Environment

Prepared for:
Bureau of Land Management
Utah State Office

Submitted by:
AECOM
Fort Collins, Colorado
November 2013

Utah State BLM Emissions Inventory Technical Support Document

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November 1, 2013

Leonard Herr
BLM Utah State Office
440 West 200 South, Suite 500
Salt Lake City, UT 84101

Subject: Final Utah State BLM Emissions Inventory Technical Support Document

Dear Mr. Herr,

AECOM Environment (AECOM) is pleased to submit the final *Utah State BLM Emissions Inventory Technical Support Document* (TSD) that describes the data development and processing methods for the Utah Bureau of Land Management (BLM) emissions inventories.

The primary objective of the emissions inventories is for assessing current and potential future air quality impacts as part of the ARMS Modeling Project. The ARMS modeling project will develop an air quality management tool that could provided a reusable modeling framework to assess the potential cumulative impacts from future project-specific NEPA actions.

The final emissions inventories are in a format compatible with the Community Multiscale Air Quality (CMAQ) Model for BLM's future use. We have enclosed an electronic copy of the Final Technical Support Document, in Adobe format (PDF), for distribution to the Resource Technical Advisory Group (RTAG). In addition, a response to RTAG comments on the draft TSD is enclosed.

If you have any questions relative to this TSD, or would like to discuss this study, please contact Courtney Taylor (Courtney.Taylor@aecom.com) or call (970) 493-8878.

Yours sincerely,

Courtney Taylor

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Executive Summary

ES.1 Introduction

This report presents the methods used for developing an air Emissions Inventory (EI) for the Air Resource Management Strategy (ARMS) Modeling Project. The ARMS Modeling Project requires a set of model-ready EIs for the assessment of potential impacts on future air quality and air quality related values (AQRVs). To develop the EIs appropriate for the ARMS Modeling Project, the following three objectives were defined as part of the Utah Emissions Inventory Development Protocol:

1. Develop a base year EI suitable for use in an air quality model performance evaluation. The base-year EI includes non-anthropogenic emissions sources, such as biogenic emissions, wild fires, and surface fugitive dust emissions, which are maintained as constants in the future year EIs.
2. Develop future year EIs for use in Photochemical Grid Modeling (PGM) models appropriate for estimating potential impacts on air quality and AQRVs and evaluate the effectiveness of potential mitigation strategies.
3. Provide the Bureau of Land Management (BLM) with the final set of model-ready EIs, focused on the State of Utah, appropriate for future cumulative National Environmental Policy Act studies for oil and gas development in the Uinta Basin.

Emissions data was developed for oxides of nitrogen (NO_X), sulfur dioxide (SO_2), particulate matter with an aerodynamic diameter less than or equal to 10 microns (PM_{10}), particulate matter with an aerodynamic diameter less than or equal to 2.5 microns ($PM_{2.5}$), carbon monoxide (CO), total volatile organic compounds (VOC), and speciated VOCs. In order to create PGM-ready EIs, the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system was used. PGM-ready air emissions data are developed for a set of nested modeling domains. To meet the study objectives, it was determined that five EIs would be developed. The development and purpose of the five EIs are summarized briefly below:

- Base Year EI. A base year EI was developed for 2010, the same year for which meteorological data are available. The primary purpose of this EI is for model evaluation purposes.
- Future Year EI. The future year with the maximum emissions in the Uinta Basin was determined to be 2021. A comprehensive emissions inventory was developed for 2021.
- Three Mitigation Scenarios. Three mitigation scenarios were developed to target reductions in VOC emissions, NO_X emissions, and combined reductions.

The EIs are configured so that future emissions control measures or mitigation strategies can be applied to specific segments of oil and gas development and production.

Emissions inventories are processed through the SMOKE model. There are several different types of emissions that were processed by SMOKE, such as point, area, non-road, on-road, fire, and biogenic emissions. These source types were processed separately and combined in a final step to prepare each of the five EIs for PGM modeling. EIs for the state of Utah oil and gas emissions, are maintained in separate files to allow flexibility when producing alternate strategies. In addition to considering source types, the study design considers the geographical importance of emission sources relative to three nested grids with 36-kilometer (km), 12-km, and 4-km horizontal resolution. **Table ES-1** summarizes the SMOKE system configuration for this study.

Table ES-1 Emissions Model Configuration for SMOKE

Emissions Component	Configuration	Details/Comments
Vertical Layer	17 layers for elevated point sources	Meteorological modeling has 36 layers, but emissions were not injected into layers above layer 17
On-Road mobile Sources	MOVES2010a	
Temporal Adjustments	USEPA surrogate data	Based on latest collected information and Continuous Emissions Monitoring System (CEMS)-based profiles
Chemical Speciation	2005 update of the Carbon Bond V (CB05)	VOC emissions will be speciated according to the lumped bond species used in CB05
Gridding	USEPA spatial surrogates	
Quality Assurance	Quality assurance tools in SMOKE	Additional quality assurance with AECOM's post-processing tools

The SMOKE model is configured to be compatible with the ARMS gridded meteorological data as well as the configuration of the ARMS PGM models (AECOM and Sonoma Technology Incorporated [STI] 2013, AECOM 2012). **Table ES-2** lists the size and dimensions of the 36-km, 12-km, and 4-km modeling domains proposed for this study.

Table ES-2 Model Domain Dimensions

Model	Domain	Number of Grid Cells	Coordinates of southwestern corner of grid (km)
SMOKE	36-km	148 x 112	-2736, -2088
	12-km	111 x 111	-1872, -612
	4-km	144 x 126	-1500, -264

ES.2 Base Year Emissions Inventory

The base year EI is developed for year 2010. This period was selected based on the availability of ozone monitoring data, a critical component for conducting the model performance evaluation (MPE). The best available data sources are used and rigorous quality assurance procedures are applied. The primary purpose of this EI is for model evaluation purposes. **Table ES-3** shows the final base year emissions inventory by source sector in the 4-km model domain.

Table ES-3 Year 2010 Emissions by Source Sector in the 4-km Domain

Source Sector	NO_X (tons per year [tpy])	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
EGU Point	86,197	1,631	7,363	29,192	424	3,348	5,314
Non- EGU Point	57,905	22,639	27,135	21,174	424	5,372	11,403
Oil and Gas	32,917	722,116	85,509	314	0	1,156	1,174
Area	10,595	721,994	240,949	1,819	170,693	16,444	30,234
Non-road	19,061	20,176	147,008	539	7	1,258	1,324
On-Road	82,041	39,262	421,224	2,000	1,215	2,902	3,497
Ammonia	0	0	0	0	23,543	0	0
Fire	4,015	14,495	77,625	655	1,986	8,490	9,556
Biogenic	5,248	465,492	69,557	0	0	0	0
Dust (fugitive and road)	0	0	0	0	0	7,633	19,023
Total	**297,979**	**2,007,804**	**1,076,368**	**55,692**	**198,292**	**46,603**	**81,524**

ES.3 Future Year Emissions Inventory

As part of the study, an analysis the Uinta Basin oil and gas base year EI was projected into the future to determine the year with the maximum NO_X and maximum VOC emissions. Future year Uinta Basin emissions are estimated by applying growth factors and applicable control requirements to oil and gas activities in Uintah, Duchesne, Carbon, Emery, and Grand counties. The total NO_X and VOC emissions in the 5-counties in the Uinta Basin were evaluated for each year between the base year and 2021 and the maximum NO_X and VOC emissions are projected to occur in 2021. All other emission sources necessary for a comprehensive PGM EI were obtained or developed and processed for 2021. **Table ES-4** shows the final 2021 emissions inventory by source sector in the 4-km model domain.

Table ES-4 Year 2021 Emissions by Source Sector in the 4-km Model Domain

Source Sector	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
EGU Point	99,514	718	9,181	34,186	373	7,595	10,154
Non-EGU Point	27,772	16,751	60,624	7,682	448	4,690	9,810
Oil and Gas	35,257	800,376	87,081	339	0	2,347	2,367
Area	13,718	720,675	234,289	1,847	170,098	15,860	29,034
Non-Road	7,224	16,369	122,367	22	21	821	870
On-Road	24,626	14,100	238,333	243	783	718	773
Ammonia	0	0	0	0	23,543	0	0
Fire	1,406	4,295	24,100	196	486	2,514	2,984
Biogenic	5,248	465,492	69,557	0	0	0	0
Dust (fugitive and road)	0	0	0	0	0	7,633	19,022
Total	**215,436**	**2,038,758**	**855,995**	**44,526**	**195,751**	**42,722**	**75,560**

ES.4 Mitigation Scenarios

Three mitigation scenarios are developed to target reductions in VOC emissions and NO_X emissions in the Uinta Basin in 2021. The scenarios are based on BLM selection of applicable control technology. The objective of developing the mitigation EIs is to provide information for the ARMS Modeling Project to evaluate and compare the effectiveness of proposed mitigation measures. The mitigation strategies consist of NO_X controls, VOC controls, and combined NO_X and VOC emissions controls. The resulting Uinta Basin emissions inventories are shown in **Table ES-5** for the three mitigation scenarios relative to the on-the-books controlled emissions included in the base case future year emissions inventory (shown in **Table ES-4**).

Table ES-5 Uinta Basin Mitigation Scenario Emissions

Scenario	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
On-the-Books	26,167	138,775	80,060	63	1,998	1,998	26,167
Scenario 1	20,527	138,343	80,060	63	1,768	1,768	20,527
Scenario 2	26,777	120,096	89,083	78	2,461	2,461	26,777
Scenario 3	19,701	119,664	60,218	56	703	703	19,701

ES.5 Application of Emissions Inventories

The objective of developing these five emissions inventories is to provide model-ready emissions files for the ARMS Modeling Project. The ARMS Modeling Project will assess the model performance of two state-of-the-science Photochemical Grid Modeling (PGM) systems in an attempt to replicate the winter ozone events and to assess cumulative impacts to air quality and air quality related values during the rest of the year. The two PGM models selected for evaluation are the: 1) Community Multi-Scale Air Quality (CMAQ) modeling system; and 2) Comprehensive Air Quality Model with Extensions (CAMx). Both CMAQ and CAMx will be run and evaluated to determine which model is more appropriate for specific conditions important to the formation of ozone and other air pollutants in the Uinta Basin.

After the preferred model has been selected, future year modeling will be conducted with the emissions inventories described in this report using the preferred air quality model. The model results will comprise a regional cumulative air quality assessment, with the focus on the change in cumulative impacts resulting from Reasonably Foreseeable Future Development scenarios. Assessment areas for the air quality model were developed to include all regional Class I areas and other sensitive Class II areas (e.g., national parks and monuments, wilderness areas, etc.) near the Uinta Basin. Year 2021 will be modeled with on-the-books controls applied. In addition, air quality impacts will be evaluated for three mitigation scenarios developed and described in this report.

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Acronyms and Abbreviations

4SRB	4-stroke rich burn
API	American Petroleum Institute’s
AQRVs	air quality-related values
ARMS	Air Resource Management Strategy
bbl	barrels
BLM	Bureau of Land Management
BMP	Best Management Practices
BTEX	benzene, toluene, ethyl benzene, and xylene
CAMx	Comprehensive Air Quality Model with Extensions
CB05	Carbon Bond V
CBM	coal bed methane
CEMS	Continuous Emissions Monitoring System
CH_4	methane
CMAQ	Community Multiscale Air Quality
CO	carbon monoxide
CO_2	carbon dioxide
DOGM	Department of Natural Resources
EA	environmental assessment
EDL	Energy Dynamics Laboratory
EGU	electric generating units
EI	emission inventory
EIA	Energy Information Administration
EIS	environmental impact statement
GHG	greenhouse gases
GIS	Geographic Information System
H_2S	hydrogen sulfide
km	kilometer
LAI	Leaf Area Index
LCC	Lambert Conformal Conic
MEGAN	Model of Emissions of Gases and Aerosols from Nature
MMscf	million standard cubic feet
MODIS	MODerate-resolution Imaging Spectroradiometer
MOU	Memorandum of Understanding

MOVES	Motor Vehicle Emission Simulator
MPE	model performance evaluation
Mscf	million standard cubic feet
NAAQS	National Ambient Air Quality Standards
NCAR	National Center for Atmospheric Research
NEI	National Emissions Inventory
NEPA	National Environmental Policy Act
NG	natural gas
NMHC	nonmethane hydrocarbons
NO	nitric oxide
NO_2	nitrogen dioxide
Non-EGU	non-electric generating units
NO_X	oxides of nitrogen
NSPS	New Source Performance Standards
O_3	ozone
PAR	paraffins
PFT	plant functional types
PGM	photochemical grid model
PM	particulate matter
PM_{10}	particulate matter with an aerodynamic diameter less than or equal to 10 microns
$PM_{2.5}$	particulate matter with an aerodynamic diameter less than or equal to 2.5 microns
ppb	parts per billion
ppmw	parts per million weight
PRP18b	2018 Preliminary Reasonable Progress Version B
QA	quality assurance
RFD	reasonably foreseeable development
RFFA	reasonable foreseeable future activity
RFFD	Reasonably Foreseeable Future Development
ROG	reactive organic gas
RPD	Rate-per-distance
RPO	Regional Planning Organization
RPV	Rate-per-vehicle
RTAG	Resource Technical Advisory Group
SCC	Source Classification Code
scfh	standard cubic feet per hour
SMOKE	Sparse Matrix Operator Kernel Emissions

SO_2	sulfur dioxide
SO_X	Oxides of sulfur
SWWY	Southwest Wyoming
TEG	triethylene glycol
TOG	toxic organic gas
tpy	tons per year
U.S.	United States
UBAQS	Uinta Basin Air Quality Study
UDAQ	Utah State Division of Air Quality
UDEQ	Utah Department of Environmental Quality
UGRB	Upper Green River Basin
ULSD	Ultra Low Sulfur Diesel
UMD	University of Maryland
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
VMT	vehicle miles traveled
VOC	volatile organic compound
VPOP	Vehicle population
WDEQ	Wyoming Department of Environmental Quality
WOGCC	Wyoming Oil and Gas Conservation Commission
WRAP	Western Regional Air Partnership
WRF	Weather Research and Forecasting

1.0 Introduction

This report presents the methods used for developing an air Emissions Inventory (EI) for the Air Resource Management Strategy (ARMS) Modeling Project. The final EIs developed are centered on the State of Utah and are suitable for use in a photochemical grid model. The development of this EI was conducted by AECOM Technical Services, Inc., (AECOM) under the direction of the Bureau of Land Management (BLM).

1.1 Study Background and Objectives

The BLM is required to complete a National Environmental Policy Act (NEPA) analysis, in the form of an environmental impact statement (EIS) or environmental assessment (EA), for each proposed project that would occur on BLM-administered federal land. In the recent past, there has been concern about the methods used to assess potential air quality impacts and air quality related values (AQRVs) associated with proposed oil and gas projects.

The Uinta Basin is an area in northeastern Utah that is projected to have extensive development of oil and gas reserves in the foreseeable future. One of the main air quality concerns related to continued development of oil and gas reserves in the Uinta Basin is the elevated ozone levels measured during winter. Several winter episodes of elevated 8-hour ozone concentrations have been measured in the Uinta Basin since monitoring began in 2009. Since then multiple ambient air monitoring studies have been conducted in the Uinta Basin in Utah. The United States (U.S.) Environmental Protection Agency's (USEPA) National Ambient Air Quality Standards (NAAQS) for the 8-hour average ozone concentration is 75 parts per billion (ppb). In the Uinta Basin, the maximum 8-hour average concentrations exceeded 130 ppb in winter 2011.[1] These episodes of elevated ozone concentrations typically occur in the late winter and early spring, but sustained ozone concentrations above natural background are evident in these areas during summer conditions, as well.

While continued winter monitoring studies are on-going in the Uinta Basin, air quality assessment tools are currently under development. The ARMS Modeling Project is one of several studies that will inform and support the Utah ARMS. As part of the ARMS, the Utah BLM, together with other state and federal agencies, has commissioned several studies to further understand and analyze current ambient air and meteorological conditions in the Uinta Basin, and to develop emissions inventories appropriate for ozone modeling applications. These projects include special monitoring studies (Energy Dynamics Laboratory [EDL] 2011, Utah Department of Environmental Quality [UDEQ] 2011) and this emissions inventory development project (AECOM 2011). The results of these studies will be used extensively in the ARMS Modeling Project and are essential to the overall understanding of the issues affecting air quality in the Uinta Basin.

The ARMS Modeling Project requires a set of model-ready EIs for the assessment of potential impacts on future air quality and air quality related values (AQRVs). To develop the EIs appropriate for the ARMS Modeling Project, the following three objectives were defined as part of the Utah Emissions Inventory Development Protocol (AECOM 2011):

1. Develop a base year EI suitable for use in an air quality model performance evaluation. The base-year EI includes non-anthropogenic emissions sources, such as biogenic emissions, wild fires, and surface fugitive dust emissions, which are maintained as constants in the future year EIs.

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[1] It is important to note that the official form of the 8-hour ozone NAAQS is the annual fourth-highest daily maximum 8-hour ozone concentration averaged over 3 years cannot exceed 75 ppb. Three full years of ozone monitoring data have not yet been collected in the Uinta Basin as of the writing of this report, and therefore the reported 8-hour average concentrations are not directly comparable to the form of the USEPA NAAQS.

2. Develop future year EIs for use in PGM models appropriate for estimating potential impacts on air quality and AQRVs and evaluate the effectiveness of potential mitigation strategies.
3. Provide the BLM with the final set of model-ready EIs, focused on the State of Utah, appropriate for future cumulative NEPA studies for oil and gas development in the Uinta Basin.

Emissions data was developed for oxides of nitrogen (NO_X), sulfur dioxide (SO_2), particulate matter with an aerodynamic diameter less than or equal to 10 microns (PM_{10}), particulate matter with an aerodynamic diameter less than or equal to 2.5 microns ($PM_{2.5}$), carbon monoxide (CO), total volatile organic compounds (VOC), and speciated VOCs. In order to create PGM-ready EIs, the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system was used. The PGM-ready air emissions data are developed for a set of nested modeling domains (shown in **Figure 1-1**). To meet the study objectives, it was determined that five EIs would be developed. The development and purpose of the 5 EIs are summarized briefly below:

- Base Year EI. A base year EI was developed for 2010, the same year for which meteorological data are available. The primary purpose of this EI is for model evaluation purposes. The development of the base year EI is described in detail in Chapter 2.0.
- Future Year EI. The future year with the maximum emissions in the Uinta Basin was determined to be 2021. A comprehensive emissions inventory was developed for 2021 and is described in detail in Chapter 4.0.
- Three Mitigation Scenarios. Three mitigation scenarios were developed to target reductions in VOC emissions, NO_X emissions, and combined reductions. The development of the three mitigation EIs is described in detail in Chapter 5.0.

The EIs are configured so that future emissions control measures or mitigation strategies can be applied to specific segments of oil and gas development and production. The three mitigation strategies are applied to the maximum emissions inventory year to enable evaluation of the effectiveness of proposed mitigation measures prior to implementation. The study approach, outlined in Section 1.2, is developed based on the overall purpose of the EI and places emphasis on the Uinta Basin Study Area (shown in **Figure 1-2**).

As part of ARMS, the Utah BLM established the Utah Air Resource Technical Advisory Group (RTAG) to provide a forum to discuss and review the results of the BLM-funded studies. The RTAG review group has participated in the review of the development and results of these EIs to facilitate collaboration and transparency among multiple federal agencies. This collaborative effort supports the goals of the June 2011 Memorandum of Understanding (MOU), referred to hereafter as the National MOU. While the procedures described in the National MOU are followed, as appropriate, during the EI development, it is important to note that this particular study is not a project-specific NEPA analysis, and the EI and reports are not NEPA products. Rather, the EI is the first step of a cumulative assessment of potential future air quality impacts associated with predicted oil and gas activity in the Uinta Basin. Therefore, the National MOU guidance applicable to project-specific emissions, impacts, and analyses will not be required as part of this study. Furthermore, it is not a policy study, analysis of regulatory actions, or an analysis of the impacts of project-specific development. While the EIs are not for a project-specific NEPA analysis, analyses of these EIs may result in specific mitigation measures or Best Management Practices (BMP) applicable to future NEPA actions.

1.2 Overview of Emissions Inventories Development Approach

A comprehensive emission inventory includes point sources, area sources, and on-road and non-road mobile sources, as well as fugitive dust, ammonia, biogenic, fire, and emissions outside the U.S., such as Mexico, Canada, and offshore sources. Given the predominance of oil and gas activities in the project area and surrounding region, special care was taken to develop a comprehensive oil and gas emissions inventory. All EIs were processed with the SMOKE modeling system for the series of 36-km, 12-km, and 4-km nested grids in a format compatible with the PGM.

1.2.1 Base Year Emissions Inventory

The base year EI is developed for year 2010. This period was selected based on the availability of ozone monitoring data, a critical component for conducting the model performance evaluation (MPE). The best available data sources are used and rigorous quality assurance procedures are applied. The primary purpose of this EI is for model evaluation purposes. The development of the base year EIs are described in detail in Chapter 2.0.

1.2.2 Future Year Emissions Inventory

As part of the study, an analysis the Uinta Basin oil and gas base year EI was projected into the future to determine the year with the maximum NO_X and maximum VOC emissions. The Uinta oil and gas Basin consists of Uintah, Duchesne, Carbon, Emery, and Grand counties. Future year emissions are estimated by applying growth factors and applicable control requirements. The total NO_X and VOC emissions in the 5-counties in the Uinta Basin are evaluated for each year between the base year and 2021. The maximum NO_X and VOC emissions are projected to occur in 2021. All other emission sources necessary for a comprehensive PGM EI were obtained or developed and processed for the maximum year. The development of maximum year EI is described in detail in Chapter 4.0.

1.2.3 Mitigation Emissions Inventories

Three mitigation scenarios are developed to target reductions in VOC emissions and NO_X emissions in the Uinta Basin in the future year. The scenarios are based on BLM selection of applicable control technology and the measures are applied to the maximum future Uinta Basin EI. The objective of developing the mitigation EIs is to provide information for the ARMS Modeling Project to evaluate and compare the effectiveness of proposed mitigation measures. The mitigation strategies consist of NO_X controls, VOC controls, and combined NO_X and VOC emissions controls. The development of the three mitigation EIs is described in detail in Chapter 5.0.

1.3 SMOKE Model

Emissions inventories are processed through the SMOKE model (Houyoux and Vukovich 1999) version 2.7 (University of North Carolina 2010). There are several different types of emissions that were processed by SMOKE, such as point, area, non-road, on-road, fire, and biogenic emissions. These source types were processed separately and combined in a final step to prepare each of the five EIs for PGM modeling. EIs for the state of Utah oil and gas emissions, are maintained in separate files to allow flexibility when producing alternate strategies. In addition to considering source types, the study design considers the geographical importance of emission sources relative to three nested grids with 36-kilometer (km), 12-km, and 4-km horizontal resolution. **Table 1-1** summarizes the SMOKE system configuration for this study.

Table 1-1 Emissions Model Configuration for SMOKE

Emissions Component	Configuration	Details/Comments
Vertical Layer	17 layers for elevated point sources	Meteorological modeling has 36 layers, but emissions were not injected into layers above layer 17
On-Road mobile Sources	MOVES2010a	
Temporal Adjustments	USEPA surrogate data	Based on latest collected information and Continuous Emissions Monitoring System (CEMS)-based profiles
Chemical Speciation	2005 update of the Carbon Bond V (CB05)	VOC emissions will be speciated according to the lumped bond species used in CB05
Gridding	USEPA spatial surrogates	
Quality Assurance	Quality assurance tools in SMOKE	Additional quality assurance with AECOM's post-processing tools

1.3.1 Horizontal Modeling Domain

The SMOKE model is configured to be compatible with the ARMS gridded meteorological data as well as the configuration of the ARMS PGM models (AECOM and Sonoma Technology Incorporated [STI] 2013, AECOM 2012). The air quality modeling domains include a coarse domain focused on the continental U.S. with a 36-km horizontal grid resolution and 2 refined domains with 12-km and 4-km grid resolutions. **Figure 1-1** shows the nested horizontal domains for each domain. The 36-km modeling domain is identical to the Western Regional Air Partnership (WRAP) 36-km modeling domain, which includes the contiguous U.S. and portions of Canada and Mexico. The 12-km modeling domain was developed to surround the 4-km domain focus area and includes portions of the states bordering Utah. The 4-km modeling domain is centered on Utah and extends slightly into areas with heavy oil and gas production, which may affect Utah's air quality.

All model domains use the map projection from the Regional Planning Organizations' (RPO) unified grid. The RPO unified grid consists of a Lambert Conformal Conic (LCC) map projection using the map projection parameters listed in **Table 1-2**. **Table 1-3** lists the size and dimensions of the 36-km, 12-km, and 4-km modeling domains proposed for this study.

Table 1-2 RPO Unified Grid Definition

Parameter	Value
projection	LCC
datum	World Geodetic System 1984
alpha	33 degrees (°) latitude
beta	45° latitude
x center	97° longitude
y center	40° latitude

Table 1-3 Model Domain Dimensions

Model	Domain	Number of Grid Cells	Coordinates of southwestern corner of grid (km)
PGM	36-km	148 x 112	-2736, -2088
	12-km	111 x 111	-1872, -612
	4-km	144 x 126	-1500, -264

1.3.2 Vertical Modeling Domain

For the purposes of creating three dimensional files for the PGM, vertical layers of emissions files are required. The vertical grid will be composed of 36 layers with thinner (more) layers in the planetary boundary layer (PBL). The proposed layer structure is summarized in **Table 1-4**. The altitudes above sea level are estimated according to standard atmosphere assumptions.[2]

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[2] Standard equations and assumptions include: surface pressure of 1,000 mb, model top at 100 mb, surface temperature of 275 degrees Kelvin (°K), and lapse rate of 50°K/ natural log-pressure (ln[p]).

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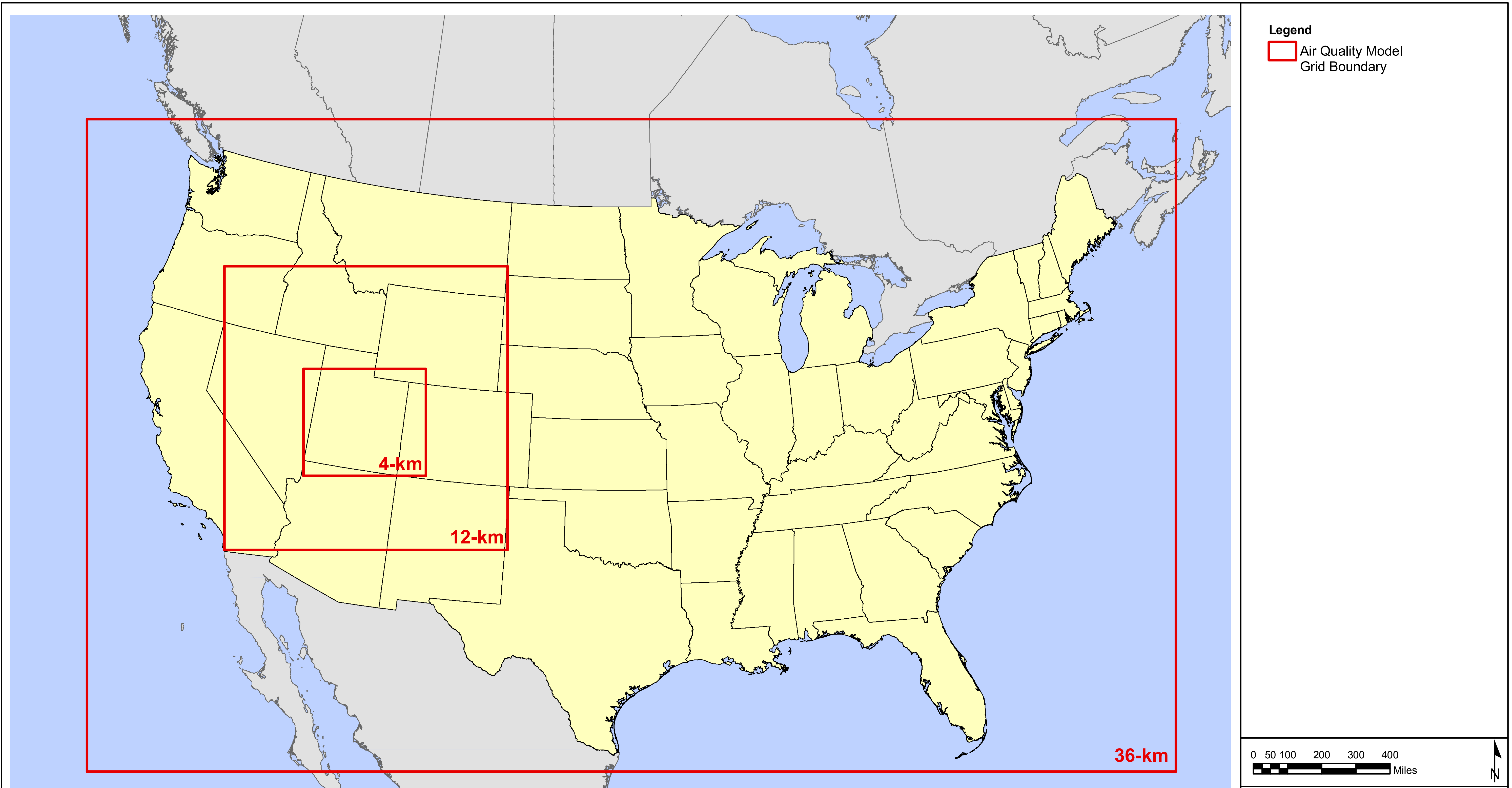
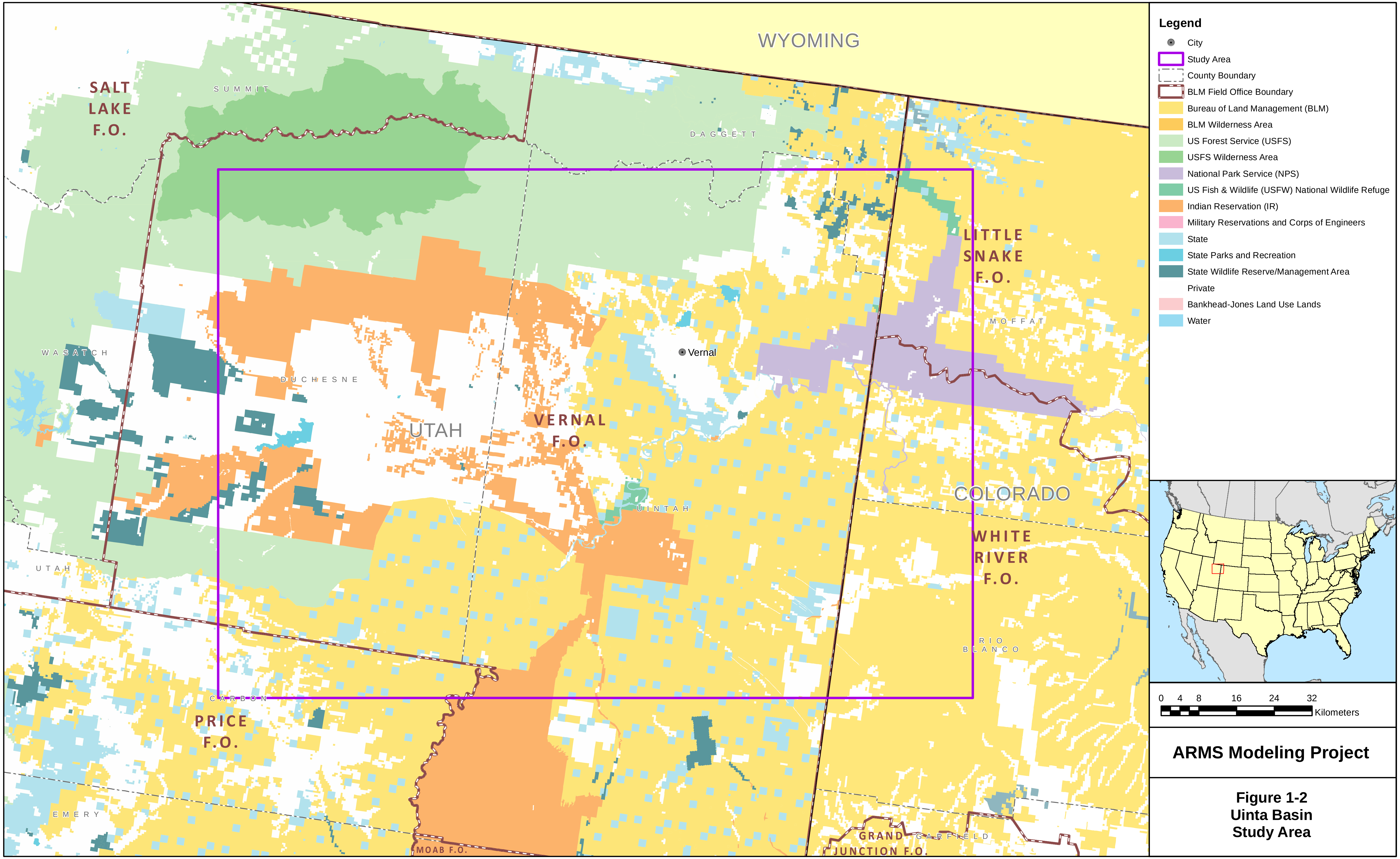


UTSO Emission Inventory Project

Figure 1-1
Air Quality Model
Grid Boundaries
36-km, 12-km and 4-km



ARMS Modeling Project

Figure 1-2
Uinta Basin
Study Area

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Table 1-4 Vertical Layer Structure

Model Layer	Sigma	Pressure (millibars [mb])	Height (meters)	Depth (meters)
36 – top	0.000	50	20,559	4,262
35	0.050	98	16,297	2,527
34	0.100	145	13,770	1,805
33	0.150	193	11,965	1,407
32	0.200	240	10,559	1,185
31	0.250	288	9,374	1,035
30	0.300	335	8,339	931
29	0.350	383	7,408	832
28	0.400	430	6,576	760
27	0.450	478	5,816	701
26	0.500	525	5,115	652
25	0.550	573	4,463	609
24	0.600	620	3,854	572
23	0.650	668	3,282	540
22	0.700	715	2,741	412
21	0.740	753	2,329	298
20	0.770	782	2,032	290
19	0.800	810	1,742	188
18	0.820	829	1,554	185
17	0.840	848	1,369	182
16	0.860	867	1,188	178
15	0.880	886	1,009	175
14	0.900	905	834	87
13	0.910	915	747	85
12	0.920	924	662	85
11	0.930	934	577	85
10	0.940	943	492	83
9	0.950	953	409	83
8	0.960	962	326	83
7	0.970	972	243	81
6	0.980	981	162	41
5	0.985	986	121	41
4	0.990	991	80	20
3	0.9929	993	60	20
2	0.995	995	40	20
1	0.9976	998	20	20
0 – ground	1.000	1,000	0	0

1.3.3 Meteorological Inputs

A gridded meteorological dataset is necessary for development of emissions for some source categories that are dependent on meteorological parameters such as temperature and relative humidity. The Weather Research and Forecasting (WRF) meteorological model was used to develop the necessary meteorological dataset. The WRF configuration was tested extensively for the Uinta Basin Study Area to determine a preferred WRF configuration. The result of these test led to two configurations: one for winter months and another for non-winter months. More information regarding the meteorological model performance and configuration tests can be found in the Meteorological Model Performance Evaluation Report (AECOM and Sonoma Technology Incorporated [STI] 2013).

1.3.4 SMOKE Modules

The SMOKE model has several processing routines used in this project. The following processes are described in more detail throughout the document in the applicable source sections:

- Spatial Allocation. The spatial resolution of the emissions must match the PGM grid cells for each domain. Initial area, on-road, and non-road emission inventories are spatially resolved at the county level. The spatial area of counties is too coarse for this project PGM grid resolution. Therefore, county-level emissions are allocated to the grid cells within each county based on spatial surrogates (e.g., population, land use categories, and economic activity). The USEPA has developed spatial surrogates which were used for spatially allocating all non-oil and gas emissions. Oil and gas area emissions were spatially allocated based on surrogates developed for this study from well location and production information.
- Temporal Allocation. Initial emissions data are provided for different averaging periods depending on each source type. Source types with annual or short-term emission rates were adjusted to seasonal or monthly profiles accounting for day-of-week and hour-of-day differences. Non-point sources, including non-road and dust emissions are allocated by monthly, daily, and hourly profiles provided by the USEPA. Biogenic and on-road emissions were modeled using hourly meteorological data. Point sources, including CEMS and fire emissions, were modeled with available day-specific, or hour-specific emissions and meteorology.
- Chemical Speciation. Emission inventories do not routinely include estimates of every chemical species emitted, rather total emissions are reported for similar pollutants. Emissions of total volatile organic compounds (VOC) are converted to estimates of carbon bond types as required by the Carbon Bond version 2005 (CB05) (Yarwood et al. 2005) chemical mechanism. Total oxides of nitrogen (NO_X) emissions are allocated to nitrogen oxide (NO), nitrous acid (HONO), and nitrogen dioxide (NO_2) components. Particulate matter (PM) is allocated to coarse PM, nitrate, sulfate, organic carbon, elemental carbon, and other fine particulates. The USEPA has developed default speciation profiles for each emissions source category. The default profiles were used for most sources, with the exception of oil and gas VOC emissions. Oil and gas VOC emissions were speciated based on chemical composition analysis for various types of equipment and processes.
- Elevated Sources. All sources were treated by SMOKE as potentially elevated.
- Quality Assurance. The SMOKE model includes quality assurance (QA) and reporting features to keep track of the adjustments at each processing stage and ensure that data integrity is not compromised. The QA tools from SMOKE were used to provide summary plots and tables of emissions.

Additional settings and configurations for each of the source categories are discussed in relevant sections in the following chapters. In general, the SMOKE model was run with the latest released temporal, spatial, speciation profiles, and cross-reference data currently provided with the model and from the USEPA. Except where noted, all ancillary data used for this study were held constant.

1.3.5 Chemical Speciation Processes

In this study, the focus is on assessment of criteria air pollutants (CAP), such as ozone, NO_X, CO, SO_2, $PM_{2.5}$, and PM_{10}, as well as AQRVs. Accordingly, the emissions inventory includes chemical species necessary to assess these impacts. The chemical speciation processes in the emission modeling is used to convert the inventory pollutants to the model species needed by the air quality model for a specific chemical mechanism. These model species are either individual chemical compounds or groups of species and are referred to as "model species." The Carbon-Bond 5 (CB-05) chemical mechanism from the USEPA National Emissions Inventory (NEI) platform package was used to create PGM-ready emissions data. The Total Organic Gases (TOG) and $PM_{2.5}$ chemical speciation factors are developed by the SPECIATE4.3 database (USEPA 2011b) that contains speciation profiles for TOG and $PM_{2.5}$, and VOC-to-TOG conversion factors associated with the TOG profiles. **Table 1-5** defines the species abbreviations used throughout the document. The TOG refers to the sum of the reactive species used in air quality modeling and is not equivalent to the VOC in the raw inventory. The reactive organic gas (ROG) refers to the sum of the reactive species used in air quality modeling and is not equivalent to the VOC in the raw inventory.

Table 1-5 Chemical Species Model Names

Chemical Initials	Full Name	Chemical Initials	Full Name
NO_X	Nitrogen oxides	ALD2	Acetaldehyde
VOC	Volatile organic compound	ALDX	Higher aldehydes
TOG[1]	Total organic gases	BENZENE	Benzene
ROG[2]	Sum of reactive organic gases	ETH	Ethene
CO	Carbon monoxide	ETHA	Ethane
SO_2	Sulfur dioxide	ETOH	Ethanol
PM_{10}	Particulates less than 10 micrometers in aerodynamic diameter	FORM	Formaldehyde
$PM_{2.5}$	Particulates less than 2.5 micrometers in aerodynamic diameter	IOLE	Internal olefin carbon bond
PEC	Particulate elemental carbon	ISOP	Isoprene
PMFINE	Soil fraction of $PM_{2.5}$	MEOH	Methanol
PNO_3	Particulate nitrate	OLE	Olefins
POC	Particulate organic carbon	PAR	Paraffins
PSO_4	Particulate sulfate	TERP	Terpenes
PMC	Coarse particulate matter	TOL	Toluene
NH_3	Ammonia	UNK	Unknown
CH_4	Methane	UNR	Unreactive
NMHC	Non-methane hydrocarbon	XYL	Xylenes

[1] TOG = ALD2+ALDX+CH4+ETH+ETHA+ETOH+FORM+IOLE+ISOP+MEOH+OLE+PAR+TERP+TOL+XYL+UNK+UNR.

[2] ROG = ALD2+ALDX+CH4+ETH+ETHA+ETOH+FORM+IOLE+ISOP+MEOH+OLE+PAR+TERP+TOL+XYL

1.4 Report Organization

Following this introduction, Chapter 2.0 details the approach and data sources used to develop the base year EI. Chapter 3.0 describes the typical year emissions inventory. Chapter 4.0 describes the approach to develop the future year EIs and the method used to select the maximum emissions years, while Chapter 5.0 describes the development of the three mitigation scenarios.

2.0 Base Year Emissions Inventory

The purpose of the base year EI is two-fold: 1) to develop an emissions inventory suitable to evaluate the air quality model performance, and 2) to provide a basis against which the future year emissions and air quality impacts can be compared. The performance of the air quality model depends on its ability to simulate the complex interactions between primary emissions sources (i.e., input emissions inventory) and meteorological conditions (i.e., output data from the meteorological model). For regional photochemical modeling, it is necessary to model the emissions of all sources in the modeling domain. Therefore, a base year EI was obtained or developed (depending on the data availability), quality assured, and processed for all sources within the 36-km, 12-km, and 4-km domains.

Consistent with the protocol (AECOM 2011), the 2010 base year EI incorporates several existing data sources, which include the following:

- Select WRAP emissions inventory products (e.g., Planning Case 2002d [Plan 02d], and Preliminary Reasonable Progress 2018b [PRP 18b] cases).
- Updated emission inventories developed by Division of Air Quality, Department of Environmental Quality, State of Utah.
- Available improvements to WRAP products (such as the most recent Oil and Gas emissions inventories (known as WRAP Phase III).
- State and Federal emissions inventory products, including:
    - Ammonia from agricultural sector from 2008 NEI information
    - Satellite-derived fire emissions produced by National Center for Atmospheric Research (NCAR)
    - CEMS data
    - Biogenic emissions using Model of Emissions of Gases and Aerosols from Nature (MEGAN) 2.03
    - Uinta Basin Air Quality Study (UBAQS)
    - Southwest Wyoming Oil and Gas Inventory

The data sources for the base year emissions inventory are summarized for each source category in **Table 2-1**. Additional details the inventories used for this study are contained in the sections below. The most current available data source was used at the time the source sector was processed. During the course of the project, more recent datasets became available, but these data were only incorporated if the source sector and geographic area had not already been processed.

Table 2-1 Base Year Emissions Inventory Data Sources

Source Group	Spatial Area	Data Source	Method to Project Data to Common Base Year	Additional Controls Applied	Spatial Surrogates
Electric generating units (EGU) Point Sources	All Areas Except Utah, Colorado, Wyoming, Arizona, and New Mexico	2009 USEPA CEMS data for NO_X and SO_2. Other pollutants estimated as function of Heat Input	None	No	NA[1]
	Utah, Colorado, Wyoming, Arizona, and New Mexico	2010 CEMS data for NO_X and SO_2. Other pollutants estimated as function of Heat Input	NA[1]	No	NA[1]
Non-EGU Point Sources	All Areas Except Utah	WRAP 2002 Plan 02d and WRAP 2018 2018 Preliminary Reasonable Progress Version B (PRP18b)	Linear Interpolation	Yes	NA[1]
	Utah	2008 Utah State Annual Emissions Inventory	NA[1]	No	NA[1]
Oil and Gas – Uinta Basin	4-km	WRAP Phase III for 2006	Emissions are adjusted to 2010 levels based on the actual oil and gas well counts and production	Yes	Uinta Basin oil and gas spatial surrogates
All Other Oil and Gas Basin	All Areas Except Uinta Basin	Various[2]	Various[2]	Yes	Spatial surrogates of well locations
All Non-Oil and Gas Area Sources	All Areas Except Utah	WRAP 2002 Plan 02d to WRAP 2018 PRP18b	Interpolation (technique differs by source type/Source Classification Code [SCC])	Yes	USEPA defaults for each SCC
	Utah	Utah State Division of Air Quality (UDAQ) 2010 Emissions Inventory Area Sources (UDAQ 2011)	NA[1]	No	USEPA defaults for each SCC

Table 2-1 Base Year Emissions Inventory Data Sources

Source Group	Spatial Area	Data Source	Method to Project Data to Common Base Year	Additional Controls Applied	Spatial Surrogates
Non-Road Motor Vehicle	All Areas Except Utah	WRAP 2002 Plan 02d to WRAP 2018 PRP18b	Interpolation (technique differs by source type/SCC)	Yes	USEPA defaults for each SCC
	Utah	UDAQ 2008 Non-Road Emissions Inventory	Extrapolation to 2010 based on Utah-specific projection data (data differs by source type/SCC)	No	USEPA defaults for each SCC
On-Road Motor Vehicle	All Areas Except Utah	Vehicle Miles Traveled (VMT) from 2008 NEI	VMT activity data modeled with Motor Vehicle Emission Simulator (MOVES)	No	Road link data
	Utah	UDAQ 2010 VMT and fleet distribution data	Activity data modeled with Motor Vehicle Emission Simulator (MOVES)	No	Road link data
Ammonia	All	2008 NEI	None	No	USEPA allocation
Road Dust and Fugitive Dust (Excluding Wind Blown Dust)	All Areas Except Utah	WRAP Mobile Source Emissions Inventories Update of the WRAP 2002 inventory	None	No	WRAP allocation method
	Utah	UDAQ 2010 Emissions Inventory Area Sources	NA[1]	No	Road link data and agricultural land surface data
Fires	All	Satellite-derived 2010 emissions data from SMARTFIRE	NA[1]	No	NA[1]

Table 2-1 Base Year Emissions Inventory Data Sources

Source Group	Spatial Area	Data Source	Method to Project Data to Common Base Year	Additional Controls Applied	Spatial Surrogates
Biogenic	All	2001 Land use data and 2010 Meteorological data modeled with Model of Emissions of Gases and Aerosols from Nature (MEGAN)	NA[1]	No	NA[1]
Mexico, Canada, and Offshore Sources	36-km	WRAP 2002 Plan 02d	None	No	WRAP allocation method

[1] NA = Not Applicable.

[2] The data sources and methodology used vary. More detailed information is provided in the applicable section.

2.1 Point Sources

Due to different data sources, the point source emissions are separated into EGU and non-electrical generation units (non-EGU) categories. In addition, these two categories are further divided and processed separately for Utah sources versus sources outside of Utah. Therefore, point source emissions consist of four source sectors: EGU point sources outside of Utah, EGU point sources inside of Utah, non-EGU point sources outside of Utah, and non-EGU point sources inside of Utah.

2.1.1 EGUs

The EGU point sources for areas outside of Utah are from the 2005 NEI (USEPA 2009) with updated CEMS data. The UDAQ provided the 2008 Utah State Annual Emissions inventory to use for the point sources for areas inside Utah (UDAQ 2011). Similar to areas outside of Utah, hourly CEMS emissions were used for EGUs located in Utah, when available.

2.1.1.1 EGU Sources Outside of Utah

For EGU sources within Colorado, Wyoming, Arizona, and New Mexico, the 2005 NEI location and plant information was used in conjunction with the 2010 CEMS data (USEPA 2011). For all other states, the 2005 NEI location and plant information was used in conjunction with the 2009 CEMS data (USEPA 2011). The CEMS data was used to update the NO_X and SO_2 emissions where a match could be made to the 2005 NEI based on facility identification information. The emissions for all other pollutants were estimated by calculating the ratio of the 2009\2010 heat input value to the 2005 heat input and applying this ratio to the 2005 emissions. Some EGU sources do not have a CEMS, in which case the 2005 NEI emissions were used unmodified. **Table 2-2** shows the emissions processed by SMOKE for EGU point sources outside of Utah.

Table 2-2 EGU Point Source Outside Utah Emissions Input

NO_X (tons per year [tpy])	VOC (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
1,988,941	27,664	439,747	6,006,124	16,122	281,937	343,753

2.1.1.1 EGU Sources Inside of Utah

Similar to the process for EGU emissions outside of Utah, the EGU emissions inside Utah coupled plant location and stack parameters with the 2010 CEMS data (USEPA 2011). The plant information was provided by UDAQ for 2008. In order to avoid duplications in other source sectors, area sources and non-EGU sources are removed from the UDAQ dataset. Where 2010 CEMS data was available and a match could be made based on facility identification information CEMS emissions information was used to update 2008 NO_X and SO_2 emissions. Some EGU sources do not have a CEMS, in which case the 2008 emissions were used unmodified. **Table 2-3** shows emissions processed by SMOKE for EGU point sources inside Utah.

Table 2-3 Utah EGU Point Source Emissions Input

NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
59,910	570	5,872	20,804	331	1,204	2,290

2.1.1.2 EGU Emissions Summary

Table 2-4 and **Table 2-5** show the final emission totals for each modeling domain for EGU point sources outside of Utah and inside of Utah, respectively. The raw input table is not directly comparable to final emissions totals due to the SMOKE processing. When emissions records are spatially allocated to grid cells, a very small amount of emissions are removed. Spatial plots of the 12-km EGU point sources outside of Utah are shown in **Figure 2-1**. **Figure 2-2** shows the spatial plot of 4-km EGU point sources inside of Utah. The monthly average of EGU point sources in the 4-km domain are shown in **Figure 2-3**.

Table 2-4 Annual EGU Point Emissions Outside of Utah

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	1,952,120	43,813	434,768	5,920,817	15,849	276,462	337,530
12-km	226,168	4,862	20,507	165,720	1,011	17,309	22,585
4-km	26,736	199	1,650	8,415	95	2,160	3,041

Table 2-5 Utah Annual EGU Point Emissions

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	59,906	1,452	5,869	20,792	331	1,203	2,288
12-km	59,906	1,452	5,869	20,792	331	1,203	2,288
4-km	59,462	1,432	5,713	20,777	329	1,188	2,273

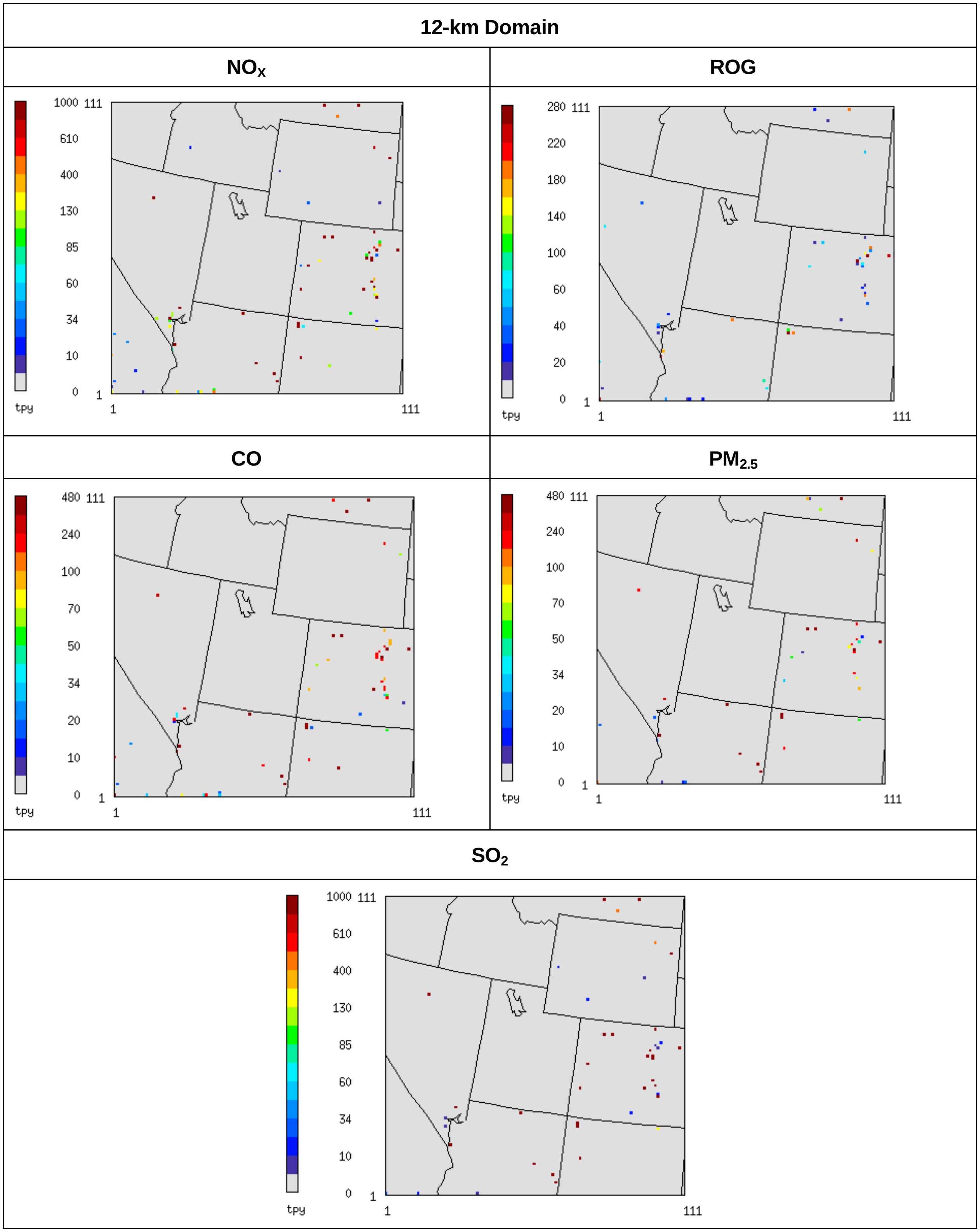
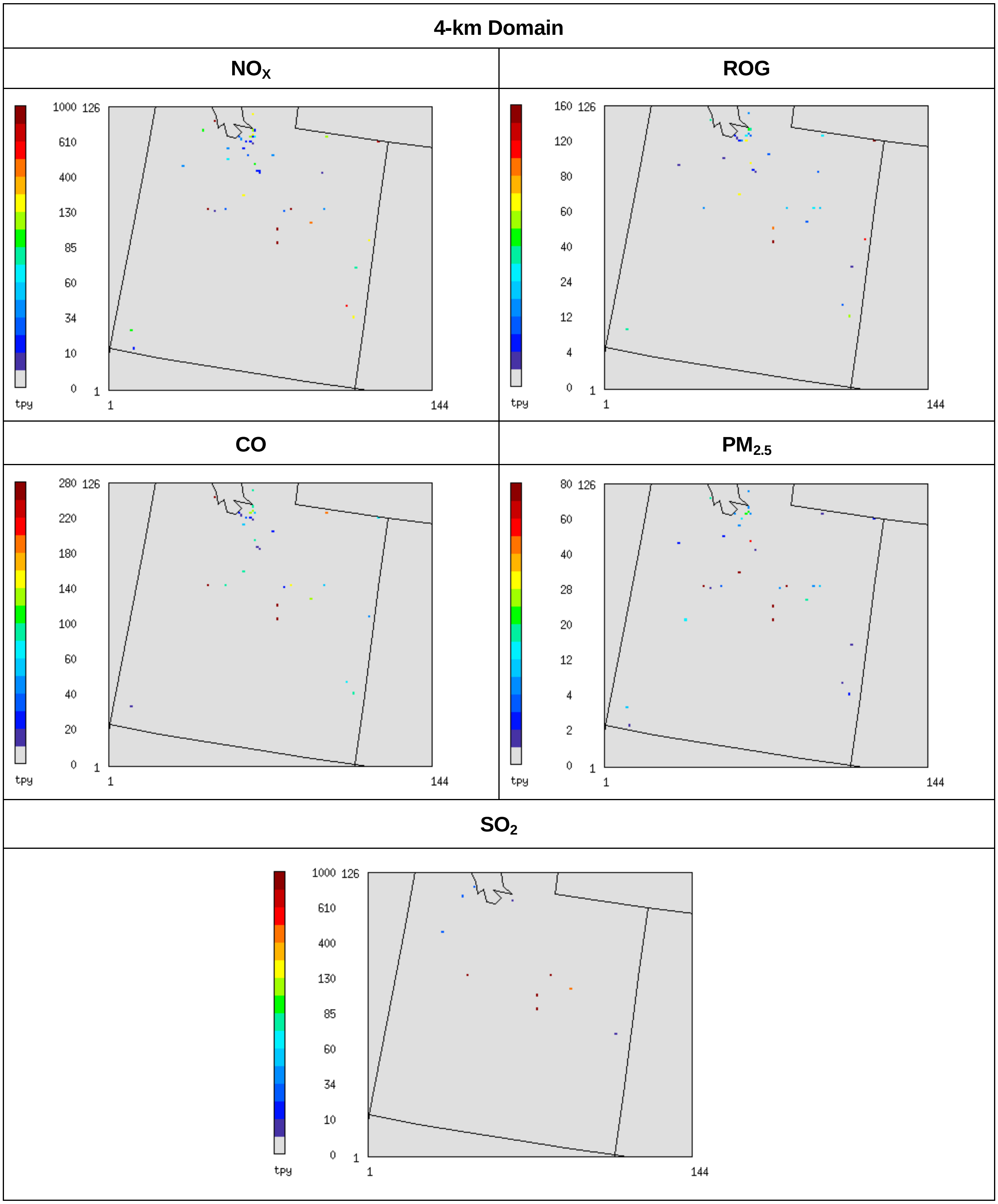


Figure 2-1 EGU Point Emissions Spatial Distribution in the 12-km Domain for Areas Outside of Utah



4-km Domain

NO_X

ROG

CO

$PM_{2.5}$

SO_2

Figure 2-2 **EGU Point Emissions Spatial Distribution in the 4-km Domain for Areas Inside of Utah**

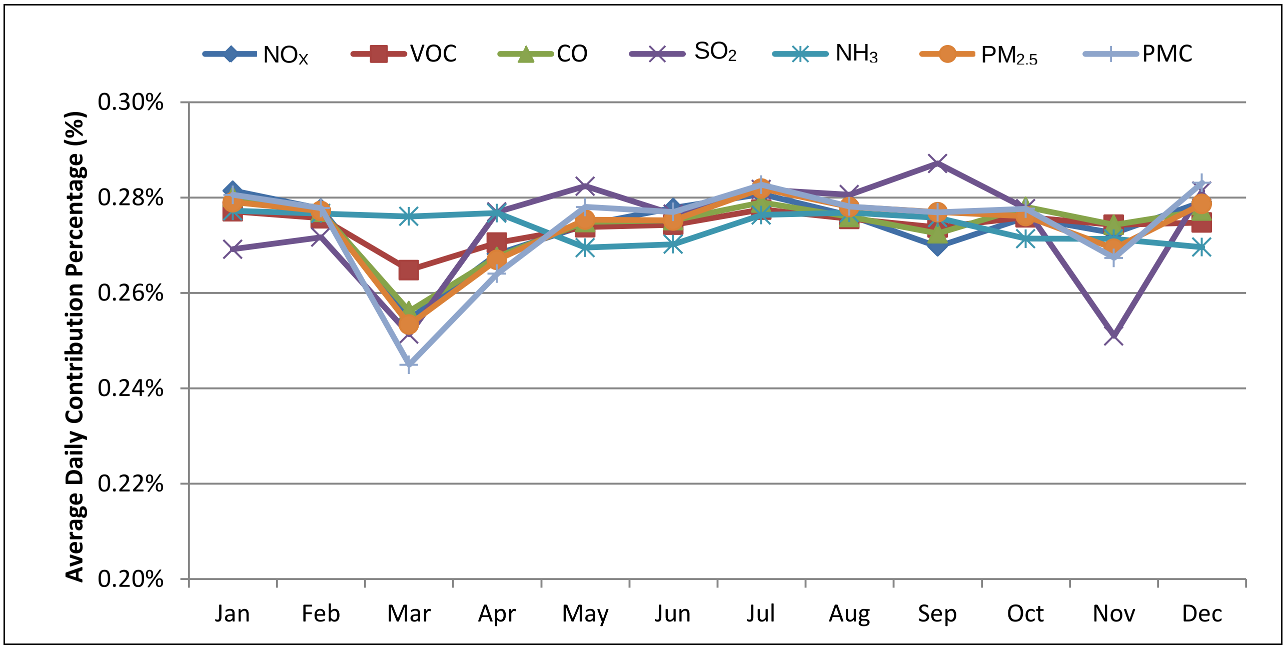


Figure 2-3 Monthly Average of Utah EGU Emissions in the 4-km Domain

2.1.2 Non-EGUs

Similar to EGU sources, the non-EGU emissions were processed separately for sources outside of Utah and inside of Utah.

2.1.2.1 Non-EGU Sources Outside of Utah

The WRAP 2002 Plan 02d and WRAP 2018 Preliminary Reasonable Progress Version B (PRP18b) model linearly interpolated to 2010 for the non-EGU point sources outside of Utah. In order to avoid double counting of emissions in other source categories, the following records were removed based on SCC and/or location. These sources were treated separately (as described elsewhere in this report) and were not linearly interpolated:

- All sources in Utah
- Oil and gas sources
- EGU point sources

Table 2-6 shows the annual emissions values processed by SMOKE for non-EGU point source outside of Utah.

Table 2-6 Non-EGU Point Source Outside of Utah Emissions Input

NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
3,376,118	1,583,669	3,944,792	3,526,817	261,006	483,727	861,436

2.1.2.2 Non-EGU Sources Inside of Utah

The 2008 Utah State Annual Emissions Inventory provided by UDAQ was used for non-EGU point sources inside of Utah. In order to avoid duplications in other source sectors, area sources and EGU sources are removed based on SCC code. While actual 2010 emissions for a specific facility could be higher or lower than 2008 emissions for a variety of reasons, such as installation of control equipment or production variations, it is assumed that the reported 2008 emissions are reasonably representative of 2010 emissions. **Table 2-7** shows the annual emission values processed by SMOKE for non-EGU point sources inside of Utah.

Table 2-7 Utah Non-EGU Point Source Emissions Input

NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
11,168	1,289	7,797	7,067	214	910	1645

2.1.2.3 SMOKE Processing

The non-EGU records do not use any day or hour-specific emissions. All non-EGU point source emissions were temporally allocated by month, day, and hour using annual emissions and SCC based allocation factors. These factors are based on the cross-reference and profile data supplied with SMOKE.

2.1.2.4 Non-EGU Emissions Summary

Table 2-8 and **Table 2-9** show the final emission totals for each modeling domain for non-EGU point sources outside of Utah and inside of Utah, respectively. Spatial plots of the 12-km EGU point sources outside of Utah are shown in **Figure 2-4**. Notice that there are several point sources showing in the state of Utah. These point sources are located in tribal land areas and therefore considered and processed as emissions outside the state of Utah. **Figure 2-5** shows the spatial plot of 4-km EGU point sources inside of Utah. The monthly average of EGU point sources in the 4-km are shown in **Figure 2-6**.

Table 2-8 Annual Non-EGU Point Emissions Outside of Utah

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	3,340,489	2,630,194	3,931,522	3,518,678	260,278	483,178	875,620
12-km	507,052	263,919	188,048	354,567	4,716	26,557	30,142
4-km	46,962	21,389	20,931	14,149	214	4,531	10,274

Table 2-9 Utah Annual Non-EGU Point Emissions

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	11,167	1,413	7,795	7,066	213	908	1,642
12-km	11,167	1,413	7,795	7,066	213	908	1,642
4-km	10,942	1,249	6,204	7,025	210	840	1,130

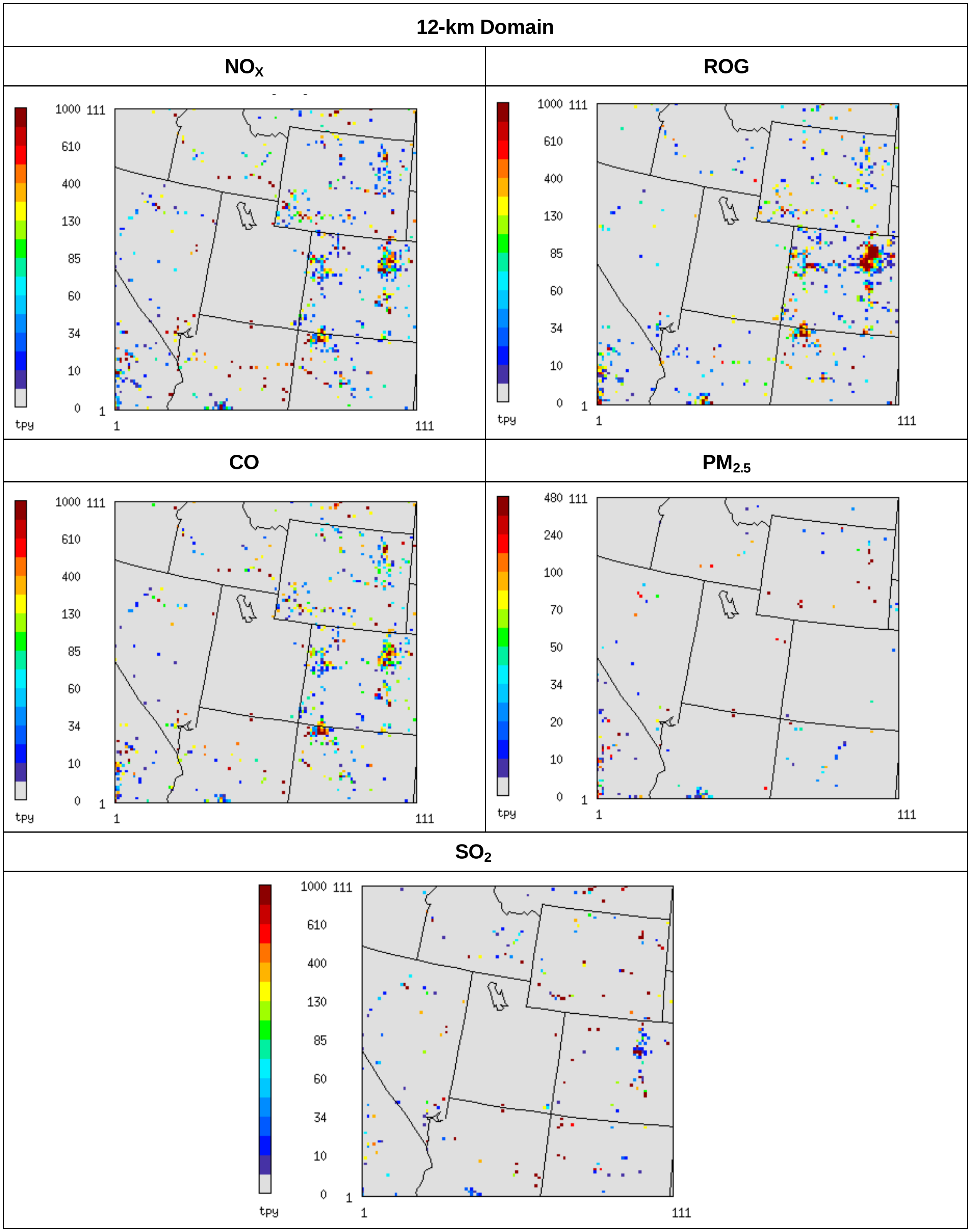
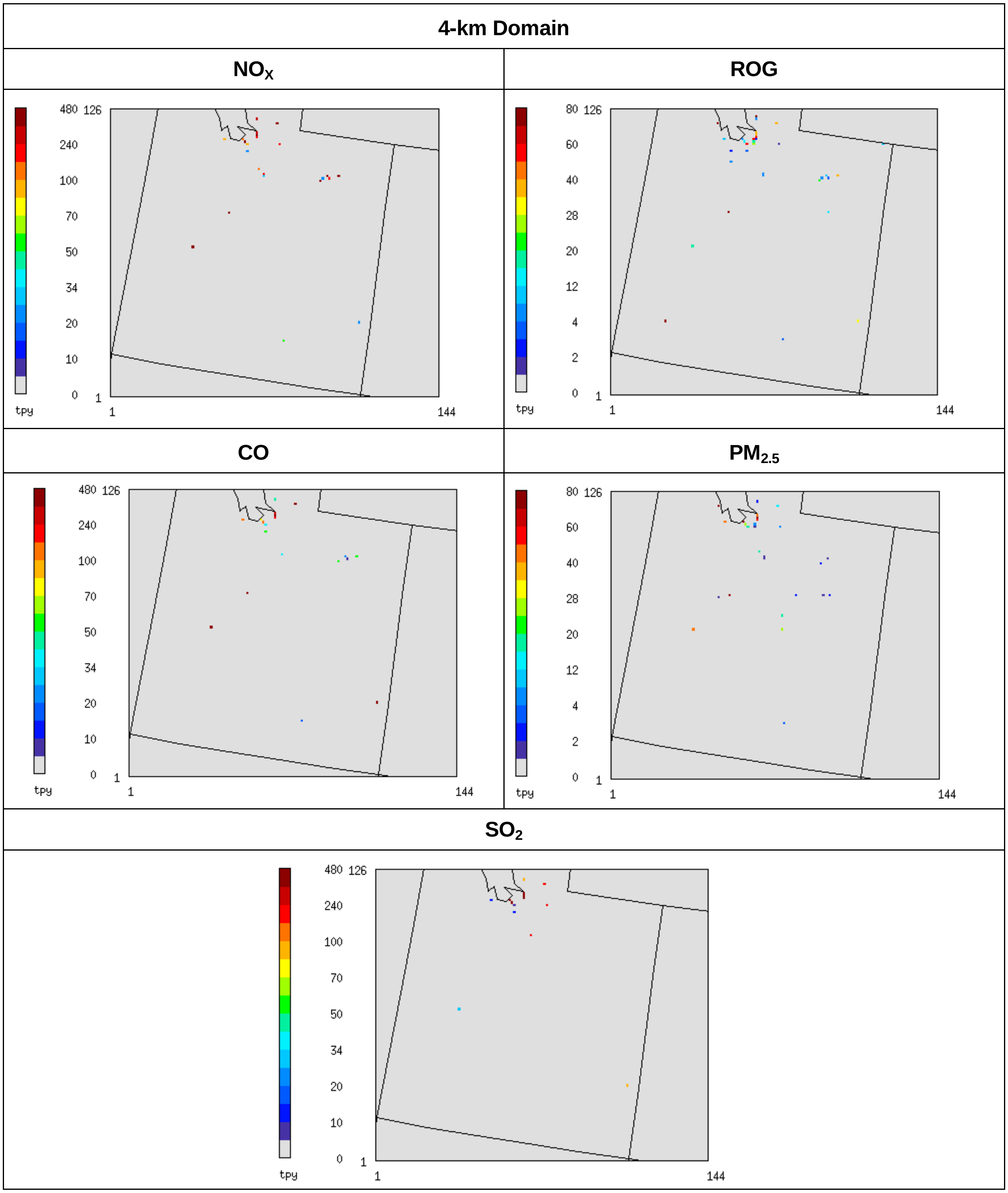


Figure 2-4 **Non-EGU Point Emissions Spatial Distribution in the 12-km Domain for Areas Outside of Utah**



4-km Domain

NO_X

ROG

CO

$PM_{2.5}$

SO_2

Figure 2-5 Non-EGU Point Emissions Spatial Distribution in the 4-km Domain for Areas Inside of Utah

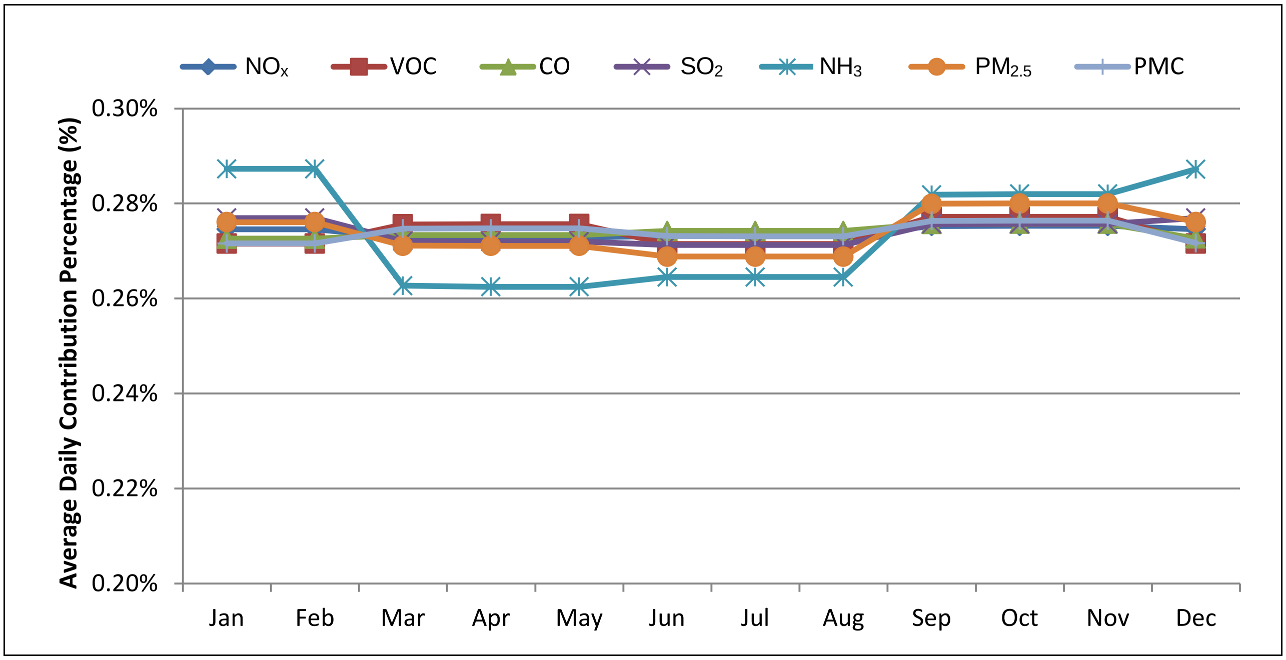


Figure 2-6 Monthly Average of Utah Non-EGU Point Emissions in the 4-km Domain

2.2 Oil and Gas

In order to ensure the best data for a given region, the point and area oil and gas emission inputs are developed from multiple data sources and processed separately.

2.2.1 Emissions Inputs

In general, the WRAP Phase III oil and gas point and area inventories are considered to be the most comprehensive sources of oil and gas emissions data. In some areas, WRAP Phase III EIs were not available in time for this project, the oil and gas emissions data sources are used in the following order of priority:

- WRAP Phase III
- Southwest Wyoming (SWWY)
- WRAP Phase II

The processing of the oil and gas emissions is described in more detail in the following sections. **Table 2-10** provides an overview of the oil and gas data sources, projection methods, and application of additional controls for each basin.

Table 2-10 Base Year Western Oil and Gas Emissions Inventory Data Sources

Basin	Data Source	Method to Project Data to Common Base Year	Additional Controls Applied
Uinta Basin	UBAQS (WRAP Phase III) for 2006	2010 emissions estimated based on the reported 2010 oil and gas activities	Yes
Denver-Julesburg Basin	UBAQS (WRAP Phase III) for 2010	NA[1]	NA[1]
South San Juan and Wind River Basins	WRAP Phase III for 2006	2010 emissions estimated based on projection data provided in WRAP Phase III reports	Yes
North San Juan Basin	WRAP Phase III for 2012	None	No
Piceance Basin	UBAQS (WRAP Phase III) for 2006 and 2012	Linear interpolation between 2006 and 2012	No
Greater Green River Basin	Southwest Wyoming 5-county 2008 EI	2010 emissions estimated based on oil and gas production	No
Powder River Basin	WRAP Phase III for 2006	None	No
Paradox Basin	WRAP Phase II 2006 and 2012	Linear interpolation between 2006 and 2012	No

[1] NA = Not Applicable.

2.2.1.1 Uinta Basin

The 2006 UBAQS (ENVIRON 2009a) model data are used as initial inputs for the Uinta Basin oil and gas area and point sources. The UBAQS data are developed from the WRAP Phase III Uinta Basin 2006 dataset and contains the required information for SMOKE processing. Emissions values from the UBAQS and WRAP Phase III dataset oil and gas sources are identical except for emissions from compressor engines. Compressor engine emissions from the UBAQS dataset are less than the final emissions from the WRAP Phase III dataset, as demonstrated in **Table 2-11**. For the purpose of this report, the Uinta Basin oil and gas inventory dataset is referred to as the WRAP Phase III dataset though this small difference in emissions exists.

Table 2-11 Compressor Engine Differences

Dataset	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
WRAP Phase III	2,207	510	2,318	0	31	31
UBAQS	2,190	506	2,284	0	30	30
Difference	17.0	4.2	34.0	0.0	0.2	0.2

While the WRAP Phase III EI is the most comprehensive dataset for Uinta Basin oil and gas activities, some oil and gas equipment are not included in the EI. To minimize data gaps, the BLM distributed an oil and gas survey to operators within the Uinta Basin. Based on the survey results, emissions for select oil and gas categories were developed. The Uinta Basin survey results and emissions calculations are described in greater detail in **Appendix A**.

Emissions Inventory Updates

Emissions for the following categories are calculated using information obtained from the survey: drilling, workover, completion, recompletion, hydraulic fracturing, and produced water ponds. **Table 2-12** shows the source category and corresponding SCC codes that were developed or modified for the Uinta Basin. Emissions factors were calculated for each source category based on information provided by operators in the survey. The emission factors and units are shown in **Table 2-13**. The annual 2010 drilling and workover emissions are calculated using the emission factors in **Table 2-13** and the 2010 spud and workovers as shown in **Table 2-14**. For the purpose of calculating drilling and workover emissions from "other wells", such as water injection or disposal wells, emissions are estimated with the emission factors for oil wells.

The fraction of wells that flare or vent flowback gas during well completion and recompletion events is calculated from survey results and presented in **Table 2-15**. The survey indicates that the majority of the flowback gas from new gas wells is captured and sold, and minimal flaring or venting activities are occurring during completion. While new oil wells tend to flare flowback gas, the total volume flared is very low. To calculate the completion and recompletion emissions, the emissions factors in **Table 2-13** are multiplied by the number of spuds or workovers (shown in **Table 2-14**) and the percent of wells that conduct flaring and venting (shown in **Table 2-15**).

Table 2-16 and **Table 2-17** show the emission totals by source category and county, respectively. Although the emission factors are developed by well type (i.e., gas or oil), the emission totals are grouped by source category (i.e., not specific to well type) for summary purposes.

When the well location latitude and longitude are available for drilling, completion, and hydraulic fracturing activities, these emissions are processed as point sources. The stack parameters are shown in **Table 2-18** for these activities. The modeled stack height for completion flares is estimated based on the heat content of the gas, the height of the bottom of the flare, and the gas flow rate. When location data for completion and hydraulic fracturing activities were unavailable, emissions were processed as a county total area source.

Table 2-19 shows the completion and hydraulic fracturing pumps emissions that are processed as area or as point sources.

Produced water evaporative ponds emissions are not included the WRAP III EI. The VOC emissions from produced water evaporation ponds were estimated for the Uinta Basin using known locations of disposal facilities, calculated throughput volumes of produced water, and representative VOC concentrations in produced waters from oil and gas operations. The methods and results for developing produced water pond emissions are provided in **Appendix B**. The maximum emissions shown in **Table B-1** were included in the Uinta Basin emissions inventory, which assumes that 100 percent of the VOC content in the produced water is emitted. Survey results (shown in **Appendix A**) indicate that approximately 10 percent of the produced water is treated via evaporation in the Uinta Basin, the majority of the water is disposed of in injection wells.

Table 2-12 Improved Emission Categories

SCC	Source Category
2310000110	Drill Rig
2310000120	Workover
2310024200	Completion-Flaring
2310020200	Completion-Venting
2310020310	Recompletion-Flaring
2310020300	Recompletion-Venting
2310121110	Hydraulic Fracturing Pumps
2310000550	Produced Water Ponds

Table 2-13 Emission Factors

Source Category	Unit	NO_X	VOC	CO	SO_2	$PM_{10}/PM_{2.5}$
Drilling-gas well	tons/spud	6.70	0.65	4.50	0.01	0.26
Drilling-oil well	tons/spud	2.38	0.24	2.07	0.00	0.11
Workover-gas well	tons/workover	0.42	0.03	0.29	0.00	0.02
Workover-oil well	tons/workover	0.57	0.06	0.31	0.00	0.02
Completion Flaring-gas well	tons/completion	0.49	0.01	2.67	0.04	0.16
Completion Venting-gas well	tons/completion	0.00	0.74	0.00	0.00	0.00
Completion Venting -oil well	tons/completion	0.00	0.02	0.00	0.00	0.00
Recompletion Flaring-gas well	tons/recompletion	0.07	0.00	0.40	0.01	0.02
Recompletion Venting-gas well	tons/recompletion	0.00	0.74	0.00	0.00	0.00
Recompletion Venting -oil well	tons/recompletion	0.00	0.02	0.00	0.00	0.00
Hydraulic fracturing pump engines	tons/hour	0.012	0.001	0.006	0.00001	0.0004

Table 2-14 2010 Spuds and Workovers by County

County	Spuds				Workovers			
	All	Oil	Gas	Other	All	Oil	Gas	Other
Carbon	60	1	57	2	88	0	88	0
Duchesne	422	419	2	1	4	24	4	0
Emery	0	0	0	0	24	0	24	0
Grand	5	1	0	4	22	0	22	0
Uintah	447	80	360	7	455	10	454	1
Total	**934**	**501**	**419**	**14**	**593**	**34**	**592**	**1**

Table 2-15 Fraction of Wells that Flare or Vent Flowback Gas

Activity	Flaring-Gas Wells	Venting-Gas Wells	Venting-Oil Wells
Recompletion	0.032	0.01	1.000
Completion	0.011	0.01	1.000

Table 2-16 2010 Uinta Basin Emissions Improvements by Source Category

Source Category	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
Drill Rig	4,037	395	2,951	5	168	168
Workover	268	22	181	0	10	10
Completion-flaring	2	0	12	0	1	1
Completion-venting	0	14	0	0	0	0
Recompletion-flaring	1	0	8	0	0	0
Recompletion-venting	0	18	0	0	0	0
Hydraulic fracturing pump engines	1,652	165	895	2	52	52
Total	**5,960**	**615**	**4,047**	**7**	**231**	**231**

Table 2-17 Uinta Basin Emissions Improvements by County for 2010

County	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
Carbon	557	57	361	1	21	21
Duchesne	1,640	174	1,219	2	68	68
Emery	18	2	11	0	1	1
Grand	30	4	22	0	1	1
Uintah	3,716	379	2,434	5	140	140
Total	**5,960**	**615**	**4,047**	**7**	**231**	**231**

Table 2-18 Stack Parameters for Drilling, Completion, and Hydraulic Fracturing Pumps Activities

Well Activity Category	Stack Height (meters)	Stack Diameter (meters)	Stack Gas Exit Temperature (K)	Stack Gas Exit Velocity (meters per second)
Drilling	6.1	0.38	700	25
Completion flaring	13.8	2.74	1273	20
Completion venting	3	0.2	298	5
Hydraulic fracturing pumps	2	0.38	700	25

Table 2-19 Completion and Hydraulic Fracturing Emission Totals by Point and Area Source Type

Source Category	Source Type	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
Completion-flaring	Point	0.49	0.01	2.67	0.04	0.16	0.16
	Area	1.77	0.02	9.65	0.14	0.57	0.57
	Total	**2.26**	**0.03**	**12.32**	**0.17**	**0.72**	**0.72**
Completion-venting	Point	0	12	0	0	0	0
	Area	0	2	0	0	0	0
	Total	**0**	**14**	**0**	**0**	**0**	**0**
Hydraulic fracturing pump engines	Point	1,273	127	690	1	40	40
	Area	378	38	205	0	12	12
	Total	**1,652**	**165**	**895**	**2**	**52**	**52**

Processing of WRAP Phase III

In the Utah Emissions Inventory Development Protocol (AECOM 2011), it was originally proposed to estimate the 2010 Uinta Basin activity from the WRAP III 2012 report. Since the Protocol was finalized, however, it was determined that actual 2010 activity data would be available for the Uinta Basin and was used for this project. **Table 2-20** shows the Uinta Basin activity data for year 2006 and 2010. The Uinta Basin oil and gas activity data are from Divisions of Oil, Gas, and Mining- Department of Natural Resources (DOGM 2012).

In general, the rate of well development between 2006 and 2010 is growing as anticipated. While the coal bed methane (CBM) well development is decreasing, other well development is increasing, including a mix of conventional oil and gas and unconventional oil and shale gas. Oil production in 2010 has increased 50 percent relative to 2006 production. Gas production between 2006 and 2010 is growing as anticipated. While the number of new wells drilled (spud count) has declined slightly since 2006, this trend is not anticipated to continue (see Section 4.1 for more information regarding future development in the Uinta Basin).

Table 2-20 Uinta Basin Oil and Gas Activity Data[1]

Year	Well Count				Oil Production (bbl)	Gas Production (Mscf)	Spud Counts
	CBM	Natural Gas	Oil	Total			
2006	775	3,130	1,480	5,358	11,518,517	331,482,705	1,036
2010	805	5,052	2,710	8,567	17,691,487	418,524,132	934

[1] DOGM (2012)

bbl = barrels

Mscf = million standard cubic feet

The 2010 base year emissions are estimated by multiplying the 2006 WRAP III emissions by the change in oil and gas activity in each of the five counties in the Uinta Basin, as shown in **Equation 1**. **Table 2-21** shows the ratio of 2010 activity to 2006 activity for each county. In general, all metrics increase between 2006 and 2010, with a few notable exceptions. The rate of development in Emery and Grand counties has slowed, as shown by the small number of new spud counts. This has resulted in declining production of natural gas. In general, Uintah and Duchesne counties have the most emissions in the Uinta Basin; therefore, ratios presented in **Table 2-21** for Uintah and Duchesne counties have a larger impact on the total emissions inventory than other counties.

The activity surrogates used to estimate the change in emissions between 2006 and 2010 are shown in **Table 2-22** for all oil and gas equipment with corresponding WRAP III 2006 emissions. The total 2006 county emissions for each of these SCCs is multiplied by the surrogates shown in **Table 2-21** to estimate the 2010 emissions for each SCC in each county.

In addition, federal, state, and local regulations restricting air emissions and requiring application of control technologies were assessed to determine the likely reductions in 2010 emissions for each equipment type. It was determined that the controls applied between 2006 and 2012 as part of the WRAP III (Environ 2009e) were appropriate to apply to the 2006 to 2010 emissions. **Table 2-23** shows the multiplicative control factor used for each pollutant and equipment type in the Uinta Basin. The control factors were developed based on the application of the New Source Performance Standards to various engine types. Control factors are applied as shown in **Equation 1**.

Equation 1 Calculation of 2010 Emissions from 2006 Emissions

$$\boxed{E_{2010CountySCC} = E_{2006CountySCC}\ x\ Ratio_{CountySCC}\ x\ CF_{SCC}}$$

Where:

$E_{2010CountySCC}$ = 2010 Emissions for a specific county and equipment type (tpy)

$E_{2006CountySCC}$ = 2006 Emissions for a specific county and equipment type (tpy)

$Ratio_{CountySCC}$ = Ratio of 2010 activity to 2006 activity for a specific county and equipment type (shown in **Table 2-21**)

CF_{SCC} = Multiplicative Control Factor for a specific equipment type (shown in **Table 2-23**)

Table 2-21 Ratio of 2010 to 2006 Activity by County and Activity Surrogate

Activity Surrogate	Carbon	Duchesne	Emery	Grand	Uintah
Total Gas Production	1.01	1.47	0.89	0.65	1.39
Total Well Count	1.28	2.02	1.14	1.02	1.61
Spud Count	1.02	1.52	0.00	0.19	0.69
Oil Well Oil Production	1.66	1.70	1.51	0.93	1.33
Non-CBM Well Count	3.01	2.02	1.74	1.02	1.61

Table 2-22 Activity Surrogate for Each Emissions Type

Source Category	SCC	Activity Surrogate
Crude oil truck loading	2310010100	Oil Well Oil Production
Oil tanks-flashing &standing	2310010200	Oil Well Oil Production
natural gas, dehydrators	2310020100	Total Gas Production
natural gas, venting-blowdowns	2310020400	Total Gas Production
natural gas, venting-compressor startup	2310020500	Total Gas Production
natural gas, venting-compressor shutdown	2310020600	Total Gas Production
natural gas, fugitives	2310020700	Total Well Count
natural gas, pneumatic devices	2310020800	Total Well Count
natural gas, pneumatic pumps	2310020900	Non-CBM Well Count
CBM, dehydrators	2310023100	Total Gas Production
CBM, venting- initial completions	2310023200	Spud Count
CBM, venting- recompletions	2310023300	Spud Count
CBM, venting- blowdowns	2310023400	Total Gas Production
CBM, venting-compressor startup	2310023500	Total Gas Production
CBM, venting-compressor shutdown	2310023600	Total Gas Production
CBM, fugitives	2310023700	Total Well Count
CBM, Pneumatic devices	2310023800	Total Well Count
natural gas, heaters	2310024100	Total Well Count
natural gas, condensate tank flaring	2310024300	Total Gas Production
natural gas, dehydrator flaring	2310024400	Total Gas Production
natural gas, compressor engines	2310025100	Total Gas Production
natural gas, miscellaneous engines	2310025200	Total Well Count
natural gas, artificial lift	2310025300	Oil Well Oil Production
natural gas liquids, gas plant truck loading	2310030100	Total Gas Production
natural gas liquids, truck loading	2310030200	Total Gas Production
natural gas liquid, tanks -flash & standing	2310030300	Total Gas Production

Table 2-23 Control Factors by Equipment Type[1]

Regulation	SCC	Source Category	Multiplicative Control Factor				
			NO_X	VOC	CO	SO_2	PM
New Source Performance Standards (NSPS)	2310025200	Miscellaneous Engines	74%	97%	206%	-	-
	2310025100	Compressor Engines	95%	90%	120%	-	-
	2310025300	Artificial Lift	97%	98%	955%	-	-
	31000000	UTDEQ Permitted Sources	89%	450%	153%	-	-
	31000000	EPA Permitted Sources	84%	116%	-	-	-

[1] From Environ 2009e

The estimated 2010 total oil and gas emissions for the five counties in the Uinta Basin are compared to the 2006 WRAP Phase III EI in **Table 2-24**. **Table 2-25** shows the estimated emissions for each county in the Uinta Basin. As described above, Uintah and Duchesne counties have the most emissions, and together account for approximately 90 percent of the total emissions in 2010.

As shown in **Table 2-25**, all of these metrics increase in all areas of the Uinta Basin, except for Emery and Grand counties, which have a relatively small amount of emissions. Therefore, 2010 VOC emissions show a substantial increase relative to 2006 levels in other counties. The CO emissions are mostly a function of oil production equipment, and therefore CO increases in all counties except Grand County.

Table 2-24 Uinta Basin Emissions Inventory for 2006 and 2010

Dataset	NO_X (tpy)	VOC (tpy)	CO (tpy)	Oxides of Sulfur (SO_X) (tpy)	PM (tpy)	
					$PM_{2.5}$	PM_{10}
2006	13,093	71,546	8,727	396	623	
2010	16,529	109,705	48,875	32	601	601

Table 2-25 2010 Uinta Basin Emissions Inventory by County

County	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
Carbon	1,300	3,154	1,249	8	46	46
Duchesne	5,517	35,417	29,925	7	217	217
Emery	167	537	195	0	6	6
Grand	355	2,358	505	1	10	10
Uintah	9,190	68,239	17,001	17	322	322
Total	**16,529**	**109,705**	**48,875**	**32**	**601**	**601**

2.2.1.1.1 Temporalization of Point Source Emissions

Hourly point source emissions files were developed for the drilling, completion, and hydraulic fracturing emissions based on information provided by survey respondents and the Utah Division of Oil, Gas, and Mining – Department of Natural Resources (DOGM).

When temporal information was provided by survey respondents, the drilling and hydraulic fracturing pump emissions are spread over the drilling duration from the drilling start date to drilling end date. The completion venting and flaring emissions are spread over the completion duration from completion start date to completion end date.

When start and end dates were not provided from survey respondents, the hourly drilling and completion emissions are calculated based on the most common drilling and completion duration from the survey respondents (shown in **Table 2-26**) coupled with the spud and completion dates from the DOGM database. Several wells had no available temporal information. For these wells the drilling and completion emissions were spread evenly throughout the year.

Table 2-26 Drilling and Completion Duration

Mode	Gas Wells (days)	Oil Wells (days)
Drilling	8	5
Completion	2	4

2.2.1.1.2 Final Uinta Basin Emissions Input

Table 2-27 shows final emissions processed by SMOKE for all oil and gas sources in the Uinta basin.

Table 2-27 2010 Uinta Basin Total Oil and Gas Emission Inputs

Source	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
Area	8,615	105,443	43,319	19	353	353
Point	7,914	4,263	5,556	13	248	248
Total	16,529	109,705	48,875	32	601	601

2.2.1.2 Other WRAP Phase III Basins

As shown in **Table 2-10**, emissions from oil and gas basins outside of the Uinta Basin are from a variety of data sources depending on the best available data at the time. Oil and gas area emissions from the 2006 WRAP Phase III reports are used for South San Juan, Powder River, and Wind River Basins (see **Table 2-29** for list of references). The 2012 WRAP Phase III report is for the North San Juan Basin. Oil and gas non-point emissions obtained from the 2010 Uintah Basin Air Quality Study (UBAQS) modeling files are used for the Denver-Julesburg Basins (ENVIRON 2009a) The Piceance Basin used the 2006 and 2012 UBAQS model files (ENVIRON 2009a). All emissions are treated as area sources for the following basins: South San Juan, North San Juan, Wind River, and Powder River Basins.

Emissions from the WRAP Phase III are grown to 2010. As shown in **Table 2-29,** linear interpolation between the 2006 and 2012 data is used for most of the basins. The South San Juan and Wind River Basins use projected growth information from their respective WRAP Phase III reports to develop growth factors for 2010. This methodology is consistent with the procedure used in the WRAP Phase III 2012 reports. The same control factors utilized for the WRAP Phase III 2012 emissions are used for generating the 2010 emissions. For Powder River Basin, the 2006 emission inventory is used as a surrogate for 2010 since the WRAP Phase III 2012 emission inventory had not been released at the time of data processing. The WRAP Phase III 2012 emission inventory is used for the North San Juan Basin. This is an acceptable approach due to downwind distance between the Powder River and North San Juan basins and the Uinta Basin study area.

The $PM_{2.5}$ emissions are estimated from PM_{10} using scaling factors shown in **Table 2-28** for the South San Juan, North San Juan, Powder River and Wind River basins. **Table 2-30** shows the 2010 total emissions for each WRAP Phase III oil and gas basin.

Table 2-28 Scaling Factors for $PM_{2.5}$

SCC code	Scaling Factor
2311000070[1]	0.2
All other SCC Codes	1.0

[1] AP-42 13.2.2

Table 2-29 WRAP Phase III Oil and Gas Basins Emissions Data Source

Basin	Source	Growth to 2008 Method
South San Juan	Phase III, 2006 (ENVIRON 2009b, ENVIRON 2009c)	Growth factors using WRAP report
Denver-Julesburg	UBAQ, 2010 (ENVIRON 2009a)	None required
Piceance	UBAQ, 2006 and 2012 (ENVIRON 2009a)	Linear interpolation
North San Juan	Phase III, 2012(ENVIRON 2009d)	None, 2012 values
Powder River	Phase III, 2006 (ENVIRON 2011)	None, 2006 values
Wind River	Phase III, 2006 and 2012 (ENVIRON 2010a, ENVIRON 2010b)	Linear interpolation

Table 2-30 WRAP Phase III 2010 Oil and Gas Basins Emissions Input

Basin	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)	NH_3 (tpy)
South San Juan	42,704	52,964	25,017	132	321	321	0
Denver-Julesburg	24,408	88,989	15,412	131	759	771	0
Piceance	10,762	23,126	7,751	155	572	584	0
North San Juan	4,195	1,598	4,661	0.34	47	47	0
Powder River	21,086	14,367	12,873	609	681	681	0
Wind River	1,652	2,633	2,430	1,432	35	35	0
Total	**104,807**	**183,677**	**68,144**	**2,459**	**2,415**	**2,439**	**0**

2.2.1.3 Southwest Wyoming

Oil and gas emissions in SWWY are from the Southwest Wyoming 5-county EI for year 2008 (referred to as the SWWY dataset) (BLM 2011). The inventory consists of emissions categorized by well activity for the following Wyoming counties: Carbon, Lincoln, Sublette, Sweetwater, and Uintah.

Drill rig emissions are projected to 2010 using 2010 actual count of well completions obtained from the Wyoming Oil and Gas Conservation Commission (WOGCC). The production and construction traffic, heaters, and production emission are not projected and remain at their 2008 levels. The emissions are summed together by activity type and county. The emissions for each activity are assigned to an appropriate SCC as shown in **Table 2-31**. For natural gas heater emissions, SO_2, $PM_{2.5}$, and PM_{10} are estimated from NO_X using the scaling factors in **Table 2-32**. The 2010 emissions for SWWY are shown in **Table 2-33**.

Table 2-31 Source Classification Code and Corresponding Well Activity Category

Emissions Type	SCC Code	SCC Description
Production and Construction Traffic	2311000070	Construction Traffic
Drill Rig (including well completions)	2310000220	Drill Rigs
Heater	31000404	Natural Gas Heaters
Well VOC	31088801	Oil and Gas Exploration and Production Fugitives

Table 2-32 Emission Factors for Natural Gas Heaters

Pollutant	Emission Factor[1] (lb/MMscf)	Scaling Factor	
NO_X	100	-	-
PM_{10}	7.6	PM_{10}/NO_X	0.076
$PM_{2.5}$	7.6	$PM_{2.5}/NO_X$	0.076
SO_2	0.6	SO_2/NO_X	0.006

[1] from AP-42 1.4

MMscf = million standard cubic feet

Table 2-33 SWWY Dataset Emissions

NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
3,593	157,207	251	1,458	216	245

2.2.1.4 WRAP II

The 2006 and 2012 WRAP Phase II emission files are used as initial inputs for the oil and gas point and area sources in the remaining oil and gas basins.

Duplicate records were consolidated and emissions from counties within the WRAP III basins and within SSWY basins were removed. A linear interpolation between the 2006 and 2012 model files was done to estimate 2010 emissions. shows the estimated 2010 emission values for WRAP Phase II Basins.

Table 2-34 WRAP Phase II Emissions

Basin	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
Paradox Basin	2,287	3,894	1,082	108	1	2
North-central Montana Basin	8,557	2,600	2,064	40	0	0
Williston Basin	23,175	22,003	5,616	3,657	5	108
Big Horn Basin	4,149	12,112	1,498	2,534	0	0
Not assigned to basin	113,093	126,865	53,371	18,046	499	1,460
Total	**151,262**	**167,474**	**63,631**	**24,384**	**506**	**1,570**

2.2.2 SMOKE Processing

2.2.2.1 Spatial Allocation

For sources modeled as area sources, SMOKE allocates the emissions to grid cells using a gridding surrogate. The SCC of the emission records determines which gridding surrogate is used. After reviewing the default gridding surrogates used for oil and gas area sources, it was determined the defaults do not allocate the oil and gas emissions to proper locations. Therefore, gridding surrogates were developed based on oil and gas well location in states where there is significant oil and gas activity. Using Geographic Information System (GIS), seven gridding surrogates were developed: all wells, gas wells, oil wells, conventional wells, CBNG wells, injection wells, and spuds. The well information is gathered for each state based on the data sources shown in **Table 2-35**. For the Colorado database, the well type is not specified. A gas production to oil production ratio of 15 is used to identify the well type based on the recommendation of the Colorado Oil and Gas Conservation Commission. For each domain, the seven gridding surrogates were calculated for each grid cell based on the percentage of the county total well activity category. The oil and gas area source emissions were then allocated to the new gridding surrogates by SCC code.

Table 2-35 Source of Oil and Gas Well Location Data by State

State	Source Description
Wyoming	Wyoming Oil and Gas Conservation Commission (WOGCC 2012)
Montana	Montana Board of Oil and Gas Conservation (MBOGC 2012)
Utah	Divisions of Oil, Gas, and Mining- Department of Natural Resources (DOGM 2012)
Colorado	Colorado Oil and Gas Conservation Commission (COGCC 2012)
North Dakota	Department of Mineral Resources, Oil, and Gas Division (NDOGD 2012)
South Dakota	Department of Environment and Natural Resources (SDENR 2012)

2.2.2.2 Temporal Allocation

The temporalization of Uinta Basin drilling, completion, and hydraulic fracturing pump was described in Section 2.2.1 for point sources. All other oil and gas equipment used the default temporal allocation profiles from the USEPA.

2.2.2.3 Chemical Speciation Profiles

Chemical speciation profiles were developed for oil and gas production activities in the Uinta Basin. The description of how the chemical profiles were developed as well as the final CB-05 compatible chemical profiles used by SMOKE is provided in **Appendix C**. All other oil and gas emissions sources used the default SMOKE speciation profiles.

2.2.3 Oil and Gas Emissions Summary

Table 2-36 and **Table 2-37** show the emission totals for of the oil and gas point and area source emissions, respectively. Spatial plots of the oil and gas sources are shown in **Figure 2-7**. The monthly average of the oil and gas point sources in the Uinta basin is shown in **Figure 2-8**.

Table 2-36 Oil and Gas Point Source Emissions

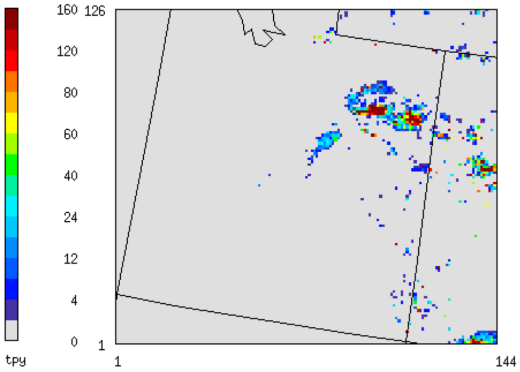
Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	102,654	141,107	69,359	187	22,862	1,417	1,633
12-km	45,091	66,546	28,489	184	2,703	508	548
4-km	16,796	27,401	12,427	68	135	349	359

Table 2-37 Oil and Gas Area Source Emissions

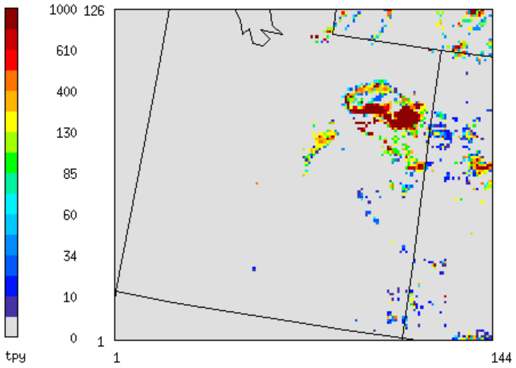
Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	151,466	1,395,325	131,007	3,642	0	2,766	2,790
12-km	107,132	1,214,025	124,717	2,675	0	2,534	2,555
4-km	16,121	694,715	73,082	112	0	807	815

4-km Domain

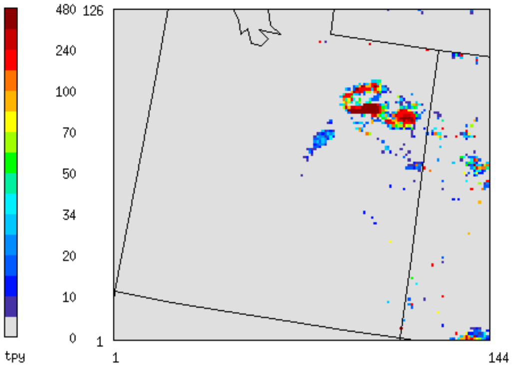
NO_X



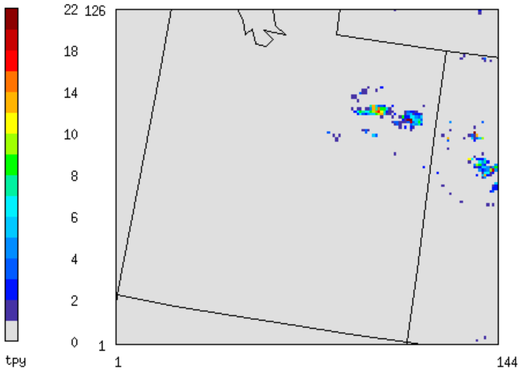
ROG



CO



$PM_{2.5}$



SO_2

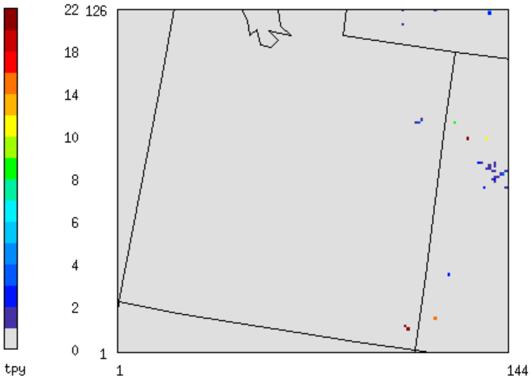


Figure 2-7 Oil and Gas Spatial Distribution in the 4-km Domain for Areas Inside of Utah

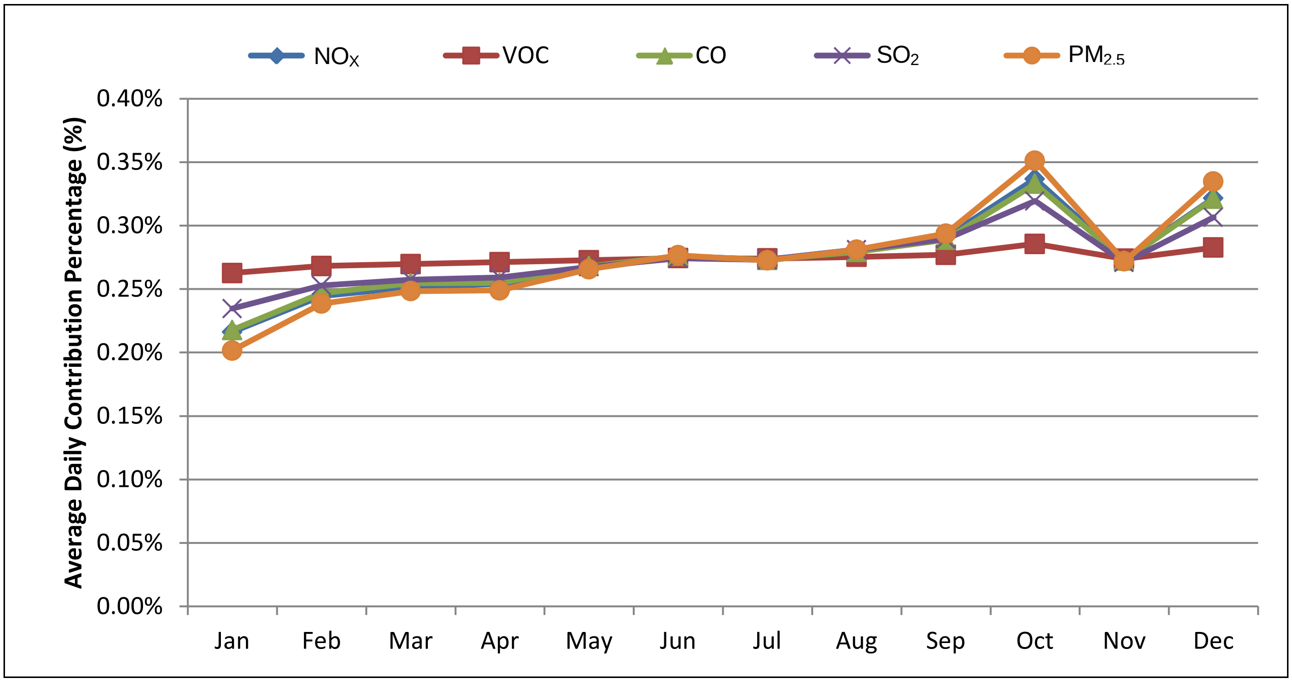


Figure 2-8 Monthly Average of Point Oil and Gas Emissions in the Uinta Basin

2.3 Area Sources

Stationary area emissions processing is described in detail in this section while other emissions sources that may be defined as area sources, such as road dust, fugitive dust, and ammonia emissions, are provided in separate sections of this report.

2.3.1 Emission Inputs

Stationary areas sources are processed separately for areas outside of Utah and inside of Utah.

2.3.1.1 Area Sources Outside of Utah

The WRAP 2002 Plan 02d and WRAP 2018 Preliminary Reasonable Progress Version B (PRP18b) model files in are used as initial inputs for the area sources outside of Utah. In order to avoid double counting emissions the following records are removed: biogenic, on-road source, agricultural, fugitive dust, and sources in Utah.

The 2010 emissions were estimate by performing a linear interpolation between the 2002 dataset and the 2018 dataset. Care was taken to ensure all sources present in the 2002 and 2018 datasets are included, as some sources were not included either the 2002 or the 2018 inventories. **Table 2-38** shows the annual total emissions processed by SMOKE for area sources outside of Utah.

Table 2-38 Area Source Emissions Input Outside of Utah

NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
1,641,965	7,533,055	4,997,139	1,185,781	157,557	796,626	969,811

2.3.1.2 Utah Area Sources

The UDAQ 2010 Area Source Emissions Inventory is used as initial input for the Utah's area source emissions. Agricultural and fugitive dust sources are removed from the inventory and processed separately to avoid double counting of emissions. **Table 2-39** shows the annual total emissions processed by SMOKE for area sources inside of Utah.

Table 2-39 Utah Area Source Emissions Input

NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
12,044	833,300	256,140	1,374	196,013	17,195	33,272

2.3.2 SMOKE Processing

All area source emissions are temporally allocated by month, day, and hour using annual emissions and SCC-based allocation factors. Area sources were spatially allocated in the domain based on SCC-based spatial allocation factor files.

2.3.3 Area Emissions Summary

Table 2-40 and **Table 2-41** show the emission totals for each dataset by modeling domain. Spatial plots of the area sources are shown in **Figure 2-9** and **Figure 2-10**.

Table 2-40 Annual Area Source Emissions Outside of Utah

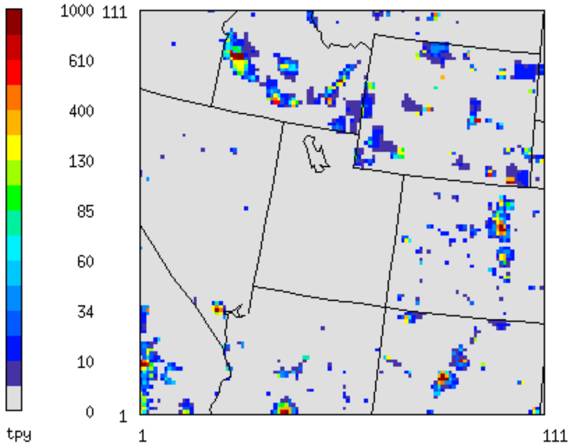
Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	1,610,217	12,301,406	4,970,557	1,151,419	156,970	791,205	959,449
12-km	101,033	585,263	276,688	47,029	8,697	45,557	52,478
4-km	1,362	11,306	12,454	623	31	1,818	1,909

Table 2-41 Annual Utah Area Source Emissions

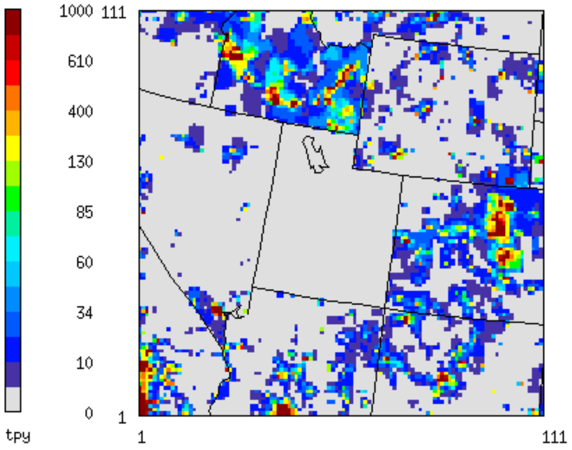
Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	10,719	772,239	263,834	1,286	196,991	17,874	34,919
12-km	10,719	772,239	263,834	1,286	196,990	17,874	34,919
4-km	9,233	710,688	228,494	1,196	170,662	14,626	28,325

12-km Domain

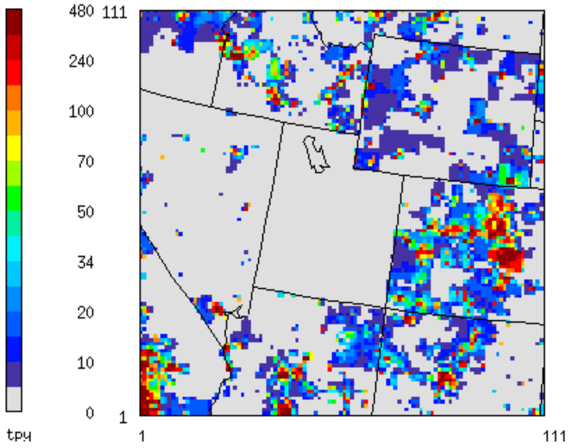
NO_X



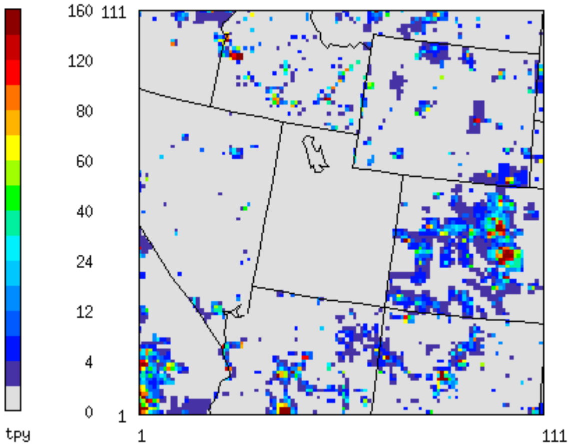
ROG



CO



$PM_{2.5}$



SO_2

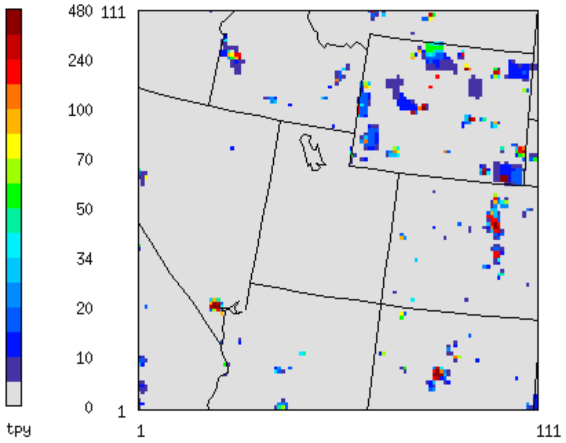


Figure 2-9 Area Emissions Spatial Distribution in the 12-km Domain for Areas Outside of Utah

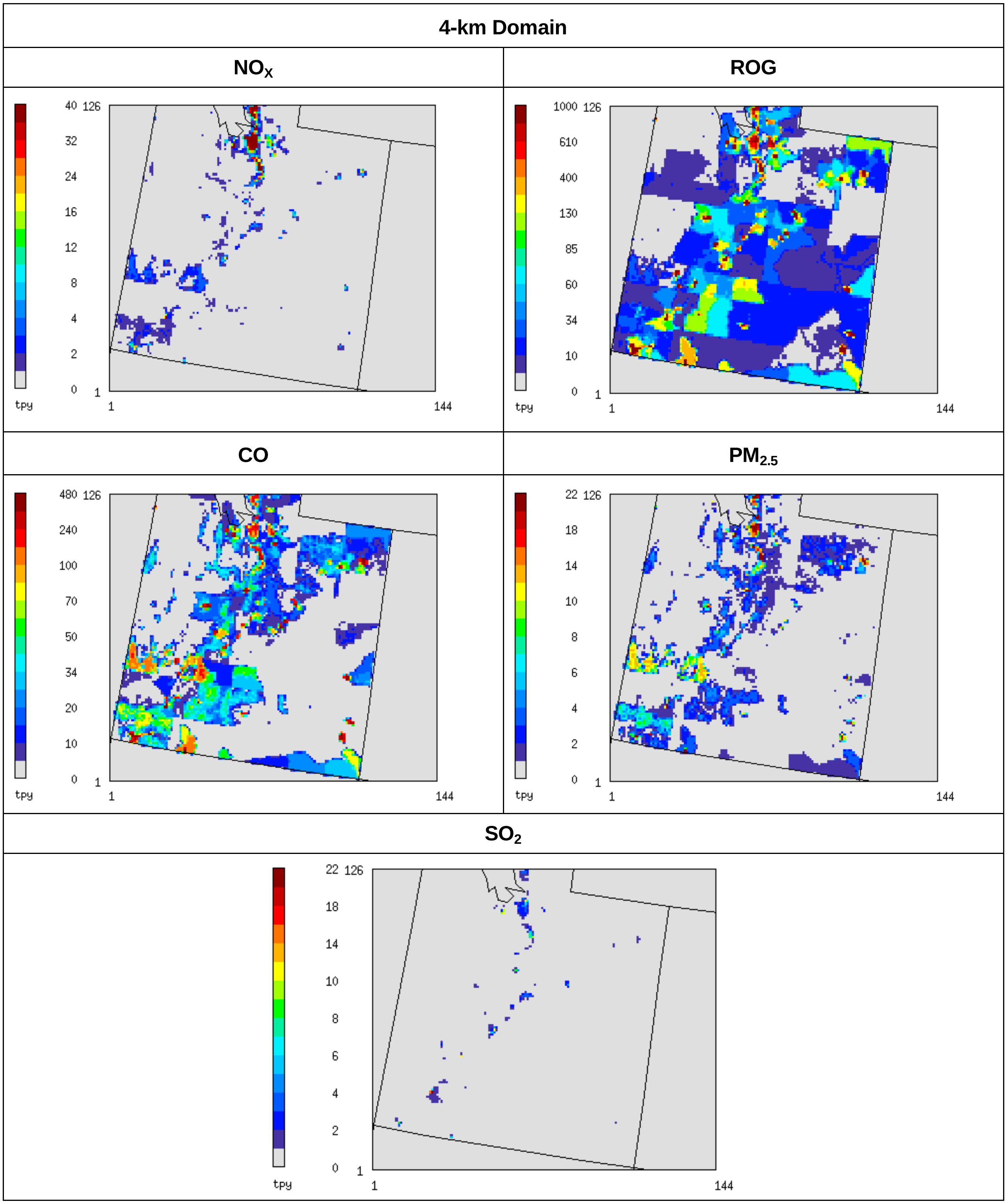


Figure 2-10 Area Emissions Spatial Distribution in the 4-km Domain for Areas Inside of Utah

2.4 Non-Road

The non-road source inventories consist of annual, seasonal, and monthly inventories for the U.S. These inventories represent emissions from recreational vehicles, locomotives, aircraft, and commercial shipping.

2.4.1 Emissions Inputs

Non-road sources outside of Utah and inside of Utah are processed separately due to different emission inventory dataset sources.

2.4.1.1 Non-Road Sources Outside of Utah

The WRAP 2002 Plan 02d and WRAP 2018 Preliminary Reasonable Progress Version B (PRP18b) model files in are used as initial inputs for the non-road sources outside of Utah. Utah state emissions were extracted from the WRAP inventory files. To estimate 2010 emissions, the WRAP emission inventories were linearly interpolated between year 2002 and 2018 inventories. Paved and unpaved road dust emissions associated with non-road sources in WRAP states are not included in the non-road inventory, instead these emissions are processed as part of the road dust source sector. **Table 2-42** shows the annual emissions processed by SMOKE for non-road sources outside of Utah.

Table 2-42 Non-Road Source Emissions Input Outside of Utah

NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
2,517,348	2,606,832	23,336,883	180,069	3,861	168,409	182,757

2.4.1.2 Utah Non-Road Sources

The UDAQ 2010 Non-Road Emissions Inventory is used as initial input for Utah's non-road emissions. Care is taken to remove emissions in this sector that are quantified elsewhere in the emissions inventory to prevent double counting. Some examples of non-road engines that are included in other source categories include drill rig engines and construction equipment. **Table 2-43** shows the annual emissions processed by SMOKE for non-road sources inside Utah.

Table 2-43 Utah Non-Road Source Emissions Input

NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
13,498	23,711	143,279	298	0	1,501	1,585

2.4.2 SMOKE Processing

To facilitate the correct application of temporal profiles, the non-road sources are split into two categories for processing: annual and monthly/seasonal. **Table 2-44** summarizes the non-road equipment that is contained within each of the inventory types. Some regions of the modeling domain, such as the WRAP, have equipment in both the annual and monthly sectors.

Table 2-44 Non-Road mobile inventories for U.S.

Annual Inventories	Monthly/Seasonal Inventories
• WRAP* locomotives • VISTAS • CENRAP • MWRPO • MANE-VU • Utah State Emissions	• WRAP* (seasonal) • WRAP* aircraft (seasonal) • CENRAP (monthly) • MRPO (monthly)

* WRAP states excluding Utah

The monthly and seasonal inventories are modeled with flat monthly temporal profiles so as not to modify the temporal variation of the raw emissions. Standard USEPA monthly temporal profiles are applied to the annual inventories. Both sets of non-road inventories use common weekly and diurnal profiles. The UDAQ provided their non-road emission inventory along with associated profiles.

2.4.3 Non-Road Emissions Summary

Table 2-45 and **Table 2-46** show the final emission totals for each modeling domain. Spatial plots are shown in **Figure 2-11** and **Figure 2-12. Figure 2-13** shows the monthly temporal trend in the 4-km domain.

Table 2-45 Annual Non-Road Emissions Outside of Utah (Annual plus Monthly/Seasonal)

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	2,514,833	2,604,228	23,313,569	179,890	3,857	168,241	182,574
12-km	206,000	93,845	956,355	7,535	281	203	223
4-km	7,448	2,590	22,944	281	7	0	0

Table 2-46 Annual Utah Non-Road Emissions

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	13,371	21,619	143,165	289	0	1,459	1,536
12-km	13,371	21,619	143,165	289	0	1,459	1,536
4-km	11,613	17,586	124,064	257	0	1,258	1,324

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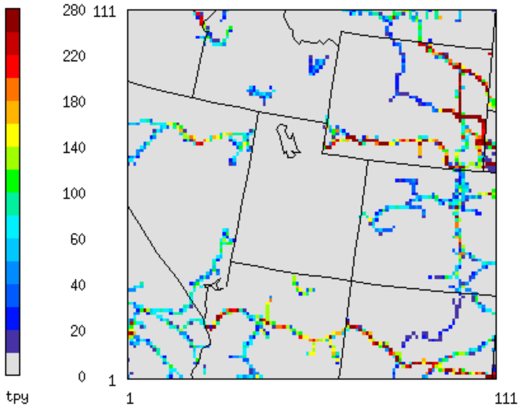
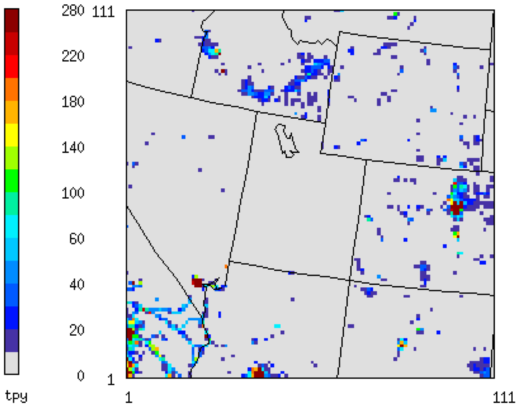
<tr><td>NO_X</td><td>
</td><td>
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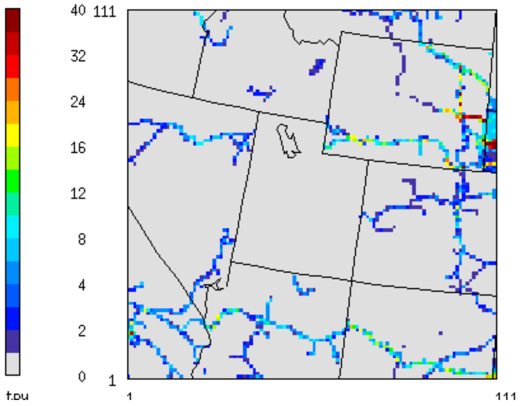
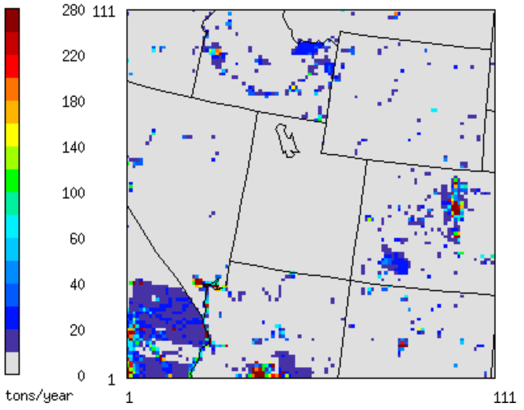
<tr><td>ROG</td><td>
</td><td>
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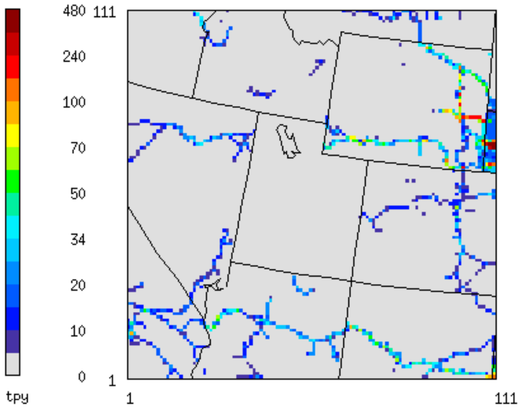
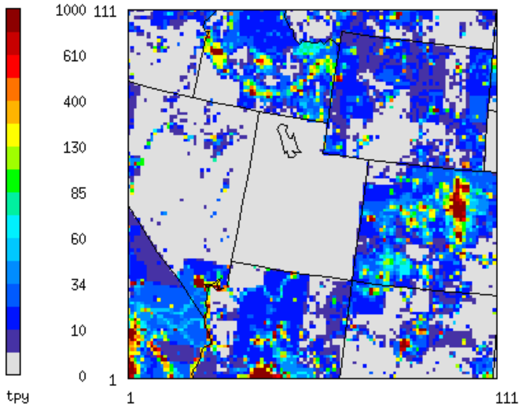
<tr><td>CO</td><td>
</td><td>
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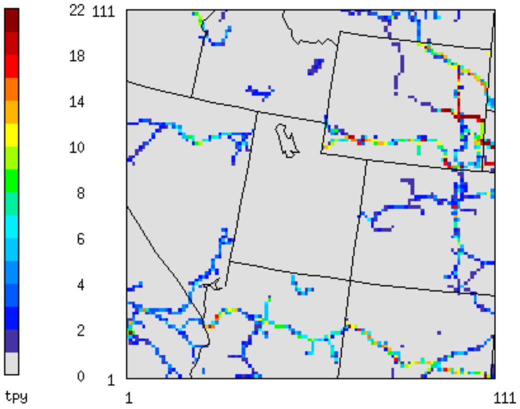
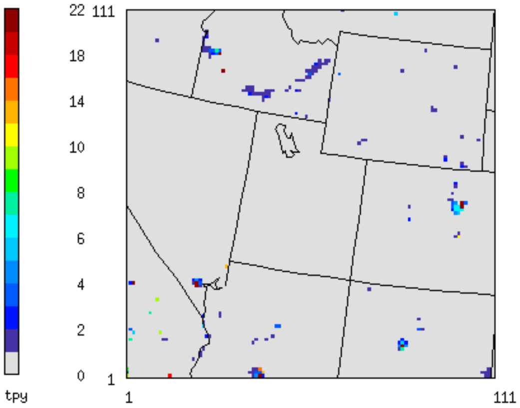
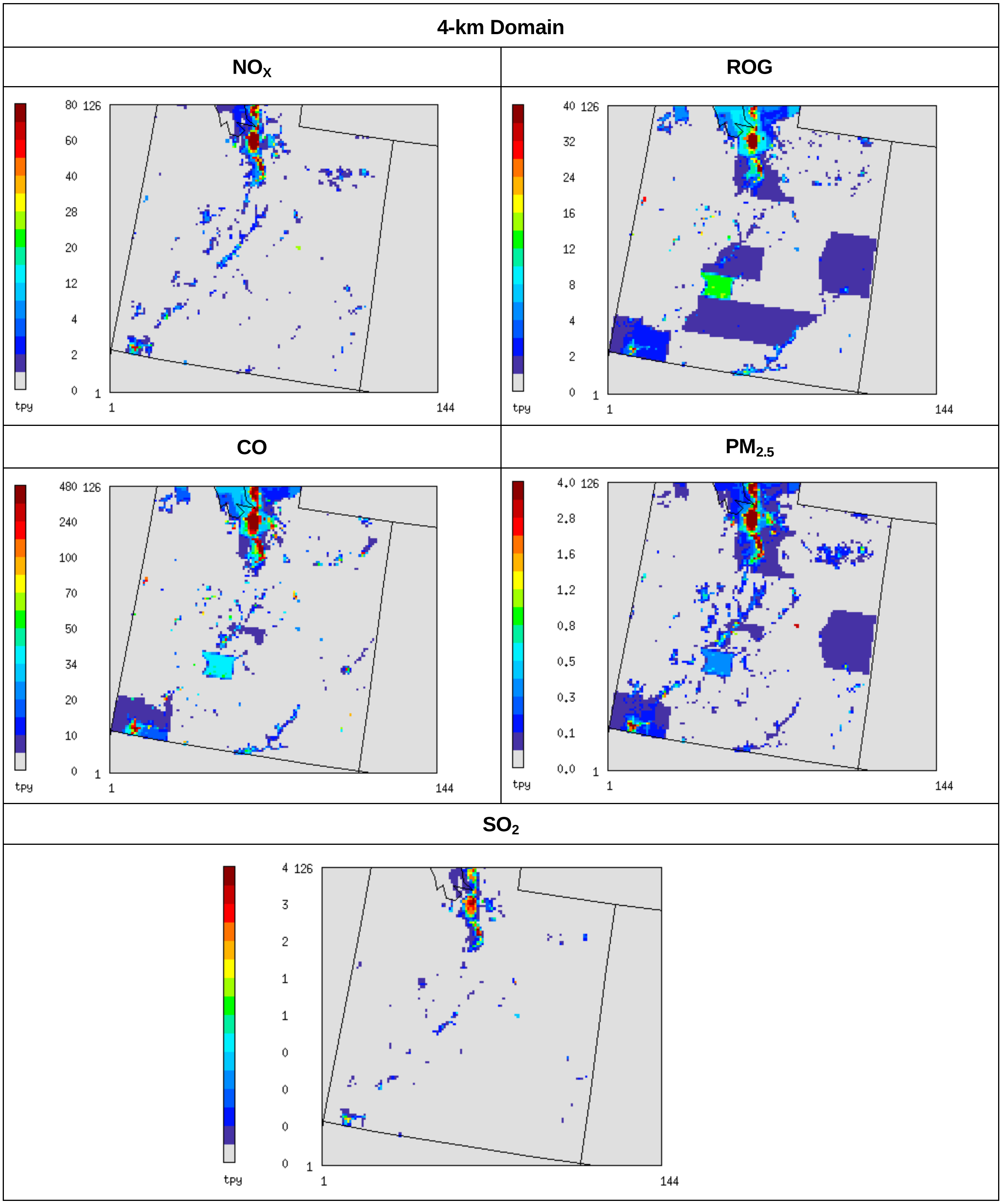
Species	12-km Domain- Annual Inventory	12-km Domain- Monthly/Seasonal Inventory
SO$_2$		

Figure 2-11 Non-Road Emissions Spatial Distribution in the 12-km Domain for Areas Outside of Utah



4-km Domain

NO_X

ROG

CO

$PM_{2.5}$

SO_2

Figure 2-12 Non-Road Emissions Spatial Distribution in the 4-km Domain for Areas Inside of Utah

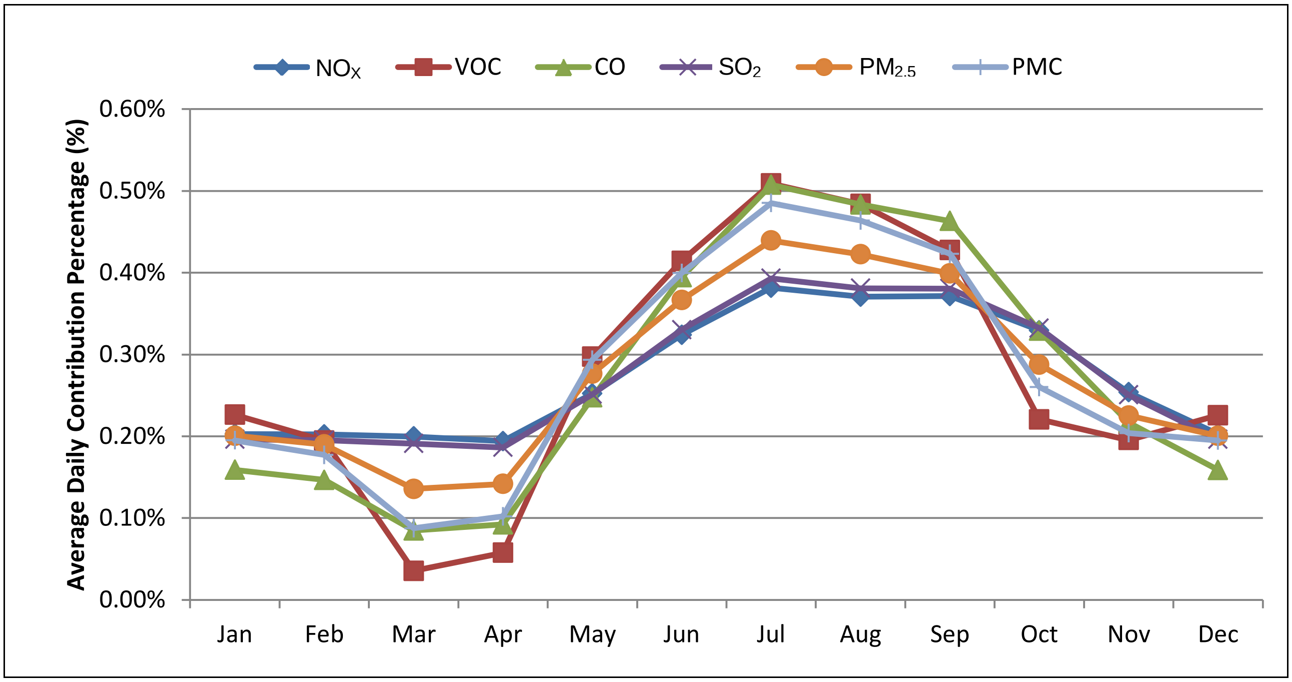


Figure 2-13 Monthly Average of Utah Non-Road Emissions in the 4-km Domain

2.5 On-Road

2.5.1 Emission Inputs

Two different data sources are used for the on-road sources. The 2008 NEI version 2 (USEPA 2012) is used for the on-road sources outside of the Uinta Basin. For on-road sources inside Uinta Basin, MOVES 2010 (USEPA 2010) is used to estimate on-road mobile source emissions.

2.5.1.1 On-Road Sources Outside Uinta Basin

All on-road mobile sources outside the Uinta basin are obtained from the 2008 NEI version 2. After the mobile Uinta Basin emissions are removed, the mobile source emissions are processed through SMOKE for all three domains without further modification. The SMOKE default temporal, chemical, and spatial allocators are used to process the emissions.

2.5.1.2 Uinta Basin On-Road Sources

The MOVES model was used for the emission factors for on-road sources inside the Uinta basin. The MOVES model calculates emission factors for three different processes using local information, including the gridded meteorological data developed for this project (AECOM and STI 2013). For more information on the use of the MOVES model for this project refer to **Appendix D**.

- Rate-per-distance (RPD) – The emission rate due to driving on-roads (referred to as on-roadway). The emissions rate is expressed in grams/vehicle mile traveled.
- Rate-per-vehicle (RPV) – The emission rate of vehicles when not moving (referred to as off-network). Off-network is represented by idling, starts, refueling, and parked vehicles. The emissions rate is given in grams/vehicle/hour.
- Rate-per-profile (RPP) – The emission rate of parked vehicle evaporation (vapor venting). The emissions rate is expressed in grams/vehicle/hour.

The MOVES RPD, RPV, and RPP emission factors are combined with local activity data, including VMT and Vehicle population (VPOP) and processed through SMOKE to calculate the emission rates. The MOVES RPD, RPV, and RPP files were processed in SMOKE for all three domains as described in detail in **Appendix D**.

In order to estimate the on-road emissions that are emitted during oil and gas exploration and production activities, the additional VMT and VPOP attributable to oil and gas activities were estimated for the Uinta Basin. Uinta Basin VMT and VPOP are shown for each county in **Table 2-47**. Details regarding the development of these values are provided in **Appendix E**.

Table 2-47 Uinta Basin Oil and Gas VMT and VPOP

County	VMT				VPOP
	Local	Highway	Interstate	Total	
Carbon	837,973	275,096	0	1,113,069	20
Duchesne	5,959,727	7,610,005	0	13,569,732	233
Emery	159,904	239,723	130,089	529,716	11
Grand	143,145	7,658	3,188,776	3,339,579	68
Uintah	26,222,809	19,700,574	637	45,924,020	867
Total	33,323,558	27,833,056	3,319,502	64,476,116	1,199

2.5.2 On-Road Emissions Summary

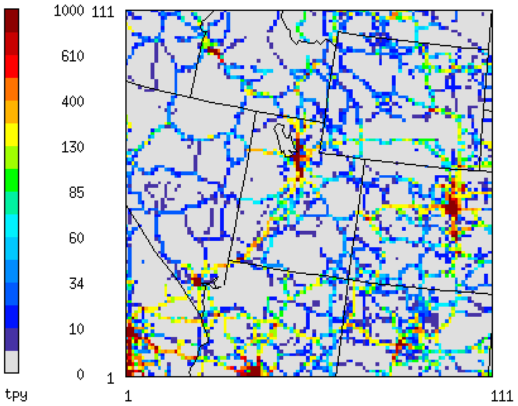
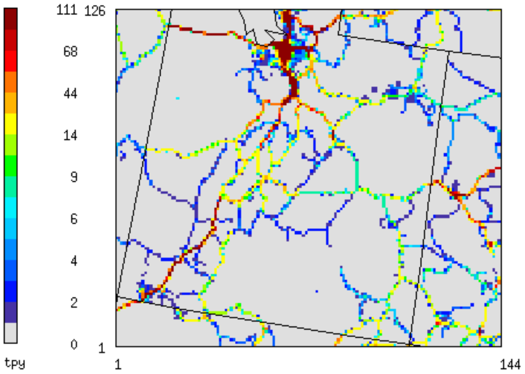
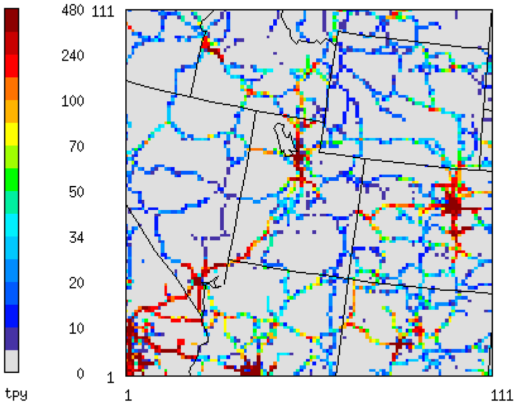
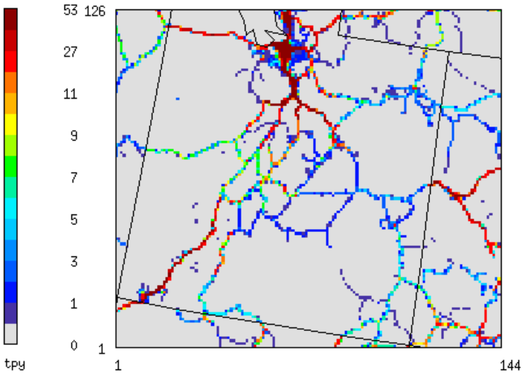
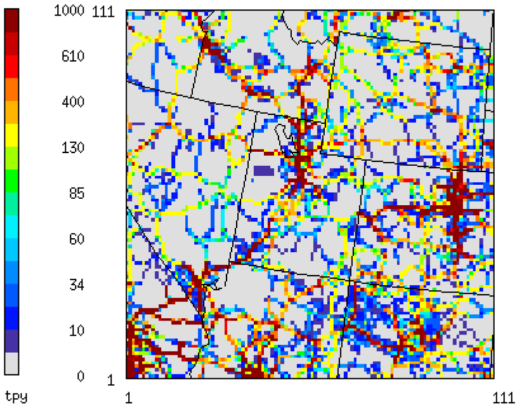
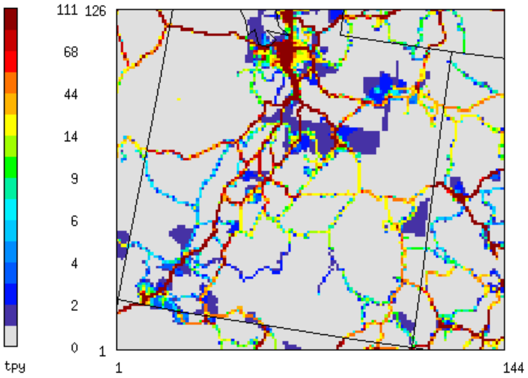
The on-road emissions outside Utah and inside Utah are combined for RPD, RPV, and RPP to provide the total emissions from the on-road source category. **Table 2-48** shows annual emissions for all on-road sources by model domain. **Figure 2-14** displays the spatial plots of on-road sources, and **Figure 2-15** shows the monthly variability of on-road emissions. **Table 2-49** shows the annual oil and gas truck traffic on-road emissions contributing to the all on-road sources.

Table 2-48 Annual On-Road Emissions

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	6,943,632	3,319,318	35,609,440	115,926	130,108	288,917	369,491
12-km	515,141	251,944	2,555,709	10,245	9,867	19,664	25,518
4-km	82,041	39,262	421,223	2,000	1,215	2,902	3,497

Table 2-49 Uinta Basin Oil and Gas Well Truck Traffic On-Road Emissions

On-Road Source Category	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
RPD	379	19	93	2	1	6	6
RPV	3	1	11	0.051	0	0.013	0.014
Total	382	20	104	2	1	6	6

Species	12-km Domain	4-km Domain
NO_X		
ROG		
CO		

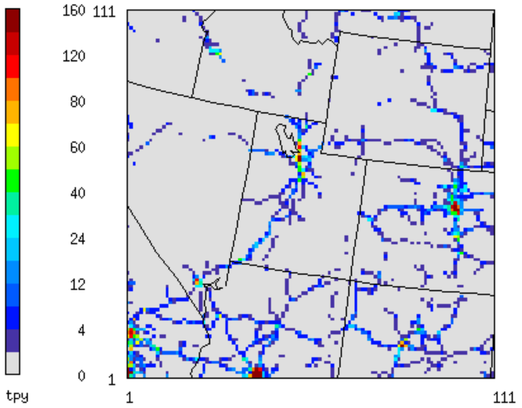
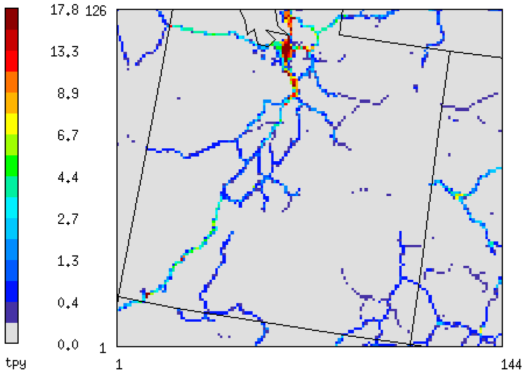
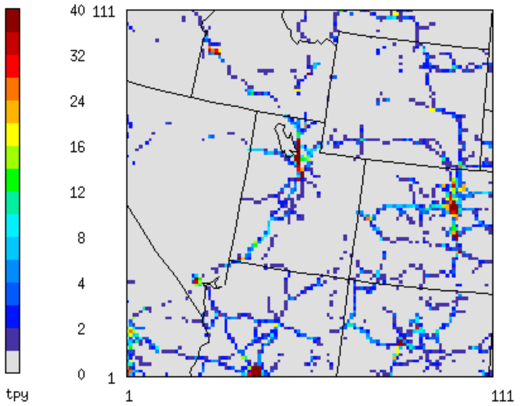
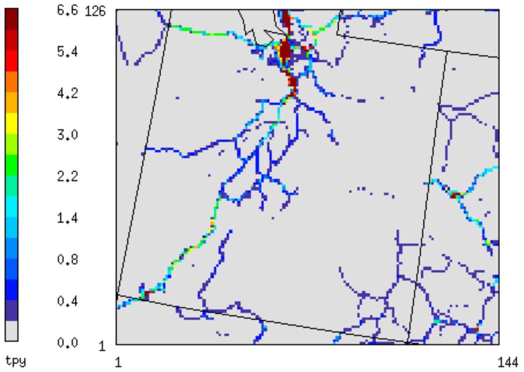
Species	12-km Domain	4-km Domain
$PM_{2.5}$		
SO_2		

Figure 2-14 Mobile Emissions Spatial Distribution in the 12-km and 4-km Domains

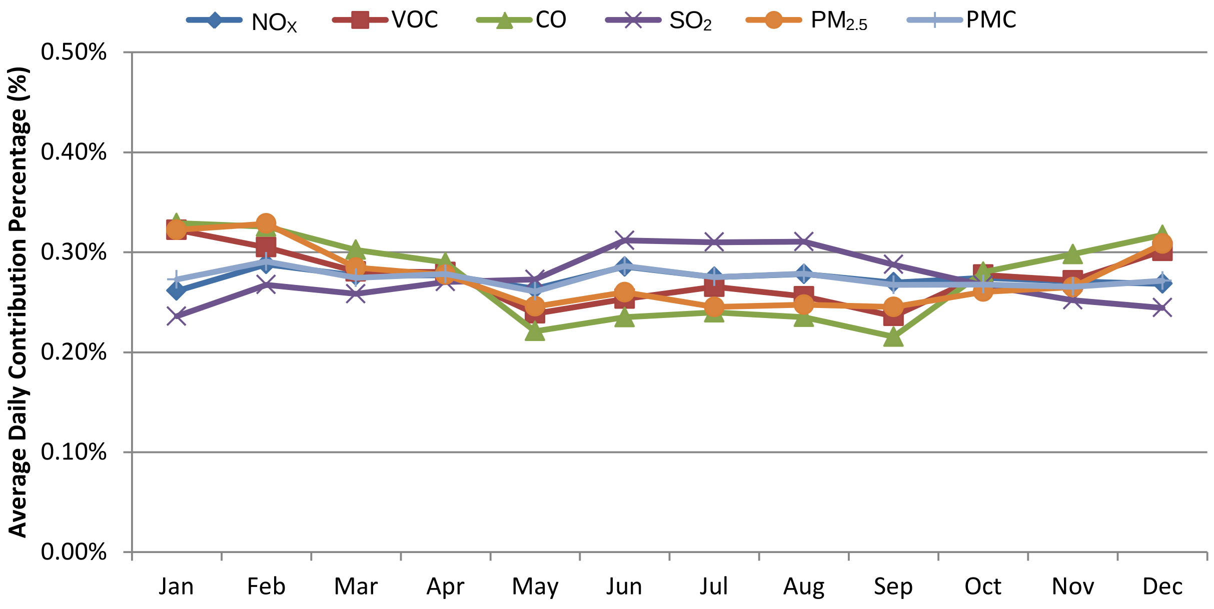


Figure 2-15 Monthly Average of Mobile Emissions in the 4-km Domain

2.6 Ammonia

Emissions from agriculture and anthropogenic activities are the primary source of NH_3 emissions in stationary area source inventories. Ammonia was held constant for all modeling simulations.

2.6.1 Emissions Inputs

Ammonia emissions records are from the U.S. 2008 NEI and include ammonia emissions from fertilizer application, feedlots, and soil. The 2008 NEI data for ammonia emissions are used without modification for the entire U.S. and in all three modeling domains. Canada and Mexico have estimates of agricultural NH_3 emissions as part of the non-U.S. area inventory, which was processed separately.

2.6.2 SMOKE Processing

Ammonia emissions are temporally allocated by month, day, and hour and spatially allocated using annual emissions and SCC-based allocation factors from SMOKE. Monthly temporal profiles were developed for ammonia emissions where the default temporal profile was constant. Table shows the percent allocated to each month based on an average monthly total (Gilliland et. al 2003).

Table 2-50 Ammonia Monthly Profile*

Month	Monthly Total (tons)	Monthly Percent
January	1,276	5%
February	*1,475*	6%
March	1,674	6%
April	2,472	10%
May	3,070	12%
June	4,226	16%
July	3,588	14%
August	3,030	12%
September	*2,014*	8%
October	997	4%
November	*997*	4%
December	*997*	4%
Total	**25,816**	100%

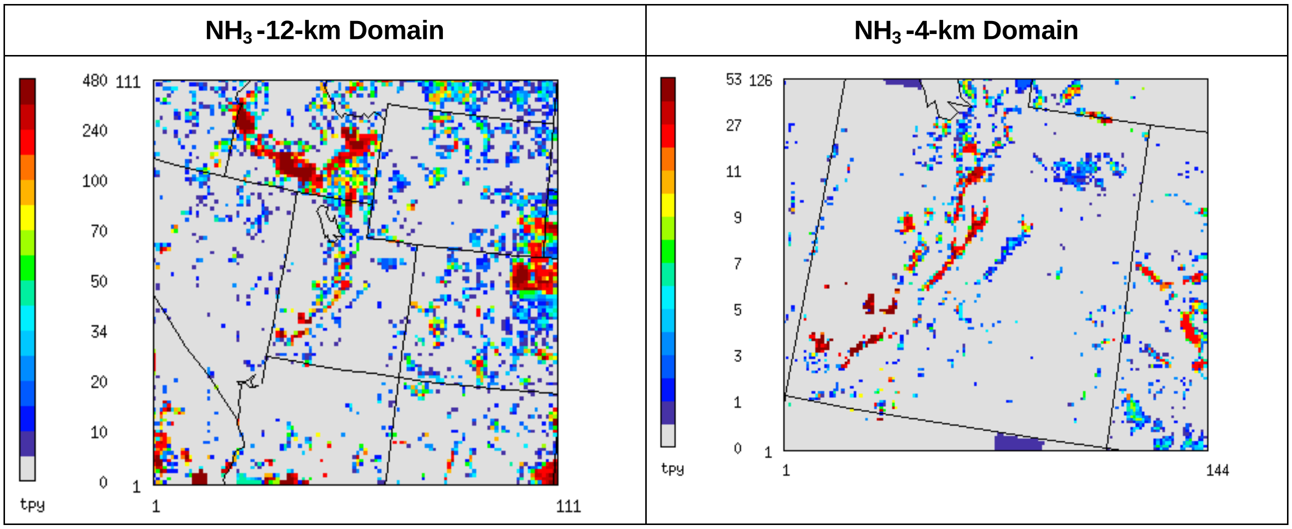
*Profiles from Gilliland et. al (2003).

2.6.3 Ammonia Emissions Summary

Table 2-51 shows the final fire emissions for each modeling domain. Spatial plots are shown in **Figure 2-16** and **Figure 2-17** shows the monthly temporal profile.

Table 2-51 Annual Emissions for Ammonia Sources by Domain

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	0	0	0	0	3,548,281	0	0
12-km	0	0	0	0	273,012	0	0
4-km	0	0	0	0	23,543	0	0



NH_3-12-km Domain | **NH_3-4-km Domain**

Figure 2-16 Agricultural Emissions Spatial Distribution in the 4-km Domain

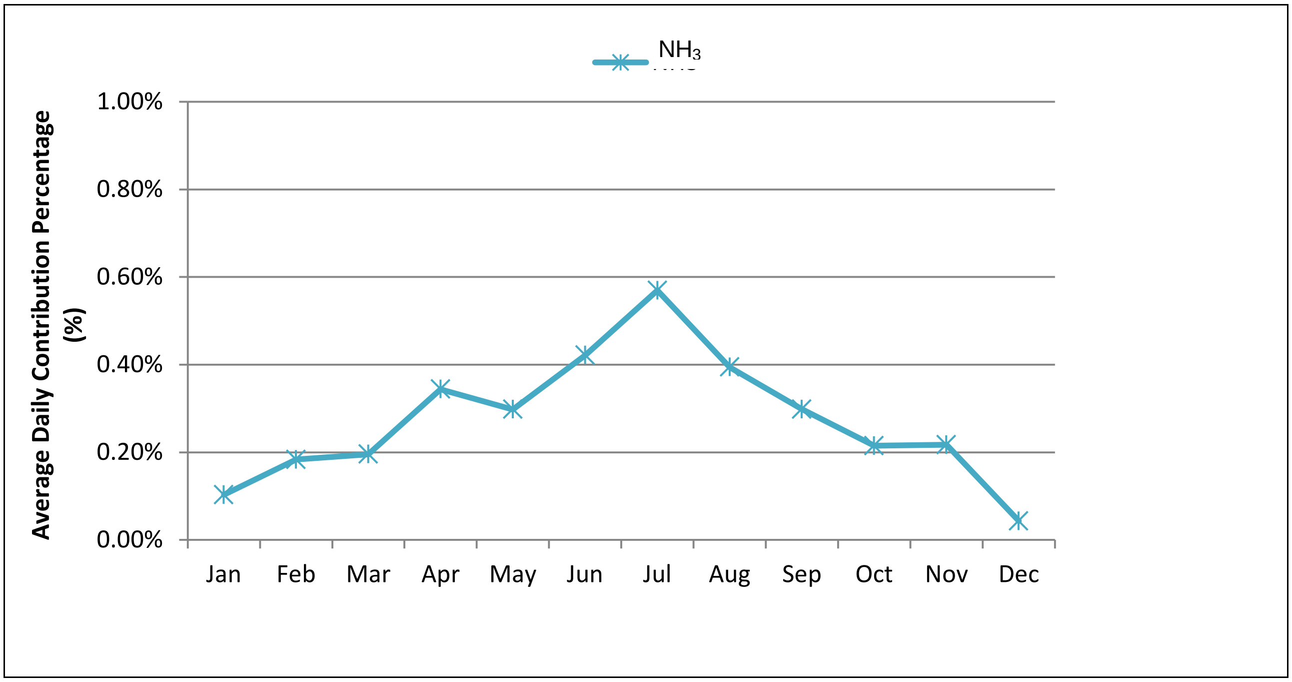


Figure 2-17 Monthly Average of Ammonia Emissions in the 4-km Domain

2.7 Dust Emissions Inventory

2.7.1 Emissions Inputs

Due to the different dust emissions inventory sources, the dust sources are processed in three separate source sectors. Dust sources outside of Utah are divided into two groups: 1) road dust which includes unpaved and paved road dust and 2) fugitive dust which includes commercial and residential construction, agricultural tilling, agricultural planting, livestock operations and mining and quarrying. Fugitive dust sources inside of Utah include all of the aforementioned dust sources: unpaved and paved road dust, commercial and residential construction, agricultural tilling, agricultural planting, livestock operations and mining and quarrying.

2.7.1.1 Road Dust and Fugitive Dust Outside of Utah

Fugitive dust from the WRAP 2002 Plan02d case is used in this study for the base year and all future year modeling. The Road dust emissions inventory is based on the WRAP Mobile Source Emissions Inventories Update of the WRAP 2002 inventory (ENVRION 2006), and is shown in **Table 2-52**. The fugitive dust and road dust inventories contained in this category have PM transport factors applied as suggested by Pace (2005) and also have revised $PM_{10}/PM_{2.5}$ ratios as suggested by MRI (2005).

Table 2-52 Fugitive Dust Source Emissions Input Outside of Utah

Inventory	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
Fugitive Dust	0	0	0	0	0	440,392	2,656,783
Road Dust	0	0	0	0	0	435,745	4,006,486

2.7.1.2 Utah Fugitive Dust

The fugitive dust sources inside of Utah are exacted from the UDAQ 2010 Emissions Inventory Area Sources. **Table 2-53** shows the annual total emissions processed by SMOKE for fugitive dust sources inside of Utah.

Table 2-53 Fugitive Dust Source Emissions Input Inside of Utah

NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
0	0	0	0	0	10,629	33,645

2.7.2 SMOKE Processing

The road dust and fugitive dust emissions are temporally allocated by month, day, and hour and spatially allocated using annual emissions and SCC-based allocation factors from SMOKE.

Following the SMOKE processing, one additional processing step was applied to the fugitive dust inventories to account for the influence of physical processes influencing the timing and removal of dust emissions. Meteorological and land surface conditions, such as snow cover and soil moisture, affect the amount of material emitted by activities that generate dust. To account for both the meteorological influence, an additional processing step was applied to the emissions inventory. The meteorology and land surface adjustment processing step was developed by Pouliot et al (2012). This processor applies a land surface adjustment to the emissions based on information from MCIP results. Note that application of this processor results in slightly different emissions for the same area when there is different grid resolution.

2.7.3 Dust Emissions Summary

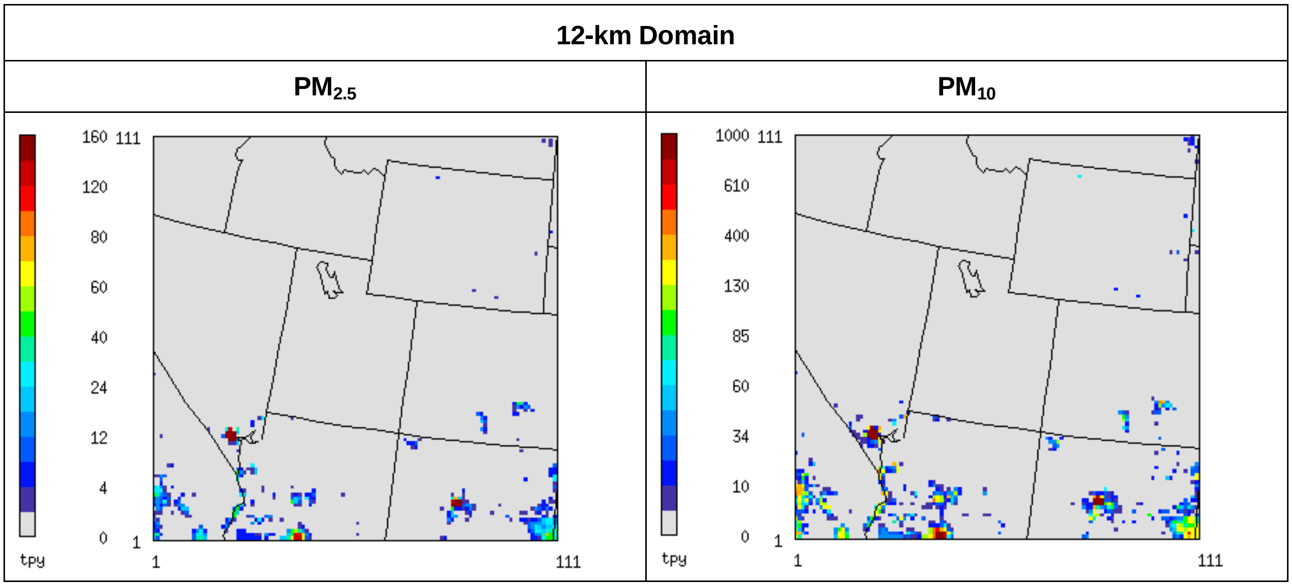
Table 2-54 shows the emission totals of fugitive dust sources before meteorology and land surface adjustment is applied. The final dust emissions for all source categories and domains are show in **Table 2-55**. **Figure 2-18**, **Figure 2-19**, and **Figure 2-20** show spatial plots of the 12-km and 4-km domains for dust sources. **Figure 2-21** shows the monthly temporal trend of fugitive dust sources inside Utah for the 4-km domain.

Table 2-54 Initial Annual Fugitive Dust Emissions

	Fugitive Dust (outside of Utah)		Fugitive Dust (within Utah)	
Domain	**$PM_{2.5}$ (tpy)**	**PM_{10} (tpy)**	**$PM_{2.5}$ (tpy)**	**PM_{10} (tpy)**
36-km	436,897	2,635,697	10,530	33,019
12-km	26,996	214,178	10,530	33,019
4-km	527	4,243	9,942	29,959

Table 2-55 Final Annual Dust Emissions

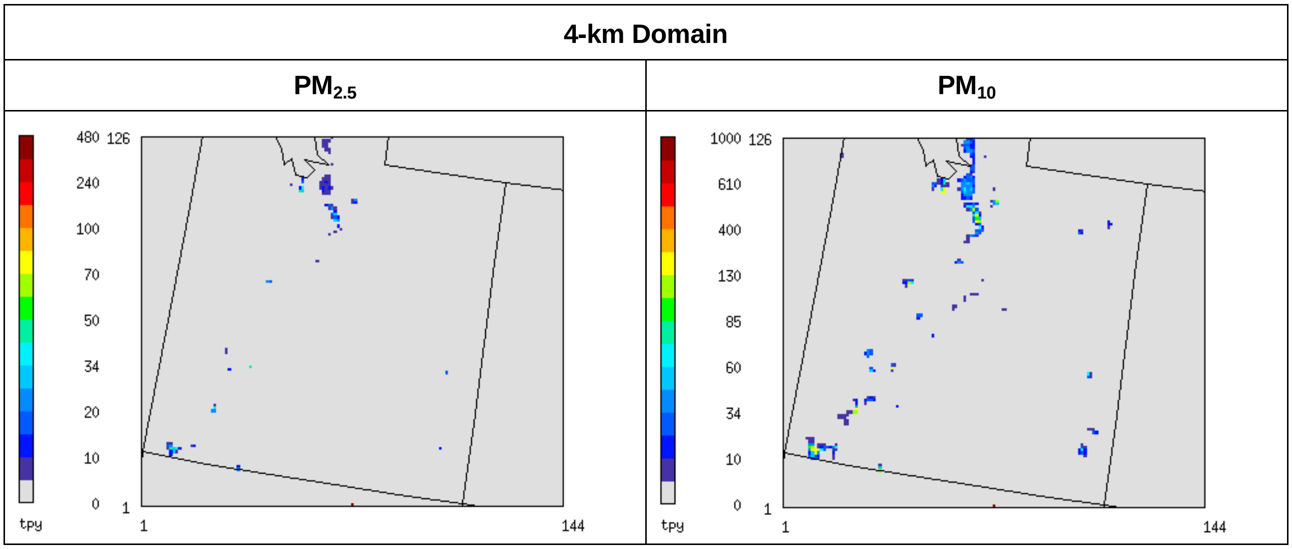
	Fugitive Dust (outside of Utah)		Fugitive Dust (within Utah)		Road Dust	
Domain	**$PM_{2.5}$ (tpy)**	**PM_{10} (tpy)**	**$PM_{2.5}$ (tpy)**	**PM_{10} (tpy)**	**$PM_{2.5}$ (tpy)**	**PM_{10} (tpy)**
36-km	98,054	602,769	7,348	17,082	432,287	3,974,688
12-km	9,976	87,015	7,684	18,778	22,141	204,727
4-km	13	102	7,464	17,634	156	1,286



12-km Domain

$PM_{2.5}$ **PM_{10}**

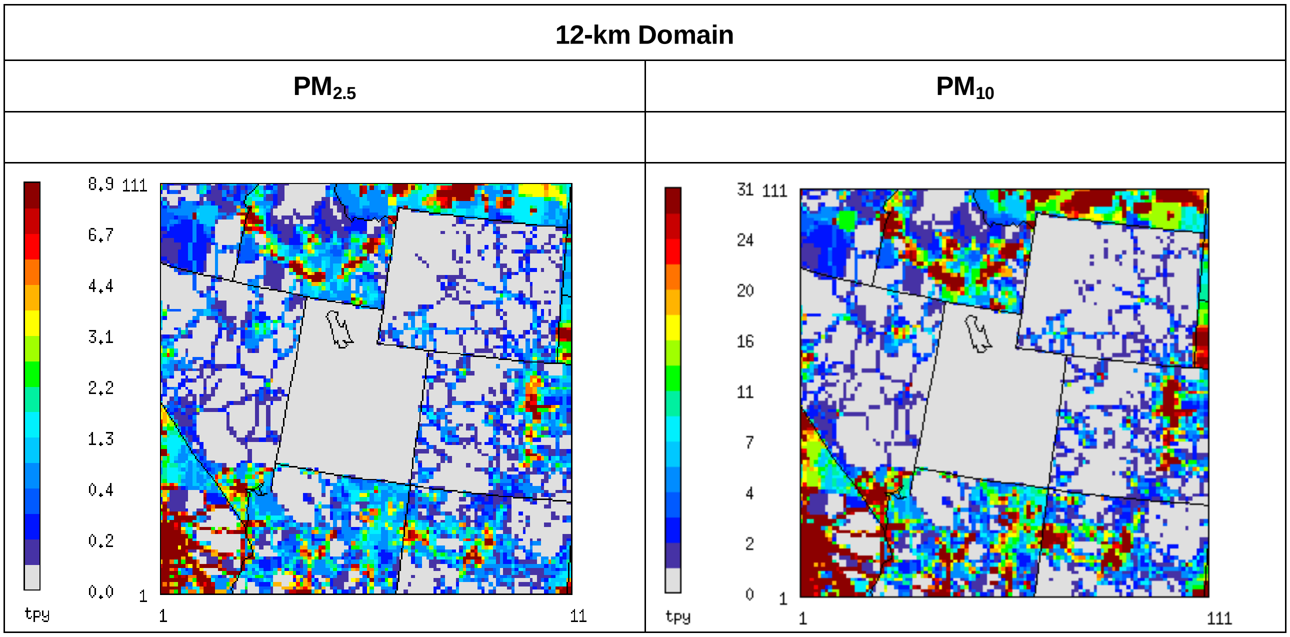
Figure 2-18 Fugitive Dust Emissions Spatial Distribution in the 12-km Domain for Areas Outside of Utah


4-km Domain

PM$_{2.5}$

PM$_{10}$

Figure 2-19 Fugitive Dust Emissions Spatial Distribution in the 4-km Domain for Areas Inside of Utah


12-km Domain

PM$_{2.5}$

PM$_{10}$

Figure 2-20 Road Dust Emissions Spatial Distribution in the 12-km Domain for Areas Outside of Utah

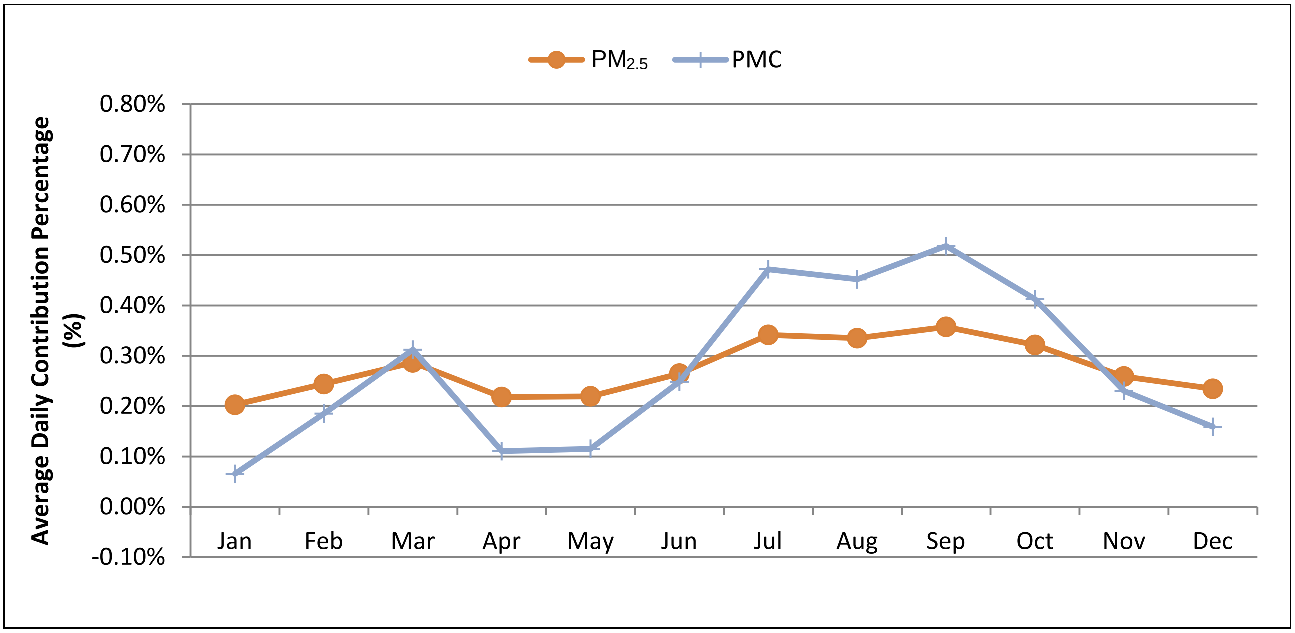


Figure 2-21 Monthly Average of Utah Fugitive Dust Emissions in the 4-km Domain

2.8 Fire

2.8.1 Emissions Inputs

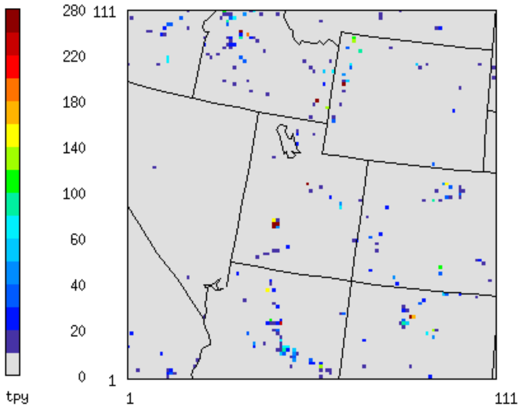
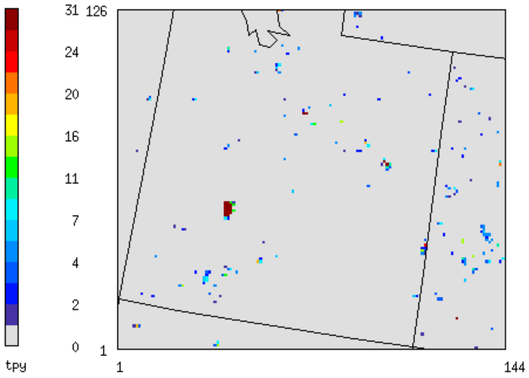
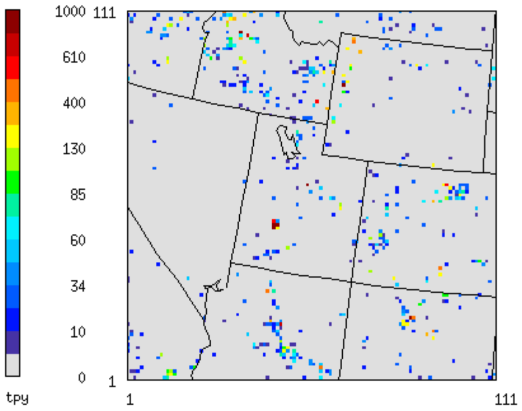
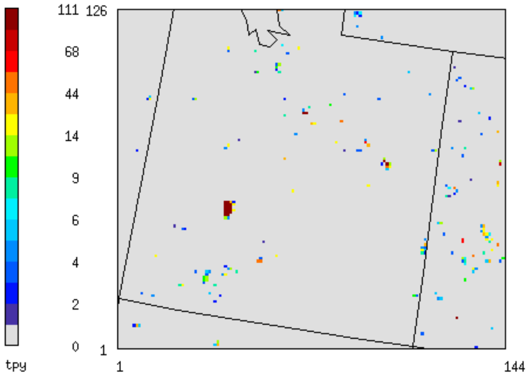
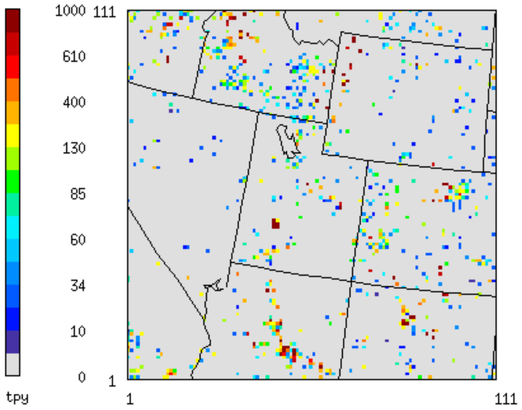
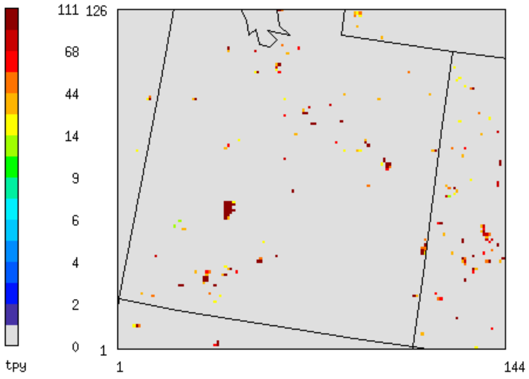
The 2010 fire emissions were provided by ENVIRON and were developed from the Nation Center for Atmospheric Research (NCAR). These emission estimates are derived from analysis of fire locations determined by satellite-borne detectors, MODerate-resolution Imaging Spectroradiometer (MODIS). The MODIS instruments detect fires as thermal anomalies (i.e. hot spots seen against a cooler background) at a spatial resolution of 1-km. The NCAR satellite-derived fire emissions data for 2010 contain daily emissions locations, acreage burned, and fuel loading at a resolution of 12-km. Fire emissions do not occur every day, so there are days without emissions files.

2.8.2 Fire Emissions Summary

Table 2-56 shows the final fire emissions for each modeling domain. Spatial plots are shown in **Figure 2-22**. **Figure 2-23** shows the monthly temporal trend in the 4-km domain.

Table 2-56 Annual Fire Emissions

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	605,059	2,257,971	11,704,231	93,938	255,240	1,245,753	1,473,204
12-km	15,247	51,150	285,384	2,408	6,766	31,369	36,045
4-km	4,015	14,495	77,625	655	1,986	8,490	9,556

Species	Fire Sources (12-km)	Fire Sources (4-km)
NO_X		
ROG		
CO		

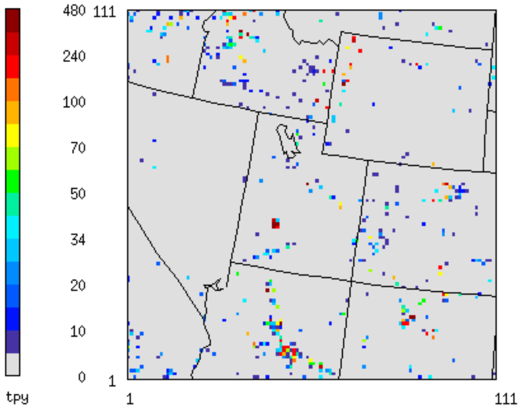
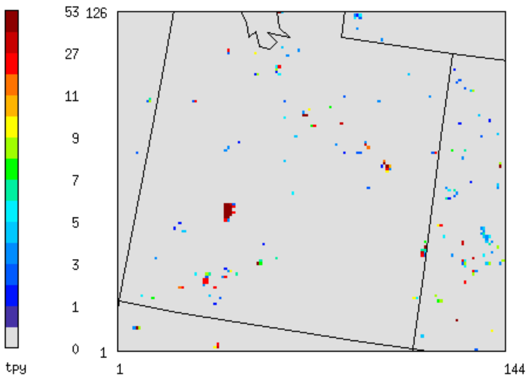
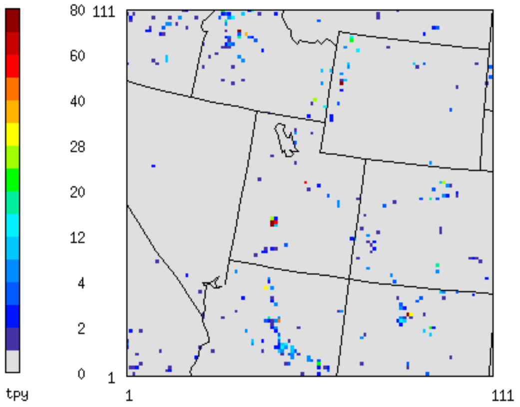
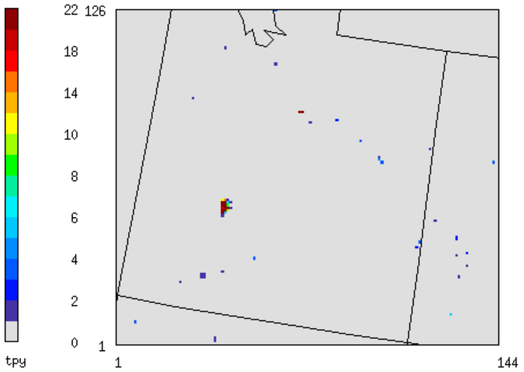
Species	**Fire Sources (12-km)**	**Fire Sources (4-km)**
$PM_{2.5}$		
SO_2		

Figure 2-22 Fire Emissions Spatial Distribution in the 12-km and 4-km Domains

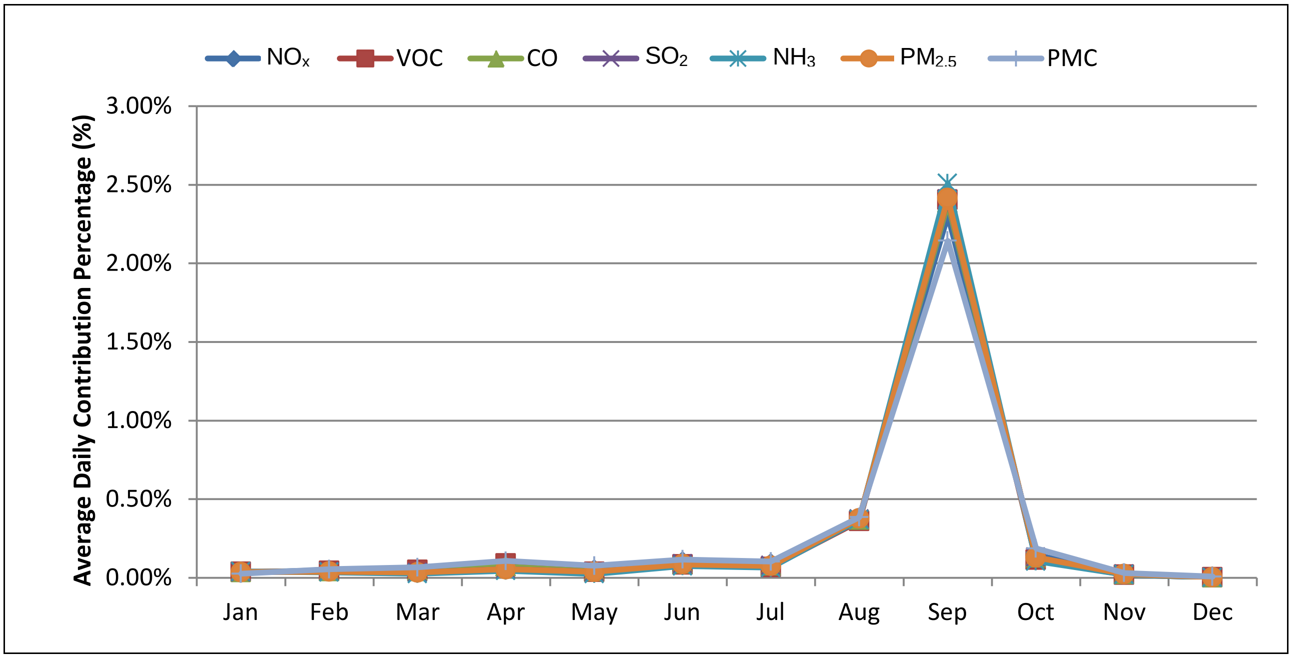


Figure 2-23 **Monthly Average for Fire Emissions in the 4-km Domain**

2.9 Biogenic

2.9.1 Emissions Inputs

Biogenic emissions were provided by ENVIRON. The emissions are modeled using the MEGAN version 2.03 (Guenther et al. 2006; Guenther and Wiedinmyer 2007). MEGAN is used to prepare gridded, hourly biogenic emission inventories suitable for input to CMAQ. MEGAN is the latest biogenic emissions model developed by researchers from the NCAR and incorporates the full range of ozone and PM precursor species. MEGAN accounts for the spatial variability of biogenic emissions through the use of high resolution estimates of vegetation type and quantity. MEGAN requires as input weather data, Leaf Area Index (LAI), plant functional type (PFT) cover, and compound-specific emission factors that are based on plant species composition. All of these variables are provided in a geo-referenced gridded database in several formats such as netcdf or ESRI GRID. The inputs to MEGAN model are:

- Landcover: The land cover available in MEGAN database has global coverage at 30 sec (~ 1km) spatial resolution (Guenther et al. 2006).
- Surface Temperature Data: Gridded, hourly temperature fields were extracted from WRF predictions for each day for each grid cell.
- Photosynthetically active radiation (PAR): The PAR data represents the intensity of solar radiation in the spectral range that is used by plants for the photosynthesis process. The PAR data were downloaded from the University of Maryland (UMD) (2010) and a FORTRAN program was used to reformat the data.

Day-specific biogenic emissions are generated for all model domains for the 2010 base year.

2.9.2 Biogenic Emissions Summary

Table 2-57 shows the final biogenic emissions for each modeling domain. Spatial plots of the biogenic emissions are shown in **Figure 2-24**. **Figure 2-25** shows the monthly temporal trend in the 4-km domain.

Table 2-57 Annual Biogenic Emissions

Domain	NO (tpy)	TOG (tpy)	CO (tpy)
36-km	716,943	61,496,400	7,702,301
12-km	36,151	2,973,530	450,968
4-km	5,248	465,492	69,557

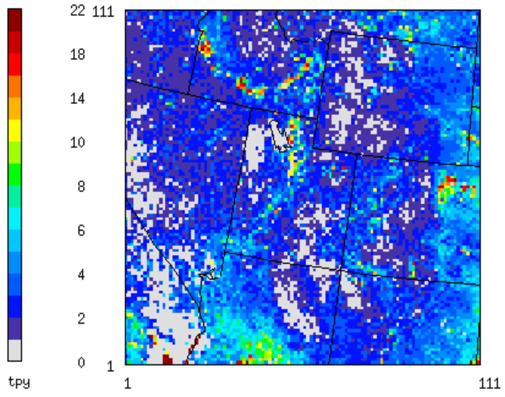
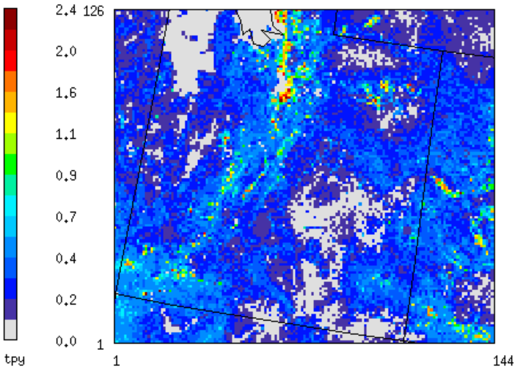
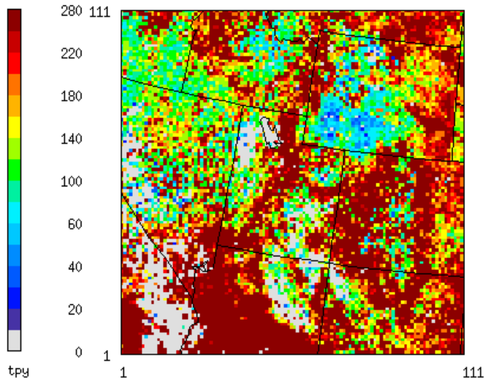
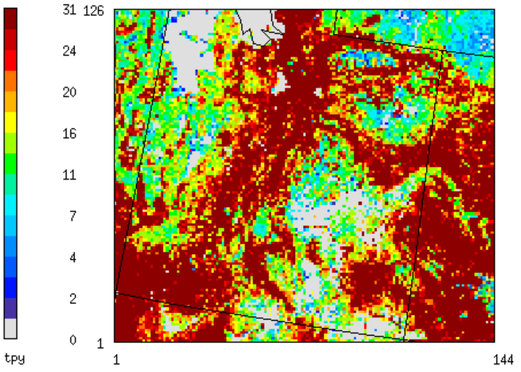
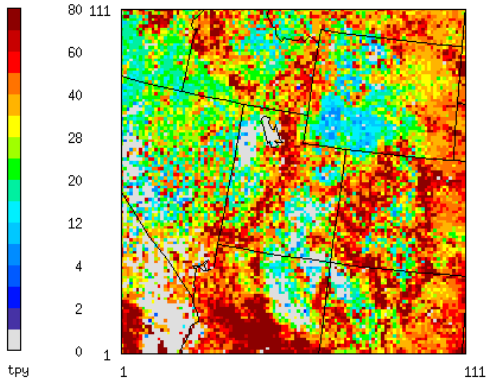
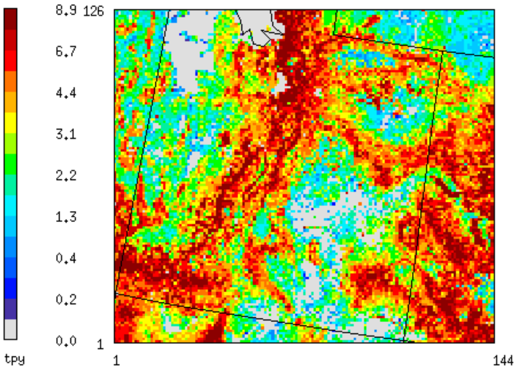
Species	12-km Domain	4-km Domain
NO		
ROG		
CO		

Figure 2-24 Biogenic Emissions Spatial Distribution in the 12-km and 4-km Domains

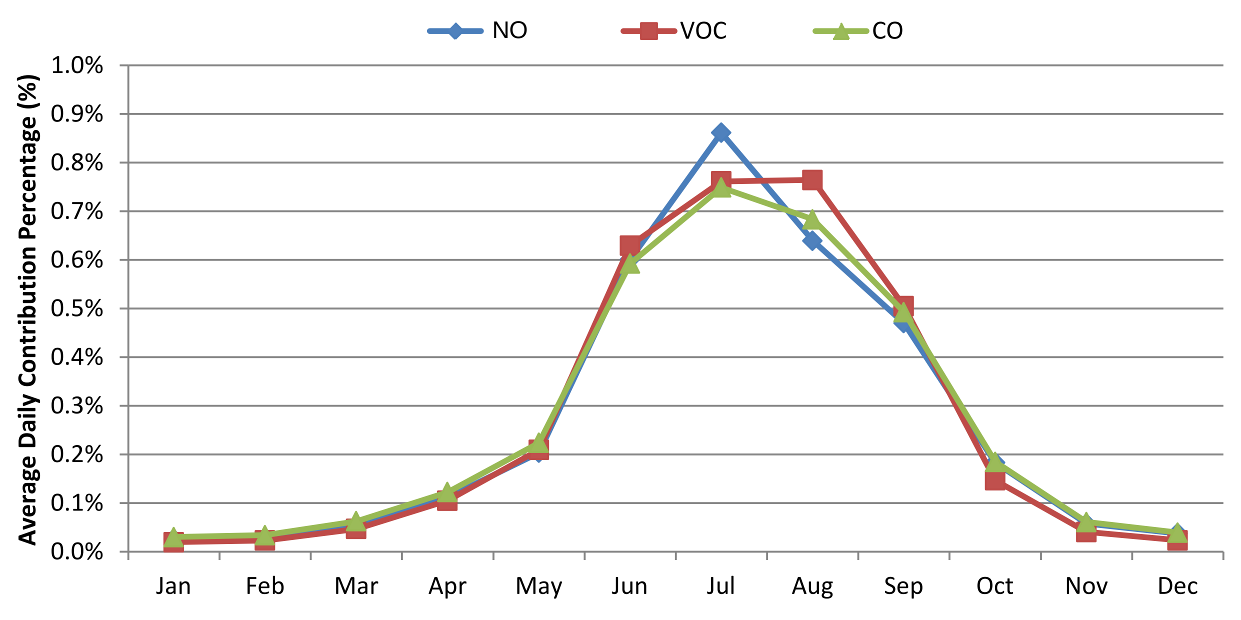


Figure 2-25 Monthly Average of Biogenic Emissions in the 4-km Domain

2.10 Non-U.S. Sources

Non-U.S. source emissions include point, area, and on-road mobile from Canada and Mexico. Offshore sources from maritime traffic were also included in this source category.

2.10.1 Emissions Inputs

The non-U.S. emissions from point, area, on-road mobile sources from Canada and Mexico, and offshore sources, were used directly from the WRAP Plan02d case.

2.10.2 SMOKE Processing

Non-U.S. emissions are temporally allocated by month, day, and hour and spatially allocated using annual emissions and SCC-based allocation factors from SMOKE. Due to the geographic location of the emissions sources, the emissions are only processed and incorporated in the 36-km domain.

2.10.3 Non-US Emissions Summary

Table 2-58 shows the final non-U.S. emissions for the 36-km domain for each source sector.

Table 2-58 Annual Non-US Emissions for the 36-km Domain

Source	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
Point	1,198,583	1,063,660	1,449,180	2,644,311	21,268	157,567	243,791
Area	905,115	3,992,334	4,767,049	187,113	1,031,566	513,963	1,753,444
Mobile	629,513	537,903	6,208,851	13,349	25,289	15,651	20,498
Offshore	1,183,960	39,091	97,622	743,853	0	89,632	97,551

2.11 Final Base Year Emissions

Emissions from each of the emissions sectors are merged together to create the CMAQ model-ready emissions files.

2.11.1 Final Emissions Processing

All source sectors are merged for each model domain. The final emissions inputs are then converted into two types of model-ready emissions files for CMAQ:

- Two-dimensional emissions file for all sources except elevated point sources; and
- Elevated-point source emissions file.

2.11.2 Final Emissions Summary

Table 2-59 shows the final 2021 emissions for the 36-km, 12-km, and 4-km modeling domains. **Table 2-60** summarizes the annual emissions for each source sector in the 4-km domain. **Figure 2-26** shows the spatial distribution of the emissions in the 12-km domain and the 4-km domain. **Figure 2-27** shows the monthly temporal trend in the 4-km domain. The pollutant contributions of each sector in the final emissions totals are shown in **Figure 2-28.**

Table 2-59 Final Annual Emissions

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	21,946,509	92,619,365	100,809,859	14,623,384	5,646,134	4,593,641	10,952,232
12-km	1,854,178	6,301,808	5,307,527	622,500	501,881	208,530	595,731
4-km	297,979	2,007,804	1,076,368	55,692	198,292	46,603	81,524

Table 2-60 Year 2010 Emissions by Source Sector in the 4-km Domain

Source Sector	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
EGU Point	86,197	1,631	7,363	29,192	424	3,348	5,314
Non- EGU Point	57,905	22,639	27,135	21,174	424	5,372	11,403
Oil and Gas	32,917	722,116	85,509	314	0	1,156	1,174
Area	10,595	721,994	240,949	1,819	170,693	16,444	30,234
Non-road	19,061	20,176	147,008	539	7	1,258	1,324
On-Road	82,041	39,262	421,224	2,000	1,215	2,902	3,497
Ammonia	0	0	0	0	23,543	0	0
Fire	4,015	14,495	77,625	655	1,986	8,490	9,556
Biogenic	5,248	465,492	69,557	0	0	0	0
Dust (fugitive and road)	0	0	0	0	0	7,633	19,023
Total	297,979	2,007,804	1,076,368	55,692	198,292	46,603	81,524

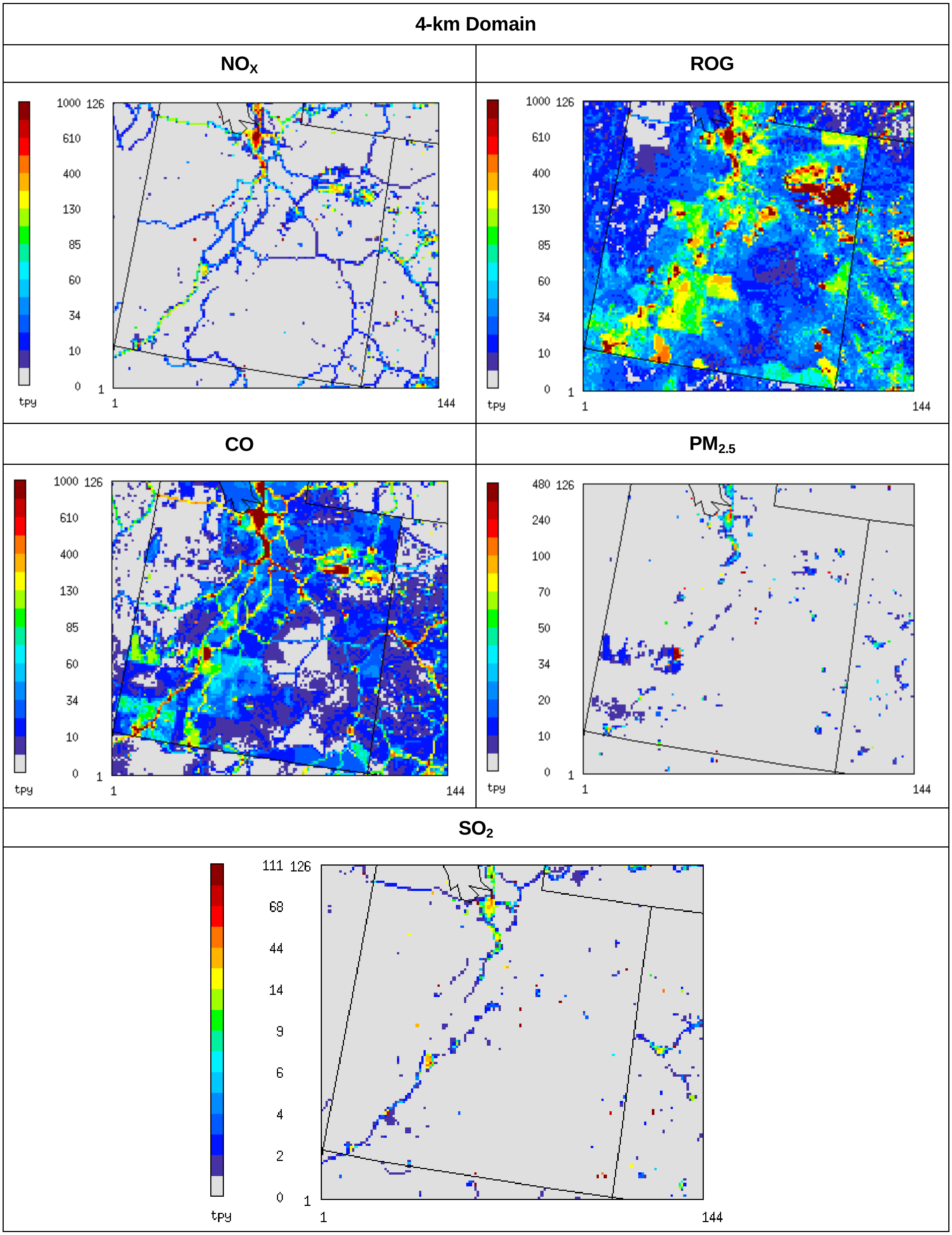


Figure 2-26 Final Annual Emissions Spatial Distribution in the 4-km Domain

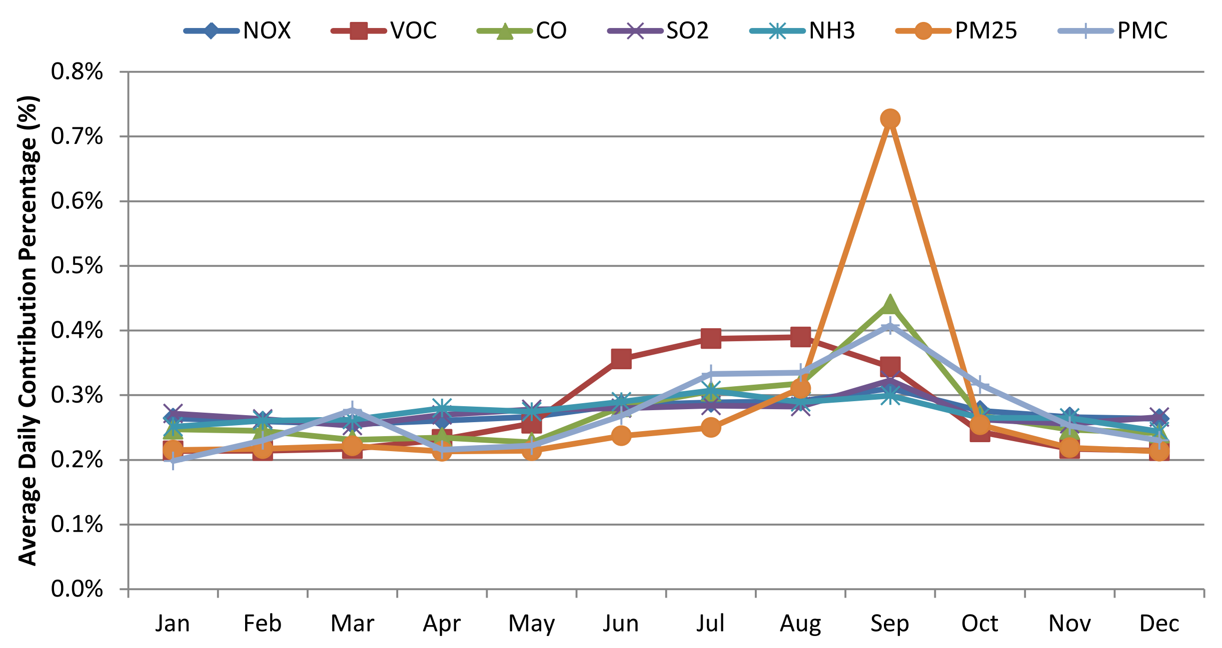


Figure 2-27 Monthly Average of the Final Emissions in the 4-km Domain

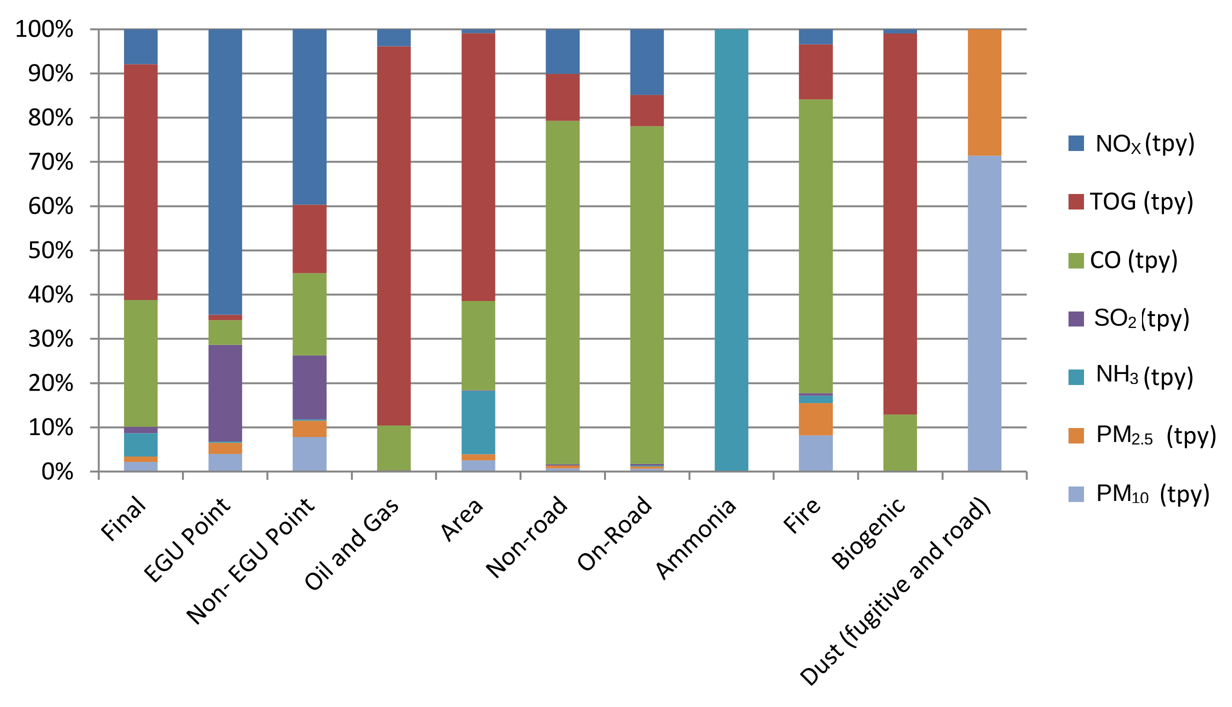


Figure 2-28 Annual Pollutant Contribution for Each Emission Source Sector

3.0 Typical Year Emission Inventories

A typical year emission inventory is developed by annualizing the base year 2010 emissions for source sectors that have temporal variability in the base year that is not reasonable to expect in future years. Annualizing the base year emission inventory provides a method to estimate the change in impacts between the base year and future years as a result of future year activities. This process removes any modeled high impacts that occur in the base year, but cannot be anticipated to occur in the future year at the same time and place. For the typical year emission inventory, the following three source sectors were temporally normalized: EGU point sources, Uinta Basin oil and gas completion and drilling activities, and fire emissions within Utah State.

3.1 EGU Point Sources

The hourly emissions inventories of EGU point sources inside and outside of Utah were averaged to provide a uniform hourly emissions rate throughout the year.

All EGU sources inside and outside Utah were processed through SMOKE together. **Table 3-1** shows the final EGU point emissions used for the 36-, 12-, and 4-km domains. The monthly average of EGU point sources in the 4-km domain are shown in **Figure 3-1**. Note that now the emissions do not have monthly variability as compared to **Figure 2-3.**

Table 3-1 Annual EGU Point Emissions

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	2,012,016	45,265	440,637	5,917,266	16,178	277,665	339,818
12-km	286,074	6,314	26,376	180,855	1,341	18,512	24,873
4-km	86,197	1,631	7,363	29,192	424	3,348	5,314

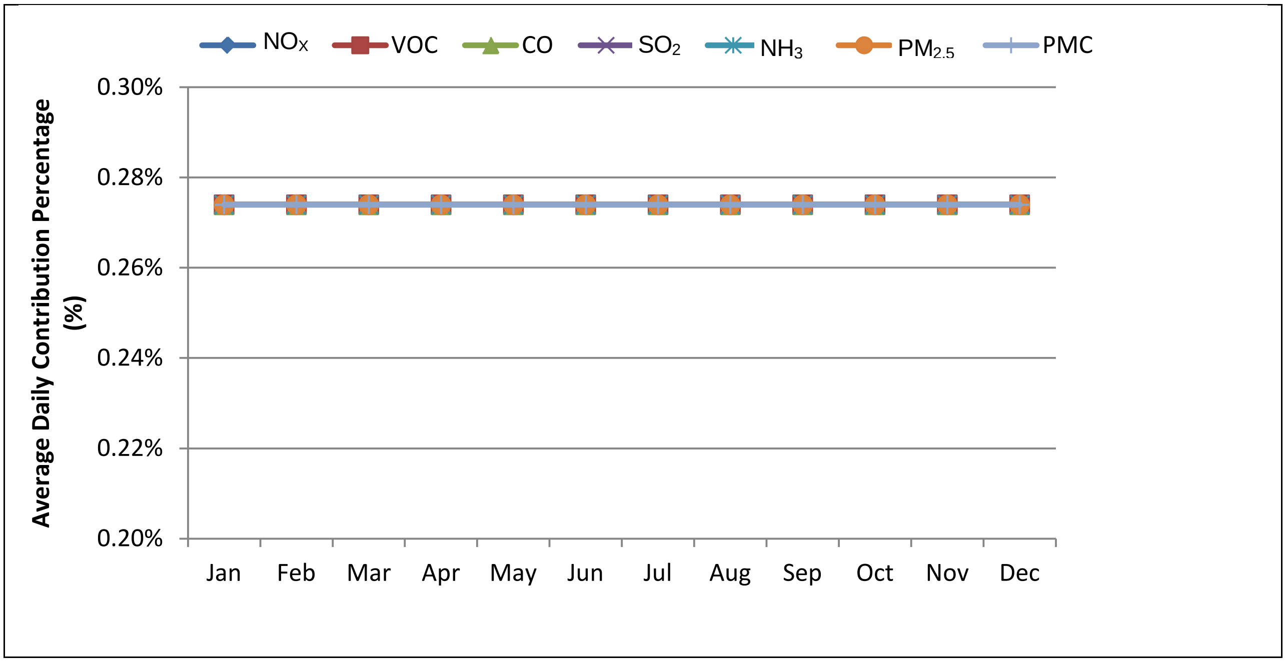


Figure 3-1 Monthly Average of EGU Emissions in the 4-km Domain

3.2 Uinta Basin Oil and Gas

For the Uinta Basin oil and gas source sector, all typical year emissions are processed as described in Section 2.2.1.1, except for the drilling, completion, and hydraulic fracturing emissions. In the base year modeling scenario, emissions from these sources were temporally allocated to each hour based on drilling and completion start and end dates. These emissions were also treated as point sources based on the well's location. For the typical year scenario, the drilling, completion and hydraulic fracturing emissions were summed by county for each source category. In order to normalize these emissions, they are processed as an area source through SMOKE without the corresponding hourly files.

For SMOKE processing, the default temporal profiles were used and the emissions were spatially allocated using the oil and gas spatial surrogates as described in Section 2.2.2.1. **Table 3-2** and **Table 3-3** show the final point and area oil and gas emissions, respectively, used for the Uinta Basin for all three domains. The monthly average of Uinta Basin oil and gas point sources in the 4-km domain are shown in **Figure 3-2**. The figure shows a normalized monthly profile for the oil and gas point sources.

Table 3-2 Uinta Basin Oil and Gas Point Source Emissions

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	2,603	3,504	1,912	7	0	40	40
12-km	2,603	3,504	1,912	7	0	40	40
4-km	2,603	3,504	1,912	7	0	40	40

Table 3-3 Oil and Gas Area Source Emissions

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	13,926	626,195	46,963	25	0	561	561
12-km	13,926	626,195	46,963	25	0	561	561
4-km	13,926	626,195	46,963	25	0	561	561

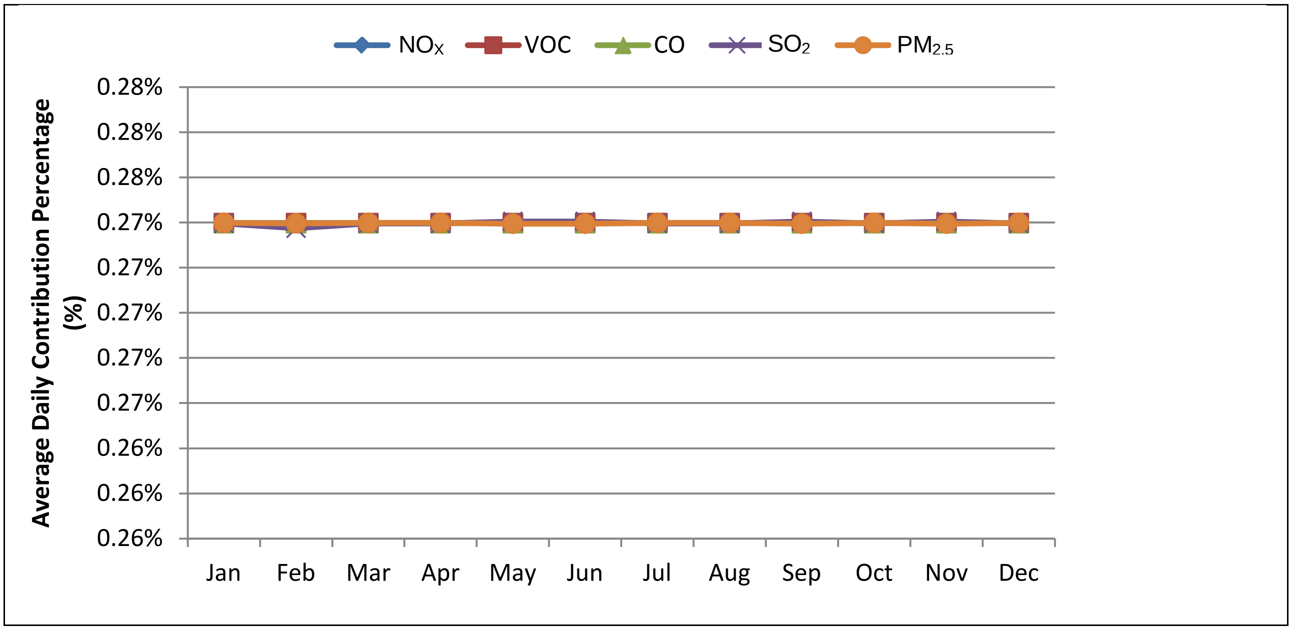


Figure 3-2 Monthly Average of Point Oil and Gas Emissions in the Uinta Basin

3.3 Fire

A review of the fire emissions inventory showed a large fire occurred in southwestern Utah in the late summer and early fall. The location of this fire corresponds with the high pollutant values in the spatial plots, as shown in **Figure 2-22** and the large September peak in monthly temporal trend, as shown in **Figure 2-23**. In order to minimalize the potential influence from this fire in the future year modeling scenarios, the emissions from the large fire are removed. The emissions in the grid cells where the fire occurred were removed from July 24 through September 27.

Table 3-4 shows the final fire emissions for each modeling domain used for typical year and future year modeling scenarios. Spatial plots are shown in **Figure 3-3** and **Figure 3-4** shows the monthly temporal trend in the 4-km domain. Note that while the fire emissions from the large fire were removed, September still shows a peak due to number of smaller fires that occurred during that month.

Table 3-4 Annual Fire Emissions

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	602,428	2,247,735	11,650,349	93,476	253,734	1,239,735	1,466,580
12-km	12,616	40,914	231,502	1,946	5,260	25,350	29,421
4-km	1,406	4,295	24,100	196	486	2,514	2,984

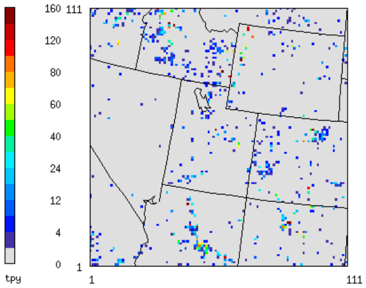
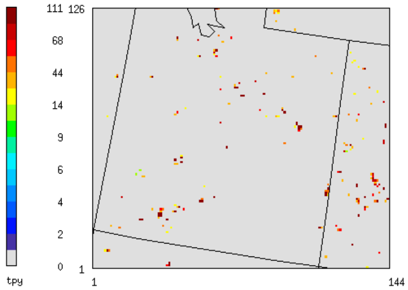
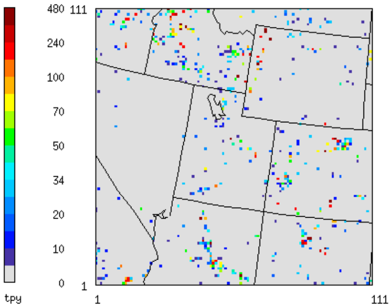
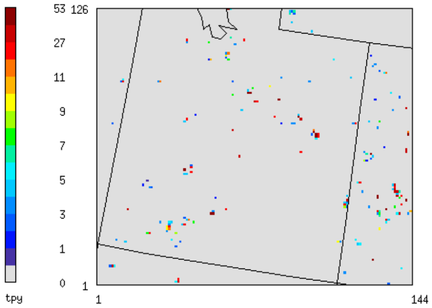
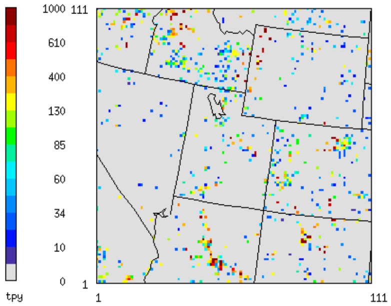
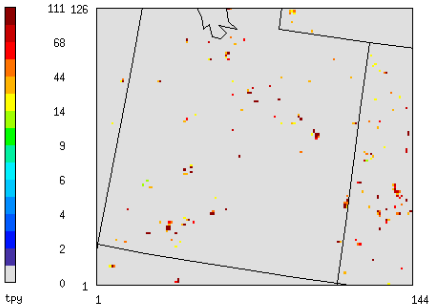
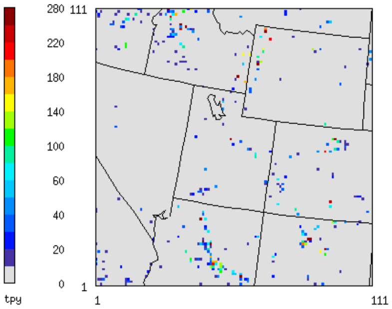
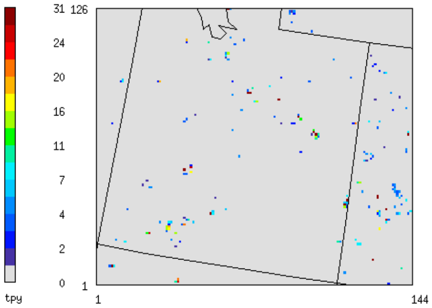
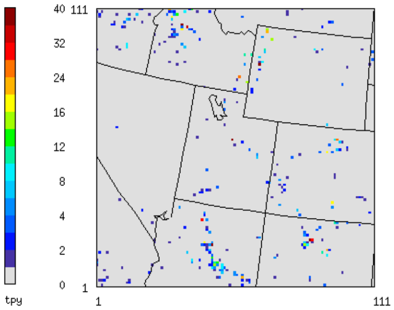
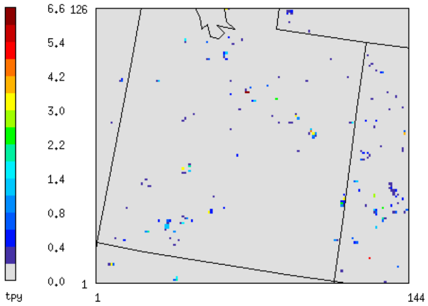
Species	Fire Sources (12-km)	Fire Sources (4-km)
NO$_X$		
ROG		
CO		
PM$_{2.5}$		
SO$_2$		

Figure 3-3 Fire Emissions Spatial Distribution in the 12-km and 4-km Domains

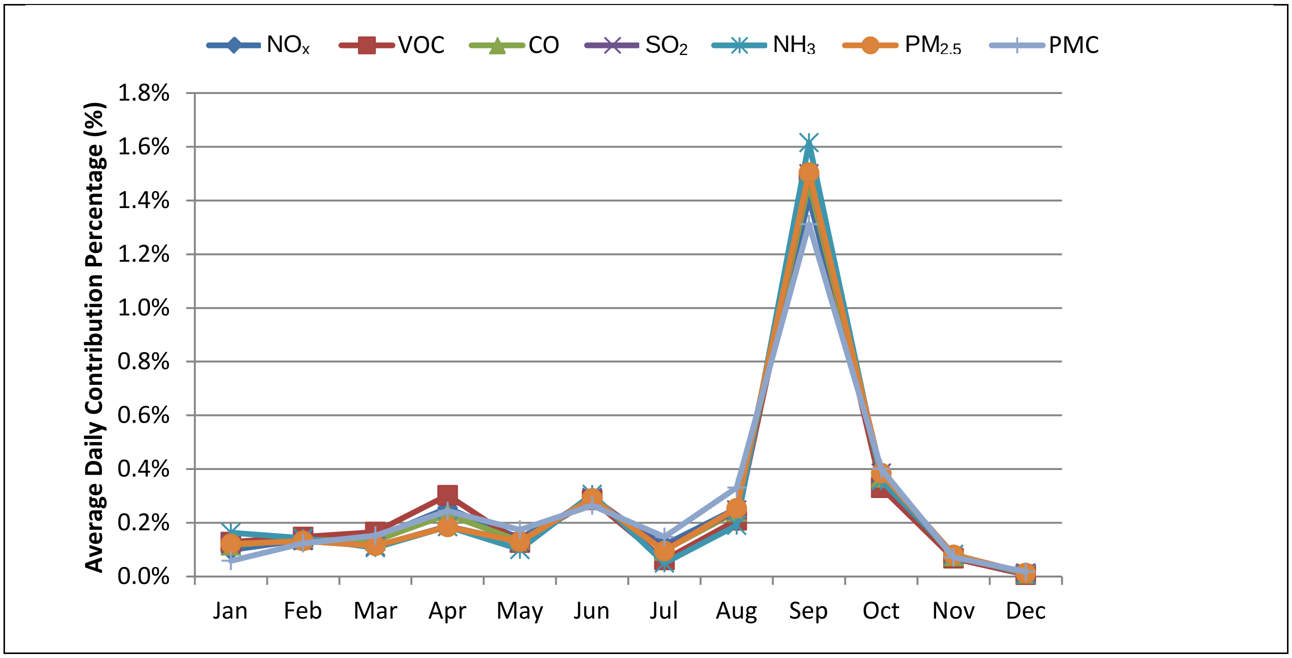


Figure 3-4 Monthly Average for Fire Emissions in the 4-km Domain

3.4 Final Typical Year Emissions

Emissions from each of the emissions sectors are merged together to create the CMAQ model-ready emissions files. They typical year emissions inventory will be modeled with the preferred model and configuration. The typical year final annual emission inventory consist of the EGU point sources, Uinta basin oil and gas sources and the revised fire emissions discussed in the previous sections and the remaining source sectors from the base year as described in Chapter 2.0.

Table 3-5 shows the final typical emissions for the 36-km, 12-km, and 4-km modeling domains. **Table 3-6** summarizes the annual emissions for each source sector in the 4-km domain. **Figure 3-5** shows the spatial distribution of the emissions in the 12-km domain and the 4-km domain. **Figure 3-6** shows the monthly temporal trend in the 4-km domain. The pollutant contributions of each sector in the final emissions totals are shown in **Figure 3-7**.

Table 3-5 Typical Year Final Annual Emissions by Domain

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	21,943,914	92,609,133	100,756,009	14,598,580	5,644,629	4,587,625	10,945,611
12-km	1,852,874	6,291,702	5,254,554	616,383	500,376	202,563	589,159
4-km	295,426	1,997,610	1,022,883	55,234	196,792	40,630	74,955

Table 3-6 Typical Year Emissions by Source Sector in the 4-km Domain

Source Sector	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
EGU Point[1]	86,197	1,631	7,363	29,192	424	3,348	5,314
Non- EGU Point[2]	57,905	22,639	27,135	21,174	424	5,372	11,403
Oil and Gas[3]	32,973	722,121	85,547	314	0	1,159	1,176
Area[2]	10,595	721,994	240,949	1,819	170,693	16,444	30,234
Non-road[2]	19,061	20,176	147,008	539	7	1,258	1,324
On-Road[2]	82,041	39,262	421,224	2,000	1,215	2,902	3,497
Ammonia[2]	0	0	0	0	23,543	0	0
Fire[1]	1,406	4,295	24,100	196	486	2,514	2,984
Biogenic[2]	5,248	465,492	69,557	0	0	0	0
Dust (fugitive and road) [2]	0	0	0	0	0	7,633	19,023
Total	**295,426**	**1,997,610**	**1,022,883**	**55,234**	**196,792**	**40,630**	**74,955**

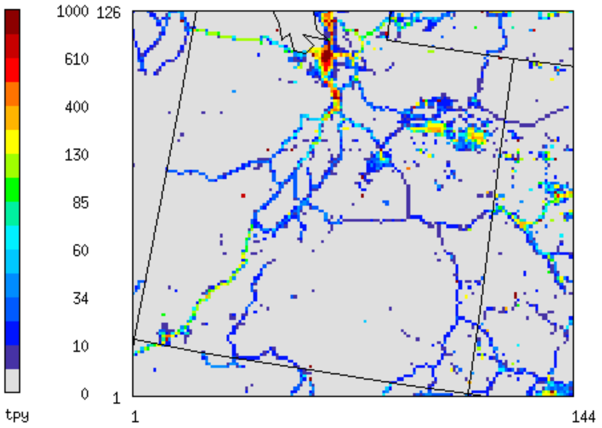
1 From the typical year inventory

2 From the base year inventory

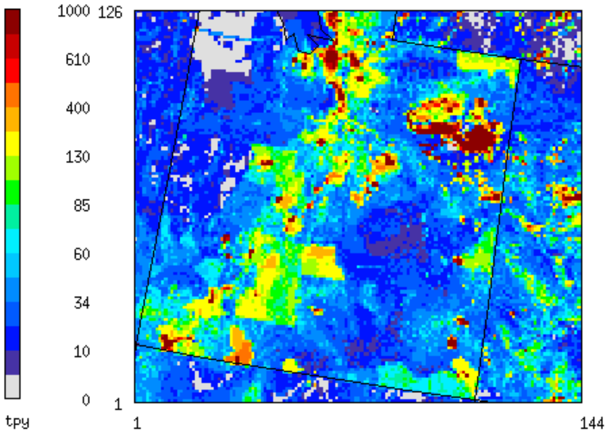
3 From the both base year and typical year inventory

4-km Domain

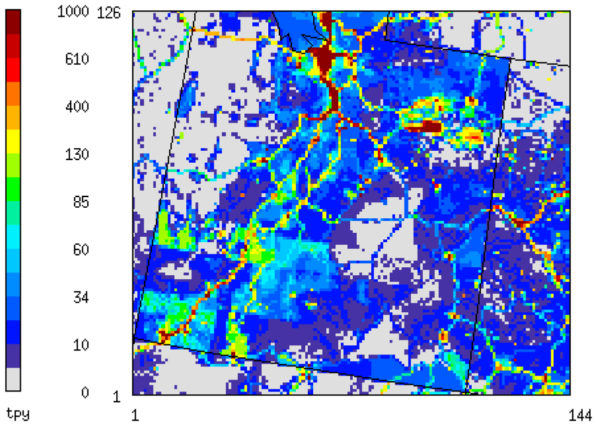
NO_X



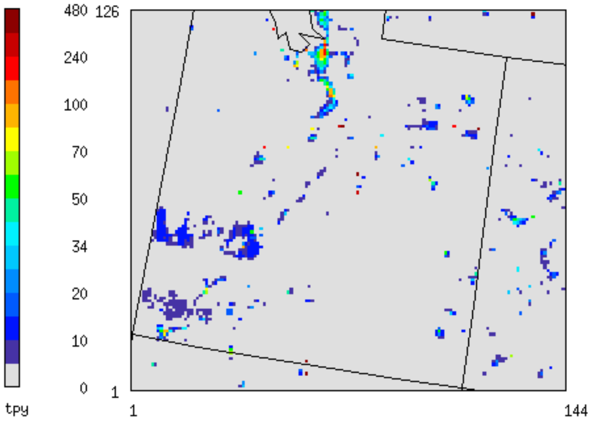
ROG



CO



$PM_{2.5}$



SO_2

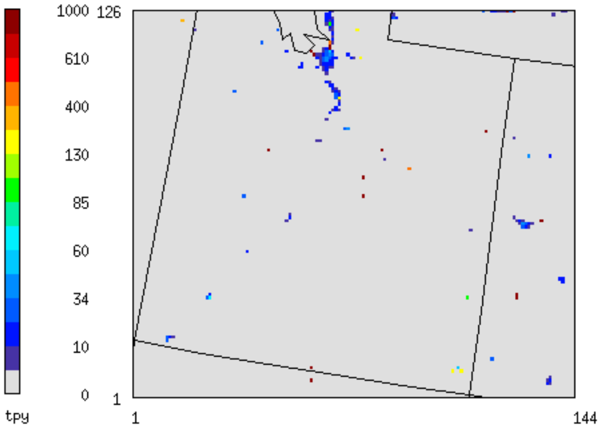


Figure 3-5 Typical Year Emissions Spatial Distribution in the 4-km Domain

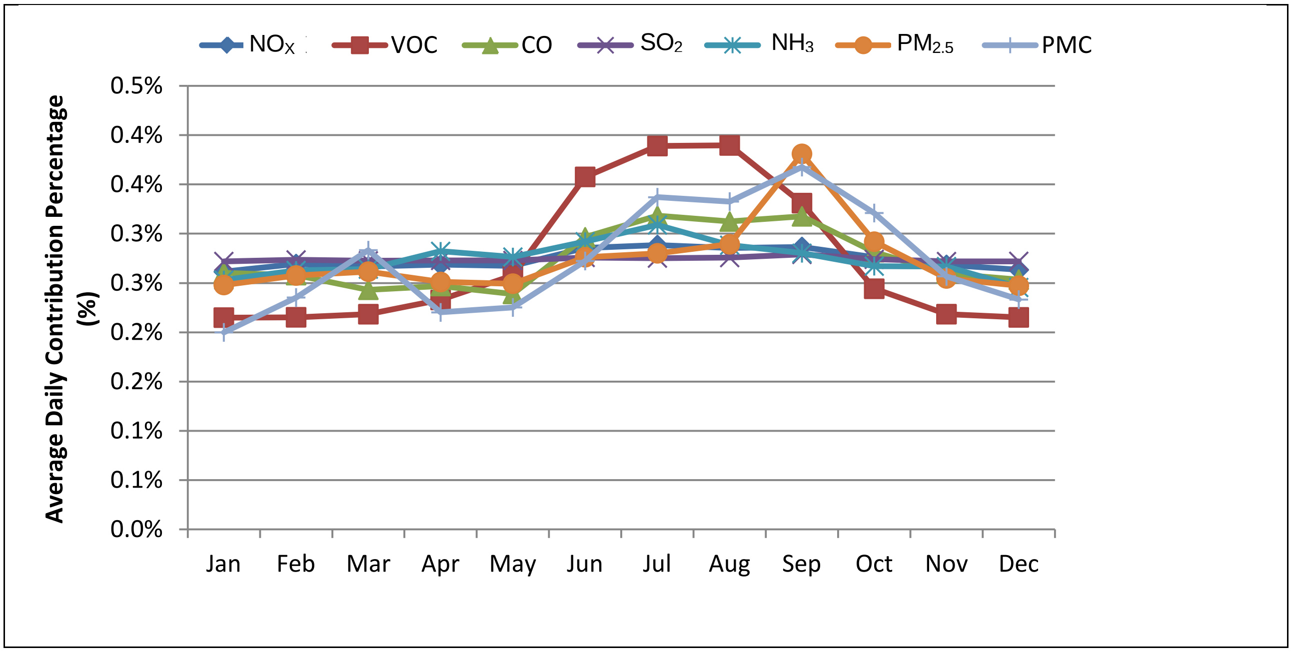


Figure 3-6 Monthly Average of the Final Emissions in the 4-km Domain

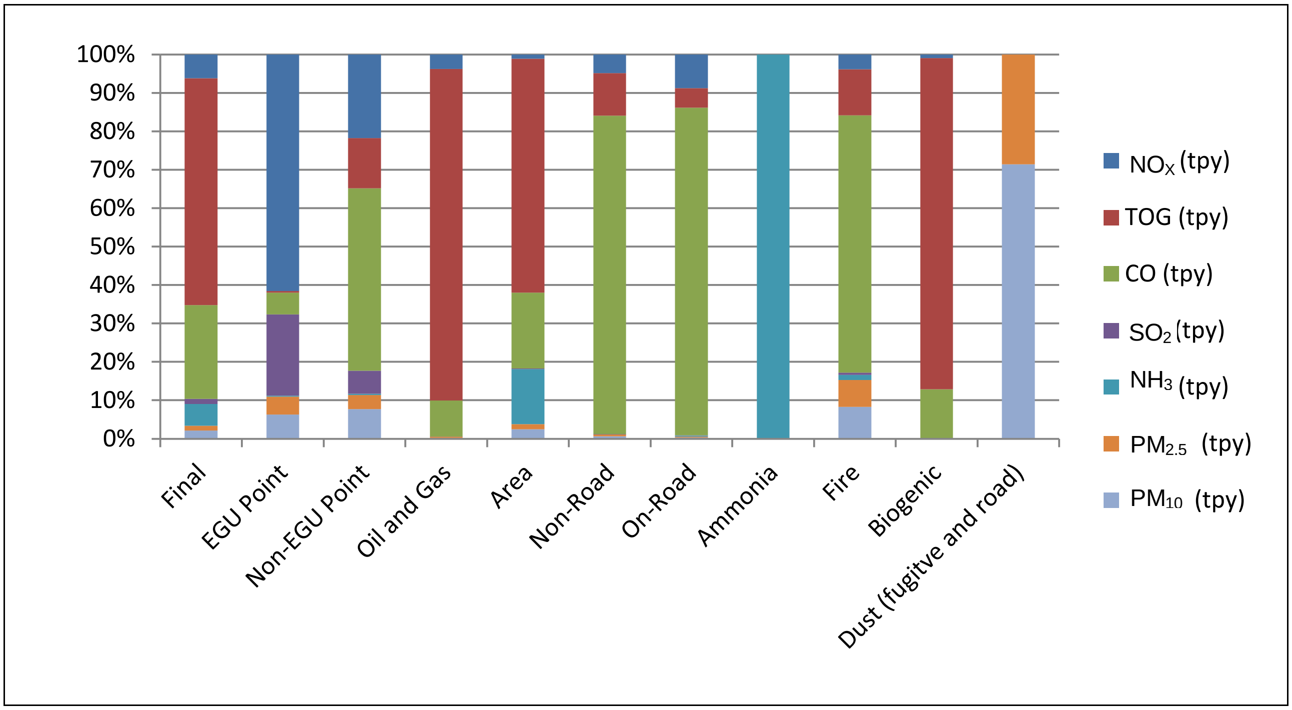


Figure 3-7 Annual Pollutant Contribution for Each Emission Source Sector

4.0 Future Year Emissions Inventories

The maximum emissions year was determined based on expected oil and gas activities in the Uinta Basin (see Section 4.1 for more information). Once this future year was determined, a comprehensive future year emissions inventory was developed for the model domains. The approach for developing the future year emissions inventories is presented for each source type in **Table 4-1**. For consistency and comparability with the base year EI, emissions that generally can be classified as non-anthropogenic sources, such as biogenic emissions, ammonia, fires, and dust, are held constant in the future year analyses. In addition, sources that have a relatively insignificant contribution to impacts in the Uinta Basin, such as sources in Canada, Mexico, and off-shore marine, are also held constant in the future year analyses.

Table 4-1 Future Year Emissions Inventory Data Sources

Source Groups	Spatial Area	Emissions Inventory for Maximum Emissions Year
Oil and Gas – Uinta Basin	Uinta Basin	Incorporate EIS/EA Data and project and extrapolate the 2010 Base Year
All other Oil and Gas Basins	United States	Base year inventories projected to future year, 2021, based on economic activity data
Point Sources (non-oil and gas)	All Areas Except Utah	2020 NEI based on 2005 platform (USEPA 2010)
Point Sources (non-oil and gas)	Utah	2020 NEI based on 2005 platform (USEPA 2010)
Area Sources (non-oil and gas)	All Areas Except Utah	2020 NEI based on 2005 platform (USEPA 2010)
Area Sources (non-oil and gas)	Utah	Methodology consistent with UDAQ
Non-road motor Vehicle (non-oil and gas)	All Areas Except Utah	2020 NEI based on 2005 platform (USEPA 2010)
Non-road motor Vehicle (non-oil and gas)	Utah	2020 NEI based on 2005 platform (USEPA 2010)
On-Road motor vehicle	All Areas	2020 NEI based on 2007 platform (USEPA 2012)

4.1 Maximum Year Selection

The 2010 emissions inventory is used to estimate future emissions in the Uinta Basin through 2021 based on anticipated changes in oil and gas related activities. The changes in future activity for the years 2011 through 2021 are estimated based on current trends and the anticipated rate of development in each county. The development of the activity data and growth of the 2010 are detailed in **Appendix F** and Section 4.3.1, respectively. **Table 4-2** shows the proposed development activities that are anticipated in the Uinta Basin for each county in addition to all approved development that had not yet occurred in 2010. The total wells were allocated to future years based on the estimated project start date and the proposed drilling schedule. Note that not all projects will be complete in 2021, which is the last year evaluated for this emissions inventory study. Therefore, not all the proposed wells shown in **Table 4-2** will be installed by 2021.

The number of wells estimated to be installed in each county per year, coupled with production decline curves and plug and abandon rates, are used to estimate yearly growth factors for each county. The growth factors for each year and county are shown in **Figure 4-1**. The these growth factors are applied to the emissions of the equipment types as described in the base year Uinta Basin oil and gas development section for the 2010 emissions inventory. Similarly, emissions reductions are also applied to each year of the emissions inventory using control factors by equipment type and county. After the selection of the maximum, the controls were revised to included recent oil and gas regulations. The revision of the control factors did not change the maximum emissions year.

The total estimated oil and gas emissions for the 5-counties in the Uinta Basin are shown in **Figure 4-2** for the years 2011 through 2021. The year with the highest emissions is year 2021 for all pollutants. There is an anticipated decline in emissions in the years 2011-2013 as the rate of development is temporally slowed until pending projects (shown in **Table 4-2**) are approved.

Table 4-2 Future Oil and Gas Development Projected for Uinta Basin Counties

Project	Estimated Starting Year	Total Number of Wells	Number of New Wells per County				
			Uintah	Carbon	Duchesne	Grand	Emery
Anadarko Greater Natural Buttes	2012	3,675	3,675	0	0	0	0
BBC West Tavaputs Plateau EIS	2011	596	0	570	26	0	0
Berry Petroleum ANF South Unit EIS/Vantage	2012	404	0	0	404	0	0
Enduring Resources Big Pack EA	2014	664	664	0	0	0	0
Enduring Resources Southam Canyon EA	2014	249	249	0	0	0	0
EOG Greater Chapita Wells EIS	2013	7,028	7,028	0	0	0	0
EOG North Alger EA	2012	22	22	0	0	0	0
Gasco Uinta Basin EIS	2012	1,538	499	0	1,039	0	0
Newfield Monument Butte EIS	2014	5,750	4,206	0	1,544	0	0
Oil and Gas Development on the Uintah and Ouray Indian Reservation[1]	2014	4,899[1]	-	-	-	-	-
Vantage Oil and Gas Project	2013	16	0	0	16	0	0
XTO Hill Creek Unit EA	2014	144	144	0	0	0	0
XTO Little Canyon EA	2014	510	510	0	0	0	0
XTO River Bend Unit Infill EA	2012	484	484	0	0	0	0
Total Project Wells		**21,080**	**17,481**	**570**	**3,029**	**0**	**0**
Existing and Ongoing	2011	156	106	0	50	0	0
Total Additional Wells		**21,236**	**17,587**	**570**	**3,079**	**0**	**0**

[1] The Uintah and Ouray Indian Reservation Oil and Gas Development EIS is a cumulative EIS. The 4,899 proposed wells assessed by this EIS are the number of wells proposed to be developed on tribal land that are already included in other NEPA projects. This EIS is included for completeness; however, since adding these wells to the projected level of development in the Uintah Basin would double count the impacts from other projects, these wells are not duplicated in the emissions inventory.

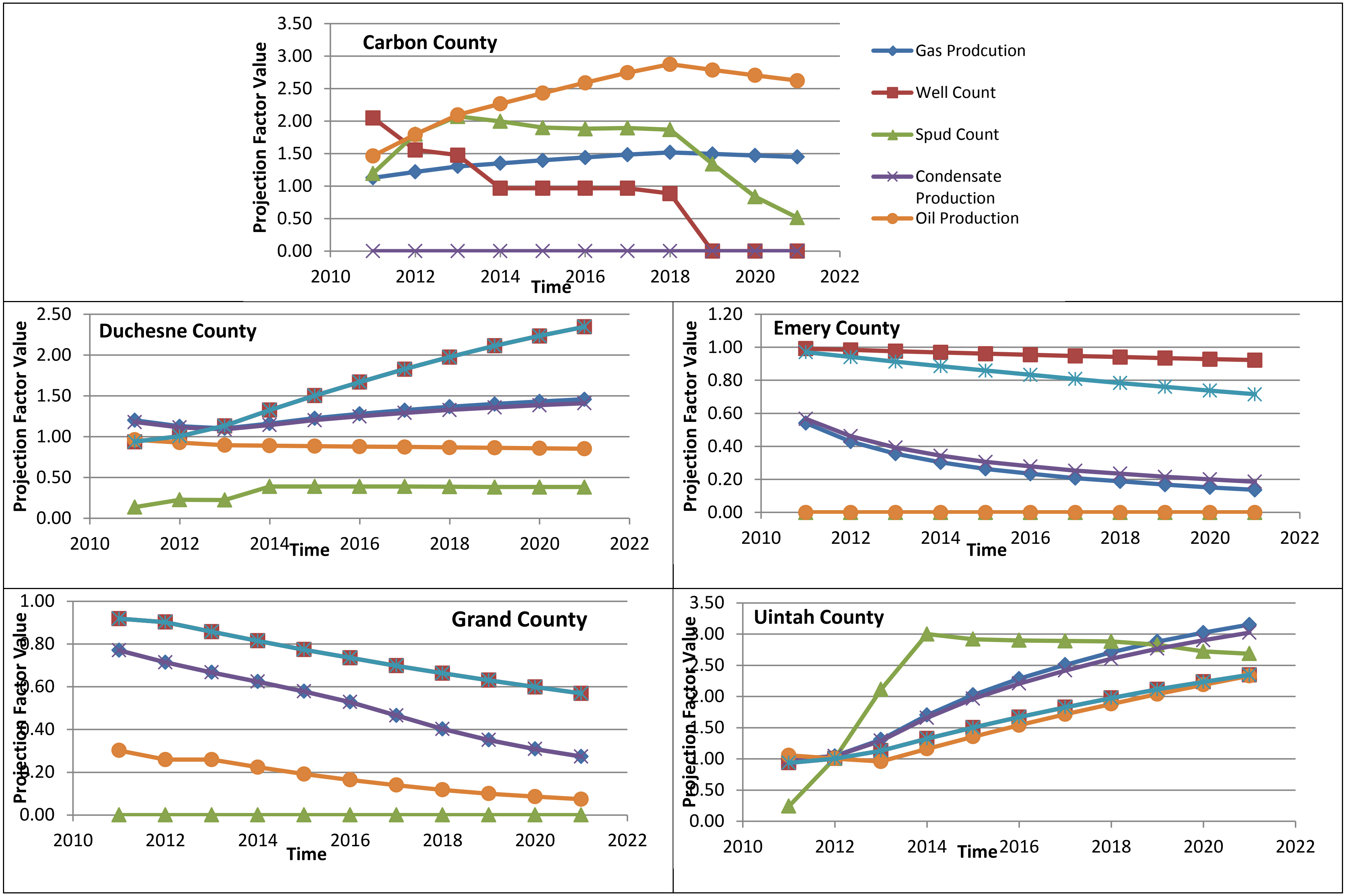


Figure 4-1 County Activity Surrogates for 2011 Through 2021

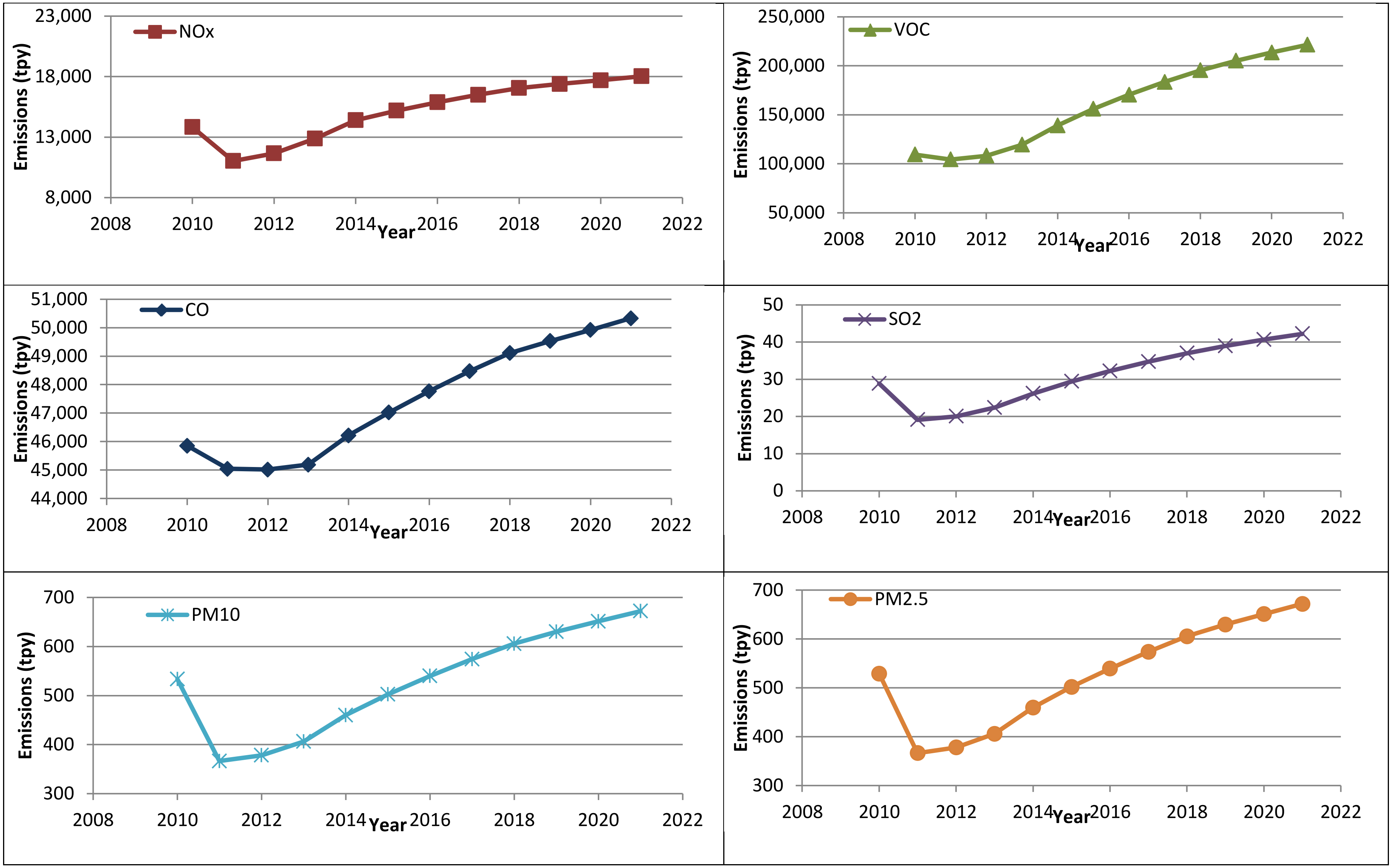


Figure 4-2 Projected Emissions from 2010 to 2021

4.2 Point Sources

For consistency with the base year point source emissions processing, the 2021 point source emissions consist of four source sectors: EGU point sources outside of Utah, EGU point sources inside of Utah, non-EGU point sources outside of Utah, and non-EGU point sources inside of Utah.

4.2.1 EGU

4.2.1.1 Emissions Input

The future year EGU point emissions for areas outside of Utah and inside of Utah are based on the 2020 projection of the CAP 2005-Based Platform, Version 4, Criteria Air Pollutants (USEPA 2010).

4.2.1.2 SMOKE Processing

The EGU point source emissions are temporally allocated by month, day, and hour using the annual emissions inputs and SCC-based allocation factors from SMOKE.

4.2.1.3 EGU Point Emissions Summary

Table 4-3 and **Table 4-4** show the final emission totals for each modeling domain for the EGU point sources outside of Utah and inside of Utah, respectively. Spatial plots of the 12-km EGU point sources outside of Utah are shown in **Figure 4-3**. **Figure 4-4** shows the spatial plot of 4-km EGU point sources inside of Utah.

Table 4-3 Annual EGU Emissions Outside of Utah

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	2,050,884	60,728	700,311	4,494,130	34,936	421,176	546,209
12-km	308,871	4,626	50,406	215,581	2,829	33,270	41,819
4-km	35,417	242	5,066	8,349	119	2,865	4,128

Table 4-4 Annual EGU Emissions Inside of Utah

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	64,097	476	4,115	25,837	253	4,731	6,027
12-km	64,097	476	4,115	25,837	253	4,731	6,027
4-km	64,097	476	4,115	25,837	253	4,731	6,027

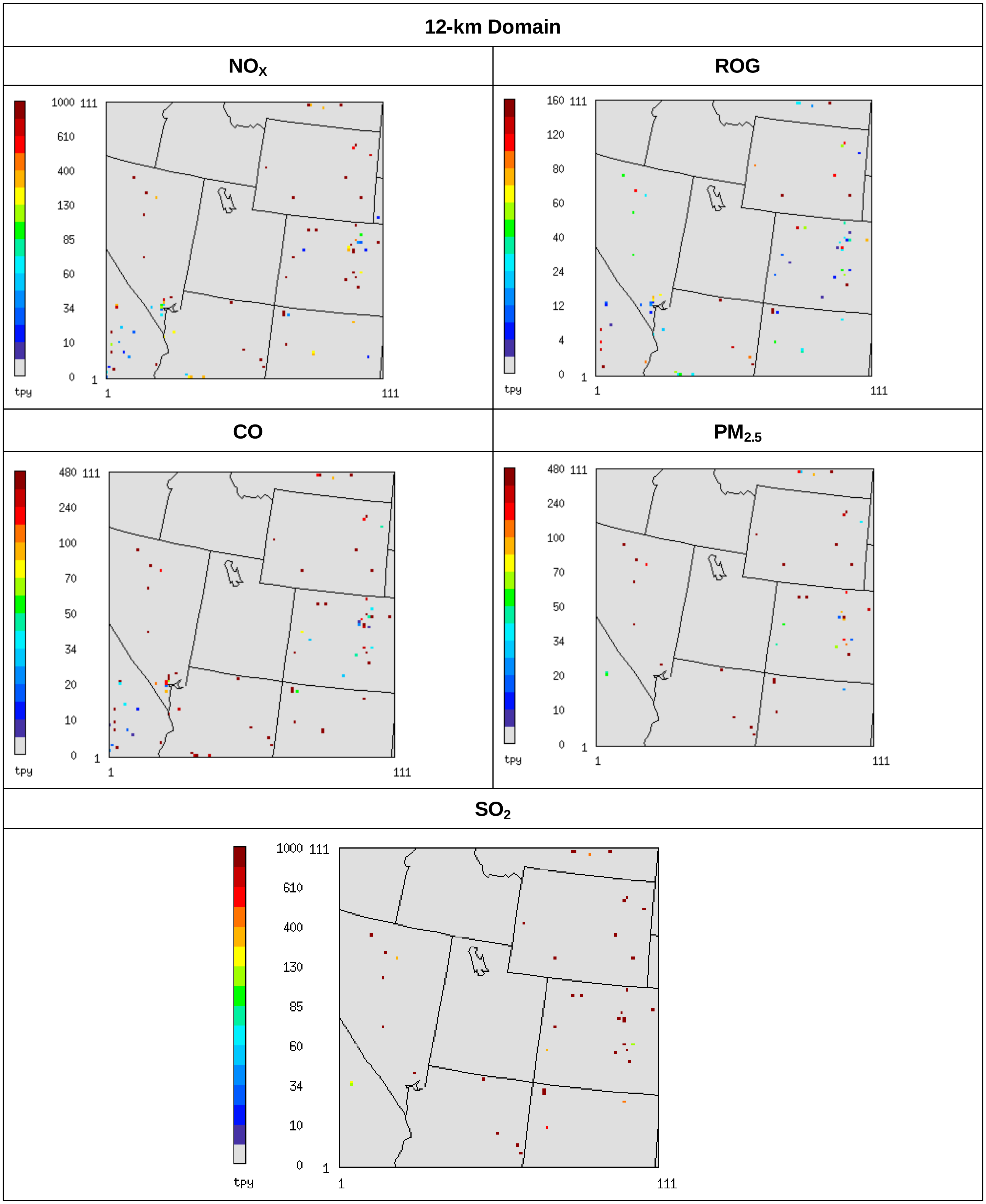
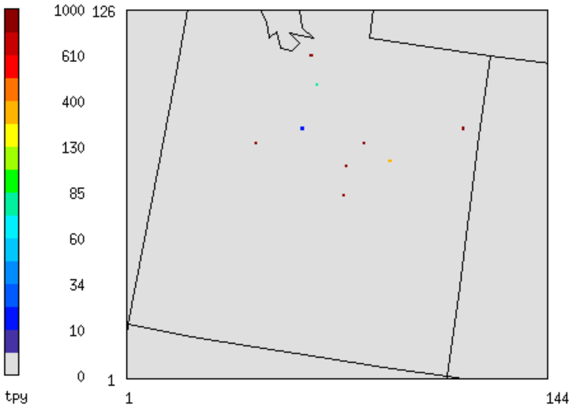


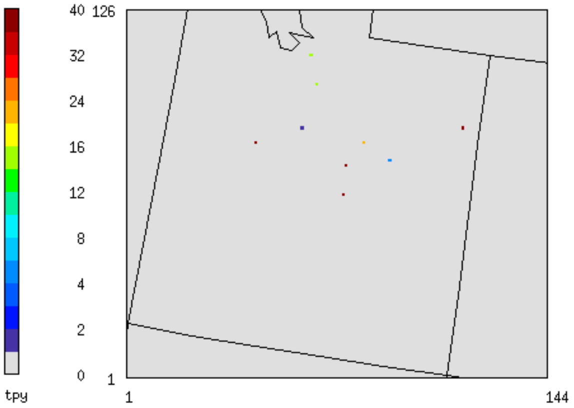
Figure 4-3 EGU Point Emissions Spatial Distribution in the 12-km Domain for Areas Outside of Utah

4-km Domain

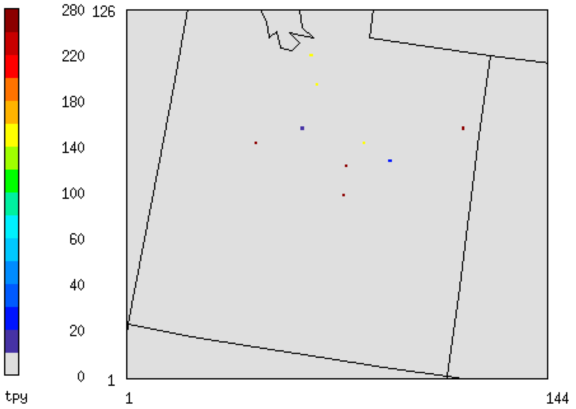
NO_X



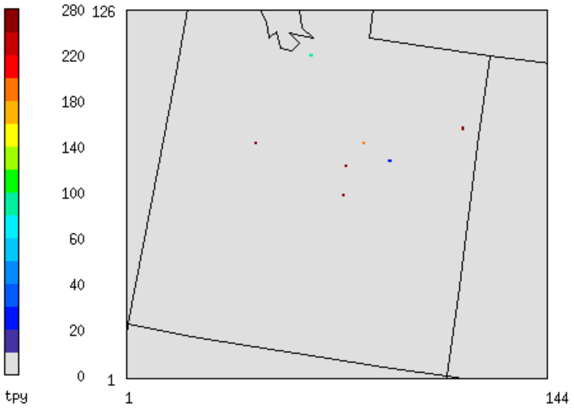
ROG



CO



$PM_{2.5}$



SO_2

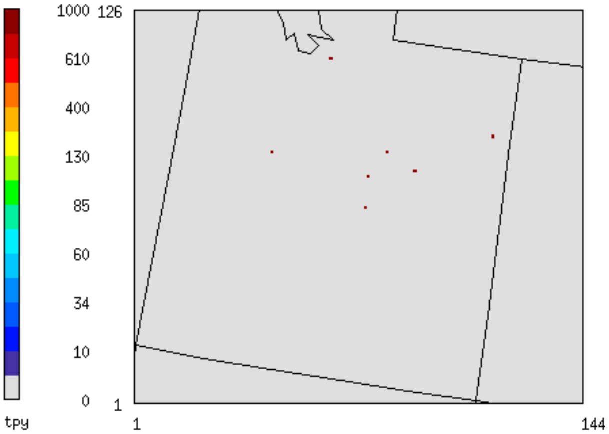


Figure 4-4 EGU Point Emissions Spatial Distribution in the 4-km Domain for Areas Inside of Utah

4.2.2 Non-EGU

4.2.2.1 Emissions Input

The future year non-EGU point emissions for areas outside of Utah and inside of Utah are based on the 2020 projection of the CAP 2005-Based Platform, Version 4, Criteria Air Pollutants (USEPA 2010).

4.2.2.2 SMOKE Processing

The Non-EGU point source emissions are temporally allocated by month, day, and hour using the annual emissions inputs and SCC-based default allocation factors from SMOKE.

4.2.2.3 Non-EGU Point Emissions Summary

Table 4-5 and **Table 4-6** show the final emission totals for each modeling domain for the non-EGU point sources outside of Utah and inside of Utah, respectively. Spatial plots of the 12-km non-EGU point sources outside of Utah are shown in **Figure 4-5**. **Figure 4-6** shows the spatial plot of 4-km non-EGU point sources inside of Utah. **Figure 4-7** shows the monthly temporal trend in the 4-km domain.

Table 4-5 Annual Non-EGU Point Emissions Outside of Utah

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	2,173,672	1,588,257	3,161,392	1,918,257	160,478	427,867	624,658
12-km	122,715	93,304	136,580	55,228	5,065	32,905	57,508
4-km	10,218	7,769	14,319	653	25	1,534	3,078

Table 4-6 Annual Non-EGU Point Emissions Inside of Utah

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	19,007	10,692	49,649	7,386	509	3,887	8,299
12-km	18,249	9,588	49,036	7,166	435	3,550	7,850
4-km	17,555	8,982	46,305	7,029	423	3,156	6,732

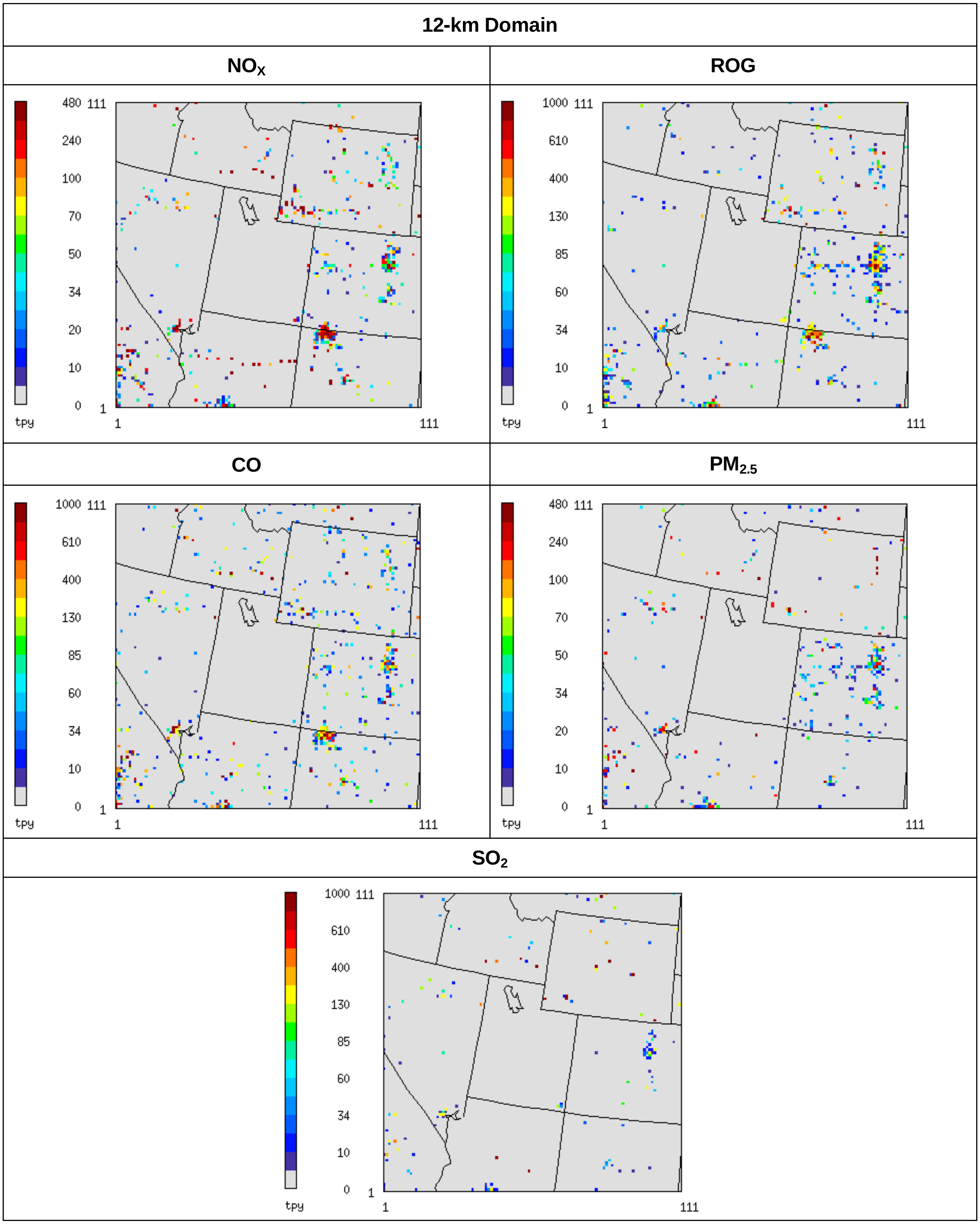
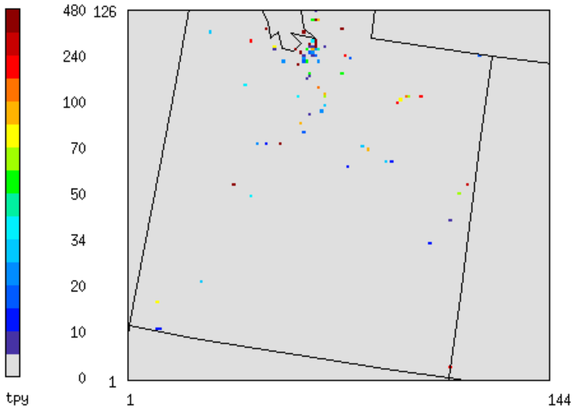


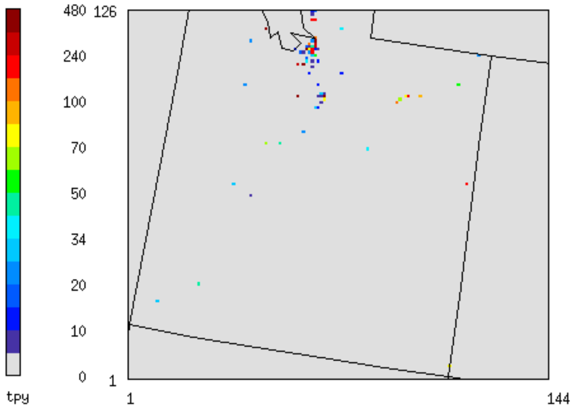
Figure 4-5 **Non-EGU Point Emissions Spatial Distribution in the 12-km Domain for Areas Outside of Utah**

4-km Domain

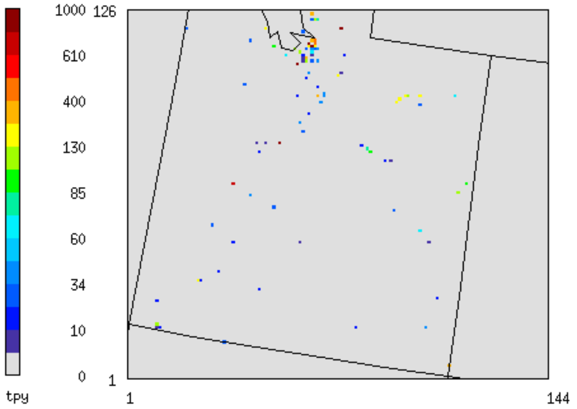
NO_X



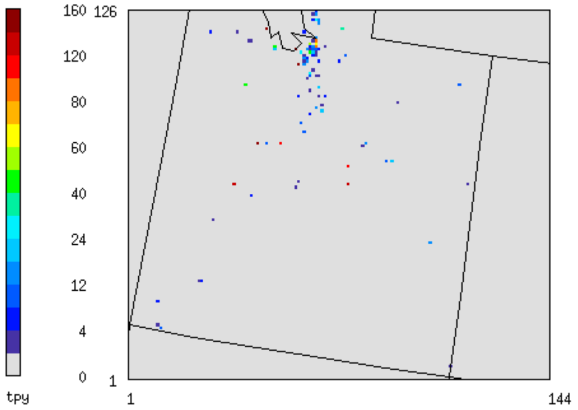
ROG



CO



$PM_{2.5}$



SO_2

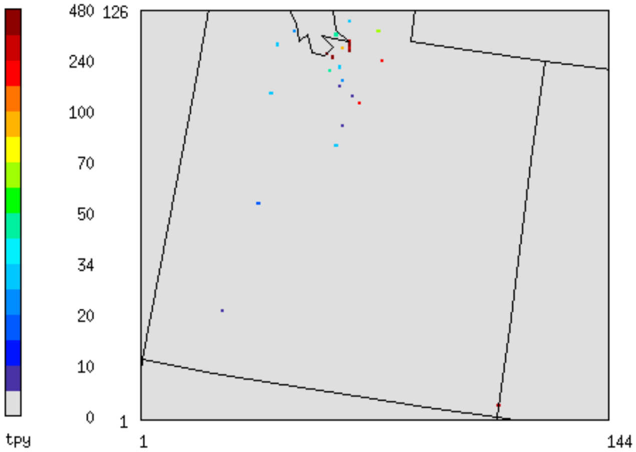


Figure 4-6 Non-EGU Point Emissions Spatial Distribution in the 4-km Domain for Areas Inside of Utah

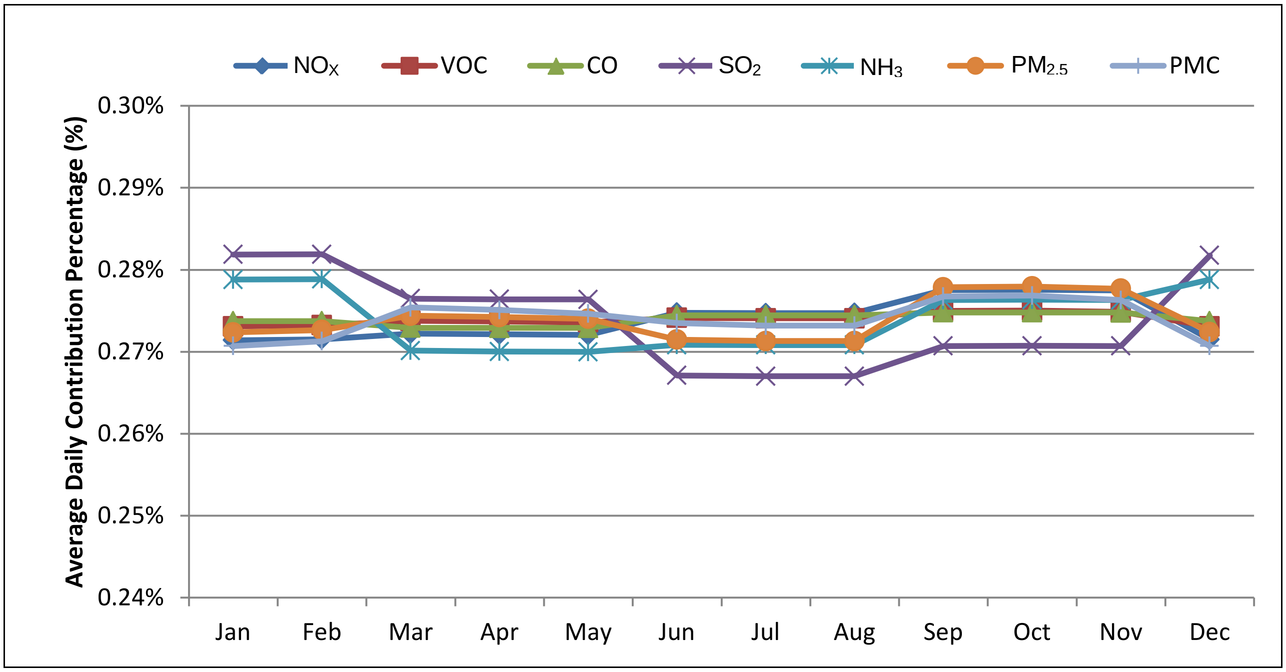


Figure 4-7 Monthly Average of Utah Non-EGU Point Emissions in the 4-km Domain

4.3 Oil and Gas

To analyze the future cumulative air quality effects of Reasonably Foreseeable Development (RFD), the future year emissions inventories are projected based on predicted activity and applicable controls. Known reasonable foreseeable future activity (RFFA) for oil and gas sources within the Uinta Basin include:

- Anadarko Greater Natural Buttes
- BBC West Tavaputs Plateau
- Berry Petroleum ANF South Unit
- Enduring Resources Big Pack
- Enduring Resources Southam Canyon
- EOG Greater Chapita Wells
- EOG North Alger
- Gasco Uinta Basin
- Newfield Monument Butte
- Oil and Gas Development on the Uintah and Ouray Indian Reservation
- Vantage Oil and Gas Project
- XTO Hill Creek Unit
- XTO Little Canyon
- XTO River Bend Unit

While projects outside the Uinta Basin were not explicitly considered, growth and controls were included for oil and gas sources in other areas of the U.S.

4.3.1 Uinta Basin

The 2010 emissions inventory is used to estimate future emissions in the Uinta Basin for 2021 based on anticipated changes in oil and gas related activities. Once the 2010 emissions are grown, on-the-books controls are the applied to the oil and gas emissions.

4.3.1.1 Growth

The same methods described for developing the 2010 emissions inventory are used to estimate the emissions for future years, with the exception that actual activity data are not available for future years. Instead, the changes in future activity for 2021 are estimated based on current trends and the anticipated rate of development in each county. Detailed information regarding the development of the projected level of oil and gas activity in year 2021 is detailed in **Appendix F**.

The activity surrogates provided in Appendix F were used to estimate 2021 emissions for all equipment except drilling, completion, recompletion, workover, and hydraulic fracturing pump engines. As with the base year development of these emissions are calculated using the operator survey data. The emissions development for those source categories follows an identical approach as described in **Section 2.2.1.1** with the exception that the projected 2021 oil and gas activity data was used instead of actual activity data. The VOC emissions from the produced water evaporation ponds for the base year are held constant. **Table 4-7** shows the total uncontrolled emissions by county.

Table 4-7 Uncontrolled 2021 Total Emissions

County	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
Carbon	775	3,371	839	2	30	30
Duchesne	5,396	38,871	28,090	7	195	195
Emery	90	344	77	0	5	5
Grand	112	1,077	102	0	4	4
Uintah	25,301	180,561	35,091	47	836	836
Total	31,675	224,224	64,199	56	1,070	1,070

4.3.1.2 Controls

When the USEPA releases a new regulation, it is either rolled out in phases over a number of years (e.g., the non-road diesel engine tier standards), or it becomes effective on a specified date. Once the regulation becomes effective, its requirements (i.e. recordkeeping, reporting, emissions controls, etc.) become known as on-the books requirements. At this time, there are numerous regulations that have on-the-books control requirements that will be required on or before the year 2021. This section discusses those on-the-books controls, specifics of the rules themselves, emission calculations, and any pollutants created as a result of control requirements (co-pollutants).

Natural Gas Pneumatic Devices

Oil and natural gas production sites often use pneumatic devices to automate various aspects of the production process such as maintaining liquid levels, flow rates, pressures, and temperatures. These pneumatic devices are driven either by compressed air or pressurized natural gas with the latter being the primary actuating gas when electricity is not available. Normal operation of a natural gas pneumatic (NG pneumatic) device involves the emitting, or bleeding, of gas to the atmosphere either continuously or intermittently. The presence of tens of thousands of NG pneumatic devices throughout the country, paired with a continuous or intermittent bleed of natural gas, results in large amounts of methane and VOC emissions to the atmosphere. Knowledge of this emissions source has prompted the USEPA to consider controls for NG pneumatic devices.

Control

Prior to federal and state requirements for NG pneumatic devices, it was common to see high bleed emission rates of 50 standard cubic feet per hour (scfh) or greater. With the release of the New Source Performance Standard (NSPS) for Crude Oil and Natural Gas Production, Transmission and Distribution (40 Code of Federal Regulations (CFR), Part 60, Subpart OOOO), all NG pneumatic devices constructed, modified, or reconstructed on or after October 15, 2013 at an oil or natural gas production site cannot exceed a bleed rate of 6 scfh (hereafter known as low bleed NG pneumatic devices).

For existing sources, NG pneumatic controllers with a bleed rate of 6 scfh or less are not required until the device is modified or reconstructed. This means the rule would not be retroactive. While the NSPS OOOO regulations are not retroactive for existing NG pneumatic devices, many operators have already started to switch to low-bleed devices. For those existing devices which are not switched to low-bleed devices, the effective life of the NG pneumatic device is estimated at 20 years, which means by 2021, approximately 30 percent of existing NG pneumatic devices will have been replaced by low-bleed pneumatic devices due to just modification, reconstruction, or replacement.

Sites that are either required to use low-bleed devices, or that voluntarily choose to switch to low-bleed devices have been conservatively estimated to reduce VOC emissions by approximately 88 percent.

Calculations

Exchanging NG pneumatic devices for low-bleed devices (bleed rates less than 6 scfh) results in, at minimum, a 88 percent reduction in VOC emissions when compared to the average bleed rate of 50 scfh for high-bleed devices. This reduction in emissions can be directly applied to existing NG pneumatic device emission rates since all devices are assumed to continuously operate throughout the year.

Co-Pollutant Creation

Changing NG pneumatic devices from high to low-bleed does not include any control methods that would result in the creation of co-pollutants.

Well Drilling and Workover Engines

Well drilling engines are non-road internal combustion engines (engines that do not power motor vehicles or remain in one location for longer than 12 months), that are used to power equipment integral to the rig operation. Well-drilling engines are primarily fueled with diesel and occasionally natural gas. Typically, a drilling rig will consist of one to three engines of various sizes depending on the type of well drilled and the intended purpose of the engine.

Control

The vast majority of drilling rigs are, and historically have been, powered through diesel fuel combustion. It was recognized by the USEPA, that non-road engines similar to those used for drilling rigs, but primarily used in construction, agriculture, and industrial settings, contribute heavily to air pollution across the country due to their widespread use (USEPA 2004). Consequently, USEPA adopted new emission standards for non-road diesel engines as well as new fuel standards which reduce the sulfur content allowable in non-road diesel fuel.

The new emission standards for the engines were implemented through a tiered approach, where new engines across a certain size range must meet specified emission rates when manufactured. This tiered approach allowed engine manufacturers time to develop a plan on how to reach the specified emission levels. By 2014, all newly manufactured engines must meet the strictest of the non-road diesel engine requirements, known as Tier 4 limits. It has been estimated that non-road diesel engines have a typical lifespan of 20 years, which means by 2021, approximately 35 percent of existing non-road diesel engines will have been replaced by Tier 4 compliant engines.

Similar to drilling rigs, workover rigs, which are used to re-stimulate or repair existing production wells, also use non-road diesel engines. Therefore, they must also meet the engine tier standards and likewise will have approximately 35 percent of their engines replaced by Tier 4 compliant engines by 2021.

As a result of the engine tier standards, which require manufacturers to use advanced emission reduction technologies, USEPA issued new fuel standards limiting the sulfur content of diesel fuel used for non-road engines. The primary driver for these standards is due to the fact that sulfur has the potential to damage emission control devices (USEPA 2013). By June 2010, all non-road diesel engines were required to meet a fuel sulfur content of 15 parts per million by weight (ppmw), therefore no additional emission reductions are expected for SO_2 in 2021 relative to 2010.

Calculations

The implementation of the engine tier standards are unique in that they staged across multiple years. Since many engines have an effective life of 20 years or more, and the tier standards only apply to newly manufactured engines, it is difficult to know the exact timeframe that drilling rigs would implement the Tier 4 standards. Based on engineering judgment and previous experience, it seems that the majority of drilling engines are currently compliant with Tier 2 standards. Therefore, emission percent decreases were calculated as the difference between the Tier 2 and Tier 4 non-road diesel engine standards. Since, Tier 2 standards do not have an emission standard for VOC, Tier 2 VOC emissions were assumed to be 10 percent of the combined NO_X and NMHC emission factor. Subsequently, Tier 2 NO_X emissions were assumed to account for the remaining 90 percent.

Co-Pollutant Creation

The adoption of Tier 4 engine standards and the switch to Ultra Low Sulfur Diesel (ULSD) result in decreases to emissions through advances in engine technology or fuel modifications. Therefore, co-pollutants are not created as a result of the increased control.

Well Initial Completions and Recompletions

After a well is drilled, it must be completed, or made ready for production. This process involves several steps including installation of production tubing, perforation of installed casings, and stimulation of the well which may or may not involve hydraulic fracturing. Periodically, existing production wells are recompleted where, an existing well is re-entered completed in a new zone or formation.

The primary emission source for well completion and well recompletion activities is the venting and/or combustion of flowback gases returned to the surface from the completion procedure. Often flowback gases include natural gas from the formation as well as liquids and inert gases injected into the formation for the completion procedure. Many operators have begun to either capture this flowback gas (to be sold) or send it to flare to control methane and VOC emissions. In general, the requirement to capture or control flowback gas was not a federal requirement until the implementation of NSPS OOOO.

Control

Under the requirements of NSPS OOOO, all new gas well completion operations with hydraulic fracturing initiated on, or after, January 1, 2015, must either capture or combust well flowback gases. The capture and/or combustion of well flowback gases is projected to result in VOC emissions reduction of 95 percent. Low formation pressures, the lack of natural gas infrastructure and gas composition can all make the capture of flowback gases infeasible. It is estimated that approximately 50 percent of completion and recompletion events will be able to capture flowback gases. However, since capture will not result in the creation of co-pollutants, combustion was assumed to be the method of control for all completion and recompletion events utilizing on the books controls.

Calculations

Capture of gas during flowback events is a very efficient process and usually results in near total capture of all gases being emitted. Nonetheless, there are some capture activities that are not 100 percent efficient or result in a small volume of gas being vented. Therefore, the total control from well flowback gas capture was conservatively estimated to be the minimum required control of 95 percent from NSPS OOOO.

Combustion is also a very efficient process that burns the flowback gas and results in a chemical reaction that converts carbon based components, such as VOC and methane (CH_4), to carbon dioxide (CO_2). Complete combustion is nearly impossible, but control into the high 90 percent range is possible with many combustion device manufacturers' assuring values of 98 or 99 percent for specific components. However, the requirements of NSPS OOOO state a minimum control efficiency of 95 percent; therefore control was set to this value.

Co-Pollutant Creation

As stated above, combustion of a fuel minimizes the emissions of several constituents of the flowback gas such as VOC and CH_4. However, the chemical reactions that occur during combustion also results in the creation of several other pollutants such as NO_X, CO, and PM.

In order to calculate the total co-pollutant emissions from completion and recompletion events, AP-42, Chapter 13.5 emission factors were used to estimate emissions for NO_X, CO, and PM. Wet gas analyses from five compressor stations in the basin were averaged together, assumed to be representative, and used to estimate VOC and HAP emissions. The SO_2 emissions were estimated assuming a hydrogen sulfide (H_2S) content in the gas of 2 grains per standard cubic foot.

Completion events were assumed to produce flowback gases at a rate of 0.5 MMscfd for 36 total hours. Recompletions were assumed to produce flowback gases at a rate of 0.25 MMscfd for 24 total hours.

Wellhead Compressor Engines

Natural gas produced from oil and gas wells typically loses pressure as it reaches the surface and progresses through the associated production equipment. Often the pressure of produced natural gas must be boosted in order to move into gathering or transmission systems. Compressors, often powered by internal combustion engines, are used to provide the boosted pressure to the natural gas.

Control

Wellhead compressor engines are natural-gas fired internal combustion engines regulated by the USEPA. The most recent regulations issued by the USEPA cover compression-ignition and spark-ignition internal combustion engines under NSPS IIII and NSPS JJJJ respectively. Both NSPS IIII and NSPS JJJJ limit the amount of NO_X, CO, and VOC emitted from internal combustion engines. The spark-ignition standards under NSPS JJJJ, the primary engine type of wellhead compressors, require that all new engines greater than 100 horsepower must be met by January 1, 2011.

Based on the expected lifespan of an internal combustion engine of 20 years, it is estimated that by 2021 approximately 50 percent of wellhead compressor engines will meet NSPS JJJJ standards. The NSPS JJJJ standards would reduce the NO_X and CO emissions by 90 percent and VOC emissions by 50 percent.

Calculations

The NSPS JJJJ standards require newly manufactured spark-ignition engines greater than 100 horsepower to meet emission standards of 1.0, 2.0, and 0.7 grams per horsepower–hour for NO_X, CO, and VOC emissions respectively, by January 1, 2011 at the latest. Based on the AP-42, Chapter 3.2 emission factors for 4-stroke rich burn (4SRB) engines, these standards result in emission reductions of 90 percent for both NO_X and CO and 50 percent for VOC.

Co-Pollutant Creation

The emission reductions as a result of the NSPS JJJJ standards will require advanced technologies to reduce emissions, none of which result in the creation of any co-pollutants.

Miscellaneous Engines

Similar to wellhead compressor engines, miscellaneous engines used in oil and gas fields are subject to National Emissions Standards for Hazardous Air Pollutants ZZZZ (also known Reciprocating Internal Combustion Engine Maximum Achievable Control Technology), NSPS IIII, and NSPS JJJJ. Therefore, all reductions assumed for wellhead compressor engines were used for miscellaneous engines.

Control

Due to the availability of natural gas, most miscellaneous engines in oil and gas fields are natural-gas fired internal combustion engines. Just as with the wellhead compression engines, the most recent regulations issued by the USEPA cover miscellaneous internal combustion engines under NSPS IIII and NSPS JJJJ, which require that all new engines greater than 100 horsepower must meet the revised emission standards by January 1, 2011.

Based on the expected lifespan of an internal combustion engine of 20 years, it is estimated that by 2021 approximately 50 percent of miscellaneous engines will meet NSPS IIII or NSPS JJJJ standards

Calculations

The NSPS JJJJ standards require newly manufactured spark-ignition engines greater than for 100 horsepower to meet emission standards of 1.0, 2.0, and 0.7 grams per horsepower-hour NO_x, CO, and VOC emissions respectively, by January 1, 2011 at the latest. Based on the AP-42, Chapter 3.2 emission factors for 4-stroke rich burn (4SRB) engines, these standards result in emission reductions of 90 percent for both NO_x and CO and 50 percent for VOC.

It was assumed that all miscellaneous engines would be spark-ignition and would meet the NSPS JJJJ standards.

Co-Pollutant Creation

The emission reductions as a result of the NSPS JJJJ standards will require advanced technologies to reduce emissions, none of which result in the creation of any co-pollutants quantified in this emissions inventory.

Natural Gas Dehydrators

Natural gas taken straight from a production well is usually saturated with water. If not removed from the gas, the presence of water in the gas stream can cause several issues downstream of the wellhead as the gas cools and water precipitates out. Issues include the water freezing in the pipelines, formation of hydrates which clog pipelines, or if acid gases, such as H_2S or CO_2, are present the free water can react with the acid gases to form corrosive acids (i.e. sulfuric or carbonic acid) which can damage the pipeline. For these reasons natural gas glycol dehydrators are used to remove the water from natural gas production streams.

Glycol dehydrators typically use triethylene glycol (TEG), a liquid desiccant that attracts water, to “contact” the wet gas stream. Through this contact process, water in the gas is removed to at a typical value of 7 pounds per MMscf (dry gas). The dry gas stream is then sent to a gathering or transmission pipeline. After contact with the produced natural gas stream, the, now water filled, glycol stream, or rich glycol, is regenerated in a reboiler where the glycol is heated above the boiling point of water to remove water from the glycol. The heat from the reboiler also causes VOCs to be released from the glycol and exit the reboiler vent stack. VOC emissions from the reboiler vent stack can vary greatly depending on the gas composition, but when summing all dehydrators in a field, the reboiler vent stack emissions may be a considerable emission source.

Control

The VOC emissions vented from the reboiler vent stack can be controlled via capture or combustion. Per 40 CFR, Part 63, Subpart HH (MACT HH), all glycol dehydration units with a gas throughput of 3 MMscfd or greater must control their emissions via capture or combustion. Either of these methods are assumed to control VOC emissions by a minimum of 95 percent; however, combustion control will result in the creation of co-pollutants.

For glycol dehydrators with a throughput less than 3 MMscfd, a combined HAP emission rate for benzene, toluene, ethyl benzene, and xylene (BTEX) must not exceed 1.10×10^{-4} for existing sources and 4.66×10^{-6} for new sources. This only applies to glycol dehydrators at major sources of HAPs or area sources of HAPs located within an Urban Area (UA) plus offset and Urban Cluster (UC) boundary. UA plus offset and UC is defined as the area occupied by each urbanized area, each urban cluster that contains at least 10,000 people, and the area located two miles or less from each urbanized area boundary. In order to simplify calculations, it was assumed that emission limits would be met via capture or combustion.

The average lifespan of a glycol dehydrator was assumed to be 20 years. With the effective date of MACT HH being 2007, by 2021 70 percent of all glycol dehydrators should meet the new source standards of MACT HH.

Calculations

Capture of gas from the reboiler stack is a very efficient process and would result in near total capture of all gases being emitted. Nonetheless, there are some capture activities that are not 100 percent efficient or result in a small volume of gas being vented. Therefore, the total control from reboiler vent stacks was conservatively estimated to be 95 percent.

Combustion of reboiler vent gas would be very similar to combustion of completion flowback. Since complete combustion is nearly impossible, but control into the high 90 percent range is possible with many combustion device manufacturers' assuring values of 98 or 99 percent for specific components, a minimum control efficiency of 95 percent was assumed.

Co-Pollutant Creation

In order to calculate the total co-pollutant emissions from glycol dehydrator vent stacks, AP-42, Chapter 13.5 emission factors were used to estimate emissions for NO_x, CO, and PM. The software simulation program GRI GlyCalc was used in conjunction with an average wet gas analysis to estimate VOC which were then assumed to be controlled by 95 percent for the combustion device.

The glycol dehydrator emissions were estimated for a 4.0 MMscfd dehydrator with a throughput of 500 standard cubic feet per hour for every hour of the year.

<u>Oil and Condensate Tanks</u>

After separation, crude oil produced from oil wells and condensate produced from gas wells is sent to aboveground storage tanks. The fluids extracted from a production well contains various components including non-methane or non-ethane hydrocarbons, most of which are in dissolved in the liquid phase under pressure and volatilize when sent to a storage tank at near ambient pressures. These hydrocarbons are emitted as VOCs, HAPs, and greenhouse gases (GHGs) in a process known as oil or condensate flashing respectively. Determining this emission rate is complex and depends on numerous process variables including the physical and chemical characteristics of the condensate or oil, as well as changes in pressure and temperature between the separator vessel and storage tank.

Once in the storage tank, ambient conditions cause the temperature inside the tank to fluctuate causing additional hydrocarbons to volatilize resulting in more VOC emissions (known as standing or breathing losses). The final form of emissions from tanks are called working losses in which the combined losses from filling and emptying the tanks are quantified. During filling operations, the liquid level in the tank rises. This rising liquid level produced a piston effect that increases the pressure the tank which expels gases in the vapor space (headspace) of the tank. During emptying of the tank, the liquid level decreases which draws air into the tank. This air becomes saturated with vapors and is expelled to the atmosphere as the liquid level again rises.

Control

Under NSPS OOOO, all storage tanks constructed, modified or reconstructed after October 15, 2013, with an uncontrolled VOC emission rate of 6 tons per year or greater, must control VOC emissions by a minimum of 95 percent via capture or combustion. Existing oil storage tanks are assumed to have an effective life of 10 years while condensate tanks have a life of 20 years. Therefore, by 2021, 100 percent of oil tanks are assumed to have been reconstructed and meeting NSPS OOOO standards while 70 percent of existing condensate tanks are assumed to be meeting NSPS OOOO standards.

Calculations

American Petroleum Institute's (API's) process simulator, E&P Tank Version 2.0, was used to determine emissions from oil and condensate flashing. Application of E&P Tank used analyses of oil and condensate data taken from basin level samples, separator conditions, and anticipated production rates.

The VOC emissions from flashing, working and breathing losses are controlled per NSPS OOOO when the combined total uncontrolled VOC emissions exceed 6 tpy. Since control via combustion results in the same assumed VOC control, as well as the production of co-pollutants, all control scenarios were conservatively assumed to utilize combustion control.

Co-Pollutant Creation

In order to calculate the total co-pollutant emissions from oil and condensate storage tanks, AP-42, Chapter 13.5 emission factors were used to estimate emissions for NO_x, CO, and PM. The software simulation program E&P Tank was utilized in conjunction with an average oil and condensate analyses to estimate total VOC emissions from flashing, working and breathing losses which were then assumed to be controlled by 95 percent through use of a combustion device.

4.3.1.3 2021 Uinta Basin Emissions Summary

Table 4-8 shows the 2021 final Uinta Basin oil and gas emissions with all growth and controls applied.

Table 4-8 2021 Uinta Basin Emissions Input

County	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
Carbon	767	3,115	2,304	2	92	92
Duchesne	4,770	19,676	28,360	7	238	238
Emery	82	255	450	0	26	26
Grand	120	863	288	1	16	16
Uintah	20,429	114,867	48,657	53	1,626	1,626
Total	**26,167**	**138,775**	**80,060**	**63**	**1,998**	**1,998**

4.3.2 Oil and Gas Sources Outside of Uinta Basin

All oil and gas sources outside of the Uinta Basin are grouped together, but point source and area source emissions are processed separately through SMOKE.

4.3.3 Emissions Inputs

Base year emissions from all WRAP Phase III basins, SWWY EI and WRAP Phase II are compiled together for future year processing. The base year emission values are grown using regional economic 2021 projections of oil and gas production taken from the U.S. Energy Information Administration (EIA) (USEIA 2011). The Rocky Mountain, Midcontinent, West Coast and Southwest oil and gas production projections for are used for the growth. **Table 4-9** shows which states are included the EIA regions. The projected oil and gas production are used to develop three types of growth factors: total oil production, total gas production, and combined production for the oil and gas basins as shown in **Table 4-10**. Since all WRAP Phase III basins are part of the Rocky Mountain region, the total oil production and total gas production growth factors are identical to t the Rocky Mountain region's growth factors. The SCC is used to determine the growth factor type used for the projections.

In addition to the natural gas and oil production growth factor, a combined production growth factor is developed to use for the projection of equipment that are not oil or gas specific. Some examples of emission categories that are used in both oil production and gas production are: heaters, fugitive emissions, drill rigs, truck loading, condensate tanks, and miscellaneous engines. The combined production growth factor was calculated for each oil and gas basin, where possible, using the basin oil and gas production ratio. For emissions from the WRAP II and SWWY EI, the combined production growth factor was calculated for the given EIA Region. After the 2010 emissions are grown to 2021 using the growth factors, on-the books controls were applied. The resulting 2021 total emissions are shown by basin in **Table 4-11**. **Table 4-12** shows the 2021 final emission for oil and gas sources outside of the Uinta Basin by point and area source type.

Table 4-9 EIA Regions

State	EIA Region	State	EIA Region
Alaska	West Coast	Montana	Rocky Mountain
Arkansas	Southwest	North Dakota	Midcontinent
Arizona	Southwest	Nebraska	Midcontinent
California	West Coast	New Mexico	Southwest
Colorado	Rocky Mountain	Nevada	Rocky Mountain
Hawaii	West Coast	Ohio	Midcontinent
Iowa	Midcontinent	Oklahoma	Midcontinent
Idaho	Rocky Mountain	Oregon	West Coast
Illinois	Midcontinent	South Dakota	Midcontinent
Indiana	Midcontinent	Tennessee	Midcontinent
Kansas	Midcontinent	Texas	Southwest
Kentucky	Midcontinent	Utah	Rocky Mountain
Michigan	Midcontinent	Washington	West Coast
Minnesota	Midcontinent	Wisconsin	Midcontinent
Missouri	Midcontinent	Wyoming	Rocky Mountain

Table 4-10 Growth Factors for 2021 by Basin

Basin	Natural Gas Production	Oil Production	Combined Production
Denver-Julesburg	1.083	1.401	1.12
Midcontinent	0.864	1.342	0.9
North San Juan	1.083	1.401	1.083
Piceance	1.083	1.401	1.094
Powder River	1.083	1.401	1.11
Rocky Mountain	1.083	1.401	1.113
South San Juan	1.083	1.401	1.085
Southwest	0.913	1.17	0.952
West Coast	0.762	0.882	0.882
Wind River	1.083	1.401	1.094

Table 4-11 2021 Oil and Gas Emissions by Basin

Basin	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
Denver-Julesburg	15,582	94,962	11,750	146	586	593
Midcontinent	8,656	10,820	2,178	2,717	4	70
North San Juan	4,174	3,042	4,849	7	46	46
Piceance	6,938	16,707	5,153	138	415	422
Powder River	13,165	12,748	9,019	608	647	647
Rocky Mountain	24,995	201,474	12,261	3,516	202	328
South San Juan	25,629	52,727	18,205	141	305	305
Southwest	36,475	79,646	15,444	15,200	116	145
West Coast	14,339	2,682	10,910	1,066	325	1,093
Wind River	1,093	9,302	1,593	1,565	32	32
Total	151,047	484,109	91,364	25,104	2,677	3,681

Table 4-12 Oil and Gas Emissions Inputs for Areas Outside of the Uinta Basin

Type	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
Area	92,558	454,751	45,851	3,320	1,863	1,909
Point	58,489	29,359	45,513	21,785	814	1,771
Total	151,047	484,109	91,364	25,104	2,677	3,681

4.3.4 SMOKE Processing

All speciation profiles and spatial allocation used for the base year processing of the oil and gas sources are applied as discussed in the base year section. All oil and gas equipment use the default temporal allocation profiles from the USEPA.

4.3.5 Oil and Gas Emissions Summary

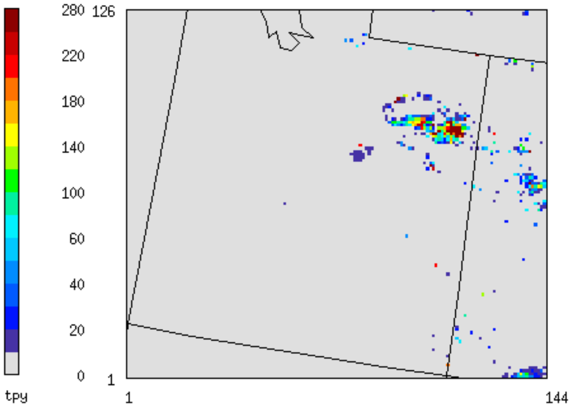
Table 4-13 shows the estimated total oil and gas emissions in 2021 for each model domain. **Figure 4-8** shows the spatial distribution of oil and gas sources in the 4-km domain.

Table 4-13 2021 Annual Oil and Gas Emissions by Domain

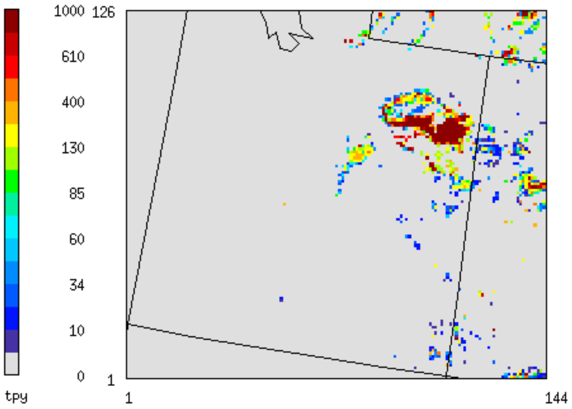
Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	167,369	1,585,613	164,771	24,790	0	4,402	4,661
12-km	108,807	1,379,183	134,845	5,851	0	4,041	4,128
4-km	35,257	800,376	87,081	339	0	2,347	2,367

4-km Domain

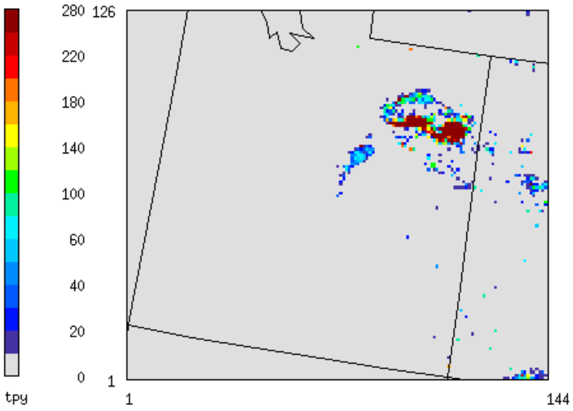
NO_X



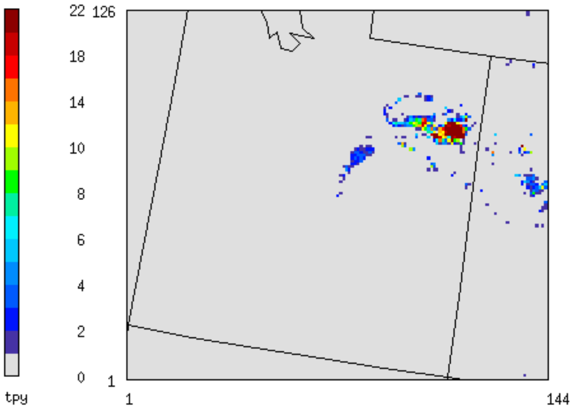
ROG



CO



$PM_{2.5}$



SO_2

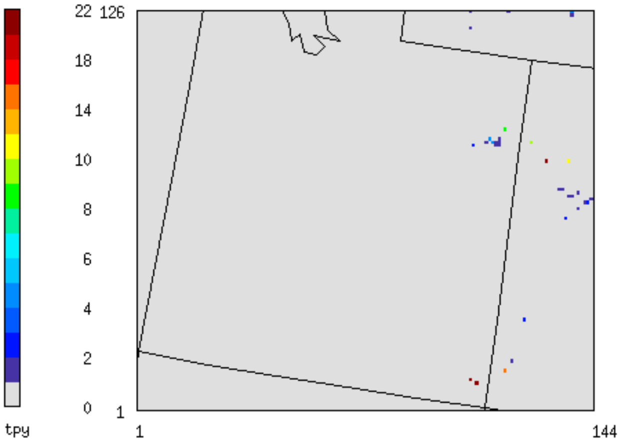


Figure 4-8 All Oil and Gas Emissions Spatial Distribution in the 4-km Domain

4.4 Area Sources

Area source emissions are processed separately for areas both outside Utah and inside Utah.

4.4.1 Emissions Inputs

4.4.1.1 Area Sources Outside of Utah

The future year area source emissions for areas outside of Utah are based on the 2020 projection of the CAP 2005-Based Platform, Version 4, Criteria Air Pollutants (USEPA 2010).

4.4.1.2 Utah Area Sources

The UDAQ 2010 Emissions Inventory Area Sources is used as initial input for the base year area sources inside of Utah as described in **Section 2.3.1.1**. The future year area source emissions inside of Utah are grown from these base year emissions by applying growth factors based on projected population and economic factors. **Table 4-14** shows the annual total of the final emissions processed by SMOKE for area sources inside of Utah.

Table 4-14 Area Source Emissions Input Inside of Utah

NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
10,716	827,805	263,834	1,294	196,991	17,874	34,907

4.4.2 SMOKE Processing

All area source emissions are temporally allocated by month, day, and hour using annual emissions and SCC-based allocation factors. These factors are based on the cross-reference and profile data supplied with the SMOKE. Area sources are spatially allocated in the domain by SCC-based spatial allocation surrogate files.

4.4.3 Area Emissions Summary

Table 4-15 and **Table 4-16** show the final emission totals for each modeling domain for area sources outside of Utah and inside of Utah, respectively. Spatial plots of the 12-km area sources outside of Utah are shown in **Figure 4-9**. **Figure 4-10** shows the spatial plot of 4-km area sources inside of Utah.

Table 4-15 Annual Area Source Emissions for Outside of Utah

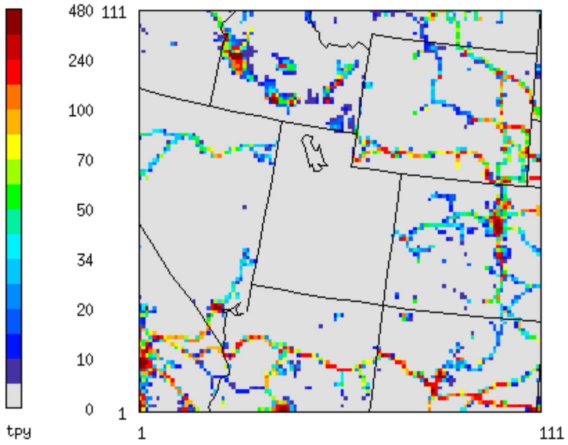
Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	2,641,588	7,831,818	7,026,497	1,216,825	131,849	1,026,453	1,293,567
12-km	142,914	395,718	296,146	30,191	6,247	56,844	87,113
4-km	3,298	5,575	10,853	576	8	1,597	1,708

Table 4-16 Annual Area Source Emissions for Inside of Utah

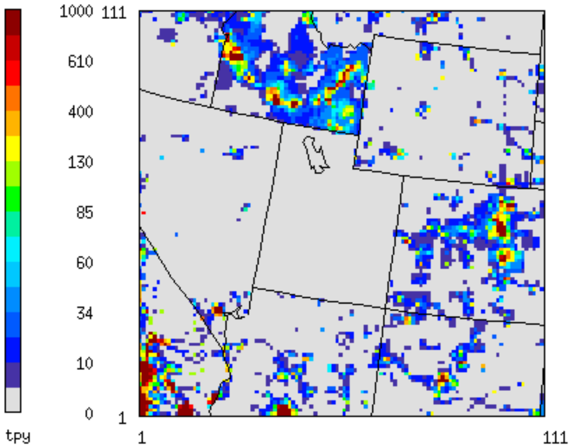
Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	12,040	776,796	256,138	1,363	196,013	17,195	33,286
12-km	12,040	776,796	256,138	1,363	196,013	17,195	33,286
4-km	10,420	715,100	223,436	1,271	170,090	14,263	27,326

12-km Domain

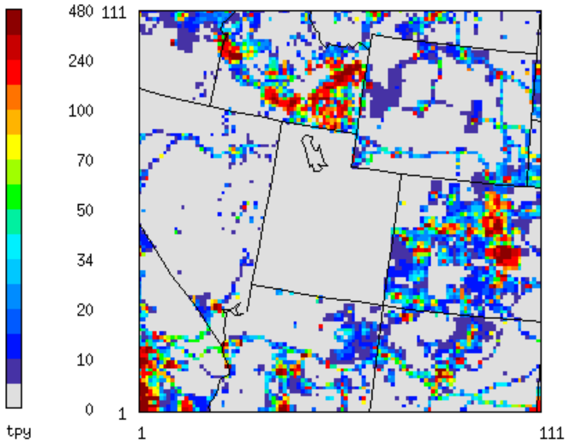
NO_X



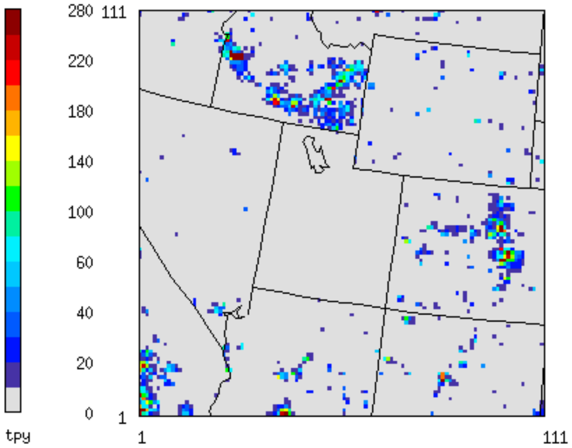
ROG



CO



$PM_{2.5}$



SO_2

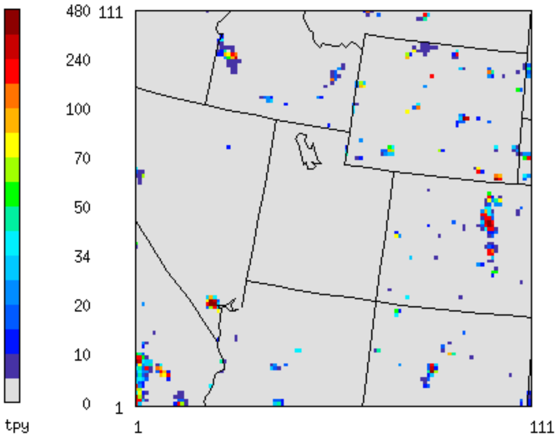
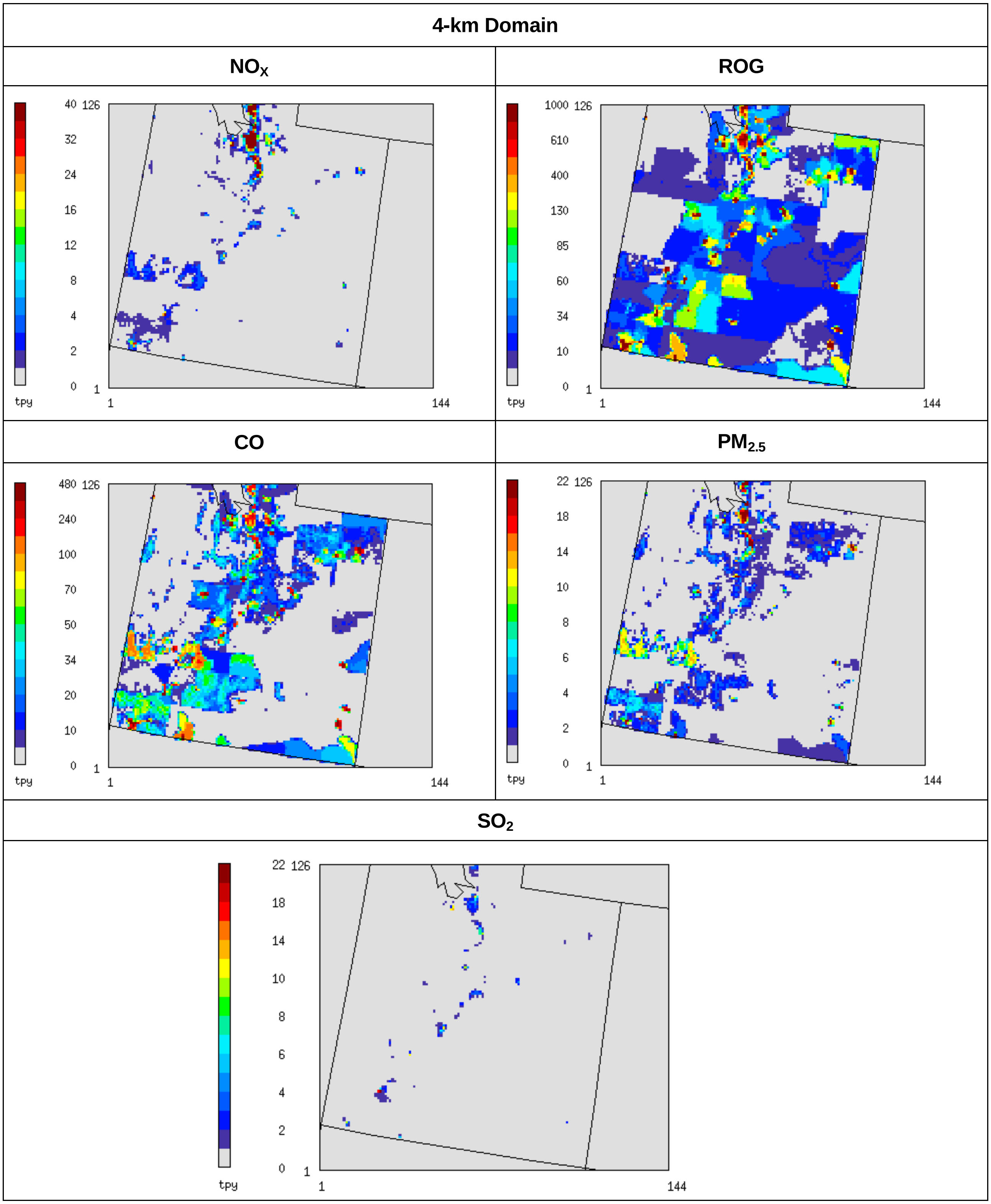


Figure 4-9 Area Emissions Spatial Distribution in the 12-km Domain for Areas Outside of Utah



4-km Domain

NO_X

ROG

CO

$PM_{2.5}$

SO_2

Figure 4-10 Area Emissions Spatial Distribution in the 4-km Domain for Areas Inside of Utah

4.5 Non-Road

For consistency with the processing of the non-road base year emissions, the non-road emissions are separated into non-road emission sources outside of Utah and inside of Utah. Both EIs, however, are from the same data source.

4.5.1 Emissions Inputs

The future year non-road source emissions for areas outside and inside of Utah are based on the 2020 projection of the CAP 2005-Based Platform, Version 4, Criteria Air Pollutants (USEPA 2010). Care is taken to remove emissions in this sector that are quantified elsewhere in the EI to prevent double counting. Some examples of non-road engines that are included in other source categories include mining equipment, construction equipment for mining, and drill rig engines. No other modifications are made to the non-road EI before SMOKE processing.

4.5.2 SMOKE Processing

The non-road source emissions are temporally allocated by month, day, and hour using the annual emissions inputs and SCC-based allocation factors from SMOKE.

4.5.3 Non-Road Emissions Summary

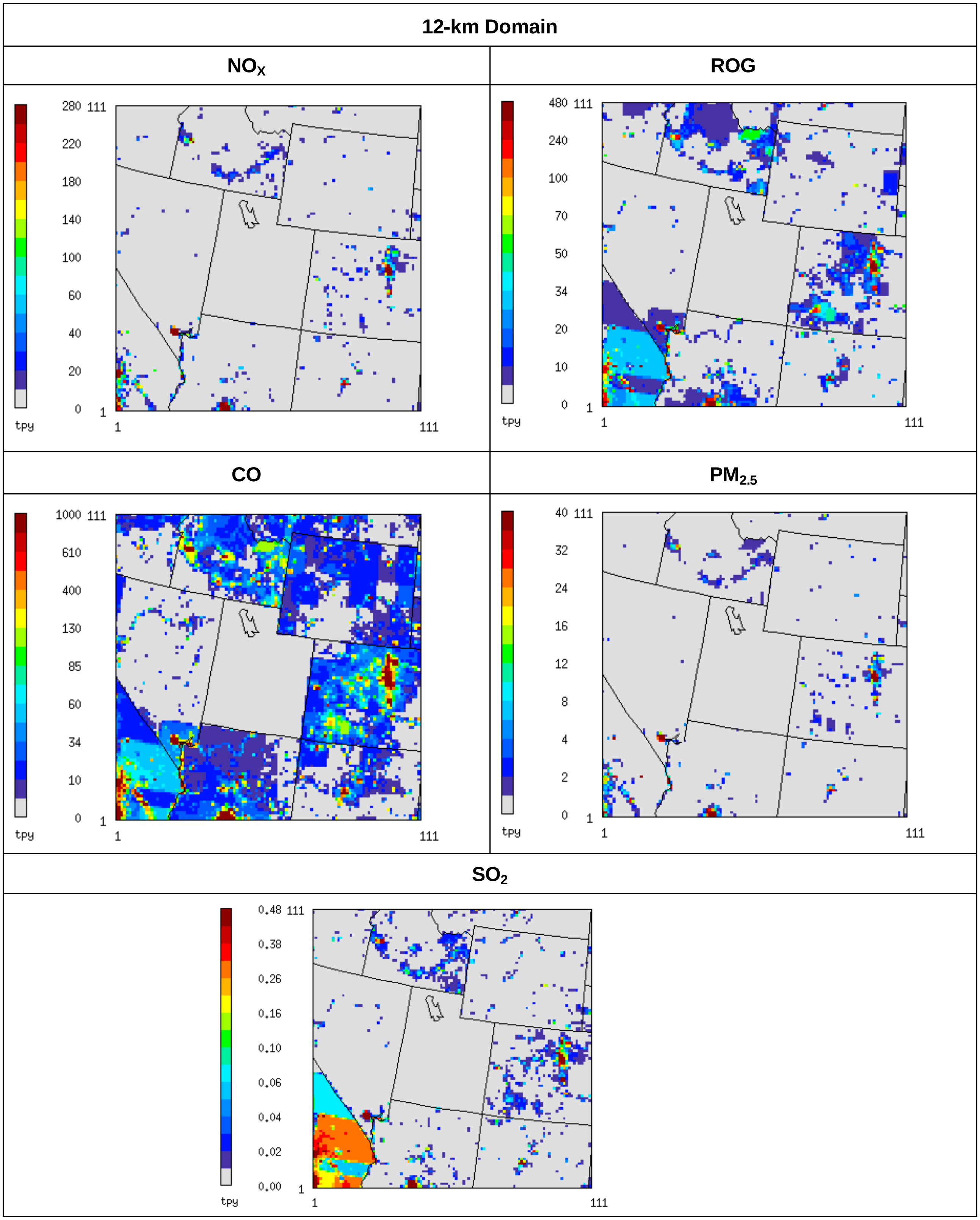
Table 4-17 and **Table 4-18** show the final emission totals for each modeling domain for the non-road sources outside of Utah and inside of Utah, respectively. Spatial plots of the 12-km non-road sources outside of Utah are shown in **Figure 4-11**. **Figure 4-12** shows the spatial plot of 4-km non-road sources inside of Utah. **Figure 4-13** shows the monthly temporal trend in the 4-km domain.

Table 4-17 Annual Non-Road Source Emissions for Outside of Utah

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	1,006,500	1,485,741	13,420,775	2,922	2,517	94,284	101,443
12-km	59,743	103,540	825,215	297	164	6,339	6,987
4-km	1,390	3,346	19,271	4	4	151	160

Table 4-18 Annual Non-Road Source Emissions for Inside of Utah

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	6,776	15,664	118,560	21	19	768	814
12-km	6,776	15,664	118,560	21	19	768	814
4-km	5,834	13,023	103,096	18	17	670	710


12-km Domain

NO_X ROG

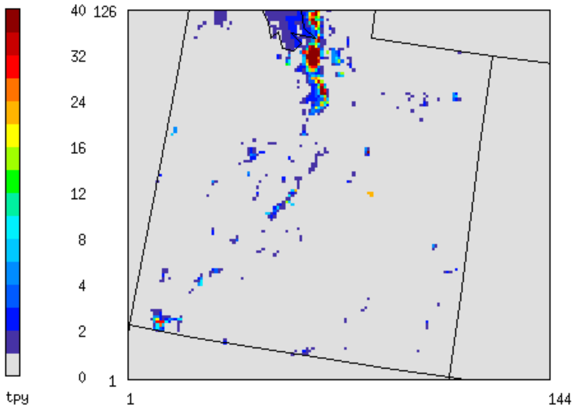
CO $PM_{2.5}$

SO_2

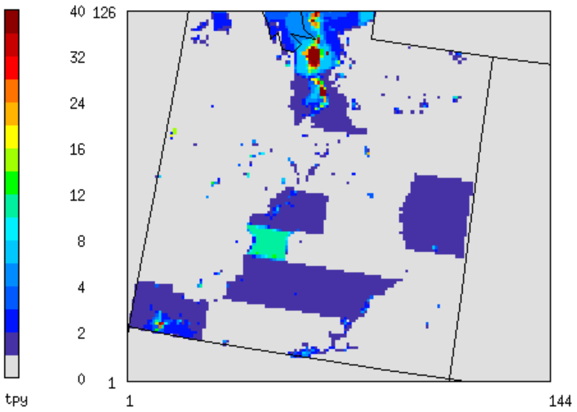
Figure 4-11 Non-Road Emissions Spatial Distribution in the 12-km Domain for Areas Outside of Utah

4-km Domain

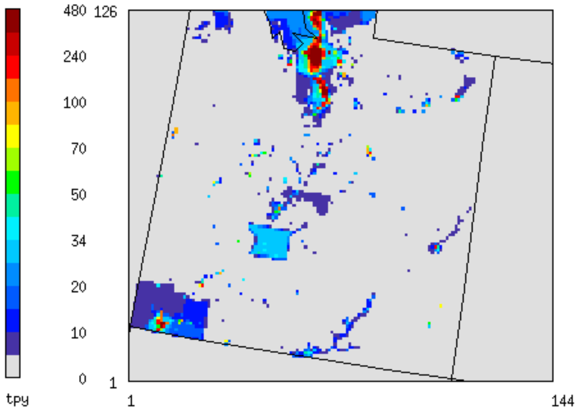
NO_X



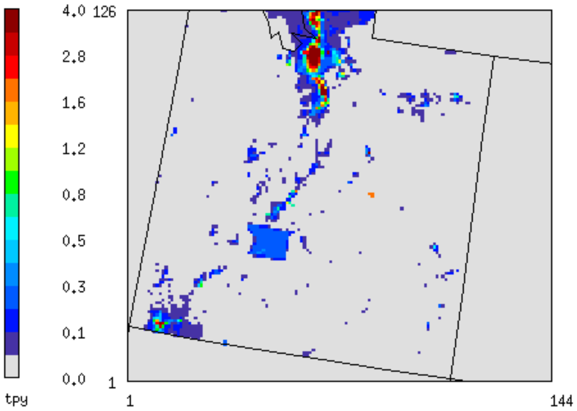
ROG



CO



$PM_{2.5}$



SO_2

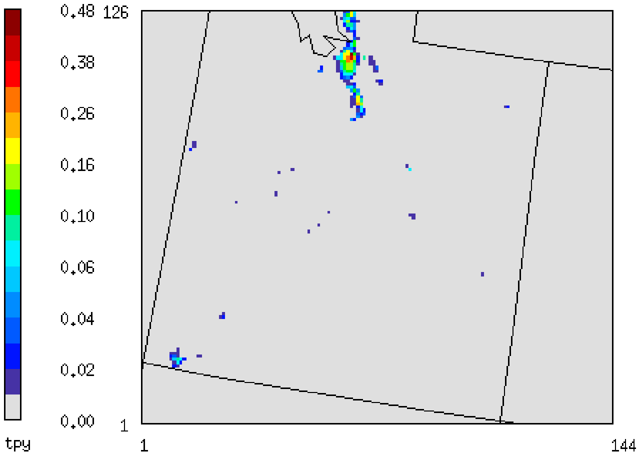


Figure 4-12 Non-Road Emissions Spatial Distribution in the 4-km Domain for Areas Inside of Utah

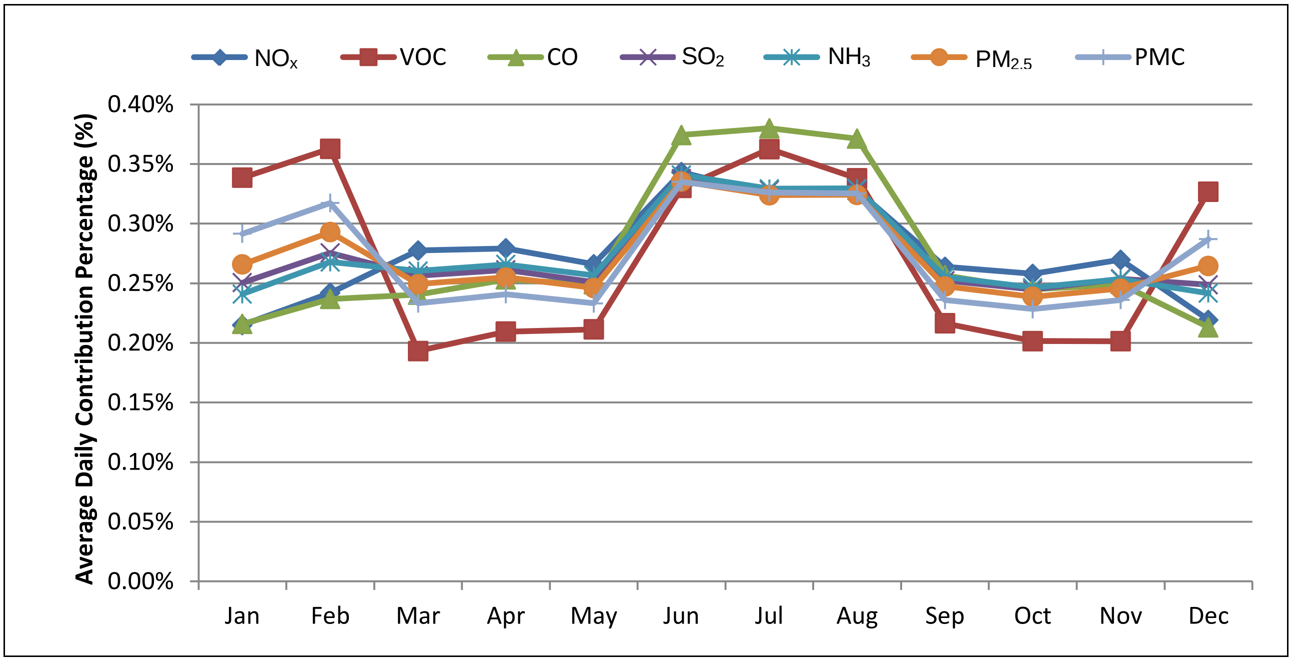


Figure 4-13 **Monthly Average of Utah Non-Road Emissions in the 4-km Domain**

4.6 On-Road

4.6.1 Emissions Inputs

On-road emissions were developed for the future year using lookup tables of emission factors combined with activity data and processed in SMOKE-MOVES. The lookup tables of emission factors and activity data were developed differently depending on the geographic area. Counties in the 4-km domains were modeled using MOVES 2010a coupled with the WRF meteorological data (AECOM and STI 2013) and a reference county approach. For more information on the MOVES2010a processing refer to **Appendix D**. For locations outside of the 4-km domain, the lookup tables of emission factors were from the 2020 CAP 2007v5 Platform (USEPA 2012) emission inventory.

The activity data was obtained from the 2020 CAP 2007v5 Platform (USEPA 2012) emission inventory; however, for counties in the Uinta Basin, the oil and gas truck traffic VMT and VPOP were adjusted. The county-specific 2010 VMT and VPOP are grown to 2021 using oil and gas activity. The VMT is grown using the projected county total oil production for 2021 and the VPOP is grown using county total well counts. The emissions for all model domains were processed in SMOKE as described in detail in **Appendix D**.

4.6.2 On-Road Emissions Summary

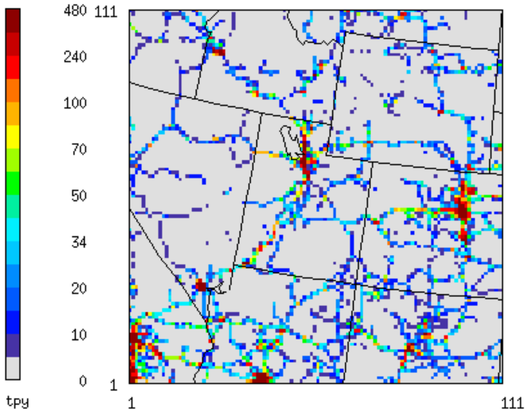
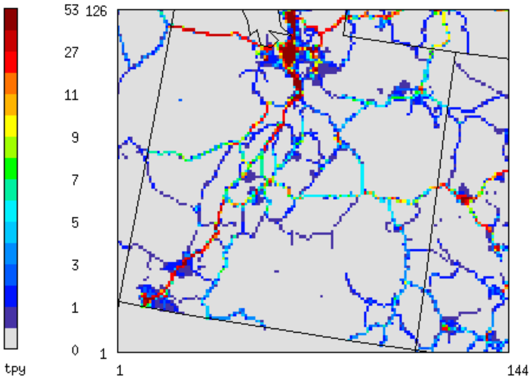
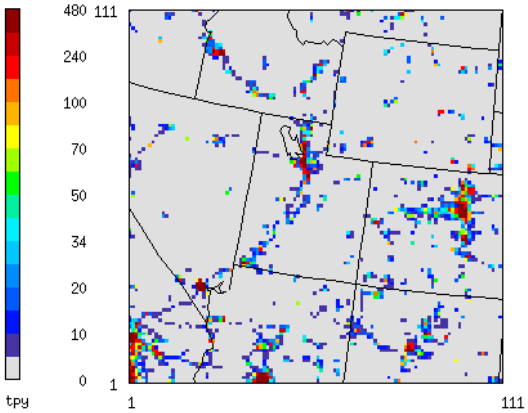
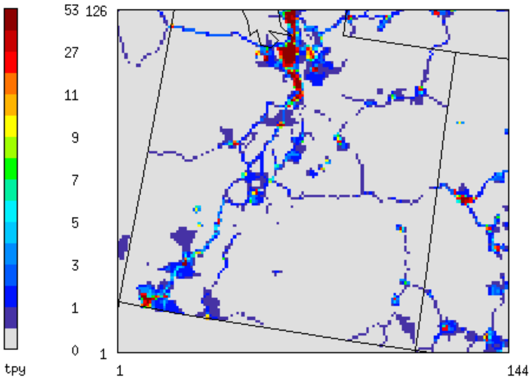
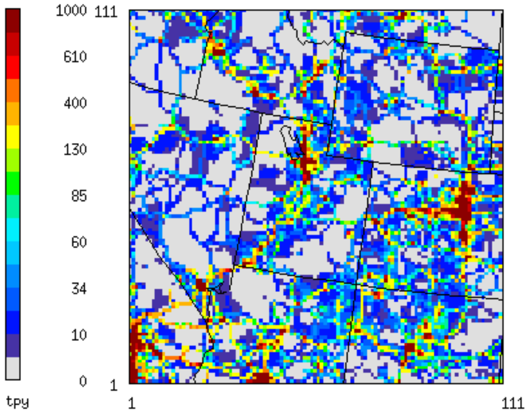
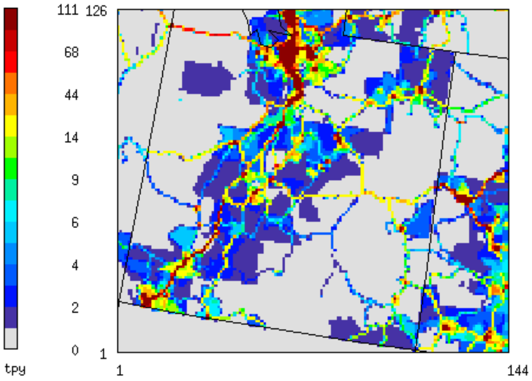
Table 4-19 shows the final emission totals for each modeling domain for the on-road mobile sources in all domains. Spatial plots of mobile sources in the 12-km and 4-km domains are shown in **Figure 4-14**. **Figure 4-15** shows the monthly temporal trend in the 4-km domain. **Table 4-20** shows the annual oil and gas truck traffic on-road emissions contributing to the all on-road sources.

Table 4-19 Annual On-Road Emissions

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	2,191,258	1,242,567	18,221,196	26,866	78,606	99,404	176,983
12-km	176,228	104,285	1,599,599	2,052	7,267	7,877	14,116
4-km	24,626	14,100	238,333	243	783	718	773

Table 4-20 Annual Oil and Gas Well Truck Traffic Contributions to Mobile Source Emissions in the 4-km Domain

Data	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
RPD	227	13	57	2	3	5	6
RPP	5	2	22	0.039	0	0.005	0.005
Total	232	15	79	2.039	3	5.005	6.005

Species	12-km Domain	4-km Domain
NO_X		
ROG		
CO		

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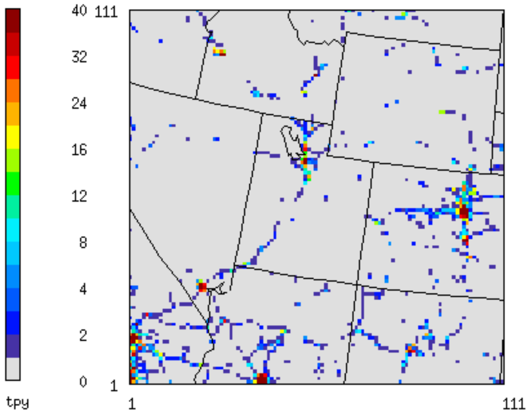
<tr><th>Species</th><th>12-km Domain</th><th>4-km Domain</th></tr>
<tr><td>$PM_{2.5}$</td><td>


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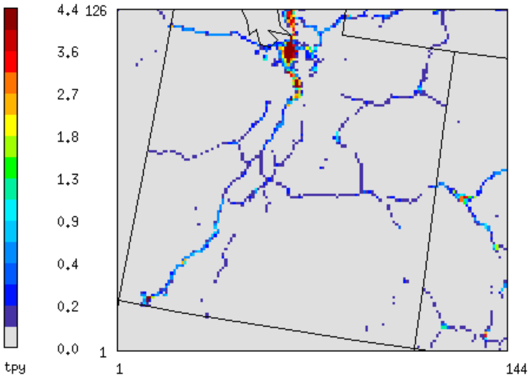
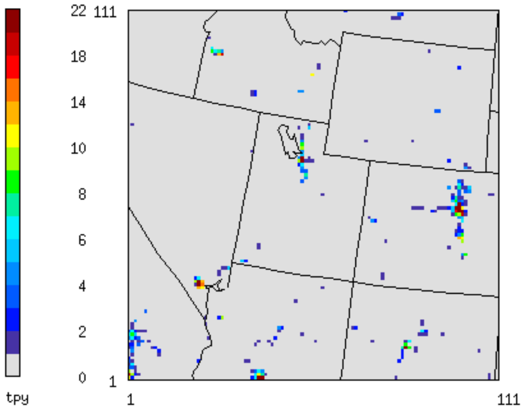


</td></tr>
<tr><td>SO_2</td><td>


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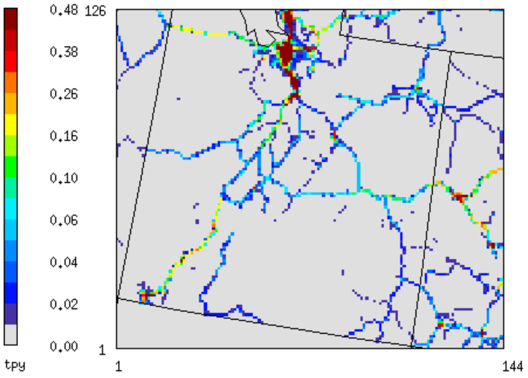

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Figure 4-14 On-Road Emissions Spatial Distribution in the 12-km and 4-km Domains

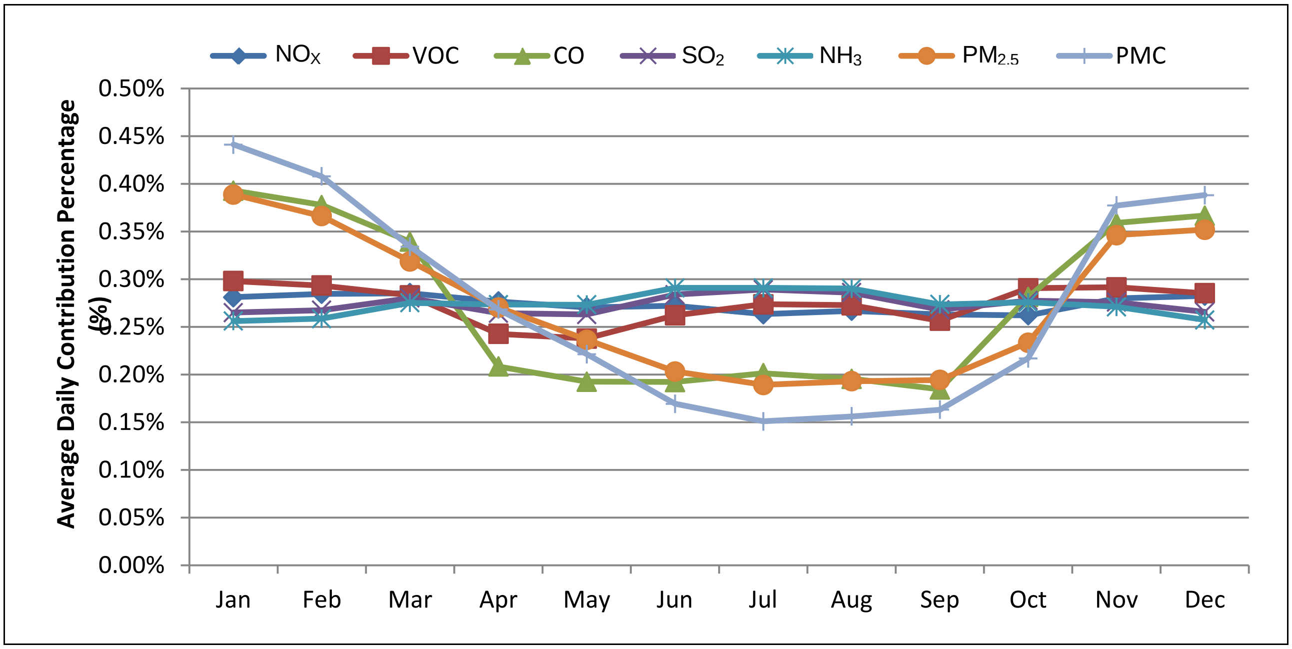


Figure 4-15 Monthly Average of On-Road Source Emissions in the 4-km Domain

4.7 Final Future Year Emissions

Emissions from each of the future year emissions sectors are merged together with the sources that are held constant (ammonia, dust, fires, biogenic, and non-U.S. emissions) to create the CMAQ model-ready emissions files.

4.7.1 Final Emissions Processing

All source sectors are merged for each model domain. The final emissions inputs are then converted into two types of model-ready emissions files for CMAQ:

- Two-dimensional emissions file for all sources except elevated point sources; and
- Elevated-point source emissions file.

4.7.2 Final Emissions Summary

Table 4-21 shows the final 2021 emissions for the 36-km, 12-km, and 4-km modeling domains. **Table 4-22** summarizes the annual emissions for each source sector in the 4-km domain. **Figure 4-16** shows the spatial distribution of the emissions in the 4-km domain. **Figure 4-17** shows the monthly temporal trend in the 4-km domain. The pollutant contributions of each sector in the final emissions totals are shown in **Figure 4-18. Figure 4-19** shows a comparison of emissions from 2010 and 2021 source sectors that differ between the two years.

Table 4-21 Final Annual Emissions

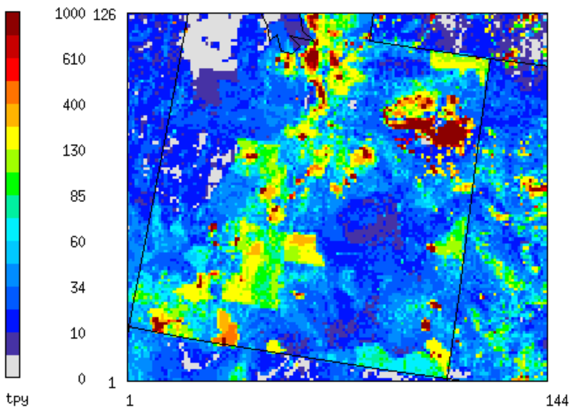
Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	15,566,493	83,975,367	74,998,488	11,398,465	5,485,214	4,654,159	10,972,083
12-km	1,069,208	5,897,623	4,153,108	345,532	496,562	232,670	599,589
4-km	215,436	2,038,758	855,995	44,526	195,751	42,722	75,560

Table 4-22 Year 2021 Emissions by Source Sector in the 4-km Domain

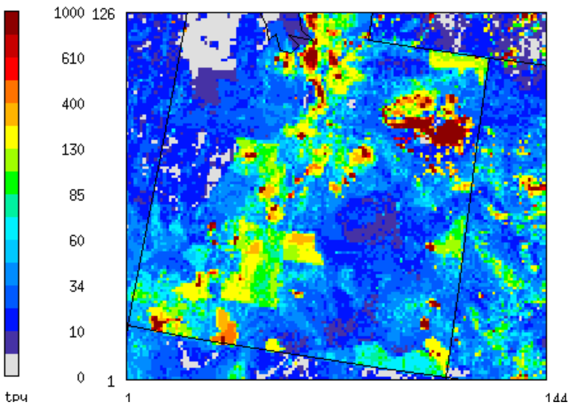
Source Sector	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
EGU Point	99,514	718	9,181	34,186	373	7,595	10,154
Non-EGU Point	27,772	16,751	60,624	7,682	448	4,690	9,810
Oil and Gas	35,257	800,376	87,081	339	0	2,347	2,367
Area	13,718	720,675	234,289	1,847	170,098	15,860	29,034
Non-Road	7,224	16,369	122,367	22	21	821	870
On-Road	24,626	14,100	238,333	243	783	718	773
Ammonia	0	0	0	0	23,543	0	0
Fire	1,406	4,295	24,100	196	486	2,514	2,984
Biogenic	5,248	465,492	69,557	0	0	0	0
Dust (fugitive and road)	0	0	0	0	0	7,633	19,022
Total	**215,436**	**2,038,758**	**855,995**	**44,526**	**195,751**	**42,722**	**75,560**

4-km Domain

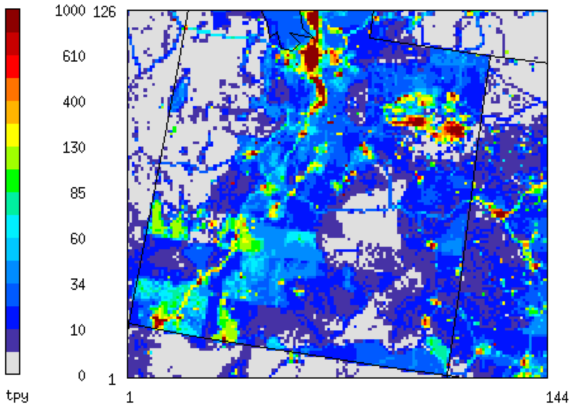
NO_X



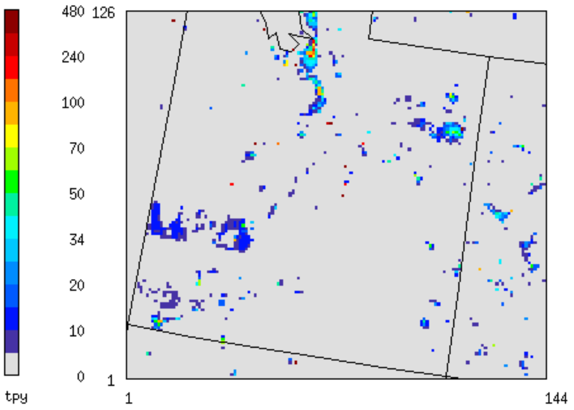
ROG



CO



$PM_{2.5}$



SO_2

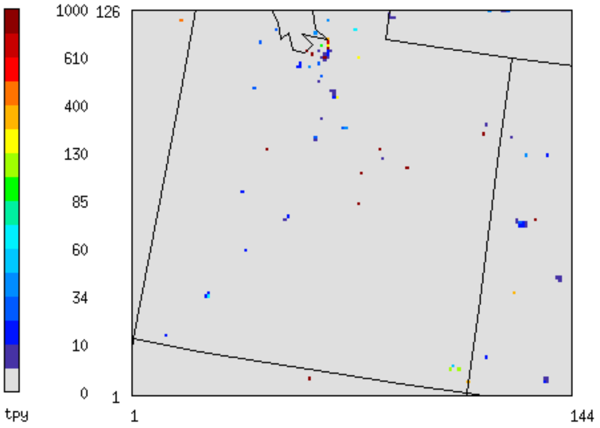


Figure 4-16 Final Annual Emissions Spatial Distribution in the 4-km Domain

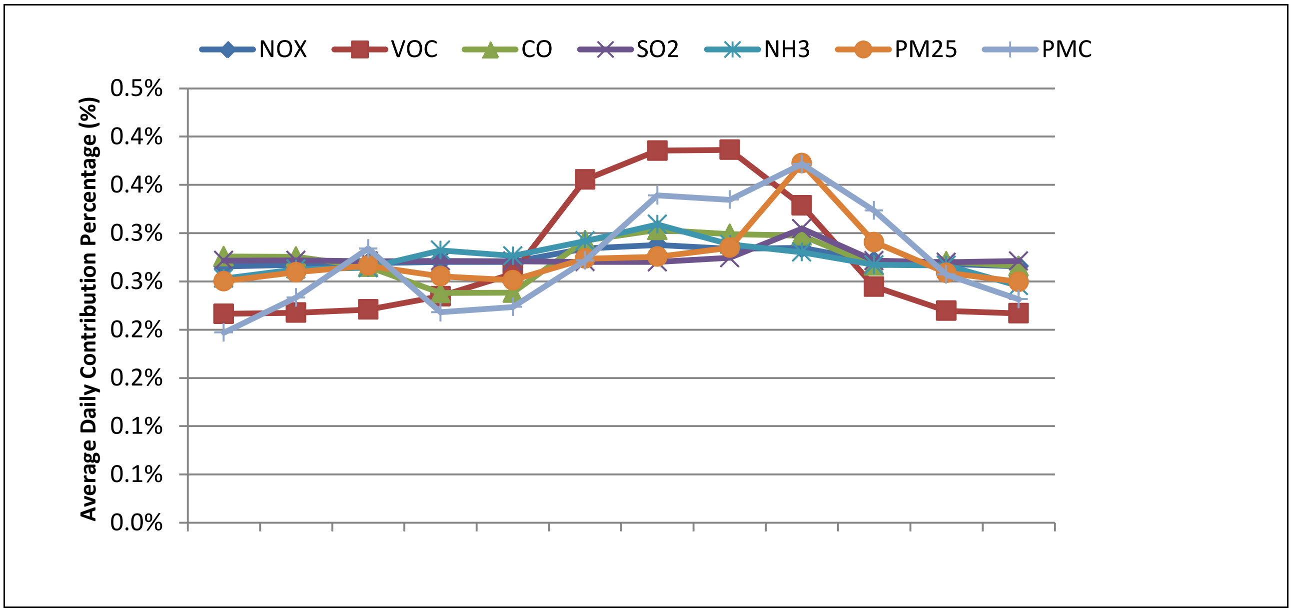


Figure 4-17 Monthly Average of the Final Emissions in the 4-km Domain

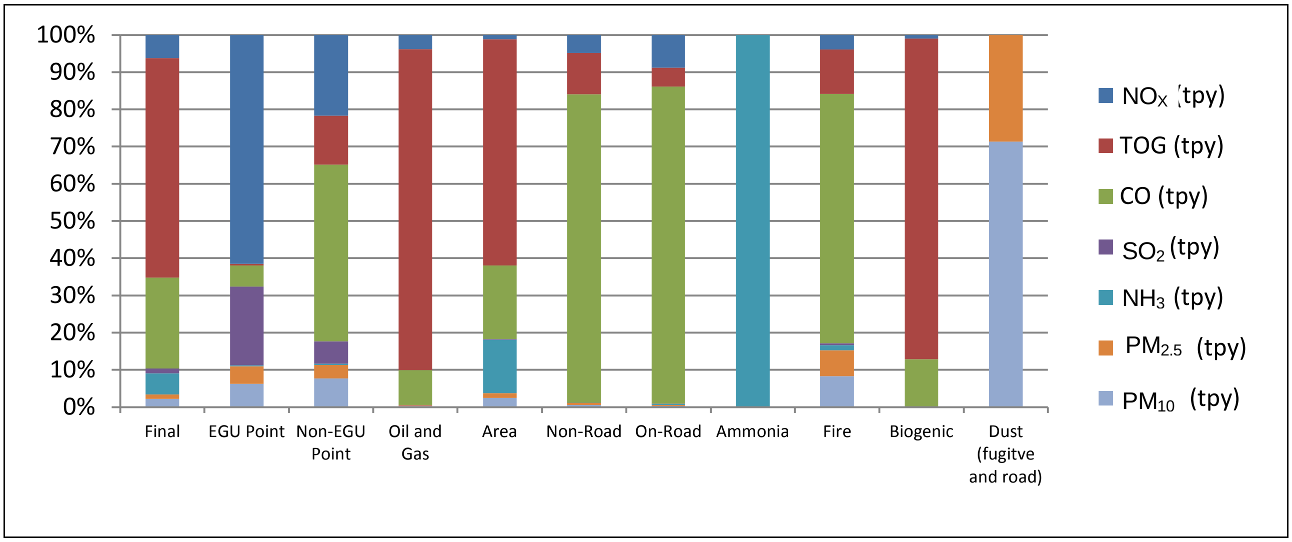


Figure 4-18 Annual Pollutant Contribution for Each Emission Source Sector

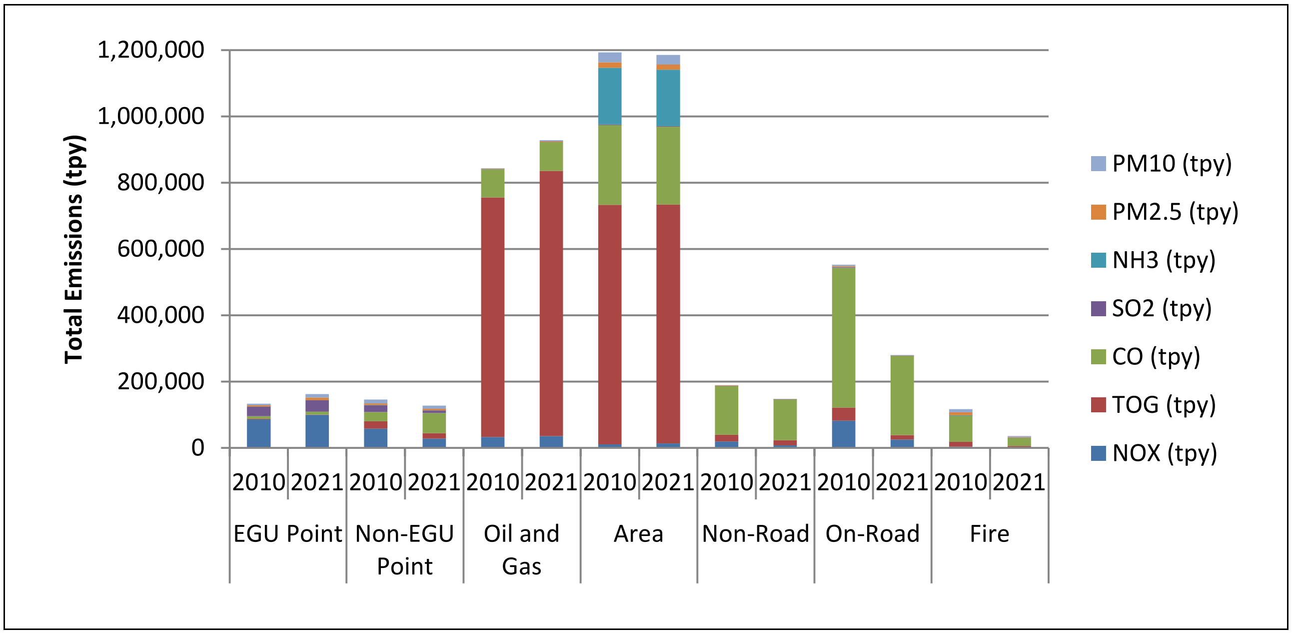


Figure 4-19 Comparison of Emissions in 2010 and 2021 by Source Sector

5.0 Mitigation Scenarios

As described in **Chapter 1.0**, three additional emissions scenarios were developed to assess the potential impact of different mitigation strategies to oil and gas emissions in the Uinta Basin. The three mitigation scenarios include strategies to minimize NO_x emissions (Scenario 1), minimize VOC emissions (Scenario 2), and minimize both NO_X and VOC (Scenario 3). The mitigation strategies described in more detail below were applied to the 2021 Uinta Basin oil and gas emissions inventory (described in **Section 4.4.1**) instead of the on-the-books controls. The following sections describe the development of the three mitigations scenarios, the resulting Uinta Basin emissions inventory, and the final annual emissions inventory.

5.1 Scenario 1: Minimize NO_X Emissions

The objective of Mitigation Scenario 1 is to reduce NO_X emissions beyond the level required by current regulations (which are described in **Section 4.4.1**). The sources that have additional controls in this mitigation scenario include: drill rig engines, workover rig engines, and hydraulic fracturing pump engines. Under this mitigation scenario, NSPS Tier 4 emissions standards are required for all non-road engines exceeding 500 hp operating in the Uinta Basin. This is implemented in the emission calculations by increasing the expected rule penetration of NSPS emission standards in 2021 from 35 percent to 95 percent.

The emissions that would result from application of these controls are shown in **Table 5-1**. In addition, **Table 5-1** also shows the change in the emissions relative to the on-the-books controls modeled as part of the 2021 future year EI described in **Chapter 4.0**. The NOx emissions under this mitigation scenario would decrease by approximately 25 percent relative to on-the-books controls. Additional benefits are realized for other pollutants due to reductions in the NSPS emissions standards between the current tier levels and Tier 4.

Table 5-1 Uinta Basin Mitigation Scenario 1 Emissions

Scenario	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
On-the-Books	26,167	138,775	80,060	63	0	1,998	1,998
Scenario 1	20,527	138,343	80,060	63	0	1,768	1,768
Difference (total mass)	-5,640	-432	0	0	0	-230	-230
Difference (percent)	-21.6%	-0.3%	0.0%	0.0%	-	-11.5%	-11.5%

5.1.1 Oil and gas Emissions Summary

The Uinta Basin oil and gas emissions were processed through SMOKE as described in Section 4.3.4. **Table 5-2** shows the estimated Uinta Basin oil and gas emissions for Mitigation Scenario 1 for each model domain.

Table 5-2 Uinta Basin Mitigation Scenario 1 Oil and Gas Emissions

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	20,527	723,364	80,060	63	0	1,767	1,767
12-km	20,527	723,363	80,060	63	0	1,767	1,767
4-km	20,527	723,358	80,060	63	0	1,767	1,767

5.1.2 Final Emissions Summary

Emissions from Mitigation Scenario 1 are merged together with all 2021 non-Uinta Basin oil and gas and other emissions for 2021 described in **Chapter 4** to create the CMAQ model-ready emissions files.

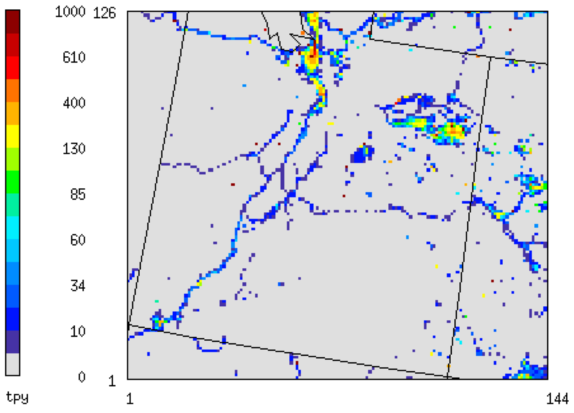
Table 5-3 shows the final Mitigation Scenario 1 emissions for the 36-km, 12-km, and 4-km modeling domains. **Figure 5-1** shows the spatial distribution of the emissions in the 4-km domain. **Figure 5-2** shows the monthly temporal trend in the 4-km domain.

Table 5-3 Mitigation Scenario 1 Total Emissions

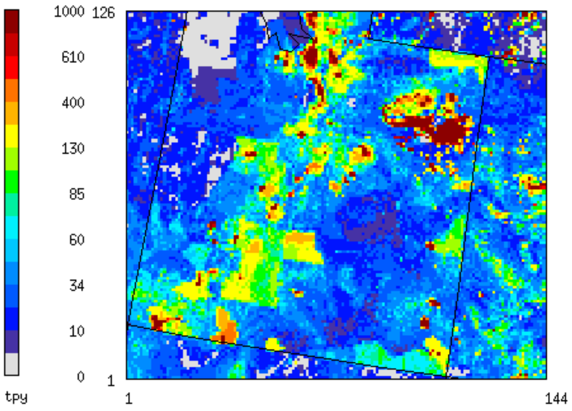
Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	15,561,063	83,975,436	75,003,372	11,398,451	5,485,276	4,760,756	11,654,499
12-km	1,063,567	5,897,202	4,153,106	345,530	496,556	236,780	662,413
4-km	209,126	2,038,359	845,532	44,515	195,745	37,286	71,998

4-km Domain

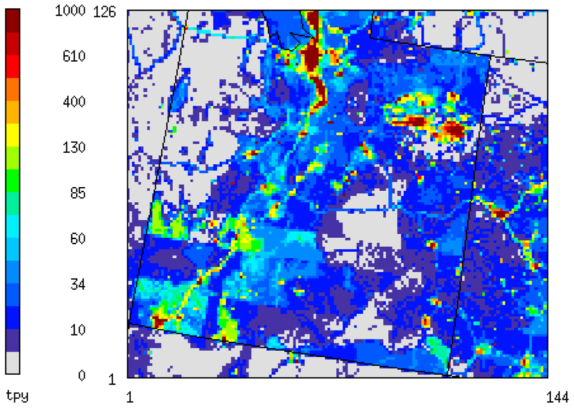
NO_X



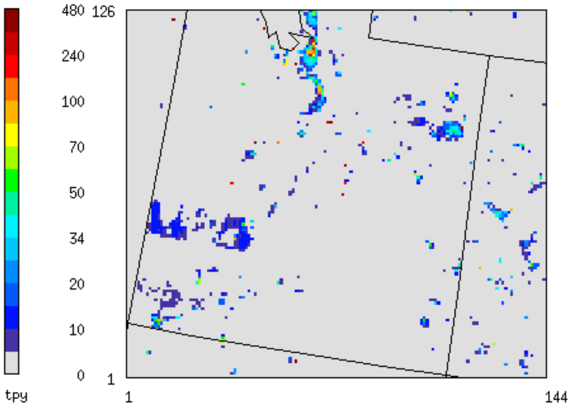
ROG



CO



$PM_{2.5}$



SO_2

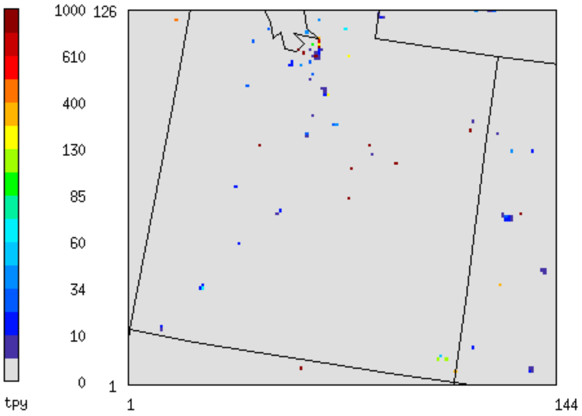


Figure 5-1 Mitigation Scenario 1 Total Emissions Spatial Distribution in the 4-km Domain

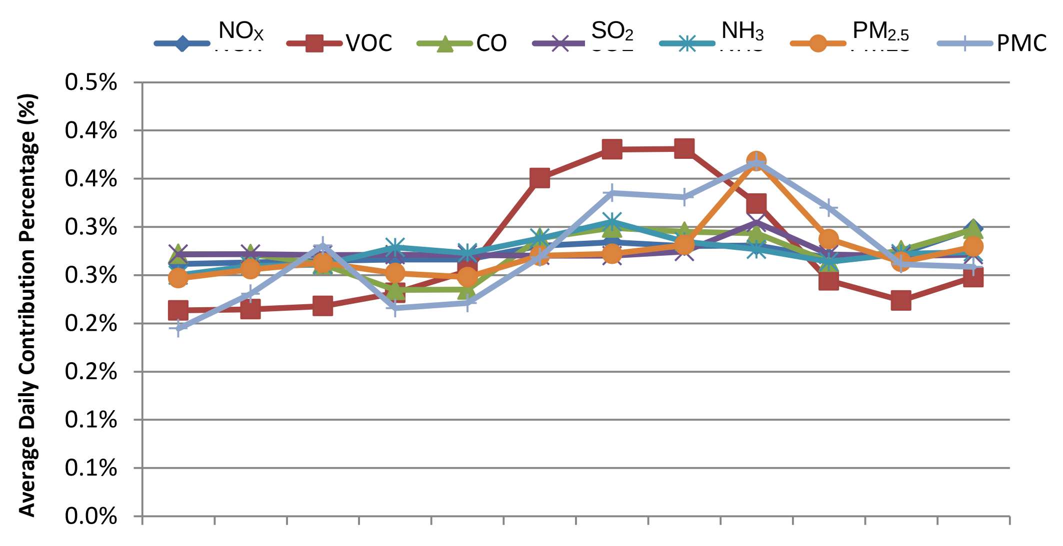


Figure 5-2 Monthly Average of the Mitigation Scenario 1 Total Emissions in the 4-km Domain

5.2 Scenario 2: Minimize VOC Emissions

The objective of Mitigation Scenario 2 is to reduce VOC emissions beyond the level required by current regulations (described in **Section 4.4.1**). The sources that have additional controls in this mitigation scenario include: natural gas dehydrators, and tanks.

The specific controls adopted as part of this mitigation strategy include the assumption that all dehydrators capture or combust 95 percent of VOC emissions, regardless of size. The rule penetration for dehydrators is assumed to be 95 percent. Similarly, all oil and condensate tanks must capture or combust 95 percent of VOC working, standing and breathing losses, regardless of size or level of emissions. A 100 percent rule penetration is assumed for tanks. Since the emissions from these sources are already controlled to some extent by current regulations, the primary difference between this mitigation strategy and the on-the-books controls is the expansion of the rules to affect all equipment rather than just a subset of equipment. While VOC controls are the objective of this mitigation strategy it is important to note that VOC emissions controlled via combustion processes would result in the increased emissions of co-pollutants including NO_X, CO, SO_2, PM_{10}, and $PM_{2.5}$.

The emissions that would result from application of these controls are shown in **Table 5-4**. In addition, **Table 5-4** also shows the change in the emissions relative to the on-the-books controls modeled as part of the 2021 future year EI described in **Chapter 4.0**. The VOC emissions under this mitigation scenario would decrease by approximately 13 percent relative to on-the-books controls. However, it is predicted that the all other emissions could increase due to co-pollutants emitted from VOC combustion controls.

Table 5-4 Uinta Basin Mitigation Scenario 2 Emissions

Area	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
On-the-Books	26,167	138,775	80,060	63	0	1,998	1,998
Scenario 2	26,777	120,096	89,083	78	0	2,461	2,461
Difference (total mass)	610	-18,679	9,023	15	0	463	463
Difference (percent)	2.3%	-13.5%	11.3%	23.6%	-	23.2%	23.2%

5.2.1 Oil and Gas Emissions Summary

The Uinta Basin oil and gas emissions were processed through SMOKE as described in Section 4.3.4. **Table 5-5** shows the estimated Uinta Basin oil and gas emissions for Mitigation Scenario 2 for each model domain.

Table 5-5 Uinta Basin Mitigation Scenario 2 Oil and Gas Emissions

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	26,777	453,982	89,083	78	0	2,461	2,461
12-km	26,777	453,983	89,083	78	0	2,461	2,461
4-km	26,777	453,980	89,083	78	0	2,461	2,461

5.2.2 Final Emissions Summary

Emissions from Mitigation Scenario 2 are merged together with all 2021 non-Uinta Basin oil and gas and other emissions for 2021 described in **Chapter 4** to create the CMAQ model-ready emissions files.

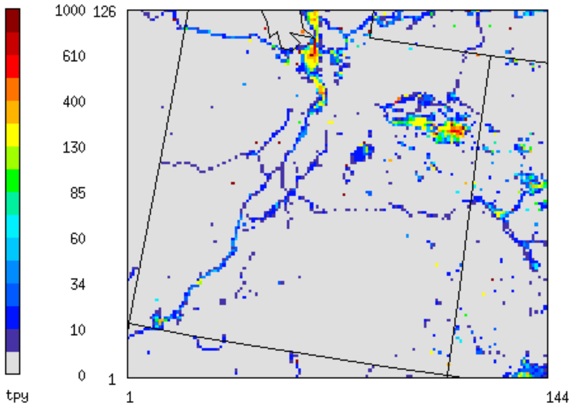
Table 5-6 shows the Mitigation Scenario 2 final emissions for the 36-km, 12-km, and 4-km modeling domains. **Figure 5-3** shows the spatial distribution of the emissions in the 4-km domain. **Figure 5-4** shows the monthly temporal trend in the 4-km domain.

Table 5-6 Mitigation 2 Final Annual Emissions

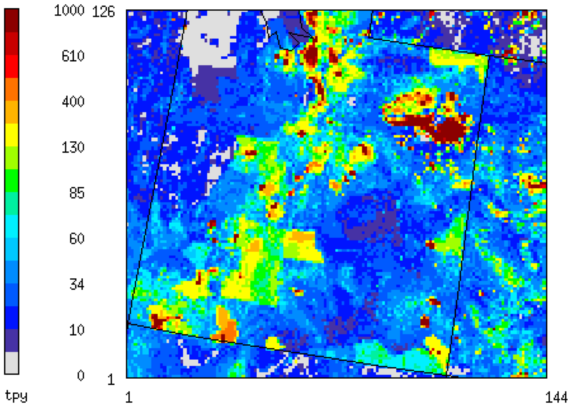
Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	15,567,313	83,706,054	75,012,395	11,398,466	5,485,276	4,761,449	11,655,192
12-km	1,069,817	5,627,821	4,162,129	345,545	496,556	237,473	663,107
4-km	215,376	1,768,982	854,554	44,530	195,745	37,980	72,691

4-km Domain

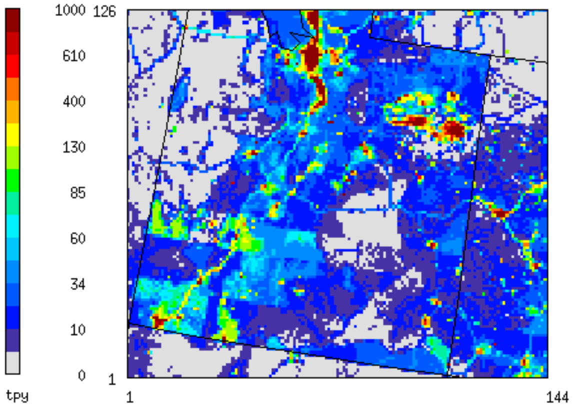
NO_X



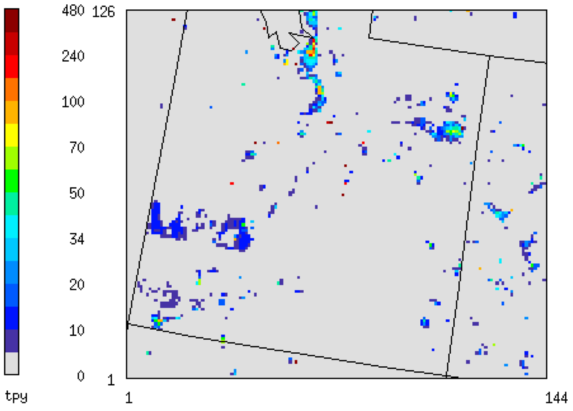
ROG



CO



$PM_{2.5}$



SO_2

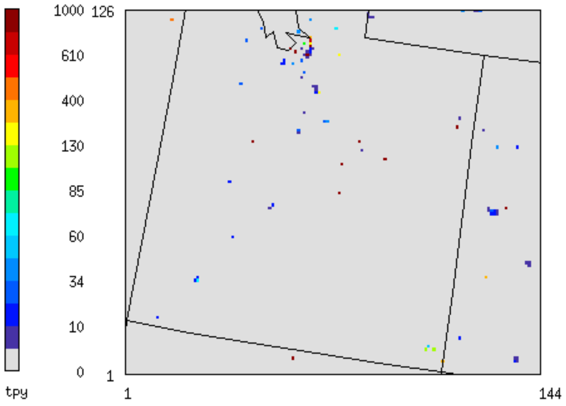


Figure 5-3 Mitigation 2 Final Annual Emissions Spatial Distribution in the 4-km Domain

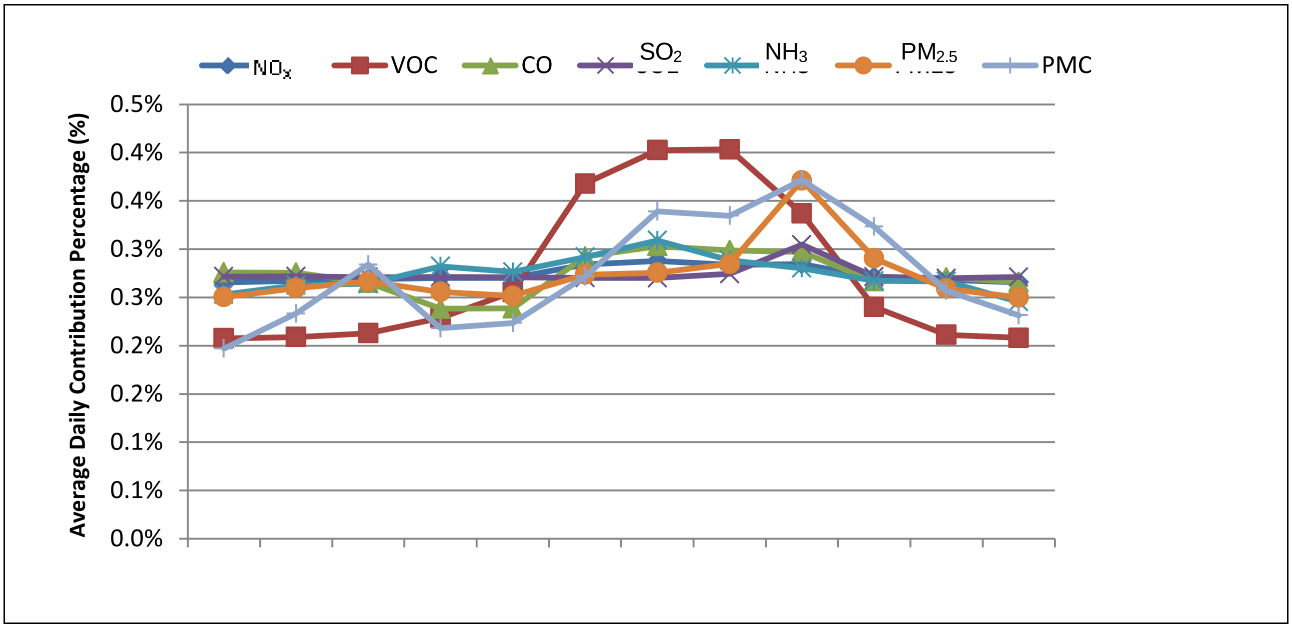


Figure 5-4 **Monthly Average of the Mitigation 2 Final Emissions in the 4-km Domain**

5.3 Scenario 3: Minimize Both NO_X and VOC Emissions

The objective of Mitigation Scenario 3 is to reduce the total emissions of both NO_X and VOC beyond the level required by current regulations (described in **Section 4.4.1**). The effect of combining Mitigation Scenarios 1 and 2 is assessed below. In addition, to minimize NOx emissions, it is assumed that VOC controls use capture technologies rather than combustion..

The sources that have additional controls in this mitigation scenario include: drill rig engines, workover rig engines, hydraulic fracturing pump engines, natural gas dehydrators, and tanks. Similar to Mitigation Scenario 1, under this mitigation scenario, NSPS Tier 4 emissions standards are required for all non-road engines exceeding 500 hp operating in the Uinta Basin. This is implemented in the emission calculations by increasing the expected rule penetration of NSPS emission standards in 2021 from 35 percent to 95 percent. In order to minimize the effects of increased emissions of co-pollutants associated with VOC controls, for this mitigation scenario, it is assumed that all VOC controls require capture of the VOCs rather than combustion. In addition, it would be required that all dehydrators capture 95 percent of VOC emissions, regardless of size. The rule penetration for dehydrators is assumed to be 95 percent. Similarly, all oil and condensate tanks must capture 95 percent of VOC working, standing and breathing losses, regardless of size or level of emissions. A 100 percent rule penetration is assumed for tanks.

The emissions that would result from application of these controls are shown in **Table 5-7**. In addition, **Table 5-7** also shows the change in the emissions relative to the on-the-books controls modeled as part of the 2021 future year EI described in **Chapter 4.0**. The NO_X emissions under this mitigation scenario would decrease by approximately25 percent and the VOC emissions would decrease by approximately 14 percent relative to on-the-books controls. Substantial additional benefits are realized for other pollutants due to the emphasis on VOC capture rather than combustion.

Table 5-7 Uinta Basin Mitigation Scenario 3 Emissions

Area	NO_X (tpy)	VOC (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
On-the-Books	26,167	138,775	80,060	63	0	1,998	1,998
Scenario 3	19,701	119,664	60,218	56	0	703	703
Difference (total mass)	-6,466	-19,112	-19,843	-7	0	-1,295	-1,295
Difference (percent)	-24.7%	-13.8%	-24.8%	-11.6%	-	-64.8%	-64.8%

5.3.1 Oil and Gas Emissions Summary

The Uinta Basin oil and gas emissions were processed through SMOKE as described in Section 4.3.4. **Table 5-8** shows the estimated Uinta Basin oil and gas emissions for Mitigation Scenario 3 for each model domain.

Table 5-8 Uinta Basin Mitigation Scenario 3 Oil and Gas Emissions

Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	19,701	453,564	60,218	56	0	703	703
12-km	19,701	453,565	60,218	56	0	703	703
4-km	19,701	453,563	60,218	56	0	703	703

5.3.2 Final Emissions Summary

Emissions from Mitigation Scenario 3 are merged together with all 2021 non-Uinta Basin oil and gas and other emissions for 2021 described in **Chapter 4** to create the CMAQ model-ready emissions files.

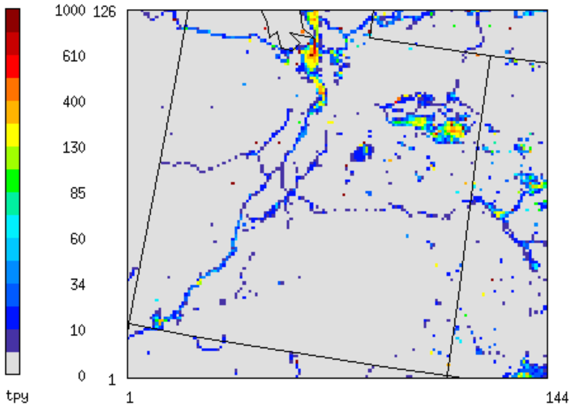
Table 5-9 shows the mitigation 3 final emissions for the 36-km, 12-km, and 4-km modeling domains. **Figure 5-5** shows the spatial distribution of the emissions in the 4-km domain. **Figure 5-6** shows the monthly temporal trend in the 4-km domain.

Table 5-9 Mitigation 3 Final Annual Emissions

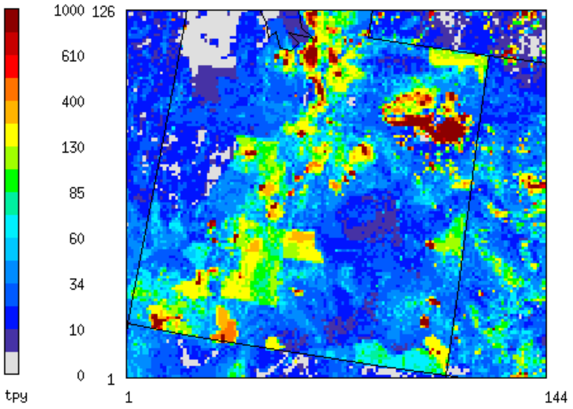
Domain	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	NH_3 (tpy)	$PM_{2.5}$ (tpy)	PM_{10} (tpy)
36-km	15,560,237	83,705,636	74,983,530	11,398,444	5,485,276	4,759,691	11,653,434
12-km	1,062,741	5,627,403	4,133,263	345,523	496,556	235,715	661,348
4-km	208,300	1,768,564	825,689	44,508	195,745	36,221	70,933

4-km Domain

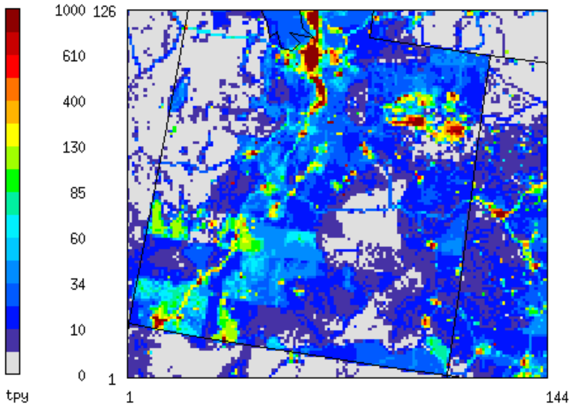
NO_X



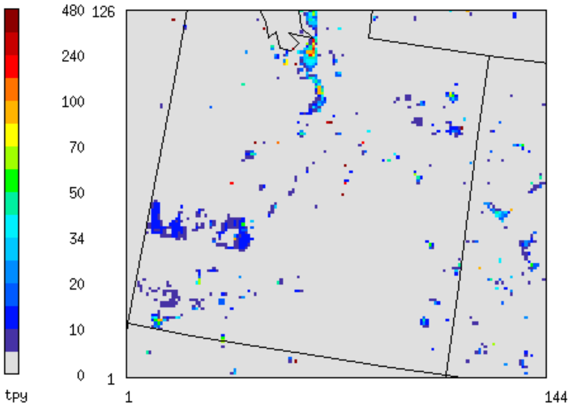
ROG



CO



$PM_{2.5}$



SO_2

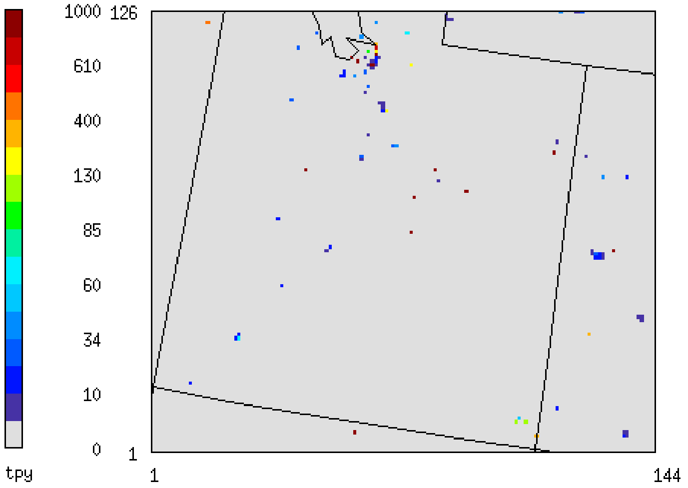


Figure 5-5 Mitigation 3 Final Annual Emissions Spatial Distribution in the 4-km Domain

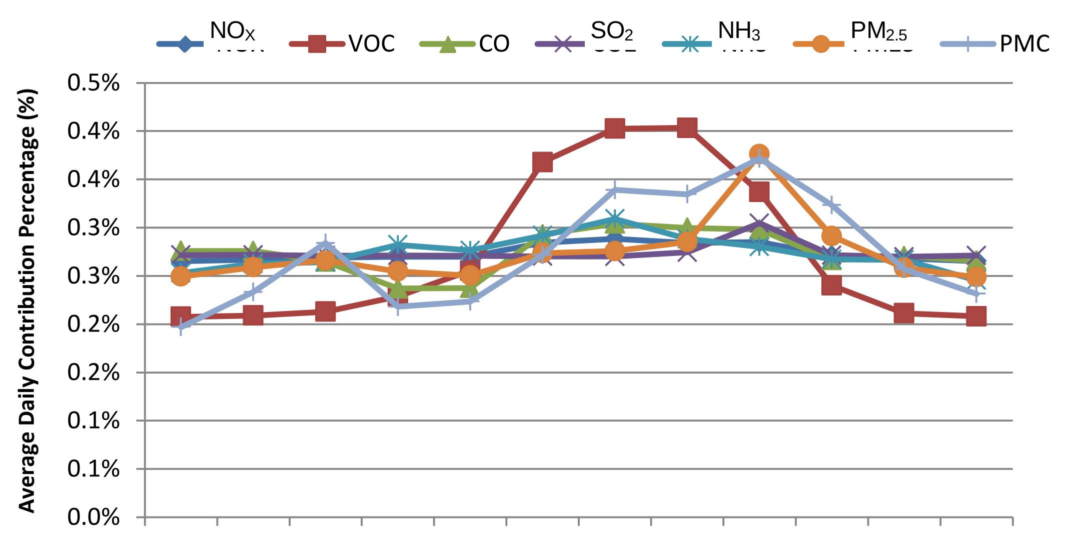


Figure 5-6 Monthly Average of the Mitigation 3 Final Emissions in the 4-km Domain

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Appendix A

Uinta Basin Oil and Gas Survey Results and Base Year Emissions Calculations Supporting Data

A.1 Overview of Operator Survey

In order to temporalize Uinta Basin oil and gas emissions, a survey was distributed to operators within the basin. The survey asked questions primary focused on data regarding drilling and completion events. Information regarding treatment of produced water was also requested.

A.2 Response Rate

A total of five operators responded to the survey. According to the IHS database (BLM 2012), these operators account for 60 percent of the producing wells in 2010 within Uintah and Duchesne counties and tribal lands (**Table A-1**). In terms of production volumes, the survey responders account for 55 percent of the total oil produced in 2010 and 67 percent of the total gas produced in 2010. Since the survey responders make up a majority of the oil and gas production activities within the study area, conclusions drawn from the responders' surveys are assumed to be representative of all activity within the study area.

Table A-1 Survey Response Rate for Uinta Basin Activities in 2010

	Producing Wells		Oil Production		Gas Production	
Operator	**Actual (Wells)**	**Percent (%)**	**Actual (bbls)**	**Percent (%)**	**Actual (mcf)**	**Percent (%)**
Survey Responders	6,164	60	9,484,034	55	279,249,588	67
All Other Operators	4,139	40	7,849,061	45	140,132,881	33
Total	**10,303**	**100**	**17,333,095**	**100**	**419,382,469**	**100**

A.3 Current Drilling, Completion, Workover, and Recompletion Activities

The survey results represent activities conducted in 2010 for 715 new wells and 486 existing wells. The well drilling and completion date or workover and recompletion date were requested for each well. The date information is used to quality assure the total emissions estimated for 2010 and future years, as well as temporally and spatially allocate the 2010 emissions. For calculation of the duration of these activities, it was assumed that the activity started the morning of the start date and ended in the evening of the end (e.g., if the end date was the day following the start date this would be two days of activity).

To supplement survey results, data from two sources were used: the IHS database (provided by BLM on July 2012) and Utah's Division of Oil, Gas, and Mining (DOGM) (accessed on November 2011). The IHS database was used to identify the well status, production volumes, and operator. The DOGM database was used to identify the well type, drilling technology (vertical, directional, or horizontal) and supply missing temporal regarding spud dates. Temporal information provided by survey respondents were assumed to be more accurate than DOGM data; therefore, survey data were the primary data source for temporal information and DOGM data were used for wells not included in the surveys responses.

Other well-specific information requested in the survey includes well depth, whether drilling was continuous or not, if well was hydraulically fractured, and details on the capture and treatment of hydrocarbon flow back gas.

A.3.1 Drilling and Completion Dates

According to DOGM there were 934 new wells drilled in 2010 in Uintah and Duchesne counties or on tribal lands. The information available from the survey responses account for 715 of these wells, which is a 69 percent response rate. **Tables A-2** and **A-3** show the survey results for drilling and completion activities, respectively, for new wells drilled in 2010. As shown in **Table A-2**, the drilling duration varied greatly from one to 90 days with a mean and median of seven and six days, respectively, with a standard deviation of 4 days. The spread in the length of time to conduct completions is similar to drilling duration, ranging from 1 to 86 days. The mean and median of the completion duration are nine and four days, respectively, with a standard deviation of 10 days.

The wide range in the length of drilling and completion days led to further analysis to differentiate continuous versus non-continuous activities, oil versus gas wells, and drilling technology (e.g., vertical versus horizontal versus directional drilling). As one would expect, wells with longer drilling or completion duration were typically not continuous over the period of activity reported by survey respondents.

Figure A-1 shows three histograms of drilling duration: one comparing the distribution of continuous and non-continuous drilling duration, a second comparing the distribution for oil versus gas wells, and the third comparing the distribution by horizontal, directional, and vertical drilling technology. Several conclusions were reached based on the information in **Table A-2** and **Figure A-1**:

- With the exception of a single well with an anomalous drilling duration of 90 days, the drilling duration distribution for non-continuous drilling operations is very similar to the distribution for continuous drilling if 2-3 days are subtracted from the drilling duration. This indicates that non-continuous drilling operations likely have 2-3 days of down-time (for repairs or similar activities) when the drilling equipment isn’t operating. Based on this, drilling emissions per well are likely very similar regardless of whether drilling is continuous or not; however, the emissions are spread out over a longer period when the drilling is not continuous.
- The drilling duration distribution for oil wells closely resembles the distribution for continuous drilling duration indicating that oil wells are more likely to be drilled continuously than gas wells.
- Gas wells tend to have a longer drilling duration than oil wells, even when both are drilled continuously.
- Directional and horizontal wells have a similar distribution of drilling duration; however, horizontal wells have a much longer drilling duration. Although the conclusions regarding the horizontal drilling technology are based on a single data point, so these conclusions are not statistically significant.

Figure A-2 shows two histograms of completion duration, one comparing the distribution of continuous and non-continuous duration and another comparing the distribution for oil versus gas wells. Several conclusions were reached based on the information in **Table A-3** and **Figure A-2**:

- There is no obvious normal or log-normal distribution for completion activities.
- Oil wells tend to have a very uniform completion duration and are more likely to be completed continuously than gas wells.
- Gas wells tend to have a longer completion duration than oil wells.

Table A-2 Drilling Duration for New Wells

Statistics	Total	Continuously Drilled versus Non-Continuously		Gas versus Oil	
		Continuous	Non-continuous	Gas Wells	Oil Wells
Mean (days)	7	6	9	9	5
Median (days)	6	6	9	8	5
Mode (days)	5	5	7	8	5
Maximum (days)	90	19	90	90	16
Minimum (days)	1	3	1	4	1
Standard Deviation (days)	4	2	6	5	1
Number of wells with drilling start and end dates	715	492	223	343	372
Number of wells without temporal information	0	0	0	0	0

Table A-3 Completion Duration for New Wells

Statistics	Total	Continuously Drilled versus Non-Continuously		Gas versus Oil	
		Continuous	Non-continuous	Gas Wells	Oil Wells
Mean (days)	9	17	5	14	4
Median (days)	4	14	4	11	4
Mode (days)	4	11	4	2	4
Maximum (days)	86	86	55	86	4
Minimum (days)	1	1	1	1	4
Standard Deviation (days)	10	13	5	12	0
Number of wells with completion start and end dates	714	222	492	343	371
Number of wells without temporal information	0	1	0	0	1

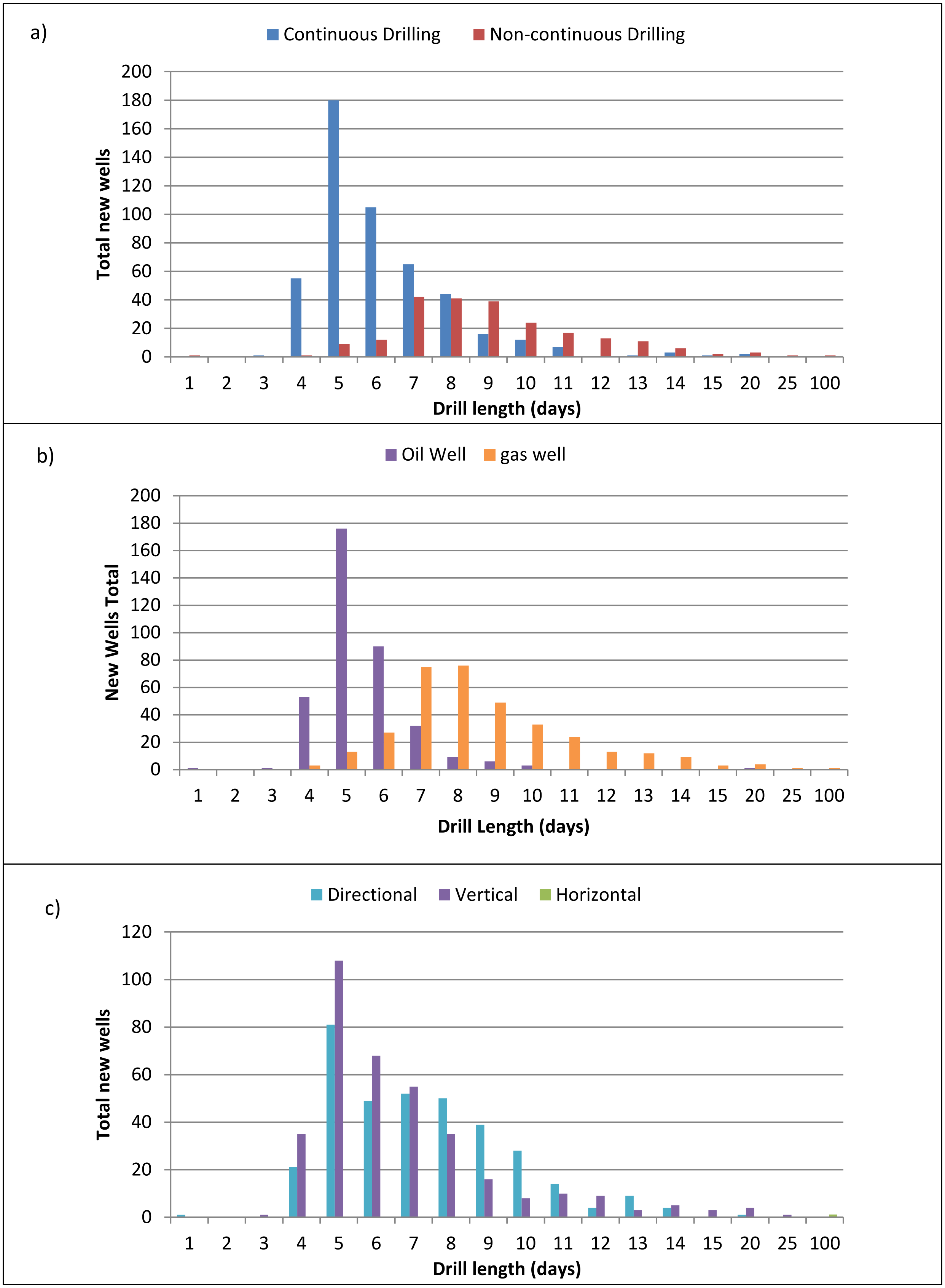


Figure A-1 **Drilling Duration for New Wells by Continuous and Non-Continuous Drilling (top), by Well Type (middle), and by Drilling Technology (bottom)**

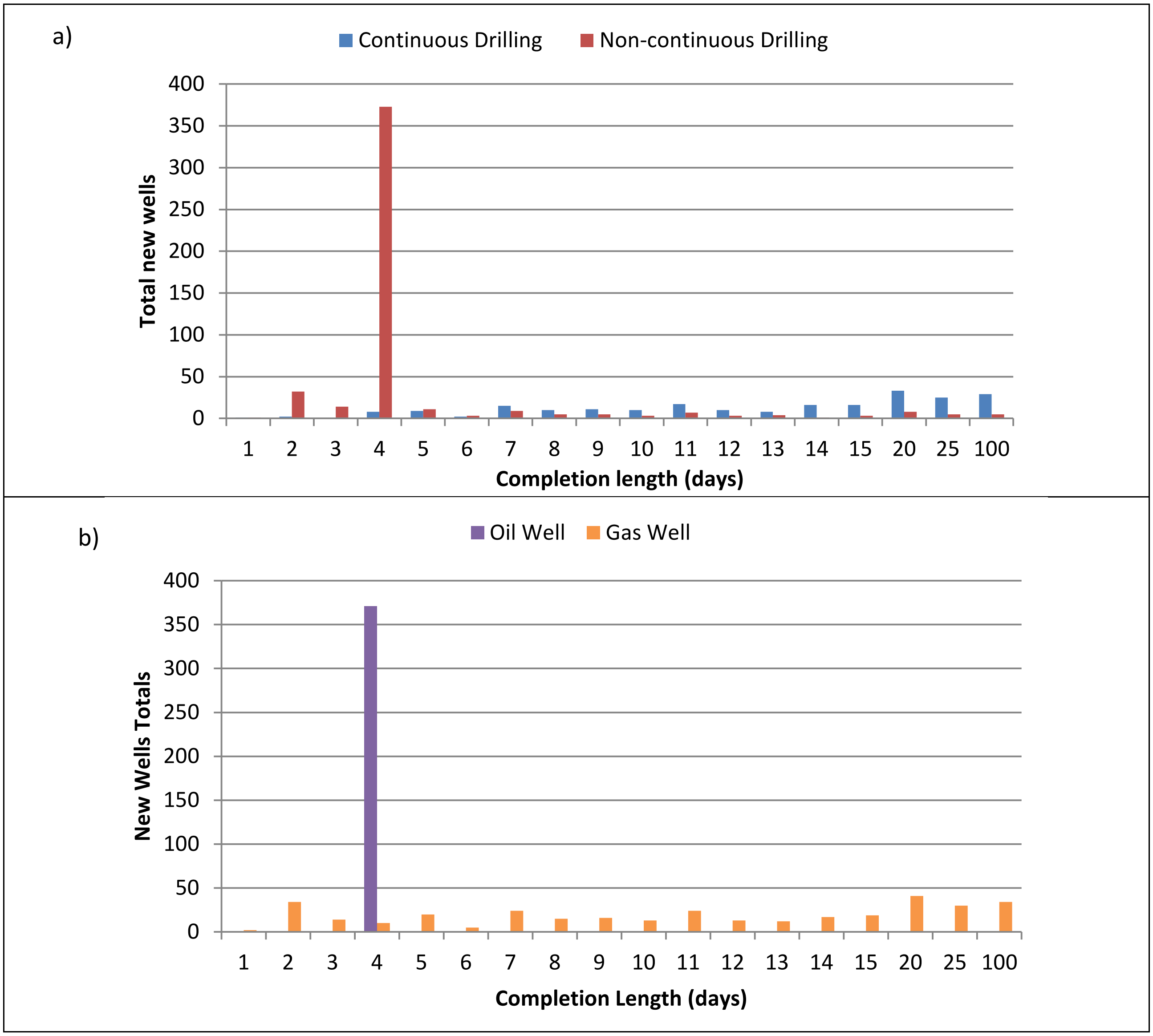


Figure A-2 **Completion Duration for New Wells by Continuous and Non-Continuous Completions (top) and by Well Type (bottom)**

A.3.2 Workover and recompletion dates

Information associated with 482 existing wells were provided in the survey responses. **Tables A-4** and **A-5** show the mean and median duration of workovers and recompletions for existing wells in 2010. Numerous respondents gave either the workover dates or recompletion dates for an existing well. Only 28 wells had both workover and recompletion dates.

For the 437 wells with information for workover duration, the mean workover duration was five days and the median duration was three days. The workover durations varied from one day to 133 days. The well with a workover duration of 133 days was twice as deep as the average workover depth and was non-continuous. Similar to drilling new wells, the histogram of the workover duration for existing wells (**Figure A-3**) shows that the workover duration for continuous activities tend to be shorter than non-continuous activities;

however, unlike new wells there isn't an obvious systematic "down time" that can be assumed for non-continuous workover operations. Additionally, there are numerous wells with continuous workovers that have a duration greater than 20 days.

The mean and median recompletion duration was 20 days and eight days, respectively, for the 73 wells with recompletion dates. The recompletion standard deviation was 25 days, which indicates a large variability in recompletion duration. The majority of workover wells did not provide temporal information for recompletions, making it difficult to draw conclusions about recompletions from the survey data.

Table A-4 Workover Duration for Existing Wells

Statistics	Total	Continuously Drilled versus Non-continuously		Gas versus Oil	
		Continuous	Non-continuous	Gas Wells	Oil Wells
Mean (days)	5	4	10	5	1
Median (days)	3	3	6	3	1
Mode (days)	2	2	1	2	1
Maximum (days)	133	53	133	133	8
Minimum (days)	1	1	1	1	1
Standard Deviation (days)	8	4	16	8	2
Number of wells with drilling start and end dates	437	351	86	408	20
Number of wells without temporal information	45	11	11	42	0

Table A-5 Recompletion Duration for Existing Wells

Statistics	Total	Continuously Drilled versus Non-continuously		Gas versus Oil	
		Continuous	Non-Continuous	Gas Wells	Oil Wells
Mean (days)	20	16	23	28	4
Median (days)	8	8.5	4	11	4
Mode (days)	4	8	4	8	4
Maximum (days)	114	92	114	114	4
Minimum (days)	4	4	4	4	4
Standard Deviation (days)	25	18	29	28	0
Number of wells with completion start and end dates	73	36	37	47	19
Number of wells without temporal information	409	359	60	403	1

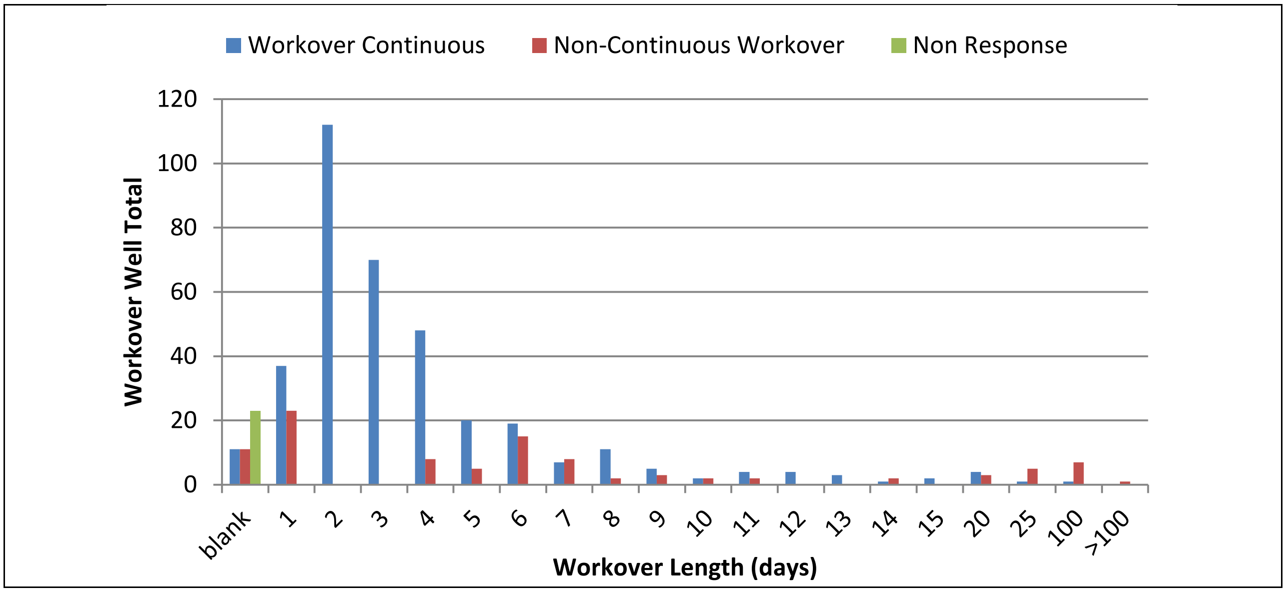


Figure A-3 Workover Duration for Existing Wells by Continuous and Non-Continuous Drilling

A.3.3 Current Drill Rigs and Workover Rigs Control Technology

Information regarding the current configuration of active drill rigs and workover rigs was requested by the survey. This information was coupled with the number of wells drilled or worked over by each rig in 2010 to determine the use of each drill rig/workover rig. **Table A-6** presents the 2010 activity grouped by drill rig engine control type. **Table A-7** presents the 2010 activity grouped by drill rig boiler control type. **Table A-8** presents the 2010 activity grouped by workover engine control type. In general there are a wide range of drill rig and workover rig engine controls, but all boilers are uncontrolled. The information in **Table A-6** is shown by engine size in **Figure A-4**. As shown in **Figure A-4**, the drill rigs operating in 2010 have a bi-modal distribution with a large proportion of new wells are drilled using a 500-700 horsepower (hp) engine or a 1400-1500 hp engine.

This information was coupled with drilling duration to estimate representative emission factors for drill rigs and workover rigs in the Uinta Basin.

Table A-6 **Drill Rig Engine Control Technology**

Primary Control	Secondary Control	Spud Count
None	None	32
No Response	No Response	293
Natural Gas-fired	Oxidation Catalyst	47
Tier 1	none	149
Tier 2	none	147
Tier 2	SCR	1
Tier 3	none	46
	TOTAL	**715**

Table A-7 Drill Rig Boiler Control Technology

Primary Control	Secondary Control	Spud Count
none	none	498
Invalid Data	Invalid Data	217
Tier 2	SCR	47
	TOTAL	**715**

Table A-8 Workover Rig Engine Control Technology

Primary Control	Secondary Control	Spud Count
none	none	448
Tier 1	Oxidation Catalyst	3
Tier 2	none	31
	TOTAL	**482**

* there are no boilers associated with workover wells

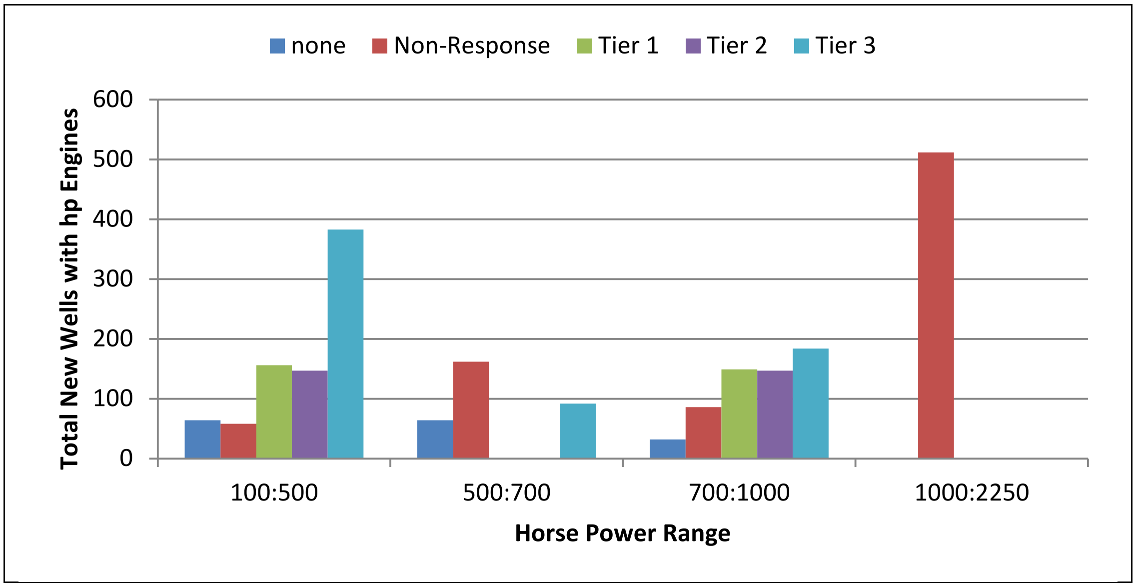


Figure A-4 Total Number of Diesel Engines by Horsepower and Control Technology

A.3.4 Flow Back Gas Treatment

Information regarding the current treatment of flow back gas was requested for both completions and recompletion events. The survey represents 715 completion events and 486 recompletions, as shown in **Table A-9**. A non-response rate for this portion of the survey was highly correlated with hydraulic fracturing activities.

Volume of flow back gas was combined by well type and process in **Table A-10**. As shown in **Table A-10**, over 98% of the total flow back gas is captured and sold, a small percent is flared and even less is vented. This proportion is consistent with gas well completions, but 100% of the flow back gas is vented from oil wells and injection wells. The amount of gas vented is approximately 5 Mscf per completion event, which is significantly less than the approximately 3,000 Mscf per completion event captured from gas wells.

This information was used to estimate the emission factors for completion and recompletion venting and flaring for the Uinta Basin.

Table A-9 Treatment of Flow Back Gas by Number of Completion and Recompletion Events

Well Type and Units	Captured and Sold	Flared	Vented	Non Response	Total
All Wells (Number)	383	2	403	411	1,199
All Wells (Percent)	31.9%	0.2%	33.6%	34.3%	100%
Gas Wells (Number)	383	2	3	404	792
Gas Wells (Percent)	48.4%	0.3%	0.4%	51.0%	100%
Oil Wells (Number)	0	0	391	1	392
Oil Wells (Percent)	0%	0%	100%	0%	100%
Other Well s (Number)	0	0	7	6	13
Other Wells (percent)	0%	0%	54%	46%	100%

Table A-10 Treatment of Flow Back Gas by Volume (Mscf)

Well Type and Units	Captured and Sold	Flared	Vented	Total
All Wells (Volume)	1,274,550	15,500	2,485	1,292,535
All Wells (Percent)	98.61%	1.20%	0.19%	100%
Gas Wells (Volume)	1,274,550	15,500	500	1,290,550
Gas Wells (Percent)	98.76%	1.20%	0.04%	100%
Oil Wells (Volume)	0	0	1,955	1,955
Oil Wells (Percent)	0%	0%	100%	100%
Other Well s (Volume)	0	0	20	20
Other Wells (percent)	0%	0%	100%	100%

A.4 Produced Water

Information regarding the processing of produced water was requested as part of this survey. As shown in **Table A-11**, a majority of produced water is disposed of via injection well and a small amount is evaporated either at a commercial facility or at well pad disposal sites. No additional information was supplied about “other” treatment methods.

Table A-11 Produced Water Treatment and Disposal Processes

Total Water Produced (bbl)	Disposal by Injection Well	Treatment		
		Commercial Surface Evaporation	In-house Surface Evaporation	Other
20,889,511	85%	7%	4%	4%

Appendix B

Oil and Gas Evaporation Pond Emissions

Sonoma Technology, Inc.
Air Quality Research and Innovative Solutions

Technical Memorandum

Introduction

Volatile organic compound (VOC) emissions from produced water evaporation ponds were estimated for the Uinta Basin using known locations of disposal facilities, calculated throughput volumes of produced water and representative VOC concentrations in produced waters from oil and gas operations. The following sections summarize the methods and literature sources used to estimate the VOC emissions.

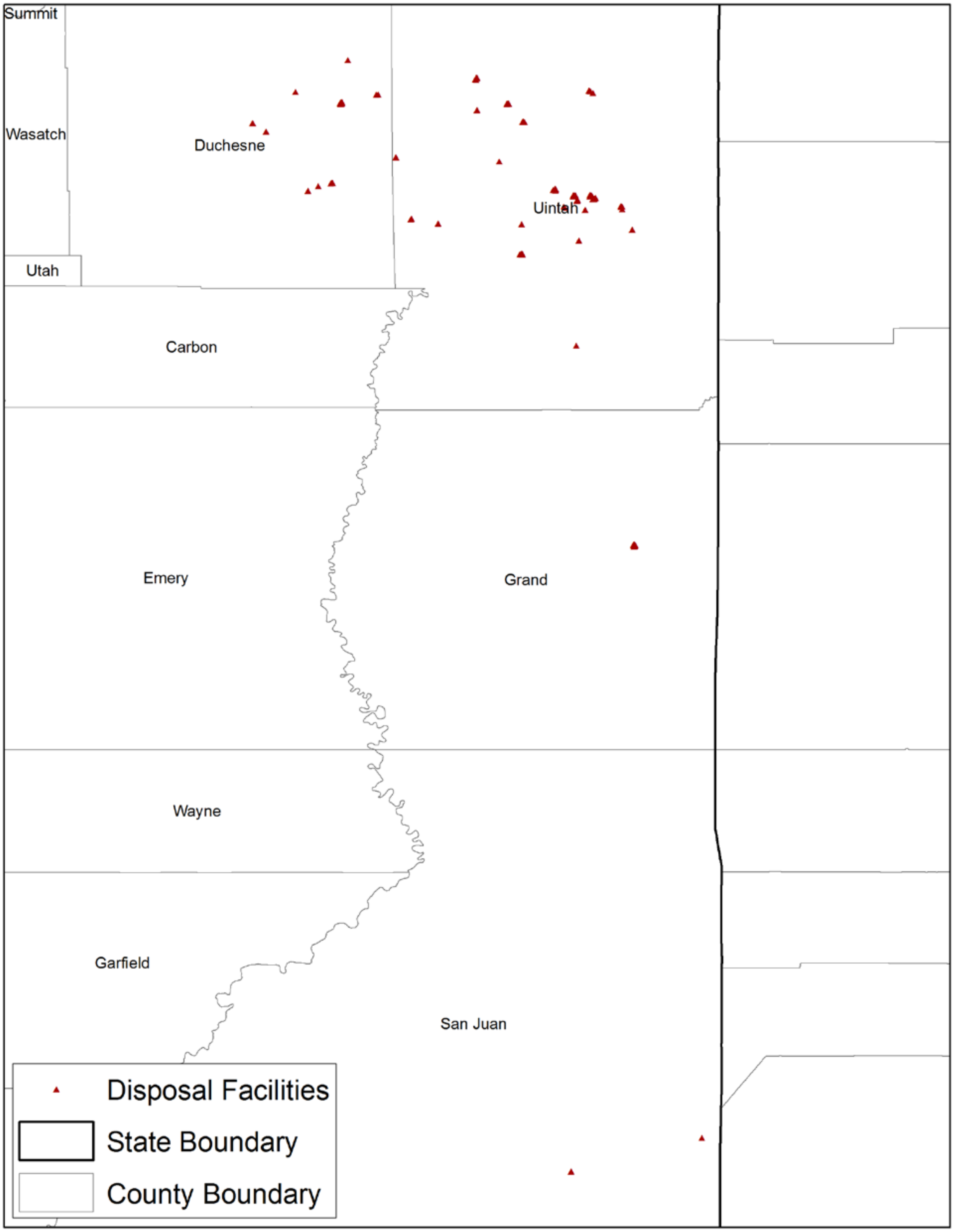
Methods

Reconcile Locations of Produced Water Evaporation Ponds

Locations of produced water evaporation ponds were provided by the Utah Division of Oil and Gas (UDOG) and Dr. Seth Lyman from Utah State University. Facilities in the list provided by UDOG represent approved disposal sites in and outside the Uinta Basin, while Dr. Lyman’s list was assembled as part of a detailed study of the Uinta Basin only. For compiling the final list of disposal sites, Dr. Lyman’s facility list was considered to more complete and better quality assured than the UDOG list and was therefore used for areas within the Uinta Basin, while the UDOG list was used for areas outside the Uinta Basin. To ensure a complete list of facilities inside the Uinta Basin, the two lists were compared and any facility from the UDOG list that did not match Dr. Lyman’s list based on operator and latitude/longitude location (within 0.01 degrees) was retained. **Figure 1** shows the complete list of disposal facilities within and outside the Uinta Basin.

Develop Representative VOC Concentrations

A literature review was performed to determine typical VOC constituent concentrations in produced water for the purpose of estimating VOC emissions from evaporation ponds. Benko and Drews (2008) present a meta-summary of published literature reports of VOC concentrations in produced waters for conventional oil and gas, and the reported total VOC concentrations ranged from 0.39 to 35 mg/L. In 2011, the state of Colorado provided constituent information for several produced water ponds located at conventional oil and gas facilities (Sullivan, 2011). The report noted that non-methane VOCs ranged from 15 to 100 mg/L, with 60 mg/L being recognized as a reasonable mid-range. Using these estimates, it was assumed that VOC concentrations in produced water from oil and gas operations range from 1 to 100 mg/L with a mid-range of 50 mg/L.


Summit
Wasatch
Duchesne
Uintah
Utah
Carbon
Emery
Grand
Wayne
Garfield
San Juan
Disposal Facilities
State Boundary
County Boundary

Estimate Flow Through

In order to estimate VOC emissions from the produced water, the amount of throughput for each pond is required. Flow throughput for the produced water ponds was estimated by assuming evaporation is steady-state with a constant rate. In the Green River Basin, between Yampa River and Colorado River, an evaporation rate of 2.8 feet (0.85 meters) per year per unit pond area was estimated for small ponds and reservoirs (Meyers, 1962). The quantity of water evaporated or input at the ponds (liters) was calculated using the evaporation rate of 0.85 meters depth per unit area each year and the total pond area (square meters).

Results

Total VOC emissions were estimated using the calculated throughput of produced water and the emissions factors presented above, assuming 100% of the VOC emissions are emitted. The resulting annual 2008 VOC emissions from produced water ranged from 2 to 191 tons per year. The emissions were then spatially allocated to the ponds according to the surface are of each pond. **Table 1** is a summary of total pond area and VOC emissions by county. The emissions from the maximum scenario are used in the model.

Table 1. Total pond area and VOC emissions (tons) by county.

County	Pond Area (m^2)	Emissions (tons)	
		Minimum	Maximum
Duchesne	373,855	0	35
Grand	262,995	0	25
San Juan	31,602	0	3
Uintah	1,369,238	1	128
Total	**2,037,690**	**2**	**191**

Speciation and Temporal Allocation

The speciation information for produced water in the Uinta Basin is unavailable. Therefore, the default speciation profile developed for all oil and gas sources is applied to the VOC emissions from produced water ponds.

Temporally, produced water ponds are likely to freeze over during winter months, inhibiting VOC emissions from pond surfaces. However, the use of flat (i.e., non-varying) temporal profiles would provide a conservative estimate of wintertime emissions for ozone modeling.

References

Benko K. and Drewes J. (2008) Produced Water in the Western United States: Geographical Distribution, Occurrence, and Composition. *Environmental Engineering Science*, **25**, 239-246.

Meyers J. (1962) Evaporation From the Surface of Lakes in 17 Western States. *U.S. Geological Survey Professional Paper* 272-D.

Sullivan D. (2011) Control strategies for reducing evaporation pond emissions Technical memorandum prepared for U.S. Environmental Protection Agency, Region 8, Denver, CO by Sonoma Technology, Inc., Petaluma, CA, STI-910210-4057-TM, September 15.

Appendix C

Volatile Organic Compound Speciation Profiles

C.1.0 Development of VOC Speciation Profiles

The total emissions of volatile organic compounds (VOC) are lumped into model species based on the chemical composition of the VOC. To do this, the Sparse Matrix Operators Kerner Emissions (SMOKE) model uses VOC composition profiles and applies this to different emissions sources using a cross-reference file. VOC profiles are developed for oil and gas sources in the Uinta Basin based on the measured VOC chemical composition from sources within and near the basin. For oil and gas sources outside of the Uinta Basin and all other source sectors, the SMOKE default chemical speciation profiles are used as described in Technical Support Document.

C.2.0 Initial Inputs

Chemical speciation profiles are developed for oil and gas processes that have a notable contribution to VOC emissions, including natural gas dehydrators, pneumatic devices, and oil and condensate tanks. Chemical composition analyses were provided by Utah Department of Environment Quality (UDAQ 2013). These data were used to develop a unique chemical composition profile for each source classification code. **Table C-1** shows the chemical composition profile identifier code for each source category (grouped into Source Classification Codes [SCC]). The same chemical composition profile is used for all counties within the Uinta Basin.

C.3.0 Speciation Profile Development

The mass of VOC emissions are calculated and reported as a part of criteria air pollutant emissions inventories; however, chemical speciation profiles are based on the mass of total organic gas (TOG) instead of VOC. Thus, prior to the speciation processes, VOC needs to be converted to TOG using a conversion factor shown in **Table C-2** for each SCC.

The chemical compositions analyses from various sources within the Uinta Basin were grouped together to generate TOG profiles for dehydrators, pneumatic devices, and tanks. The chemical distribution is then converted into VOC profiles compatible with the Carbon-Bond 5 (CB05) chemical mechanism that is invoked in the air quality model. **Table C-3** provides the chemical abbreviations for the CB05 model species.

C.4.0 Final SMOKE Input

The SMOKE-ready TOG speciation profiles applied to Uinta Basin oil and gas VOC emissions are shown in **Table C-4**.

Table C-1 VOC Speciation Profile Identifier by SCC

SCC	Pollutant Name	VOC Speciation Profile Number
2310010200	VOC	9001
2310020100	VOC	9002
2310020800	VOC	9003
2310023100	VOC	9002
2310023800	VOC	9003
2310030300	VOC	9001
2310020900	VOC	9003
2310024100	VOC	9003
2310025100	VOC	9003
2310025200	VOC	9003
2310025300	VOC	9003

Table C-2 Conversion Factors Applied to VOC Profiles to Calculate TOG

Pollutant Converting from:	Pollutant Converting to:	VOC Speciation Profile Number	Conversion Factor
VOC	TOG	9001	1.003258
VOC	TOG	9002	16.44518
VOC	TOG	9003	5.255506

Table C-3 Air Quality Model Species Names

Chemical Initials	Full Name
VOC	Volatile organic compound
TOG	Total organic gas
CH_4	Methane
ETHA	Ethane
PAR	Paraffins
TOL	Toluene
UNR	Unreactive
XYL	Xylenes

Table C-4 Uinta Basin SMOKE TOG Speciation Profiles

Profile Number	Pollutant Name	Species Name	Split Factor	Divisor	Mass Fraction
9001	TOG	PAR	0.759399	14.29218	0.759399
9001	TOG	TOL	0.002257	92.14823	0.002257
9001	TOG	XYL	0.018973	106.165	0.018973
9001	TOG	CH4	0.798828	16.04246	0.798828
9001	TOG	ETHA	0.087048	30.06904	0.087048
9001	TOG	UNR	0.037706	14.47567	0.037706
9002	TOG	PAR	0.042872	14.57137	0.042872
9002	TOG	TOL	9.11E-05	92.17009	9.11E-05
9002	TOG	XYL	3.41E-05	106.165	3.41E-05
9002	TOG	CH4	0.867827	16.04246	0.867827
9002	TOG	ETHA	0.071365	30.06904	0.071365
9002	TOG	UNR	0.017811	14.68769	0.017811
9003	TOG	PAR	0.1387	14.53827	0.1387
9003	TOG	TOL	0.00326	92.14962	0.00326
9003	TOG	XYL	0.000625	106.165	0.000625
9003	TOG	CH4	0.681881	16.04246	0.681881
9003	TOG	ETHA	0.127842	30.06904	0.127842
9003	TOG	UNR	0.047692	14.55293	0.047692

Appendix D

On-road Emissions Modeled with MOVES

D.1.0 Introduction

The Mobile Vehicle Emissions Simulator (MOVES) model developed by the U.S. Environmental Protection Agency (USEPA) is a state of the art model that incorporates current emissions data from numerous sources such as vehicle inspection and maintenance programs (I/M) and certified source testing data to provide estimates of mobile source emissions, referred to as on-road sources. MOVES can be run with the default National County Database (NCB), which includes all necessary input data required to run the model, or by incorporating local data where possible as recommended by the USEPA (USEPA 2010a). In the modeling process, the user specifies vehicle types, time periods, geographical areas, pollutants, vehicle operating characteristics, and road types to be modeled. The model then performs a series of calculations, which have been carefully developed to accurately reflect vehicle operating processes (such as cold start, exhaust running, extended idle, and so on) and provide estimates of bulk emissions or emission rates.

An important feature of MOVES2010 is that it allows users to choose between (1) the Inventory calculation type, which provides emission rates in terms of total quantity of emissions for a given time, and (2) the Emission Rate calculation type, which gives emission rates in terms of grams/mile or grams/vehicle/hour. Due to the high demands of computational resources in MOVES, USEPA recommends the community to set up the MOVES model to provide the Emission Rate calculation type especially for the large-scale regional emission modeling. It populates emission rate lookup tables that can then be applied to many times and places, thus reducing the total number of MOVES runs required. The MOVES lookup tables can be used as inputs to regional emissions modeling systems that model many different types of emissions and provide results that are used in performing air quality modeling.

For the computational efficiency of the MOVES emission rate lookup tables approach, inventory counties with similar fuel parameters, I/M programs, and urban, and rural characteristics can be represented by a reference county. Similar to the reference county concept, the fuel month reduces the computational time of MOVES by using a single month to represent a set of months with similar fuel characteristics. The use of reference counties coupled with fuel months reduces the significant computational burden and the number or total MOVES runs required (USEPA 2010b) when conducting modeling over a large modeling domain. Reference county per fuel month is modeled at a range of speeds and temperatures to produce emission rate lookup tables (grams/mile or grams/vehicle/hour, depending on emission process). This approach allows any county with unique distributions of vehicle miles traveled (VMT), vehicle population, roadway speed, and ambient temperatures to be modeled in the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system without having to rerun MOVES. In the latest SMOKE version 3.1, the new feature has been developed to facilitate the process of using MOVES to create emissions estimates appropriate for air quality modeling. Additional technical details of how to process SMOKE-MOVES integration approach will be available from CMAS website (Baek and DenBleyker, 2010).

For the large-scale regional emissions modeling, the latest SMOKE-MOVES tool was used to integrate the emission rates created by MOVES into SMOKE modeling system. This tool consists of a set of scripts that automate the emission rate calculations for estimating mobile source emissions from on-roadway and off-network for air quality modeling. Prior to the use of this tool, meteorological data must be pre-processed to set up the meteorological input conditions for both MOVES and SMOKE. MOVES model will be performed under the preconditioned meteorological conditions and create the MOVES emission rate lookup tables for SMOKE modeling system.

D.2.0 SMOKE-MOVES Integration Tool

Prior to perform MOVES and SMOKE models, users must prepare the meteorological input data for mobile source emissions modeling. The meteorological pre-processor will prepare temporally and spatially averaged ambient temperature and relative humidity (RH) data for use by both MOVES and SMOKE. It produces specific meteorological metrics for the reference county(s) for MOVES and additional meteorological metrics for all inventory counties in the county group (a.k.a. reference county) for SMOKE. The pre-processed meteorological input data contain absolute minimum and maximum temperatures, average RH, and a set of diurnal temperature profiles based on combinations of min/max temperature bins for each reference county in a fuel month.

D.2.1 MOVES Model Processing

When the MOVES model runs as a part of the SMOKE-MOVES tool, it runs for all mobile emissions processes, including on-road and off-network emissions processes, for the selected pollutants. Off-network emission processes (e.g., parked engine-off, engine starts, and idling, and fuel vapor venting) in MOVES are hour-dependent due to vehicle activity assumptions built into the MOVES model; the emission rate depends on both hour of the day and temperature. On-roadway emission processes (e.g., running exhaust, crankcase running exhaust, brake wear, tire wear, and on-road evaporative), on the other hand, do not depend on hour. In MOVES, these emission processes are categorized into three major groups:

Rate-Per-Distance (RPD) – The emission rate of vehicles on-network (i.e., driving) from MOVES. The emission rate is expressed in grams/mile traveled.

Rate-Per-Vehicle (RPV) – The emission rate of vehicles off-network (e.g., idling, starts, refueling, parked) from MOVES. The emission rate is given in grams/vehicle/hour.

Rate-Per-Profile (RPP) – The emission rate of vehicles off-network—specifically, the evaporation from parked vehicles (vapor-venting emissions) from MOVES. The emission rate is expressed in grams/vehicle/hour.

With pre-processed meteorological input data, MOVES model can be performed to generate three processes (i.e., RPD, RPV, and RPP) emission rates lookup tables for reference counties and fuel month. This involves two scripts: The MOVES driver script generates the MOVES input file (a.k.a. runspec) for three processes, which specifies the characteristics of the particular scenario to be modeled based on meteorological conditions. Once the MOVES driver script has completed, the MOVES post-processing script extracts the emission factor tables from the MOVES MySQL database and converts to the ASCII-format emission rate lookup tables for SMOKE modeling system.

D.2.1.1 MOVES Driver Script Processing

U.S. EPA does encourage the use of local data for all of these inputs where possible, but MOVES contains default values at the county level for all required inputs. For this project, meteorological input data are based on the meteorological model developed for the ARMS Modeling project (AECOM 2013). In addition, vehicle population (VPOP) and VMT based on EPA’s NEI 2008 data were used. The remaining data inputs were populated with the default values available in the MOVES database.

D.2.1.2 MOVES Post-Processing

Once a MOVES runspec batch file run completes, MOVES will create the three output lookup tables for RPD, RPV and RPP emission processes. These files are not compatible with SMOKE. Therefore, USEPA created a Perl-based script to reconfigure the MOVES emission rate outputs (stored in MySQL databases) into lookup tables compatible with SMOKE modeling.

D.2.2 SMOKE Model Processing

Once SMOKE-ready emissions rate lookup tables for RPD, RPV and RPP mode are ready, the SMOKE model will estimate emissions from on-road sources based on these lookup tables and hourly local meteorology data. The SMOKE processing method varies depending on whether SMOKE is modeling on-roadway or off-network emissions processes.

For on-roadway emission process (RPD), SMOKE requires county-total VMT and average hourly speed inventory data to estimate emission rate of on-roadway emission processes (e.g., exhaust, evaporative, tire and brake wear). SMOKE uses this data with the hourly temperature to select the appropriate emission rate from the RPD lookup tables. For off-network emission processes (RPV and RPP), SMOKE requires county total vehicle population data by vehicle type to estimate emissions for off-network emissions processes. These data are combined with hourly temperature to select the emission rates in the RPV and rate-per-profile RPP lookup tables.

A significant difference in the processing steps between the on-roadway and the off-network emissions processes in SMOKE modeling system is that off-network emissions processing does not require application of temporal allocation processes because the underlying activity data (vehicle population) is not time dependant. In the RPV table, gridded hourly temperature and hour of the day are lookup fields SMOKE uses to estimate hourly off-network emissions in unit of grams/vehicle/hour. For the evaporative fuel off-network vapor venting emissions process, the RPP lookup table is used to estimate the hourly emission rates based on daily the minimum and maximum temperatures by inventory county.

For this project, the SMOKE-MOVES integration tool was used to generate on-road emissions for the 12-km and 4-km modeling domains. The emissions from each emission process (on-roadway [RPD] and off-network [RPV and RPP]) are computed individually, since the SMOKE emission rate calculation methods in are quite different. Once all three emissions processes have been computed, the emission output files are merged to create 2-D hourly, gridded, and speciated emissions.

References

United States Environmental Protection Agency (USEPA). 2010a. Technical guidance on the use of MOVES2010 for emission inventory preparation in state implementation plans and transportation conformity. Prepared by the EPA's Office of Transportation and Air Quality, Ann Arbor, MI, EPA-420-B-10-023, April. http://www.epa.gov/otaq/models/moves/420b10023.pdf.

_____. 2010b. Motor vehicle emission simulator (MOVES) user guide for MOVES2010a. Assessment and Standards Division, Office of Transportation and Air Quality, Research Triangle Park, NC, EPA-420-B-10-036, August. http://www.epa.gov/otaq/models/moves/MOVES2010a/420b10036.pdf; additional resources are available at http://www.epa.gov/otaq/models/moves/index.htm.

Baek B.H. and DenBleyker A. (2010) User’s guide for the SMOKE-MOVES integration tool. User's guide prepared for the U.S. Environmental Protection Agency by UNC Institute for the Environment, Chapel Hill, NC, and ENVIRON, Novato, CA, July. Available on the Internet at http://www.smoke-model.org/smoke_moves_tool/SMOKE-MOVES_Tool_Users_Guide.htm.

Appendix E

Oil and Gas On-road Equipment

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Technical Memorandum

Introduction

To support the estimation of 2010 emissions from oil and gas-related on-road mobile sources, per-well truck trip information from the Utah Department of Transportation (UDOT) was converted into vehicle miles traveled (VMT) estimates. These estimates were based on the distance from wells to major roads and to disposal facilities with produced-water evaporation ponds, and VMT estimates were calculated by county and road type. The following sections summarize the methods used to estimate the number of trucks per well for 2010, the distance the trucks traveled by road type, and the final truck activity data (VMT).

Methods

Truck Calculations

The first component needed to calculate VMT is the number of trucks that visit a given well in a year. The number of truck trips depends on well characteristics such as well type (oil or gas) and the stage of the well (new well/spud or producing). Truck activity information for oil and gas wells in the State of Utah was acquired from a Utah Department of Transportation (UDOT) study on oil and gas-related mobile source activities (Kuhn 2006). The study provides an outline of the processes involved in developing a new oil or gas well, a range of truck traffic for each process, and an overview of where the trucks are coming from and which routes are used. The information in the study was obtained from the State of Utah Division of Oil, Gas, and Mining, the Federal Bureau of Land Management, and energy Companies drilling in the Uintah Basin.

Table 1 summarizes the number of trucks by process for oil and gas wells and the origin/destination of the trucks (out of state, local, or produced-water disposal facility). The study provided a range of trucks for each process which depends on the status of the well (spud or producing). For a new well, the total number of trucks (i.e., trucks for all trip purposes in Table 1 summed) needed to set up the well ranges from 444 to 1,457, with an average value of 950.5. For a currently producing well, the number of trucks per year for an oil well ranges from 60 to 3,602 with an average of 1,831 trucks, while the number of trucks per year for a gas well ranges from 48 to 1,802 trucks with an average value of 925.

Table 1. Summary of truck information from the UDOT study by well status.

Well Status	Activity	Purpose of Trucks	Number of Trucks			Origin
			Min	Max	Avg	
Spud	Construction	Bring in heavy equipment to prepare well site for drilling	10	45	27.5	Out of State
	Drilling	Moving drill rig to well site	30	30	30	Out of State
		Fresh water for drilling ponds	25	25	25	Local
		Additional fresh water truck loads	100	1,000	550	Local
		Waste water/rock disposal	50	100	75	Local
		Drill mud (drilling mud)	10	20	15	Local
		Well casing	10	10	10	Out of State
		Cement powder and fly ash	4	9	6.5	Out of State
		General rig maintenance	10	10	10	Local
		Removal of drill rig from well site	30	30	30	Out of State
	Completion	Completion rig preparation	1	2	1.5	Local
		Rig set-up	3	4	3.5	Out of State
		Well tubing	1	2	1.5	Out of State
		Perforate casing and cement outer lining	2	2	2	Out of State
		Frac sand mix	5	6	5.5	Out of State
		Frac tanks	20	20	20	Out of State
		Water for frac tanks	100	100	100	Local
		Remove completion rig	20	25	22.5	Out of State
		Close reserve pits and restore ground cover	3	5	4	Local
		Build facility	10	12	11	Out of State
Producing	Well Operation	Crude oil transport	12	1,800	906	Out of State
		Water removal	48	1,800	924	Closest pond
		General well maintenance	0	2	1	Local

For most processes, the difference between the minimum and maximum number of trucks needed is relatively small, therefore the average value was used. The processes with the greatest truck variability are those pertaining to water use and transport of oil for producing wells. To estimate water use and oil transport at oil and gas wells in the State of Utah, production activity information from a dataset of wells in the Uintah Basin[1] and an average

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[1] Production activity is from the Indian Health Service (HIS) database which contains the well activity information (amount of oil, gas, and water produced) for the Uintah Basin for 2010.

capacity of water/oil trucks[2] was used to calculate the number of trucks needed for each well in the database on an annual basis. For 2010, the number of water trucks needed per well to remove the produced water averaged 70 trucks per year. For oil transport, the number of trucks needed per well averaged 19 trucks per year. The average values for water use and oil transport for the wells in the Uinta Basin fall within the range of the study and were used in the final calculations for all wells in the state[3].

Since the number of trucks depends on the status and type of well, well information for Utah well locations in 2010 were provided by AECOM. Each well has a unique American Petroleum Institute (API) number, latitude, longitude, county, type of well (oil or gas), and if the well is a coalbed methane (CBM) well. The well status was not provided; therefore, to determine the status of the well, a list of spud wells for 2010 was downloaded from the State of Utah Department of Natural Resources Division of Oil, Gas, and Mining (see http://oilgas.ogm.utah.gov/). In Microsoft Access, the spud list was linked to the list of all wells by API number, and this process resulted in the identification of 683 of the 9,684 wells as spuds.

In addition to well locations, AECOM provided a list of produced-water disposal facilities where the wells send their waste water for disposal[4]. To identify the closest disposal facility to each well, the latitude and longitude of each well and facility were used to create shapefiles using Environmental Systems Research Institute, Inc. (ESRI) ArcGIS. **Figure 1** shows the locations of the wells and the disposal facilities.

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[2] For oil and gas operations, water and oil are transported in tanker trucks with an average capacity of 5,000 gallons. This is based on truck manufacturer's specifications from http://www.currysupply.com/products/vacuum_frac.php and oil transport services website http://www.maclaskey.com/index_files/transport.htm.

[3] Well specific water truck counts were not used since the sample dataset is only for the Uintah basin and only a portion of the well identifications matched between the two datasets.

[4] Information on which pond each wells sends its waste water was not provided.

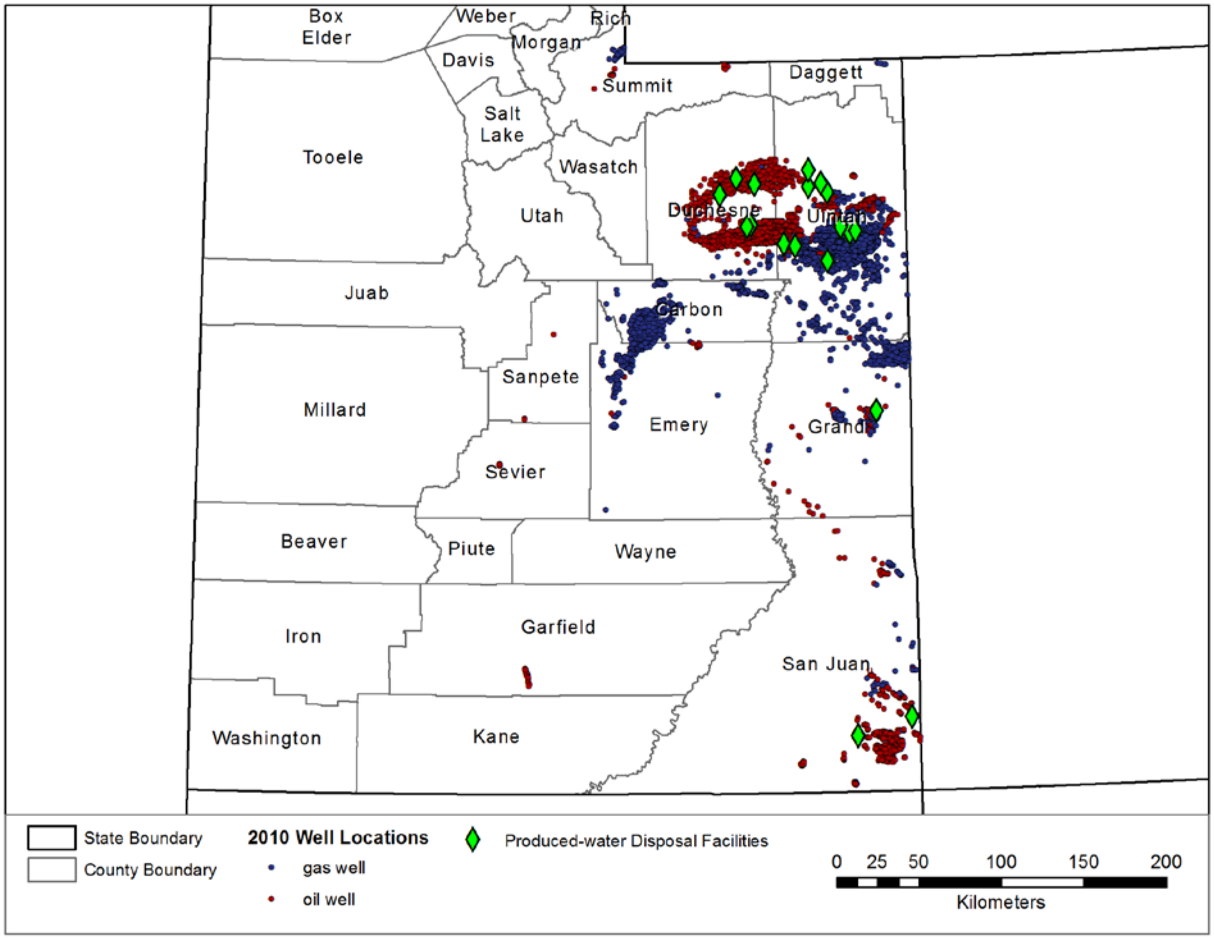

Figure 1. Location of 2010 gas and oil wells and locations of produced-water disposal facilities.

Distance Calculations

The second component needed to calculate VMT is the distance each truck must travel to reach the well, which depends on the origin of the truck.

- For local trucks, we assumed that they are transporting equipment from within the same county and only travel 8 miles from the well. This estimate is based on a survey of well owners conducted during a recent pilot study sponsored by the Western Regional Air Partnership (WRAP). This study was undertaken to estimate VMT from oil and gas mobile sources in the Piceance Basin of Northwestern Colorado (Bar-Ilan et al., 2011).

- For out of state trucks, data from the UDOT truck study indicates that the origin/destination points of the out-of-state trucks are mainly along Interstate 70 to the east or Interstate 80 to the north.

- For trucks traveling to and from produced-water disposal facilities, we assumed that trucks would travel to the closest facility.

Using a default road network from ESRI, we selected only the highway and interstate road types in Utah to simplify the calculations, and these roadway representations were converted into a new shapefile. Since VMT data are needed by county and road type, intersections between different road types (i.e., the point where a highway interests with an interstate) and county borders (the point where the road crosses from one county to another) were generated in GIS. **Figure 2** shows the major road network used to calculate distances trucks have to travel to reach individual wells, as well as the locations of the identified intersection points.

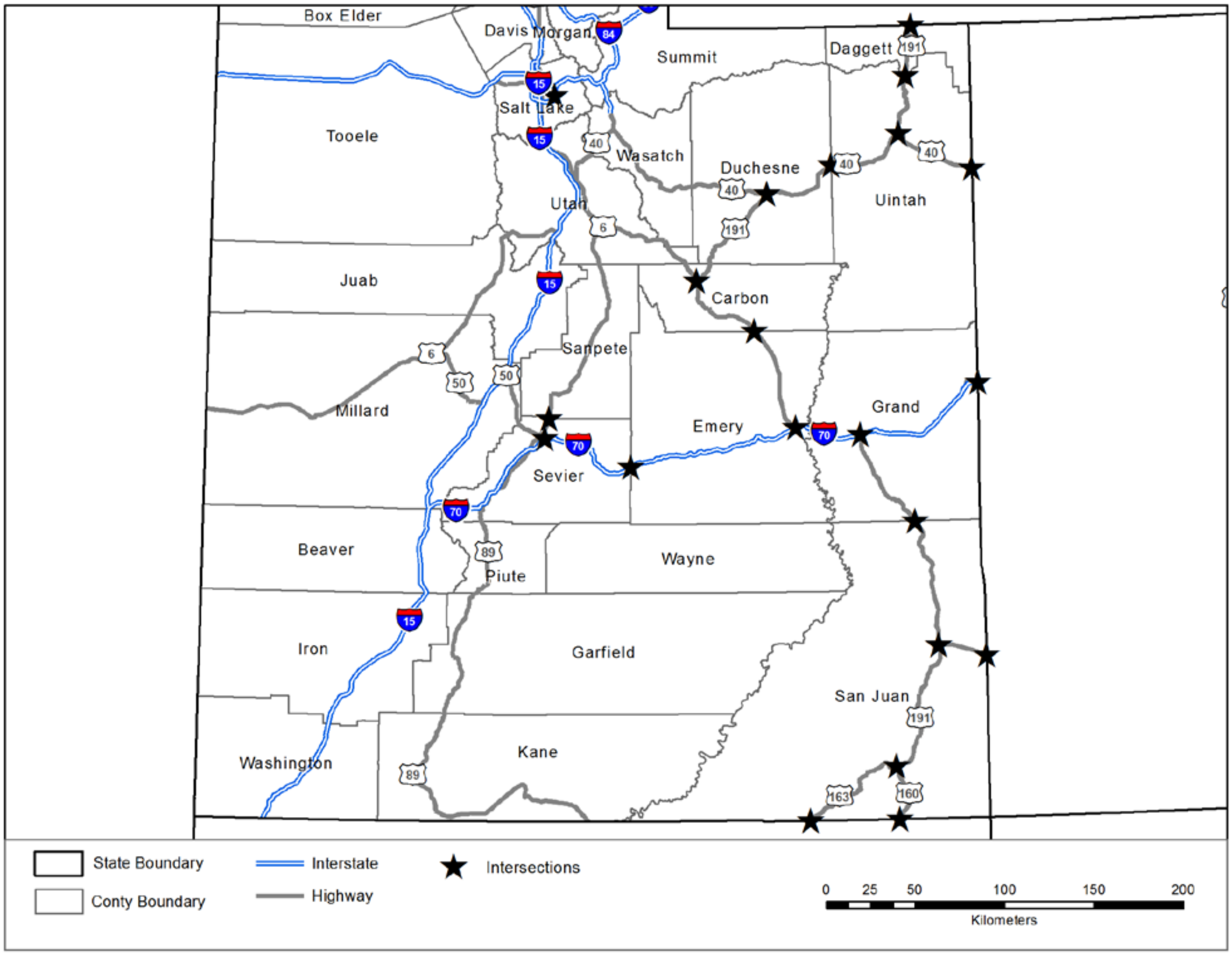

Figure 2. Road network and intersections used to calculate truck VMT to and from wells.

As previously stated, out-of-state trucks are coming mainly from the east along Interstate 70 and the north from interstate 80. For wells north of the road intersection of Highways 191 and 6 in Carbon County, the trucks are assumed to use Interstate 80; for all other wells, trucks are assumed to use Interstate 70. The red arrows in **Figure 3** represent the direction trucks would take leaving the well (a reverse direction would be used to reach the well).

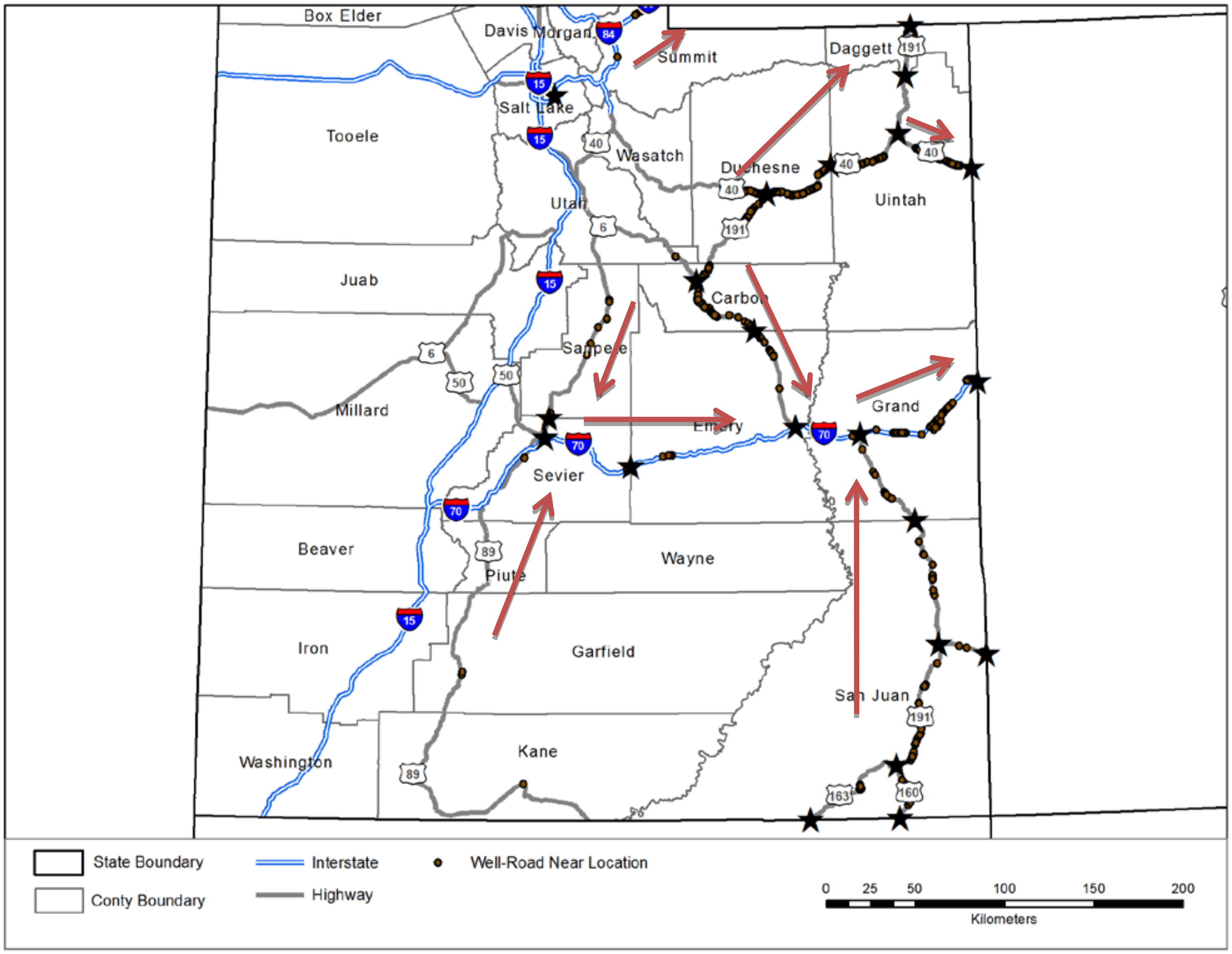

Figure 3. The locations where the access road and major road intersect for each well and the direction the trucks travel to get to the well.

For the trucks to reach a well, they must exit the major road network and travel on roads constructed specifically to access the oil and gas locations. This road network also connects the wells to the produced-water disposal facilities, allowing the trucks to not reenter the major road network. Since this access road network is very detailed and not available in GIS, a simplified method was developed to estimate the distance from the well to the nearest major road and the distance to the closest produced-water disposal facility. These distances were calculated using the “near” geoprocessing tool in ArcGIS. This tool is part of the proximity toolset in ArcGIS and is used to calculate the distance from a feature (specific well location) to the nearest feature of a selected feature class (location of major roads and disposal facilities).

Table 2 is a summary of the processing steps used to calculate the distance from the well to the state border and to the produced-water disposal facility. These steps were repeated for each well to estimate truck travel distances.

Table 2. Processing steps to calculate the distance from the well to the state border and to the produced-water disposal facility.

Step	Description	Details
1	Calculate distance to nearest major road	Select a well and calculate the distance to the nearest major road state using the “near” geoprocessing tool in ArcGIS.
2	Export the output text file	Export the output table from ArcGIS to a text file. This file contains the well number, distance to nearest major road, and the road type of the nearest road (highway or interstate).
3	Calculate distance to nearest produced-water disposal facility	Select a well and calculate the distance to the nearest waste water disposal facility using the “near” geoprocessing tool.
4	Export the output text file	Export the output table from ArcGIS to a text file. This file contains the well number, distance to nearest disposal facility, and name of disposal facility.
5	Calculate distance to first intersection	Calculate the distance from intersection of the access road and major road to the first intersection on the path out of the state using the “near” geoprocessing tool
6	Export the output text file	Export the output table from ArcGIS to a text file. This file contains the type of road traveled, county name, and distance to intersection.
7	Repeat for intersections on path	Repeat the “near” geoprocessing tool and export for each intersection on the path out of the state.

For trucks traveling to and from the produced-water disposal facility, the “near” tool was used to identify the nearest facility to each well and calculate the distance from the well to that facility. The output was exported to a text file to be used in Access.

VMT Calculations

After the number of trucks was estimated and the distance the trucks travel to reach the wells was calculated, the total VMT was estimated by county and road type. First, all distance output GIS text files were imported into a Microsoft Access database. A query was then written that summarized key information for each well, including the distance and road type of the nearest road, the distance to the nearest produced-water disposal facility, and well status (i.e., spud or producing). Based on well status, an annual truck traffic field was populated using the average truck values from UDOT study. For spud wells, we assumed a total of 170 out-of-state trucks and 780 local trucks. For producing wells, we assumed a total of 70 trucks bound for produced water disposal facilities, 19 trucks for oil transport (oil wells only), and 1 maintenance truck.

Using the above well information query, VMT was estimated by county and road type using the following methods:

- To calculate VMT on oil and gas access roads, the distance from the well to the nearest major road was multiplied by the number of out of state trucks, local trucks, trucks for oil transport, and trucks carrying maintenance equipment. In addition, if the closest disposal facility to the well is closer than 50 km, then we assumed the water trucks will travel the distance to the nearest facility using only access roads. For wells with a nearest pond distance greater than 50 km, the distance from the major road times the number of pond trucks was assigned to access road class. The rest of the distance was assigned to the highway road class. This is due to the fact that the ponds are located close enough to the wells that the trucks should not have to get back on the highway.
- To calculate VMT for highway and interstate roads, the distance from each wells intersection of the access road and the major road to the state boundary is multiplied by the number of out-of-state, maintenance, oil trucks, and select pond trucks. In addition, for local trucks, we used a trip length of 8 miles on major roads and multiplied this value by the number of local trucks.
- To calculate total VMT by county, the VMT from all road types were multiplied by 2 to represent both the arriving and returning trips.

Results

Table 3 is a summary of the total annual VMT (miles) for 2010 for trucks associated with oil and gas sources using the average truck counts from the UDOT survey and from 2010 activity data for the Uintah Basin. We estimated a total annual VMT of 69 million miles for oil and gas-related trucks in the Basin. Uintah County has 63% of the total truck VMT, and local road traffic accounts for the majority of the truck activity. On a statewide basis, VMT estimates from EPA's MOVES mobile source emissions model indicate that heavy duty truck activity in Utah amounts to about 1,120 million miles per year.

Table 3. Total annual VMT (miles) by county and road type.

County	Local	Highway	Interstate
Carbon	837,973	275,096	0
Daggett	4,287	46	0
Duchesne	5,959,727	7,610,005	0
Emery	159,904	239,723	130,089
Garfield	36,213	28,386	0
Grand	143,145	7,658	3,188,776
Piute		46,114	0
San Juan	1,725,718	2,597,304	0
Sanpete	2,521	385	0
Sevier	19,946	0	136,750
Summit	103,427	14,608	6,835
Uintah	26,222,809	19,700,574	637
Total	**35,215,670**	**30,519,900**	**3,463,088**

We compared these results to the WRAP study cited above (Bar-Ilan et al., 2011) and found that the total annual VMT estimated oil and gas-related trucking in Colorado' Piceance Basin was much lower at around 2.3 million miles. However, the team performing the WRAP study compared their truck trip estimates to those from the UDOT study and noted that their survey results for drilling rig movement and completion traffic were consistent at the low end of the UDOT study range, and that production traffic in the Piceance Basin was significantly lower than the UDOT study. As a result, the assumed number of truck trips per well in the WRAP study is much lower than in the UDOT study, resulting in significantly lower VMT estimates.

References

Bar-Ilan A., Grant J., Parikh R., and Morris R. (2011) Oil and gas mobile sources pilot study. Available on the Internet at http://www.wrapair2.org/pdf/2011-07_P3%20Study%20Report%20(Final%20July-2011).pdf.

Kuhn D.B., (2006) Highway freight traffic associated with the development of oil and gas wells. Available on the Internet at http://www.drillingsantafe.info/highwayfreight%20traffic.pdf.

Appendix F

Uinta Basin Oil and Gas Future Year Emissions Projection Supporting Data

F.1.0 Overview of Uinta Basin 2021 Projection Approach

In the Uinta basin, the 2010 oil and gas emissions are projected to 2021 based on predicted changes in key operating activity parameters. Six different activity surrogates were developed for the purposes of emissions projection. These parameters included:

- Total well count – total number of operating wells for all operators in each county;
- Spud count – number of wells drilled by all operators in each county;
- Total gas production – total gas produced by all operators in each county;
- Total condensate production – total condensate produced by all operators in each county;
- Total oil well production – total oil produced from oil wells by all operators in each county; and
- Non-CBM well count – total number of operating conventional wells for all operators in each county.

These activity surrogates are applied to oil and gas emissions based on similarity between the activity surrogate and the emissions source category, grouped by Source Classification Codes (SCC) and county. The activity surrogates were developed based on the reasonably foreseeable future development demonstrated by pending or proposed projects filed with the BLM. These projects and associated well counts are summarized in **Table F-1**.

Table F-1 Summary of New Well Development for Proposed Projects in the Uinta Basin

Project	Total Wells	Total Wells by 2021	Wells per County by 2021		
			Uintah	Duchesne	Carbon
Anadarko Greater Natural Buttes	3,675	3,580	3,580	0	0
BBC West Tavaputs Plateau EIS	596	596	0	26	570
Berry Petroleum ANF South Unit EIS/Vantage	404	204	0	204	0
Enduring Resources Big Pack EA	664	440	440	0	0
Enduring Resources Southam Canyon EA	249	200	200	0	0
EOG Greater Chapita Wells EIS	7,028	4,220	4,220	0	0
EOG North Alger EA	22	22	22	0	0
Gasco Uinta Basin EIS	1,538	1,000	334	666	0
Newfield Monument Butte EIS	5,750	2,000	1,464	536	0
Vantage Oil and Gas Project	16	16	0	16	0
XTO Hill Creek Unit EA	144	144	144	0	0
XTO Little Canyon EA	510	480	480	0	0
XTO River Bend Unit Infill EA	484	484	484	0	0
Total	**21,080**	**13,386**	**11,368**	**1,448**	**570**

In reviewing proposed projects, no reasonably foreseeable future development is anticipated for Grand or Emery counties. While Grand and Emery do not have any proposed new wells in the future, projected emissions are calculated based on expected changes in the oil and gas production and well counts.

Uncontrolled emissions of criteria pollutants for 2021 are calculated for each source category as the product of the 2010 emissions and the ratio of 2021 predicted activity level to the historic 2010 level for that parameter. The list of the source categories and the relevant activity surrogate are summarized in **Table F-2**.

Table F-2 Activity Parameters Used for Emissions Scaling by Source Category Code

SCC	Description	Activity Surrogate
31000000	Permitted Sources	Total gas production
2310025300	Artificial lift	Total well oil production
2310023100	CBM- Dehydrator	Total gas production
2310023700	CBM- Fugitives	Total well count
2310023800	CBM- Pneumatic Devices	Total well count
2310023400	CBM- Venting - Blowdowns	Total gas production
2310023600	CBM- Venting - Compressor Shutdown	Total gas production
2310023500	CBM- Venting - Compressor Startup	Total gas production
2310023200	CBM- Venting - Initial Completions	Spud count
2310023300	CBM- Venting - Recompletions	Spud count
2310025100	Compressor engines	Total gas production
2310030300	Condensate tank	Total condensate production
2310024300	Condensate tank flaring	Total condensate production
2310020100	Dehydrator	Total gas production
2310024400	Dehydrator flaring	Total gas production
2310030100	Gas plant truck loading	Total condensate production
2310024100	Heaters	Total well count
2310025200	Miscellaneous engines	Total well count
2310010200	Oil tank	Total oil production
2310023800	Pneumatic devices	Total well count
2310020900	Pneumatic pumps	Total well count
2310030200	Truck loading of condensate	Total condensate production
2310010100	Truck loading of oil	Total oil production
2310020700	Unpermitted fugitives	Total well count
2310023400	Venting - blowdowns	Total gas production
2310023600	Venting - compressor shutdown	Total gas production
2310023500	Venting - compressor startup	Total gas production

F.2.0 Development of Total Well Counts

New wells from the proposed projects listed in **Table F-3** and are spatially and temporally allocated to each county based on the fraction of the project area in each county and the estimated project start date, drilling rate, and drilling schedule. This information was taken from pending EA or EIS documents for each project and was accumulated with recorded total well counts for each county for 2010 from the IHS, Inc. Exploration and Production Information database. Although development of many projects will continue beyond 2021, for the purposes of this study, a summary of the incremental and cumulative well counts from 2010 to 2021 is provided in **Table F-3**. In addition to new wells, total wells are estimated assuming a uniform rate of plugging and abandoning existing wells.

Table F-3 Projected Total New and Cumulative Well Count by Year and County

Project/Activity	Year											
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Uintah County												
Existing Wells (Conventional and Coal Bed Methane [CBM])	5,252											
Remaining Ongoing and Approved		106										
Anadarko Greater Natural Buttes			358	358	358	358	358	358	358	358	358	358
Enduring Resources Big Pack EA					70	70	50	50	50	50	50	50
Enduring Resources Southam Canyon EA					25	25	25	25	25	25	25	25
EOG Greater Chapita Wells EIS				469	469	469	469	469	469	469	469	468
EOG North Alger EA			5	5	5	5	2					
Gasco Uinta Basin EIS			34	34	34	34	33	33	33	33	33	33
Newfield Monument Butte EIS					183	183	183	183	183	183	183	183
XTO Hill Creek Unit EA					17	17	24	24	24	24	14	
XTO Little Canyon EA					60	60	60	60	60	60	60	60
XTO River Bend Unit Infill EA			46	60	93	57	66	64	61	37		
New Wells Per Year		106	443	926	1,314	1,278	1,270	1,266	1,263	1,239	1,192	1,177
Cumulative Total	5,252	5,358	5,801	6,727	8,041	9,319	10,589	11,855	13,118	14,357	15,549	16,726
Carbon County												
Existing Wells (Conventional and Coal Bed Methane [CBM])	871											
BBC West Tavaputs Plateau EIS		119	90	86	56	56	56	56	51			
New Wells Per Year	28	119	90	86	56	56	56	56	51	0	0	0
Cumulative Total	871	990	1,080	1,166	1,222	1,278	1,334	1,390	1,441	1,441	1,441	1,441
Duchesne County												
Actuals-gas	1,963											
Remaining Ongoing and Approved		50										
BBC West Tavaputs Plateau EIS		5	4	3	3	3	3	3	2			
Berry Petroleum ANF South Unit EIS			21	21	21	21	20	20	20	20	20	20
Gasco Uinta Basin EIS			66	66	66	66	67	67	67	67	67	67
Newfield Monument Butte EIS					67	67	67	67	67	67	67	67
Vantage Oil and Gas Project	16			4	4	4	4					
New Wells Per Year	380	55	91	94	161	161	161	157	156	154	154	154
Cumulative Total	1,963	2,018	2,109	2,203	2,364	2,525	2,686	2,843	2,999	3,153	3,307	3,461

F.3.0 Development of Projected Spud Counts

Spud counts are estimated based on the total proposed well count for 2021 in each county plus an additional 5 percent to account for unsuccessful wells and ancillary drilling activities including monitoring and injection wells. **Table F-5** summarizes the estimated spud rate for each county.

Table F-1 Spud Count for 2021 by County

County	Propose Well Count	Spud/Well Ratio	Spud Count 2021
Uintah	1,177	1.05	1,236
Carbon	0		0
Duchesne	154		162

F.4.0 Development of Projected Total Gas Production

Gas production in 2021 was predicted for each county using a county-specific estimated well production decline over time as shown in **Tables F-6**, **F-7**, **F-8**, **F-9**, and **F-10**, for Uintah, Duchesne, Grand, Carbon and Emery counties, respectively. The number of wells at each given age was estimated as the number of new wells in 2021 based on data shown in **Table F-4.** Gas production in per year is the product of the number of new wells and the assigned gas production rate for a well of that age; the total 2021 gas production is the sum of these products. New well production must account for wells that begin production throughout the year and the “average” would be one-half of the calculated new well production rate. Therefore, only one-half of the production rate is considered due to well completion and shakedown for year 2021.

Table F-6 Projected 2021 Gas and Condensate Production for Uintah County

Year	Age	Wells Installed	Gas Production		Condensate Production	
			(MMscf/well)	(MMscf)	(bbl/well)	(bbl)
2021	1	12,326	72,383	892,170,511	739	9,103,567
2020	2	11,735	72,901	855,533,092	745	8,737,193
2019	3	11,098	73,451	815,186,398	751	8,333,726
2018	4	10,378	73,834	766,276,849	756	7,844,631
2017	5	9,595	73,982	709,862,757	759	7,280,490
2016	6	8,767	73,736	646,480,241	758	6,646,665
2015	7	7,892	72,621	573,129,807	749	5,913,160
2014	8	6,962	69,146	481,404,026	718	4,995,903
2013	9	5,945	62,341	370,644,139	654	3,888,304
2012	10	5,284	56,039	296,090,859	595	3,142,771
2011	11	4,922	57,007	280,594,278	607	2,987,805
2010	12	5,252	53,883	282,993,518	573	3,011,797

Table F-7 Projected 2021 Gas and Condensate Production for Duchesne County

		Conventional Wells	Gas Production		Condensate Production	
Year	Age	Installed	(MMscf/well)	(MMscf)	(bbl/well)	(bbl)
2021	12	2,374	20,607	48,912,519	223	528,644
2020	11	2,324	20,642	47,974,365	223	519,263
2019	10	2,273	20,660	46,963,403	224	509,153
2018	9	2,221	20,630	45,811,674	224	497,636
2017	8	2,164	20,526	44,427,625	224	483,795
2016	7	2,105	20,364	42,875,753	222	468,277
2015	6	2,045	20,099	41,096,392	220	450,483
2014	5	1,982	19,628	38,901,734	216	428,537
2013	4	1,917	19,262	36,930,575	213	408,825
2012	3	1,921	19,658	37,765,461	217	417,174
2011	2	1,828	22,017	40,252,756	242	442,047
2010	1	1,963	16,829	33,035,337	188	369,873

Table F-8 Projected 2021 Gas and Condensate Production for Grand County

		Conventional Wells	Gas Production		Condensate Production	
Year	Age	Installed	(MMscf/well)	(MMscf)	(bbl/well)	(bbl)
2010	12	240	2,232	4,486,408	22	**5,384**
2011	11	220	1,719	3,457,215	19	4,149
2012	10	217	1,592	3,204,092	18	3,845
2013	9	206	1,486	2,992,100	17	3,591
2014	8	195	1,390	2,799,670	17	3,360
2015	7	186	1,287	2,593,770	17	3,113
2016	6	176	1,176	2,370,382	16	2,844
2017	5	168	1,036	2,089,392	15	2,507
2018	4	159	894	1,804,510	14	2,165
2019	3	151	780	1,574,285	12	1,889
2020	2	144	685	1,383,500	12	1,660
2021	1	137	608	1,227,777	11	1,473

F.5.0 Development of Projected Total Condensate Production

For Uintah and Duchesne counties, condensate production in 2021 was predicted in a similar manner to gas production by using a county-specific condensate production decline over time. The number of wells at each given age was estimated as the number of new wells in each year based on data shown in **Table F-4** and historical data. Condensate production in each year was the product of the number of new wells and the condensate production for a well of that age; the total 2021 condensate production is the sum of these products. For year 2021, only one-half of the production from new wells was considered due to well completion activities throughout the year. Calculations of total condensate production in Uintah, Duchesne, and Grand counties are summarized in **Tables F-6, F-7,** and **F-8**, respectively. However, for Carbon and Emery Counties, condensate production data was not available. Therefore, condensate production in Carbon and Emery Counties was predicted based on the historical ratio of the change in condensate production to the change in gas production. **Tables F-9** and **F-10** summarizes the projected condensate production for Carbon County and Emery County based on this approach.

Table F-9 Historic and Projected 2021 Gas and Condensate Production for Carbon County

		Gas Production (MMscf/year)		Condensate Production (bbl/year)	
Year		Volume	Change Year-to-Year	Volume	Change Year-to-Year
Historic	2010	83,618,904	-12,973,918	46,254	-15,569
Projected	2011	91,098,500	7,479,596	55,230	8,976
	2012	114,468,000	23,369,500	83,273	28,043
	2013	124,938,000	10,470,000	95,837	12,564
	2014	122,018,000	-2,920,000	92,333	-3,504
	2015	118,326,000	-3,692,000	87,903	-4,430
	2016	117,598,000	-728,000	87,029	-874
	2017	118,056,000	458,000	87,579	550
	2018	117,077,500	-978,500	86,404	-1,174
	2019	96,756,000	-20,321,500	62,019	-24,386
	2020	77,378,000	-19,378,000	38,765	-23,254
	2021	64,887,000	-12,491,000	23,776	-14,989

F.5.1.1.1 Development of Projected Total Oil Production

The Newfield Monument Butte EIS indicate there will be 2,000 oil wells installed in Uintah and Duchesne counties over the life of the project and Berry Petroleum ANF South Unit EIS indicate there will be 204 oil wells installed in Duchesne County. However, no data were available to predict oil production based on well schedule. Therefore, oil well production estimates are calculated using a linear regression. A linear regression trend line was applied to a plot of oil production values and oil well counts from 2000 to 2010. A summary of projected oil production in Uintah, Duchesne, and Grand counties is provided in **Table F-11**.

Table F-10 Historic and Projected 2021 Gas and Condensate Production for Emery County

Year		Gas Production (MMscf)		Condensate Production (bbl)	
		Volume	Change Year-to-Year	Volume	Change Year-to-Year
Historic	2010	14,389,965	-2,193,413	6,106	-877
Projected	2011	7,776,000	-6,613,965	3,460	-2,646
	2012	6,171,000	-1,605,000	2,818	-642
	2013	5,119,000	-1,052,000	2,398	-421
	2014	4,362,000	-757,000	2,095	-303
	2015	3,788,000	-574,000	1,865	-230
	2016	3,371,000	-417,000	1,698	-167
	2017	2,984,000	-387,000	1,544	-155
	2018	2,706,000	-278,000	1,432	-111
	2019	2,414,000	-292,000	1,316	-117
	2020	2,178,000	-236,000	1,221	-94
	2021	1,957,000	-221,000	1,133	-88

Table F-11 Historic and Projected 2021 Oil Production for Uintah, Duchesne, and Grand Counties

Year		Oil Production (bbl)		
		Uintah	Duchesne	Grand
Historic	2008	6,558,732	8,702,500	268,410
	2009	6,702,566	8,767,934	168,751
	2010	6,610,463	10,911,061	117,603
Projected	2011	6,760,366	10,552,186	45,949
	2012	6,829,543	10,245,134	39,335
	2013	7,493,577	9,968,714	34,061
	2014	8,944,786	9,992,082	29,630
	2015	10,188,475	10,017,502	25,653
	2016	11,232,088	10,034,740	22,184
	2017	12,160,517	10,049,730	18,967
	2018	13,004,531	10,063,069	15,975
	2019	13,759,506	10,074,110	13,639
	2020	14,415,559	10,083,767	11,750
	2021	15,021,889	10,092,718	10,113

F.6.0 Summary of Projected Activity Parameters and 2021 Scaling Ratios

Table F-12 summarizes the historical 2010 activity data and the projected 2021 activity levels. The ratio of 2021 to 2010 levels is the activity surrogate value (i.e., scaling ratio) used for projecting 2010 emissions to predict 2021 emissions by source category for each county.

Table F-12 Summary of Uinta Basin Activity and Calculated Activity Surrogates for 2021

	Total Well Count (total wells)			Spud Count (spuds)			Total Gas Production (MMscf)			Total Condensate Production (bbl)			Total Oil Production (bbl)			Total Non-CBM Well Count (total wells)		
County	**2010**	**2021**	**Scaling Ratio**	**2010**	**2021**	**Scaling Ratio**	**2010**	**2021**	**Scaling Ratio**	**2010**	**2021**	**Scaling Ratio**	**2010**	**2021**	**Scaling Ratio**	**2010**	**2021**	**Scaling Ratio**
Uintah	5,252	12,326	2.35	447	1236	2.77	282,993,518	892,170,511	3.15	3,011,797	9,103,567	3.02	3,598,666	5,918,322	1.64	5,252	12,326	2.35
Carbon	871	1,262	1.45	60	0	0.00	83,618,904	64,887,000	0.78	46,254	23,776	0.51	0	0	0.00	241	632	2.62
Duchesne	1,963	2,374	1.21	422	162	0.38	33,035,337	48,912,519	1.48	369,873	528,644	1.43	10,541,188	9,564,074	0.91	1,963	2,374	1.21
Emery	241	222	0.92	1	0	0.00	14,389,965	1,957,000	0.14	6,106	1,133	0.19	0	0	0.00	66	47	0.72
Grand	240	137	0.57	5	0	0.00	4,486,408	1,227,777	0.27	5,384	1,473	0.27	112,219	8,640	0.08	240	137	0.57