	**501.2**	**25,149,808.2**

[a] Calculated using GWPs from Reference 70.
[b] Includes only emissions from new sources and from sources expected to change under the projection scenario (i.e., future new oil and gas production facilities; new pipelines; Liberty (gravel) Island; airports, aircraft and supply boat terminal; TAPS; and certain non-oil and gas stationary point and area sources).

Table 10. Summary of emissions projections – other pollutants (tons/yr).

Sector	Pollutant		
	HAPs	H_2S	NH_3
Offshore – Beaufort Sea	68.3	0	2.3
Offshore – Chukchi Sea	55.9	0	1.8
Onshore[a]	71.9	0	0.002
Total	**196.1**	**0**	**4.1**

[a] Includes only emissions from new sources and from sources expected to change under the projection scenario (i.e., future new oil and gas production facilities; new pipelines; Liberty (gravel) Island; airports, aircraft and supply boat terminal; TAPS; and certain non-oil and gas stationary point and area sources).

Tables 11 and 12 show the projected offshore emissions by source for the CAPs and GHGs, respectively. The largest contributors to the projected offshore emissions are platform operation, resupply of drilling vessels, pipelaying activities, production support, and drilling vessels.

Table 11. Summary of emissions projections by source – criteria air pollutants (tons/yr).

Source	Pollutant						
	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	Pb
Survey Operations	553.8	0.5	28.3	62.9	8.6	6.3	0.001
Exploratory Drilling	6,550.8	12.3	442.1	1,043.2	138.3	102.2	0.021
Pipelaying and Support Vessels	1,705.1	1.0	87.0	191.4	26.3	19.3	0.004
Platform Construction	537.9	0.6	30.5	62.5	14.0	10.3	0.002
Platform Operations and Support Vessels	5,061.7	1,306.0	181.7	1,650.1	159.0	154.8	0.002
Spills	26.8	9.4	1.2	3.1	1.5	1.3	0.0002
Total	**14,436.1**	**1,329.9**	**770.9**	**3,013.1**	**347.7**	**294.3**	**0.031**

Table 12. Summary of emissions projections by source – greenhouse gases (tons/yr).

Source	Pollutant			
	CO_2	CH_4	N_2O	CO_2e[a]
Survey Operations	36,805.3	0.2	1.7	37,332.2
Exploratory Drilling	572,142.2	3.5	27.0	580,393.1
Pipelaying and Support Vessels	112,413.0	0.7	5.4	114,037.8
Platform Construction	60,024.7	0.4	2.9	60,890.4
Platform Operations and Support Vessels	2,042,439.1	125,988.7	387.3	5,307,451.6
Spills	1,928.6	0.0	0.1	1,949.3
Total	**2,825,753.0**	**125,993.5**	**424.4**	**6,102,054.4**

[a] Calculated using GWPs from Reference 70.

NEXT STEPS IN THE ARCTIC AIR QUALITY MODELING STUDY

The Arctic Air Quality Modeling Study emissions inventory was developed on an annual basis. However, for use in air quality models, it is necessary to allocate these emissions to their locations, as well as to determine the temporal variation in the emissions during the year. These refinements of spatial and temporal resolution must be applied to both the baseline and future year projected emissions.

For spatial allocation of emissions, ERG determined the specific location of stationary sources, and developed spatial surrogates to be used to allocate emissions from other sources to a 4-km modeling grid. Although some emission sources may operate continuously throughout the year with a constant level of activity, for most sources, there is some sort of seasonal, weekly, and diurnal variability. ERG developed temporal profiles to apply to annual emissions from sources that vary throughout the year. The spatial surrogates and temporal allocation profiles will be applied to the annual inventory within the emissions modeling framework and in conjunction with the air quality modeling work to be conducted under a future task as part of the Arctic Air Quality Modeling Study.

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