Final Report

DEVELOPMENT OF BASELINE 2006 EMISSIONS FROM OIL AND GAS ACTIVITY IN THE UINTA BASIN

Prepared by
Ron Friesen
Rajashi Parikh
John Grant
Amnon Bar-Ilan
Alison K. Pollack
ENVIRON International Corporation
773 San Marin Drive, Suite 2115
Novato, CA 94998

Doug Henderer
Daniel Pring
Buys & Associates
300 E. Mineral Ave., Suite 10
Littleton, CO 80122

Kathleen Sgamma
Phil Schlagel
Independent Petroleum Association of Mountain States (IPAMS)
410 17th Street, Suite 1920
Denver, CO 80202

March 25, 2009

TABLE OF CONTENTS

Page

TABLES

FIGURES

EXECUTIVE SUMMARY

This study provides an analysis of the criteria pollutant emissions for oil and gas exploration and production operations the Uinta Basin of Utah. The analysis is part of an effort sponsored by the Independent Petroleum Association of Mountain States (IPAMS) jointly with the Western Regional Air Partnership (WRAP) for the development of a Phase III regional oil and gas emission inventory for the inter-Mountain West. The overall effort will build on the Phase I and Phase II oil and gas inventory projects previously sponsored by WRAP. The Uinta Basin emissions inventory is part of an overall effort that is focused on creating a comprehensive criteria pollutant emissions inventory for all activities associated with oil and gas field operations in the basins throughout the study region for year 2006 as well as future projection years; that includes all point and area sources related to the oil and gas industry.

The primary source of information was a survey outreach effort to the producers in the Uinta Basin. Survey forms consisting of Excel spreadsheets were forwarded to major participating operators in the Uinta basin. Each spreadsheet contained a request for specific data related to the identified oil and gas source categories. All data requested from participating companies were for these companies' activities in the calendar year 2006. Well count and production data for the basin were obtained from a commercially available database of oil and gas data maintained by IHS Corporation ("the IHS database"). As with the emissions estimates, the focus of the IHS database was calendar year 2006.

The companies participating in the survey process for the Uinta Basin represented 71% of well ownership in the basin, 82% of gas production in the basin, and 78% of oil production in the basin. This large percentage of oil and gas activity in the basin made it possible to obtain an excellent representation of oil and gas operations in the basin. The exception was for the categories of salt water disposal engines, water disposal pits and pipeline fugitive emissions. Limited or no responses from the participating companies were received for salt water disposal engines and water disposal pits because these operations would be performed mainly by private contractors. As private contractors were not queried as part of this effort, no emissions for this category were estimated. In addition, we did not estimate potential fugitive emissions from oil and gas pipelines from well heads to the main compressor stations. While we were able to obtain some data on the number potential leaking components per mile of pipeline but data on the length of pipeline were not available from sources queried as part of this effort or other data bases that we analyzed.

Overall, the results show that most oil and gas activities are concentrated in Uintah and Duchesne counties. Accordingly, these two counties also represent the most significant portion of Oxides of Nitrogen (NOx) and Volatile Organic Compound (VOC) emissions. Total emissions of NOx in the Uinta Basin were 13,093 in 2006 while total emissions of VOCs in the Uinta Basin were 71,546 tons in 2006. Production activity in Uintah County was mostly dry gas while a majority of the oil production is concentrated in Duchesne County. Coal Bed Methane (CBM) wells and production are located in Carbon and Emery Counties. Overall, drilling rigs, compressor engines, artificial lift engines, and heaters combined accounted for approximately 78% of NOx emissions. Similarly, condensate and oil tanks, dehydrators, pneumatic pumps and pneumatic devices accounted for approximately 89% of VOC emissions. The majority of these emissions are from unpermitted sources. Overall in the basin, 82 percent of the NOx emissions are from unpermitted sources and 98 percent of the VOC emissions are from unpermitted sources. Emissions of CO, SOx and PM from unpermitted sources represented 89 percent, 99 percent and 95 percent respectively of the total emissions for these pollutants.

Table ES-1 below contains a summary of the total emissions from oil and gas operations in the Uinta Basin.

Table ES-1. Summary of emissions from oil and gas operations in Uinta Basin.

County	NOx [tons/yr]	VOC [tons/yr]	CO [tons/yr]	SOx [tons/yr]	PM [tons/yr]
Carbon	1,024	2,748	833	23	43
Duchesne	3,709	19,280	3,232	97	178
Emery	273	453	199	9	14
Grand	698	2,429	331	16	26
Uintah	7,390	46,637	4,133	251	362
Wasatch	0	0	0	0	0
Total	**13,093**	**71,546**	**8,727**	**396**	**623**

Table ES-2 below shows a summary of the emissions inventory results for the Uinta Basin from 3 studies: (1) the current IPAMS/WRAP Phase III work; (2) an inventory of oil and gas emissions in Uintah and Duchesne counties conducted jointly by the Utah Department of Environmental Quality (UTDEQ) and IPAMS; and (3) the previous WRAP Phase II inventory of oil and gas area sources. This comparison is presented for discussion purposes only. It is very important to note that these studies did not address the same source categories, the same pollutants, or the same temporal or geographic scope. The UTDEQ and IPAMS joint study was conducted to estimate emissions for Duchesne and Uintah counties from well completions, engines, separators/line heaters/treaters, dehydrators, condensate/oil tanks, truck loading, fugitive wellsite emissions, pneumatic devices and fugitives from roadways area source categories. Emissions from point sources, drill rigs, pipeline compressor stations, gas plants, and permitted facilities were not considered in the UTDEQand IPAMS joint inventory. The WRAP Phase II emission inventory focused on NOx and SOx emissions from oil and gas area sources only. The primary focus of the WRAP Phase II inventory was on NOx emissions from drilling rigs and compressor engines only; the most important sources of VOC emissions were not considered as part of this study. As with the UTDEQ and IPAMS joint study, point source emissions were not included in the WRAP Phase II area source inventory estimates that are presented in Table ES-2.

Table ES-2. Comparison of Uinta Basin emissions with other studies

Study	Inventory Year	Basin/County	Emissions (tons/yr)				
			NOx	VOC	CO	SOx	PM
IPAMS/WRAP Phase III	2006	Uinta Basin wide[1]	**13,093**	**71,546**	**8,727**	**396**	**623**
		Duchesne County	3,709	19,280	3,232	97	178
		Uintah County	7,390	46,637	4,133	251	362
UTDEQ/IPAMS	2005	Duchesne County	2,485	3,437	921	2	318
		Uintah County	1,839	17,942	1,460	2	2,482
WRAP Phase II	2005	Uinta Basin wide	6,371	N/A	1,396	146	N/A

[1] Note: For the purposes of the IPAMS/WRAP Phase III Study, the Unita Basin includes the following counties: Uintah, Duchesne, Carbon, Emery, Grand and Wasatch.

INTRODUCTION

The Independent Petroleum Association of Mountain States (IPAMS) is sponsoring the development of a Phase III regional oil and gas emission inventory for the inter-Mountain West jointly with the Western Regional Air Partnership (WRAP), to build on the WRAP Phase I and Phase II inventory projects. This effort is focused on creating a comprehensive criteria pollutant emissions inventory for all activities associated with oil and gas field operations in the basins throughout the study region for year 2006 as well as future projection years; that includes all point and area sources related to the oil and gas industry.

The region of interest for this report is the Uinta Basin. The 2006 baseline inventory consists of two primary categories: sources subject to state or federal reporting requirements, and sources exempt from such reporting requirements, which are collectively termed ”area” sources in this document. This document describes the methodologies by which the 2006 inventory was constructed. This methodology is specific to the Uinta Basin and will have additions and changes for other basins in the Phase III project. For each source category, a basic description is given of the methodology used to estimate emissions from a single source or from all sources belonging to companies that participated in the survey effort (“participating companies”), and a description of how those emissions were scaled up to the county level and basin-wide level.

In general, the inventory was developed using a combination of well count and production activity from a commercially available database of oil and gas data maintained by IHS Corporation (“the IHS database”), permitted sources for which data was obtained from the US Environmental Protection Agency (EPA), the State of Utah Department of Environmental Quality (UTDEQ), and detailed survey responses of oil and gas activity from several major participating companies that operate in the Uinta Basin. Some additional data sources were also used, including American Petroleum Institute (API) technical literature, the EPA’s AP-42 emissions factor technical guidance, the EPA’s NONROAD emissions model, and the EPA’s Natural Gas Star program technical guidance.

TEMPORAL & GEOGRAPHIC SCOPE

This inventory considers a base year of 2006 for purposes of estimating emissions. All data requested from participating companies were for these companies’ activities in the calendar year 2006. Similarly, all well count and production data for the basin obtained from the IHS database were for the calendar year 2006. Emissions from all source categories are assumed to be uniformly distributed throughout the year except for heaters and pneumatic pumps, which are assigned seasonality fractions as they are typically used primarily in winter.

The geographic scope of this inventory is the Uinta Basin in Utah. For the purposes of this study, the boundaries for the Uinta Basin were modified from those of the US Geological Survey (USGS) to wholly include the counties of Carbon, Duchesne, Emery, Grand, Uintah and Wasatch. Figure 1 shows the boundaries of the Uinta Basin, with the 2006 well locations extracted from the IHS database overlaid, and the boundaries of the tribal airshed in the Uinta Basin.

Uinta Basin - 2006 Well Location

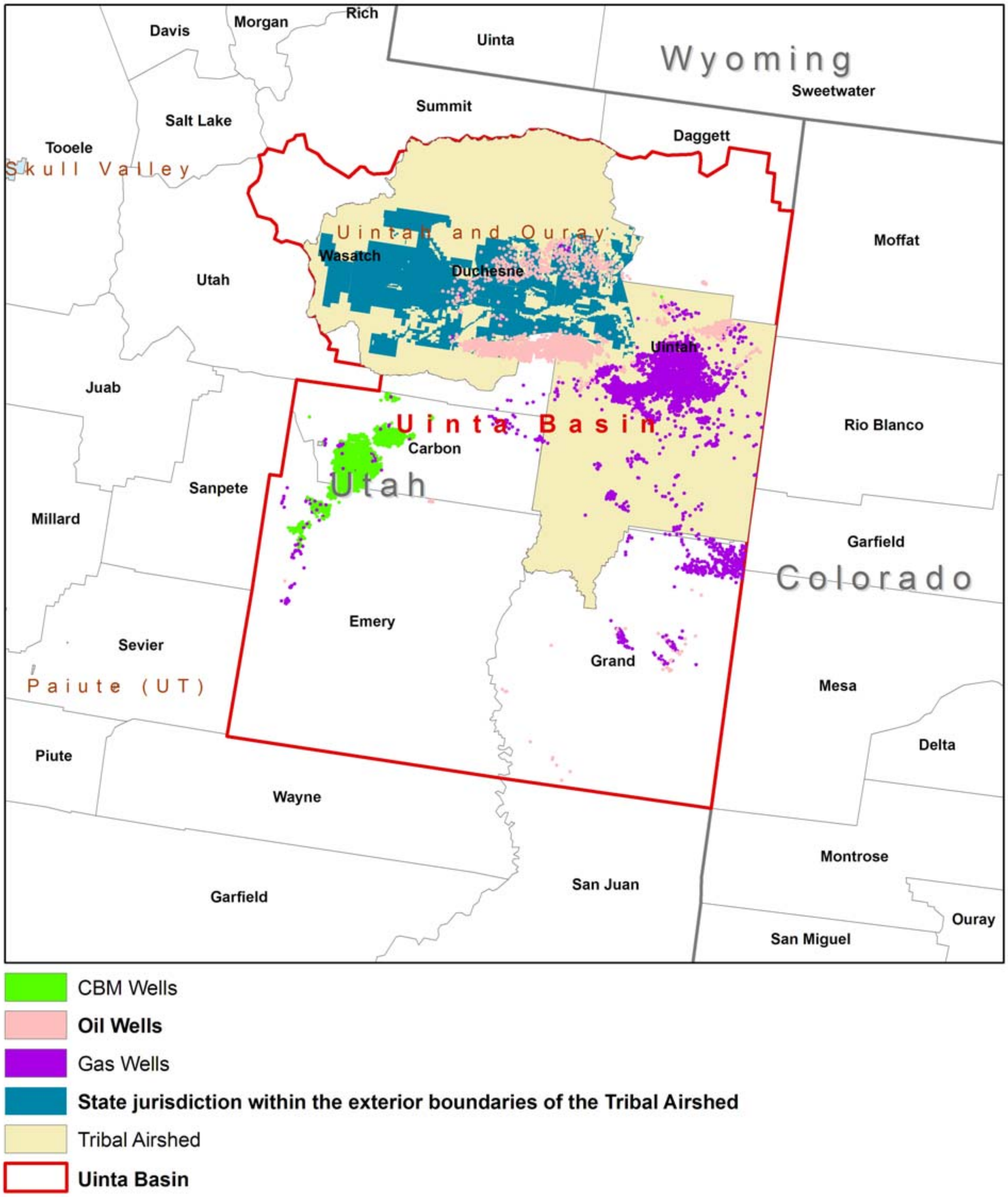

Figure 1. Uinta Basin boundaries overlaid and 2006 oil and gas well locations.

TRIBAL AIRSHED

The UTDEQ provided to Buys & Associates, in hard copy, the land coverage which defined the tribal airshed boundaries. Based on this hard copy, a GIS coverage delineating tribal airshed boundaries in the Uinta Basin was developed. The tribal airshed boundaries were defined as the areas within the Uinta Basin boundaries not subject to state air regulations. As shown in Figure 1, the boundaries of the tribal airshed represent a significant portion of the Uinta Basin. Within the tribal airshed boundaries, there are also vast areas under the jurisdiction of state air regulations. Oil and gas emissions that did not occur in the tribal airshed and emissions that occurred within the tribal airshed boundaries, but on land designated as under state jurisdiction were designated as non-tribal airshed emissions. Oil and gas emissions that occurred within the tribal airshed boundaries and not on land designated as under state jurisdiction were designated as tribal airshed emissions.

WELL PRODUCTION DATA

Oil and gas related activity data across the entire Uinta Basin were obtained from the IHS Enerdeq database queried via online interface. The IHS database uses data from the Utah Division of Oil Gas and Mining (UTOGM) as a source of information for Utah oil and gas activity. Two types of data were queried from the Enerdeq database: production data and well data. Production data includes information relevant to producing wells in the basin while well data includes information relevant to drilling activity ("spuds") and completions in the basin.

Production data were obtained for the counties that make up the Uinta Basin in the form of PowerTools input files. PowerTools is an IHS application which, given PowerTools inputs queried from an IHS database, analyzes, integrates, and summarizes production data in an ACCESS database. The Uinta Basin PowerTools input files were loaded into the PowerTools application. From the ACCESS database created by PowerTools, extractions of the following data relevant to the emissions inventory development were made:

1. 2006 active wells, i.e. wells that reported any oil or gas production in 2006.
2. 2006 oil, gas, and water production by well.

The production data are available by API number. The API number in the IHS database consists of 14 digits as follows:

- Digits 1 to 2: state identifier
- Digits 3 to 5: county identifier
- Digits 6 to 10: borehole identifier
- Digits 11 to 12: sidetracks
- Digits 13 to 14: event sequence code (recompletions)

Based on the expectation that the first 10 digits, which include geographic and borehole identifiers, would predict unique sets of well head equipment, the unique wells were identified by the first 10 digits of the API number.

Well data were also obtained from the IHS Enerdeq database for the counties that make up the Uinta basin in the form of "297" well data. The "297" well data contain information regarding spuds and completions. The "297"well data were processed with a PERL script to arrive at a database by-API-number, spud and completion dates with latitude and longitude information. Drilling events in 2006 were identified by indication that the spud occurred within 2006. If the well API number indicated the well was a recompletion (by examining digits 13 to 14 in the full 14-digit API number), it was not counted as a drilling event, though if the API number indicated the well was a sidetrack (by examining digits 11 to 12 in the full 14-digit API number), it was counted as a drilling event.

Activity occurring within the tribal and non-tribal airshed was estimated based on IHS data and the tribal airshed definition as provided to Buys & Associates by UTDEQ. IHS data includes by well latitude and longitude. Based on the IHS latitude and longitude data, GIS was used to designate whether a well occurred within the tribal or non-tribal airshed based on intersection with the tribal airshed boundary definition. A portion of land within the tribal airshed boundaries has been designated as under state jurisdiction. Oil and gas activity occurring within the tribal airshed, but on land designated as under state jurisdiction was designated as non-tribal activity.

The well counts and oil, gas and water production by county and tribal status for the basin are presented in Table 1, and the spuds by county and tribal status are presented in Table 2.

Table 1. 2006 well count and oil, gas and water production by county for the Uinta Basin.

County	Conventional Well Count	CBM Well Count	Oil Production [bbl]	Conventional Gas Production [mcf]	CBM Gas Production [mcf]	Water Production [bbl]
Activity Outside of Tribal Airshed Boundaries						
Carbon	86	639	37,385	16,428,169	62,069,296	18,314,404
Duchesne	721	0	3,271,275	9,506,793	0	12,984,220
Emery	56	218	4,036	951,436	15,247,456	6,596,841
Grand	368	0	125,626	6,854,659	0	34,988
Uintah	78	0	659,366	680,182	0	26,960,364
Wasatch	0	0	0	0	0	0
Total	**1,309**	**857**	**4,097,688**	**34,421,239**	**77,316,752**	**64,890,817**
Activity Within Tribal Airshed Boundaries						
Carbon	5	0	5,977	4,068,375	0	12,820
Duchesne	753	0	3,130,362	13,018,822	0	4,667,306
Emery	0	0	0	0	0	0
Grand	0	0	0	0	0	0
Uintah	3,951	6	4,294,094	202,710,996	308,152	17,770,351
Wasatch	0	0	0	0	0	0
Total	**4,709**	**6**	**7,430,433**	**219,798,193**	**308,152**	**22,450,477**
Total Activity						
Carbon	91	639	43,362	20,496,544	62,069,296	18,327,224
Duchesne	1,474	0	6,401,637	22,525,615	0	17,651,526
Emery	56	218	4,036	951,436	15,247,456	6,596,841
Grand	368	0	125,626	6,854,659	0	34,988
Uintah	4,029	6	4,953,460	203,391,178	308,152	44,730,715
Wasatch	0	0	0	0	0	0
Total	**6,018**	**863**	**11,528,121**	**254,219,432**	**77,624,904**	**87,341,294**

Table 2. 2006 spud counts by county for the Uinta Basin.

County	Non-tribal Airshed	Tribal Airshed	Total
Carbon	57	0	57
Duchesne	120	157	277
Emery	23	0	23
Grand	27	0	27
Uintah	2	683	685
Wasatch	0	0	0
Total	229	840	1069

MAJOR POINT SOURCES

Major point sources located within the tribal airshed fall under the jurisdiction of the US EPA and are required to obtain Prevention of Significant Deterioration (PSD) and Title V permits from the EPA. On January 15, 2008, EPA Region VIII provided a list of major point sources that are located on the Uintah and Ouray Reservations in the Uinta Basin. The information included emissions of NOx, VOC, SO_2, and PM_{10} from each of the major point sources identified by EPA. EPA defines major point sources as those sources with the potential to emit (PTE) greater than 100 tons per year for criteria pollutants. The emissions inventory provided by EPA represents actual emissions (not PTE) for sources in the Uintah and Ouray Reservations for the year 2006 and is based on fees paid in 2007. The sources are all compressor stations with the exception of one gas processing plant. Primary sources of emissions at the compressor stations included compressor engines, heaters, dehydrators and other gas processing activities. Table 3 below provides the list of the major point sources in operation in 2006 and associated emissions.

Table 3. Major point source emissions inventory for 2006 on Uinta and Ouray Reservations.

Company & Source Name	County	NOx [tpy]	VOC [tpy]	SO_2 [tpy]	PM_{10} [tpy]
Natural Buttes CS	Uintah	266.6	118.6	2	6.2
Mesa Tap CS	Uintah	13.7	8	0	0
Chapita CS	Uintah	71.69	102.68	0.02	0
Coyote Wash CS	Uintah	80.45	139.94	0.2	1.3
Cottonwood Wash CS	Uintah	86.99	71	0	2.02
Ouray CS	Uintah	99.63	90.27	0	2.3
Flat Rock CS	Uintah	9.2	6.13	0.01	0.21
Island CS	Uintah	231.37	64	0.09	1.04
Riverbend CS	Uintah	66.99	176.96	0.11	0.28
Red Wash 24B Gas Plant	Uintah	49.47	36.73	0.06	0.33
Wonsits CS	Uintah	170	87.61	0.42	0.23
Fidlar/Chapita-Ouray	Uintah	25.1	12.2	0.6	1.5
North Hill Creek CS	Uintah	20.4	19.7	0.7	0.8
Bridge CS	Uintah	102.58	56.52	0	2.32

Criteria pollutant emissions from major point sources that are located in the State of Utah but outside the tribal airshed are under the jurisdiction of the Utah Department of Environmental Quality (UTDEQ). The UTDEQ provided a list of major point sources and associated emissions on February 8, 2008. As with the EPA, major point sources are defined as sources with the PTE greater than 100 tons per year of any criteria pollutant. Table 4 provides 2006 emissions from major point sources permitted by the UTDEQ.

To complete the emissions inventory for the Uinta Basin, emissions from major point sources on tribal lands and non-tribal lands were added to the 2006 baseline emissions inventory that was developed from the surveys. With a couple exceptions, point source operators both within and outside of the tribal airshed were not producers that responded to the surveys for this emissions inventory but rather companies that operated compressor stations and gas processing plants. For cases where a point source operator also provided survey data, to avoid double-counting emissions, point source emissions for these producers were removed from the survey responses. Because the emissions in tables 3 and 4 are not broken down by source category, the total emissions for each pollutant were assigned to the SCC code 31000000 (Oil and Gas Production). For purposes of speciating the emissions for modeling, it was assumed that the NOx emissions are from combustion sources (compressor engines and heaters) and the VOC emissions are from evaporation and venting of natural gas (dehydrators, tanks etc).

Table 4. Major point source emissions inventory for 2006-Non-Tribal Lands.

Company & Source Name	County	NOx [tpy]	VOC [tpy]	SO_2 [tpy]	PM_{10} [tpy]
Altamont Main Gas Processing Plant	Duchesne	107.94	86.91	1.2	0.88
Altamont East Compressor Station	Duchesne	66.76	47.52	40.95	0.36
Altamont West Compressor Station	Duchesne	79.69	36.29	0.013	0.41
Altamont South Compressor Station	Duchesne	216.99	36.95	790.05	2.03
Bluebell Gas Plant	Duchesne	178.24	50.21	28.85	1.24
Blind Canyon Compressor station	Duchesne	6.07	2.26	0	0.26
Cisco Compressor Station	Grand	53.98	2.76	72.99	1.05
Kane Springs Well #19-1A	Grand	8.87	2.51	39.73	0.05
Kane Springs Well #27-1	Grand	8.82	2.49	6.07	0.06
Harley Dome Station	Grand	2.53	0.287	0.28	0.18
Kane Springs Well #25-19-34-1	Grand	1.18	3.12	0	0.06
Kane Springs Well #10-1	Grand	2.46	5.29	0	0.04
San Arroyo Plant	Grand	282.79	52.48	0	3.24
Oak Spring Turbine Compressor Station	Carbon	28.85	1.03	0	3.16

MINOR POINT & AREA SOURCES

Survey forms consisting of 25 Excel spreadsheets were forwarded to participating operators in the Uinta basin. Each spreadsheet contained a request for specific data related to one of the following source categories:

- Well blowdowns
- Well completions
- Drilling rigs
- Miscellaneous engines
- Fugitive emissions
- Heaters
- Gas composition analysis for the basin
- Pneumatic devices
- Pneumatic pumps
- Water tanks
- Workover rigs

- Compressor engines
- Artificial lift engines
- Compressor startups and shutdowns
- Dehydrators
- Amine units
- Oil and Gas well truck loading
- Gas plant truck loading
- NGL plant truck loading
- Salt water disposal engines
- Water disposal pits
- Condensate and Oil tanks
- Flaring
- CBM pump engines
- Vapor recovery units.

The companies that participated in the survey process by providing some survey responses for the Uinta Basin represented 71% of well ownership in the basin, 82% of gas production in the basin, and 78% of oil production in the basin. This represented a sufficiently large percentage of oil and gas activity in the basin that it was felt that the responses obtained from the participating companies would be representative of all oil and gas operations in the basin. The exception was for the categories of salt water disposal engines, water disposal pits and pipeline fugitive emissions. We received either limited or no responses from the producers for salt water disposal engines and water disposal pits because these operations would be performed mainly by private contractors. As private contractors were not queried as part of this effort, no emissions for this category were estimated. In addition, we did not estimate potential fugitive emissions from oil and gas pipelines from well heads to the main compressor stations. While we were able to obtain some data on the number potential leaking components per mile of pipeline, data on the length of pipeline were not available from sources queried as part of this effort or other data bases that we analyzed.

Detailed inventory methodologies for each of the source categories follow. Extrapolation of these data was necessary to account for emissions from all oil and gas activity in the basin. The extrapolation methodology to obtain county-level, tribal county-level, non-tribal county-level and basin-wide emissions for each source category is described below, but is largely based on scaling by the proportional representation of the respondents of basin-wide well count or oil or gas production, as appropriate.

For emissions from those source categories that relied on estimates of volume of gas vented or leaked, such as well blowdowns, completions, and fugitive emissions, gas composition analyses were requested from all participating companies for CBM & conventional gas. These composition analyses were averaged to derive two basin-wide produced gas composition averages one for conventional gas and one for CBM gas. The average composition analysis was used to determine the average VOC volume and mass fractions of the vented gas basin-wide.

It should be noted that the emission estimates calculated for minor point and area sources rely on data that is not as rigorously documented as permitted sources. Much of the data provided for these sources is based upon estimates and extrapolation from the survey responses. However the level of detail of the surveys and the extent of participation in the survey effort allow for emissions estimates of minor point and area sources which are a significant improvement on the previous WRAP Phase I and Phase II emissions inventory efforts for the Uinta Basin.

MINOR POINT & AREA SOURCE EMISSION CALCULATION METHODOLOGIES

Well Blowdowns

Methodology

Emissions from well blowdowns were calculated using the estimated volume of gas vented during blowdown events, the frequency of the blowdowns, and the VOC content of the vented gas as documented by representative compositional analyses.

The calculations were made separately for conventional and CBM wells, and applied the ideal gas law and gas characteristics defined from laboratory analyses to estimate emissions according to Equations 1 to 5:

Equation (1) $V_{vented} \times f = V_{vented,TOTAL}$

where:

V_{vented} is the volume of vented gas per blowdown [mscf/event]
f is the frequency of blowdowns [events/year]
$V_{vented,TOTAL}$ is the total volume of vented gas from the participating companies [mscf/year]

Equation (2) $V_{vented,CONV} = V_{vented,TOTAL} \times P_{CONV,PCO} / P_{PCO}$

where:

$V_{vented,CONV}$ is the total volume of vented gas from participating companies conventional well production [mscf]
$P_{CONV,PCO}$ is the total conventional well gas production in the basin in 2006 by the participating companies [mscf]
P_{PCO} is the total gas production in the basin in 2006 by the participating companies [mscf]

Equation (3) $V_{vented,CBM} = V_{vented,TOTAL} \times P_{CBM,PCO} / P_{PCO}$

where:

$V_{vented,CBM}$ is the total volume of vented gas from participating companies CBM well production [mscf]
$P_{CBM,PCO}$ is the total CBM well gas production in the basin in 2006 by the participating companies [mscf]

Equation (4) $E_{blowdown,CONV} = V_{vented,CONV} \times 1000 \times MW_{VOC,CONV} \times R \times Y_{VOC,CONV}$

where:

$E_{blowdown,CONV}$ is the total VOC emissions from blowdowns conducted by the participating companies [lb-VOC/yr]

$MW_{VOC,CONV}$ is the molecular weight of the VOC for conventional well vented gas [lb/lb-mol]
R is the universal gas constant [L-atm/K-mol]
$Y_{VOC,CONV}$ is the volume fraction of VOC in the conventional well vented gas

Equation (5) $$E_{blowdown,CBM} = V_{vented,CBM} \times 1000 \times MW_{VOC,CBM} \times R \times Y_{VOC,CBM}$$

where:
$E_{blowdown,CBM}$ is the total VOC emissions from blowdowns conducted by the participating companies [lb-VOC/yr]
$MW_{VOC,CBM}$ is the molecular weight of the VOC for CBM well vented gas [lb/lb-mol]
R is the universal gas constant [L-atm/K-mol]
$Y_{VOC,CBM}$ is the volume fraction of VOC in the CBM well vented gas

The conversion from volume of gas vented to mass of VOC produced was evaluated at standard temperature and pressure.

Extrapolation to Basin-Wide Emissions

The total VOC emissions from conventional well and CBM well blowdowns reported by participating companies were scaled by the proportional production ownership of the participating companies according to Equations 6 to 8:

Equation (6) $$E_{blowdown,CONV,TOTAL} = E_{blowdown,CONV} \times P_{TOTAL,CONV} / P_{PCO,CONV}$$

where:
$E_{blowdown,CONV,TOTAL}$ are the total emissions basin-wide from blowdowns at conventional wells [tons/year]
$E_{blowdown,CONV}$ are the blowdown emissions from the participating companies at conventional wells [tons/year]
$P_{TOTAL,CONV}$ is the total gas production in the basin in 2006 from conventional wells [mscf]
$P_{PCO,CONV}$ is the total gas production in the basin in 2006 by the participating companies from conventional wells [mscf]

Equation (7) $$E_{blowdown,CBM,TOTAL} = E_{blowdown,CBM} \times P_{TOTAL,CBM} / P_{PCO,CBM}$$

where:
$E_{blowdown,CBM,TOTAL}$ are the total emissions basin-wide from blowdowns at CBM wells [tons/year]
$E_{blowdown,CBM}$ are the blowdown emissions from the participating companies at CBM wells [tons/year]
$P_{TOTAL,CBM}$ is the total gas production in the basin in 2006 from CBM wells [mscf]
$P_{PCO,CBM}$ is the total gas production in the basin in 2006 by the participating companies from CBM wells [mscf]

Equation (8) $E_{blowdown,TOTAL} = E_{blowdown,CONV,TOTAL} + E_{blowdown,CBM,TOTAL}$

where:

$E_{blowdown,,TOTAL}$ are the total emissions basin-wide from blowdowns [tons/year]

County-level emissions from conventional wells were estimated by allocating the total basin-wide blowdown emissions from conventional wells into each county according to the fraction of conventional 2006 gas production occurring in that county. County-level emissions from CBM wells were estimated by allocating the total basin-wide blowdown emissions from CBM wells into each county according to the fraction of CBM 2006 gas production occurring in that county. Tribal and non-tribal emissions from conventional wells were estimated in each county by allocating the county conventional well blowdown emissions into the tribal airshed according to the fraction of 2006 conventional well gas production occurring in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 conventional well gas production not occurring in the tribal airshed in that county. Tribal and non-tribal emissions from CBM wells were estimated in each county by allocating the county CBM well blowdown emissions into the tribal airshed according to the fraction of 2006 CBM well gas production occurring in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 CBM well gas production not occurring in the tribal airshed in that county.

Well Completions and Recompletions

Methodology

Emissions from well completions were estimated on the basis of the volume of gas vented during completion and the average VOC content of that gas, obtained from the gas composition analyses.

The calculation methodology for completion emissions is very similar to the method for blowdown emissions, and follows Equations 9 to 14:

Equation (9) $V_{vented} \times f = V_{vented,TOTAL}$

where:

V_{vented} is the volume of vented gas per initial completion or re-completion [mscf/event]
f is the frequency of completions [events/year]
$V_{vented,TOTAL}$ is the total volume of vented gas from completions for participating companies [mscf/year]

Equation (10) $V_{vented,CONV} = V_{vented,TOTAL} \times {W_{CONV,PCO}}/{W_{PCO}}$

where:

$V_{vented,CONV}$ is the total volume of vented gas from participating companies conventional well production [mscf]
$W_{CONV,PCO}$ is the total conventional well count ownership in the basin in 2006 by the participating companies [mscf]
W_{PCO} is the total well count ownership in the basin in 2006 by the participating companies [mscf]

Equation (11) $V_{vented,CBM} = V_{vented,TOTAL} \times W_{CBM,PCO} / W_{PCO}$

where:

$V_{vented,CBM}$ is the total volume of vented gas from participating companies CBM well production [mscf]

$W_{CBM,PCO}$ is the total CBM well count ownership in the basin in 2006 by the participating companies [mscf]

Equation (12) $E_{completion} = V_{vented,TOTAL} \times 1000 \times MW_{VOC} \times R \times Y_{VOC}$

where:

$E_{completions}$ is the total VOC emissions from completions conducted by all participating companies [lb-VOC/yr]

MW_{VOC} is the molecular weight of the VOC [lb/lb-mol]

R is the universal gas constant [lb-mol/379scf]

Y is the volume fraction of VOC in the vented gas

Equation (13) $E_{completiona,CONV} = V_{vented,CONV} \times 1000 \times MW_{VOC,CONV} \times R \times Y_{VOC,CONV}$

where:

$E_{completion,CONV}$ is the total VOC emissions from completions at conventional wells conducted by the participating companies [lb-VOC/yr]

$MW_{VOC,CONV}$ is the molecular weight of the VOC for conventional well vented gas [lb/lb-mol]

R is the universal gas constant [L-atm/K-mol]

Y_{CONV} is the volume fraction of VOC in the conventional well vented gas

Equation (14) $E_{completions,CBM} = V_{vented,CBM} \times 1000 \times MW_{VOC,CBM} \times R \times Y_{VOC,CBM}$

where:

$E_{completion,CBM}$ is the total VOC emissions from completions at CBM wells conducted by the participating companies [lb-VOC/yr]

$MW_{VOC,CBM}$ is the molecular weight of the VOC for CBM well vented gas [lb/lb-mol]

R is the universal gas constant [L-atm/K-mol]

$Y_{VOC,CBM}$ is the volume fraction of VOC in the CBM well vented gas

The conversion from volume of gas vented to mass of VOC produced was evaluated at standard temperature and pressure.

<u>Extrapolation to Basin-Wide Emissions</u>

The total VOC emissions from all completions reported by participating companies was scaled by the total number of completions in the basin to the number of completions conducted by the participating companies according to Equations 15 to 18:

Equation (15) $E_{completion,TOTAL} = E_{completion} \times C_{TOTAL} / C$

where:

$E_{completion,TOTAL}$ are the total emissions basin-wide from completions [tons/year]
$E_{completion}$ are the completion emissions from the participating companies [tons/year]
C_{TOTAL} is the total number of completions in the basin in 2006
C is the total number of completions in the basin in 2006 by the participating companies.

Equation (16) $$E_{completion,CONV,TOTAL} = E_{completion,CONV} \times W_{TOTAL,CONV} / W_{PCO,CONV}$$

where:

$E_{completion,CONV,TOTAL}$ are the total emissions basin-wide from completions at conventional wells [tons/year]
$E_{completion,CONV}$ are the completion emissions from the participating companies at conventional wells [tons/year]
$W_{TOTAL,CONV}$ is the total conventional well count in the basin in 2006 from conventional wells [mscf]
$W_{PCO,CONV}$ is the total conventional well count ownership in the basin in 2006 by the participating companies from conventional wells [mscf]

Equation (17) $$E_{completion,CBM,TOTAL} = E_{completion,CBM} \times P_{TOTAL,CBM} / P_{PCO,CBM}$$

where:

$E_{completion,CBM,TOTAL}$ are the total emissions basin-wide from completions at CBM wells [tons/year]
$E_{completion,CBM}$ are the blowdown emissions from the participating companies at CBM wells [tons/year]
$W_{TOTAL,CBM}$ is the total CBM well count in the basin in 2006 from conventional wells [mscf]
$W_{PCO,CBM}$ is the total CBM well count ownership in the basin in 2006 by the participating companies from conventional wells [mscf]

Equation (18) $$E_{completion,TOTAL} = E_{completion,CONV,TOTAL} + E_{completion,CBM,TOTAL}$$

where:

$E_{completion,,TOTAL}$ are the total emissions basin-wide from completions [tons/year]

County-level emissions from conventional wells were estimated by allocating the total basin-wide completion emissions from conventional wells into each county according to the fraction of conventional 2006 well count occurring in that county. County-level emissions from CBM wells were estimated by allocating the total basin-wide completion emissions from CBM wells into each county according to the fraction of CBM 2006 well count occurring in that county. Tribal and non-tribal emissions from conventional wells were estimated in each county by allocating the county conventional well completion emissions into the tribal airshed according to the fraction of 2006 conventional well count occurring in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 conventional well count not occurring in the tribal airshed in that county. Tribal and non-tribal emissions from CBM wells were estimated in each county by allocating the county CBM well completion emissions into the tribal airshed according to the fraction of 2006 CBM well count occurring in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 CBM well count not occurring in the tribal airshed in that county.

Drill Rigs – Drilling Operations

Methodology

The participating companies were surveyed for information on drilling rigs operating in 2006 in the Uinta Basin. Because many drill rigs are operated by contractors to the oil and gas producers, data were not always available to the level of detail requested in the surveys. Some of the companies surveyed were able to provide exact configurations for all rigs used in their operations, while others were able to provide information on only one or several representative rigs. In all cases, complete information for every parameter needed to estimate drilling rig emissions was not available, and in these cases engineering analysis was used to fill in missing information. Because the nature of the survey responses for drilling rigs varied so much by company, the methodology used was to first estimate each company's total drilling rig emissions given the nature of the data available for that company, and then to sum the emissions and scale up to the basin level.

In general, the emissions for an individual rig engine were estimated according to Equation 19:

Equation (19) $$E_{drilling,engine} = \frac{EF_i \times HP \times LF \times t_{drilling}}{907{,}185}$$

where:

- $E_{drilling,engine}$ is the emissions from one engine on the drilling rig for drilling one well [ton/engine/spud]
- EF_i is the emissions factor for the engine for pollutant i [g/hp-hr]
- HP is the horsepower of the engine [hp]
- LF is the load factor of the engine
- $t_{drilling}$ is the actual on-time of the engine for a typical drilling event in the basin [hr/spud]

A single drilling rig may contain from 3 – 7 or more engines, including draw works, mud pump, and generator engines. The total emissions from drilling one well are thus the sum of emissions from each engine, according to Equation 20:

Equation (20) $$E_{drilling} = \sum_i E_{drilling,engine,i}$$

where:

- $E_{drilling}$ is the total emissions from drilling one well [tons/spud]
- $E_{drilling,engine,i}$ is the total emissions from engine i from drilling one well [tons/engine/spud]

It should be noted that SO_2 emissions were estimated using the brake-specific fuel consumption (BSFC) of the engine, as obtained from the US EPA's NONROAD model for a similarly sized drill/bore rig engine, and the 2006 sulfur content of the off-road diesel fuel (2,400 ppm) as obtained from the WRAP Mobile Sources Emission Inventory Update[1]. The EPA NONROAD model guidance was used to determine the fraction of fuel sulfur that would go to forming PM

[1] Pollack, A.K., L. Chan, P. Chandraker, J. Grant, C. Lindhjem, S. Rao, J. Russell, C. Tran. 2006. "WRAP Mobile Emission Inventories Update." Prepared for Western Governors' Association. May.

emissions – for drilling rig engines this was only 2.2% of sulfur content. It was assumed that the remaining sulfur in the fuel would be emitted as SO_2.

Emissions factors were either provided by the survey respondent or were obtained from the US EPA's NONROAD model. For emissions factors taken from the NONROAD model, in cases where it was not possible to ascertain the engine's technology type, uncontrolled, undeteriorated drill/bore rig engines of the same size class were assumed. When a producer supplied emission factors for some, but not all pollutants, the technology type of the engine was estimated based on the supplied emission factors and emissions factors from the NONROAD model were taken for the estimated technology type for drill/bore rig engines of the same size class. This allowed the calculations to incorporate information about specific rig engines when it was available, and defaulted to the NONROAD model where this information was not available. Load factors were similarly estimated by using respondent information where such detailed information was available.

The resulting rig configurations included engines of several Tier models, several different counts of number of engines per rig, and differing load factors for the different engines on a rig.

Extrapolation to Basin-Wide Emissions

Due to the variability in the type of information provided by the participating companies, it was decided to sum the drilling emissions for each company separately using the data and assumptions for that company, and then to sum all participating companies' drilling emissions and scale this to the basin-wide drilling emissions. Participating companies' drilling emissions were estimated using the emissions from drilling one well using that company's representative rig or rigs, and then multiplying by the number of spuds drilled by that company in 2006. If more than one representative rig was provided, all spuds drilled by that company were divided evenly among the representative rigs. In the case of one respondent, all of that company's rigs were detailed including the total hours of usage during the year for all rigs. This was used to sum the company's drilling emissions, rather than the number of spuds.

The basin-wide drilling emissions were derived by scaling up the combined participating companies' drilling emissions according to Equation 21:

Equation (21) $$E_{drilling,TOTAL} = E_{drilling} \times \frac{S_{TOTAL}}{S}$$

where:

$E_{drilling,TOTAL}$ is the total emissions in the basin from drilling activity [tons/yr]
$E_{drilling}$ is the total emissions in the basin from drilling activity conducted by the participating companies (summed as described above) [tons/yr]
S_{TOTAL} is the total number of spuds that occurred in the basin in 2006
S is the total number of spuds in the basin in 2006 drilled by the participating companies

County-level emissions were estimated by allocating the total basin-wide drilling rig emissions into each county according to the fraction of total 2006 spuds that occurred in each county. Tribal and non-tribal emissions were estimated in each county by allocating the county total emissions into the tribal airshed according to the fraction of total 2006 spuds that occurred in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 spuds not occurred in the tribal airshed in that county.

Workover Rigs

Methodology:

The nature of workover engine data provided in the survey responses for workover rigs varied significantly by company. In order to utilize the wide range of data provided, the methodology used was to first estimate each company's total workover rig emissions, and then to sum the emissions over all companies, and scale up to the basin level. When a producer supplied emission factors for some, but not all pollutants, the technology type of the engine was estimated based on the supplied emission factors and emission factors from the NONROAD model which were taken for the estimated technology type for drill/bore rig engines of the same size class. This allowed the calculations to incorporate information about specific rig engines when it was available, and defaulted to the NONROAD model where this information was not available. Load factors were similarly estimated by using respondent information where such detailed information was available.

The basic methodology for estimating the emissions from a workover rig follows Equation 22:

Equation (22) $$E_{workover,engine} = \frac{EF_i \times HP \times LF \times t_{workover}}{907{,}185}$$

where:

- $E_{workover,engine}$ is the emissions from one workover [ton/workover]
- EF_i is the emissions factor of the workover rig engine of pollutant i [g/hp-hr]
- HP is the horsepower of the workover rig engine [hp]
- LF is the average load factor of the workover rig engine
- $t_{workover}$ is the average duration of a workover event [hr/workover]

It should be noted that SO_2 emissions were estimated using the brake-specific fuel consumption (BSFC) of the engine, as obtained from the US EPA's NONROAD model for a similarly sized drill/bore rig engine, and the 2006 sulfur content of the off-road diesel fuel (2,400 ppm) as obtained from the WRAP Mobile Sources Emission Inventory Update[1]. The EPA NONROAD model guidance was used to determine the fraction of fuel sulfur that would go to forming PM emissions – for drilling rig engines this was only 2.2% of sulfur content. It was assumed that the remaining sulfur in the fuel would be emitted as SO_2.

Extrapolation to Basin-Wide Emissions

The total workover rig emissions for the participating companies were derived by multiplying the per-workover emissions above for each pollutant by the total number of workovers conducted by the participating companies. This was then scaled up by the ratio of total well count in the basin to wells owned by the participating companies, following Equation 23:

Equation (23) $E_{workover,TOTAL} = E_{workover} \times {W_{TOTAL}}/{W}$

where:

$E_{workover,TOTAL}$ are the total emissions basin-wide from workovers [tons/year]
$E_{workover}$ are the total workover rig emissions from the participating companies [tons/year]
W_{TOTAL} is the total number of wells in the basin
W is the number of wells owned by the participating companies

County-level emissions were estimated by allocating the total basin-wide workover rig emissions into each county according to the fraction of total 2006 well counts that are located in each county. Tribal and non-tribal emissions were estimated in each county by allocating the county total emissions into the tribal airshed according to the fraction of total 2006 well counts in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 well counts not in the tribal airshed in that county.

Miscellaneous Engines

Methodology:

The participating companies provided a complete inventory of all miscellaneous engines in use in their operations. Miscellaneous engines do not include engines used for such applications as drilling rigs, workover rigs, CBM pumps, salt-water disposal engines, artificial lift engines, vapor recovery units and compressors. Emission calculations for miscellaneous engines follow a similar methodology as for drilling rig or workover rig engines.

The basic methodology for estimating emissions from miscellaneous engine is shown in Equation 24:

Equation (24) $E_{engine} = \frac{EF_i \times HP \times LF \times t_{annual}}{907,185}$

where:

E_{engine} are emissions from miscellaneous engine [ton/year/engine]
EF_i is the emissions factor of pollutant i [g/hp-hr]
HP is the horsepower of the engine [hp]
LF is the load factor of the engine
t_{annual} is the annual number of hours the engine is used [hr/yr]

Note that, similar to drilling rig and workover rig engines, SO_2 emissions are estimated using the BSFC of the engine with diesel fuel, and the assumed sulfur content of the fuel, assuming that all sulfur emissions are in the form of SO_2. For natural gas-fired engines, gas composition analyses indicate no sulfur present in the natural gas; therefore SO_2 emissions are negligible from these engines.

Extrapolation to Basin-Wide Emissions

Emissions from all miscellaneous engines from the participating companies were summed. The total emissions from all participating companies were scaled by the ratio of total well count in the basin to wells owned by the participating companies according to Equation 25:

Equation (25) $$E_{engine,TOTAL} = E_{engine}\frac{W_{TOTAL}}{W}$$

where:

$E_{engine,TOTAL}$ is the total emissions from miscellaneous engines in the basin [ton/yr]
E_{engine} is the total emissions from exempt engines owned by the participating companies [ton/yr]
W_{TOTAL} is the total number of wells in the basin
W is the number of wells owned by the participating companies

County-level emissions were estimated by allocating the total basin-wide compressor engine emissions into each county according to the fraction of total 2006 well counts that are located in each county. Tribal and non-tribal emissions were estimated in each county by allocating the county total emissions into the tribal airshed according to the fraction of total 2006 well counts in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 well counts not in the tribal airshed in that county.

Compressor Engines

Methodology:

The participating companies provided a complete inventory of all compressor engines in use for their operations. Emission calculations for compressor engines follow a similar methodology as for drilling rig or workover rig engines. Emission factors for the compressor engines were directly obtained from the respondent companies where such information was provided. If emissions factors were not provided, if available, emission factors from engine specification sheets were used. If emission factors were neither supplied in survey responses or available from engine specification data, AP-42 emission factors for compressor engines were used. Load factors were directly obtained from respondent companies where such information was provided. For engines where a load factor was not provided, the load factor was estimated by taking the average of compression engine load factors supplied in producer surveys.

The basic methodology for estimating emissions from compressor engines is shown in Equation 26:

Equation (26) $$E_{engine} = \frac{EF_i \times HP \times LF \times t_{annual}}{907{,}185}$$

where:

E_{engine} are emissions from a compressor engine [ton/year/engine]
EF_i is the emissions factor of pollutant i [g/hp-hr]
HP is the horsepower of the engine [hp]
LF is the load factor of the engine

t_{annual} is the annual number of hours the engine is used [hr/yr]

For natural gas-fired engines, gas composition analyses indicate no sulfur present in the natural gas; therefore SO_2 emissions were assumed negligible from these engines.

Extrapolation to Basin-Wide Emissions

Emissions from all compressor engines from the participating companies were summed. The total emissions from all participating companies were scaled by the ratio of total gas production in the basin to gas production from the wells owned by the participating companies according to Equation 27:

Equation (27) $E_{engine,TOTAL} = E_{engine} \frac{W_{TOTAL}}{W}$

where:

$E_{engine,TOTAL}$ is the total emissions from compressor engines in the basin [ton/yr]
E_{engine} is the total emissions from compressor engines owned by the participating companies [ton/yr]
W_{TOTAL} is the total gas production in the basin
W is the total gas production from the wells owned by the participating companies

County-level emissions were estimated by allocating the total basin-wide compressor engine emissions into each county according to the fraction of total 2006 gas production that are located in each county. Tribal and non-tribal emissions were estimated in each county by allocating the county total emissions into the tribal airshed according to the fraction of total gas production in the tribal airshed in that county and into non-tribal land according to the fraction of total gas production that are not in the tribal airshed in that county.

Fugitive Emissions (Leaks)

Methodology

Fugitive emissions from well sites were estimated using AP-42 emissions factors and equipment counts provided in the survey responses. The participating companies provided total equipment counts for all of their operations in the basin by type of equipment and by the type of service to which the equipment applies – gas, light liquid, heavy liquid, or water.

Fugitive VOC emissions for an individual component were estimated similar to blowdown or completion emissions, according to Equation 28:

Equation (28) $E_{fugitive} = EF_i \times N \times t_{annual} \times Y$

where:

$E_{fugitive}$ is the fugitive VOC emissions for all participating companies [ton-VOC/yr]
EF_i is the emission factor of TOC [kg/hr/source]
N is the total number of devices from the participating companies
Y is the ratio of VOC to TOC in the vented gas

In order to account for differences in vented gas composition, fugitive devices were distributed to conventional and CBM wells. It was assumed that liquid devices occurred only at conventional wells and that gas devices occurred at conventional and CBM wells, based on the fraction of wells that were conventional or CBM.

Extrapolation to Basin-Wide Emissions

Basin-wide fugitive emissions are estimated by scaling the fugitive emissions from all participating companies by the ratio of the total number of conventional and CBM wells in the basin to the number of wells owned by the participating companies, according to Equation 17 to Equations 29 to 31:

Equation (29) $$E_{fugitive,TOTAL,CONV} = \frac{E_{fugitive,CONV}}{2000} \times \frac{W_{TOTAL,CONV}}{W_{PCO,CONV}}$$

where:

$E_{fugitive,TOTAL,CONV}$ is the total fugitive emissions in the basin from conventional wells [ton/yr]
$E_{fugitive,TOTAL,CONV}$ is the fugitive VOC emissions for all participating companies' conventional wells [lb-VOC/yr]
$W_{TOTAL,CONV}$ is the total number of conventional wells in the basin
$W_{PCO,CONV}$ is the total number of conventional wells in the basin owned by the participating companies

Equation (30) $$E_{fugitive,TOTAL,CBM} = \frac{E_{fugitive,CBM}}{2000} \times \frac{W_{TOTAL,CBM}}{W_{PCO,CBM}}$$

where:

$E_{fugitive,TOTAL,CBM}$ is the total fugitive emissions in the basin from CBM wells [ton/yr]
$E_{fugitive,CBM}$ is the fugitive VOC emissions for all participating companies' CBM wells [lb-VOC/yr]
$W_{TOTAL,CBM}$ is the total number of CBM wells in the basin
$W_{PCO,CBM}$ is the total number of CBM wells in the basin owned by the participating companies

Equation (31) $$E_{fugitive,TOTAL} = E_{fugitive,CONV,TOTAL} + E_{fugitive,CBM,TOTAL}$$

where:

$E_{fugitive,,TOTAL}$ are the total emissions basin-wide from blowdowns [tons/year]

County-level emissions from conventional wells were estimated by allocating the total basin-wide fugitive emissions from conventional wells into each county according to the fraction of conventional 2006 well count occurring in that county. County-level emissions from CBM wells were estimated by allocating the total basin-wide fugive emissions from CBM wells into each county according to the fraction of CBM 2006 well count occurring in that county. Tribal and non-tribal emissions from conventional wells were estimated in each county by allocating the county conventional well fugitive emissions into the tribal airshed according to the fraction of

2006 conventional well count occurring in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 conventional well count not occurring in the tribal airshed in that county. Tribal and non-tribal emissions from CBM wells were estimated in each county by allocating the county CBM well fugitive emissions into the tribal airshed according to the fraction of 2006 CBM well count occurring in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 CBM well count not occurring in the tribal airshed in that county.

Heaters

Methodology

Heater emissions were calculated on the basis of the emissions factor of the heater, and the annual flow rate of gas to the heater. The annual gas flow rate was calculated from the BTU rating of the heater and the local BTU content of the gas. Participating companies' surveys showed a small number of heaters utilizing propane fuel, though a vast majority of heaters were natural-gas fired. AP-42 emission factors for an uncontrolled small boiler for natural gas and propane fuel were used for specific pollutants.

The basic methodology for estimating emissions for a single heater is shown in Equation 32:

Equation (32) $$E_{heater} = EF_{heater} \times Q_{heater} \times \frac{HV_{local}}{HV_{rated}} \times t_{annual} \times hc$$

where:

E_{heater} is the emissions from a given heater
EF_{heater} is the emission factor for a heater for a given pollutant [lb/million scf]
Q_{heater} is the heater MMBTU/hr rating [$MMBTU_{rated}$/hr]
HV_{local} is the local natural gas heating value [$MMBTU_{local}$/scf]
HV_{rated} is the heating value for natural gas used to derive heater MMBTU rating, Q_{heater} [MMBTU/scf]
t_{annual} is the annual hours of operation [hr/yr]
hc is a heater cycling fraction to account for the fraction of operating hours that the heater is firing (if available)

Emissions for all heaters in the basin operated by the participating companies were estimated according to Equation 33:

Equation (33) $$E_{heater,companies} = E_{heater} \times N_{heater}$$

where:

$E_{heater,companies}$ is the total emissions from all heaters operated by participating companies [lb/yr]
E_{heater} is the emissions from a single heater [lb/yr/heater]
N_{heater} is the total number of heaters owned by the participating companies

The participating companies were requested to provide seasonal utilization rates to account for changes in usage throughout the year.

Extrapolation to Basin-Wide Emissions

Basin-wide heater emissions were estimated according to Equation 34:

Equation (34) $$E_{heater,TOTAL} = \frac{E_{heater,companies}}{2000} \times \frac{W_{TOTAL}}{W}$$

where:

$E_{heater,TOTAL}$ is the total heater emissions in the basin [ton/yr]
$E_{heater,companies}$ is the total emissions from all heaters operated by participating companies [lb/yr]
W_{TOTAL} is the total number of non CBM wells in the basin
W is the total number of non CBM wells in the basin owned by the participating companies

County-level emissions were estimated by allocating the total basin-wide heater emissions into each county according to the fraction of total 2006 non CBM well counts that are located in each county. Tribal and non-tribal emissions were estimated in each county by allocating the county total emissions into the tribal airshed according to the fraction of total 2006 non-CBM well counts in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 non-CBM well counts not in the tribal airshed in that county.

Pneumatic Control Devices

Methodology

Pneumatic device emissions were estimated by determining the numbers and types of pneumatic devices used at all wells in the basin owned by the participating companies. Emissions were estimated separately for conventional and CBM wells based on conventional and CBM gas composition analyses. The bleed rates of these devices per unit of gas produced were determined by using guidance from the EPA's Natural Gas Star Program.

The methodology for estimating the emissions from all pneumatic devices owned by participating companies are shown in Equations 35 to 39:

Equation (35) $$V_{vented,TOTAL} = \dot{V}_i \times N_i \times t_{annual}$$

where:

$V_{vented,TOTAL}$ is the total volume of vented gas from all pneumatic devices for all participating companies [mscf/year]
$\dot{V}_i$ is the volumetric bleed rate from device i [mscf/hr/device]
N_i is the total number of device $\underline{i}$ owned by the participating companies
t_{annual} is the number of hours per year that devices were operating [hr/yr]

Equation (36) $V_{vented,CONV} = V_{vented,TOTAL} \times W_{CONV,PCO} / W_{PCO}$

where:

$V_{vented,CONV}$ is the total volume of vented gas from participating companies conventional well production [mscf]
$W_{CONV,PCO}$ is the conventional well count in the basin in 2006 owned by the participating companies [mscf]
W_{PCO} is the well count in the basin in 2006 owned by the participating companies [mscf]

Equation (37) $V_{vented,CBM} = V_{vented,TOTAL} \times W_{CBM,PCO} / W_{PCO}$

where:

$V_{vented,CBM}$ is the total volume of vented gas from participating companies CBM well production [mscf]
$W_{CBM,PCO}$ is the total CBM well cont in the basin in 2006 owned by the participating companies [mscf]

Equation (38) $E_{pneumatic,CONV} = V_{vented,CONV} \times 1000 \times MW_{VOC,CONV} \times R \times Y_{VOC,CONV}$

where:

$E_{pneumatic,CONV}$ is the total conventional well pneumatic device VOC emissions [lb-VOC/yr]
$MW_{VOC,CONV}$ is the molecular weight of the VOC for conventional well vented gas [lb/lb-mol]
R is the universal gas constant [L-atm/K-mol]
$Y_{VOC,CONV}$ is the volume fraction of VOC in the conventional well vented gas

Equation (39) $E_{pneumatic,CBM} = V_{vented,CBM} \times 1000 \times MW_{VOC,CBM} \times R \times Y_{VOC,CBM}$

where:

$E_{pneumatic,CBM}$ is the total CBM well pneumatic device VOC emissions [lb-VOC/yr]
$MW_{VOC,CBM}$ is the molecular weight of the VOC for CBM well vented gas [lb/lb-mol]
R is the universal gas constant [L-atm/K-mol]
$Y_{VOC,CBM}$ is the volume fraction of VOC in the CBM well vented gas

The conversion from volume of gas vented to mass of VOC produced was evaluated at standard temperature and pressure.

<u>Extrapolation to Basin-Wide Emissions</u>

Basin-wide pneumatic device emissions were estimated according to Equations 40 to 42:

Equation (40) $E_{pneumatic,TOTAL,CONV} = \frac{E_{pneumatic,CONV}}{2000} \times \frac{W_{TOTAL,CONV}}{W_{PCO,CONV}}$

where:

$E_{pneumatic,TOTAL,CONV}$ is the total pneumatic device emissions in the basin from conventional wells [ton/yr]

$E_{pneumatic}$ is the pneumatic device VOC emissions for all participating companies' conventional wells [lb-VOC/yr]
$W_{TOTAL,CONV}$ is the total number of conventional wells in the basin
$W_{PCO,CONV}$ is the total number of conventional wells in the basin owned by the participating companies

Equation (41) $$E_{pneumatic,TOTAL,CBM} = \frac{E_{pneumatic,CBM}}{2000} \times \frac{W_{TOTAL,CBM}}{W_{PCO,CBM}}$$

where:
$E_{pneumatic,TOTAL,CBM}$ is the total pneumatic device emissions in the basin from CBM wells [ton/yr]
$E_{pneumatic,CBM}$ is the pneumatic device VOC emissions for all participating companies' CBM wells [lb-VOC/yr]
$W_{TOTAL,CBM}$ is the total number of CBM wells in the basin
$W_{PCO,CBM}$ is the total number of CBM wells in the basin owned by the participating companies

Equation (42) $$E_{pneumatic,TOTAL} = E_{pneumatic,CONV,TOTAL} + E_{pneumatic,CBM,TOTAL}$$

where:
$E_{pneumatic,,TOTAL}$ are the total emissions basin-wide from blowdowns [tons/year]

County-level emissions from conventional wells were estimated by allocating the total basin-wide pneumatic emissions from conventional wells into each county according to the fraction of conventional 2006 well count occurring in that county. County-level emissions from CBM wells were estimated by allocating the total basin-wide pneumatic emissions from CBM wells into each county according to the fraction of CBM 2006 well count occurring in that county. Tribal and non-tribal emissions from conventional wells were estimated in each county by allocating the county conventional well pneumatic emissions into the tribal airshed according to the fraction of 2006 conventional well count occurring in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 conventional well count not occurring in the tribal airshed in that county. Tribal and non-tribal emissions from CBM wells were estimated in each county by allocating the county CBM well pneumatic emissions into the tribal airshed according to the fraction of 2006 CBM well count occurring in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 CBM well count not occurring in the tribal airshed in that county.

Pneumatic (Gas Actuated) Pumps

Methodology

Participating companies provided data indicating either the average gas consumption rate per gallon of chemical or compound pumped, or the volume rate of gas consumption per day per pump.

The gas consumption rate per gallon of chemical pumped was multiplied by the total volume of chemical pumped by the respondent in the basin in 2006 to derive total gas consumption from gas-actuated pumps for the respondent. If the respondent company did not specify the total gas consumption rate then the average gas consumption rate from other participating companies was used.

Pneumatic pumps were assumed to operate exclusively at conventional gas wells. VOC emissions were estimated similarly to pneumatic devices, following Equation 43:

Equation (43) $E_{pump} = V_{vented,TOTAL} \times 1000 \times MW_{VOC,CONV} \times R \times Y_{VOC,CONV}$

where:

E_{pump} is the gas-actuated pump VOC emissions for all participating companies [lb-VOC/yr]
$V_{vented,TOTAL}$ is the total volume of vented gas from all gas-actuated pumps for all participating companies [mscf/year]
$MW_{VOC,CONV}$ is the molecular weight of the VOC for conventional well vented gas [lb/lb-mol]
R is the universal gas constant [L-atm/K-mol]
$Y_{VOC,CONV}$ is the volume fraction of VOC in the conventional well vented gas

The participating companies were requested to provide seasonal utilization rates to account for changes in usage throughout the year.

Extrapolation to Basin-Wide Emissions

Basin-wide gas-actuated pump emissions were estimated according to Equation 44:

Equation (44) $E_{pump,TOTAL} = \frac{E_{pump}}{2000} \times \frac{W_{TOTAL,CONV}}{W_{PCO,CONV}}$

where:

$E_{pump,TOTAL}$ is the total pneumatic pump emissions in the basin [ton/yr]
E_{pump} is the gas-actuated pump VOC emissions for all participating companies [lb-VOC/yr]
$W_{TOTAL,CONV}$ is the total number of conventional wells in the basin
$W_{PCO,CONV}$ is the total number of conventional wells in the basin owned by the participating companies

County-level emissions were estimated by allocating the total basin-wide gas-actuated pump emissions into each county according to the fraction of total 2006 conventional well counts that are located in each county. Tribal and non-tribal emissions were estimated in each county by allocating the county total emissions into the tribal airshed according to the fraction of total 2006 conventional well counts in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 conventional well counts not in the tribal airshed in that county.

Flaring

Methodology

For this source category the AP-42 methodology was applied to estimate flare emissions associated with condensate tanks, dehydrators, and initial completions as provided in survey responses by participating companies. Vent rates were combined with the heat content of the gas being flared and the appropriate AP-42 emission factor to determine the NOx and CO emissions.

Emissions were estimated according to AP-42 methodology, following Equation 45.

Equation (45) $E_{flare} = EF_i \times P_{flare} \times Q \times HV$

where:

E_{flare} is the basinwide flaring emissions [lb/yr]
EF_i is the emissions factor for pollutant i [lb/MMBtu]
Q is the vent rate as supplied by participating companies [scf/bbl]
HV is the heating value of the gas as estimated by participating companies [BTU/scf]
P_{flare} is the condensate production that is controlled by flare [bbl]

Extrapolation to Basin-Wide Emissions

Basin-wide flaring emissions were estimated according to Equation 46:

Equation (46) $E_{flare,TOTAL} = \frac{E_{flare}}{2000} \times \frac{S_{TOTAL}}{S}$

where:

$E_{flare,TOTAL}$ is the total flaring emissions in the basin [ton/yr]
E_{flare} is the flaring emissions for all participating companies [lb/yr]
S_{TOTAL} is the participating company ownership of the surrogate appropriate for each flaring source (oil production, gas production, and spuds for condensate tank, dehydrator and initial completions, respectively)
S is the total surrogate ownership in the basin owned by the participating companies

County-level emissions were estimated by allocating the total basin-wide flaring emissions into each county according to the fraction of total surrogate (oil production, gas production, and spuds for condensate tank, dehydrator and initial completions, respectively) that are located in each county. Tribal and non-tribal emissions were estimated in each county by allocating the county total emissions into the tribal airshed according to the fraction of total surrogate in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 surrogate not in the tribal airshed in that county.

Artificial Lift (Pumpjack) Engines

Methodology

The participating companies provided a complete inventory of all artificial lift engines in use in their operations. Emission calculations for artificial lift engines follow a similar methodology as for drilling rig or workover rig engines.

The basic methodology for estimating emissions from an artificial lift engine is shown in Equation 47:

Equation (47) $$E_{engine} = \frac{EF_i \times HP \times LF \times t_{annual}}{907{,}185}$$

where:

E_{engine} are emissions from an artificial lift engine [ton/year/engine]
EF_i is the emissions factor of pollutant i [g/hp-hr]
HP is the horsepower of the engine [hp]
LF is the load factor of the engine
t_{annual} is the annual number of hours the engine is used [hr/yr]

Emission factors were adjusted to account for deterioration due to engine wear and tear and also the sub-optimal field conditions under which the engines operate. To make this adjustment the deterioration factors from the EPA NONROAD2005 model were applied. Given the lack of survey data regarding engine age, all engines were assumed fully deteriorated.

Note that, similar to drilling rig and workover rig engines, SO_2 emissions are estimated using the BSFC of the engine, and the assumed sulfur content of the fuel, assuming that all sulfur emissions are in the form of SO_2. For natural gas-fired exempt engines, gas composition analyses indicate no sulfur present in the natural gas; therefore SO_2 emissions were also assumed negligible from artificial lift engines powered by natural gas.

Extrapolation to Basin-Wide Emissions

Emissions from all artificial engines from the participating companies were summed. The total emissions from all participating companies were scaled by the ratio of total oil production in the basin to oil production ownership by the participating companies according to Equation 48:

Equation (48) $$E_{engine,TOTAL} = E_{engine} \frac{P_{TOTAL}}{P}$$

where:

$E_{engine,TOTAL}$ is the total emissions from artificial lift engines in the basin [ton/yr]
E_{engine} is the total emissions from artificial engines owned by the participating companies [ton/yr]
P_{TOTAL} is the total oil production from oil wells in the basin
P is the oil production from oil wells by the participating companies

County-level emissions were estimated by allocating the total basin-wide artificial lift engine emissions into each county according to the fraction of total 2006 oil production from oil wells located in each county. Tribal and non-tribal emissions were estimated in each county by allocating the county total emissions into the tribal airshed according to the fraction of total 2006 oil production from oil wells occurring in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 oil production from oil wells not occurring in the tribal airshed in that county.

Compressor Engine Startups and Shutdowns

Methodology

Emissions from compressor engine startups and shutdowns were calculated separately using the estimated volume of gas vented during compressor engine startup and shutdown events, the frequency of the startup and shutdown events, the number of compressor engines, and the VOC content of the vented gas as documented by representative compositional analyses.

The calculations were made separately for conventional and CBM wells, and applied the ideal gas law and gas characteristics defined from a laboratory analysis to estimate emissions according to Equations 49 to 54:

Equation (49) $V_{vented} \times n \times f = V_{vented,TOTAL}$

where:

V_{vented} is the volume of vented gas per startup or shutdown [mscf/event/engine]
n is the number of compressor engines for which startup and shutdown data was provided by producing companies [engines]
f is the frequency of startup or shutdown [events/year]
$V_{vented,TOTAL}$ is the total volume of vented gas from the participating companies for startup or shutdown[mscf/year]

Equation (50) $V_{vented,CONV} = V_{vented,TOTAL} \times P_{CONV,PCO} / P_{PCO}$

where:

$V_{vented,CONV}$ is the total volume of vented gas from participating companies conventional well production [mscf]
$P_{CONV,PCO}$ is the total conventional well gas production in the basin in 2006 by the participating companies [mscf]
P_{PCO} is the total gas production in the basin in 2006 by the participating companies [mscf]

Equation (51) $V_{vented,CBM} = V_{vented,TOTAL} \times P_{CBM,PCO} / P_{PCO}$

where:

$V_{vented,CBM}$ is the total volume of vented gas from participating companies CBM well production [mscf]
$P_{CBM,PCO}$ is the total CBM well gas production in the basin in 2006 by the participating companies [mscf]

Equation (52) $E_S = V_{vented,TOTAL} \times 1000 \times MW_{VOC} \times R \times Y_{VOC}$

where:

E_S is the total VOC emissions from startups or shutdowns conducted by the participating companies [lb-VOC/yr]
MW_{VOC} is the molecular weight of the VOC [lb/lb-mol]
R is the universal gas constant [lb-mol/379scf]
Y_{VOC} is the volume fraction of VOC in the vented gas

Equation (53) $E_{S,CONV} = V_{vented,CONV} \times 1000 \times MW_{VOC,CONV} \times R \times Y_{VOC,CONV}$

where:

$E_{S,CONV}$ is the total VOC emissions from CBM well compressor engine startups or shutdowns conducted by the participating companies [lb-VOC/yr]
$MW_{VOC,CONV}$ is the molecular weight of the VOC for conventional well vented gas [lb/lb-mol]
R is the universal gas constant [L-atm/K-mol]
$Y_{VOC,CONV}$ is the volume fraction of VOC in the conventional well vented gas

Equation (54) $E_{S,CBM} = V_{vented,CBM} \times 1000 \times MW_{VOC,CBM} \times R \times Y_{VOC,CBM}$

where:

$E_{S,CBM}$ is the total VOC emissions from CBM well compressor engine startups or shutdowns conducted by the participating companies [lb-VOC/yr]
$MW_{VOC,CBM}$ is the molecular weight of the VOC for CBM well vented gas [lb/lb-mol]
R is the universal gas constant [L-atm/K-mol]
$Y_{VOC,CBM}$ is the volume fraction of VOC in the CBM well vented gas

The conversion from volume of gas vented to mass of VOC produced was evaluated at standard temperature and pressure.

Extrapolation to Basin-Wide Emissions

The total VOC emissions from all startups and shutdowns reported by participating companies were scaled by the proportional production ownership of the participating companies according to Equations 55 to 58:

Equation (55) $E_{S,TOTAL} = E_S \times {P_{TOTAL}}/{P}$

where:

$E_{S,TOTAL}$ are the total emissions basin-wide from compressor engine startup or shutdown [tons/year]
E_S are the compressor startup or shutdown emissions from the participating companies [tons/year]
P_{TOTAL} is the total gas production in the basin in 2006 [mscf]
P is the total gas production in the basin in 2006 by the participating companies [mscf]

Equation (56) $E_{S,CONV,TOTAL} = E_{S,CONV} \times P_{TOTAL,CONV} / P_{PCO,CONV}$

where:

$E_{S,CONV,TOTAL}$ are the total emissions basin-wide from compressor engine startup or shutdown at conventional wells [tons/year]
$E_{S,CONV}$ are the compressor engine startup or shutdown emissions from the participating companies at conventional wells [tons/year]
$P_{TOTAL,CONV}$ is the total gas production in the basin in 2006 from conventional wells [mscf]
$P_{PCO,CONV}$ is the total gas production in the basin in 2006 by the participating companies from conventional wells [mscf]

Equation (57) $E_{S,CBM,TOTAL} = E_{S,CBM} \times P_{TOTAL,CBM} / P_{PCO,CBM}$

where:

$E_{S,CBM,TOTAL}$ are the total emissions basin-wide from compressor engine startup or shutdown at CBM wells [tons/year]
$E_{S,CBM}$ are the compressor engine startups or shutdowns emissions from the participating companies at CBM wells [tons/year]
$P_{TOTAL,CBM}$ is the total gas production in the basin in 2006 from CBM wells [mscf]
$P_{PCO,CBM}$ is the total gas production in the basin in 2006 by the participating companies from CBM wells [mscf]

Equation (58) $E_{S,TOTAL} = E_{S,CONV,TOTAL} + E_{S,CBM,TOTAL}$

where:

$E_{S,,TOTAL}$ are the total emissions basin-wide from compressor engine startup or shutdown [tons/year]

County-level emissions from conventional wells were estimated by allocating the total basin-wide compressor startup and shutdown emissions from conventional wells into each county according to the fraction of conventional 2006 gas production occurring in that county. County-level emissions from CBM wells were estimated by allocating the total basin-wide compressor startup and shutdown emissions from CBM wells into each county according to the fraction of CBM 2006 gas production occurring in that county. Tribal and non-tribal emissions from conventional wells were estimated in each county by allocating the county conventional well compressor startup and shutdown emissions into the tribal airshed according to the fraction of 2006 conventional well gas production occurring in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 conventional well gas production not occurring in the tribal airshed in that county. Tribal and non-tribal emissions from CBM wells were estimated in each county by allocating the county CBM well compressor startup and shutdown emissions into the tribal airshed according to the fraction of 2006 CBM well gas production occurring in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 CBM well gas production not occurring in the tribal airshed in that county.

Condensate and Oil Tanks

Methodology

Based on producer responses, representative emission factors were derived for condensate tank flashing, working, and breathing losses as well as oil tank working and breathing losses in the Uinta Basin. Developed emission factors were applied directly to IHS estimated oil production from oil wells for oil tanks and condensate production from gas wells for condensate tanks. Oil and gas wells were identified based on IHS database well designation as either an oil or gas well. The IHS database designates a well as either an oil well or gas well based on the gas-oil-ratio (GOR). Based on state supplied GOR thresholds, wells with a GOR higher than the threshold are gas wells and wells with a GOR lower than the threshold are oil wells. For the condensate tank emission factors, the operator's supplied emission data from EP Tank model runs were used to calculate the representative weighted average emissions per for a throughput of 1 barrel/day condensate production. For oil tank emissions, the TANKS model was run with an average RVP of 5 and emissions for an average throughput of 1 bbl per day production was used to obtained emissions.

Equation (59) $$E_{oil\tan ks} = \frac{P_{oil\tan ks} \times EF_{oil,\tan ks}}{2000}$$

and

Equation (60) $$E_{condensate\tan ks} = \frac{P_{condensate\tan ks} \times EF_{condensate\tan ks}}{2000}$$

where:

$E_{oiltanks}$ is the basin-wide emissions from oil tanks [tons/yr]
$E_{condensate,tanks}$ is the basin-wide emissions from condensate tanks [tons/yr]
$EF_{oiltanks}$ is the derived VOC emissions factor for oil tanks [lb-VOC/bbl]
$EF_{condensate,tank}$ is the derived VOC emissions factor for condensate tanks [lb-VOC/bbl]
$P_{oiltanks}$ is the oil production from oil wells thoughput [bbl]
$P_{condensatetanks}$ is the condensate production from gas wells thoughput [bbl]

County-level oil tank emissions were estimated by allocating the total basin-wide oil tank emissions into each county according to the fraction of total 2006 oil production from oil wells occurring in that county. County-level condensate tank emissions were estimated by allocating the total basin-wide condensate tank emissions into each county according to the fraction of total 2006 condensate production occurring in that county. Tribal and non-tribal oil tank emissions were estimated in each county by allocating the county total oil tank emissions into the tribal airshed according to the fraction of total 2006 oil production from oil wells occurring in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 oil production from oil wells not occurring in the tribal airshed in that county. Tribal and non-tribal condensate tank emissions were estimated in each county by allocating the county total condensate tank emissions into the tribal airshed according to the fraction of total 2006 condensate production occurring in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 condensate production from oil wells not occurring in the tribal airshed in that county.

Dehydrators

Methodology

Dehydrator emissions were calculated from two distinct sources: still vent emissions and reboiler emissions. Reboiler emissions were calculated on the basis of the emissions factor of the reboiler, and the annual flow rate of gas to the reboiler. The annual gas flow rate was calculated from the BTU rating of the reboiler and the local BTU content of the gas. It was assumed that reboiler was running all the time. AP-42 emission factors for an uncontrolled small boiler were utilized as the basis of emission estimates.

The basic methodology for estimating emissions for a single reboiler is shown in Equation 61:

Equation (61) $$E_{reboiler} = EF_{reboiler} \times Q_{reboiler} \times \frac{HV_{local}}{HV_{rated}} \times t_{annual} \times hc$$

where:

$E_{reboiler}$ is the emissions from a given heater
$EF_{reboiler}$ is the emission factor for a reboiler for a given pollutant [lb/million scf]
$Q_{reboiler}$ is the reboiler MMBTU/hr rating [$\text{MMBTU}_{\text{rated}}$/hr]
HV_{local} is the local natural gas heating value [$\text{MMBTU}_{\text{local}}$/scf]
HV_{rated} is the heating value for natural gas used to derive reboiler MMBTU rating, $Q_{reboiler}$ [MMBTU/scf]
t_{annual} is the annual hours of operation [hr/yr]
hc is a heater cycling fraction to account for the fraction of operating hours that the heater is firing (if available)

Dehydrator still vent emissions were taken directly from producer responses which indicated tons of VOC per year emitted for each dehydrator.

Emissions for all dehydrators in the basin operated by the participating companies were estimated according to Equation 62:

Equation (62) $$E_{dehydrator,companies} = E_{reboiler} \times N_{reboiler} + E_{stillvent} \times N_{dehydrator}$$

where:

$E_{dehydrator,companies}$ is the total emissions from all dehydrators operated by participating companies [lb/yr]
$E_{reboiler}$ is the emissions from a single reboiler [lb/yr/reboiler]
$N_{reboiler}$ is the total number of reboilers owned by the participating companies
$E_{stillvent}$ is the still vent emissions from a single dehydrator [lb/yr/dehydrator]
$N_{dehydrator}$ is the total number of dehydrators owned by the participating companies

Extrapolation to Basin-Wide Emissions

Basin-wide dehydrator emissions were estimated according to Equation 63:

Equation (63) $E_{dehydrator,TOTAL} = \frac{E_{dehydrator,companies}}{2000} \times \frac{P_{TOTAL}}{P}$

where:

$E_{dehydrator,TOTAL}$ is the total dehydrator emissions in the basin [ton/yr]
$E_{dehydrator,companies}$ is the total emissions from all dehydrator operated by participating companies [lb/yr]
P_{TOTAL} is the total gas production in the basin
P is the total gas production in the basin owned by the participating companies

County-level *reboiler* emissions were estimated by allocating the total basin-wide heater emissions into each county according to the fraction of total 2006 gas production that is located in each county. Tribal and non-tribal *reboiler* emissions were estimated in each county by allocating the county total emissions into the tribal airshed according to the fraction of total 2006 gas production in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 gas production not in the tribal airshed in that county.

County-level *still vent* emissions from conventional wells were estimated by allocating the total basin-wide *still vent* emissions from conventional wells into each county according to the fraction of conventional 2006 gas production occurring in that county. County-level *still vent* emissions from CBM wells were estimated by allocating the total basin-wide *still vent* emissions from CBM wells into each county according to the fraction of CBM 2006 gas production occurring in that county. Tribal and non-tribal *still vent* emissions from conventional wells were estimated in each county by allocating the county conventional well *still vent* emissions into the tribal airshed according to the fraction of 2006 conventional well gas production occurring in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 conventional well gas production not occurring in the tribal airshed in that county. Tribal and non-tribal *still vent* emissions from CBM wells were estimated in each county by allocating the county CBM well *still vent* emissions into the tribal airshed according to the fraction of 2006 CBM well gas production occurring in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 CBM well gas production not occurring in the tribal airshed in that county.

Truck Loading: Oil and Gas Well and Gas Plant

Methodology

Based on surveyed producer responses, oil and gas well and gas plant truck loading emissions were estimated based on loading losses per EPA AP-42, Section 5.2 methodology combined with survey provided oil product volume loaded. The surveyed producer loading loss rate was estimated based on EPA AP-42, Section 5.2 methodology, following Equation 64:

Equation (64) $L = 12.46 \times \left(\frac{S \times V \times M}{T} \right)$

where:

L is the loading loss rate [lb/1000gal]
S is the saturation factor taken from AP-42 default values based on operating mode

V is the true vapor pressure of liquid loaded [psia]
M is the molecular weight of the vapor [lb/lb-mole]
T is the temperature of the bulk liquid [^oR]

Truck loading emissions for participating companies were then estimated by combining, separately for oil well, gas well, and gas plant truck loading, the calculated loading loss rate with surveyed producer provided annual volume of product loaded as shown in Equation 65:

Equation (65) $$E_{loading} = L \times P \times \frac{42}{1000}$$

where:
E is the oil well, gas well, or gas plant truck loading emissions [lb/yr]
L is the oil well, gas well, or gas plant loading loss rate [lb/1000gal]
P is the oil well, gas well, or gas plant product loaded for the surveyed producers [bbl]

<u>Extrapolation to Basin-Wide Emissions</u>

Basin-wide oil and gas well and gas plant truck loading emissions were estimated separately according to Equation 66:

Equation (66) $$E_{loading,TOTAL} = \frac{E_{loading}}{2000} \times \frac{P_{TOTAL}}{P}$$

where:
$E_{loading,,TOTAL}$ is the oil well, gas well, or gas plant total truck loading emissions in the basin [ton/yr]
$E_{loading}$ is the oil well, gas well, or gas plant truck loading pump VOC emissions for all participating companies
[lb-VOC/yr]
P_{TOTAL} is the total oil (for oil wells) or condensate (for gas wells or gas plants) production in the basin
P is the oil (for oil wells) or condensate (for gas wells or gas plants) production for the surveyed producers [bbl]

County-level emissions were estimated by allocating the total basin-wide truck loading emissions into each county according to the fraction of oil or condensate production for each county. Tribal and non-tribal emissions were estimated in each county by allocating the county total emissions into the tribal airshed according to the fraction of total 2006 oil or condensate production in the tribal airshed in that county and into non-tribal land according to the fraction of total 2006 oil or condensate production not in the tribal airshed in that county.

Amine Units

Emissions from this source category were assumed negligible. Surveyed producers indicated no operational amine units within Uinta Basin.

CBM Pump Engines

Emissions from this source category were assumed negligible. Surveyed producers indicated that all CBM pumps were electric.

Natural Gas Liquid Plant Truck Loading

Emissions from this source category were assumed negligible. Surveyed producers who indicated the presence of such activity indicated that the NGL liquids are transferred from a pressurized storage tank to a pressurized tanker-truck vessel through a closed-loop system with little appreciable venting to the atmosphere.

Saltwater Disposal Engines

Emissions from this source category were not estimated. A limited number of producers supplied data with engine operation characteristics. Based on the limited response and knowledge of Uinta Basin oil and gas operations, the determination was made that these operations would be performed mainly by private contractors. As private contractors were not queried as part of this effort, no emissions for this category can be estimated.

Vapor Recovery Units

Emissions from this source category were not estimated. Of all surveyed producers, only one producer indicated one vapor recovery unit (VRU) in the Uinta Basin. Based on this response emissions from VRUs were assumed negligible.

Water Disposal Pits

Emissions from this source category were not estimated. Of all surveyed producers, only one producer provided data for water disposal pit operations. Based on the limited response and knowledge of Uinta Basin oil and gas operations, the determination was made that these operations would be performed mainly by private contractors. As private contractors were not queried as part of this effort, no emissions for this category can be estimated. Further, a methodology to estimate emissions from water disposal pits has yet to gain broad acceptance.

Water Tanks

Emissions from this source category were assumed negligible. This assumption is based on the extremely small emissions factors and emissions from water tanks as estimated for the DJ Basin.

SUMMARY RESULTS

Results from the combined permitted sources and the combined unpermitted sources are presented below on a county level and as summaries for the entire Uinta Basin as a series of pie charts and bar graphs. The quantitative emissions summaries are presented at the end of this document in table format. It should be noted that NOx emissions from unpermitted sources in the Uinta Basin represent 82 percent of all emissions while NOx emissions from permitted sources represent only 18 percent of the total emissions. The VOC emissions from unpermitted sources in the Uinta Basin represent 98 percent of all VOC emissions. The emissions of CO, SOx and PM from unpermitted sources represented 89 percent, 99 percent and 95 percent respectively of the total emissions for these pollutants.

Figures 2 and 3 show that NOx emissions are primarily concentrated in Uintah and Duchesne counties, as evidenced by the areas of large concentrations of well locations, as shown in Figure 1. Figures 4 and 5 also show that VOC emissions are concentrated only in Uintah and Duchesne counties. Production activity in Uintah County is mostly dry gas while a majority of the oil production is concentrated in Duchesne Count.

Figure 6 shows that drilling rigs, compressor engines, artificial lift engines, and heaters combined accounted for almost 78% of NOx emissions. Similarly, Figure 7 shows that condensate and oil tanks, dehydrators, pneumatic pumps and pneumatic devices accounted for approximately 89% of VOC emissions.

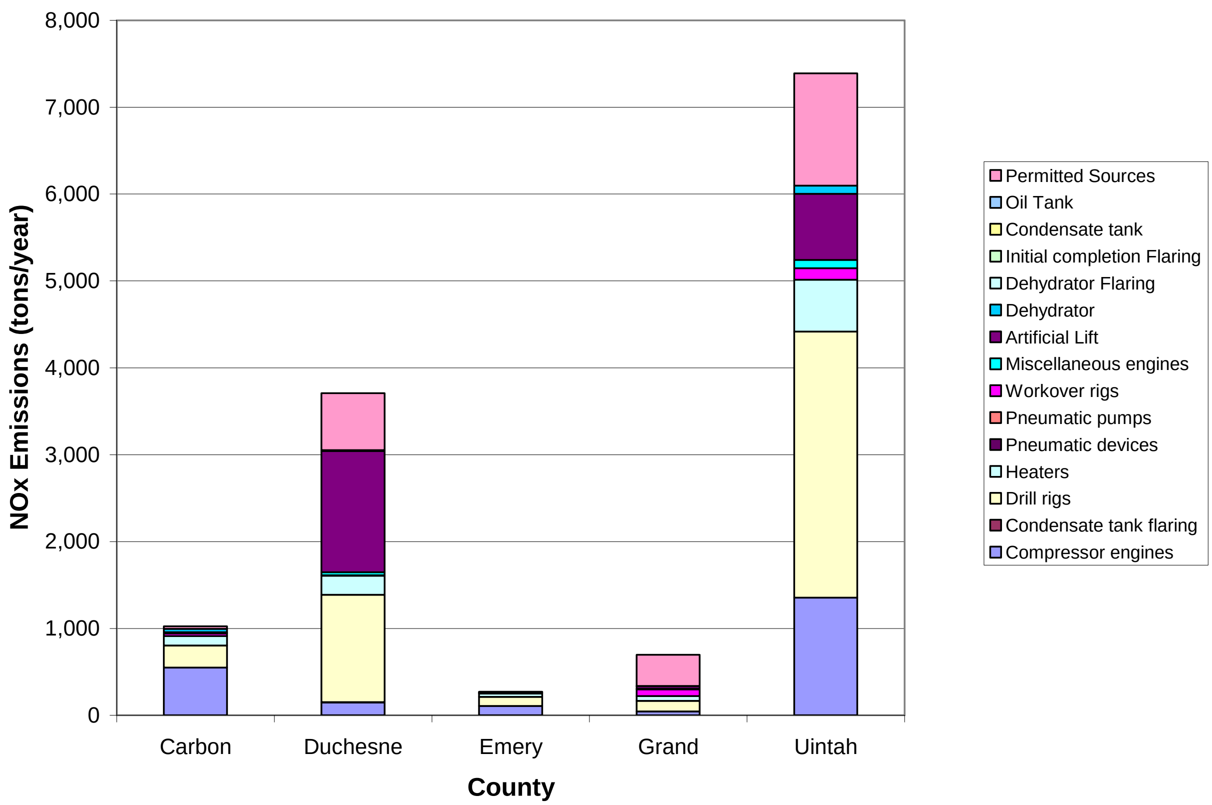

Figure 2. 2006 NOx emissions by source category and by county in the Uinta Basin.

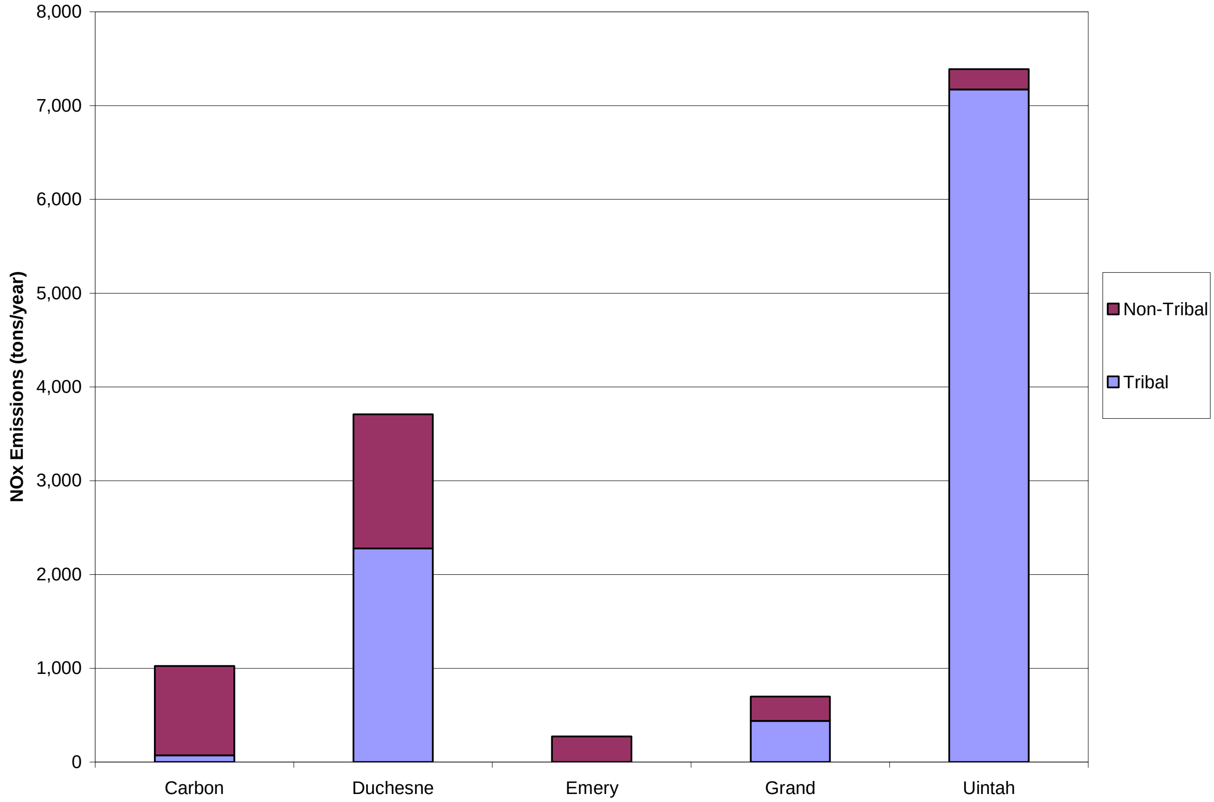

Figure 3. 2006 NOx emissions on tribal and non-tribal land by county in the Uinta Basin.

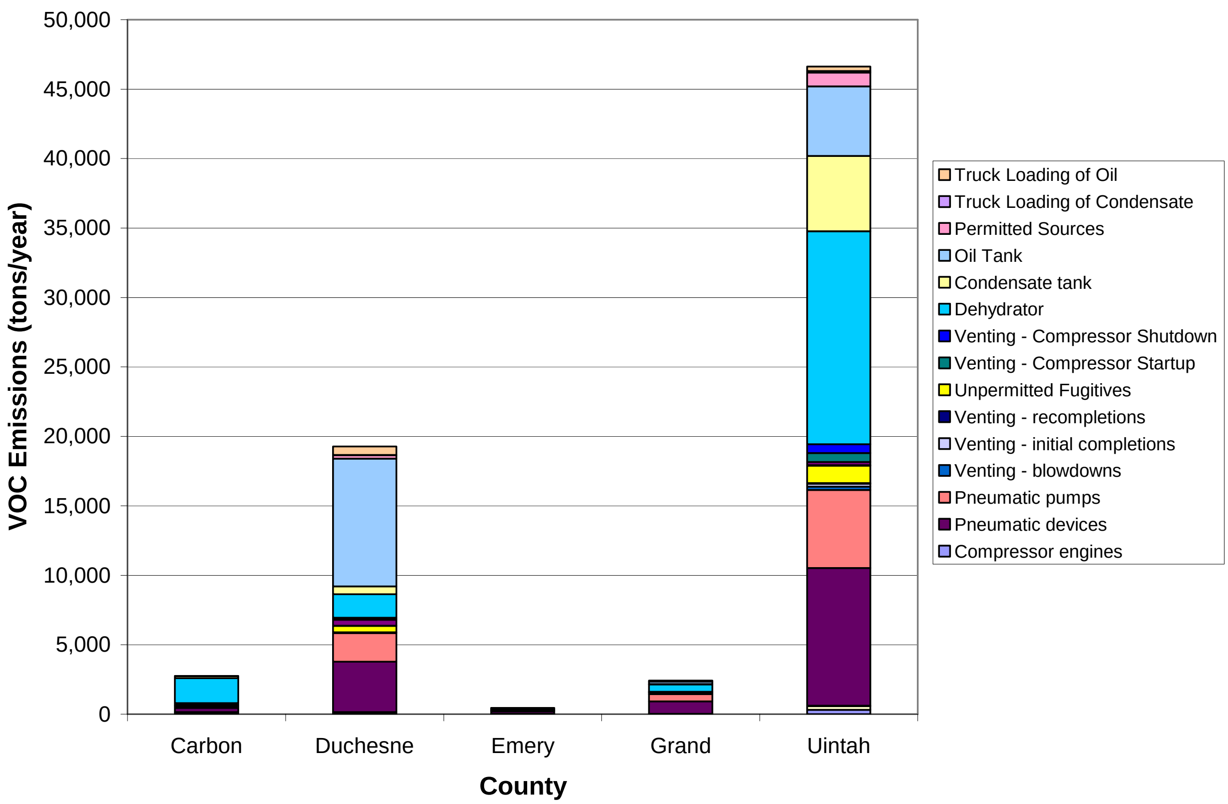

Figure 4. 2006 VOC emissions by source category and by county in the Uinta Basin.

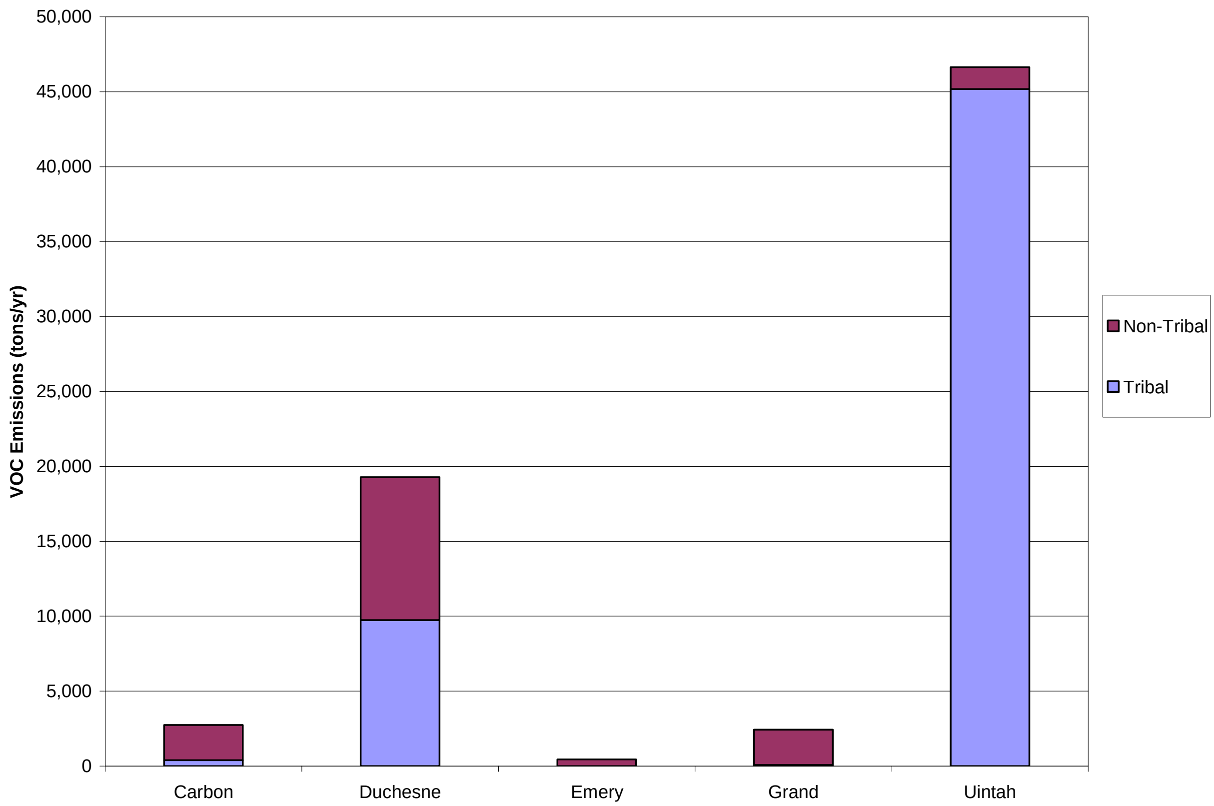

Figure 5. 2006 VOC emissions on tribal and non-tribal land by county in the Uinta Basin.

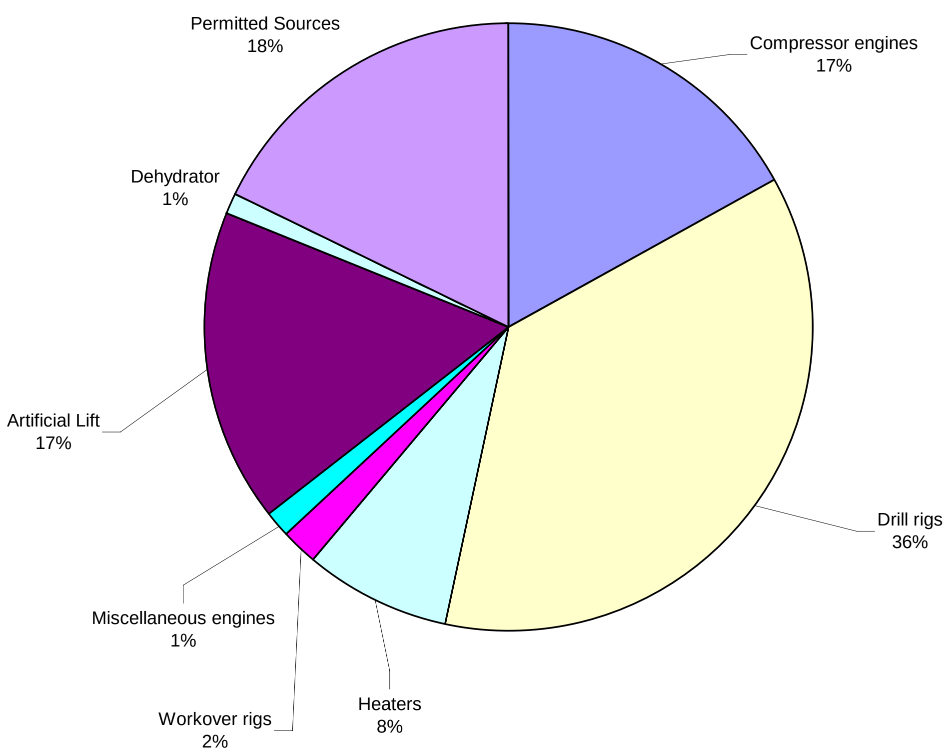

Figure 6. Uinta Basin NOx emissions proportional contributions by source category.

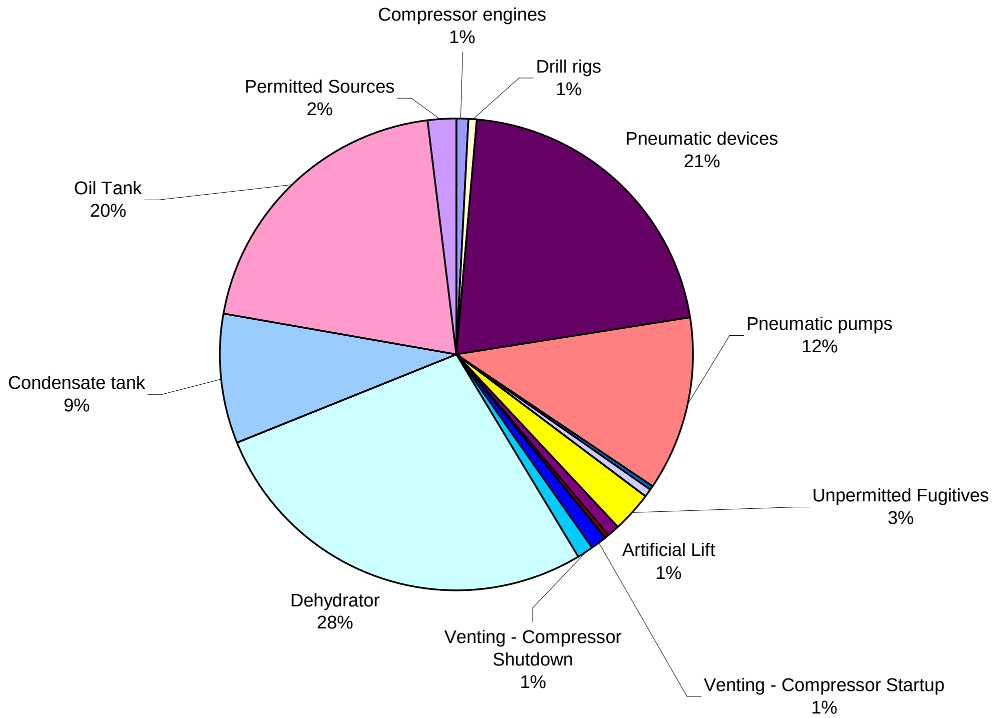

Figure 7. Uinta Basin VOC emissions proportional contributions by source category.

A summary of total emissions for each county are shown in Table 5. A breakdown of NOx and VOC emissions for each source category by county is shown in Tables 6 and 7.

Table 5. 2006 emissions of all criteria pollutants by county for the Uinta Basin.

County	NOx [tons/yr]	VOC [tons/yr]	CO [tons/yr]	SOx [tons/yr]	PM [tons/yr]
Carbon	1,024	2,748	833	23	43
Duchesne	3,709	19,280	3,232	97	178
Emery	273	453	199	9	14
Grand	698	2,429	331	16	26
Uintah	7,390	46,637	4,133	251	362
Wasatch	0	0	0	0	0
Carbon (Tribal)	73	387	56	2	5
Duchesne (Tribal)	2,278	9,739	2,053	55	98
Emery (Tribal)	0	0	0	0	0
Grand (Tribal)	438	76	154	7	11
Uintah (Tribal)	7,173	45,167	3,926	247	351
Wasatch (Tribal)	0	0	0	0	0
Carbon (Nontribal)	950	2,360	777	21	38
Duchesne (Nontribal)	1,431	9,540	1,178	42	80
Emery (Nontribal)	273	453	199	9	14
Grand (Nontribal)	260	2,353	176	10	15
Uintah (Nontribal)	217	1,470	206	4	12
Wasatch (Nontribal)	0	0	0	0	0
Totals	**13,093**	**71,546**	**8,727**	**396**	**623**
Total Tribal	**9,962**	**55,370**	**6,190**	**310**	**465**
Total Nontribal	**3,131**	**16,176**	**2,537**	**86**	**159**

Table 6. 2006 NOx emissions [tons/yr] by county and by source category for the Uinta Basin.

County	Compressor engines	Condensate tank flaring	Drill rigs	Heaters	Workover rigs	Miscellaneous engines	Artificial Lift	Dehydrator	Dehydrator Flaring	Initial completion Flaring	Permitted Sources	Total
Carbon	549.2	0.0	254.8	107.7	28.8	17.3	0.1	36.8	0.0	0.0	28.9	1023.7
Duchesne	149.8	0.3	1238.3	217.6	5.4	35.0	1396.5	10.1	0.0	0.1	655.7	3708.7
Emery	107.7	0.0	102.8	40.4	7.2	6.5	0.9	7.2	0.0	0.0	0.0	272.8
Grand	45.6	0.0	120.7	54.3	79.0	8.7	26.1	3.1	0.0	0.0	360.6	698.1
Uintah	1354.9	0.3	3062.2	595.5	134.6	95.8	761.0	90.9	0.1	0.4	1294.2	7389.7
Carbon (Tribal)	27.1	0.0	0.0	0.7	14.7	0.1	0.0	1.8	0.0	0.0	28.9	73.3
Duchesne (Tribal)	86.6	0.2	701.8	111.1	0.0	17.9	698.6	5.8	0.0	0.1	655.7	2277.8
Emery (Tribal)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grand (Tribal)	0.0	0.0	0.0	0.0	77.4	0.0	0.0	0.0	0.0	0.0	360.6	438.1
Uintah (Tribal)	1350.3	0.2	3053.2	584.0	92.3	93.9	613.4	90.6	0.1	0.4	1294.2	7172.6
Carbon (Nontribal)	522.1	0.0	254.8	107.0	14.1	17.2	0.1	35.0	0.0	0.0	0.0	950.4
Duchesne (Nontribal)	63.2	0.2	536.4	106.4	5.4	17.1	697.9	4.2	0.0	0.1	0.0	1430.9
Emery (Nontribal)	107.7	0.0	102.8	40.4	7.2	6.5	0.9	7.2	0.0	0.0	0.0	272.8
Grand (Nontribal)	45.6	0.0	120.7	54.3	1.5	8.7	26.1	3.1	0.0	0.0	0.0	260.0
Uintah (Nontribal)	4.5	0.0	8.9	11.5	42.4	1.9	147.6	0.3	0.0	0.0	0.0	217.2
Totals	**2207.2**	**0.6**	**4778.8**	**1015.6**	**255.0**	**163.3**	2184.5	**148.1**	**0.1**	**0.6**	**2339.3**	13093.0
Total Tribal	**1464.0**	**0.4**	**3755.1**	**695.9**	**184.4**	**111.9**	1312.0	**98.2**	**0.1**	**0.4**	**2339.3**	9961.7
Total Nontribal	**743.2**	**0.2**	**1023.7**	**319.7**	**70.6**	**51.4**	872.5	**49.9**	**0.0**	**0.1**	**0.0**	3131.3

Table 7. 2006 VOC emissions [tons/yr] by county and by source category for the Uinta Basin.

County	Oil Well Truck Loading	Gas Well Truck Loading	Pneumatic devices	Pneumatic pumps	Unpermitted Fugitives	Glycol Dehydrator	Condensate Tank	Oil Tank	Permitted Sources	Venting - Compressor Startup	Venting - Compressor Shutdown	Other Categories*	Total
Carbon	0.0	3.1	297.1	126.8	36.7	1795.9	150.8	0.4	1.0	74.8	70.9	190.6	2748.1
Duchesne	616.2	11.7	3629.2	2053.9	465.1	1697.4	571.8	9178.0	260.1	72.1	68.4	655.8	19279.6
Emery	0.4	0.0	162.8	78.0	20.4	133.5	0.8	5.6	0.0	5.3	5.0	40.8	452.6
Grand	11.5	0.7	906.1	512.8	116.1	516.5	32.0	171.4	68.9	21.9	20.8	50.2	2428.9
Uintah	335.8	111.5	9920.6	5614.2	1271.3	15327.3	5439.3	5001.3	990.3	651.2	617.2	1356.9	46636.8
Carbon (Tribal)	0.0	0.4	12.3	7.0	1.6	306.6	20.9	0.0	1.0	13.0	12.3	12.3	387.5
Duchesne (Tribal)	308.2	0.7	1854.0	1049.3	237.6	981.0	34.0	4591.2	260.1	41.7	39.5	342.1	9739.4
Emery (Tribal)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grand (Tribal)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68.9	0.0	0.0	7.2	76.1
Uintah (Tribal)	270.6	111.5	9728.5	5505.5	1246.7	15276.0	5439.3	4031.2	990.3	649.0	615.2	1303.0	45166.9
Carbon (Nontribal)	0.0	2.7	284.7	119.8	35.1	1489.3	129.9	0.4	0.0	61.8	58.6	178.1	2360.5
Duchesne (Nontribal)	307.9	11.0	1775.2	1004.7	227.5	716.4	537.8	4586.7	0.0	30.4	28.8	313.7	9540.2
Emery (Nontribal)	0.4	0.0	162.8	78.0	20.4	133.5	0.8	5.6	0.0	5.3	5.0	40.8	452.6
Grand (Nontribal)	11.5	0.7	906.1	512.8	116.1	516.5	32.0	171.4	0.0	21.9	20.8	43.1	2352.8
Uintah (Nontribal)	65.1	0.0	192.0	108.7	24.6	51.3	0.0	970.1	0.0	2.2	2.1	53.9	1469.9
Totals	**963.9**	**127.0**	**14915.7**	**8385.7**	**1909.6**	**19470.5**	**6194.6**	**14356.7**	**1320.4**	**825.4**	**782.4**	2294.3	71546.0
Total Tribal	**578.9**	**112.6**	**11594.8**	**6561.7**	**1485.9**	**16563.6**	**5494.2**	**8622.4**	**1320.4**	**703.7**	**667.0**	1664.6	55369.8
Total Nontribal	**385.0**	**14.4**	**3320.8**	**1824.0**	**423.7**	**2906.9**	**700.4**	**5734.2**	**0.0**	**121.7**	**115.3**	629.5	16176.0

* All the source categories with <1% VOC contribution are summed together under Other Categories.