# Appendix Q

## Summary of Air Emission Inventory Technical Support Document

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# APPENDICES

*Appendices are available in the complete Air Emission Inventory Technical Support Document (November 2015), which is available on Uncompahgre RMP revision Web site (http://www.blm.gov/co/st/en/fo/ufo/uncompahgre_rmp.html) and at the BLM Uncompahgre Field Office in Montrose, Colorado.*



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# APPENDIX Q
# SUMMARY OF AIR EMISSION INVENTORY TECHNICAL SUPPORT DOCUMENT

## Q.1 INTRODUCTION

This appendix summarizes the Air Emission Inventory Technical Support Document (November 2015), which is available on the Uncompahgre RMP revision Web site (http://www.blm.gov/co/st/en/fo/ufo/uncompahgre_rmp.html) and at the Bureau of Land Management (BLM) Uncompahgre Field Office (UFO) in Montrose, Colorado.

### Q.1.1 Scope and Goals

The Emission Inventory Technical Support Document explains the data and methodologies used to estimate emissions associated with future development in the UFO planning area. For this effort, an emission inventory was developed for emission sources affected by BLM management decisions for the UFO planning area.

### Q.1.2 Study Area

The emission inventory was developed for the UFO planning area. The UFO planning area is located in western Colorado sharing a small section of the border with Utah (**Figure Q-1**) and incorporates all or part of Delta, Gunnison, Mesa, Montrose, Ouray, and San Miguel Counties.

The UFO manages more than 900,000 surface acres in southwestern Colorado, including the Gunnison Gorge National Conservation Area and Wilderness, as well as portions of the Dominguez-Escalante National Conservation Area, Dominguez Canyon Wilderness Area, and four river systems (the Gunnison, San Miguel, Dolores, and Uncompahgre Rivers). The varied topography within the UFO ranges from lowland riparian along the Dolores River (4,706 feet) to red rock desert to pinion-juniper woodland to subalpine forest up on Storm King Mountain (11,449 feet). These lands offer a wealth of resources and opportunities for public use and enjoyment. The UFO is revising the UFO Resource Management Plan (RMP). The UFO RMP planning area encompasses approximately 675,677 surface acres within the UFO boundary. It does not include the Gunnison Gorge National Conservation Area or the Dominguez-Escalante National Conservation Area, which are managed under separate RMPs. Major activities

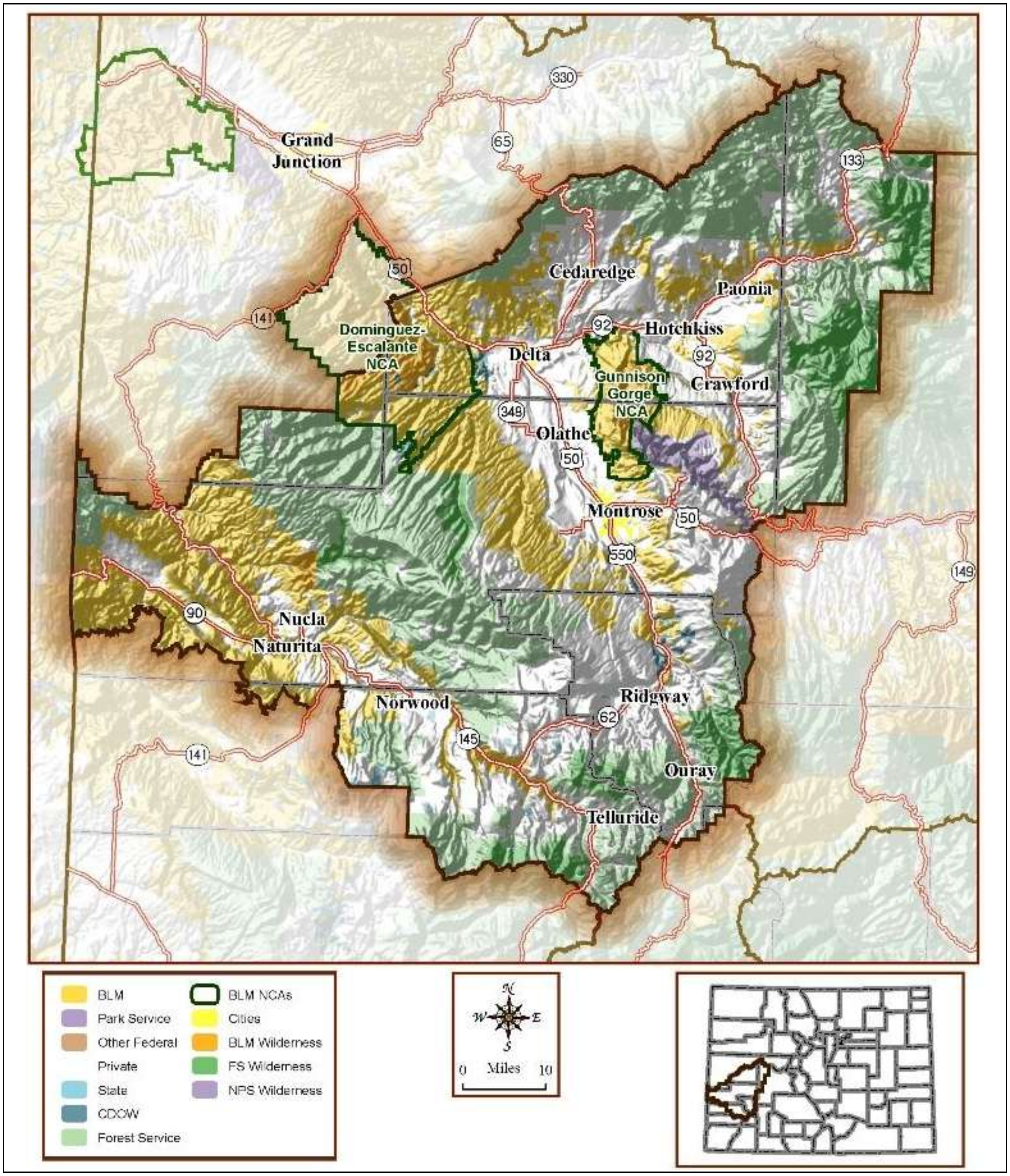


Figure Q-1. Uncompahgre Field Office Planning Area.

occurring in the UFO planning area that have the potential to affect air quality include oil and gas development, off-highway vehicle (OHV) activity, solid minerals mining, locatable minerals mining, and prescribed fires and vegetation management.

### Q.1.3 Relationships to Existing Plans and Documents

The most recent documents describing activities in the UFO planning area are the Reasonably Foreseeable Development Scenario for Oil and Gas for the Uncompahgre Field Office (BLM 2012a), the Mineral Potential Report for the Uncompahgre Planning Area (BLM 2011), and the Coal Resource and Development Potential Report (BLM 2010). The Mineral and Coal Potential Reports indicates relatively stable coal production and potential significant increases in uranium and vanadium mining in the UFO planning area. The Reasonably Foreseeable Development Scenario for oil and gas also indicates potential significant increases in oil and gas activity in the UFO planning area.

### Q.1.4 Emission Inventory Overview

#### *Q.1.4.1 Emission Generating Activities*

The following list of emission generating activities were identified as those management actions and activities authorized, permitted, allowed or performed under this RMP that could potentially emit regulated air pollutants and could potentially cause impacts to air quality within the planning area and Class I and sensitive Class II areas within 100 kilometers of the planning area:

- Fluid Leasable Minerals – Conventional Oil and Gas
- Fluid Leasable Minerals – Coal Bed Natural Gas
- Solid Leasable Minerals – Coal
- Locatable Minerals – Uranium and Vanadium
- Salable Minerals – Sand and Gravel
- Lands and Realty – Rights-of-Way
- Livestock Grazing
- Comprehensive Travel and Transportation Management
- Vegetation – Prescribed Fire and Mechanical Treatment

#### *Q.1.4.2 Pollutants*

The emission inventory includes estimation of emissions of criteria air pollutants (CAPs), greenhouse gases (GHGs), and hazardous air pollutants (HAPs) as follows:

- Criteria Pollutants
  - Carbon monoxide (CO)
  - Nitrogen oxides (NOX)
  - Particulate matter less than or equal to 10 microns in diameter ($PM_{10}$)
  - Particulate matter less than or equal to 2.5 microns in diameter ($PM_{2.5}$)

– Sulfur dioxide ($SO_2$)

– Volatile Organic Compounds (VOCs)

– Greenhouse Gases

– Carbon dioxide ($CO_2$)

– Methane ($CH_4$)

– Nitrous oxide ($N_2O$)

- Hazardous Air Pollutants (HAPs)

While lead (pb) is a criteria pollutant, emissions of lead in the UFO planning area are expected to be extremely low and are therefore not included in this analysis.

HAP emissions were estimated for each emissions source. For oil and gas emissions sources, HAP emissions from venting and combustion source categories were estimated for formaldehyde, n-hexane, benzene, toluene, ethylbenzene, and xylenes (BTEX).

Anthropogenic greenhouse gas emission inventories typically include carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), and fluorinated gases. Fluorinated gases are not expected to be emitted in appreciable quantities by any category considered in this emission inventory and were therefore not included in this analysis.

#### *Q.1.4.3 Temporal*

The analysis focused on estimating annual emissions associated with peak construction, production, and operation activities associated with the identified emission generating management actions. The base year 2011 was chosen as the base year for estimating actual emissions as this was the most recent year that reliable production and emissions data was available for existing sources within the planning area and this base year is consistent with the base year emission inventory developed for the Colorado Air Resource Management Modeling Study (CARMMS). Future year estimated emissions were calculated for 2012 to 2021. Potential peak construction and operation years for projected oil and gas development occur in Year 10 (i.e., 2021); therefore, Year 10 was selected to evaluate future air quality impacts.

## Q.2 EMISSION INVENTORY DEVELOPMENT

The UFO emission inventory was developed based on activity data for emission generating activities obtained from UFO staff, the *Reasonably Foreseeable Development Scenario for Oil and Gas for the Uncompahgre Field Office* (BLM 2012a), the *Mineral Potential Report* (BLM 2011), the *Coal Resource and Development Potential Report* (BLM 2010), and from NEPA analyses currently being conducted for BLM actions within the planning area. There is one oil and gas development which is currently under NEPA review, SG Interests Bull Mountain Unit (BLM 2012b). *The Decision Record, Finding of No Significant Impact, and Final Environmental Assessment for the Whirlwind Mine Uranium Mining Project* (BLM 2008) was used as a reference to identify the level of emissions associated with uranium mining. *The Bowie Coal Lease Modification Application, Preliminary Environmental Assessment* (BLM 2012c), *Environmental Assessment for the West Elk Coal Lease Modifications Application* (BLM 2012d), *Environmental Assessment for the Elk Creek Mine* (BLM

2012f) and the *Oak Mesa Coal Environmental Assessment* (BLM 2012e) describe environmental impacts associated with each project.

## Q.2.1 Alternatives

For the UFO RMP, the BLM developed four alternatives to prepare different combinations of resource uses to address the identified major planning issues, enhance or expand resources or resource uses, and resolve conflicts among resources and resource uses.

- Alternative A is the No Action alternative; a continuance of current management practices.
- Alternative B emphasizes non-consumptive use and management of resources through protective, restorative, and enhancement measures, while also providing for multiple uses, such as livestock grazing, recreational opportunities and settings, and mineral development.
- Alternative B.I is a partial alternative specific to oil and gas leasing and development in the North Fork and Smith Fork drainages of the Gunnison River (referred to as North Fork), primarily in portions of Delta and Gunnison Counties. While future oil and gas planning differs from Alternative B for Alternative B.I, future planning for non-oil and gas resources is equivalent to Alternative B for Alternative B.I.
- Alternative C emphasizes intensive management of natural resources, commodity production, and public use opportunities.
- Alternative D is the Preferred Alternative, which emphasizes balancing resources and resource use among competing human interests, land uses, and the conservation of natural and cultural resource values, while sustaining and enhancing ecological integrity across the landscape, including plant, wildlife, and fish habitat.

Estimates of future activity for each emissions source category were made specific to each alternative for activities expected to be affected by the chosen management alternative.

### *Q.2.1.1 Activity by Alternative*

#### *Q.2.1.1.1 Oil and Gas Sources*

Future oil and gas activity estimates were provided by BLM staff (BLM 2014). **Table Q-2-1** shows estimates of well, rig, and compressor station counts for each alternative Year 10 development. Included in **Table Q-2-1** is oil and gas activity on BLM-administered lands and cumulative development on BLM- and non BLM-administered lands in the UFO area.

For the emission inventory analysis, conventional well emissions were developed separately from coalbed natural gas (CBNG, also called coalbed methane) emissions based on the assumption that they differ significantly due to differences in drilling, completion, and production practices used in the development and operation. Additionally, midstream emissions were developed separately from well site emissions based on Colorado Department of Public Health and Environment Air Pollutant Emission Notices (APENs) emission data for the base year 2011 and forecasts to future years based on total annual UFO area-wide gas production.

**Table Q-2-1. Oil and gas well counts by alternative.**

| Description | BLM Historical Years 1-3[1] | BLM Projected Years 4-10[2] | Cumulative Historical Years 1-3[1] | Cumulative Projected Years 4-10[2] |
|---|---|---|---|---|
| **Alternative A** | | | | |
| Annual Number of Wells Drilled (Conventional) | 1 | 16.2 | 1.3 | 17.0 |
| Annual Number of Wells Drilled (CBNG) | 0 | 25.8 | 0 | 27.0 |
| Number of Drill Rigs Operating | 1 | 2 | 1 | 2 |
| Number of Operating Compressor Stations | 4 | 13 | 4 | 14 |
| **Alternative B** | | | | |
| Annual Number of Wells Drilled (Conventional) | 1 | 17.4 | 1.3 | 22.5 |
| Annual Number of Wells Drilled (CBNG) | 0 | 25.4 | 0 | 33.3 |
| Number of Drill Rigs Operating | 1 | 2 | 1 | 3 |
| Number of Operating Compressor Stations | 4 | 13 | 4 | 17 |
| Alternative B.I | | | | |
| Annual Number of Wells Drilled (Conventional) | 1 | 16.0 | 1.3 | 21.1 |
| Annual Number of Wells Drilled (CBNG) | 0 | 22.9 | 0 | 30.8 |
| Number of Drill Rigs Operating | 1 | 2 | 1 | 3 |
| Number of Operating Compressor Stations | 4 | 12 | 4 | 16 |
| **Alternative C** | | | | |
| Annual Number of Wells Drilled (Conventional) | 1 | 18.8 | 1.3 | 24.0 |
| Annual Number of Wells Drilled (CBNG) | 0 | 30.9 | 0 | 39.0 |
| Number of Drill Rigs Operating | 1 | 2 | 1 | 3 |
| Number of Operating Compressor Stations | 4 | 16 | 4 | 20 |
| **Alternative D** | | | | |
| Annual Number of Wells Drilled (Conventional) | 1 | 18.8 | 1.3 | 24.0 |
| Annual Number of Wells Drilled (CBNG) | 0 | 27.9 | 0 | 36.0 |
| Number of Drill Rigs Operating | 1 | 2 | 1 | 3 |
| Number of Operating Compressor Stations | 4 | 15 | 4 | 19 |

[1] For years 2012 to 2014 for which historical drilling data were available
[2] For years 2015 to 2021 for which alternative specific oil and gas development estimates of drilling activity were used

For each year, the suite of existing and newly spudded wells along with individual well production estimates are used to estimate total annual gas production; total annual gas production is used to make future projections of certain oil and gas emissions sources including midstream sector gathering and treating facilities. For conventional and CBNG wells, CARMMS estimates of annual gas production per well and each alternative's well development scenario were used to estimate future year gas production for each alternative. Midstream emissions were forecasted to future years based on the assumption that total UFO planning area-wide midstream emissions would scale linearly with increases in total gas production. As necessary, for accounting purposes, total midstream sector emissions are allocated to each well type (CBNG or conventional) and/or mineral designation (BLM or cumulative) based on the corresponding percentage of annual gas production by well type and/or annual gas production by mineral designation.

*Q.2.1.1.2 Non-Oil and Gas Sources*

Comparisons of activities by source category for non-oil and gas sources are presented in **Table Q-2-2** below.

**Table Q-2-2. Activity by alternative for non-oil and gas sources (year 10).**

| Key Assumption | Base Year | A | B | B.I | C | D |
|---|---|---|---|---|---|---|
| **Coal Mining** | | | | | | |
| **tons produced (MMt/yr)** | 14 (21)[1] | 14 (21)[1] | 14 (21)[1] | 14 (21)[1] | 14 (21)[1] | 14 (21)[1] |
| Coal mining activity was estimated for the Somerset Coal Field which includes the Bowie Mine, Elk Creek Mine, and West Elk Mine as well as the Oak Mesa area which may be developed in the future. Emissions were not estimated for the New Horizon Mine which is not subject to BLM review. The Coal Resource and Development Potential Report (BLM 2010) indicated that Somerset Field coal production is likely to remain stable at recent levels into the future. While demand for the bituminous coal produced by the Somerset Coal Field is likely to increase, production is limited by the capacity of the rail line spur that transports coal away from the Somerset Coal Field. It was assumed that Somerset Coal Field production would remain at 2008 levels. | | | | | | |
| **Uranium Mining** | | | | | | |
| **tons produced (MMt/yr)** | 0 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 |
| The Mineral Potential Report (BLM 2011) stated that the development potential of the Morrison Formation in the Uravan Mineral Belt is high. Based on input from UFO BLM personnel, it was assumed that 20 mines would be developed under each alternative, each assumed to have construction and operational characteristics similar to the estimates for the Whirlwind Mine, presented in Whirlwind Mine Environmental Assessment (BLM 2008). | | | | | | |
| **Sand and Gravel** | | | | | | |
| **Production (tons processed)** | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| Sand and gravel mining activities were assumed to remain unchanged from base year levels for all alternatives based on input from BLM UFO Personnel. | | | | | | |
| **Fire** | | | | | | |
| **Acres Burned** | 800 | 800 | 1,120 | 1,120 | 640 | 1,000 |
| BLM UFO Personnel estimated that prescribed burning activities would remain similar to the base year for Alternative A, increase by 40% from the base year for Alternatives B and B.I, decrease by 20% from the base year for Alternative C, and increase from the base year by 25% for Alternative D. Estimates of changes in prescribed burning activity are based on stated objectives by alternative in the draft RMP for wildlife species management, vegetation mosaic objectives, and Wildland Urban Interface. | | | | | | |
| **Travel and Transportation Management** | | | | | | |
| **1000 vehicle miles traveled per year** | 1,910 | 2,433 | 1,831 | 1,831 | 2,433 | 2,032 |
| For Alternatives A and C, growth rate estimates similar to those estimated for the BLM Grand Junction Field Office (ENVIRON, 2012) were used to estimate 27% increase in off-road recreational vehicle activity in Year 10. For Alternatives B and B.I, off-road recreational vehicle activity was assumed to decrease by 4% from the base year for Year 10. For Alternative D, off-road recreational vehicle activity was assumed to remain at 2012 levels. | | | | | | |
| **Livestock Grazing** | | | | | | |
| **AUMs** | 38,364 | 38,364 | 34,184 | 34,184 | 36,833 | 36,424 |
| BLM UFO Personnel indicated the 38,364 animal unit months (AUMs), 34,184 AUMs, 34,184 AUMs, 36,833 AUMs, and 36,424 AUMs for Alternatives A, B, B.I, C, and D respectively. | | | | | | |
| **Lands-ROWs and Realty** | | | | | | |
| **# of sites** | 28 | 28 | 28 | 28 | 28 | 28 |
| BLM UFO Personnel indicated no change in activity for this emissions source from the base year for any alternative. | | | | | | |

### *Q.2.1.2 Emission Controls*

The UFO emission inventory accounted for all applicable emissions controls such as New Source Performance Standards (NSPS). **Table Q-2-3** shows the emissions control measures for each emissions source category (except oil and gas) that were modeled in this analysis. **Table Q-2-4** presents the emission controls applied to oil and gas sources along with the associated numerical estimates of the level of control.

**Table Q-2-3. Emission controls summary table for non-oil and gas source categories (note all controls listed in this table apply to each management alternative).**

| Applicable Pollutants | Control Description |
|---|---|
| **Coal Mining** | |
| $PM_{10}$, $PM_{2.5}$ | Emissions from coal mining and assumed emission controls were based on available NEPA documents for Somerset Coal Field development.<br>Fugitive Dust Control: Mitigation measures would be implemented to reduce particulate matter/fugitive dust emissions during construction and production activities. Unpaved roads would be treated with water to control fugitive road dust emissions. Storage piles would be watered to limit wind erosion potential and reduce fugitive emissions. It is assumed that most coal transfer points and processing activities would be enclosed and would therefore reduce fugitive particulate emissions. |
| **Uranium Mining** | |
| $NO_X$, $PM_{10}$, $PM_{2.5}$ | Emissions from uranium mining and assumed emission controls were based on the Whirlwind Mine Environmental Assessment (BLM 2008)<br>**Generators:** Generators would meet NSPS standards and incorporate best available control technology.<br>**Particulate:** $PM_{10}$ emissions would be limited to Colorado Department of Public Health and Environment APEN permitted levels. The ore loading area would be treated with magnesium chloride and water would be used for dust suppression at the waste rock storage and other disturbed areas. |
| **Sand and Gravel** | |
| $PM_{10}$, $PM_{2.5}$ | **Fugitive Dust Control:** Fugitive road dust emissions would be controlled by watering and/or application of magnesium chloride. |
| **Fire** | |
| - No specific emission controls identified - | |
| **Travel and Transportation Management** | |
| - No specific emission controls identified - | |
| **Livestock Grazing** | |
| $PM_{10}$, $PM_{2.5}$ | **Fugitive Dust Control:** Fugitive road dust emissions would be controlled by watering. |
| **Land and Realty ROW** | |
| $PM_{10}$, $PM_{2.5}$ | **Fugitive Dust Control:** Fugitive road dust emissions would be controlled during land and realty right-or-way projects by watering and/or application of magnesium chloride. |

**Table Q-2-4. Oil and gas emission controls description and percent changes.**

| Applicable Pollutant(s) | Description | Percent Change |
|---|---|---|
| **Dust Control** | | |
| $PM_{10}$, $PM_{2.5}$ | watering | 50% |
| **Drill Rig Engines** | | |
| $NO_X$, PM | Tier II engines | 0% |
| **Completion Engines** | | |
| $NO_X$, PM | Tier II engines | 0% |
| **Green Completions** | | |
| VOC, HAPs | closed loop system and flaring control | 88% |
| **Liquids Removal System** | | |
| All | none | 0% |
| **Production Site Dehydrators** | | |
| VOC, HAPs | none | 0% |
| **Production Site Condensate Tanks** | | |
| VOC, HAPs | none | 0% |
| **Production Site Pneumatic Devices** | | |
| VOC, HAPs | usage of low-bleed pneumatic devices per Colorado requirements | 100% |
| **Production Site Pneumatic Pumps** | | |
| VOC, HAPs | none | 0% |
| **Wellhead and Lateral Compressor Engines Electrification** | | |
| All | none | 0% |
| **Wellhead, Lateral, Centralized Compressor Engines** | | |
| VOC, CO, $NO_X$ | All engines required to meet Colorado RICE and Federal NSPS Standards | |

## Q.2.2 Emission Calculations

Emission calculations for all emission-generating activities were derived from Operator-supplied data whenever possible. The detailed calculations shown in Appendices A, B, C, and D (of the Air Emission Inventory Technical Support Document) indicate the origin of the input data and how these data were used in the emissions estimates.

Methods used to estimate emissions from each source category are explained in Sections 2.2.1 and 2.2.2. For oil and gas sources, the estimation methods used for the conventional wells were the same as those used for CBNG wells unless noted otherwise. For each source category, emissions for the base year were estimated. Emissions were then forecasted to future years, accounting for activity growth and for applicable sources, emissions controls. More detailed assumptions, emission factors and calculations by source category are included in Appendices A, B, C, and D (of the Air Emission Inventory Technical Support Document).

#### *Q.2.2.1 Oil and Gas Sources*

The methodologies implemented to estimate base year and future year emissions by alternative from oil and gas sources are explained in this section. Methodologies apply to conventional and CBNG oil and gas developments, unless noted otherwise. More detailed assumptions, emission factors, and emission estimates by source category are included in Appendix A (of the Air Emission Inventory Technical Support Document) for conventional activities, Appendix B for CBNG activities, and Appendix C for the midstream sector.

Emissions are generated in three main phases of oil and gas systems:

- Emissions from Well Construction and Development
- Emissions from the Production Phase (occurring at-or-nearby the wellpad)
- Emissions from Midstream Sources (Central Gas Compression and Processing)

##### *Q.2.2.1.1 Emissions from Well pad Construction and Development*

Emissions from Well pad Construction and Development include those generated by equipment, vehicles and activities related to well pad construction, access roads construction, pipeline construction, wellbore drilling and well completions. **Table Q-2-5** includes the emission sources identified for the well pad construction and development phase. Pollutant emissions are initially estimated on a per surrogate basis and later scaled with the projected surrogate estimate to obtain area-wide annual emissions from each source.

**Table Q-2-5. Construction source categories and scaling surrogates.**

| Equipment Source Category | Emissions Units per Event | Scaling Surrogate |
|---|---|---|
| Well Pad, Access Road, and Pipeline Construction Equipment | tons/new pad | New pads per year |
| Well Pad, Access Road and Pipeline Construction Traffic | tons/new pad | New pads per year |
| Drilling Equipment and Completion Equipment | tons/spud | Spuds per year |
| Fracing Equipment | tons/spud | Spuds per year |
| Refracing Equipment | tons/well | Active wells per year |
| Drilling and Well Completion Traffic | tons/spud | Spuds per year |
| Rig Hauling and Rig Moving Traffic | tons/pad | New pads per year |
| Well Pad, Access Road and Pipeline Construction Wind Erosion | tons/new pad | New pads per year |
| Well Completion Venting | tons/spud | Spuds per year |

###### <u>Q.2.2.1.1.1 Well Pad, Access Road, and Pipeline Construction Equipment</u>

This category refers to emissions associated with off-road engines used during construction of well pads, access roads and pipelines and is also inclusive of well pad reclamation activity. Detailed data for each engine type such as horsepower rating, hours of operation, fuel type, engine technology and load factors were derived from the literature. The EPA NONROAD2008a model (EPA 2009b) was used to compile emission factors for each equipment type. The $N_2O$ emissions factor was obtained from the 2009 American Petroleum Institute O&G GHG Methodologies Compendium, Tables 4-13 and 4-17 (American Petroleum Institute 2009). Engines were classified in three types as activity data and emissions factors vary by utility: well pad construction equipment, access road construction equipment and pipeline construction equipment.

Emissions on a per event (new well pads) basis for an engine type for which data was provided were estimated according to Equation 1:

$$E_{engine\ k,i} = \frac{EF_i \times HP \times LF \times t_{event} \times n}{907{,}185} \qquad \text{Equation (1)}$$

where:

$E_{engine}$ are emissions of pollutant *i* from an engine type k [ton/pad]
$EF_i$ is the emissions factor of pollutant *i* [g/hp-hr]
*HP* is the horsepower of the engine k [hp]
*LF* is the load factor of the engine k
$t_{event}$ is the number of hours the engine is used [hr/pad]
*907,185* is the mass unit conversion [g/ton]
*n* is the number of type-k engines

#### *Q.2.2.1.1.1.1 Area-Wide Annual Emissions from Source Category*

Annual emissions from well pad construction equipment by pollutant were estimated from the sum of engine emissions from each of the construction engine types ($E_{engineTOTAL,i} = \sum E_{engine\ k,i}$) according to Equation 2:

$$E_{well\ pad\ equip,i} = E_{engineTOTAL,i} \times S_{well\ pad} \qquad \text{Equation (2)}$$

where:

$E_{well\ pad\ equip}$ are annual emissions of pollutant i from well pad construction and development equipment [ton/yr]
$E_{engineTOTAL,i}$ is sum of all engine emissions per event [ton/pad]
$S_{well\ pad}$ is the scaling surrogate for well pad construction [new pads/yr]

#### Q.2.2.1.1.2 Well Pad, Access Road and Pipeline Construction Traffic

This category refers to the exhaust emissions from light-duty and heavy-duty vehicle traffic during well pad, access road and pipeline construction. Emission factors were developed using the MOVES2010a model (EPA 2010). For each field office, by project year representative county emissions factors were developed. The emission factors were prepared for two vehicle classes, heavy duty trucks (source type combination short-haul truck) and pick-up trucks (source type light commercial truck). MOVES2010a emissions factors were modeled to include exhaust running, idle and start, brake wear, tire wear, and evaporative processes. The $N_2O$ emission factor was obtained from 2012 Climate Registry Default Emission Factors (The Climate Registry 2012).

Emissions from two distinct fleet types were estimated in this source category dependent on the vehicle destination/use: (1) well pad and access road construction vehicles and (2) pipeline construction vehicles. Annual vehicle miles traveled (VMT) to well site were available for each vehicle class (light duty and heavy duty) within each fleet type (well pad and access road, and pipeline construction), thus exhaust emissions for each of four vehicle groups were calculated using the MOVES2010a emission factors on a grams per mile basis, as shown in Equation 3.

$$E_{traffic,i} = \frac{EF_i \times N_{trips} \times D}{907185} \qquad \text{Equation (3)}$$

where:

$E_{traffic,i}$ is traffic exhaust emissions for pollutant i per well pad [ton/pad]
$EF_i$ is the average emission factor of pollutant i [g/mile]
$N_{trips}$ is the annual number of round trips per activity [trips/pad]
*D* is the round trip distance [miles/trip]
*907185* is the mass conversion [g/ton]

*Q.2.2.1.1.2.1 Area-Wide Annual Emissions from Source Category*

Annual emissions for well pad, pipeline and access road construction traffic by pollutant were propagated with the appropriate scaling surrogate according to Equation 4:

$$E_{well\,pad\,traffic,i} = E_{traffic,i} \times S_{well\,pad} \qquad \text{Equation (4)}$$

where:

$E_{well\,pad\,traffic,\,i}$ is the annual exhaust emissions of pollutant i from well pad, pipeline and access road construction traffic [ton/yr]

$E_{traffic,i}$ are the emissions of pollutant i per new well pad [ton/wellpad]
$S_{well\,pad}$ is the scaling surrogate for well pad and access road construction traffic [new pads/yr]

Q.2.2.1.1.3 Drilling, Completion and Hydraulic Fracturing Equipment

This section refers to emissions associated with off-road engines used during drilling and completion activities. Detailed data for each engine type per source category such as horsepower rating, hours of operation, fuel type, engine technology and load factors was derived from the literature. Emissions for four distinct engine groups were estimated: (1) drilling equipment, (2) completion equipment, (3) fracing equipment, and (4) refracing equipment. Emissions were estimated separately by engine type as inputs and surrogates (see **Table Q-2-5**) varied by type; however the same methodology delineated by Equations 5 and 6 was used in all calculations.

For drilling, completion and hydraulic fracturing equipment, the EPA Tier 2 Federal Diesel Engine Standard emission rates were applied for $NO_X$, VOC, CO, $PM_{10}$ and $PM_{2.5}$ emissions. The $N_2O$ emissions factor was obtained from the 2009 American Petroleum Institute O&G GHG Methodologies Compendium, Tables 4-13 and 4-17 (American Petroleum Institute 2009).

Emissions on a per event (spuds or active wells) basis for an engine type were estimated according to Equation 5:

$$E_{engine\ k,i} = \frac{EF_i \times HP \times LF \times t_{event} \times n}{907{,}185} \qquad \text{Equation (5)}$$

where:

$E_{engine}$ are exhaust emissions of pollutant *i* from an engine type k [ton/event]
$EF_i$ is the emissions factor of pollutant *i* [g/hp-hr]
*HP* is the horsepower of the engine k [hp]
*LF* is the load factor of the engine k
$t_{event}$ is the number of hours engine k is used [hr/event]
*907,185* is the mass unit conversion [g/ton]
*n* is the number of type-k engines

*Q.2.2.1.1.3.1 Area-Wide Annual Emissions from Source Category*

Annual equipment emissions by pollutant were estimated separately for each of the four engine groups and scaled with the appropriate scaling surrogate according to Equation 6:

$$E_{D\&C\ equipment,i} = E_{engineTOTAL,i} \times S_{event} \qquad \text{Equation (6)}$$

where:

$E_{D\&C\ equipment,i}$ is annual emissions of pollutant i from completion/drilling equipment [ton/yr]
$E_{engineTOTAL,i}$ is sum of all engine emissions per event [ton/event]
$S_{event}$ is the scaling surrogate for completion/drilling operations [event/yr] according to **Table Q-2-5**.

*Q.2.2.1.2 Drilling and Well Completion Traffic*

This section refers to on-road emissions from light-duty and heavy-duty vehicle traffic during drilling and completion operations. Methodology to estimate traffic emissions from these source categories was similar to that of source category *Well Pad, Access Road and Pipeline Construction Traffic*. However, emissions for *Drilling Traffic* and *Completion Traffic* were calculated separately since activity inputs and surrogates varied by source category. Input data to estimate the annual vehicle miles traveled (VMT) per activity was derived from the literature for each vehicle class (light duty and heavy duty) within each fleet. Fleets were defined by the vehicle destination or utility. These are shown in **Table Q-2-6** below. Annual average emission factors from EPA's MOVES2010a model as described in Section 2.2.1.2 were applied.

**Table Q-2-6. Vehicle fleets used during drilling and completion.**

| Vehicle Use/Destination | Vehicle Class | | Fleet group ID |
|---|---|---|---|
| | Type | Class | |
| Drilling Traffic | Semi Trucks | Heavy Duty Truck | 1 |
| | Pickup Trucks | Light Duty Truck | 2 |
| Rig Move Drilling Traffic | Semi Trucks | Heavy Duty Truck | 3 |
| Rig Hauling | Semi Trucks | Heavy Duty Truck | 4 |
| Well Completion & Testing | Semi Trucks | Heavy Duty Truck | 5 |
| | Pickup Trucks | Light Duty Truck | 6 |

Exhaust emissions for each of the fleet groups were calculated using the appropriate MOVES2010a emission factors on a grams per mile basis, as shown in Equation 7:

$$E_{traffic,i} = \frac{EF_i \times N_{trips} \times D}{907185} \qquad \text{Equation (7)}$$

where:

$E_{traffic,i}$ is the traffic emissions for pollutant i per spud [tons/spud]
$EF_i$ is the average emission factor of pollutant i [g/mile]
$N_{trips}$ is the annual number of round trips per activity [trips/spud]
*D* is the round trip distance [miles/trip]
*907185* is the mass unit conversion [g/ton]

Given that emissions from the vehicle fleets are based on the same surrogate (spuds), total emissions from drilling and completion traffic will be the sum of emissions per spud from each fleet (calculated with Equation 7), as shown in Equation 8:

$$E_{traffic,D\&C,i} = \sum_{fleet=1}^{7} \left(E_{traffic,i}\right)_{fleet} \qquad \text{Equation (8)}$$

where:

$E_{traffic,D\&C,i}$ is the total drilling and completions emissions of pollutant i per spud [ton/spud]
$E_{traffic,i}$ is the traffic emissions for pollutant i per spud for a vehicle fleet [tons/spud]

Q.2.2.1.2.1 Area-Wide Annual Emissions from Source Category

Annual emissions for drilling/completion traffic by pollutant were propagated with the appropriate scaling surrogate (spuds per year) according to Equation 9:

$$E_{traffic,i} = E_{traffic,D\&C,i} \times S_{spud} \qquad \text{Equation (9)}$$

where:

$E_{category\ traffic,\ i}$ are annual emissions of pollutant i from drilling/completion traffic [ton/yr]
$E_{traffic,D\&C,i}$ is the total drilling and completions emissions of pollutant i per spud [ton/spud]

$S_{spud}$ is the scaling surrogate for drilling/completion traffic [spuds/yr]

*Q.2.2.1.3 Construction Equipment Fugitive Dust*

Fugitive dust emissions from disturbed land by well pad construction and reclamation equipment were estimated based on AP-42 Chapter 13 Section 13.2.3 guidance for estimating emissions from Heavy Construction Operations (EPA 1995a). A construction fugitive dust emission factor for total suspended particles (TSP) is available in the AP-42 guidance (1.2 tons-TSP/acre/month of activity).

Total suspended particle emissions from wellpad construction equipment on a per wellpad basis are estimated based on Equation 10:

$$E_{equip.dust,TSP} = EF \times A \times t \times \frac{(1-C)}{30} \qquad \text{Equation (10)}$$

where:

$E_{equip,dust,TSP}$ is the TSP emissions from construction equipment fugitive dust [tons/wellpad]
$A$ is the average number of acres disturbed per wellpad [acres/wellpad]
$t$ is the number of construction days per wellpad [days]
$C$ is the control efficiency
*30* is the conversion factor for days/month

Conversion factors for TSP to particulate matter $PM_{10}$ (EPA 2006b) and from $PM_{10}$ to $PM_{2.5}$ (Midwest Research Institute, 2006) were used to estimate other fugitive dust pollutant emissions ($PM_{10}$ and $PM_{2.5}$). A control efficiency of 50% was assumed for well pad construction watering control.

<u>Q.2.2.1.3.1 Area-Wide Annual Emissions from Source Category</u>

Annual emissions for construction equipment fugitive dust, by pollutant i, were propagated with the appropriate scaling surrogate (wellpads per year) according to Equation 11:

$$E_{equip,dust,i_{TOTAL}} = E_{equip.dust,i} \times S_{new\ pads} \qquad \text{Equation (11)}$$

where:

$E_{equip,dust,i_{TOTAL}}$ is the annual dust emissions of pollutant i from construction equipment [ton/yr]
$E_{equip.dust,i}$ is the fugitive dust emissions of pollutant i from construction equipment per pad [tons/wellpad]
$S_{new\ pads}$ is the scaling surrogate for construction equipment fugitive dust [new pads/yr]

*Q.2.2.1.4 Fugitive Dust Emissions from Construction, Drilling and Completion Support Vehicles*

Fugitive dust emissions from vehicle travel on unpaved roads were estimated based on the AP-42 technical guidance in Section 13.2.2.1 Unpaved Roads (EPA 2006a). Road dust emission factors for vehicles traveling on unpaved surfaces at industrial sites can be estimated with Equation 12.

$$EF_i = k\left(\frac{s}{12}\right)^a\left(\frac{W}{3}\right)^b \qquad \text{Equation (12)}$$

where:

*EF* is the size-specific particulate emissions factor for pollutant i (lb/mile)
*s* is the surface material silt content (%)
*W* is the mean vehicle weight (tons)
*k, a, b* are empirical constants according to **Table Q-2-7**.

**Table Q-2-7. Empirical constants by pollutant to estimate road dust emissions factor.**

| Parameter | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|
| k | 1.5 | 0.15 |
| a | 0.9 | 0.9 |
| b | 0.45 | 0.45 |

Because the emissions factor is a function of vehicle weight, individual emissions factor for heavy duty vehicles and light duty vehicles were derived with Equation 12. To account for natural mitigation of road dust emissions due to annual precipitation and from watering control, Equation 13 was applied:

$$EF_{mitigated} = EF_i \times \frac{365-P}{365} \times \frac{100-CE}{100} \qquad \text{Equation (13)}$$

where:

$EF_{mitigated}$ is the annual average emission factor for uncontrolled conditions including natural mitigation [lb/mile]

$EF_i$ is the size-specific emission factor [lb/mile]
*P* is number of precipitation days (>0.01" rainfall) at the site
*CE* is the control efficiency for watering in unpaved roads; CE =50%

Emissions were estimated for all types of vehicles involved in construction, drilling and completion activities. The vehicle groups were classified according to their vehicle class and utility, and literature data was collected to estimate annual vehicle miles traveled per activity (or event), which varied by vehicle groups and by the type of oil and gas development (conventional gas and CBNG). The vehicle fleets used in each type of development are shown in **Table Q-2-8**.

**Table Q-2-8. Vehicles groups related to fugitive road dust emissions in well construction and development.**

| Vehicle Group ID | Utility/Destination | Vehicle Class | Event (Surrogate) |
|---|---|---|---|
| 1 | Well Pad Access Road Construction | Heavy Duty Truck | New pads |
| 2 | | Light Duty Truck | |
| 3 | Pipeline Construction | Heavy Duty Truck | |
| 4 | | Light Duty Truck | |
| 5 | Drilling Traffic | Heavy Duty Truck | Spuds |
| 6 | | Light Duty Truck | |
| 7 | Rig Move Drilling Traffic | Heavy Duty Truck | New pads |
| 8 | | Light Duty Truck | |
| 9 | Rig Hauling | Heavy Duty Truck | |
| 10 | Well Completion & Testing | Heavy Duty Truck | Spuds |
| 11 | | Light Duty Truck | |
| 12 | Fuel Haul Truck | Heavy Duty Truck | Spuds |

Fugitive dust road emissions were calculated using the mitigated emissions factor ($EF_{mitigated}$) from Equation 13, along with the vehicle miles traveled for each vehicle group as shown in Equation 14.

$$E_{traffic,i} = \frac{EF_{mitigated} \times N_{trips} \times D}{2000} \qquad \text{Equation (14)}$$

where:

$E_{traffic,i}$ is the traffic fugitive dust emissions for pollutant i per event [ton/event]

$EF_{mitigated}$ is the average emission factor of pollutant i for fugitive dust emissions [lb/mile]

$N_{trips}$ is the annual number of round trips per activity [trips/event]
*D* is the round trip distance [miles/trip]
*2000* is the mass conversion [lb/ton]

Q.2.2.1.4.1 Area-Wide Annual Emissions from Source Category

Annual emissions for road fugitive dust from construction/drilling/completion traffic were propagated with the appropriate scaling surrogate according to Equation 15:

$$E_{dust,traffic,i} = E_{traffic,i} \times S_{event} \qquad \text{Equation (15)}$$

where:

$E_{dust,traffic,i}$ are annual emissions of pollutant i for road fugitive dust from construction/drilling/completion traffic [ton/yr]
$E_{traffic,i}$ are the emissions of pollutant i per event (spuds or new pads) [ton/event]
$S_{event}$ is the scaling surrogate for the vehicle group [event/yr]

*Q.2.2.1.5 Construction Wind Erosion*

Wind erosion dust emissions associated with well pad construction, and road, pipeline construction operations, and well pad reclamation activity were estimated based on AP-42 guidance for the estimation of emissions from industrial wind erosion (EPA 2006b). Wind erosion emissions per well pad were estimated based on Equation 16:

$$E_{dust,i} = \frac{P \times A \times r}{907{,}185} \qquad \text{Equation (16)}$$

where:

$E_{dust,\,i}$ are dust emissions for pollutant i from construction wind erosion [ton/pad]
$P$ is the erosion potential [$g/m^2$]
$A$ is the well pad construction area [$m^2$/pad]
$r$ is the particle size multiplier for $PM_{10}$ or $PM_{2.5}$
*907,185* is a mass unit conversion [g/ton]

The erosions potential is a function of the wind friction velocity, as shown in equation 17 and 18:

$$P = 58 \times (u^* - u_t)^2 + 25(u^* - u_t) \qquad \text{Equation (17)}$$

where:

$u^*$ is the friction velocity (m/s)
$u_t$ is the threshold friction velocity (m/s)

$$P = 0 \quad \text{for} \quad (u^* \le u_t) \qquad \text{Equation (18)}$$

Friction velocity estimates (u*) were made by multiplying the average annual fastest wind speed by 0.053 per AP-42 guidance (EPA 2006b). Particle size multipliers of 0.5 and 0.075 were assumed for $PM_{10}$ and $PM_{2.5}$ respectively per AP-42 guidance.

Q.2.2.1.5.1 Area-Wide Annual Emissions from Source Category

The annual construction dust wind erosion emissions were scaled by multiplying per well pad emissions by the scaling surrogate (new pads) according to Equation 19:

$$E_{wind\ erosion\ total,i} = E_{dust,i} \times S_{well\ pad} \qquad \text{Equation (19)}$$

where:

$E_{.dust\ erosion\ total,i}$ are the annual emissions of pollutant *i* from construction dust wind erosion [ton/yr]
$E_{dust,\,i}$ are the dust emissions of pollutant i per well pad [ton/pad]
$S_{well\ pad}$ is the scaling surrogate for construction dust wind erosion [pad/yr]

*Q.2.2.1.6 Well Completion Venting*

This section describes emissions from well completion venting. The calculation methodology for estimating venting emissions from a single completion event is shown below in Equation 20:

$$E_{completion,i} = \left[\frac{P \times Q_{completion}}{\frac{R}{MW_{gas}} \times T \times 3.5 \times 10^{-5}}\right] \times \frac{f_i}{907185} \times (1 - 0.95F_{flare} - F_{green}) \quad \text{Equation (20)}$$

where:

$E_{completion,i}$ is the uncontrolled emissions of pollutant *i* from a single completion event [ton/event]
$P$ is atmospheric pressure [1 atm]
$Q_{completion}$ is the volume of gas generated per completion [MCF/event]
$R$ is the universal gas constant [0.082 L-atm/mol-K]
$MW_{gas}$ is the molecular weight of the gas [g/mol]
$T$ is the atmospheric temperature [298 K]
$f_i$ is the mass fraction of pollutant *i* in the completion venting gas
$F_{green}$ is the fraction of completions that were controlled by green completion techniques
$F_{flare}$ is the fraction of completions controlled by flare
*0.95* is the control efficiency of the flare

Q.2.2.1.6.1 Extrapolation to Area-Wide Annual Emissions

Annual emissions are obtained by scaling-up emissions per event by the number of spuds for a particular year. The total emissions from completion venting are estimated following Equation 21:

$$E_{completion,TOTAL,i} = E_{completion,i} \times S_{spuds} \quad \text{Equation (21)}$$

where:

$E_{completion,TOTAL}$ are the annual emissions for pollutant i from completion venting [tons/year]
$E_{completion,i}$ are the completion emissions from a single completion event [tons/event], event=spuds
$S_{spuds}$ is the scaling surrogate for completion venting in a particular year [spuds/year]

*Q.2.2.1.7 Well Completion Flaring*

This section describes the methodology for estimating flaring emissions from completion venting as described in Equation 22. It was assumed the efficiency of the flare was 95 percent.

$$E_{flare,completion} = \left(\frac{EF_i \times Q_{completion} \times F_{flared} \times HV}{1000}\right) \Big/ 2000 \quad \text{Equation (22)}$$

where:

$E_{flare,completion}$ is the area-wide flaring emissions of pollutant i for well completions [ton/event]
$EF_i$ is the flaring emissions factor for pollutant *i* [lb/MMBtu]
$Q_{completion}$ is the volume of gas generated per completion [MCF/event]
$HV$ is the local heating value of the gas [BTU/SCF]
$F_{flared}$ is the fraction of well completions with flares

Q.2.2.1.7.1 Extrapolation to Area-Wide Annual Emissions

Annual area-wide flaring emissions for well completions are scaled-up using the total number of spuds per year as shown in Equation 23:

$$E_{heater,TOTAL,i} = E_{heater,i} \times S_{TOTAL}$$ Equation (23)

where:

$E_{heater,TOTAL}$ is the annual emissions from well completion flaring for pollutant i [ [ton/yr]
$E_{heater}$ is the emissions from well completion flaring for pollutant i per event [ton/event]
$S_{TOTAL}$ is the total number of spuds for a particular year [spuds]. The number of well completions is assumed equal to the spuds count for the year.

*Q.2.2.1.8 Emissions from the Production Phase*

Emissions from the Production phase include those generated by equipment, vehicles and activities related to oil and gas production at well sites after a well has been completed. Pollutant emissions are initially estimated on a per event basis and later scaled with the projected number of events per year (scaling surrogate) to obtain UFO planning area-wide annual emissions from each source.

Q.2.2.1.8.1 Well Workovers Equipment

This category refers to emissions associated with off-road engines used during well workovers. Detailed data for a typical workover engine such as horsepower rating, hours of operation, fuel type, engine technology and load factor was derived from the literature. The EPA NONROAD2008a model (EPA 2009b) was used to compile emission factors for 'other oil field equipment' representative of workover engines. The $N_2O$ emissions factor was obtained from the 2009 American Petroleum Institute O&G GHG Methodologies Compendium, Tables 4-13 and 4-17 (American Petroleum Institute 2009).

Emissions on a per well basis for a workover engine were estimated according to Equation 24:

$$E_{engine,i} = f \times \frac{EF_i \times HP \times LF \times t \times n}{907{,}185}$$ Equation (24)

where:

$E_{engine}$ are emissions of pollutant *i* from a workover engine [ton/well]
$EF_i$ is the emissions factor of pollutant *i* [g/hp-hr]
*HP* is the horsepower of the engine [hp]
*LF* is the load factor of the engine
*t* is the number of hours of use per day [hr/day]
*907,185* is the mass unit conversion [g/ton]
*n* is the number of operating days per well [days/well]
*f* is the well workover frequency per year

Q.2.2.1.8.2 Extrapolation to Area-Wide Annual Emissions

Annual emissions from well workover equipment by pollutant were estimated according to Equation 25:

$$E_{WO-equip,i} = E_{engine\ i} \times S_{wells}$$ Equation (25)

where:

$E_{WO\text{-}equip,i}$ are annual emissions of pollutant i from workover equipment [ton/yr]
$E_{engine,i}$ is emissions of pollutant i from workover equipment per well [ton/well]
$S_{well\,pad}$ is the scaling surrogate for workovers [active wells/yr]

*Q.2.2.1.9 Production Traffic (Well workovers, Road Maintenance, Well Pad Reclamation and Production)*

This section describes the estimation of exhaust emissions from light-duty and heavy-duty vehicle traffic used for Well Workovers, Maintenance, Well Pad Reclamation and Production. This excludes traffic from tank loading and compressor stations maintenance. Vehicle classes within the four source categories are shown in **Table Q-2-9**. Emissions from these vehicle fleets were first estimated on a per well basis and later on scaled to annual Area-wide emissions with the scaling surrogate, active wells per year.

**Table Q-2-9. Vehicle fleets comprising production traffic.**

| Vehicle Fleets ID | Utility (Source Category) | Vehicle Class | Event (Surrogate) |
|---|---|---|---|
| 1 | Well Workover Commuting Vehicles | Light Duty Truck | Active Wells |
| 2 | | Heavy Duty Truck | |
| 3 | Road Maintenance | Light Duty Truck | |
| 4 | Road and Well Pad Reclamation | Light Duty Truck | |

Emission factors were developed using the MOVES2010a model as described in Section 2.2.1.2 above.

Exhaust emissions for the five vehicle groups were estimated as shown in Equation 26.

$$E_{fleet,traffic,i} = \frac{EF_i \times N_{trips} \times D}{907185} \qquad \text{Equation (26)}$$

where:

$E_{fleet,traffic,i}$ is the fleet's traffic emissions for pollutant i per well [tons/well]
$EF_i$ is the average emission factor of pollutant i [g/mile]
$N_{trips}$ is the annual number of round trips per activity [trips/well]
*D* is the round trip distance [miles/trip]
*907185* is the mass unit conversion [g/ton]

Q.2.2.1.9.1 Extrapolation to Area-Wide Annual Emissions

Annual emissions for each category (fleet) of production traffic were propagated with the appropriate scaling surrogate (active wells per year) according to Equation 27:

$$E_{fleet,TOTAL,i} = E_{fleet,traffic,,i} \times S_{wells} \qquad \text{Equation (27)}$$

where:

$E_{fleet,TOTAL,\,i}$ are annual emissions of pollutant i from a production fleet [ton/yr]
$E_{fleet,traffic,i}$ is the emissions of pollutant i per well for a production traffic fleet [ton/well]
$S_{wells}$ is the scaling surrogate for the source category [active wells/yr]

*Q.2.2.1.10 Fugitive Dust Emissions from Production Traffic (Well Workovers, Road Maintenance, Well Pad Reclamation and Other Production)*

Fugitive dust emissions from vehicle travel on unpaved roads were estimated based on the AP-42 technical guidance Section 13.2.2.1 Unpaved Roads (EPA 2006a). Road dust emission factors for vehicles traveling on unpaved surfaces at industrial sites can be estimated with Equation 28.

$$EF_i = k\left(\frac{s}{12}\right)^a\left(\frac{W}{3}\right)^b \qquad \text{Equation (28)}$$

where:

*EF* is the size-specific particulate emissions factor for pollutant i (lb/mile)
*s* is the surface material silt content (%)
*W* is the mean vehicle weight (tons)
*k, a, b* are empirical constants according to **Table Q-2-10**.

**Table Q-2-10. Empirical constants by pollutant to estimate road dust emissions factor.**

| Parameter | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|
| k | 1.5 | 0.15 |
| a | 0.9 | 0.9 |
| b | 0.45 | 0.45 |

Because the emissions factor is a function of vehicle weight, individual emissions factor for heavy duty vehicles and light duty vehicles were calculated with Equation 28. To account for natural mitigation of road dust emissions due to annual precipitation and from watering control, Equation 29 was applied:

$$EF_{mitigated} = EF_i \times \frac{365-P}{365} \times \frac{100-CE}{100} \qquad \text{Equation (29)}$$

where:

$EF_{mitigated}$ is the annual average emission factor for uncontrolled conditions including natural mitigation [lb/mile]
$EF_i$ is the size-specific emission factor [lb/mile]
*P* is number of precipitation days (>0.01" rainfall) at the site
*CE* is the control efficiency for watering in unpaved roads

Vehicle fleets comprising production traffic are shown in **Table Q-2-9**. Fugitive dust emissions from these vehicle fleets were first estimated on a per well basis and later scaled to annual Area-wide emissions with the scaling surrogate, active wells per year.

Fugitive dust road emissions per well were calculated using the mitigated emissions factor ($EF_{mitigated}$) from Equation 29, along with the vehicle miles traveled for each vehicle group. This is shown in Equation 30

$$E_{fleet,traffic,i} = \frac{EF_{mitigated} \times N_{trips} \times D}{2000} \qquad \text{Equation (30)}$$

where:

$E_{fleet,traffic,i}$ is the traffic fugitive dust emissions for pollutant i per well [ton/well]
$EF_{mitigated}$ is the average emission factor of pollutant i for fugitive dust emissions [lb/mile]
$N_{trips}$ is the annual number of round trips per activity [trips/well]
*D* is the round trip distance [miles/trip]
*2000* is the mass conversion [lb/ton]

Q.2.2.1.10.1 Extrapolation to Area-Wide Annual Emissions

Annual fugitive dust emissions for each category (fleet) of Production traffic were propagated with the appropriate scaling surrogate (active wells per year) according to Equation 31:

$$E_{fleet,TOTAL,i} = E_{fleet,traffic,,i} \times S_{wells} \qquad \text{Equation (31)}$$

where:

$E_{fleet,TOTAL,\,i}$ are annual fugitive dust emissions of pollutant i from a production fleet [ton/yr]
$E_{fleet,traffic,i}$ is the fugitive dust emissions of pollutant i per well for a production traffic fleet [ton/well]
$S_{wells}$ is the scaling surrogate for the source category [active wells/yr]

*Q.2.2.1.11 Blowdown Venting*

This section refers to the estimation of emissions from venting during well blowdowns. The calculation methodology for estimating emissions from a single blowdown event is shown below in Equation 32:

$$E_{blowdown,i} = \left( \frac{P \times \left(V_{vented}\right)}{\left( R/MW_{gas} \right) \times T \times 3.5 \times 10^{-5}} \right) \times \frac{f_i}{907185} \qquad \text{Equation (32)}$$

where:

$E_{blowdown,i}$ is the emissions of pollutant *i* from a single blowdown event [ton/event]
*P* is atmospheric pressure [1 atm]
$V_{vented}$ is the volume of vented gas per blowdown (uncontrolled) [MCF/event]
*R* is the universal gas constant [0.082 L-atm/mol-K]
$MW_{gas}$ is the molecular weight of the gas [g/mol]
*T* is the atmospheric temperature [298 K]
$f_i$ is the mass fraction of pollutant *i* in the vented gas

Q.2.2.1.11.1 Extrapolation to Area-Wide Annual Emissions

The total emissions from all annual blowdowns events occurring are estimated with Equation 33:

$$E_{blowdown,TOTAL} = E_{blowdown,i} \times N_{blowdown} \times S_{wells} \qquad \text{Equation (33)}$$

where:

$E_{blowdown,TOTAL}$ are the total annual emissions from blowdowns [tons/yr]
$E_{blowdown,i}$ are the blowdown emissions from a single blowdown event [tons/event]
$N_{blowdown}$ is the frequency of blowdowns per well per year [events/yr-well]
$S_{wells}$ is the total number of active wells for a particular year [wells]

*Q.2.2.1.12 Well Recompletion Venting*

This section describes emissions from well recompletion venting. The calculation methodology for estimating venting emissions from a single recompletion event is shown below in Equation 34:

$$E_{recompletion,i} = \left[\frac{P \times Q_{recompletion}}{\frac{R}{MW_{gas}} \times T \times 3.5 \times 10^{-5}}\right] \times \frac{f_i}{907185} \qquad \text{Equation (34)}$$

where:

$E_{recompletion,i}$ is the uncontrolled emissions of pollutant *i* from a single recompletion event [ton/event]
$P$ is atmospheric pressure [1 atm]
$Q_{recompletion}$ is the volume of gas generated per recompletion [MCF/event]
$R$ is the universal gas constant [0.082 L-atm/mol-K]
$MW_{gas}$ is the molecular weight of the gas [g/mol]
$T$ is the atmospheric temperature [298 K]
$f_i$ is the mass fraction of pollutant *i* in the recompletion venting gas

Q.2.2.1.12.1 Extrapolation to Area-Wide Annual Emissions

Annual emissions are obtained by scaling-up emissions per event with the total number of recompletion events in a particular year. The total emissions from recompletion venting are estimated following Equation 35:

$$E_{recompletion,TOTAL,i} = E_{recompletion,i} \times f \times S_{well\ count} \qquad \text{Equation (35)}$$

where:

$E_{completion,TOTAL}$ are the annual emissions for pollutant i from recompletion venting [tons/year]
$E_{completion,i}$ are the venting emissions from a single recompletion event [tons/event]
$f$ is the frequency of recompletion events per well per year [events/yr-well]
$S_{well\ count}$ is the scaling surrogate for recompletion venting in a particular year [active wells]

*Q.2.2.1.13 Wellhead Fugitives*

This source category refers to fugitive emissions or *leaks* from well equipment such as pump seals, valves, connectors, flanges, etc. Fugitive emissions were estimated for three main streams identified: gas service stream, liquids service stream and high oil stream. VOC, $CO_2$ and $CH_4$ emissions per stream were estimated using device-specific TOC emission factors for oil and gas production (EPA 1995b) and equipment counts. Input data was obtained from the literature on total device counts per well by type of equipment and by the type of service to which the equipment applies – gas, liquids and high oil.

Fugitive VOC emissions for an individual device in a given stream (gas, liquids, and high oil) were estimated according to Equation 36:

$$E_{fugitiveVOC,k} = EF_{TOC} \times N \times t_{annual} \times Y$$ Equation (36)

where:

$E_{fugitive\ VOC,\ k}$ is the fugitive VOC emissions for a given device k [ton/yr-well]
$EF_{TOC}$ is the emission factor of TOC [kg/hr/device]
*N* is the total number of devices type-k for a given stream per well [devices/well]
*Y* is the ratio of VOC to TOC in the vented gas

Total VOC fugitive emissions for a given stream are equal to the sum of all fugitive emissions from devices in that stream per Equation 37:

$$E_{fugitiveVOC,stream} = \sum E_{fugitiveVOC,k}$$ Equation (37)

where:

$E_{fugitive\ VOC,stream}$ is the total fugitive VOC emissions in a given stream per well [ton/yr-well]

$CO_2$ and $CH_4$ fugitive emissions per stream were estimated according to Equations 38 and 39:

$$E_{fugitiveCH4,stream} = E_{fugitiveVOC,stream} \times \frac{weight\ fraction_{CH4}}{weight\ fraction_{VOC}}$$ Equation (38)

$$E_{fugitiveCO2,stream} = E_{fugitiveVOC,stream} \times \frac{weight\ fraction_{CO2}}{weight\ fraction_{VOC}}$$ Equation (39)

where:

$E_{fugitive\ CO2,stream}$ is the total fugitive $CO_2$ emissions in a given stream per well [ton/yr-well]
$E_{fugitive\ CH4,stream}$ is the total fugitive $CH_4$ emissions in a given stream per well [ton/yr-well]
*Weight fractions* per pollutant were based on gas compositions. For gas and well streams, sales gas composition was used. For condensate stream, fugitive-post flash compositions were used.

Q.2.2.1.13.1 Extrapolation to Area-Wide Annual Emissions

Fugitive emissions were propagated annually according to Equation 40 using the scaling surrogate, active well counts:

$$E_{fugitive,i} = E_{fugitive\ i,stream} \times S_{well\ count}$$ Equation (40)

where:

$E_{fugitive,\ i}$ are the annual fugitive emissions for pollutant i in a given stream [ton/yr]
$E_{fugitive\ I,\ stream}$ are fugitive emissions of pollutant i in a stream per well [ton/yr-well]
$S_{well\ count}$ is the number of active wells for a particular year [active wells]

*Q.2.2.1.14 Pneumatic Devices*

Emissions for pneumatic devices will vary by the bleed rate of the device. The methodology for estimating the emissions from a mix of pneumatic devices i (liquid level controllers, pressure controllers, etc.) for a single typical well is shown in Equation 41:

$$E_{pneumatic,j} = \frac{f_j}{907185}\left(\sum_i \dot{V}_i \times N_i \times t_{annual}\right) \times \frac{P}{\left(\left(R/MW_{gas}\right) \times T \times 3.5 \times 10^{-5}\right)}$$ Equation (41)

where:

$E_{pneumatic,j}$ is the total emissions of pollutant *j* from all pneumatic devices for a typical well [ton/year/well]
$\dot{V}_i$ is the volumetric bleed rate from device *i* [MCF/hr/device]
$N_i$ is the average number of devices <u>*i*</u> found in a well [devices/well]
$t_{annual}$ is the number of hours per year that devices were operating [8760 hr/yr]
*P* is the atmospheric pressure [1 atm]
*R* is the universal gas constant [0.082 L-atm/mol-K]
$MW_{gas}$ is the molecular weight of the gas [g/mol]
*T* is the atmospheric temperature [298 K]
$f_j$ is the mass fraction of pollutant *j* in the vented gas

<u>Q.2.2.1.14.1 Extrapolation to Area-Wide Annual Emissions</u>

Annual emissions from pneumatic devices were estimated according to Equation 42:

$$E_{pneumatic,TOTAL,j} = E_{pneumatic,j} \times N_{well}$$ Equation (42)

where:

$E_{pneumatic,TOTAL,j}$ is the total annual emissions of pollutant *j* from pneumatic devices [ton/yr]
$E_{pneumatic,j}$ is the pneumatic device emissions of pollutant *j* for a single typical well [ton/yr/well]
$N_{well}$ is the total number of active wells in the basin [wells]

*Q.2.2.1.15 Pneumatic Pumps*

To estimate emissions from pneumatic pumps, literature data indicating the average rate of gas consumption per gallon of chemical injected and the annual chemical throughput for a single pump was applied. Emissions per well from pneumatic pumps were estimated as shown in Equation 43:

$$E_{pump,i} = \frac{N_{CIP} \times V_{vented,gas} \times t_{pump} \times MW_i \times R \times Y_i}{2000} \qquad \text{Equation (43)}$$

where:

$E_{pump,\,i}$ is the pneumatic pump emissions for pollutant i per well [ton/yr-well]
$V_{vented,TOTAL}$ is the average gas venting rate per pump [SCF/pump/hr]
$N_{CIP}$ is the number of gas-actuated pneumatic pumps per well [pump/well]
$t_{pump}$ is the annual hours of operation of a pump [hrs/yr]
$MW_i$ is the molecular weight of pollutant i [lb/lb-mol]
*R* is the universal gas constant [lb-mol/391.9scf]
$Y_i$ is the molar fraction of pollutant i in pneumatic pump vented gas
*2000* is the mass unit conversion [lb/ton]

Q.2.2.1.15.1 Extrapolation to Area-Wide Annual Emissions

To estimate area-wide annual emissions from pneumatic pumps the scaling surrogate, active wells, was used according to Equation 44

$$E_{pneumaticpumps,i} = E_{pump,i} \times S_{well\ count} \qquad \text{Equation (44)}$$

where:

$E_{pneumaticpumps,\,i}$ are the annual emissions for pollutant i from pneumatic pumps [ton/yr]
$E_{pump,\,i}$ is the emissions from all pneumatic pumps per well [ton/yr-well]
$S_{well\ count}$ is the number of active wells for a particular year [wells]

*Q.2.2.1.16 Water Injection Pumps*

This category refers to exhaust emissions associated with diesel combustion in water injection pump engines. Detailed data for each engine type such as horsepower rating, hours of operation, fuel type, engine technology and load factors was derived from the literature. The EPA NONROAD2008a model (EPA 2009b) was used to compile emission factors. The $N_2O$ emissions factor was obtained from the 2009 American Petroleum Institute O&G GHG Methodologies Compendium, Tables 4-13 and 4-17 (American Petroleum Institute 2009).

Emissions on a per well basis for a water injection pump were estimated according to Equation 45:

$$E_{engine\,,i} = \frac{EF_i \times HP \times LF \times t_{event} \times n}{907{,}185} \qquad \text{Equation (45)}$$

where:

$E_{engine}$ are per-well emissions of pollutant *i* from water injection pumps [ton/well]
$EF_i$ is the emissions factor of pollutant *i* [g/hp-hr]
*HP* is the horsepower of the pump [hp]

*LF* is the load factor of the pump
$t_{event}$ is the number of hours the engine is used annually [hrs/unit]
*907,185* is the mass unit conversion [g/ton]
*n* is the number of water injection pumps per well [units/well]

Q.2.2.1.16.1 Extrapolation to Area-Wide Annual Emissions

Annual emissions from water injection pumps for pollutant i were estimated according to Equation 46:

$$E_{water\ pumps,i} = E_{engine,i} \times S_{well} \qquad \text{Equation (46)}$$

where:

$E_{well\ pad\ equip}$ are annual emissions of pollutant i from water injection pumps [ton/yr]
$E_{engine,i}$ is engine emissions per well [ton/well]
$S_{well}$ is the scaling surrogate for water injection pumps [active wells/yr]

*Q.2.2.1.17 Miscellaneous Engines*

This category refers to exhaust emissions associated with miscellaneous engines at well sites. Detailed data for miscellaneous engines such as horsepower rating, hours of operation, fuel type, engine technology and load factors was derived from the literature. The EPA NONROAD2008a model (EPA 2009b) was used to compile emission factors. The $N_2O$ emissions factor was obtained from the 2009 American Petroleum Institute O&G GHG Methodologies Compendium, Tables 4-13 and 4-17 (American Petroleum Institute 2009).

Emissions on a per well basis for miscellaneous engines were estimated according to Equation 47:

$$E_{engine\ ,i} = \frac{EF_i \times HP \times LF \times t_{event} \times n}{907{,}185} \times f \qquad \text{Equation (47)}$$

where:

$E_{engine}$ are per-well emissions of pollutant *i* from miscellaneous engines [ton/well]
$EF_i$ is the emissions factor of pollutant *i* [g/hp-hr]
*HP* is the horsepower of the pump [hp]
*LF* is the load factor of the pump
$t_{event}$ is the number of hours the engine is used [hrs/unit]
*f* is the fraction of wells served by a miscellaneous engine
*907,185* is the mass unit conversion [g/ton]
*n* is the number of engines per well [units/well]

Q.2.2.1.17.1 Extrapolation to Area-Wide Annual Emissions

Annual emissions from miscellaneous engines for pollutant i were estimated according to Equation 48:

$$E_{water\ pumps,i} = E_{engine,i} \times S_{well} \qquad \text{Equation (48)}$$

where:

$E_{well\ pad\ equip}$ are annual emissions of pollutant i from miscellaneous engines [ton/yr]
$E_{engine,i}$ is engine emissions per well [ton/well]
$S_{well}$ is the scaling surrogate for miscellaneous engines [active wells/yr]

*Q.2.2.1.18 Compressor Station Maintenance Traffic Exhaust*

This section describes the estimation of exhaust emissions from light-duty vehicles (pickup trucks) used for compressor maintenance at compressor stations. Emission factors were developed using the MOVES2010a model (EPA 2010) as described in Section 2.2.1.2. The total vehicle miles travelled annually from maintenance visits to a single compressor station were obtained from the literature.

Exhaust emissions for this fleet were estimated as shown in Equation 49.

$$E_{fleet,traffic,i} = \frac{EF_i \times VMT_{CS}}{907185} \qquad \text{Equation (49)}$$

where:

$E_{fleet,traffic,i}$ is the fleet's traffic emissions for pollutant i per well [tons/station]
$EF_i$ is the average emission factor for light duty vehicles of pollutant i [g/mile]
$VMT_{CS}$ is the annual miles travelled for maintenance compressor station [miles/station]
*907185* is the mass unit conversion [g/ton]

Q.2.2.1.18.1 Extrapolation to Area-Wide Annual Emissions

Annual emissions for the compressor maintenance fleet were propagated with the scaling surrogate "total count of active compressor stations" according to Equation 50:

$$E_{fleet,TOTAL,i} = E_{fleet,traffic,,i} \times S_{CS} \qquad \text{Equation (50)}$$

where:

$E_{fleet,TOTAL,\ i}$ are annual emissions of pollutant i from compressor station maintenance traffic [ton/yr]
$E_{fleet,traffic,i}$ is the emissions of pollutant i per station for the fleet [ton/station]
$S_{CS}$ is the scaling surrogate for the source category [number of active compressor stations per year]

*Q.2.2.1.19 Fugitive Dust Emissions from Compressor Station Maintenance Traffic*

Road dust emission factors for light duty vehicles traveling on unpaved surfaces to and from compressor stations were estimated with the same methodology as in Section 2.2.1.2.6 using Equations 28 and 29. Fugitive dust road emissions per station (visited) were calculated using the mitigated emissions factor ($EF_{mitigated}$) from Equation 29, along with the annual vehicle miles traveled per compressor station. This is shown in Equation 51.

$$E_{fleet,traffic,i} = \frac{EF_{mitigated} \times VMT}{2000} \qquad \text{Equation (51)}$$

where:

$E_{fleet,traffic,i}$ is the traffic fugitive dust emissions for pollutant i per station [ton/station]
$EF_{mitigated}$ is the average emission factor of pollutant i for fugitive dust emissions [lb/mile]
*VMT* is the annual miles travelled for maintenance compressor station [miles/station]
*2000* is the mass conversion [lb/ton]

Q.2.2.1.19.1 Extrapolation to Area-Wide Annual Emissions

Annual fugitive dust emissions for compressor station maintenance traffic were propagated with the "total number of compressor stations" according to Equation 52:

$$E_{fleet,TOTAL,i} = E_{fleet,traffic,,i} \times S_{CS} \qquad \text{Equation (52)}$$

where:

$E_{fleet,TOTAL,\,i}$ are annual fugitive dust emissions of pollutant i from compressor station maintenance traffic [ton/yr]
$E_{fleet,traffic,i}$ is the emissions of pollutant i per station for the fleet [ton/station]
$S_{CS}$ is the scaling surrogate for the source category [number of active compressor stations per year]

*Q.2.2.1.20 Condensate Tanks Flashing*

An uncontrolled VOC emissions factor applicable to Garfield, Mesa, Rio Blanco, and Moffat Counties (Colorado Department of Public Health and Environment 2006) was used to estimate emissions for condensate tanks in conventional gas and coalbed natural gas developments on a per barrel basis. The published emissions factor was 10 lbs VOC/bbl [0.005 tons/bbl]; for planning areas outside of those counties the emission factor of 11.8 lbs VOC/bbl [0.0059 tons/bbl] was used (Colorado Department of Public Health and Environment 2006). The VOC emissions factor was multiplied by the annual condensate production from each type of well to propagate VOC emissions to the planning area level for each year. $CO_2$ and $CH_4$ total emissions were then calculated using the weight fraction ratios from local flash gas composition analyses using Equations 53 and 54.

$$E_{tanks,CH4} = E_{tanks,VOC} \times \frac{weight\ fraction_{CH4}}{weight\ fraction_{VOC}} \qquad \text{Equation (53)}$$

$$E_{tanks,CO2} = E_{tanks,VOC} \times \frac{weight\ fraction_{CO2}}{weight\ fraction_{VOC}} \qquad \text{Equation (54)}$$

where:

$E_{tanks,VOC}$ is the total annual condensate tanks emissions from APENS database [tons/yr]
$E_{tanks,CO2}$ is the total condensate tank $CO_2$ emissions [tons/yr]
$E_{tanks,CH4}$ is the total condensate $CH_4$ emissions [tons/yr]
*Weight fractions* of each pollutant in flash gas

*Q.2.2.1.21 Loading Emissions from Condensate or Oil Tanks*

This section describes emissions from truck loading of condensate tanks. The loading loss rate is estimated following Equation 55:

$$L = 12.46 \times \left( \frac{S \times V \times M}{T} \right)$$ Equation (55)

where:

*L* is the loading loss rate [lb/1000gal]
*S* is the saturation factor taken from AP-42 default values based on operating mode. The operating mode for loading assumed was submerged loading: dedicated normal service.
*V* is the true vapor pressure of the liquid loaded [psia]
*M* is the molecular weight of the vapor [lb/lb-mole]
*T* is the temperature of the bulk liquid [°R], T=540 R

VOC tank loading emissions are then estimated by Equation 56:

$$E_{loading,VOC} = L \times Y_{voc} \times \frac{42}{2000}$$ Equation (56)

where:

$E_{loading}$ are the VOC tank loading emissions [ton/bbl]
*L* is the loading loss rate [lb/1000gal]
$Y_{VOC}$ is the weight fraction of VOC in the vapor in the liquid loaded
*42* is a unit conversion [gal/bbl]
*2000* is a unit conversion [lbs/ton]

$CO_2$ and $CH_4$ emissions are calculated based on Equations 57-58:

$$E_{loading,CH4} = E_{loading,VOC} \times \frac{weight\ fraction_{CH4}}{weight\ fraction_{VOC}}$$ Equation (57)

$$E_{loading,CO2} = E_{loading,VOC} \times \frac{weight\ fraction_{CO2}}{weight\ fraction_{VOC}}$$ Equation (58)

where:

$E_{loading,CO2}$ is the total loading $CO_2$ emissions per barrel of liquid [ton/bbl]
$E_{loadingCH4}$ is the total loading $CH_4$ emissions per barrel of liquid [ton/bbl]
*Weight fractions* of each pollutant in the vapor losses from the liquid loaded

Q.2.2.1.21.1 Area-Wide Annual Emissions from Source Category

Annual emissions per pollutant i from condensate loading were scaled by annual condensate production per Equation 59:

$$E_{tank\ loadout,i} = E_{loading,i} \times S_{bbl\ condensate}$$ Equation (59)

where:

$E_{tank\ loadout,\ i}$ is the total condensate loading emissions for pollutant i from tank load-out [ton/yr]
$E_{loading,\ i}$ is the condensate loading emissions for pollutant i from per barrel [ton/bbl]

$S_{bbl\ condensate}$ is the total annual of barrels condensate [bbl/yr]

*Q.2.2.1.22 Condensate, and Produced Water Hauling Traffic Exhaust*

This section describes the estimation of exhaust emissions from heavy-duty vehicles (haul trucks) used for produced condensate hauling from the well site. Emission factors were developed using the MOVES2010a model (EPA 2010) as described in Section 2.2.1.2. The total round trip distance for each hauling trip was derived from the literature. A hauling volume of per truck of 200 barrels of condensate, hence the number of round trips per barrel was estimated (1/200).

Exhaust emissions for condensate hauling fleet were estimated as shown in Equation 60a.

$$E_{fleet,traffic,i} = \frac{EF_i \times N_{trips} \times D}{907185} \qquad \text{Equation (60a)}$$

where:

$E_{fleet,traffic,i}$ is the hauling traffic exhaust emissions for pollutant i per barrel [ton/bbl]
$EF_i$ is the average emission factor of pollutant i for heavy duty vehicles [g/mile]
$N_{trips}$ is the annual number of round trips per barrel [trips/bbl]. N=1/200
*D* is the round trip distance [miles/trip]
*907185* is the mass conversion [g/ton]

Q.2.2.1.22.1 Area-Wide Annual Emissions from Condensate Hauling

Annual emissions for the condensate hauling fleet were propagated with the annual condensate production according to Equation 61a:

$$E_{fleet,TOTAL,i} = E_{fleet,traffic,,i} \times S_{bbl,condensate} \qquad \text{Equation (61a)}$$

where:

$E_{fleet,TOTAL,\ i}$ are annual emissions of pollutant i from condensate hauling traffic [ton/yr]
$E_{fleet,traffic,i}$ is the emissions of pollutant i per barrel for the hauling fleet [ton/bbl]
$S_{bbl,condensate}$ is the scaling surrogate for the source category [barrels of condensate produced per year]

Q.2.2.1.22.2 Produced Water Hauling Exhaust Emissions

Produced water refers to the water produced with the gas once the well has been completed and is under operation. This water is typically hauled from the well site storage tanks with water trucks or sent via pipeline to injection wells. Annual produced water rates will vary by the type of well. It was assumed that the annual rate of water production for conventional gas and CBNG wells was 33,632 and 1,671 barrels per year, respectively based on IHS Enerdeq Datbase estimates of 2011 water production by well type. It was assumed that produced water truck capacity is 130 bbl and that 50 percent of the water is hauled out.

Exhaust emissions for produced water hauling fleet were estimated as shown in Equation 60b:

$$E_{fleet,traffic,i} = \frac{EF_i \times N_{trips} \times D}{907185} \quad \text{Equation (60b)}$$

where:

$E_{fleet,traffic,i}$ is the produced water hauling exhaust emissions for pollutant i per well [ton/well]
$EF_i$ is the average emission factor of pollutant i for heavy duty vehicles [g/mile]
$N_{trips}$ is the annual number of round trips per well [trips/well]
*D* is the round trip distance [miles/trip]
*907185* is the mass conversion [g/ton]

##### *Q.2.2.1.22.2.1 Area-Wide Annual Emissions from Produced Water Hauling*

Annual emissions for the produced water hauling fleet were propagated to the planning area according to Equation 61b:

$$E_{fleet,TOTAL,i} = E_{fleet,traffic,,i} \times S_{active\ wells} \quad \text{Equation (61b)}$$

where:

$E_{fleet,TOTAL,\ i}$ are annual emissions of pollutant i from produced water hauling traffic [ton/yr]
$E_{fleet,traffic,i}$ is the emissions of pollutant i per well for the hauling fleet [ton/well]
$S_{active\ wells}$ is the scaling surrogate for the source category, active wells per year [wells/yr]

#### Q.2.2.1.22.3 Fugitive Dust Emissions from Condensate and Produced Water Hauling Traffic

Road dust emission factors for heavy duty vehicles traveling on unpaved surfaces for condensate hauling and produced water hauling were estimated with the same methodology as in Section 2.2.1.2.6 using Equations 28 and 29. Because the number of trips for both of these activities is based on different surrogates - per barrel for condensate hauling and per well for produced water hauling - as shown in Section 2.2.1.2.15, fugitive dust road emissions of each fleet were calculated using the mitigated emissions factor ($EF_{mitigated}$) from Equation 29. This is shown in Equation 62.

$$E_{fleet,traffic,i} = \frac{EF_{mitigated} \times D \times N_{trips}}{2000} \quad \text{Equation (62)}$$

where:

$E_{fleet,traffic,i}$ is the traffic fugitive dust emissions for pollutant i per (1) barrel of condensate [ton/bbl] for condensate hauling or (2) well [ton/well] for produced water hauling
$EF_{mitigated}$ is the average emission factor of pollutant i for fugitive dust emissions [lb/mile]
$N_{trips}$ is the annual number of round trips per (1) barrel of condensate hauled [trips/bbl] for condensate hauling or (2) well [trips/well] for produced water hauling
*D* is the round trip distance per hauling trip [miles/trip]
*2000* is the mass conversion [lb/ton]

*Q.2.2.1.22.3.1 Area-Wide Annual Emissions from Condensate and Produced Water Hauling Traffic*

Annual fugitive dust emissions for condensate hauling were propagated with the annual condensate production according to Equation 63:

$$E_{fleet,TOTAL,i} = E_{fleet,traffic,,i} \times S_{bbl,condensate\ or\ active\ wells} \quad \text{Equation (63)}$$

where:

$E_{fleet,TOTAL,\ i}$ are annual fugitive dust emissions of pollutant i from condensate hauling traffic [ton/yr]
$E_{fleet,traffic,i}$ is the dust emissions of pollutant i per barrel for the hauling fleet [ton/surrogate]
$S_{bbl,condensate\ or\ active\ wells}$ is the scaling surrogate for the source category: (1) [barrels of condensate produced per year] for condensate hauling or (2) [active wells per year] for produced water hauling

*Q.2.2.1.23 Heaters*

This section describes the methodology for estimating emissions from heaters and reboilers. Heater emissions are a function of the properties of the local produced gas used as a fuel. Emissions factors for external combustion of natural gas were obtained from AP-42 Section 1.4 Natural Gas Combustion (EPA 1995a). Emissions per well from heaters and reboilers can be estimated individually using Equation 64.

$$E_{heater,i} = N_{heaters} \times \frac{EF_i \times Q_{heater} \times t_{annual}}{(HV_{local} \times 2000)} \quad \text{Equation (64)}$$

where:

$E_{heater,i}$ is the per well emissions for pollutant from a given heater [ton/well-yr]
$EF_i$ is the heater emission factor for a given pollutant i [lb/MM SCF]
$Q_{heater}$ is the heater MMBTU/hr rating [$MMBTU_{rated}$/hr]
$HV_{local}$ is the local natural gas heating value [$BTU_{local}$/SCF]
$t_{annual}$ is the annual hours of operation [hr/yr]
$N_{heaters}$ is the number of heaters per well

Q.2.2.1.23.1 Area-Wide Annual Emissions from heaters

Annual emissions for heaters and reboilers are estimated with Equation 65 using the scaling surrogate active wells.

$$E_{heater,TOTAL,i} = E_{heater,i} \times W_{TOTAL} \quad \text{Equation (65)}$$

where:

$E_{heater,TOTAL}$ is the total emissions of pollutant i for a given heater type in the Project [ton/yr]
$E_{heater}$ is the per well annual emissions from a given heater type for pollutant i [ton/well-yr]
$W_{TOTAL}$ is the total number of wells for a particular year [wells]

*Q.2.2.1.24 Dehydrator Emissions*

This section describes the methodology to estimate emissions from dehydrator still vents. Uncontrolled emission factors per unit of gas production for emissions of VOC, $CH_4$ and $CO_2$ were derived from the literature for the various well types. Total emissions were propagated using the gas production by well type, assuming 100 percent of the gas undergoes well site dehydration. This was done applying Equation 66.

$$E_{dehyTOTAL,i,j} = EF_{dehy,i} \times S_{gas\ production,j} \qquad \text{Equation (66)}$$

where:

$E_{dehy,TOTAL,\ ,I,j}$ are the total area-wide emissions from dehydrators still vents for pollutant i in year j [tons/yr]

$EF_{dehy,i}$ is the dehydrator still vent emissions rate [tons/MCF]

$S_{gas\ production}$ is the annual gas production in year j [MCF/yr]

### *Q.2.2.2 Midstream Sources*

Midstream sources include gathering and treating emissions associated with facilities such as compressor stations and gas plants. Base year midstream emissions are taken from the 2011 APEN (Air Pollutant Emission Notice) emissions database provided by Colorado Department of Public Health and Environment (2013). Colorado Department of Public Health and Environment provided APEN emissions for all oil and gas related emission sources covered by the following SCC and SIC codes:

- All of the SCCs 202002*, 310*, 404003* (where * indicates all sub-SCCs for the SCC)
- And only those with the following SICs: 13*, 492*, 4612

UFO planning area sources were identified based on whether the latitude and longitude of each source was within the UFO planning area. The APEN oil and gas emissions database includes both well site and midstream sources. Midstream sources were identified for inclusion in the calculator based on the facility name and the suite of equipment included at a given facility. Appendix C (of the Air Emission Inventory Technical Support Document) includes a table of emissions by facility for the UFO planning area.

Emissions were available in the APEN emissions database for the pollutants VOCs, CO, $NO_X$, $PM_{10}$ and $SO_2$ in tons per year. Emissions for $CH_4$ and $CO_2$ were calculated using the vented gas speciation according to Equations 67 and 68 for the following sources.

- Glycol Dehydrator
- Natural Gas Processing Facilities, Gas Sweeting: Amine Process
- Condensate Tanks
- Natural Gas Processing Facilities, Flanges and Connections

$$E_{source,CH4} = E_{tanks,VOC} \times \frac{weight\ fraction_{CH4}}{weight\ fraction_{VOC}} \qquad \text{Equation (67)}$$

$$E_{sourceCO2} = E_{tanks,VOC} \times \frac{weight\ fraction_{CO2}}{weight\ fraction_{VOC}}$$ Equation (68)

where:

$E_{source,VOC}$ is the total annual emissions from APENS database *a source* [tons/yr]
$E_{source,CO2}$ is the total $CO_2$ emissions from *a source* [tons/yr]
$E_{source,CH4}$ is the total $CH_4$ emissions from *a source* [tons/yr]
*Weight fractions* of each pollutant in the vented gas

For combustion sources such as compressor engines, process heaters and flares, emissions for $CH_4$, $N_2O$ and $CO_2$ were estimated using the ratios of each greenhouse gas to NOx of emissions factors from AP-42.

Emissions in future years were estimated by multiplying 2011 emissions by the ratio of gas production in a given future year to gas production in 2011. As necessary, for accounting purposes, total midstream sector emissions are allocated to each well type (CBNG or conventional) and/or mineral designation (BLM or cumulative) based on the corresponding percentage of annual gas production by well type and/or annual gas production by mineral designation.

#### *Q.2.2.3 Non-Oil and Gas Sources*

The methodologies implemented to estimate base year and future year emissions by alternative from non-oil and gas sources are explained in this section. More detailed assumptions, emission factors, and emission estimates by source category are described in Appendix D (of the Air Emission Inventory Technical Support Document).

##### *Q.2.2.3.1 Coal Mining*

Annual base year emissions from coal mining were estimated for the Somerset Coal Fields based on existing emission estimates for the operation of producing mines, Bowie #2 (BLM 2012c), West Elk (BLM 2012d), and Elk Creek (BLM 2012f), as well as exploration and construction emissions from the Oak Mesa Project (BLM 2012e). Emissions were not estimated for the New Horizon Mine which is not subject to BLM review. Based on the *Coal Resource and Development Potential Report* (BLM 2010), which indicated that Somerset Coal Field production is likely to remain stable at recent levels into the future, emissions for all future years for all scenarios were set equal to base year emissions.

##### *Q.2.2.3.2 Uranium Mining*

Annual emissions from uranium mining were estimated according to the number of mines constructed and/or producing in a given year combined with estimates of emissions per mine from discrete emission producing activities: wind erosion, fugitive dust, heavy equipment, and on-road vehicles. Activity inputs such as the equipment and vehicle operations, tons of material processed, and disturbed area were taken primarily from the Whirlwind Mine EA (BLM 2008). The estimated number of uranium mines in operation is shown in **Table Q-2-11**.

**Table Q-2-11. Schedule of uranium mines in production.**

| Year | Uranium Mining Facilities, All Alternatives |
|---|---|
| 2008-2012 | 0 |
| 2013 | 1 |
| 2014 | 3 |
| 2015 | 5 |
| 2016 | 7 |
| 2017 | 9 |
| 2018 | 10 |
| 2019 | 11 |
| 2020 | 12 |
| 2021 | 13 |
| 2022 | 14 |
| 2023 | 15 |
| 2024 | 16 |
| 2025 | 17 |
| 2026 | 18 |
| 2027 | 19 |
| 2028 | 20 |
| 2029 | 20 |
| 2030 | 20 |

Q.2.2.3.2.1 Wind Erosion

Wind erosion dust emissions were estimated based on AP-42 guidance for the estimation of emissions from industrial wind erosion (EPA 2006b) based on Equation 71:

$$E_{dust,i} = \frac{k \times P \times M \times N}{907{,}185} \qquad \text{Equation (71)}$$

where:

$E_{dust,\ i}$ are dust emissions for pollutant i from construction wind erosion [ton/mine]
$k$ is the particle size multiplies [0.5 for $PM_{10}$ and 0.075 from $PM_{2.5}$]
$P$ is the erosion potential [g/m$^2$]
$M$ is the number of disturbed acres [m$^2$/pad]
$N$ is the number of disturbances
*907,185* is a mass unit conversion [g/ton]

The erosions potential is a function of the wind friction velocity, as shown in Equation 72 and 73:

$$P = 58 \times (u^* - u_t)^2 + 25(u^* - u_t) \qquad \text{Equation (72)}$$

where:

$u^*$ is the friction velocity (m/s)
$u_t$ is the threshold friction velocity (m/s)

$$P = 0 \qquad for \qquad (u^* \leq u_t) \qquad \text{Equation (73)}$$

Friction velocity estimates (u*) were made by multiplying the average annual fastest wind speed from Uncompahgre, Colorado from 1947 to 1979 by 0.053 per AP-42 guidance (EPA 2006b).

Q.2.2.3.2.2 Fugitive Dust

Fugitive dust emissions from ventilation and surface facilities were taken from Whirlwind Mine Environmental Assessment (BLM 2008) permit not-to-exceed values.

Q.2.2.3.2.3 Heavy Equipment

This category refers to emissions associated with off-road equipment used in uranium mining. The EPA NONROAD2008a model (EPA 2009b) was used to compile emission factors for each equipment type included in surveys. The $N_2O$ emissions factor was obtained from the 2009 American Petroleum Institute O&G GHG Methodologies Compendium, Tables 4-13 and 4-17 (American Petroleum Institute 2009).

Emissions on per piece of equipment were estimated according to Equation 74:

$$E_{engine,i} = \frac{EF_i \times HP \times LF \times t_{event} \times n}{907{,}185} \qquad \text{Equation (74)}$$

where:

$E_{engine}$ are emissions of pollutant *i* [ton/equipment]
$EF_i$ is the emissions factor of pollutant *i* [g/hp-hr]
*HP* is the horsepower [hp]
*LF* is the load factor
$t_{event}$ is the number of hours the engine is used [hr/pad]
*907,185* is the mass unit conversion [g/ton]

Q.2.2.3.2.4 On-road Vehicles – Exhaust

This category refers to the exhaust and road dust emissions from light-duty and heavy-duty vehicle traffic used in uranium mining.

Emission factors were developed using the MOVES2010a model (EPA 2010). The emission factors were prepared for two vehicle classes, Semi-Trucks (Heavy Duty) and Pick-up Trucks (Light Duty), and represent annual average per-mile emissions in 2008 for Mesa County, Colorado. MOVES2010a emissions factors were modeled to include exhaust running, idle and start, brake wear, and tire wear, and evaporative processes. The $N_2O$ emission factor was obtained from 2012 Climate Registry Default Emission Factors (The Climate Registry 2012). Emissions were calculated using the MOVES2010a emission factors on a grams per mile basis, as shown in Equation 75.

$$E_{traffic,i} = \frac{EF_i \times N_{trips} \times D}{907185} \qquad \text{Equation (75)}$$

where:

$E_{traffic,i}$ is traffic exhaust emissions for pollutant i per well pad [ton/pad]
$EF_i$ is the average emission factor of pollutant i [g/mile]. For exhaust emissions, $EF_i$ = MOVES emission factors.
$N_{trips}$ is the annual number of round trips per activity [trips/pad]
*D* is the round trip distance [miles/trip]
*907185* is the mass conversion [g/ton]

Q.2.2.3.2.5 On-road Vehicles – Road Dust

Fugitive dust emissions from vehicle travel on unpaved roads were estimated based on the AP-42 technical guidance Section 13.2.2.1 Unpaved Roads (EPA 2006a). Road dust emission factors for vehicles traveling on unpaved surfaces at industrial sites can be estimated with Equation 76.

$$EF_i = k\left(\frac{s}{12}\right)^a\left(\frac{W}{3}\right)^b \qquad \text{Equation (76)}$$

where:

*EF* is the size-specific particulate emissions factor for pollutant i (lb/mile)
*s* is the surface material silt content (%)
*W* is the mean vehicle weight (tons)
*k, a, b* are empirical constants according to Table Q-2-10.

Because the emissions factor is a function of vehicle weight, individual emissions factors for heavy duty vehicles and light duty vehicles were derived with Equation 76. To account for natural mitigation of road dust emissions due to annual precipitation and from watering control, Equation 77 was applied:

$$EF_{mitigated} = EF_i \times \frac{365-P}{365} \times \frac{100-CE}{100} \qquad \text{Equation (77)}$$

where:

$EF_{mitigated}$ is the annual average emission factor for uncontrolled conditions including natural mitigation [lb/mile]
$EF_i$ is the size-specific emission factor [lb/mile]
*P* is number of precipitation days (>0.01" rainfall) at the site (Precipitation days at Uncompahgre Walker, CO; from Western Regional Climate Center. Mean data 1990-2010)
*CE* is the control efficiency for watering in unpaved roads

Fugitive dust road emissions were calculated using the mitigated emissions factor ($EF_{mitigated}$) from Equation 77, along with the vehicle miles traveled for each vehicle group as shown in Equation 78.

$$E_{traffic,i} = \frac{EF_{mitigated} \times N_{trips} \times D}{2000} \qquad \text{Equation (78)}$$

where:

$E_{traffic,i}$ is the traffic fugitive dust emissions for pollutant i per event [ton]
$EF_{mitigated}$ is the average emission factor of pollutant i for fugitive dust emissions [lb/mile]
$N_{trips}$ is the annual number of round trips per activity [trips]
$D$ is the round trip distance [miles/trip]
$2000$ is the mass conversion [lb/ton]

#### *Q.2.2.3.3 Sand and Gravel*

Annual emissions from sand and gravel extraction were estimated based on the data provided by BLM UFO personnel on the quantity of sand and gravel material extracted, equipment operation, and vehicle use for sand and gravel extraction.

Wind erosion, heavy equipment, and on-road vehicle exhaust and road dust emissions were estimated with sand and gravel source category activity inputs using the similar methodology to uranium mining as described above.

##### Q.2.2.3.3.1 Extraction and Processing Fugitive Dust

Fugitive dust emissions associated with sand and gravel extraction were estimated based on AP-42 methodology. Extraction emissions were estimated using AP-42, Chapter 11.9 methodology and include estimates of emissions from the following processes: scraping, removal of overburden, grading, scraper unloading, batch drop, and truck loading. AP-42 methodology for estimating emissions from rock crushing (Chapter 11.19) and concrete batching (11.12) were used to estimate processing emissions for the following processes: tertiary crushing, fines crushing, screening, fines screening, conveyor transfer point, truck drop unloading, and batch plant crushed rock transfer. For all processes except removal of overburden, grading, and batch drop, AP-42 particulate matter emission rates were applied directly to UFO sand and gravel activity. For removal of overburden, grading, and batch drop standard AP-42 equations were used to estimate particulate matter emissions.

#### *Q.2.2.3.4 Vegetation – Prescribed Fire and Mechanical Treatment*

Annual emissions from prescribed fires and mechanical treatments were estimated based on the data provided by BLM UFO personnel on the heavy equipment operation and vehicle use during prescribed fires and mechanical treatments as well as recent estimates of prescribed fire acreage burned. BLM UFO Personnel estimated that prescribed burning activities would remain similar to the base year for Alternative A, increase by 40% from the base year for Alternatives B and B.I, decrease by 20% from the base year for Alternative C, and increase from the base year by 25% for Alternative D. BLM UFO Personnel estimated that mechanical treatment activities would remain similar to the base year for Alternative A, decrease by 20% from the base year for Alternatives B and B.I, increase by 50% from the base year for Alternative C, and increase from the base year by 20% for Alternative D. Estimates of changes in prescribed burning and mechanical treatment activity are based on stated objectives by alternative in the draft RMP for wildlife species management, vegetation mosaic objectives, and Wildland Urban Interface.

Heavy equipment and on-road vehicle exhaust emissions were estimated with prescribed fire and mechanical treatment source category activity inputs using the similar methodology to uranium mining as described above.

Q.2.2.3.4.1 Smoke

Smoke emissions from prescribed fires were estimated by applying the annual estimate of acreage burned to a tons/acre burned emission factor. The tons/acre burned emission factor was derived estimated based on average emission rates from prescribed fires in the Western Governor's Association, Western Regional Air Partnership 2002 Fire Emission Inventory (Western Governors' Association, Western Regional Air Partnership 2005).

Q.2.2.3.4.2 Fugitive Dust from Heavy Equipment

Fugitive dust emissions from heavy equipment were estimated based on AP-42 Chapter 13 Section 13.2.3 guidance for estimating emissions from Heavy Construction Operations (EPA 1995a). A construction fugitive dust emission factor for total suspended particles (TSP) is available in the AP-42 guidance (1.2 tons-TSP/acre/month of activity).

Total suspended particle emissions from wellpad construction equipment on a per wellpad basis are estimated based on Equation 79:

$$E_{equip.dust,TSP} = EF \times A \times t \times \frac{(1-C)}{30} \qquad \text{Equation (79)}$$

where:

$E_{equip,dust,TSP}$ is the TSP emissions from construction equipment fugitive dust [tons]
*EF* is the construction fugitive dust emission factor [tons/acre/month]
*A* is the average number of acres disturbed annually [acres]
*t* is the number of days to completion[days]
*C* is the control efficiency for watering
*30* is the conversion factor for days/month

Conversion factors for TSP to particulate matter $PM_{10}$ (EPA, 2006b) and from $PM_{10}$ to $PM_{2.5}$ (Midwest Research Institute, 2006) were used to estimate other fugitive dust pollutant emissions ($PM_{10}$ and $PM_{2.5}$).

Q.2.2.3.4.3 On-road Vehicle Road Dust

Fugitive dust emissions from vehicle travel on unpaved roads were estimated based on the AP-42 technical guidance Section 13.2.2.1 Unpaved Roads (EPA 2006a). Road dust emission factors for vehicles traveling on unpaved surfaces at industrial sites can be estimated with Equation 80.

$$EF_i = \frac{k\left(\frac{s}{12}\right)^a \left(\frac{S}{30}\right)^b}{\left(\frac{M}{0.5}\right)^c} - \mathrm{C} \qquad \text{Equation (80)}$$

where:

*EF* is the size-specific particulate emissions factor for pollutant i (lb/mile)
*s* is the surface material silt content (%)

*S* is the mean vehicle speed (mi/hr)
*M* is the surface material moisture content (%)
*k, a, b* are empirical constants
*C* is the emission factor for 1980's vehicle fleet exhaust, brake wear, and tire wear (lb/VMT)

To account for natural mitigation of road dust emissions due to annual precipitation and from watering control, Equation 81 was applied:

$$EF_{mitigated} = EF_i \times \frac{365-P}{365} \times \frac{100-CE}{100} \qquad \text{Equation (81)}$$

where:

$EF_{mitigated}$ is the annual average emission factor for uncontrolled conditions including natural mitigation [lb/mile]
$EF_i$ is the size-specific emission factor [lb/mile]
*P* is number of precipitation days (>0.01" rainfall) at the site (Precipitation days at Uncompahgre Walker, CO; from Western Regional Climate Center. Mean data 1990-2010)
*CE* is the control efficiency for watering in unpaved roads

Fugitive dust road emissions were calculated using the mitigated emissions factor ($EF_{mitigated}$) from Equation 81, along with the vehicle miles traveled for each vehicle group as shown in Equation 82:

$$E_{traffic,i} = \frac{EF_{mitigated,i} \times N_{trips} \times D}{2000} \qquad \text{Equation (82)}$$

where:

$E_{traffic,i}$ is the traffic fugitive dust emissions for pollutant i per event [ton]
$EF_{mitigated,i}$ is the average emission factor of pollutant i for fugitive dust emissions [lb/mile]
$N_{trips}$ is the annual number of round trips per activity [trips]
*D* is the round trip distance [miles/trip]
*2000* is the mass conversion [lb/ton]

#### *Q.2.2.3.5 Comprehensive Travel and Transportation Management*

Annual emissions from Travel and Transportation Management were estimated for off-road recreational vehicles based on annual estimates of activity by recreational equipment type (ATV, motorcycle, or snowmobile). Annual activity estimates were calculated based on the number of annual visitors per year using each recreational equipment type combined with estimates of activity per visit (14 miles per visit for ATVs and motorcycles and 4 hours per visit for snowmobiles). BLM UFO personnel also provided estimates of activity for heavy equipment used in road maintenance operations.

Heavy equipment emissions were estimated with Travel and Transportation Management activity using the similar methodology to uranium mining as described above. Recreational vehicle road dust emissions were estimated using methodology similar to road dust from Prescribed Fire and Mechanical Treatment activities.

Q.2.2.3.5.1 Recreational Vehicles

This category refers to emissions associated with off-road motorcycles and all-terrain vehicles (ATVs). The EPA NONROAD2008a model (EPA 2009b) was used to estimate emission rates on a grams per mile basis for motorcycle and ATV use and on a grams per hour basis for snowmobile use within the UFO planning area. The $N_2O$ emissions factor was obtained from the 2009 American Petroleum Institute O&G GHG Methodologies Compendium, Tables 4-13 and 4-17 (American Petroleum Institute 2009).

Emissions were estimated according to Equation 83:

$$E_{vehicle\ type,i} = \frac{EF_i \times A}{907{,}185} \qquad \text{Equation (83)}$$

where:

$E_{vehicle\ type}$ are emissions of pollutant *i* for motorcycles or ATVs [ton]
$EF_i$ is the emissions factor of pollutant *i* [g/mi or g/hr]
*A* is the number of miles travelled annually by motorcycles or ATVs [mi] or the number of hours of annual use for snowmobiles [hr]
*907,185* is the mass unit conversion [g/ton]

*Q.2.2.3.6 Livestock Grazing*

Annual emissions from livestock grazing and associated activities were estimated based on the data provided by BLM UFO personnel on the number of animals in the UFO planning area for the base year and for the future year for each alternative as well as information about the annual frequency, type, and duration of livestock associated construction projects.

Wind erosion, heavy equipment, and on-road vehicle exhaust emissions were estimated with livestock grazing associated activity using the similar methodology to uranium mining as described above. Road dust emissions were estimated using methodology similar to road dust from Prescribed Fire and Mechanical Treatment described above.

Q.2.2.3.6.1 Enteric Fermentation

Enteric fermentation emissions were estimated by applying the Intergovernmental Panel on Climate Change (2006) $CH_4$ emission rate per animal to the number of animals in the UFO planning area.

*Q.2.2.3.7 Lands and Realty – Rights-of-Way*

Annual emissions from land and realty – right-of-way activities were estimated based on the data provided by BLM UFO personnel on the annual frequency and type of projects.

Wind erosion, heavy equipment, and on-road vehicle exhaust emissions were estimated with land and realty – right-of-way source category activity inputs using the similar methodology to uranium mining as described above. Road dust emissions were estimated using methodology similar to road dust from Prescribed Fire and Mechanical Treatment described above.

## Q.3 EMISSION INVENTORY RESULTS

This section presents emissions plots and tables summarizing the UFO planning area emissions. For more detailed emissions results, see Appendices A, B, C, and D (of the Air Emission Inventory Technical Support Document), which show detailed emission estimates. Appendix E (of the Air Emission Inventory Technical Support Document) includes a number of tables and figures summarizing the emission inventory results.

### Q.3.1 BLM Action Emissions

**Table Q-3-1** shows BLM action total emissions across all source categories for the base year and for each alternative. Notably, Alternative B.I has the lowest emissions except for $SO_2$, while Alternative C has the highest emissions across all pollutants. A comparison of emissions from Alternative A and D indicates that Year 10 $PM_{10}$ emissions are lower for Alternative D relative to Alternative A, but for all other pollutants are higher for Alternative D relative to Alternative A for the future year. Note that **Table Q-3-1** uses the standard convention of reporting criteria pollutant emissions using short tones (tons), but GHG emissions are reported using long (metric) tonnes.

**Table Q-3-1. Estimated annual emissions summary BLM actions within the UFO planning area.**

| Scenario | Emissions (tons per year) | | | | | | | Emissions (metric tonnes per year) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | VOC | CO | NOX | $PM_{10}$ | $PM_{2.5}$ | $SO_2$ | HAPs | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2e$ (million metric tonnes) |
| Base Year | 243 | 894 | 438 | 771 | 283 | 9 | 25 | 81,978 | 128,840 | 6 | 2.79 |
| Year 10 | | | | | | | | | | | |
| Alternative A | 742 | 1,896 | 1,430 | 1,444 | 533 | 19 | 70 | 256,212 | 134,569 | 9 | 3.08 |
| Alternative B | 727 | 1,870 | 1,430 | 1,339 | 527 | 19 | 68 | 258,174 | 134,475 | 11 | 3.09 |
| Alternative B.I | 686 | 1,801 | 1,381 | 1,330 | 524 | 19 | 64 | 247,280 | 133,955 | 11 | 3.06 |
| Alternative C | 863 | 2,176 | 1,575 | 1,487 | 544 | 19 | 82 | 283,901 | 135,609 | 8 | 3.13 |
| Alternative D | 800 | 2,054 | 1,511 | 1,400 | 538 | 20 | 75 | 273,027 | 135,082 | 10 | 3.11 |

**Figure Q-2**, **Figure Q-3**, and **Figure Q-4** show BLM action emissions by aggregate source for the base year and for each alternative in Year 10. 79% of base year $NO_X$ emissions are from oil and gas and non-oil and gas minerals while 78% of base year VOC emissions are from oil and gas minerals and other activities. Non-oil and gas minerals are the dominant source of base year $CO_2e$ emissions, accounting for 98% of base year $CO_2e$ emissions. For Year 10, across all alternatives, oil and gas emissions are the dominant source of VOC emissions. Oil and gas mineral emissions account for 39% to 44% of $NO_X$ emissions for Year 10 across all alternatives with greater contribution from non-oil and gas minerals of 48% to 55%, and minor contributions of 8% or less from other sources.

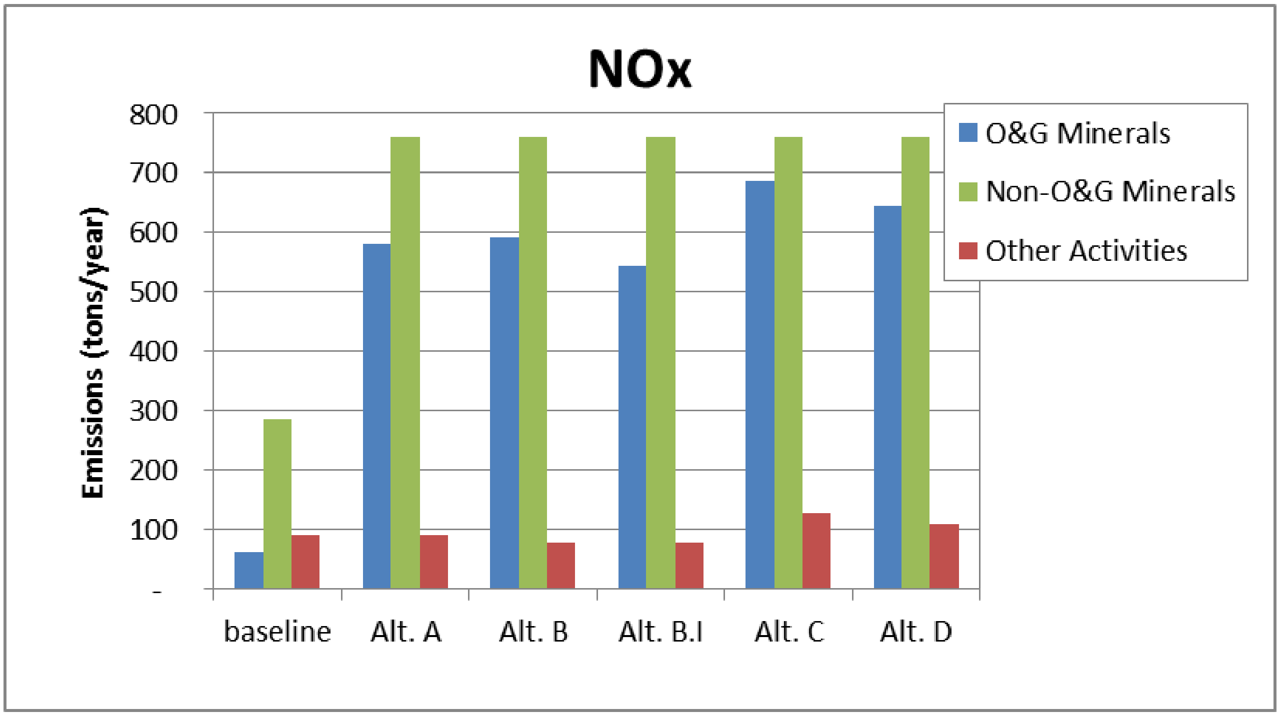


**Figure Q-2. BLM action $NO_X$ emissions by alternative and source.**

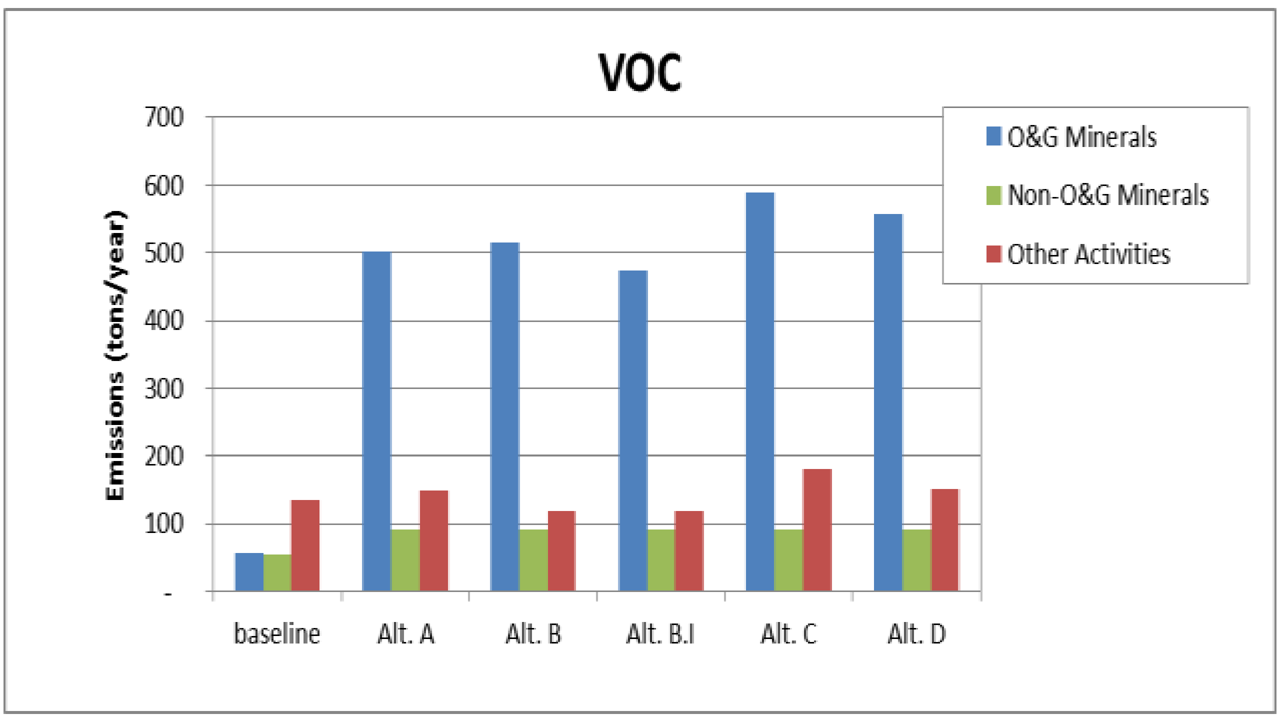


**Figure Q-3. BLM action VOC emissions by alternative and source.**

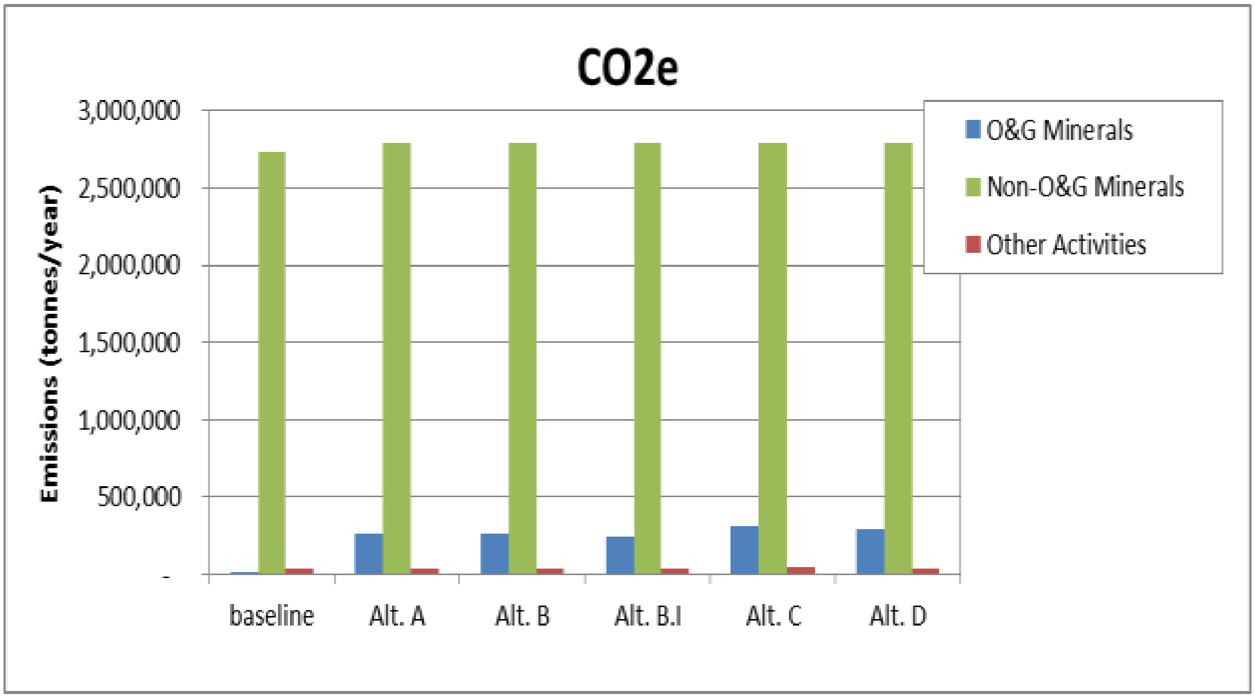


**Figure Q-4. BLM action $CO_2e$ emissions by alternative and source.**

### Q.3.2 Cumulative Emission Calculations and Emission Summary

Cumulative emissions incorporate all BLM action emissions as well as additional oil and gas development not subject to direct BLM control. **Table Q-3-2** shows cumulative action emissions for the base year and for each alternative for Year 10. Alternative A shows the lowest emission for VOC, CO, $NO_X$, HAPs, and $CO_2e$ while Alternative B.I shows the lowest emissions for $PM_{10}$ and $PM_{2.5}$. Alternative C has the highest emissions across all pollutants.

**Table Q-3-2. Estimated annual emissions summary cumulative actions within the UFO planning area.**

| Scenario | Emissions (tons per year) | | | | | | | Emissions (metric tonnes per year) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | VOC | CO | NOX | $PM_{10}$ | $PM_{2.5}$ | $SO_2$ | HAPs | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2e$ (million metric tonnes) |
| Base Year | 308 | 1,009 | 514 | 782 | 285 | 9 | 32 | 90,985 | 129,128 | 6 | 2.80 |
| **Year 10** | | | | | | | | | | | |
| Alternative A | 806 | 2,010 | 1,501 | 1,454 | 537 | 19 | 76 | 270,416 | 135,087 | 9 | 3.11 |
| Alternative B | 913 | 2,183 | 1,646 | 1,378 | 538 | 20 | 85 | 305,138 | 136,497 | 11 | 3.18 |
| Alternative B.I | 871 | 2,111 | 1,595 | 1,368 | 535 | 19 | 81 | 294,060 | 135,978 | 11 | 3.15 |
| Alternative C | 1,055 | 2,500 | 1,797 | 1,527 | 555 | 20 | 99 | 332,080 | 137,674 | 9 | 3.23 |
| Alternative D | 991 | 2,375 | 1,732 | 1,440 | 549 | 20 | 92 | 321,058 | 137,147 | 11 | 3.20 |

**Figure Q-5**, **Figure Q-6**, and **Figure Q-7** show cumulative action emissions by aggregate source for the base year and each alternative in Year 10. Similar to BLM action emissions, the majority of $NO_X$ emissions in the base year (82%) are from oil and gas and non-oil and gas minerals while a majority of base year VOC emissions (83%) are from oil and gas minerals and other activities. Non-oil and gas minerals are the dominant source of base year $CO_2e$ emissions, accounting for 98% of base year $CO_2e$ emissions. In Year 10, VOC emissions are dominated by oil and gas minerals across all alternatives. Non-oil and gas minerals is the primary and oil and gas minerals the secondary contributor to $NO_X$ emissions in Year 10 for Alternatives A and B.I. For Alternatives B, C, and D in Year 10, oil and gas minerals is the primary contributor to $NO_X$ emissions, with non-oil and gas minerals the secondary contributor. For $CO_2e$, non-oil and gas minerals is the primary and oil and gas minerals is the secondary contributor in Year 10.

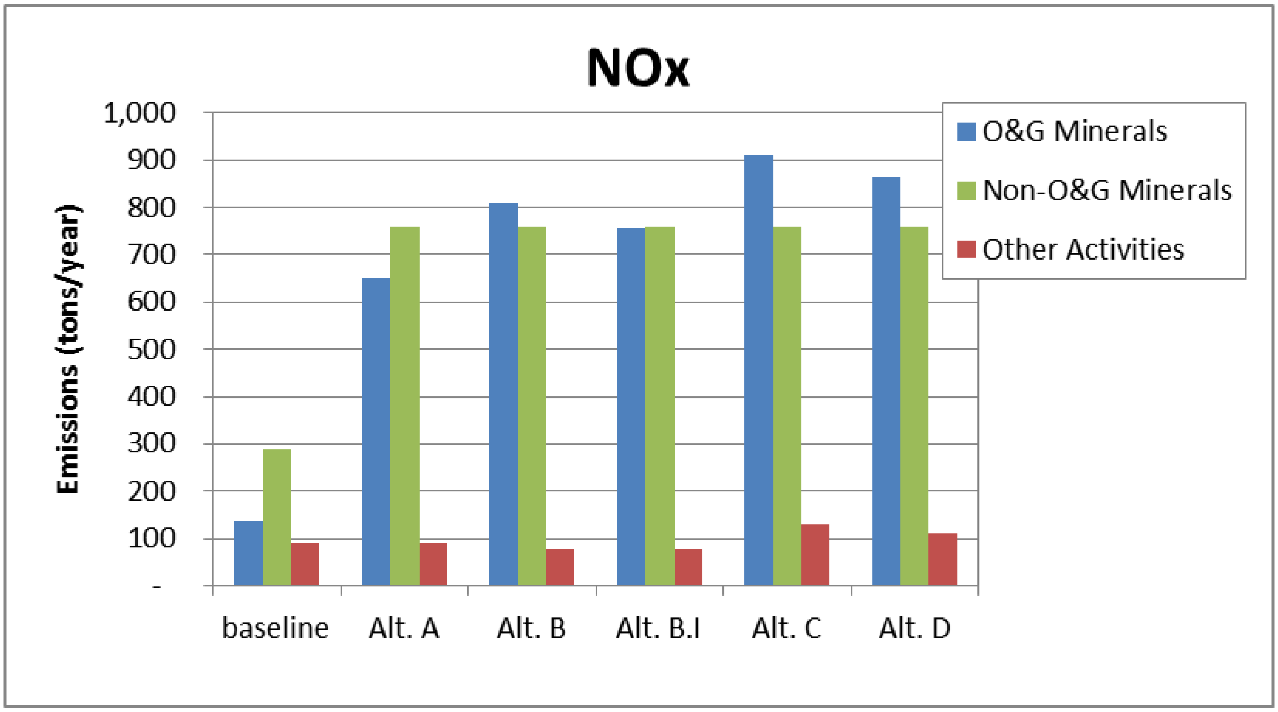


**Figure Q-5. Cumulative action $NO_X$ emissions by alternative and source.**

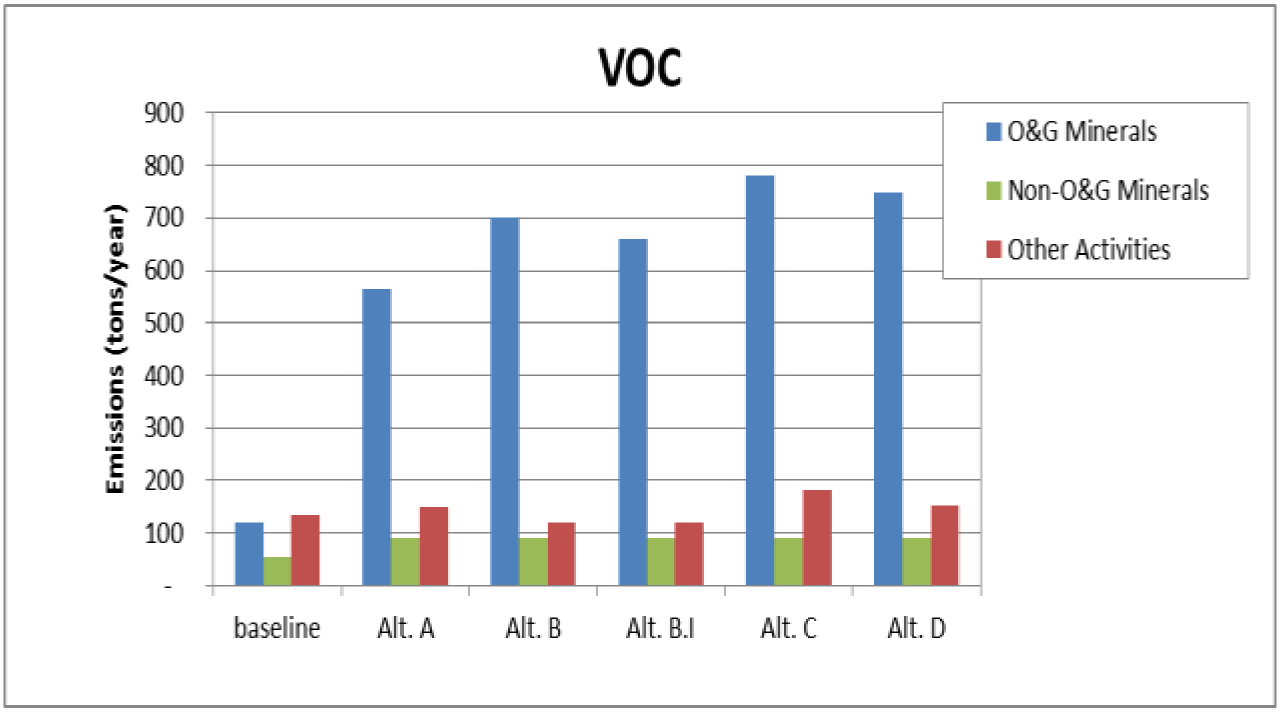


**Figure Q-6. Cumulative action VOC emissions by alternative and source.**

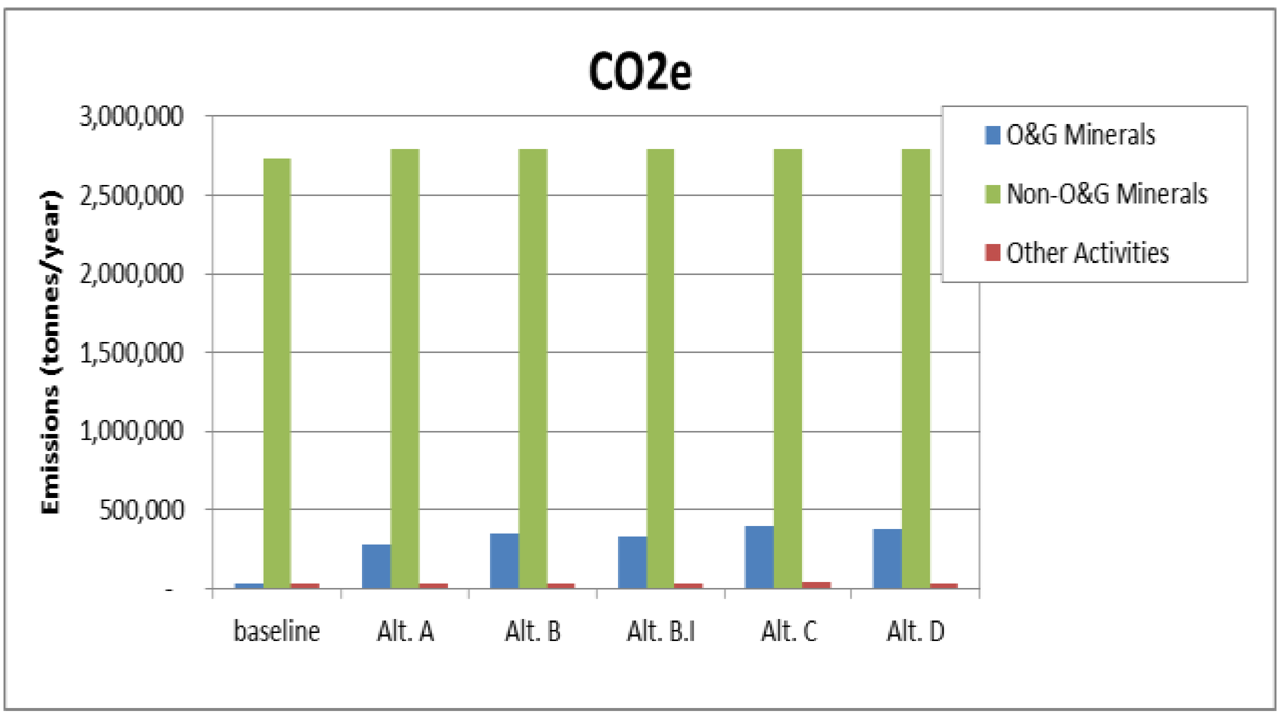


**Figure Q-7. Cumulative action $CO_2e$ emissions by alternative and source.**

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