Specialist Report - Greenhouse Gas Analysis for BLM Utah Oil and Gas Leasing

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1. Introduction

1.1. Purpose

The purpose of this report is to provide an environmental analysis of cumulative greenhouse gas (GHG) emissions for use in Utah Bureau of Land Management (BLM) oil and gas leasing EAs. This analysis includes direct and indirect emissions from existing wells, foreseeable well development, and from past lease sales.

1.2. Regulations and Policy

Greenhouse gases (GHGs) became regulated pollutants on January 2, 2011 under the Clean Air Act (CAA) Prevention of Significant Deterioration and Title V Operating Permit Programs (EPA, Clean Air Act Permitting for Greenhouse Gases, 2019) because of their contribution to global climate change effects. These gases absorb energy emitted from the earth's surface and re-emit a larger portion of the heat back to the earth rather than allowing the heat to escape into space which would be the case under more natural conditions.

The Environmental Protection Agency (EPA) GHG permitting programs only apply to major stationary sources emitting over 100,000 tons carbon dioxide equivalent (CO2e) per year (e.g., power plant, landfill, etc.) or modifications of major sources with emission increases greater than 75,000 tons CO2e per year. Additionally, the EPA requires annual reporting for facilities with stationary sources that emit 25,000 metric tons (mt) CO2e per year to provide a basis for future policy decisions and regulatory initiatives regarding GHG's. Oil and gas wells are not considered major stationary sources that fall under EPA rules and permitting programs. However, emissions thresholds from these programs provide a point of comparison for analyzing GHG emissions in National Environmental Policy Act documents.

1.3. Data Sources

Data and descriptions used in this analysis were collected from a variety of sources, including but not limited to the Utah Division of Oil Gas and Mining (UDOGM, 2018) application for permit to drill (APD) and annual production data, and the EPA GHG emission factors (EPA, Emission Factors for Greenhouse Gas Inventories, 2018), and foreseeable development from the four most recent lease sales (December 2018, March 2019, June 2019, and September 2019).

1.4. Edits to Specialist Report Since the September 2019 Draft Lease Sale EA

Based on public feedback received of the draft September 2019 Lease Sale EAs, the specialist report has been updated. Updates were made based on comment suggestions, to include updated information, and to correct errors that were identified. A list of edits follows.

- Updated foreseeable development from APDs. The APD data used in the draft EA analysis was obtained from the BLM Automated Fluid Minerals Support System, which only includes federal APDs. This report has been updated to use APD data from UDOGM, which includes both federal and non-federal APDs.
- The analysis for the draft EA used four years of APD data (2015-2018). However, APDs are only valid for a two year period. The specialist report has been updated to evaluate the most recent two years of APD information (2017-2019).
- Corrected the GHG emission for construction of new wells in the Color Country and West Desert District. Original emissions estimates were based on the draft emission inventory that assumed hydraulic fracturing engines would operate for 8 hours. The emissions estimates were updated to match single well emission values listed in the Grand Staircase Escalante National Monument and Kanab RMP DEIS (BLM, 2018).
- Corrected the GHG emissions estimates from the Moab Master Lease Plan (BLM, 2016) for well construction and operation emissions. The original emissions estimates didn't include some emission sources that should have been included. Updates include refined emissions from heavy equipment exhaust during construction, and added operational emissions from well workovers, recompletion, and blowdown.
- Added information from the USGS Federal GHG emission report (USGS, 2018), to describe the impacts to the lands carbon storage capability dues to oil and gas surface disturbing activities.
- Updated the December 2019 lease sale foreseeable development.
- Added GHG emission estimates for total leasable acres within each field office planning area and potential remaining emissions from undeveloped lands.
- Added additional information about mitigation.
- Minor edits in the text and tables to clarify the information presented in the report.

2. Affected Environment

This section describes the current climate conditions in Utah and the temperature and precipitation trends. Existing levels of local, national, and global emissions of GHGs are also presented.

2.1. Climate and Historical Climate Change

Climate is the composite of generally prevailing weather conditions of a particular region throughout the year, averaged over a series of years such as temperature and precipitation. Climate change includes both historic and predicted climate shifts that are beyond normal weather variations. The 2018 BLM Utah Air Monitoring Report (BLM, 2019) discusses the current climate conditions in Utah, and is incorporated by reference. The report presents the three-decade average and trends of temperature and precipitation for each of the seven climate divisions in Utah.

Utah's climate has average annual temperatures ranging between 45-52 ºF and average precipitation of 10-13 inches (BLM, 2019). Mountainous areas have annual average temperatures near 40 ºF with average precipitation of 23 inches. Southern Utah low elevation areas in the St George Field Office have average temperatures of about 59 ºF. Trends over the most recent climate normal period (1981-2010) show average temperatures increase 0.5 ºF while precipitation decrease between 0.3 and 1.5 inches. However, it is noted that decreases in precipitation are heavily influenced by the historic rain and snowfall in the early 1980's and recent precipitation is near the 1895-2017 average.

In November 2018 the Fourth National Climate Assessment (NCA4) Volume II was published. Compared to previous reports, NCA4 provides greater detail on regional scales as impacts and adaptation tend to be realized at a more local level. The Southwest region (Arizona, California, Colorado, New Mexico, Nevada, and Utah) encompasses diverse ecosystems, cultures, and economies, reflecting a broad range of climate conditions, including the hottest and driest climate in the United States. The average annual temperature of the Southwest increased 1.6°F (0.9ºC) between 1901 and 2016. Moreover, the region recorded more warm nights and fewer cold nights between 1990 and 2016, including an increase of 4.1°F (2.3°C) for the coldest day of the year. Each NCA has consistently identified drought, water shortages, and loss of ecosystem integrity as major challenges that the Southwest confronts under climate change. Since the last assessment, published field research has provided even stronger detection of hydrological drought, tree death, wildfire increases, sea level rise and warming, oxygen loss, and acidification of the ocean that have been statistically different from natural variation, with much of the attribution pointing to human-caused climate change (USGCRP, 2018).

The American Meteorological Society also produces annual State of the Climate Reports (AMS, 2017) for documenting the status and trajectory of the observed climate. Chapter 7 of the 2017 report provides summaries of the temperature and precipitation conditions observed in the United States. The annual average temperature in 2017 for the continental U.S. was 54.5 ºF, 1.8 ºF above the 1981-2010 climate normal average. This is the third warmest year since 1895. Over 120 years temperatures have increased by 0.2 ºF per decade, with 0.5 ºF per decade warming occurring since 1970. The 20^{th} wettest year on record occurred in 2017. National average annual precipitation is increasing by 0.17 inches per decade.

A number of activities contribute to the phenomenon of climate change, including emissions of GHGs (especially CO_2 and methane) from fossil fuel development, large wildfires, activities using combustion engines, changes to the natural carbon cycle, and changes to radiative forces and reflectivity (albedo). It is important to note that GHGs will have a sustained climatic impact over different temporal scales due to their differences in global warming potential (described above) and lifespans in the atmosphere. For example, CO_2 may last 50 to 200 years in the atmosphere while methane has an average atmospheric life time of 12 years.

2.2. Greenhouse Gas Emissions

In order to assess the potential for climate change, and the resultant effects of climate change, the standard approach is to measure and predict emissions of GHGs. Greenhouse gases are composed of molecules that absorb and reradiate infrared electromagnetic radiation. When present in the atmosphere the gas contributes to the greenhouse effect. Some GHGs such as carbon dioxide occur naturally and are emitted to the atmosphere through natural processes and human activities. Other GHGs (e.g., fluorinated gases) are created and emitted solely through human activities. The primary GHGs that enter the atmosphere as a result of anthropogenic activities include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_20), and fluorinated gases such as hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Fluorinated gases are generally unrelated to the activities authorized by the BLM and will not be discussed further in this document. Since the pre-industrial era (approximately 1750) to 2017, concentrations of GHG's have increased 45% for CO_2, 164% for CH_4, and 22% for N_2O, Table 1.

Table 1 Global Atmospheric Concentration and Rate of Change of Greenhouse Gases

	CO_2	CH_4	N_2O
Pre-Industrial Concentration	280 ppm	0.700 ppm	0.270 ppm
2017 Atmospheric Concentration	407 ppm	1.850 ppm	0.330 ppm
2007-2017 Rate of Change	2.2 ppm/yr	0.007 ppm/yr	0.008 ppm/yr

Source: EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2017 (EPA, 2019)

Each GHG has a global warming potential (GWP) that accounts for the intensity of each GHG's heat trapping effect and its longevity in the atmosphere. GWP values allow for a comparison of the impacts of emissions and reductions of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of CO2. According to the IPCC, GWPs typically have an uncertainty of ±35 percent. GWPs have been developed for several GHGs over different time horizons including 20 year, 100 year, and 500 year. The choice of emission metric and time horizon depends on type of application and policy context; hence, no single metric is optimal for all policy goals. The 100-year GWP (GWP100) was adopted by the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol and is now used widely as the default metric. In addition, the EPA uses the 100 year time horizon in its *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2017* (EPA, 2019), GHG Reporting Rule requirements under 40 CFR Part 98 Subpart A, and uses the GWPs and time horizon consistent with the IPCC Fifth Assessment Report, Climate Change Synthesis Report (chapter 8, page 714, Table 8.7) (IPCC, 2014), 2014 in its science communications. BLM Utah uses GWPs that reflect the current state of science and the 100 year time horizon to allow for direct comparison to state and national emissions.

2.2.1.State, National, and Global Greenhouse Gas Emissions

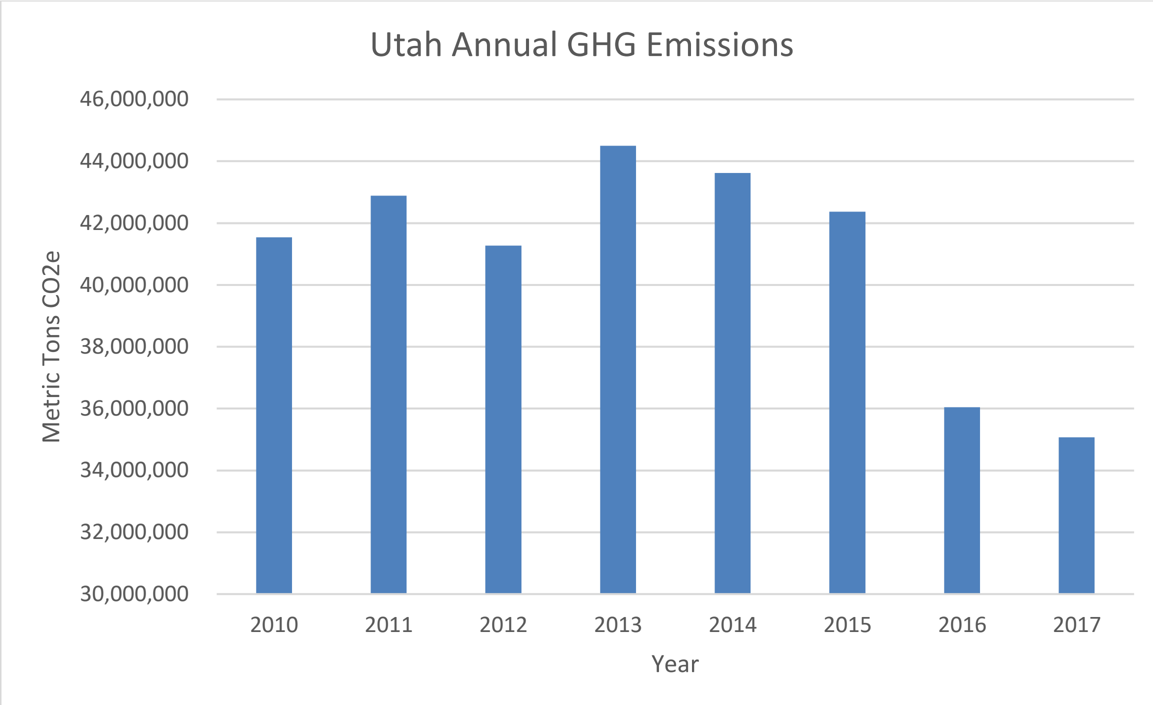
Because GHGs circulate freely throughout Earth's atmosphere, climate change is a cumulative global issue. For context, BLM related emissions can be compared with state, national, and global total GHG emissions in Table 2. Sources of GHG emissions include the EPA's GHG Reporting Program FLIGHT tool (EPA, 2018) for state emission, the EPA inventory report on GHG emissions and sinks (EPA, 2019) for national emissions, and the European Commission Joint Research Centre Fossil CO_2 & GHG Emission of All World Countries report (Janssens-Maenhout, et al., 2017) for global emissions. State emissions information only includes major stationary industrial sources.

Table 2, Annual State, National, and Global GHG Emissions (CO_2e) in Million Metric Tons (MMT) per Year

Utah	US Energy Sector	United States	Global
35.0	5,424.8	6,456.7	46,423.3

Source: EPA Inventory of US Greenhouse Gases Emission and Sinks 1990-2017 (EPA, 2019)
EPA GHG Reporting Program FLIGHT tool (EPA, 2018)
Fossil CO2 & GHG Emissions of all World Countries, recent year 2012 (Janssens-Maenhout, et al., 2017)

GHG reported emissions from major sources in Utah in 2017 totaled 35.0 million metric tons (MMT) of CO_2e. A total of 64 facilities reported GHG emissions in 19 of Utah's 29 counties. Utah annual emission from 2010 to 2017 are shown in Figure 1. From 2013 to 2017 emissions in Utah decreased 9.4 MMT CO_2e, or 19.6%.



Source: EPA GHG Reporting Program FLIGHT tool (EPA, 2018)

Figure 1. Annual GHG emissions in Utah in MMT CO2e

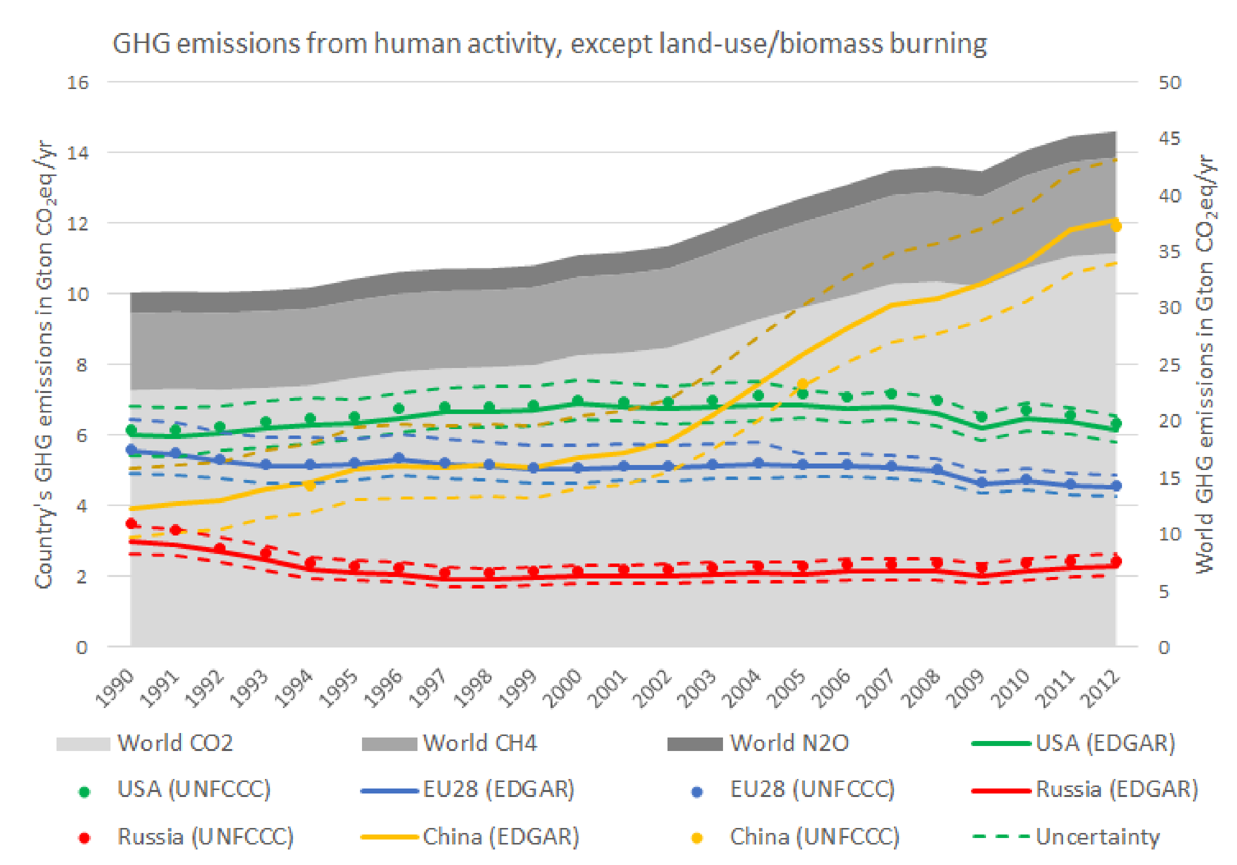
Total U.S. greenhouse gas emissions in 2017 were 6,456.7 MMT of CO_2e, Table 3. This represents a 1.3% increase in emissions compared to the 1990 baseline year. Emissions decreased from 2016 to 2017 by 0.5 percent (35.5 MMT CO_2e), driven in large part by a decrease in CO_2 emissions from fossil fuel combustion (EPA, 2019). The energy sector accounts for 84% (5,424.8 CO_2e) of GHG emissions in the United States.

Table 3 Recent Trends in U.S. Greenhouse Gas Emissions (MMT CO_2e)

	1990	2013	2014	2015	2016	2017
Total U.S. Emissions	6,371.0	6,710.2	6,760.0	6,623.8	6,492.3	6,456.7

Global emissions information is obtained from the European Commission Emission Database for Global Atmospheric Research (EDGAR) (Janssens-Maenhout, et al., 2017). Other sources for global emissions were not considered since they are incomplete or haven't been scientifically reviewed. The EDGAR database provides a comprehensive picture of anthropogenic CO_2 emissions through 2016, and includes all IPCC sectoral classifications. Emissions data for all other GHG's is available through 2012. More recent estimates for all GHG's isn't possible since there is no recent global agriculture information, a major source sector for CH_4 and N_2O.

Total global emissions in 2012 were 46,423.3 MMT CO_2e. Figure 2 shows the annual global emissions from 1990-2012. The global GHG emissions trends have increased since the beginning of the 21st century, driven mainly by increases in CO_2 emissions from China and other emerging economies. Methane and N_2O emissions were 19% and 6% respectively of total emissions in 2012.



Source: European Commission Emission Database for Global Atmospheric Research (EDGAR) (Janssens-Maenhout, et al., 2017)

Figure 2. Total GHG emissions in gigatons CO2e/yr.

2.2.2. Greenhouse Gas Emissions from Energy Sector

Energy related GHG emissions are presented in Table 4 (EPA, 2019). Fossil fuel combustion is the largest source of energy-related GHG emissions in the U. S. Energy related emissions increased 1.5% from 1990 to 2017. These increases were largely from fossil fuel combustion, non-energy use of fuels, and petroleum systems. Emissions decreases were seen in natural gas systems, coal mining, and mobile combustion.

Table 4 Recent Trends in U.S. Energy Sector Greenhouse Gas Emissions (MMT CO_2e)

	1990	**2013**	**2014**	**2015**	**2016**	**2017**
Fossil Fuel Combustion	4,738.8	5,157.4	5,199.3	5,047.1	4,961.9	4,912.0
Natural Gas Systems	223.1	190.8	190.6	192.2	191.2	191.9
Non-Energy Use of Fuels	119.6	123.5	119.9	126.9	113.7	123.2
Petroleum Systems	51.0	66.8	71.7	71.2	60.4	61.0
Coal Mining	96.5	64.6	64.6	61.2	53.8	55.7
Stationary Combustion	33.7	41.5	41.9	39.0	38.0	36.4
Mobile Combustion	55.0	26.6	24.3	22.4	21.2	20.1
Incineration of Waste	8.4	10.6	10.7	11.1	11.1	11.1
Abandoned Oil and Gas Wells	6.6	7.0	7.1	7.1	7.2	6.9
Abandoned Underground Coal Mines	7.2	6.2	6.3	6.4	6.7	6.4
Total	**5,339.8**	**5,695.0**	**5,736.4**	**5,584.7**	**5,465.3**	**5,424.8**

Source: EPA Inventory of US Greenhouse Gases Emission and Sinks 1990-2017 (EPA, 2019)

Gas wells tend to have higher methane emissions due to the nature of the fossil fuel being extracted. The U.S. natural gas systems include hundreds of thousands of wells, hundreds of processing facilities, and over a million miles of transmission and distribution pipelines. Details on methane emissions from natural gas systems are provided in Table 5, and include emissions from well exploration, production, processing, transmission and storage, and distribution. Methane emissions occur from un-combusted exhaust, venting and flaring, pressure relief systems, and equipment or pipeline leaks. In 2017 1% of non-combustion methane emissions from natural gas systems came from exploration, 65% from production, 7% from processing facilities, 20% from transmission and storage, and 7% from distribution.

Table 5 Methane Emissions from Natural Gas Systems (MMT CO_2e)

	1990	**2013**	**2014**	**2015**	**2016**	**2017**
Exploration	4.0	3.0	1.0	1.0	0.7	1.2
Production	67.0	108.5	108.5	108.8	107.1	108.4
Processing	21.3	10.8	11.1	11.1	11.4	11.7
Transmission and Storage	57.2	31.0	32.4	34.2	34.5	32.4
Distribution	43.5	12.3	12.2	12.0	12.0	11.9
Total	**193.1**	**165.6**	**165.1**	**167.2**	**165.7**	**165.6**

The U.S. Geological Survey (USGS) has produced estimates of the GHG resulting from the extraction and end-use combustion of fossil fuels produced on Federal lands in the United States, as well as estimates of ecosystem carbon emissions and sequestration on those lands (USGS, 2018). The study reports GHG emissions from extraction, transport, fugitives, and combustion of fuel over a ten year period (2005-2014). In 2014, nationwide gross GHG emissions from fossil fuels extracted from Federal lands was 1,332.1 MMT CO_2e. Emissions from fossil fuels produced on Federal lands represent, on average, 23.7 percent of national emissions for CO_2, 7.3 percent for CH_4, and 1.5 percent for N2O over the 10 years included in this estimate (USGS, 2018). Uncertainty associated with emission estimates is 2-5% for combustion, 25-42% for fugitives, and 12-15% for degassed CH_4 emissions from coal mines. Trends and relative magnitude of emissions are roughly parallel to production volumes.

Utah Federal fossil-fuel-related gross emissions in 2014 were 46.75 MMT CO_2e, approximately 3.5% of the estimate of national emissions from Federal fossil fuels (USGS, 2018). Emissions from the adjacent fossil fuel producing states of Colorado, New Mexico, and Wyoming were 55.78, 91.63, and 744.2 MMT CO_2e, respectively, in 2014.

Federal lands also uptake carbon in vegetation, soils, and water. In 2014, carbon storage on Federal lands was 83,600 MMT CO_2e nationally and 3,611 MMT CO_2e in Utah. Soils stored 63% of carbon with vegetation and dead organic matter storing 26% and 11% respectively. The national rate of net carbon uptake (sequestration) varies from 475 MMT CO_2e/yr. to a source (emission) of 51 MMT CO_2e due to changes in climate/weather, land use, land cover change, wild fire frequency, and other factors. From 2005 to 2014, terrestrial ecosystems on Federal lands sequestered an average of 195 MMT CO_2e/yr, offsetting about 15% of emissions resulting from Federal fossil fuel extraction and combustion nationally. In Utah, the annual average ecosystem carbon storage is 3,581 MMT CO_2e, with soils accounting for about 70%. In Utah, the annual average sequestration over the ten years was 8.6 MMT CO_2e/yr, offsetting about 18% of extraction and combustion emissions from fossil fuels produced on Federal lands in Utah. Carbon emissions from Utah ecosystems due to land-use and land-cover change, including surface disturbing activities such as well pad construction, averaged 1.3 MMT CO2e/yr from 2005 to 2014 (USGS 2018). While surface disturbance from well pad construction contributes to ecosystem carbon emission and a reduction in the lands ability to store carbon, these impacts are anticipated to be temporary during the life of a well, as reclamation requirements should return the land to a condition approximately equal to that which existed prior to the disturbance (BLM, 2007).

3. Greenhouse Gas Emissions From Oil and Gas Development

While the leasing of parcels by itself does not generate any GHG emissions, the BLM recognizes that the reasonably foreseeable consequence of leasing may lead to oil and gas development, and such development could result in an increase in GHG emissions due to well development and operations, and from downstream uses of the petroleum products produced from these parcels. This section describes the methods and assumptions used to calculate emissions for well construction, operations, and downstream combustion of produced oil and gas.

3.1. Emissions from Lease Parcel Development

Direct GHG emissions from oil and gas activates occur during construction and operations of a well. Construction related emissions occur from the use of heavy machinery during pad construction, drilling, testing and completion, venting and flaring, interim reclamation, and vehicles. Construction emissions are typically a onetime occurrence. Operation related emissions occur from well workovers, pump engines, heaters, tanks, truck loading, fugitive leaks, pneumatics, dehydrators, compressor engines, reclamation, and vehicle traffic. Emissions from operation activities occur throughout the life of a well. Several factors may influence actual emissions including location, geological formation, well depth, equipment used, supporting infrastructure, and other factors. For these reasons, this documents presents GHG emissions by BLM District Office from typical oil and gas activity occurring in each area.

3.1.1. Green River District Direct Emissions

GHG emission estimates for the Green River District are incorporated from the Monument Butte FEIS (BLM, 2016), Alternative B No Action Alternative. All methods and assumptions used to develop the emissions in the Monument Butte FEIS apply, and are incorporated by reference. The no action alternative emission inventory is used because it does not include applicant committed emission reduction measures, and would be representative of potential wells that may result from leasing in the Green River District. Emissions estimate for construction and operation of a single well are presented in Table 6. Emissions are listed by well type, with gas wells having higher construction emissions mainly due to deeper drilling depths and oil wells having higher operation emissions mainly from heaters and pump engines. Well types are not easily identifiable when calculating the cumulative emissions from existing and reasonably foreseeable wells, so calculations for the Green River District are based on gas well construction emissions (678.5 CO_2e/yr. per well) combined with oil well operation emissions (427.7 CO_2e/yr per well). This provides a conservative estimate when well type is unknown. Additional details related to the emission estimates is provided in Appendix A.

Table 6 Single Well GHG Emissions Based on the Monument Butte FEIS Alternative B Inventory

	Single Oil Well Emissions Metric Tons per year			
Development Phase	**CO_2**	**CH_4**	**N_2O**	**CO_2e**

Construction	89.3	0.08	0.0007	91.8
Operations	388.6	1.40	0.0007	427.7
Total	477.9	1.48	0.001	519.5
	Single Gas Well Emissions Metric Tons per year			
Development Phase	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Construction	676.3	0.03	0.005	678.5
Operations	1.3	3.00	0.000004	85.3
Total	677.6	3.03	0.005	763.8

3.1.2. Canyon Country District Direct Emission

Emissions estimate for the Canyon Country District are incorporated by reference from the Moab Master Lease Plan (MLP) FEIS (BLM, 2016). All methods and assumptions used to develop the emissions in the Moab MLP FEIS apply, and are incorporated by reference. Single well annual emissions were computed by taking the total annual GHG emissions from the Moab MLP FEIS high emissions scenario and dividing by the number of wells constructed each year for the construction emissions, and divided by the number of producing wells for the operations emissions. Emissions were also converted from short tons to metric tons, and the CO2e was updated using GWP from the IPCC Fifth Assessment Report. This emission inventory is representative of oil and gas operations occurring within the Canyon Country District. Additional details related to the emission estimates is provided in Appendix A.

Table 7 Single Well GHG Emissions Based on the Moab MLP FEIS Inventory

	Single Well Emissions Metric Tons per year			
Development Phase	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Construction	2485.0	8.44	0.044	2733.0
Operations	374	50.41	0.009	1788.4
Total	2859.4	58.86	0.053	4521.4

3.1.3. Color Country and West Desert District Direct Emissions

The Color Country and West Desert Districts have lower oil and gas potential than the Green River and Canyon Country Districts. As a result existing wells tend to be farther from supporting infrastructure and processing facilities. The emission inventory from the Grand Staircase Escalante National Monument and Kanab RMP DEIS (BLM, 2018) accounts for a well far from supporting infrastructure. The emissions inventory and all methods and assumptions from the Grand Staircase Escalante National Monument and Kanab RMP DEIS are incorporated by reference. It is considered representative GHG emission inventory for oil and gas development resulting from this lease sale. Additional details related to the emission estimates is provided in Appendix A.

Table 8 Single Well GHG Emissions Based on the GSENM Kanab DEIS Inventory

	Single Well Emissions Metric Tons per year			
Development Phase	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Construction	836.5	3.60	0.021	942.9
Operations	1756.2	9.38	0.021	2024.6
Total	2592.7	13.0	0.042	2967.5

3.2. Emissions from Combustion of Produced Oil and Gas

Calculations of indirect emissions from downstream combustion can be made by multiplying the produced number of barrels (bbl) of oil and thousand cubic feet (mcf) of gas with GHG emission factors from the EPA Greenhouse Gases Equivalencies Calculator – Calculations and References website (EPA, 2019). These emission factors are used because they provide an easy calculation of the amount of GHGs produced from a bbl of oil or mcf of gas. The emission factors also follow IPCC guidance by accounting for 100% oxidation of carbon in the fossil fuel to CO_2, regardless if the carbon atom is part of a CO_2, CH_4, or other hydrocarbon molecule. Existing oil and gas annual production data is obtained from the Utah Division of Oil, Gas and Mining (UDOGM, 2018).

Downstream combustion emissions from foreseeable development is difficult to quantify since the amount of produced oil and gas is unknown until after a well is drilled. It is assumed that future wells will produce oil and gas in similar amounts as other existing nearby wells. Annual data from 2008 to 2018 is used to determine the average production per well. However, some wells may produce more or less than the average. To better inform decision makers and the public a low and high production estimates are also used for calculating downstream combustion emissions.

Estimates of production and combustion emissions for a single well are presented in Table 11. The average annual production and standard deviation between 2008 and 2018 is first calculated for each field office using data from the Utah Division of Oil, Gas and Mining (UDOGM, 2018). Low and high production estimates are established by subtracting and adding two standard deviations to the average annual production. Two standard deviations are chosen as it would account for 95% of wells, assuming a Gaussian distribution of well production. At the field office level it is assumed that active wells produce both oil and gas since the Utah Division of Oil, Gas and Mining reports only identify well type at the state level. For comparison, the low, average, and high emissions for an oil well in Utah is 1,857 mt CO_2e/yr, 3,156 mt CO_2e/yr, and 4,455 mt CO_2e/yr respectively. Gas well emissions are 2,410 mt CO_2e/yr (low), 3,483 mt CO_2e/yr (average), and 4,556 mt CO_2e/yr (high). State average emissions by well type compare appropriately with the average emissions for all field offices. The average emissions per well from Table 9 is used for leasing in the Cedar City, Fillmore, and St George field offices since there are no producing wells in these areas for estimating foreseeable combustion emissions.

Table 9. Production of Oil and Gas for a Single Well and Associated GHG Combustion Emissions

	2008-2018 Range of Oil Production (bbl/well)			2008-2018 Range of Gas Production (mcf/well			Range of Emissions per well (metric tons CO2e/yr)		
Field Office	**Low**	**Ave**	**High**	**Low**	**Ave**	**High**	**Low**	**Ave**	**High**
Cedar City	-	-	-	-	-	-	-	-	-
Fillmore	-	47	360	-	-	-	-	20	155
Kanab	5,326	6,702	8,078	339	383	428	2,309	2,903	3,497
Moab	-	1,002	2,649	5,407	8,576	11,746	298	904	1,786
Monticello	4,753	5,555	6,356	10,264	13,635	17,006	2,609	3,140	3,670
Price	25	49	73	28,508	62,133	95,758	1,581	3,445	5,308
Richfield	28,727	74,408	120,089	-	13,028	41,557	12,352	32,713	53,928
Salt Lake	2,124	3,630	5,137	-	83,055	171,860	913	6,137	11,678
St George	-	-	-	-	-	-	-	-	-

Vernal	797	2,254	3,711	14,344	29,171	43,997	1,133	2,577	4,020
Average	963	2,329	3,694	15,069	31,106	47,142	1,244	2,715	4,186

EPA Emission factors: 0.43 metric tons CO2e/bbl, and 0.0551 metric tons CO2e/mcf. (EPA, 2019).
Production data obtained from the Utah Division of Oil, Gas and Mining (UDOGM, 2018).

3.2.1. Uncertainty

The direct and indirect emission estimates above provide an estimate of the full potential for GHGs released into the atmosphere from initial wellsite construction, well drilling and completion, production, and end use. Although this EA presents quantified estimates of direct and indirect GHG emissions associated with the potential for oil and gas development on the leases, GHG emission estimates involve significant uncertainty due to unknown factors including actual production, how produced minerals are used, the form of regulation of GHG parameters by delegated agencies, and whether any Best Available Control Technologies are utilized at the upstream or downstream emission location(s). Deeper wells require engines with a greater horsepower, and take longer to drill but may produce for shorter or longer periods of time. The British thermal unit content of the product can also vary substantially which will ultimately influence any estimates of GHGs produced or combusted, as can the total volume of liquids produced with the gas stream, which also requires handling. Ultimately, while estimates in this EA are based on the best available data, including information from existing operators regarding future drilling plans and targets, these estimates are subject to many conditions that are largely beyond the BLM's control. Unforeseen changes in factors such as geologic conditions, drilling technology, economics, demand, and federal, state, and local laws and policies could result in different outcomes than those projected in this EA.

The rough estimates of combustion CO_2e emissions presented above are qualified by uncertainty in potential future production, and in predicting the end uses for the fuels extracted from a particular leasehold. Future production is uncertain with regard to the actual levels of development over time, levels of development over the life of the lease, new technology, geologic conditions, and the ultimate level of production from any given well (whether reservoir related, or for economic reasons). BLM is using an average production estimate per well for each planning area; this approach may overestimate or underestimate in areas where resource conditions depart from "average" but it allows the BLM to assume for analysis purposes that all lands have equal potential for production. While this may not hold true based on site-specific geology, it is a reasonable forecast that assumes all lands may be produced at some point in the future. After extraction from federal leases, end uses of oil and gas may include refining for transportation fuels, fuel oils for heating and electricity generation, or production of asphalt and road oil. Oil and gas may also be used in the chemical industry, for the manufacture of medicines and everyday household items, plastics, military defense and for the manufacture of synthetic materials. The BLM does not control the specific end use of the oil and gas produced from federal leases. As a result, the BLM can only provide an estimate of potential GHG emissions by assuming that all produced oil and gas would eventually be combusted.

Fossil fuels can be consumed, but not combusted, when they are used directly as construction materials, chemical feedstock, lubricants, solvents, waxes, and other products. Common examples include petroleum products used in plastics, natural gas used in fertilizers, and coal tars used in skin treatment products.

3.2.2. Climate Impacts

As climate change is a cumulative response to global emissions of GHGs, it is difficult to assign a "significance" value or impact based on a single action. Emissions estimates themselves are presented for disclosure purposes and as a proxy for impacts. Foreseeable emissions from leasing can be compared to state, and national emissions for context. Climate change impacts are further discussed in the cumulative impacts section of this document.

3.3. Mitigation of Impacts from Greenhouse Gas Emissions

The BLM regulates portions of natural gas and petroleum systems identified in the EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks report (EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2017, 2019). In carrying out its responsibilities, BLM has developed a list of best management practices (BMPs) designed to reduce emissions from field production and operations. Analysis and approval of future development on the lease parcels may include application of BMPs within BLM's authority, as Conditions of Approval, to reduce or mitigate GHG emissions. Additional measures developed at the project development stage also may be incorporated as applicant-committed measures by the project proponent, or added to necessary air quality permits.

BMPs to reduce the impacts of climate change and GHG emissions may include, but are not limited to:

- Flare hydrocarbon and gases at high temperatures in order to reduce emissions of incomplete combustion through the use of multi-chamber combustors;
- Require that vapor recovery systems be maintained and functional in areas where petroleum liquids are stored;
- Installation of liquids gathering facilities or central production facilities to reduce the total number of sources and minimize truck traffic;
- Use of natural gas fired or electric drill rig engines;
- The use of selective catalytic reducers and low-sulfur fuel for diesel-fired drill rig engines; and,
- Implementation of directional and horizontal drilling technologies whereby one well provides access to petroleum resources that would normally require the drilling of several vertical wellbores;

Additionally, the BLM encourages natural gas companies to adopt proven cost-effective technologies and practices that improve operation efficiency and reduce natural gas emissions, to reduce the ultimate impact from the emissions.

In October 2012, the EPA promulgated air quality regulations for completion of hydraulically fractured gas wells. These rules require air pollution mitigation measures that reduce the emissions of VOCs during gas well completions. Mitigation includes a process known as "green completion" in which the recovered products are sent through a series of aboveground, closed, separators which negates the need for flowing back into surface pits as the product is immediately sent to gas lines and the fluids are transferred to onsite tanks.

EPA Inventory data show that by adopting the BMPs proposed by the EPA Natural Gas Energy Star program, the industry has reduced emissions from oil and gas exploration and development: "During calendar year 2018, Partners submitted an annual report detailing their efforts in 2017 to reduce methane emissions from their operations. These voluntary activities consisted of 45 technologies and practices and resulted in emissions reductions of 96.8 Bcf for the year. These methane emissions reductions have crosscutting benefits on domestic energy supply, industrial efficiency, revenue generation, improved air quality, and greenhouse gas emissions reductions. The emission reductions are equivalent to additional revenue of approximately $291 million in natural gas sales (assumes an average natural gas price of $3.00 per thousand cubic feet)." (EPA, 2019)

Specifically, EPA reports that 89% of the methane reductions came from the oil and gas production sector, by utilizing a variety of technologies including: reducing blow down frequency, installing vapor recovery units, and converting gas-driven pumps to electric, mechanical, or solar driven pumps. The BLM will continue to work with industry to promote the use of the relevant BMPs for operations proposed on Federal mineral leases where such mitigation is consistent with agency authorities and policies, and is supported by BLM's NEPA analysis.

In addition to efforts to better respond and adapt to climate change, other Federal initiatives are being implemented to mitigate climate change. The Carbon Storage Project was implemented to develop carbon sequestration methodologies for geological (i.e., underground) and biological (e.g., forests and rangelands) carbon storage. The project is a collaboration of Federal and nonfederal stakeholders to enhance carbon storage in geologic formations and in plants and soils in an environmentally responsible manner. The Carbon Footprint Project (Carbon, 2019) is an effort to develop a unified GHG emission reduction program for the DOI, including setting a baseline and reduction goal for the Department's GHG emissions and energy use.

4. Cumulative Greenhouse Gas Emissions from Oil and Gas Development

The cumulative analysis considers GHG emissions from existing and reasonably foreseeable oil and gas projects. Existing emissions come from operation of active producing wells and the downstream combustion of produced oil and gas. Foreseeable emissions are based on the number of existing APDs and estimated emissions from drilling, production, and downstream combustion for these wells. Emission from the recent and upcoming quarterly lease sales (December 2018, March 2019, June 2019, September 2019, and December 2019) are also included in the foreseeable estimates. The estimated portion of the field office RFDs have not yet been developed for the December 2019 lease sale, therefore BLM Utah assumed one well per parcel (24 parcels) for this analysis. Other past lease sales are not considered since there will start to be overlap with foreseeable development from APD's and potential double counting of emissions. Considering the four most recent lease sales should account for the time lag it takes for companies to submit APDs after obtaining a lease. The reasonable foreseeable development from recent lease sales is shown in Table 10.

Table 10. Reasonably Foreseeable Development from Recent BLM Lease Sales

	Number of Reasonably Foreseeable Wells					
Field Office	**Dec-18**	**Mar-19**	**Jun-19**	**Sep-19**	**Dec-19**	**FO Total**
Cedar City	0	0	0	2	0	2
Fillmore	0	0	0	0	0	0
Kanab	0	0	0	0	0	0

	Number of Reasonably Foreseeable Wells					
Moab	3	0	0	5	2	10
Monticello	8	0	0	4	9	21
Price	4	0	0	16	5	25
Richfield	2	0	0	24	7	33
Salt Lake	0	1	1	1	0	3
St George	0	0	0	0	0	0
Vernal	690	400	0	48	1	1139
Total	707	401	1	100	24	1233

4.1. Direct Emissions from Well Construction and Operation

Calculations of cumulative annual direct emissions can be made by multiplying the number of existing and foreseeable wells with per well construction and operation emissions from Section 3.1. Existing wells include all (federal and non-federal) active producing oil and gas wells as reported by the Utah Division of Oil, Gas and Mining (UDOGM, 2018) at the end of 2018. Foreseeable wells include federal APDs, where wells are not yet completed, as reported in the BLM Automated Fluid Minerals Support System on April 18, 2019. As described in section 3.1 construction emissions include pad construction and well drilling, testing, and completion. Construction emissions are only applied to foreseeable wells, as existing wells have already completed all construction activities that producing GHG emissions. Operational emissions are described in Section 3.1.2 and account for the maintenance and operation of each well. This provides a conservative estimate since some well pads will have multiple wells, and foreseeable new wells will not be operating for an entire year.

4.1.1.Existing Oil and Gas Wells

Existing GHG emissions from the operations of all (federal and non-federal) producing oil and gas wells are presented in Table 11. Emissions are presented for existing wells in each field office and as a state total. No active producing wells are reported in Cedar City, Fillmore, and St George Field Offices.

Table 11. Direct Emissions from Existing Federal and Non-Federal Oil and Gas Wells

Field Office	CO2e/yr per well	Number of Active Wells	Total (Metric Tons CO2e/yr)
Cedar City	2025	0	-
Fillmore	2025	0	-
Kanab	2025	23	46,566
Moab	1788	454	811,943
Monticello	1788	716	1,280,509
Price	428	1366	584,252
Richfield	2025	31	62,763
Salt Lake	2025	50	101,231
St George	2025	0	-
Vernal	428	11112	4,752,716
		State Total	**7,639,980**

4.1.2.Foreseeable Oil and Gas Wells

GHG emissions from drilling, operation, maintenance, and reclamation of foreseeable oil and gas wells are presented in Table 12. Foreseeable development includes recent and future BLM lease sales (include May 2015 and September 2016), and from APDs (Federal and non-federal) as reported by the Utah Division of Oil, Gas, and Mining (UDOGM, 2018). Since APDs are valid for a 2 year period, this analysis only includes APDs from 2017 through 2019. Wells that have been drilled to completion from the APDs are included in the existing emissions.

Table 12. Direct GHG Emissions from Foreseeable Federal Wells.

Field Office	Drilling CO2e/yr per well	Operation CO2e/yr per well	APDs (Federal and non-federal)	UT BLM Lease Sales	Drilling Total Metric Tons CO2e/yr	Operations Total Metric Tons CO2e/yr
Cedar City	943	2,025	-	2	1,886	4,049
Fillmore	943	2,025	-	-	-	-
Kanab	943	2,025	-	-	-	-
Moab	2,733	1,788	10	10	54,660	35,768
Monticello	2,733	1,788	13	21	92,922	60,806
Price	678	428	3	25	18,997	11,976
Richfield	943	2,025	6	33	36,773	78,960
Salt Lake	943	2,025	2	3	4,714	10,123
St George	943	2,025	-	-	-	-
Vernal	678	428	486	1,138	1,102,506	695,029
		Total	520	1,233	1,312,457	896,712

4.2. Indirect Emissions from Combustion of Produced Oil and Gas

Emissions from existing wells are calculated by multiplying 2018 annual production data (UDOGM, 2018) with emission factors from the EPA Greenhouse Gases Equivalencies Calculator – Calculations and References website (EPA, 2019). Calculations of GHG combustion emissions from foreseeable development follows the same methodology described in Section 3.2. These estimates are conservative since some APDs may not be drilled, and some wells may be dry.

4.2.1.Existing Oil and Gas Combustion Emissions

Emissions of GHGs from downstream combustion for all oil and gas produced within Utah are presented in Table 13. Production data reported by the Utah Division of Oil, Gas and Mining database (UDOGM, 2018) for each county was obtained for all (federal and non-federal) producing wells in 2018. As mentioned above emissions are calculated by multiplying the production amounts by EPA emission factors (EPA, 2019).

Table 13. Annual GHG Emissions from Combustion of Produced Oil and Gas

	2018 Total Production		Metric Tons CO2e/yr		
Field Office	**Oil (bbl)**	**Gas (mcf)**	**Oil**	**Gas**	**Total**
Cedar City	-	-	-	-	-
Fillmore	-	-	-	-	-

Kanab	133,801	9,125	57,534	503	58,037
Moab	349,430	3,059,650	150,255	168,587	318,842
Monticello	3,916,113	9,631,838	1,683,929	530,714	2,214,643
Price	47,597	49,181,909	20,467	2,709,923	2,730,390
Richfield	1,345,937	708,139	578,753	39,018	617,771
Salt Lake	173,320	1,980,016	74,528	109,099	183,626
St George	-	-	-	-	-
Vernal	30,929,312	230,867,520	13,299,604	12,720,800	26,020,405
Total	36,895,510	295,438,197	15,865,069	16,278,645	32,143,714

EPA Emission factors: 0.43 metric tons CO2e/bbl, and 0.0551 metric tons CO2e/mcf. (EPA, 2019)
Production data obtained from the Utah Division of Oil Gas and Mining (UDOGM, 2018).

4.2.2.Estimate of Foreseeable Oil and Gas Combustion Emissions

It is difficult to predict future oil and gas production due to uncertainties described in Section 3.2.1. Additionally oil and gas production can vary from one well to another. For these reasons, and to disclose emission possibilities, a range of emissions from downstream combustion are presented in Table 14. These emissions are calculated by multiplying the estimated per well emissions from Table 9, with the reasonably foreseeable number of new wells within the field office (APDs and lease sales). As discussed in Section 3.2, the foreseeable emissions for the Cedar City, Fillmore, and St George Field Offices use the average emissions from Table 9. While a range of combustion emissions are presented in Table 14, the average is used for simplicity when discussing the total cumulative for comparison with state and national emissions.

Table 14. Combustion GHG Emissions from Foreseeable Federal Oil and Gas Wells

	Range per well (metric tons CO2e/yr)					**Total Range of Emissions (metric tons CO2e/yr)**		
Field Office	**Low**	**Ave.**	**High**	**APDs (Federal and non-federal)**	**UT BLM Lease Sales**	**Low**	**Ave.**	**High**
Cedar City	1,244	2,715	4,186	-	2	2,489	5,430	8,372
Fillmore	1,244	2,715	4,186	-	-	-	-	-
Kanab	2,309	2,903	3,497	-	-	-	-	-
Moab	298	904	1,786	10	10	5,959	20,843	35,727
Monticello	2,609	3,140	3,670	13	21	88,717	106,752	124,787
Price	1,581	3,445	5,308	3	25	44,278	96,446	148,615
Richfield	12,352	32,713	53,928	6	33	481,745	1,292,467	2,103,188
Salt Lake	913	6,137	11,678	2	3	4,566	31,479	58,392
St George	1,244	2,715	4,186	-	-	-	-	-
Vernal	1,133	2,577	4,020	486	1,139	1,841,050	4,186,912	6,532,773
Total	-	-	-	520	1,233	2,468,803	5,740,329	9,011,855

4.3. Total Annual Emissions

Total Annual GHG emissions from existing and foreseeable oil and gas sources are presented in Table 15. Emissions from foreseeable development are listed separately as they would only occur one time during construction, drilling, and completion of new wells and not occur annually.

Table 15. Annual Cumulative GHG Emissions from Oil and Gas Wells.

	Metric Tons CO2e/yr					
Field Office	**Existing Direct**	**Existing Indirect**	**Foreseeable Direct**	**Foreseeable Indirect**	**Total Annual Emissions**	**Foreseeable One-Time Emissions**
Cedar City	-	-	4,049	5,430	9,480	1,886
Fillmore	-	-	-	-	-	-
Kanab	46,566	58,037	-	-	104,603	-
Moab	811,943	318,842	35,768	20,843	1,187,396	54,660
Monticello	1,280,509	2,214,643	60,806	106,752	3,662,710	92,922
Price	584,252	2,730,390	11,976	96,446	3,423,064	18,997
Richfield	62,763	617,771	78,960	1,292,467	2,051,961	36,773
Salt Lake	101,231	183,626	10,123	31,479	326,459	4,714
St George	-	-	-	-	-	-
Vernal	4,752,716	26,020,405	695,029	4,186,912	35,655,061	1,102,506
Total	7,347,577	32,143,714	896,712	5,740,329	46,420,735	1,312,457

Cumulative annual emissions are compared to state and national emissions in Table 16.

Table 16. Comparison of Total Annual GHG Emissions with Annual State and National Emissions

Field Office	**Total Annual Emissions**	**Major Source + O&G Emissions**	**Percent of Utah (Major +O&G) Emissions**	**Percent of U.S. Energy**	**Percent of U.S. Total**
Cedar City	9,480	53,441	0.01%	<0.01%	<0.01%
Fillmore	-	9,808,748	0.00%	0.00%	0.00%
Kanab	104,603	104,603	0.13%	<0.00%	<0.00%
Moab	1,187,396	1,187,396	1.46%	0.02%	0.02%
Monticello	3,662,710	3,662,710	4.49%	0.07%	0.06%
Price	3,423,064	17,566,057	4.20%	0.07%	0.06%
Richfield	2,051,961	2,051,961	2.52%	0.04%	0.03%
Salt Lake	326,459	7,385,489	0.40%	0.01%	0.01%
St George	-	-	0.00%	0.00%	0.00%
Vernal	35,655,061	39,673,525	43.75%	0.66%	0.55%
Total	46,420,735	81,493,931	56.96%	0.86%	0.72%

4.4. Field Office Planning Area Foreseeable Emissions

BLM also considered potential annual GHG emissions for each planning area, across all lease sales (regardless of date) throughout the life of the plans. The Resource Management Plan (RMP) for each field office planning area includes an RFD scenario describing the number of expected wells over the life of the plan. These expected wells can be used to estimate the potential total GHG emissions for all of the lands open to leasing in each planning area. Planning-area-wide emissions are estimated by multiplying the expected number of wells by the single well construction, operation, and combustion emissions, assuming all lands would be leased, and fully developed concurrently (Table 17). Total annual oil and gas emissions from the RMP expected number of wells is 43,855,596 MT CO_2e/yr, with additional one-time emissions of 6,636,988 MT CO_2e from well construction.

Table 17. Expected wells from Each Field Office RMP, and Corresponding GHG Emissions

Field Office	RMP Expected wells	Construction (MT CO_2e)	Operation (MT CO_2e/yr)	Average Combustion (MT CO_2e/yr)
Cedar City	30	28,287	60,738	81,456
Fillmore	10	9,429	20,246	27,152
Kanab	20	18,858	40,492	58,058
Moab	390	1,065,867	697,484	352,409
Moab MLP	128	349,823	228,918	115,663
Monticello	195	532,934	348,742	612,253
Price	1,900	1,289,084	812,649	6,544,567
Richfield	454	428,073	919,176	14,851,756
Salt Lake	10	9429	20,246	61,374
St George	20	18,858	40,492	54,304
Vernal	6,530	3,224,780	1,260,667	16,824,944
BLM Utah	9,687	6,975,421	4,449,851	39,583,936

Some oil and gas development has occurred since the implementation of each RMP. Table 18 lists the remaining number of estimated wells from the RMP that have not yet been developed, and the estimate of GHG emissions that are foreseeable from future development in each field office. The estimates are made by multiplying the remaining number of wells projected in the respective RMPs by the average GHG emissions from single well construction, operation, and combustion of the average quantity of produced oil or gas. For instance, in the Vernal FO 3,205 wells have been developed since the RMP finalized, with an additional 3,325 wells (6,530 Table 17, minus 3,325) still projected to be developed over the life of the RMP. These remaining 3,325 expected wells would produce 1,865,384 MT CO_2e from construction, 463,421 MT CO_2e/yr from operations, and 13,367,059 MT CO_2e/yr from combustion of produced oil and gas.

Table 18. Undeveloped Portion of RMP RFD Scenarios and Corresponding Potential GHG Emissions for Each Field Office

Field Office	Undeveloped Portion of RMP RFD[1]	Construction (MT CO_2e)	Operation (MT CO_2e/yr)	Average Combustion (MT CO_2e/yr)
Cedar City	30	28,287	60,738	81,456
Fillmore	10	9,429	20,246	27,152
Kanab	20	18,858	40,492	58,058
Moab	339	926,484	606,275	306,325
Moab MLP	125	341,624	223,553	112,952
Monticello	189	516,536	338,011	593,414
Price	1,622	1,100,470	693,746	5,586,993
Richfield	439	413,930	888,807	14,361,059
Salt Lake	10	9,429	20,246	61,374
St George	20	18,858	40,492	54,304

[1] This number represents the estimated wells from the most recent, respective RMP RFD minus the number of wells developed since the adoption of that RMP.

Field Office	Undeveloped Portion of RMP RFD[1]	Construction (MT CO_2e)	Operation (MT CO_2e/yr)	Average Combustion (MT CO_2e/yr)
Vernal	3,325	1,865,384	463,421	13,367,059
Statewide	6,129	5,249,289	3,396,028	29,810,154

5. Cumulative Climate Impacts

As climate impacts and trends tend to be realized at local levels (USGCRP, 2018) this section will discuss climate change on a regional scale. BLM prepared several Rapid Ecoregional Assessments (REA) to predict future conditions, including climate change, in various regions. Utah lies within two ecoregions, the Colorado Plateau and the Central Basin and Range. The Colorado Plateau REA (Bryce, 2012) covers areas east of the Wasatch Mountains and south of the Uinta Mountains, include the Kanab, Moab, Monticello, Price, Richfield, and Vernal field offices. The Central Basin and Range REA (Comer, 2013) covers most of the Great Basin and western parts of Utah including the Cedar City, Fillmore, St George, and Salt Lake BLM field offices.

The Colorado Plateau REA analysis covered the years 1968 to 2060. Past, present, and reasonably foreseeable activities in the analysis include energy development, agricultural development, urban and road development, and recreation development. The assumption details and modeling methodology are incorporated by reference. The Colorado Plateau REA depicts the data sources for potential oil and gas leasing, development and production, and oil shale and tar sand extraction. Modeled average annual future temperatures in the Colorado Plateau REA are generally predicted to increase. Average annual precipitation predicted by the model in general are predicted to decrease (drier) through 2030 and increase (wetter) through 2060. Figure 3 shows the potential for climate related change and is a composite of predicted changes to temperature, precipitation, runoff, and vegetation. Potential for climate related change in the Colorado Plateau area generally predicted to be mostly moderate or lower (about 70%), with areas with high or very high (approximately 30%) potential for change are generally seen in higher elevations. Due to inherent uncertainties described in the Colorado Plateau REA, caution should be used for interpreting climate change potential at site specific scales (Bryce, 2012).

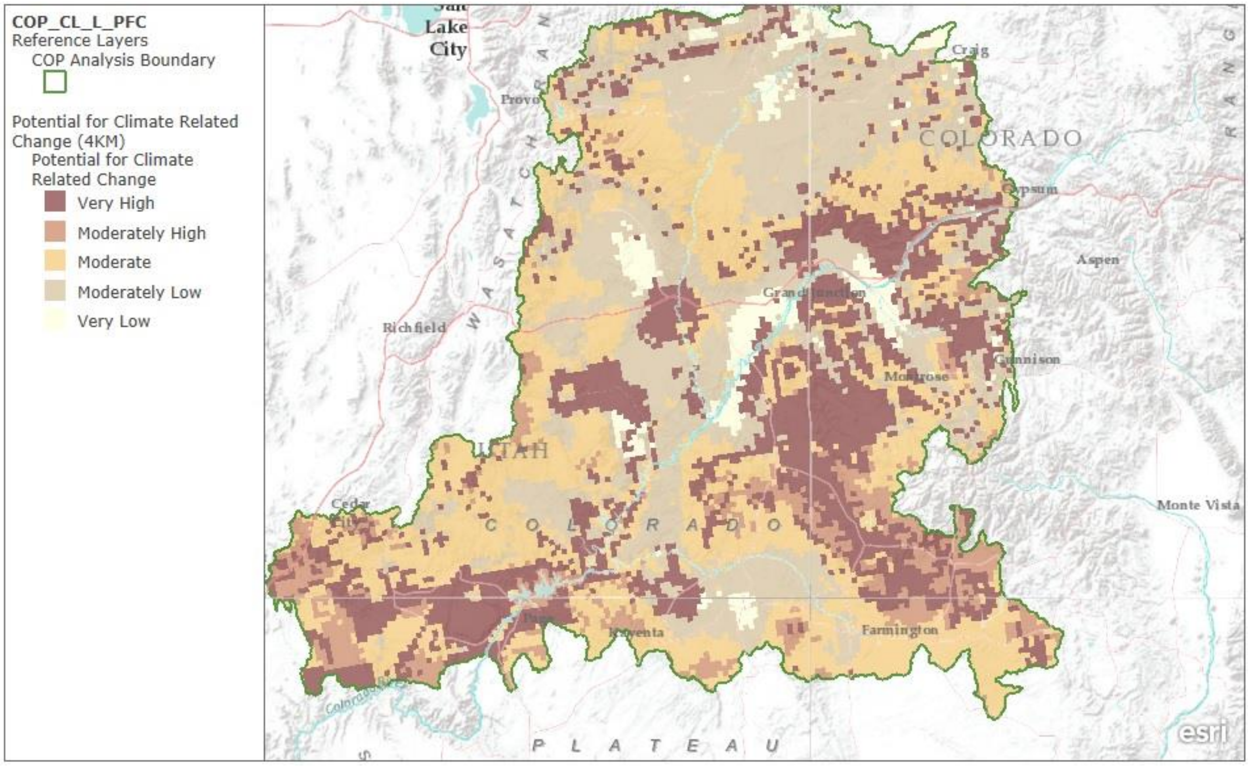


Figure 3. Potential for climate change impacts for the Colorado Plateau

The Central Basin and Range REA used an ensemble mean from 6 global climate models to determine future climate change projections in the Great Basin and western portions of Utah. Details and assumptions about climate change projects are discussed in the report and included by reference. Results for precipitation suggest there is no strong trend toward either wetter or drier conditions in any month for the Central Basin. With the exception of a slight increase in summer "monsoon" rains toward the south and east, there are no significant forecasted trends in precipitation for any other months in either the near term (2020s) or midcentury (2050s) time slices. The Central Basin and Range REA projected changes to temperature by 2060 by showing areas where the one or more of the 24 monthly maximum and minimum temperatures deviate by two standard deviations or more from the baseline 20th century mean temperature, as shown in Figure 4. From this, areas can be identified where concentrated climate change or lack of climate change is projected to occur. Areas with a larger number of monthly deviations are more likely to experience temperature related climate change. In general, temperatures are projected to increase, with mountainous areas expected to see the most change. Potential impacts to individual resources from projected climate change are further described in the Central Basin and Range REA (Comer, 2013).

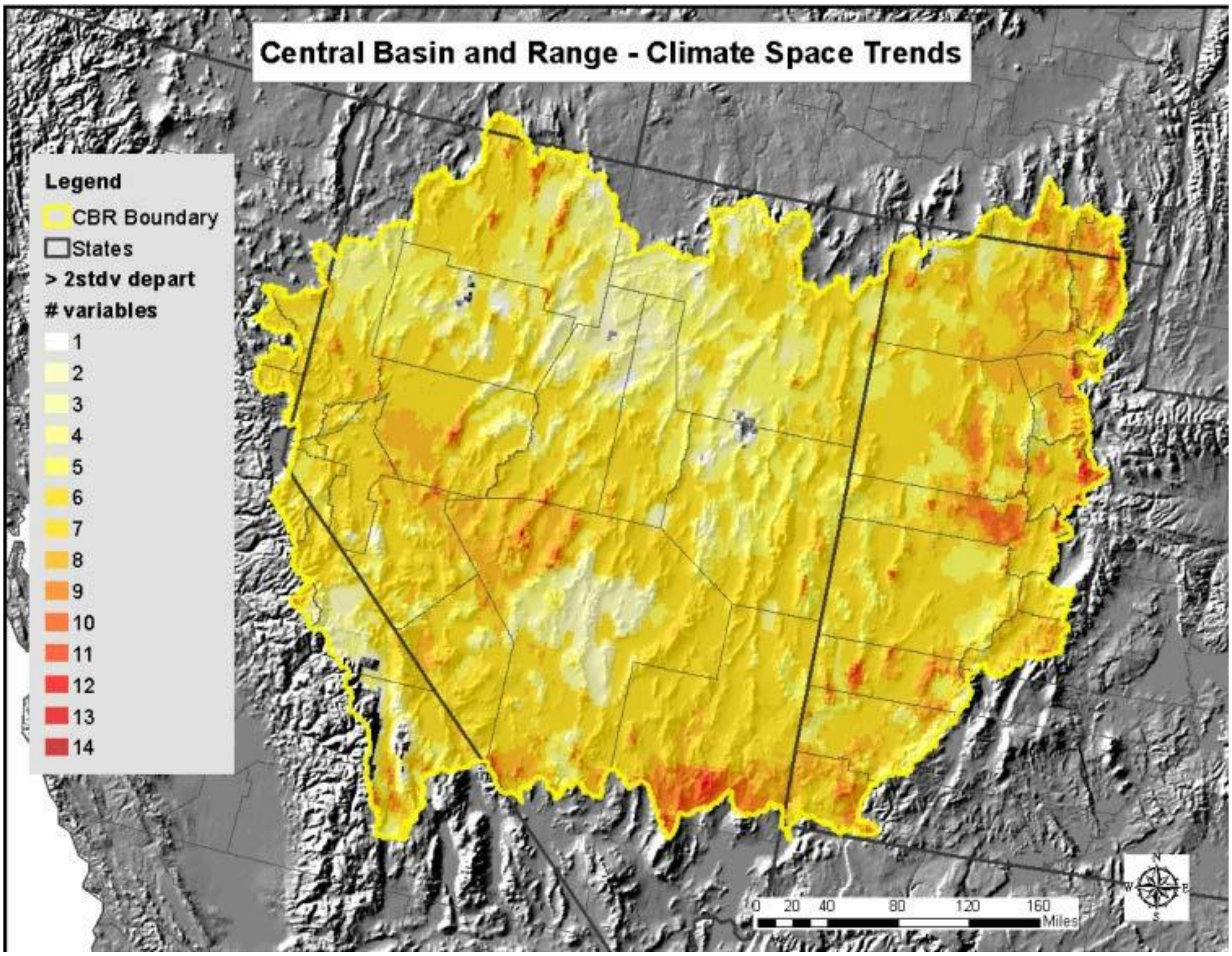


Figure 4. Composite 2060 forecast for temperature departure from the baseline.

"Social cost of carbon" estimates are one approach that an agency can take to examine climate consequences from greenhouse gas emissions resulting from a proposed action. However, leasing action Environmental Assessments provide no quantitative monetary estimates of any benefits or costs. The National Environmental Policy Act (NEPA) does not require an economic cost-benefit analysis (40 C.F.R. § 1502.23), although NEPA does require consideration of "effects" that include "economic" and "social" effects (40 C.F.R. 1508.8(b)). Quantifying only the costs of oil and gas development by using the social cost of carbon metrics but not the benefits (as measured by the economic value of the proposed oil and gas development and production generally equaling the price of oil and gas minus the cost of producing, processing, and transporting the minerals) would yield information that is both inaccurate and not useful for the decision-maker, especially given that there are no current criteria or thresholds that determine a level of significance for social cost of carbon monetary values.

Instead, BLM's approach to GHG and climate change impacts analysis is to include calculations to show estimated direct, indirect, and cumulative GHG emissions from potential future development. BLM also includes a qualitative discussion of potential climate impacts. BLM's approach recognizes that there are adverse environmental impacts related to climate change associated with the development and use of fossil fuels, provides potential GHG emission estimates, and discusses potential climate change impacts qualitatively. This effectively informs the decision-maker and the public of the potential for GHG emissions and the potential implications of climate change. This approach presents the data and information in a manner that follows many of the guidelines for effective climate change communication developed by the National Academy of Sciences (Council, 2010) by making the information more readily understood and relatable to the decision-maker and the general public.

References

AMS. (2017). Blunden, J., D. S. Arndt, and G. Hartfield , Eds., 2018: State of the Climate in 2017. *Bull. Amer. Meteor. Soc., 99 (8), Si–S310, doi:10.1175/2018BAMSStateoftheClimate.1*.

BLM. (2007). Surface Operating Standards and Guideline for Oil and Gas Exploration and Development. The Gold Book, Fourth Edition. Denver, Colorado: BLM/WO/ST-06/021+3071/REV 07. Bureau of Land Management. 84pp. Retrieved from https://www.blm.gov/sites/blm.gov/files/uploads/The%20Gold%20Book%20-%204th%20Ed%20-%20Revised%202007.pdf

BLM. (2016, July). *Moab Master Leasing Plan and Proposed Resource Management Plan Amendments/Final Enviornmental Impact Statement.* Retrieved from https://eplanning.blm.gov/epl-front-office/eplanning/planAndProjectSite.do?methodName=renderDefaultPlanOrProjectSite&projectId=68430&dctmId=0b0003e880d9ffc7

BLM. (2016, 06). *Monument Butte Oil and Gas Development Project Final Enviornmental Impact Statement.* Retrieved from https://eplanning.blm.gov/epl-front-office/eplanning/planAndProjectSite.do?methodName=renderDefaultPlanOrProjectSite&projectId=62904&dctmId=0b0003e880ba28f6

BLM. (2018, August). *Grand Staircase Escalanten National Monument and Kanab Field Office Resource Management Plan Draft Environemental Impact Statment.* Retrieved from https://eplanning.blm.gov/epl-front-office/eplanning/planAndProjectSite.do?methodName=renderDefaultPlanOrProjectSite&projectId=94706&dctmId=0b0003e881033dcd

BLM. (2019). *2018 BLM Utah Air Monitoring Report.* Retrieved from https://go.usa.gov/xmDkx

Bryce, S. J. (2012). *Colorado Plateau Rapid Ecoregional Assessment Report. Prepared for the U.S. DOI.* Retrieved from https://landscape.blm.gov/REA_General_Docs/COP_Final_Report_Body.pdf

Carbon. (2019, 5 2). *Carbon Offset Projects*. Retrieved from https://www.carbonfootprint.com/carbonoffsetprojects.html

Comer, P. P. (2013). *Central Basin and Range Rapid Ecoregional Assessment Report.* Retrieved from https://landscape.blm.gov/REA_General_Docs/CBR_1_ReportBody.pdf

Council, N. R. (2010). *Informing an Effective Response to Climate Change.* Retrieved from http://nap.edu/12784

EPA. (2018, 3 9). *Emission Factors for Greenhouse Gas Inventories*. Retrieved from https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf

EPA. (2018). *Facility Level Information on GreenHouse Gases Tool (FLIGHT)*. Retrieved from https://ghgdata.epa.gov/ghgp/main.do

EPA. (2019). *Clean Air Act Permitting for Greenhouse Gases*. Retrieved from https://www.epa.gov/nsr/clean-air-act-permitting-greenhouse-gases

EPA. (2019). *Greenhouse Gases Equivalencies Calculator - Calculations and References*. Retrieved from https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

EPA. (2019, 5 6). *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2017.* Retrieved from https://www.epa.gov/sites/production/files/2019-04/documents/us-ghg-inventory-2019-main-text.pdf

EPA. (2019). *Natural Gas STAR Program Accomplishments*. Retrieved from https://www.epa.gov/natural-gas-star-program/natural-gas-star-program-accomplishments

IPCC. (2014). *IPCC Fifth Assessment Report, Chapter 8 Anthropogenic and Natural Radiative Forcing.* Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf

Janssens-Maenhout, G., Crippa, M., Guizzardi, D., Muntean, M., Schaaf, E., Olivier, J., . . . Schure, K. (2017). *Fossil CO2 and GHG Emissions of All World Countries.* Luxembourg: Publications Office of the European Union. doi:10.2760/709792

UDOGM. (2018). *Utah Oil and Gas Monthly Production Reports by County*. Retrieved from https://oilgas.ogm.utah.gov/oilgasweb/publications/monthly-rpts-by-cnty.xhtml?rptType=CNTY

USGCRP. (2018). *Impacts, Risks, and Adaptation in the United States: Fourth National Climate [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K.* Washington, DS, USA: U.S. Global Change Research Program.

USGS. (2018). *Federal lands greenhouse emissions and sequestration in the United States—Estimates for 2005–14: Merrill, M.D., Sleeter, B.M., Freeman, P.A., Liu, J., Warwick, P.D., and Reed, B.C.*

Appendix A

Single Well Emissions Scenarios

Monument Butte FEIS, Alternative B Emission Scenario

Single Oil Well Emissions	CO2 (MT)	CH4 (MT)	N2O (MT)	CO2e (MT)
Construction	6.6	0.0	0.0	6.6
Drilling	71.0	0.0	0.0	71.3
Completion	11.4	0.1	0.0	13.7
Interim Reclamation	0.3	0.0	0.0	0.3
Total	89.3	0.1	0.0	91.8
Well Heaters	278.7	0.0	0.0	279.0
Pump Engines	108.7	0.0	0.0	108.8
Stock Tanks	0.0	0.4	0.0	11.6
Fugitive	0.0	0.5	0.0	15.0
Truck Loading	0.0	0.0	0.0	1.2
Pneumatics	0.0	0.4	0.0	11.0
Vehicles	1.2	0.0	0.0	1.2
Total	388.6	1.4	0.0	427.7

Single Gas Well Emissions	CO2 (MT)	CH4 (MT)	N2O (MT)	CO2e (MT)
Construction	6.6	0.0	0.0	6.6
Drilling	644.0	0.0	0.0	646.1
Completion	25.5	0.0	0.0	25.5
Interim Reclamation	0.3	0.0	0.0	0.3
Total	**676.3**	**0.0**	**0.0**	**678.5**
Stock Tanks	0.1	0.6	0.0	17.4
Fugitive	0.0	1.4	0.0	39.4
Truck Loading	0.0	0.0	0.0	1.2
Pneumatics	0.0	0.4	0.0	11.0
Wellsite Dehydrators	0.0	0.5	0.0	15.0
Vehicles	1.2	0.0	0.0	1.2
Total	**1.3**	**3.0**	**0.0**	**85.3**

Moab MLP FEIS High Emission Scenario

	Greenhouse Gases				
Activity	**CO_2 (tons)**	**CH_4 (tons)**	**N_2O (tons)**	**CO_{2eq} (tons)**	**CO_{2eq} metric tons**
Heavy Equipment Combustive	409.76	0.00	0.00	411.10	373.05
Commuting Vehicles	9.60	0.00	0.00	9.86	8.95
Completion Venting	0.66	9.26	0.00	259.89	235.83
Completion Flaring	2,318.40	0.04	0.04	2330.91	2115.16

Sub-total: Construction	**2,738.41**	**9.31**	**0.05**	**3,011.76**	**2,732.99**
Well Workover - On-site Exhaust	15.43	0.00	0.00	15.48	14.05
Well Workover - On-road Exhaust	0.18	0.00	0.00	0.18	0.16
Well Visits for Inspection & Repair	2.00	0.00	0.00	2.20	2.00
Recompletion Traffic	0.19	0.00	0.00	0.19	0.17
Water Pumps, Tanks & Traffic	0.97	0.02	0.00	1.46	1.33
Oil Tanks & Traffic	35.04	0.00	0.00	35.61	32.31
Well Pad Heaters	51.60	0.00	0.00	51.88	47.08
Re-Completion Venting and Flaring	231.91	0.93	0.00	259.08	235.10
Blowdown Venting and Flaring	0.00	0.00	0.00	0.00	0.00
Compression and Well Pumps	0.00	0.00	0.00	0.00	0.00
Dehydrators	51.60	0.00	0.00	51.88	47.08
Fugitives	3.90	54.60	0.00	1532.73	1390.86
Sub-total: Operations	**392.81**	**55.55**	**0.01**	**1,950.69**	**1,770.13**
Road Maintenance	17.34	0.00	0.00	17.60	15.97
Sub-total: Maintenance	**17.339**	**0.000**	**0.00**	**17.60**	**15.97**
Road Reclamation	1.20	0.00	0.00	1.20	1.09
Well Reclamation	1.34	0.00	0.00	1.35	1.22
Sub-total: Reclamation	**2.5411**	**0.0000**	**0.0000**	**2.5504**	**2.3143**
Total Emissions	**3,151.11**	**64.86**	**0.06**	**4,982.60**	**4,521.41**

Grand Staircase NM Kanab RMP DEIS Emission Scenario

Single Well Construction Emissions	**CO_2 (tons)**	**CH_4 (tons)**	**N_2O (tons)**
Well Pad Const Equip (diesel ICE) - New Pads	8.87	0.00	0.00
Construction Traffic, Road and Well pad - New Pads (LD)	4.04	0.00	0.00
Construction Traffic, Road and Well pad - New Pads (HD)	3.36	0.00	0.00
Construction Traffic, Road and Well pad - New Pads (LD) Dust	0.00	0.00	0.00
Construction Traffic, Road and Well pad - New Pads (HD) Dust	0.00	0.00	0.00
Drilling Equip (diesel ICE)	584.01	0.00	0.01
Drilling Traffic (LD)	5.25	0.00	0.00

Drilling Traffic from Cedar City (HD)	8.95	0.00	0.00	
Drilling Traffic Infield (HD)	21.25	0.00	0.00	
Drilling Traffic (LD) Dust	0.00	0.00	0.00	
Drilling Traffic from Cedar City (HD) Dust	0.00	0.00	0.00	
Drilling Traffic Infield (HD) Dust	0.00	0.00	0.00	
Completion Equipment (diesel ICE)	235.39	0.00	0.01	
Completion Traffic (LD)	2.69	0.00	0.00	
Completion Traffic from Cedar City (HD)	8.95	0.00	0.00	
Completion Traffic Infield (HD)	39.15	0.00	0.00	
Completion Traffic (LD) Dust	0.00	0.00	0.00	
Completion Traffic from Cedar City (HD) Dust	0.00	0.00	0.00	
Completion Traffic Infield (HD) Dust	0.00	0.00	0.00	
Initial Completion Venting	0.13	3.96	0.00	
Well Pad Construction Dust, Fugitive - New Pads	0.00	0.00	0.00	
Construction Dust, Wind Erosion - New Pads	0.00	0.00	0.00	CO2e 100yr
TOTAL converted to metric tons	**836.47**	**3.60**	**0.02**	**942.87**

Single Well Operations Emissions	CO2 (tons)	CH4 (tons)	N2O (tons)	
Heavy Duty Traffic	120.87	0.01	0.00	
Light Duty Traffic	2.69	0.00	0.00	
Condensate Tank Flashing/Working/Breathing	336.77	0.10	0.00	
Heaters	96.29	0.00	0.00	
Tank Loadout (vapor losses)	0.01	0.03	0.00	
Pneumatic Devices	0.52	0.13	0.00	
Workover Equipment (diesel ICE)	0.09	0.00	0.00	
Blowdown	0.26	8.08	0.00	
Fugitive Devices	0.06	1.78	0.00	
Dehydrators (proposed action)	680.14	0.22	0.02	
Combustion of Fuel Oil	0.00	0.00	0.00	
Gas Flaring	698.24	0.00	0.00	
Gas Venting	0.00	0.00	0.00	CO2e 100yr
Total –Converted to metric tons	**1756.24**	**9.38**	**0.02**	**2024.62**