U.S. Department of the Interior

Bureau of Land Management

Cumulative BLM New Mexico Greenhouse Gas Emissions, A Supplemental White Paper, BLM 2019

U.S. Department of the Interior

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Introduction

This document serves as a supplemental Greenhouse Gas and Climate Change Analysis in support of NEPA documents. It is an interim document and information in this report will be transferred, maintained and updated to the *2019 Air Resources Technical Report* as well as subsequent updates of the technical report. Additional information related to climate change, greenhouse gases (GHGs) and detailed GHG emission summaries of national and state level emissions as well as information on GHGs isolated by sector is included in the BLM, NMSO, March 2018, *Air Resources Technical Report for Oil and Gas Development*, herein referred to as the *AR Technical Report* (BLM 2018). While information as to upstream and midstream GHG phases may be present, this analysis' major focus is on greenhouse gases (GHGs) on a cumulative basis and the expected end-use (downstream) of GHGs from the fossil fuels produced on federal lands within the U.S. and New Mexico.

Background of Climate, Climate Change and Greenhouse Gases

Climate

Climate is the composite of generally prevailing weather conditions of a particular region throughout the year, averaged over a series of years. Climate averages for 1981-2010, known as the current normal as defined by the World Meteorological Organization, are 30 year averages of temperature and precipitation for the previous three decades and are included in Appendix C of the *2018 AR Technical Report.*

Natural Greenhouse Effect

The natural greenhouse effect is critical to the discussion of climate change. The greenhouse effect refers to the process by which greenhouse gases (GHGs) in the atmosphere absorb heat energy radiated by earth's surface. Water vapor is the most abundant GHG, followed by carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and several trace gases. These GHGs trap heat that would otherwise be radiated into space, causing earth's atmosphere to warm and making temperatures suitable for life on earth. Without the natural greenhouse effect, the average surface temperature of the earth would be about zero degrees Fahrenheit. Water vapor is often excluded from the discussion of GHGs and climate change since its atmospheric concentration is largely dependent upon temperature rather than being emitted by specific sources.

Atmospheric concentrations of naturally-emitted GHGs have varied for millennia and earth's climate fluctuated accordingly. However, since the beginning of the industrial revolution around 1750, human activities have significantly increased GHG concentrations and introduced man-made compounds that act as GHGs in the atmosphere. The atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) have increased to levels unprecedented in at least the last 800,000 years. From pre-industrial times until today, the global average concentrations of CO_2, CH_4, and N_2O in the atmosphere have increased by around 40%, 150%, and 20%, respectively Intergovernmental Panel on Climate Change (IPCC) 2013. Table 1 shows the average global concentrations of CO_2, CH_4, and N_2O in 1750, 2011 and 2017. Atmospheric concentrations of GHGs are reported in parts per million (ppm) and parts per billion (ppb).

Table 1. Average global concentrations of greenhouse gases in select years (IPCC 2007, 2013 & EPA 2019)

Greenhouse Gas	Pre-Industrial 1750	2011	2017	Increase 1750 – 2011
Carbon dioxide, CO_2	278 ppm	390.5 ppm	407 ppm[a]	46%
Methane, CH_4	722 ppb	1803 ppb	1850 ppb[b]	156%
Nitrous oxide, N_2O	270 ppb	324 ppb	330 ppb[b]	22%

[a]The atmospheric CO_2 concentration is the 2017 annual average at the Mauna Loa, HI station (NOAA/ESRL 2018a). The concentration in 2018 at Mauna Loa was 409 ppm. The global atmospheric CO_2 concentration, computed using an average of sampling sites across the world, was 405 ppm in 2017 (EPA 2019).
[b] The values presented are global 2017 annual average mole fractions (EPA 2019).

Human activities emit billions of tons of carbon dioxide (CO_2) every year. Carbon dioxide is primarily emitted from fossil fuel combustion, but has a variety of other industrial sources. Methane (CH_4) is emitted from oil and natural gas systems, landfills, mining, agricultural activities, waste and other industrial processes. Nitrous oxide (N_2O) is emitted from anthropogenic activities in the agricultural, energy-related, waste and industrial sectors. The manufacture of refrigerants and semiconductors, electrical transmission, and metal production emit a variety of trace GHGs (including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride, (SF_6). These trace gases have no natural sources and come entirely from human activities. Carbon dioxide, methane, nitrous oxide, and the trace gases are considered well-mixed and long-lived GHGs (BLM 2018)

Several gases do not have a direct effect on climate change, but indirectly affect the absorption of radiation by impacting the formation or destruction of GHGs. These gases include carbon monoxide (CO), oxides of nitrogen (NO_X), and non-methane volatile organic compounds (NMVOCs). Fossil fuel combustion and industrial processes account for the majority of emissions of these indirect GHGs. Unlike other GHGs, these gases are short-lived in the atmosphere.

Atmospheric aerosols, or particulate matter (PM), also contribute to climate change. Aerosols directly affect climate by scattering and absorbing radiation (aerosol-radiation interactions) and indirectly affect climate by altering cloud properties (aerosol-cloud interactions). Particles less than 10 micrometers in diameter (PM_{10}) typically originate from natural sources and settle out of the atmosphere in hours or days. Particles smaller than 2.5 micrometers in diameter ($PM_{2.5}$) often originate from human activities such as fossil fuel combustion. These so-called “fine” particles can exist in the atmosphere for several weeks and have local short-term impacts on climate. Aerosols can also act as cloud condensation nuclei (CCN), the particles upon which cloud droplets form.

Light-colored particles, such as sulfate aerosols, reflect and scatter incoming solar radiation, having a mild cooling effect, while dark-colored particles (often referred to as “soot” or “black carbon”) absorb radiation and have a warming effect. There is also the potential for black carbon to deposit on snow and ice, altering the surface albedo (or reflectivity), and enhancing melting. There is high confidence that aerosol effects are partially offsetting the warming effects of GHGs, but the magnitude of their effects contribute the largest uncertainly to our understanding of climate (IPCC 2013).

Climate Change

Climate change is a statistically-significant and long-term change in climate patterns. The terms climate change and "global warming" are often used interchangeably, although they are not the same thing. Climate change is any deviation from the average climate, whether warming or cooling, and can result from both natural and human (anthropogenic) sources. Natural contributors to climate change include fluctuations in solar radiation, volcanic eruptions, and plate tectonics. Global warming refers to the apparent warming of climate observed since the early-twentieth century and is primarily attributed to human activities such as fossil fuel combustion, industrial processes, and land use changes.

Climate change may reinforce (positive feedback) or reduce (negative feedback) an expected temperature increase. A feedback is the process by which changing one quantity results in the amplification or diminishment of another. An example of a positive feedback is the reduced albedo (reflectivity) of land surfaces from the melting of snow and ice. A warming climate is also expected to increase methane release from hydrates, thereby reinforcing the warming trend. There are also feedbacks related to carbon, water, and geochemical cycles. The results of most climate feedbacks are expected to amplify warming, but the exact magnitudes of these effects are difficult to quantify (Intergovernmental Panel on Climate Change (IPCC) 2013).

Climate change is a global process that is impacted by the sum total of GHGs in the Earth's atmosphere. The incremental contribution to global GHGs from a proposed land management action cannot be translated into effects on climate change globally or in the area of any site-specific action. Currently, Global Climate Models are unable to forecast local or regional effects on resources (IPCC 2013). However, there are general projections regarding potential impacts to natural resources and plant and animal species that may be attributed to climate change from GHG emissions over time; however these effects are likely to be varied, including those in the southwestern United States (Karl 2009). For example, if global climate change results in a warmer and drier climate, increased particulate matter impacts could occur due to increased windblown dust from drier and less stable soils. Cool season plant species' spatial ranges are predicted to move north and to higher elevations, and extinction of endemic threatened or endangered plants may be accelerated. Due to loss of habitat or competition from other species whose ranges may shift northward, the populations of some animal species may be reduced or increased. Less snow at lower elevations would likely impact the timing and quantity of snowmelt, which, in turn, could impact water resources and species dependent on historic water conditions (Karl 2009).

Climate Change Projections

Our current understanding of the climate system comes from the cumulative results of observations, experimental research, theoretical studies, and model simulations. Climate change projections are based on a hierarchy of climate models that range from simple to complex, coupled with comprehensive Earth System Models. For the Fifth Assessment Report (AR5), scientists estimated future climate impacts based on a range of Representative Concentration Pathways (RCPs) for well-mixed GHGs in model simulations carried out under the Coupled Model Intercomparison Project Phase 5 (CMIP5) of the World Climate Research Programme (IPCC 2013). The RCPs represent a range of mitigation scenarios that are dependent upon socio-economic and geopolitical factors and have different targets for radiative forcing (RF) in 2100 (2.6, 4.5, 6.0, and 8.5 W m^{-2}). The scenarios are considered to be illustrative and do not have probabilities assigned to them.

AR5 uses terms to indicate the assessed likelihood of an outcome ranging from *exceptionally unlikely* (0 – 1% probability) to *virtually certain* (99 – 100% probability) and level of confidence ranging from *very low* to *very high*. The findings presented in AR5 indicate that warming of the climate system is unequivocal and many of the observed changes are unprecedented over decades to millennia. It is *certain* that Global Mean Surface Temperature (GMST) has increased since the late 19th century and *virtually certain* (99 – 100% probability) that maximum and minimum temperatures over land have increased on a global scale since 1950. The globally averaged combined land and ocean surface temperature data show a warming of 0.85°C (1.5°F) (NOAA National Climate Data Center, 2013) (Intergovernmental Panel on Climate Change (IPCC), 2013). Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes. It is *extremely likely* (95 – 100% probability) that human influence has been the dominant cause of the observed warming since the mid-20th century (IPCC 2013).

Additional near-term warming is inevitable due to the thermal inertia of the oceans and ongoing GHG emissions. Assuming there are no major volcanic eruptions or long-term changes in solar irradiance, global mean surface temperature increase for the period 2016 – 2035 relative to 1986-2005 will likely be in the range of 0.3 – 0.7°C (0.5 – 1.3°F). Global mean temperatures are expected to continue rising over the 21st century under all of the projected future RCP concentration scenarios. Global mean temperatures in 2081 – 2100 are projected to be between 0.3 – 4.8°C (0.5 – 8.6°F) higher relative to 1986 – 2005 IPCC 2013. The IPCC projections are consistent with reports from other organizations (e.g. (NASA Goddard Institute for Space Studies 2013);(Joint Science Academies 2005)).

Climate change will impact regions differently and warming will not be equally distributed. Both observations and computer model predictions indicate that increases in temperature are likely to be greater at higher latitudes, where the temperature increase may be more than double the global average. Warming of surface air temperature over land will very likely be greater than over oceans (IPCC 2013). There is also high confidence that warming relative to the reference period will be larger in the tropics and subtropics than in mid-latitudes. Frequency of warm days and nights will increase and frequency of cold days and cold nights will decrease in most regions. Warming during the winter months is expected to be greater than during the summer, and increases in daily minimum temperatures are more likely than increases in daily maximum temperatures. Models also predict increases in duration, intensity, and extent of extreme weather events. The frequency of both high and low temperature events is expected to increase. Near- and long-term changes are also projected in precipitation, atmospheric circulation, air quality, ocean temperatures and salinity, and sea ice cover.

Findings from AR5 and reported by other organizations (NASA Goddard Institute for Space Studies 2013); (NOAA National Climate Data Center 2013) also indicate that changes in the climate system are not uniform and regional differences are apparent. Some regions will experience precipitation increases, and other regions will have decreases or not much change. The contrast in precipitation between wet and dry regions and between wet and dry seasons is expected to increase. The high latitudes are *likely* (66 – 100% probability) to experience greater amounts of precipitation due to the additional water carrying capacity of the warmer troposphere. Many mid-latitude arid and semi-arid regions will *likely* (66 – 100% probability) experience less precipitation (IPCC 2013).

In the region encompassing southern Colorado and New Mexico, average temperatures rose just under 0.7 degrees Fahrenheit per decade between 1971 and 2011, which is approximately double the global rate of temperature increase (Rahmstorf 2012). These rates of warming are unprecedented over the past 11,300 years (Marcott 2013). Climate modeling suggests that average temperatures in this region may rise by 4-6 degrees Fahrenheit by the end of the 21st century, with warming increasing from south to north. By 2080-2090, the southwestern U.S. will see a 10-20% decline in precipitation, primarily in winter and spring, with more precipitation falling as rain (Cayan 2013).

In a recent report, the Bureau of Reclamation (Bureau of Reclamation, Sandia National Laboratories, U.S. Army Corps of Engineers 2013) made the following projections through the end of the 21st century for the Upper Rio Grande Basin (Southern Colorado to central southern New Mexico) based on the current and predicted future warming:

- There will be decreases in overall water availability by one quarter to one third.
- The seasonality of stream and river flows will change with summertime flows decreasing.
- Stream and river flow variability will increase. The frequency, intensity and duration of both droughts and floods will increase.

Texas, Oklahoma and Kansas are part of the Great Plains region, which will see increases in temperatures and more frequent drought in the future. Temperature increases and precipitation decreases will stress the region's primary water supply, the Ogallala Aquifer. Seventy percent of the land in this area is used for agriculture. Threats to the region associated with climate change include:

- Pest migration as ecological zones shift northward;
- Increases in weeds; and
- Decreases in soil moisture and water availability (U.S. Environmental Protection Agency 2013).

The IPCC concludes in AR5 that "cumulative emissions of CO_2 largely determine global mean surface warming by the late 21st century and beyond. Most aspects of climate change will persist for many centuries even if emissions of CO_2 are stopped. This represents a substantial multi-century climate change commitment created by past, present and future emissions of CO_2 (IPCC 2013). Increasing concentrations may accelerate the rate of climate change in the future.

Greenhouse Gases and GWPs

Although incremental contributions to global GHGs from a proposed land management action cannot currently be translated into effects on climate change globally or in the area of any site-specific action we can use GHG emission volumes as a proxy in determining impacts. In this way we can estimate emissions from a project or land management action and then compare those activities to the regional, national or global level of GHGs or GHGs emitted by a certain industry with a regional, the United States or globally.

Common air emissions related to oil and gas activities are GHGs. These gases include carbon dioxide (CO2), methane (CH4), Nitrous Oxide (N2O), and several fluorinated species of gases such as hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Carbon dioxide is emitted from the combustion of fossil fuels (oil, natural gas and coal), solid waste, trees and wood products, and as a result of other chemical reactions (e.g., manufacture of cement). The production and transport of coal, natural gas and oil emit methane. Methane can be emitted from coal mining operations, naturally-occurring coal methane seepages, leaks from the oil and gas industry, from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills. Agricultural and industrial activities emit nitrous oxide, as well as during combustion of fossil fuels and solid waste. Fluorinated gases are powerful greenhouse gases that are emitted from a variety of industrial processes and are often used as substitutes for ozone-depleting substances (i.e., CFCs, HCFCs, and halons), but typically not from oil and gas operations.

All of the different greenhouse gases have various capacities to trap heat in the atmosphere, known as global warming potentials (GWPs). Several different time horizons can express GWPs to fully account for the gases ability to absorb infrared radiation (heat) over their atmospheric lifetime. The BLM uses the 100-year time horizon since most of the climate change impacts derived from climate models are expressed toward the end of the century. In accordance with international GHG reporting standards under the United Nations Framework Convention on Climate Change (UNFCCC) and in order to maintain consistent comparisons over the years, official GHG emission estimates for the United States are reported based on the GWP values given in the Fourth Assessment Report (AR4) of the IPCC (IPCC 2007).

It is understood by the BLM that updated GWPs are reported in the Fifth Assessment Report (AR5) as our level of scientific understanding increases. The atmospheric lifetimes and GWPs for the major GHGs over the 20-year and 100-year time horizons are listed below in Table 2 for comparison. Carbon dioxide has a GWP of one, and for the purposes of analysis a GHGs GWP is generally standardized to a carbon dioxide equivalent (CO2e), or the equivalent amount of CO_2 mass the GHG would represent. In the AR5 report, methane has a current GWP estimated to be 28 and nitrous oxide has a GWP of 265 (IPCC 2013).

Table 2. Global Warming Potentials (100-year time horizon) (IPCC), 2007, 2013

Greenhouse Gas	**GWP values for 100-year time horizon**	
	AR4	**AR5**
Carbon dioxide, CO_2	1	1
Methane, CH_4	25	28
Nitrous oxide, N_2O	298	265
Select Hydrofluorocarbons, HFCs	124-14,800	4-12,400
Sulfur hexafluoride, SF_6	22,800	23,500
Greenhouse Gas	**GWP values for 20-year time horizon**	

	AR4	AR5
Carbon dioxide, CO_2	1	1
Methane, CH_4	72	84
Nitrous oxide, N_2O	299	264
Select Hydrofluorocarbons, HFCs	437-12,000	<1-10,800
Sulfur hexafluoride, SF_6	16,300	17,500

1 For consistency with the U.S. EPA and its Inventory of Greenhouse Gas Reporting; the BLM has represented values from AR4 of the IPCC report in this report.

Downstream GHG Analysis

United States Geological Survey (USGS) End-Use & Extraction Analysis

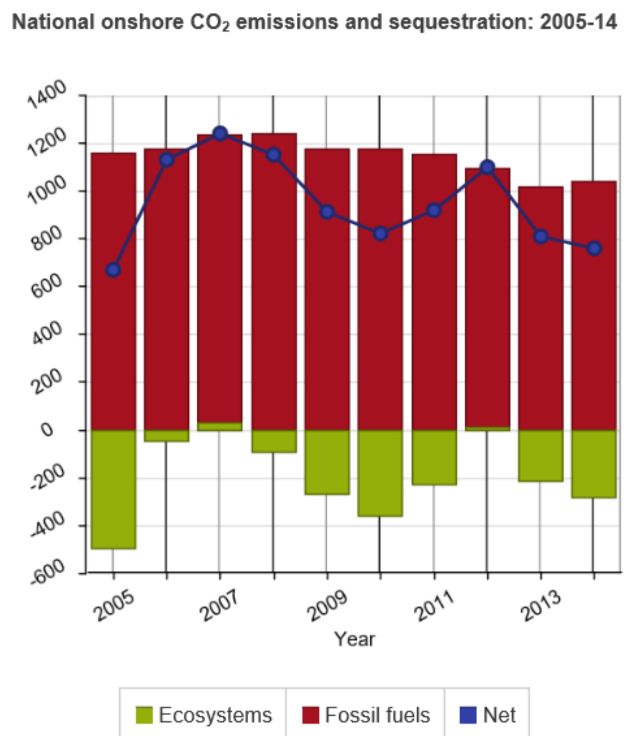
In November of 2018, the USGS published a scientific investigation report, *Federal Lands Greenhouse Gas Emissions and Sequestration in the United States: Estimates 2005-2014* (Merrill et al 2018). The report consists of a 44-page document with four companion datasets and an interactive online mapping site in which the user can pull up data for each state (28 states included in analysis) and two offshore sites. The data itself consists of 10 years of emissions and sequestration estimates in which the emissions from combustion and extraction activities on federal lands from fossil fuels is converted into carbon dioxide equivalents (CO_2e) and measured in million metric tons/year of CO_2e. The estimates include the three most prominent greenhouse gases (GHGs), carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The results are presented by state and year and the estimates are broken into categories by the sector of the economy where the combustion or extraction related emissions occurred or the biologic process being quantified occurred. The data presents both gross and net emissions after sequestration is accounted for. For the purpose of this analysis the BLM quantifies all emissions in CO_2 equivalents (CO_2e). For context of gross and net emissions as well as sequestration activities the BLM shows the total U.S. and New Mexico emissions from combustion and extraction activities on federal lands as well as sequestration activity (Figures 1 and 2). American Indian and Tribal lands were not included in the analysis. Additionally, the national total (gross) emissions includes two offshore areas (Merrill et al 2018).

GHG Emissions (Combustion and Extraction) from U.S. Federal Lands (CO2e)

In 2014, end-use combustion & extraction (C&E) of fossil fuels produced on U.S. federal lands was 1,332 million metric tons (MMT) of carbon dioxide equivalent (CO_2e). This reported value includes emissions from the combustion of coal, oil and natural gas from fossil fuels produced on U.S. federal lands as well as extraction emissions from activities occurring on federal lands. When compared to 2005 emissions, this results in a decrease of emissions throughout all the three prominent GHG emissions. From 2005-2014 GHG emissions from end-use C&E of fossil fuels produced on federal lands have resulted in an overall trend of decreased emissions (Figure 1). When compared to global and national total CO_2e emissions, 48,257 and 6,870.5 MMT respectively, from all sources (Table 3), CO2e emissions from these activities (end-use combustion and extraction activities) of fossil fuels produced on federal lands is 2.8% and 19.4% respectively (World Resources Institute & EPA 2016). Of the 1,332 MMT CO2e, 80.53 MMT were exported end-use combustion emissions, 752.50 MMT represented emissions from coal sources while 498.76 MMT were the result of oil and natural gas sources. Figures 3 & 4 provide a graphical representation of CO_2e emissions from the fossil fuels produced on U.S. federal lands associated with end-use combustion and extraction activities.

U.S. federal lands also contribute a great deal to the sequestration of CO_2 and provide carbon storage (sinks) for CO_2 emissions. In 2014 U.S. federal lands provided 283.2 MMT of carbon storage. U.S. federal lands sequestered an average of 195 MMT of CO2e between 2005 and 2014 offsetting approximately 15 percent of the CO_2 emissions resulting from the extraction of fossil fuels on Federal lands and their end-use combustion (Figure 1) (Merrill et al 2018).

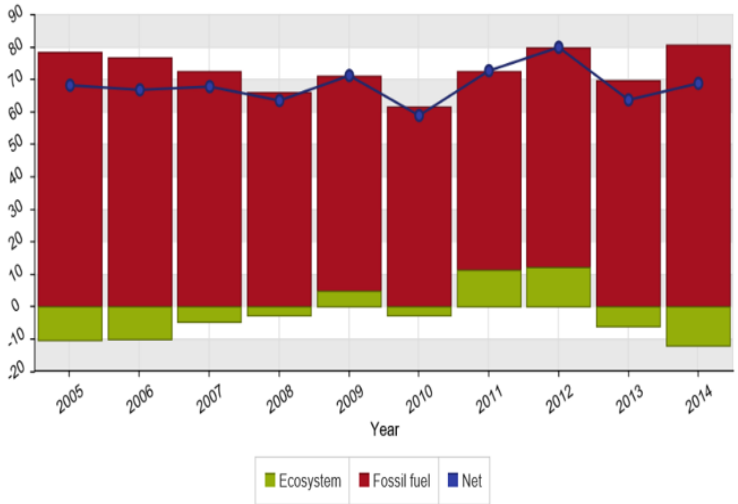
Figure 1. National CO_2 emissions and sequestration: 2005-2014



Year	Total fossil fuels	Onshore fossil fuels	Onshore ecosystems	Onshore net
2005	1,361.9	1,162.3	-493.5	668.8
2006	1,378.6	1,178.1	-47.4	1,130.7
2007	1,398.3	1,207.3	32.7	1,240.0
2008	1,427.9	1,243.7	-92.3	1,151.4
2009	1,422.5	1,178.5	-266.6	911.9
2010	1,429.4	1,180.6	-359.5	821.1
2011	1,362.4	1,156.2	-237.5	918.7
2012	1,280.5	1,085.8	13.0	1,098.8
2013	1,210.5	1,022.3	-213.6	808.7
2014	1,279.0	1,042.2	-283.2	759.0

Figure provided from (USGS. Merrill et al 2018).**Values may not sum to reported totals due to rounding.*
All values are in million metric tons of CO_2 equivalent (MMT CO_2 Eq.) Total fossil fuels includes offshore emissions from two areas.

Figure 2. New Mexico CO_2 emissions and sequestration: 2005-2014



Year	Gross Fossil Fuels CO_2, CH_4 and N_2O	Onshore ecosystems	Net Fossil Fuels
2005	91.40	-10.5	80.9
2006	89.48	-10.2	79.28
2007	84.36	-4.8	79.56
2008	78.94	-2.8	76.14
2009	78.65	4.7	83.35
2010	73.74	-2.9	70.84
2011	72.44	11.1	83.54
2012	78.18	12	90.18
2013	80.68	-6.1	74.58
2014	91.63	-12	79.63

Source: Merrill et al 2018

**Values may not sum to reported totals due to rounding. All values are in million metric tons of CO_2 equivalent (MMT CO_2 Eq.)*

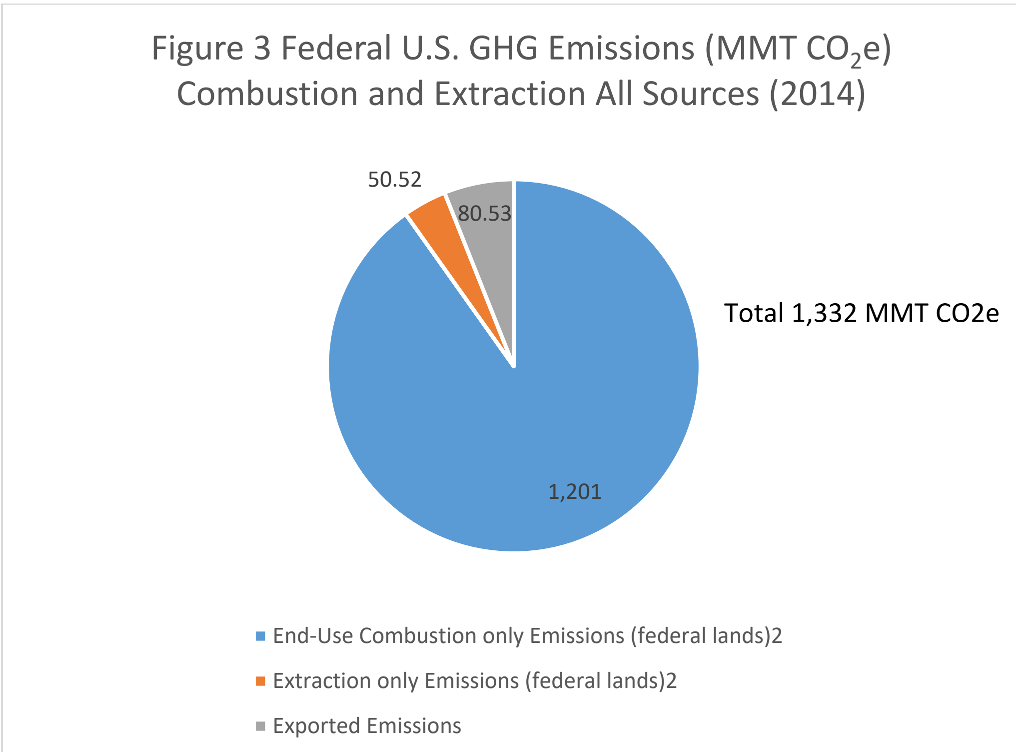
While the USGS total values include GHG emissions from end-use combustion and from extraction activities of coal, oil and gas, in this section the BLM focuses on the end-use combustion emissions generated from the oil and natural gas sector, the BLM excludes coal totals (Table 3 and Figure 4).

Table 3. GHG Emissions, *Combustion and Extraction*, from U.S. Federal Lands (CO_2e) (World Resources Institute 2017, EPA 2016, Merrill et al 2018)

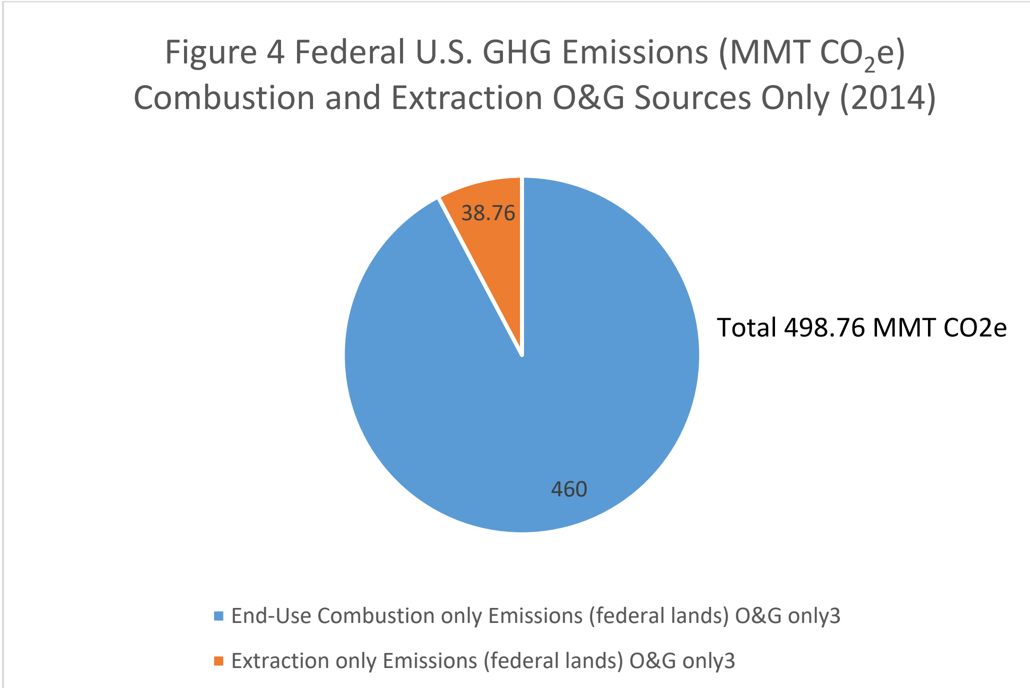
Level/Sector	MMT CO2e
Global emissions, All sources	48,257
National emissions, All sources*	6870.5
End-use C&E Emissions (federal lands)[1, 2]	1,332
% End-use C&E Emissions (federal lands) to Global Emissions[2]	2.76
% End-use C&E Emissions (federal lands) to National Emissions[2]	19.39
End-Use Combustion only Emissions (federal lands)[2]	1,201
% End-use Combustion only Emissions (federal lands) to Global Emissions[2]	2.49
% End-use Combustion only Emissions (federal lands) to National Emissions[2]	17.48
Extraction only Emissions (federal lands)[2]	50.52
% of Extraction only Emissions (federal lands) to Global Emissions[2]	0.10
% of Extraction only Emissions (federal lands) to National Emissions[2]	0.74
End-use C&E Emissions (federal lands) O&G only [3]	499
% End-use C&E Emissions (federal lands) O&G only to Global Emissions[3]	1.03
% End-use C&E Emissions (federal lands) O&G only to National Emissions[3]	7.26
End-Use Combustion only Emissions (federal lands) O&G only[3]	460

% End-use Combustion only Emissions (federal lands) O&G only to Global Emissions[3]	0.95
% End-use Combustion only Emissions (federal lands) O&G only to National Emissions[3]	6.70
Extraction only Emissions (federal lands) O&G only[3]	38.76
% Extraction only Emissions (federal lands) O&G only to Global Emissions[3]	0.08
% Extraction only Emissions (federal lands) O&G only to National Emissions[3]	0.56

1 Includes 80.53 MMT of exported CO_2e emissions. Emission totals are: CO_2 1,290 MMT, CH4 47.6 MMT of CO_2e, N2O 5.5 MMT of CO_2e
2 Includes emissions from coal, oil and natural gas
3 Isolates coal from the total and only includes oil and natural gas CO_2e emissions
C&E=Combustion and Extraction
Global emissions represented are for 2013, national emissions and federal land emissions are for 2014.
O&G=Oil and Gas
*Emissions reflect data from 2016 EPA GHG Inventory report, newer inventories may correct this value somewhat.



See Table 3 (above) for legend key to this figure.



See Table 3 (above) for legend key to this figure.

GHG Emissions (Combustion and Extraction) from New Mexico Federal Lands (CO2e)

In 2014, end-use combustion & extraction (C&E) of fossil fuels produced on New Mexico federal lands was 91.63 (MMT) of carbon dioxide equivalent (CO_2e). This reported value includes emissions from the combustion of coal, oil and natural gas from fossil fuels produced on federal lands as well as extraction emissions from activities occurring on federal lands. When compared to 2005 emissions this results in increased emissions throughout all the three prominent GHG emissions. From 2005-2014 GHG emissions from end-use C&E of fossil fuels produced on federal lands have resulted in average annual emissions of 81.95 MMT of CO_2e (Figure 2). When compared to global and national total CO_2e emissions, 48,257 and 6,870.5 MMT respectively, from all sources (Table 4), CO_2e emissions from these activities (end-use combustion and extraction activities) of fossil fuels produced on New Mexico federal lands is 0.19% and 1.33% respectively (World Resources Institute 2017 & EPA 2016).

In 2014 New Mexico federal lands provided 12 MMT of carbon storage. Federal lands sequestered an average of 9.5 MMT of CO_2e between 2005 and 2014 (Figure 2) (Merrill et al, 2018). While the USGS total values include GHG emissions from end-use combustion and from extraction activities of coal, oil and gas, for the purposes of this analysis the BLM only focuses on the end-use combustion emissions generated from the oil and natural gas sector, the BLM exclude coal totals (Table 4 and Figures 5 & 6).

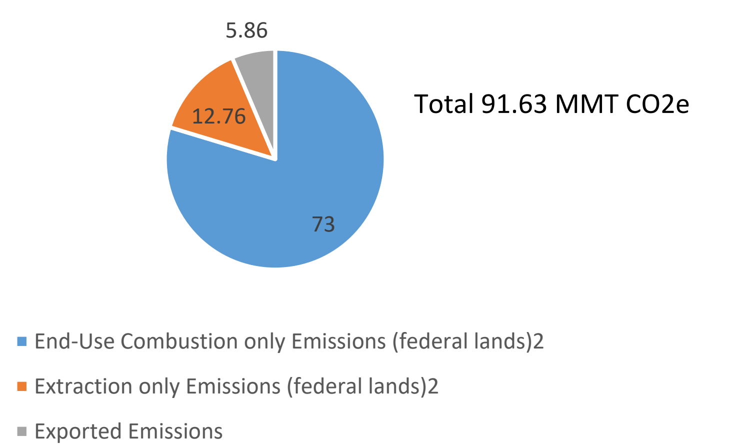
Table 4. GHG Emissions, *Combustion and Extraction,* from BLM New Mexico (CO_2e) (World Resources Institute 2017, EPA 2016, Merrill et al 2018)

Level/Sector	MMT CO2e
Global emissions, All sources	48,257
National emissions, All sources*	6870.5

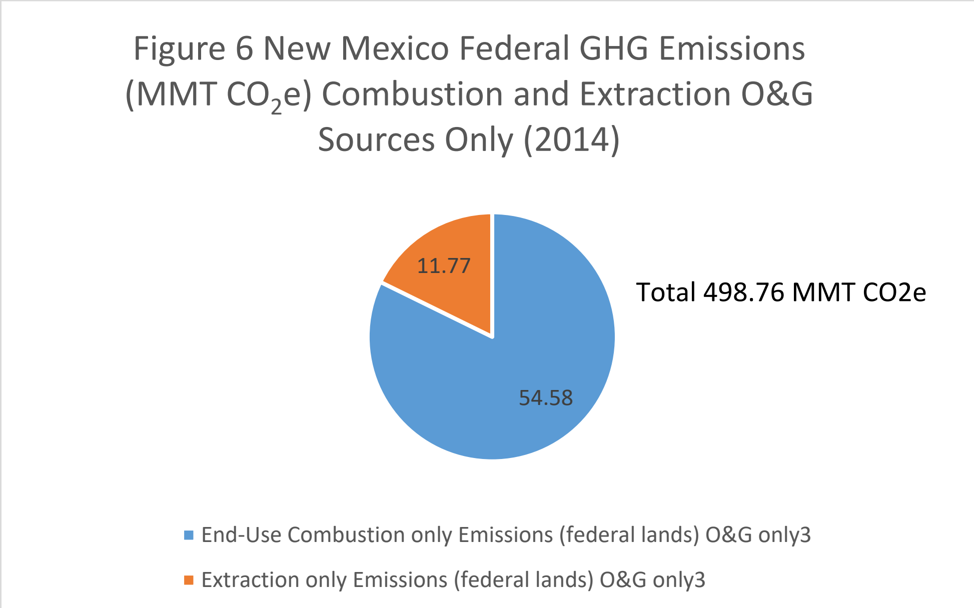
End-use C&E Emissions (BLM NM)[1, 2]	91.63
% End-use C&E Emissions (BLM NM) to Global Emissions[2]	0.19
% End-use C&E Emissions (BLM NM) to National Emissions[2]	1.33
End-Use Combustion only Emissions (BLM NM)[2]	73
% End-use Combustion only Emissions (BLM NM) to Global Emissions[2]	0.15
% End-use Combustion only Emissions (BLM NM) to National Emissions[2]	1.06
Extraction only Emissions (BLM NM)[2]	12.76
% of Extraction only Emissions (BLM NM) to Global Emissions[2]	0.03
% of Extraction only Emissions (BLM NM) to National Emissions[2]	0.19
End-use C&E Emissions (BLM NM) O&G only [3]	66.35
% End-use C&E Emissions (BLM NM) O&G only to Global Emissions[3]	0.14
% End-use C&E Emissions (BLM NM) O&G only to National Emissions[3]	0.97
End-Use Combustion only Emissions (BLM NM) O&G only[3]	54.58
% End-use Combustion only Emissions (BLM NM) O&G only to Global Emissions[3]	0.11
% End-use Combustion only Emissions (BLM NM) O&G only to National Emissions[3]	0.79
Extraction only Emissions (BLM NM) O&G only[3]	11.77
% Extraction only Emissions (BLM NM) O&G only to Global Emissions[3]	0.02
% Extraction only Emissions (BLM NM) O&G only to National Emissions[3]	0.17

1 Includes 5.86 MMT of exported CO_2e emissions. Emission totals are: CO_2 74.78 MMT, CH4 10.78 MMT of CO_2e, N2O 0.22 MMT of CO_2e
2 Includes emissions from coal, oil and natural gas
3 Isolates coal from the total and only includes oil and natural gas CO_2e emissions
C&E=Combustion and Extraction
Global and state-wide emissions represented are for 2013, national emissions and federal land emissions are for 2014.
O&G=Oil and Gas
*Emissions reflect data from 2016 EPA GHG Inventory report, newer inventories may correct this value somewhat.

Figure 5 New Mexico Federal GHG Emissions ($MMT\ CO_2e$) Combustion and Extraction All Sources (2014)



See Table 4 (above) for legend key to this figure.



See Table 4 (above) for legend key to this figure.

Cumulative

BLM Greenhouse Gas and Climate Change Report

In 2017, BLM developed a *Greenhouse Gas (GHG) and Climate Change Report* and calculator tool with an energy focus (Golder Associates 2017). The report calculates GHG emissions associated with production and consumption activities related to coal, oil, natural gas and natural gas liquids. The baseline year is 2014 and forecasts production/consumption GHG emissions for 2020 and 2030 for federal and non-federal, lands on a national level and for 13 energy producing states, including New Mexico. Inputs for the report and tool was developed using publically available online information such as: U.S. Energy Information Administration (EIA), U.S. Environmental Protection Agency (EPA) – Greenhouse Gas Inventory Report: 1990– 2014, U.S. Department of the Interior – Office of Natural Resources Revenue (ONRR), U.S. Extractive Industries Transparency Initiative (USEITI), Bureau of Land Management – Oil & Gas Statistics and others as applicable to each state. More information on the methodology, assumptions as well as other data sources from the report can be found in the *Greenhouse Gas and Climate Change Report, 2017* (Golder Associates, 2017) and is herein incorporated by reference. Table 5 shows the results of the BLM New Mexico baseline GHG emissions as well as projected emissions for 2020 and 2030.

Table 5 and Figures 7 & 8 summarizes BLM New Mexico federal and non-federal GHG emissions from production and consumption activities. In this analysis the BLM uses, as a proxy, the total New Mexico federal and non-federal emissions to be representative of current and expected annual future New Mexico GHG emissions from production and consumption activity. Several assumptions were used in order to determine the appropriate production and consumption values and to determine the greenhouse gas emissions from the activities and are included in Section 2.4 (Golder Associates 2017). For example state specific oil consumption is equal to state total production minus export and reserves for the state based on national averages, national averages for sector breakdown percentages (power, industrial, etc.). Additionally for oil and natural gas liquids, consumptions were applied to state –specific data. At the state level, production does not translate to 100% consumption of the fossil fuel. New Mexico is an important supplier of electricity to the Western US. The State's power plants have historically produced more electricity than consumed in the State, and have exported significant amounts of electricity to Arizona, California, and other Western states. In 2000, for instance, New Mexico power plants produced 36% more electricity than needed for in-state use. The New Mexico electricity sector is also dominated by coal, which accounts for nearly 90% of all electricity generated in recent years. Coal-fired power plants produce as much as twice the CO_2 emissions per kilowatt-hour of electricity as natural gas-fired power plants. As a result of these factors, New Mexico power plants are the largest source of GHG emissions in the State (New Mexico Environment Department 2016).

Table 5. Federal and Non-federal Production and Consumption GHG Emissions (Golder Associates 2017)

NM GHG Emissions (Federal) (MMT CO_2e/yr)			
Fossil Fuel	2014 Baseline	2020 High	2030 High
Coal	15.05	13.89	10.14
Oil	24.86	25.49	25.6
NG	46.83	49.6	57.44
NGL	6.98	6.11	6.17
Total	93.72	95.09	99.35
Total O&G Only	71.69	75.09	83.04
NM GHG Emissions (Federal +Non-Federal) (MMT CO_2e/yr)			
Fossil Fuel	**2014 Baseline**	**2020 High**	**2030 High**
Coal	46.73	43.12	31.52
Oil	53.9	55.28	55.51
NG	78.63	83.28	96.45
NGL	13.86	12.14	12.25
Total	193.12	193.82	195.7
Total O&G Only	132.53	138.56	152

Figure 7. New Mexico GHG Emissions (Federal)

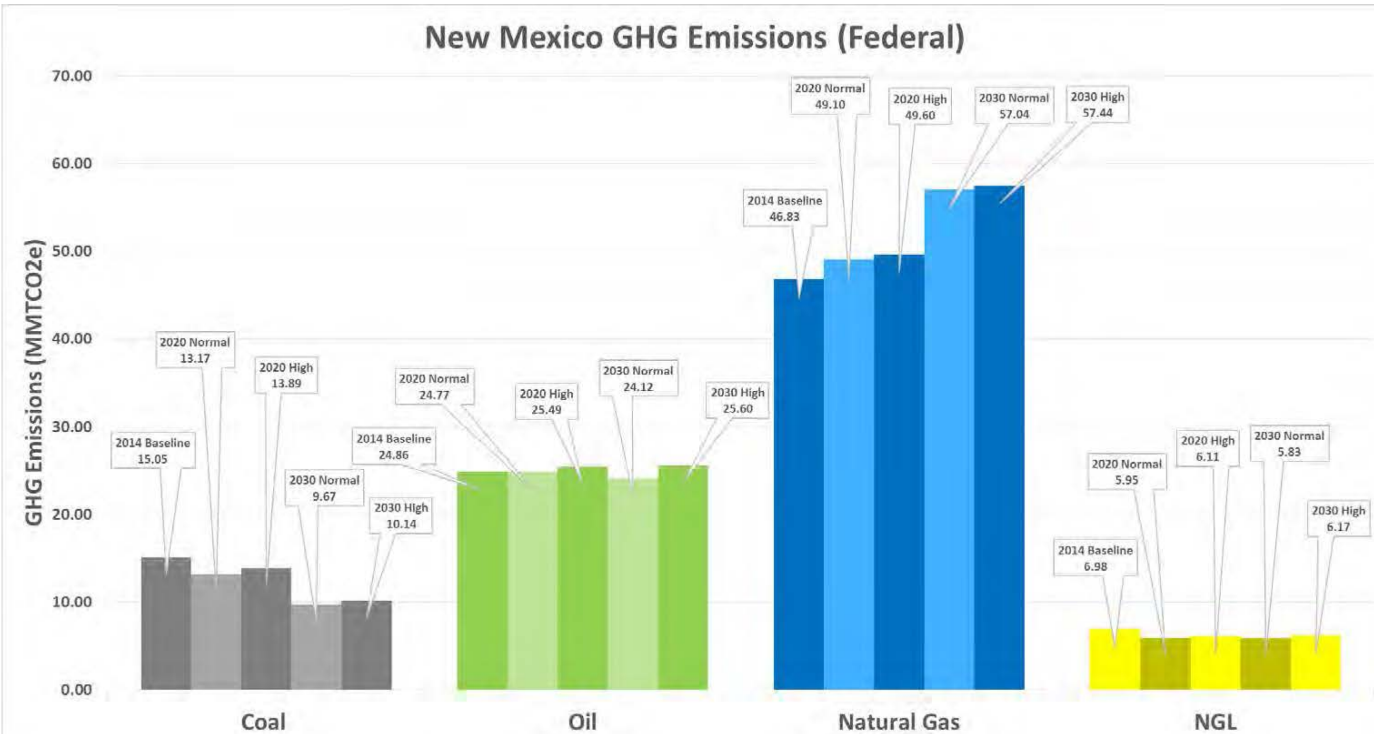
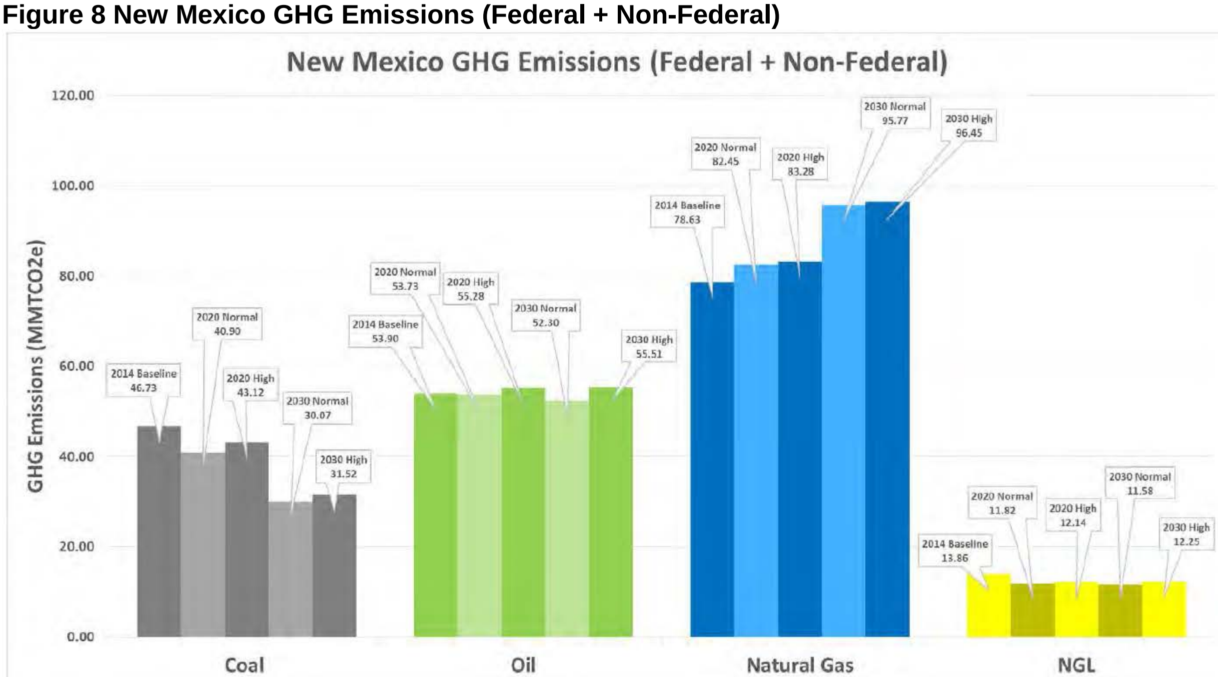


Figure 8 New Mexico GHG Emissions (Federal + Non-Federal)



BLM also approximated national GHG emissions (CO_2e) from energy production for the baseline year 2014 and future years 2020 and 2030. Growth factors are applied as compound growth, where the exponents of each factor is raised to represent the number of years ahead of the baseline year of 2014, (see Golder Associates, 2017 report). Baseline growth or decline factors were developed based on data taken from Tables A1 and B1 of the Energy Information Administration's (EIA) 2016 Annual Energy Outlook (AEO). Two scenarios were developed: normal growth and high growth. Table 6 shows the 2014 baseline CO_2e emissions from fossil fuel production as well as future projections of 2020 and 2030 with the United States across federal and non-federal sectors. All projections rely on Energy Information Administration's (EIA) 2016 Annual Energy Outlook (AEO) growth factors. GHG emissions for future projections present only the high growth scenario, the normal growth scenario can be found in the Golder Associates report (Golder Associates, 2017).

Table 6. Fossil Fuel Production and Future Year Scenarios Using AEO 2016 Outlook (Golder Associates, 2017)

2014 Baseline Fossil Fuel Production in the U.S.							
	Oil Barrels (bbl)	CO_2e (MMT)	Gas (MMcf)	CO_2e (MMT)	Coal (short tons)	CO_2e (MMT)	Total CO_2e (MMT) All Fossil Fuels
U.S.	3,196,889,000	1,375	25,889,605	1,417	1,000,048,758	1900.09	4691.39
BLM	155,424,817	67	3,399,894	186	409,345,817	777.76	1030.63
Non-BLM	3,041,464,183	1,308	22,489,711	1,231	590,702,941.00	1122.34	3660.76
New Mexico	125,021,000	54	1,140,626	62	21,963,311	41.73	157.90
BLM New Mexico	57,098,252	25	753,691	41	0	0.00	65.79

2020 Future Fossil Fuel Production in the U.S. Future, High Growth Scenarios							
	Oil Barrels (bbl)	CO_2e (MMT)	Gas (MMcf)	CO_2e (MMT)	Coal (short tons)	CO_2e (MMT)	Total CO_2e (MMT) All Fossil Fuels
U.S. High Growth	3,639,277,000	1,565	30,743,208	1,682	898,459,853	1707.07	4954.17
BLM High Growth	177,967,000	77	4,062,563	222	363,786,038	691.19	990.02
Non-BLM High Growth	3,461,310,000	1,488	26,680,645	1,460	534,673,815	1015.88	3964.16

2030 Future Fossil Fuel Production in the U.S. Future, High Growth Scenarios							
	Oil Barrels (bbl)	CO_2e (MMT)	Gas (MMcf)	CO_2e (MMT)	Coal (short tons)	CO_2e (MMT)	Total CO_2e (MMT) All Fossil Fuels
U.S. High Growth	3,907,285,000	1,680	37,628,912	2,059	665,345,945	1264.16	5003.27
BLM High Growth	191,073,000	82	4,972,475	272	269,398,309	511.86	866.10
Non-BLM High Growth	3,716,212,000	1,598	32,656,437	1,787	395,947,636	752.30	4137.17

Cumulative Impacts

The following sections outline past, present and reasonable foreseeable future actions or trends within the U.S and State of New Mexico with potential to affect GHG emissions. The temporal analysis area focuses on year 2020 estimates, and more specifically wells that might be developed as a result of reasonably foreseeable lease sales. This temporal analysis area was chosen because it represents the best available information on reasonably foreseeable annual development (the context in which GHG emissions are usually reported).

Past and Present Actions Affecting GHG Emissions

In 2013, annual global GHG emissions were 48,257 million metric tons of CO_2e, including land-use change and forestry (BLM 2018). Estimated annual GHG emissions in 2014 for the United States are 6,870 million metric tons CO_2e (EPA 2016). The BLM *2018 AR Technical Report* provides an overview of past and present GHG emissions. Relevant statistics include the following:

- Fossil fuel combustion is the largest source of global CO_2e.
- Within the U.S.:
    - Electricity generation and transportation are the largest sources of GHGs, accounting for 30% and 25.6% of emissions since 1990, respectively. In 2013, fossil fuel combustion associated with transportation contributed 1,801.7 million metric tons CO_2e to total U.S. GHG emissions, which accounted for 27% of U.S. GHG emissions that year.
    - U.S. GHG emissions increased by 3.5 percent from 1990 to 2015 but decreased from 2014 to 2015 by 2.3 percent due in large to a decrease in fossil fuel combustion. Fossil fuel combustion decreases were a result of: 1) substitution from coal to natural gas consumption in the electric power sector; 2) warmer winter conditions in 2015 resulting in a decreased demand for heating fuel in the residential and commercial sectors; and 3) a slight decrease in electricity demand (BLM 2018).
    - In 2013, GHG from oil and gas refineries accounted for 177 million metric tons CO_2e emitted, which is 5.6% of the total GHG emissions reported to EPA. Emissions from processing, transmission and storage and distribution in the U.S. totaled 98 million metric tons of CO_2e in 2013, which was about 3% of total U.S. GHG emissions reported to EPA in 2013. For natural gas, extraction accounts for 55% of total life cycle CO_2e emissions, processing accounts for 27% and transmission accounts for 18% of life cycle CO_2e emissions. For oil, drilling and development is responsible for 8% of the total life cycle CO_2e emissions, whereas transportation of the petroleum to refineries represents about 10% of the emissions, and final consumption as transportation fuel represents fully 80% of emissions.
    - In 2013, coal mining in the U.S. contributed 10.8% of total U.S. CH_4 emissions, and 1.1% of total U.S. GHG emissions).
- Within the State of New Mexico:
    - Oil and gas production in New Mexico comprise about 0.10 percent of the annual U.S. GHG emissions.
    - The New Mexico Greenhouse Gas Inventory and Reference Case Projection 1990-2020 projected that approximately 17.3 million metric tons of GHGs from the natural gas industry and 2.3 million metric tons of GHGs from the oil industry were produced in 2010 as a result of oil and natural gas production, processing, transmission and distribution. This represented 22% of the total gross New Mexico 2010 emissions.

- Of that total, about 29 percent (5.6 million metric tons of CO_2e) is associated with oil and gas production; the remaining emissions are associated with processing, transmission, and distribution.

Table 7 shows estimated global emissions as well as GHG emissions for the United States, New Mexico, and the major oil and gas basins of New Mexico. Emissions are expressed in million metric tons of CO_2e.

Table 7. 2016 Estimated Annual GHG Emissions from Oil and Gas Field Production (World Resources Institute 2017, EPA 2018).

Annual GHG Emissions	Million Metric Tons-per-year (MMT CO_2e)	% US Emissions	% of NM O&G Emissions
Global emissions, All sources	48,257	NA	NA
U.S emissions from All Sources	6,511	100	NA
U.S. emissions from O&G Field Production Activities	164	2.52	NA
New Mexico emissions from O&G Field Production Activities	6.8	0.10	100.00
BLM New Mexico emissions from O&G Field Production Activities	3.96	0.06	58.21
BLM San Juan Basin emissions from O&G Field Production (16,139 wells) *	1.68	0.03	24.71
BLM Permian Basin emissions from O&G Field Production (17,735 wells) †	2.25	0.03	33.10

* Includes federal mineral development in McKinley, Rio Arriba, Sandoval, and San Juan Counties (BLM 2018)

† Includes federal mineral development in Chaves, Eddy, Lea, and Roosevelt Counties (BLM 2018)

Note the value used for U.S. emissions from All Sources has different reporting values of 6,511 MMT of CO2e/year and 6,870 MMT of CO2e depending on the data year of the other data being compared. The differences will not change the order of magnitude of comparison.

Reasonably Foreseeable Future Actions (RFFAs) Affecting GHG Emissions

Overall, total New Mexico statewide gross GHG emissions are expected to increase (New Mexico Environment Department 2016). The New Mexico Greenhouse Gas Inventory and Reference Case Projection 1990-2020 (CCS 2005) projects the following for year 2020 in New Mexico for emissions produced within the State (i.e., production-based emissions):

- Gross GHG emissions of 101.7 million metric tons of CO_2e— an increase of 48 percent relative to 1990 and 23 percent relative to 2000. New Mexico's emissions are well above the national average largely because of coal-based electricity generation and natural gas production activities.
- Top sources of GHG emissions: electricity production (38.1 million metric tons of CO_2e,) transportation fuel use (22.3 million metric tons of CO_2e,) and fossil fuel industry (20.7 million metric tons of CO_2e,). All have increased over 2010 estimates, but electricity and transportation fuel use increased at a higher rate than oil and gas development.

- Within the fossil fuel industry, approximately 20 million metric tons of CO_2e are projected as a result of oil and natural gas production, processing, transmission and distribution. This is 20 percent of the gross New Mexico emissions (a slight decrease over the relative contribution of oil and gas production in 2010, see past and present activity, above). About 28 percent (5.6 million metric tons of CO_2e) of the fossil fuel total is associated with oil and gas production; the remaining emissions are associated with processing, transmission, and distribution.

Although it is expected that vehicle fuel efficiency and increased use of public transportation will reduce vehicle emissions, these reductions may eventually be offset by an increased number of vehicles in use due to population growth in the region (BLM 2018).

Reasonably Foreseeable Development Scenarios (RFDs)

Farmington Field Office (FFO)

Table 8 provides the reasonably foreseeable future GHGs (CO_2e emissions) associated with end-use oil and gas combustion emissions for the 2018 Mancos Gallop RFD scenario from federal, state (fee) as well as Indian minerals in the planning area. Total cumulative well development will result in 3,200 new wells from 2018-2037. Of that number, 1,980 are federal new well development. The methodology for estimating new well development as well as the volumes for oil and gas is described in the Mancos Gallup 2018 RFD (Crocker and Glover 2018).

CO_2e emissions from downstream/end-use combustion of oil and gas products are estimated annually and cumulatively for BLM development and an all development (federal & non-federal) well production development scenario (Table 8). Under the all development scenario (includes Federal, Indian, state and fee minerals), cumulative emissions during the 20-year period is estimated to produce 398.4 MMT of CO_2e from the end-use combustion of products from 3,200 wells. The range of annual CO_2e emissions is 15.3 MMT/year in 2024 during the development of 126 additional oil and gas wells to 28.5 MMT/yr of CO_2e in 2037 when 253 annual oil and gas wells are added that year.

Over the 20-year period, cumulative federal only wells would produce 247.4 MMT of CO_2e emissions from end-use combustion of oil and gas fossil fuels from 1,980 wells. The range of annual CO_2e emissions is 9.6 MMT/year in 2024 during the development of 78 oil and gas wells to 17.3 MMT/year of CO_2e in 2037 during the development of 156 annual oil and gas wells. This would represent 0.93 percent to 1.67 percent respectively of BLM's annual 2014 fossil fuel end-use combustion (Table 6). It would represent a contribution of 0.97 percent to 1.74 percent respectively to BLM's annual 2030 future estimated GHG emissions (Table 6). It should be noted that Table 6 also includes emissions from coal which produces 50 to 60 percent more carbon dioxide emissions than natural gas.

Table 8. Estimated Cumulative Downstream/End Use GHG Emissions Resulting from Oil and Gas Production BLM 2018 Mancos Gallup RFD Scenario (Crocker and Glover 2018)

Federal Wells in the Planning Area (Federal development only)

Year	Number of Wells	Annual CO2e-(MMT) Oil	Annual CO2e-(MMT) Gas	Annual CO2e (MMT) Oil & Gas	CO2e % of Total RFD
2018	41	2.14	13.04	15.18	6.14
2019	48	2.34	10.77	13.12	5.30
2020	53	2.51	9.08	11.60	4.69
2021	59	2.69	7.89	10.58	4.28

2022	65	2.86	7.08	9.94	4.02
2023	72	3.02	6.68	9.70	3.92
2024	78	3.20	6.43	9.62	3.89
2025	84	3.39	6.30	9.69	3.92
2026	90	3.59	6.33	9.92	4.01
2027	96	3.80	6.47	10.28	4.16
2028	103	4.03	6.72	10.75	4.35
2029	109	4.26	7.05	11.31	4.57
2030	112	4.44	7.38	11.82	4.78
2031	120	4.70	7.81	12.52	5.06
2032	127	4.96	8.28	13.24	5.35
2033	133	5.22	8.76	13.99	5.65
2034	139	5.49	9.28	14.78	5.97
2035	145	5.77	9.82	15.59	6.30
2036	150	6.05	10.40	16.45	6.65
2037	156	6.32	10.98	17.29	6.99
TOTAL	1980	80.80	166.57	247.37	100

All Wells in the Planning Area (including Federal, Indian, state, and fee minerals)

Year	Number of Wells	Annual CO2e- (MMT) Oil	Annual CO2e- (MMT) Gas	Annual CO2e (MMT) Oil & Gas	CO2e % of Total RFD
2018	67	3.32	20.72	24.04	6.03
2019	76	3.61	17.14	20.76	5.21
2020	86	3.85	14.50	18.35	4.61
2021	96	4.10	12.65	16.75	4.20
2022	106	4.33	11.42	15.74	3.95
2023	116	4.55	10.82	15.37	3.86
2024	126	4.79	10.49	15.28	3.84
2025	136	5.06	10.36	15.42	3.87
2026	146	5.34	10.49	15.84	3.98
2027	156	5.65	10.81	16.46	4.13
2028	166	5.99	11.30	17.29	4.34
2029	176	6.34	11.91	18.25	4.58
2030	180	6.23	12.54	18.77	4.71
2031	194	6.88	13.37	20.25	5.08
2032	204	7.32	14.25	21.57	5.41
2033	214	7.73	15.13	22.86	5.74
2034	224	8.15	16.07	24.22	6.08
2035	234	8.58	16.99	25.56	6.42
2036	244	8.99	18.07	27.06	6.79
2037	253	9.39	19.14	28.53	7.16
TOTAL	3200	120.21	278.17	398.38	100

Pecos District Office Planning Area (PDO)

Table 9 provides the reasonably foreseeable future GHGs (CO_2e emissions) associated with end-use oil and gas combustion emissions for Pecos District Office from federal, state (fee) as well as Indian minerals in the planning area. The Pecos District Office federal planning area includes oil and gas well development from Carlsbad Field Office (FO), Roswell FO as well as Hobbs FO. Total cumulative well development will result in 16,000 new wells from 2016-2035. Of that number, 6,400 are federal new well development. The methodology for estimating new well development as well as the volumes for oil and gas is described in Engler and Cather 2012 and SENM 2014.

CO_2e emissions from downstream/end-use combustion of oil and gas products are estimated annually and cumulatively for BLM development and for an all development (federal and non-federal) well production scenario (Table 9). Under the all development scenario (includes Federal, Indian, state and fee minerals), cumulative emissions during the 20-year period is estimated to produce 5,574 MMT of CO_2e from the end-use combustion of oil and gas from 16,000 wells. The range of annual CO_2e emissions is 97.3 MMT/year in 2016 to 595.21 MMT/yr of CO_2e in 2035 when additional wells are added to production.

Over the 20-year period, cumulative federal only wells could produce 1163.64 MMT of CO_2e emissions from end-use combustion of oil and gas fossil fuels from 6,400 wells. The range of annual CO_2e emissions is 47.9 MMT/year in 2016 to 69.77 MMT/year of CO_2e in 2035. This would represent 4.65 percent to 6.77 percent respectively of BLM's 2014 annual fossil fuel end-use combustion (Table 6). It would represent a contribution of 4.84 percent to 7.05 percent respectively to BLM's 2030 annual future estimated GHG emissions (Table 6). It should be noted that Table 6 also includes emissions from coal which produces 50 to 60 percent more carbon dioxide emissions than natural gas.

Table 9. Estimated Cumulative Downstream/End Use GHG Emissions Resulting from Oil and Gas Production BLM 2018 RFD PDO Scenario (Engler and Cather 2012, SENM 2014)

Federal Wells in the Planning Area (Federal development only)

Year	Annual CO2e-(MMT) Oil	Annual CO2e-(MMT) Gas	Annual CO2e (MMT) Oil & Gas	CO2e % of Total RFD
2016	32.17	15.72	47.89	4.12
2017	32.81	16.04	48.85	4.20
2018	33.47	16.36	49.83	4.28
2019	34.14	16.69	50.82	4.37
2020	34.82	17.02	51.84	4.45
2021	35.52	17.36	52.88	4.54
2022	36.23	17.71	53.93	4.63
2023	36.95	18.06	55.01	4.73
2024	37.69	18.42	56.11	4.82
2025	38.44	18.79	57.23	4.92
2026	39.21	19.17	58.38	5.02
2027	40.00	19.55	59.55	5.12
2028	40.80	19.94	60.74	5.22

2029	41.61	20.34	61.95	5.32
2030	42.45	20.75	63.19	5.43
2031	43.29	21.16	64.46	5.54
2032	44.16	21.58	65.74	5.65
2033	45.04	22.02	67.06	5.76
2034	45.94	22.46	68.40	5.88
2035	46.86	22.91	69.77	6.00
TOTAL	781.61	382.03	1163.64	100

All Wells in the Planning Area (including Federal, Indian, state, and fee minerals)

Year	Annual CO2e-(MMT) Oil	Annual CO2e-(MMT) Gas	Annual CO2e (MMT) Oil & Gas	CO2e % of Total RFD
2016	65.10	32.22	97.32	1.75
2017	71.61	35.44	107.05	1.92
2018	78.77	38.99	117.76	2.11
2019	86.65	42.89	129.54	2.32
2020	95.31	47.18	142.49	2.56
2021	104.85	51.89	156.74	2.81
2022	115.33	57.08	172.41	3.09
2023	126.86	62.79	189.65	3.40
2024	139.55	69.07	208.62	3.74
2025	153.50	75.98	229.48	4.12
2026	168.85	83.57	252.43	4.53
2027	185.74	91.93	277.67	4.98
2028	204.31	101.12	305.44	5.48
2029	224.75	111.24	335.98	6.03
2030	247.22	122.36	369.58	6.63
2031	271.94	134.60	406.54	7.29
2032	299.14	148.06	447.19	8.02
2033	329.05	162.86	491.91	8.82
2034	361.95	179.15	541.10	9.71
2035	398.15	197.06	595.21	10.68
TOTAL	3,728.64	1,845.48	5,574.12	100

Table 10 shows historical U.S., New Mexico and BLM New Mexico federal production in the major oil and gas basins and their associated end-use combustion GHG emissions during calendar years 2014 through 2017. Production of oil and gas on federal lands has varied over the 10-year period due to market conditions, technological advances as well as pipeline and storage infrastructure availability. In 2015, total CO_2e end-use emissions resulting from oil and gas production in the U.S. was 2791.29 MMT. New Mexico, 2014 GHG emissions associated with oil and gas production end-use was 116.17 MMT, which is 4.16 percent of national emissions in 2014.

GHG emissions from O&G gas production in the BLM Pecos District Office planning area in 2014 was 40.10 MMT of CO2e, which is 1.44 percent of national O&G GHG emissions and 34.5 percent of New Mexico O&G GHG emissions from production in 2014. GHG end-use emissions from the BLM PDO planning area has increased to 48.85 MMT/year of CO_2e in 2017.

GHG emissions from O&G production in the BLM Farmington Field Office planning area in 2014 was 38.82 MMT of CO_2e, which is 1.39 of national O&G GHG emissions and 34.5 percent of New Mexico O&G GHG emissions from production in 2014. GHG end-use emissions from the BLM PDO planning area has decreased to 28.00 MMT/year of CO2e in 2017.

Table 10. Historical oil and gas production (EIA 2018a, 2018b, ONRR 2018)

Oil and Gas Production	2014	2015	2016	2017
U.S. Oil Production (Mbbls)	3,196,889	3,442,188	3,232,025	3,413,376
New Mexico Oil Production (Mbbls)	125,021	147,663	146,389	171,440
PDO Oil Production (Mbbls)	62,007	73,344	74,810	76,307
FFO Oil Production (Mbbls)	5,755	8,457	6,889	5,980
U.S. Gas Production (MMcf)	25,889,605	27,065,460	26,592,115	27,291,222
New Mexico Gas Production (MMcf)	1,140,626	1,151,493	1,139,826	1,196,514
PDO Gas Production (MMcf)	245,550	281,713	287,347	293,094
FFO Gas Production (MMcf)	664,211	642,211	596,747	464,709
GHG Emissions				
Total U.S. O&G GHG Emissions (MMT) CO2e	2791.29	2961.11	2844.84	2961.08
Total New Mexico O&G GHG Emissions (MMT CO2e)	116.17	126.50	125.32	139.19
Total PDO O&G GHG Emissions (MMT CO2e)	40.10	46.95	47.89	48.85
Total FFO O&G GHG Emissions (MMT CO2e)	38.82	38.78	35.62	28.00

Table 10 shows historical U.S., New Mexico and BLM New Mexico federal production in the major oil and gas basins and their associated end-use combustion GHG emissions during calendar years 2014 through 2017. Production of oil and gas on federal lands has varied over the 10-year period due to market conditions, technological advances as well as pipeline and storage infrastructure availability. In 2015, total CO_2e end-use emissions resulting from oil and gas production in the U.S. was 2791.29 MMT. New Mexico, 2014 GHG emissions associated with oil and gas production end-use was 116.17 MMT, which is 4.16 percent of national emissions in 2014.

GHG emissions from O&G gas production in the BLM Pecos District Office planning area in 2014 was 40.10 MMT of CO2e, which is 1.44 percent of national O&G GHG emissions and 34.5 percent of New Mexico O&G GHG emissions from production in 2014. GHG end-use emissions from the BLM PDO planning area has increased to 48.85 MMT/year of CO_2e in 2017.

GHG emissions from O&G production in the BLM Farmington Field Office planning area in 2014 was 38.82 MMT of CO_2e, which is 1.39 of national O&G GHG emissions and 34.5 percent of New Mexico O&G GHG emissions from production in 2014. GHG end-use emissions from the BLM PDO planning area has decreased to 28.00 MMT/year of CO2e in 2017.

Well Development GHG Emissions

The *2018 AR Technical Report* describes the increased criteria pollutant emissions as a result of well development. The most substantial criteria pollutants emitted by oil and gas development and production are VOCs, particulate matter, carbon monoxide and nitrogen dioxides. To facilitate quantification, this analysis assumes that all wells would be developed concurrently and in the same year, though it is more likely that future potential development would not occur in this manner. Emission calculations for construction, operations, maintenance and reclamation are included in in the *Calculators* Appendix section of the *2018 AR Technical Report.*

Construction emissions for either an oil or gas well include well pad construction (fugitive dust), heavy equipment combustive emissions, commuting vehicles and wind erosion. Emissions from operations for an oil well include well workover operations (exhaust and fugitive dust), well site visits for inspection and repair, recompletion traffic, water and oil tank traffic, venting, compression and well pumps, dehydrators and compression station fugitives. Operations emissions for a gas well include well workover operations (exhaust and fugitive dust), wellhead and compressor station fugitives, well site visits for inspection and repair, recompletions, compression, dehydrators, and compression station fugitives. Maintenance emissions for wither an oil and gas well are for road travel, and reclamation emission activities are for interim and final activities and include truck traffic, a dozer, blade, and track hoe equipment.

Emissions are anticipated to be at their highest level during the construction and completion phases of implementation (approximately 30 days in duration) because these phases require the highest degree of earth-moving activity, heavy equipment use, and truck traffic, compared with the operations and maintenance phases of implementation. Emissions are anticipated to decline during operations and maintenance as the need for earth-moving and heavy equipment declines.

Table 11 provides past well completion data and associated GHG emissions (CO_2e) based on APD activity from the BLM AFMSS system (BLM 2019). GHG emissions (CO_2e) are calculated for the total number of well completions using a per well emission factor based on activities during well construction, completion and production (extraction emissions not associated with end-use combustion emissions) as explained in the *2018 AR Technical Report* (BLM 2018). The emissions provide a maximum emissions scenario as the number of wells each year is multiplied by approximately 1,229 and 1,253 metric tons of CO_2e/year in the Farmington Field Office and Pecos District Office respectively, which assumes all wells are gas wells. It is likely that emissions in the Permian basin (PDO) would be lower due to the predominant well type being oil wells. In the San Juan Basin (FFO) more gas wells have been developed, and emissions may be more representative in which we use the gas well emission factor.

Table 11. Well Completions and estimated GHG emissions based on APD Activity (BLM 2019)

Farmington Field Office	**2014**	**2015**	**2016**	**2017**	**2018**	**BLM RFD (2018-2037)**	**# of Wells Post RFD**
# of BLM Well Completions*	94	71	15	30	33	1,980	33
Metric Tons of CO2e/year	115,603	87,317	18,447	36,895	40,584	2,435,037	40,584
Pecos District Office	**2014**	**2015**	**2016**	**2017**	**2018**	**BLM RFD (2016-2035)**	**# of Wells Post RFD**
# of BLM Well Completions*	584	400	389	378	518	6,400	1285
Metric Tons of CO2e/year	731,517	501,039	487,260	473,482	648,846	8,016,624	1,609,588

FFO # of BLM federal & non-federal Wells in PDO RFD (2016-2037) is 3,200
PDO # of BLM federal & non-federal Wells in PDO RFD (2016-2037) is 16,000
*PDO BLM wells Includes completions from Carlsbad, Hobbs and Roswell Field Offices
*FFO BLM wells Includes completions from Farmington and Rio Puerco Field Offices
*Wells completed reported from BLM AFMSS 1&2 with run date June 20, 2019 (BLM 2019).

Mitigation

Rapid development could result in an increase of criteria and HAP emissions in the planning areas. Limiting development through a phased approach could help to reduce concentrations of emissions in the air basins. Emissions associated with the RFD, including future potential development of lease parcels, would be offset by substantial decreases in emissions--including a 67% reduction in SO2, 62% reduction in NOx, 50% reduction in particulate matter, 44% reduction in CO, and 51% reduction in VOCs--resulting from power generation due to the recent shutdown of two of the units at the San Juan Generating Station. Additionally, selective catalytic reduction technology installed on the two remaining coal-fired generators at the Four Corners Power Plant would result in additional reductions in emissions from the facility, including a 36% reduction in NOx, 43% reduction in particulate matter, and 24% reduction in SO2 (BLM 2018). The San Juan Generating Station is also proposed for full closure by 2022, which would result in even further drops in future pollutant emissions for the analysis area. Additional measures taken to comply with recent revisions to the Regional Haze Rule in January 2017 would further reduce pollutant emissions. New Mexico will have to comply with these revisions as it develops its SIP for the second planning period. Cumulatively, it is expected that future levels of criteria pollutant, VOC, and HAP and GHG emissions would be lower than current levels due to the aforementioned factors despite the increases in emissions associated with reasonably foreseeable oil and gas development and future potential development of the nominated lease parcels.

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