U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF LAND MANAGEMENT

2023 BLM Specialist Report on Annual Greenhouse Gas Emissions and Climate Trends

from Coal, Oil, and Gas Exploration and Development on the Federal Mineral Estate

Published on August 22, 2024

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Executive Summary

The ***"2023 BLM Specialist Report on Annual Greenhouse Gas Emissions and Climate Trends"*** presents the estimated emissions of greenhouse gases (GHGs) attributable to fossil fuels produced on lands and mineral estate managed by the Bureau of Land Management (BLM). More specifically, this report is focused on estimating GHG emissions from coal, oil, and gas development that is occurring, and is projected to occur, on the federal onshore mineral estate. The report includes a summary of emissions estimates from reasonably foreseeable federal fossil fuel development and production over the next 12 months, as well as longer term assessments of potential federal fossil fuel GHG emissions and the anticipated climate change impacts resulting from the cumulative global GHG burden. The report is an important tool for evaluating the cumulative impacts of GHG emissions from fossil fuel energy leasing and development authorizations on the federal onshore mineral estate relative to several emission scopes and base years.

Emissions estimates were developed using fiscal year (FY) 2023 data for both direct and indirect emissions. Direct emissions can result from authorized activities such as drilling or venting, while indirect emissions occur as a consequence of the authorized action and can include activities such as the processing, transportation, and any end-use combustion of the fossil fuel mineral products. The emission estimates are expressed as megatonnes (Mt) of carbon dioxide equivalents (CO_2e) on either a rate or absolute basis. Table ES-1 shows the estimated GHG emissions from actual fossil fuel production from the federal mineral estate in FY 2023. Table ES-2 shows the estimated 2023 GHG emissions by mineral boundary, from which extraction is the direct portion of the emissions, and processing and transport represent a portion of the indirect emissions along with the end-use estimates.

Table ES-1. Estimated Annual GHG Emissions from Federal Fossil Fuel Production in 2023 (Mt $C0_2e$)

BLM Authorized Development		Direct	Indirect	End Use	Total
	Coal	3.75	8.14	422.89	434.78
	Oil	40.99	33.82	240.90	315.71
	Gas	22.49	57.10	216.25	295.84
	Total 2023 Existing	**67.23**	**99.06**	**880.04**	**1,046.33**

2023 annual emissions based on fiscal year production data (i.e., Oct. 1 - Sept. 30)

Table ES-2. Estimated Annual Emissions by Mineral Boundary - 2023 (Mt $C0_2e$)

Area	Extraction	Processing	Transport	Combustion	Total C02e
U.S Total	678.2966	328.1346	641.0649	5,672.86	7,260.36
Federal Total	93.8464	72.9485	78.7689	1,216.72	1,462.29
Onshore Total	67.2291	37.0548	62.0045	880.04	1,046.33
Wyoming	12.098	5.1635	18.8005	440.96	477.02
Offshore	26.6173	35.8937	16.7644	336.68	415.96
New Mexico	43.6984	26.0576	29.9265	300.28	399.96
Colorado	4.0628	1.6939	6.7454	45.43	57.94
North Dakota	3.8991	2.3967	2.0184	31.45	39.76
Utah	1.3774	0.7088	1.8118	25.05	28.95
Montana	0.354	0.1736	0.5483	2308	24.16

Area	Extraction	Processing	Transport	Combustion	Total C02e
Louisiana	0.4035	0.1445	0.8474	3.81	5.2
California	0.6331	0.4218	0.1706	3.87	5.1
Texas	0.2474	0.0878	0.524	2.34	3.2
Oklahoma	0.1227	0.0593	0.1665	0.99	1.34
Alaska	0.1222	0.0634	0.1401	0.94	1.27
Alabama	0.0754	0.0215	0.1054	0.7	0.9
Arkansas	0.0458	0.0157	0.1006	0.44	0.6
Ohio	0.0185	0.0065	0.0399	0.18	0.24
Kansas	0.0199	0.0087	0.0326	0.17	0.23
Nevada	0.0167	0.0115	0.0024	0.1	0.13
Mississippi	0.0139	0.0093	0.0035	0.08	0.11
South Dakota	0.0106	0.0064	0.007	0.07	0.1
Michigan	0.0048	0.0018	0.0094	0.04	0.06
Nebraska	0.0018	0.0013	0.0003	0.01	0.01
Virginia	0.0007	0.0002	0.0014	0.01	0.01
Kentucky	0.0007	0.0003	0.001	0.01	0.01
Illinois	0.001	0.0007	0.0002	0.01	0.01
West Virginia	0.0003	0.0001	0.0007	0	0
Pennsylvania	0.0003	0.0001	0.0006	0	0
New York	0	0	0	0	0
Idaho	0	0	0	0	0
Washington	0	0	0	0	0

2023 annual emissions based on fiscal year production data (i.e.. Oct. 1 - Sept. 30)

Figure ES-1. Federal Onshore Mineral Estate Emissions

Table ES-3 provides an estimate of (7) present emissions from existing production that is anticipated to keep producing and (2) reasonably foreseeable future GHG emissions, including (a) emissions from previously authorized development that is not currently producing but may begin production and (b) potential new leasing that could begin producing. This table also provides estimated cumulative (life-of-project) GHG emissions over the typical production life for existing and projected development. The typical production life for an oil and gas well can vary considerably based on multiple factors but generally ranges from 20 to 25 years. The projected emissions estimates generated in this report are based on a conservative assumption that the production life for new oil and gas wells is 30 years (with decline). The typical production life assumed for coal is 1 year as most coal is typically produced and consumed in a single year. The annualized emissions rates shown in Table ES-3 are a subset of the life-of-project emissions data, specifically the emissions from year one (i e., the next 12 months).

Table ES-3. Estimated GHG Emissions from Reasonably Foreseeable Projected Federal Fossil Fuel Production over the Next 12 Months

BLM Authorized Development	Mt C02e/yr (Annual)				Mt C02e (Cumulative)
	Direct	**Indirect**	**End Use**	**Totals**	**Life-of-Project**
Existing Federal Production					
Coal	0	0	0	0	0
Oil	33.29	27.46	195.63	256.38	2,271.38
Gas	18.82	47.79	181.01	247.63	2,548.72
Subtotal Existing Production	**52.1**	**75.3**	**376.6**	**504.0**	**4,820.1**
Permitted but NOT yet developed Minerals					
Coal	7.84	6.79	352.69	367.32	6,396.46
Oil	25.49	21.03	149.78	196.30	612.89
Gas	7.88	20.00	75.73	103.61	354.06
Subtotal Permitted	**41.4**	**47.8**	**578.2**	**667.2**	**7,363.4**
Potential New Leases					
Coal	0	0	0	0	0
Oil	10.11	8.34	59.41	77.86	246.57
Gas	4.91	12.46	47.19	64.56	248.19
Subtotal Potential Leases	**15.0**	**20.8**	**106.6**	**142.4**	**494.8**
Total Projected Emissions					
Coal	7.84	6.79	352.69	367.32	6,396.46
Oil	68.89	56.83	404.83	530.55	3,130.85
Gas	31.61	80.25	303.93	415.79	3,150.97
Total C02e	**108.5**	**143.9**	**1,061.4**	**1,313.7**	**12,678.3**

Emissions are based on life-cycle-assessment (LCA) data that are relative to total production and include noncombusted GHGs (e.g., fugitive CH_4).
Indirect emissions include LCA values for transportation/distribution, processing/refining, but NOT end use (combustion), shown separately for illustrative purposes.
Direct and Indirect emissions are additive for life-cycle accounting but represent a double count for annual reporting.
Life-of-Project emissions for Oil and Gas are a 30-year declined-projection for each authorization type shown. Coal emissions are based on forecasted production (see coal discussion in Chapter 6.2).
Projected existing federal coal emissions from operating mines (i.e., mines with currently leased reserves) are shown in the permitted but not yet developed subheading.

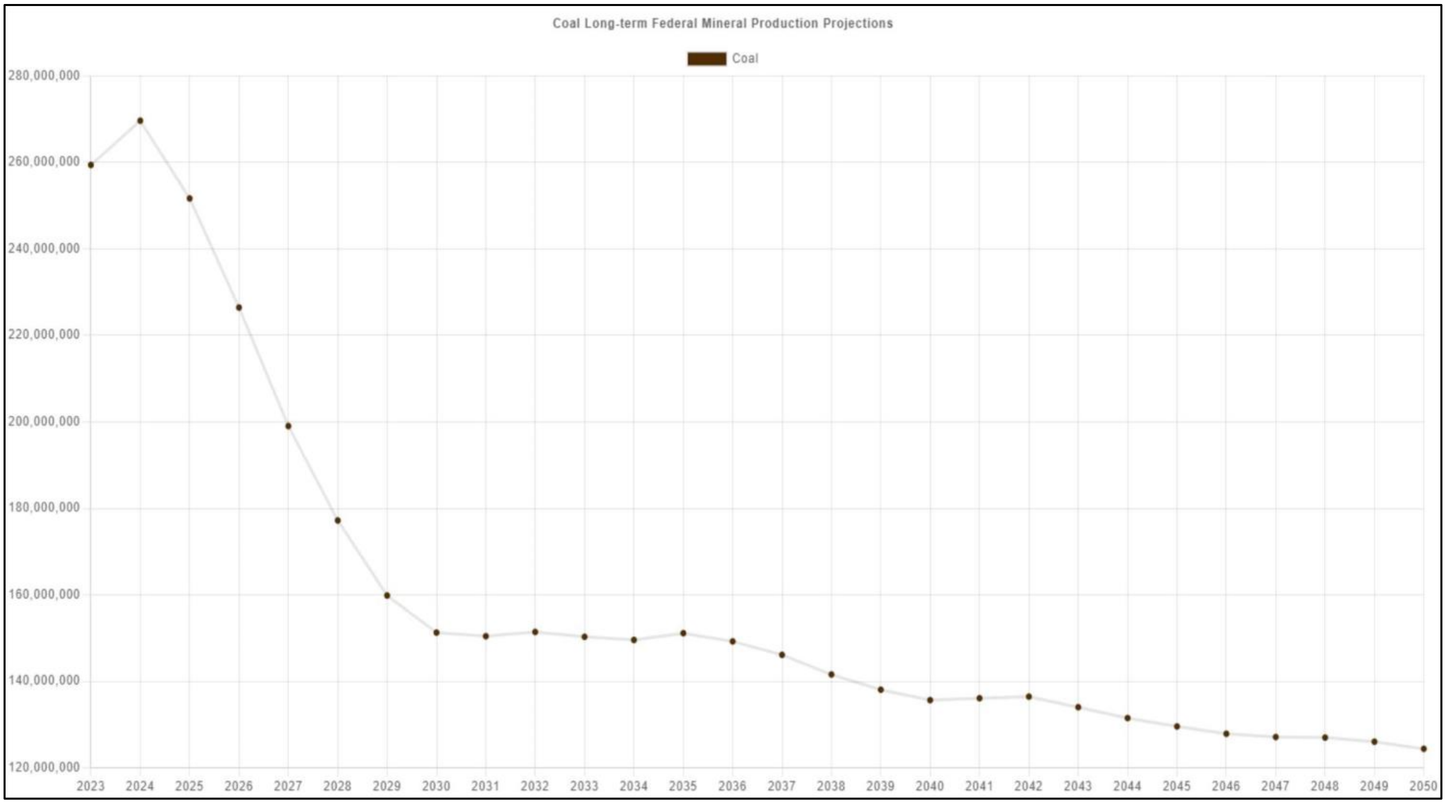

Figure ES-2. Long-Term Onshore Federal Mineral Production

Units for Coal, Oil, and Gas production are tons, bbls, and Mcf, respectively.
No updated AEO in 2024.

Table ES-4. Long-Term Onshore Federal Mineral Projections

Federal Minerals	Production	Energy (Quads)	Emissions (Mt CO_2e)
Coal (MM short tons)	4,799	7.57E+01	7,582
Oil (MM bbl)	15,207	8.81 E+0l	8,640
Gas (Bcf)	115,674	1.19E+02	8,624
Projected Totals	**NA**	**2.83E+02**	**24,845**

AEO Reference Case used for series projections, totals are the sum of the series (2024 - 2050)
See methodology discussion in Chapter 6.7.

Report Recap

The total federal mineral production forecasts for 2023 were significantly higher than the actual totals recorded. Federal coal production came in the closest, recording 96% of the forecast value, while onshore federal oil and gas production totaled only 59% and 69% of forecasted volumes, respectively. Factoring out the speculative projected leasing production shows the actual federal oil and gas production was closer to 71% and 84% of the forecasts. In general, the leasing projections will always be conservative since first-year leases almost never produce, and certainly not at the full projected development pace that is assumed for this report. A roundup of the BLM oil and gas statistics shows that the projected approved application for permit to drill (APD) forecasts (average of the past 2 years) were significantly low, by about 667 units. The number of producible well counts rose slightly but failed to reach the forecast value of 93,387. In terms of leasing, specifically the number of new lease acres sold, the data indicates that just 10.1% of the 5-year average was acquired at auction, significantly below forecast estimates. Regardless, 2023 production of onshore federal oil and gas and their associated emissions were higher than the previous report year by about 16% and 9%, respectively. Due to an 11% decrease in federal coal production, total onshore federal fossil fuel mineral emissions only ticked up 1.27%. Federal coal, oil, and gas accounted for 43.89%, 9.41%, and 8.33% of total U.S. production and their related GHG emissions in 2023.

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1.0 Introduction

The *"2023 BLM Specialist Report on Annual Greenhouse Gas Emissions and Climate Trends"* provides a detailed assessment of greenhouse gas (GHG) emission trends and potential climate impacts from energy development projects, specifically those that may result from Bureau of Land Management (BLM)-authorized coal, oil, and gas leases. and approved development on public lands (including the federal mineral estate) managed by the BLM. This report examines carbon emissions from authorized development of the onshore federal mineral estate in the context of the nation's carbon economy and the relationship between energy generation and climate issues by providing life-cycle estimates of fossil fuel GHG emissions from that development. The report provides estimates of both direct and indirect emissions from development and consumption of onshore federal fossil fuel minerals, including those fuels that are combusted by end users (when off-lease). This report incorporates current climate science and discussions of scientific values relevant to the context within which the BLM authorizes development of the onshore federal mineral estate. This report is designed to be updated on an annual basis and serves as a tool to track the evolution of climate science and policy in order to provide decision makers with the best available data to implement management strategies consistent with regulatory requirements.

Chapters 2 through 5 provide background information relevant to the existing affected environment concerning GHG emissions and climate change science. Chapters 6 and 7 describe the methodologies and data utilized by the BLM for projecting federal fossil fuel mineral emissions and the results of the projection calculations for various scopes. The remainder of the document (Chapters 8 through 10) provides comparative context and analysis for the estimated emissions, discloses the potential impacts of projected climate change relative to projected emissions, and presents mitigation strategies that could be utilized by BLM to contribute towards combating climate change.

1.1 Background

Coal, oil, and gas are examples of fossil fuels found in the earth's crust that formed from decomposing plants and animals. These fuels contain high concentrations of carbon and hydrogen that can be burned for energy The extraction, production, and consumption of these fossil fuels produce GHGs, particularly carbon dioxide and methane, which in turn trap heat in the atmosphere causing the "greenhouse effect," resulting in an increase in average global temperatures and other climatic changes over time. The BLM's authorization of fossil fuel energy development can result in both direct and indirect emissions of GHGs that contribute to global climate change. Direct emissions can result from authorized activities such as drilling or venting, while indirect emissions occur as a consequence of the authorized action and can include activities such as the processing, transportation, and any end-use combustion of the fossil fuel mineral products.

As the steward of the greatest percentage of federal lands, the BLM manages about 245 million acres of public lands encompassing approximately 10 percent of the nation's total surface area. In addition, the BLM administers the onshore federal mineral estate (subsurface) which covers a total of about 712 million acres from the Eastern United States to Alaska (BLM 2027) [1]. In keeping with its multiple use and sustained yield mandate in accordance with the Federal Land Policy and Management Act (FLPMA) of 1976 and the Mineral Leasing Act (MLA) of 1920 (30 U.S.C 181 et seq.), the BLM leases minerals including coal, oil, and gas on the onshore federal mineral estate and authorizes development of these leased minerals. Approximately 24.96 million acres of the federal mineral estate have been leased through BLM's coal leasing and oil and gas leasing programs. About half (approximately 50.57%, or 12.62 million acres) of the leased mineral estate are currently producing federal fossil fuels (coal, oil, gas). Statistics maintained by the Office of Natural Resources Revenue (ONRR) show that approximately 242.8 million tons of coal, 555.7 million barrels of oil, and 3.9 billion cubic feet of gas were produced from these leased acres in 2023, or about 42% of the nation's coal supply and 11.7% and 8.7% of the nation's oil and gas supply, respectively. **Note:** The total area of onshore federal mineral estate does not imply that economically recoverable quantities of minerals exist at that scale; it is simply an administrative area.

1.2 Using this Report

Consistent with 40 CFR § 1501.12 (Incorporation by reference) and mandates to reduce paperwork, National Environmental Policy Act (NEPA) document preparation time, and overall NEPA document lengths, this report may be incorporated by reference (IBR) into applicable NEPA documents to aid in describing reasonably foreseeable environmental trends in the affected environment (40 CFR § 1502.15), and to provide context for impacts analysis of GHG emissions resulting from the federal action being analyzed. Consistent with Council on Environmental Quality (CEO) regulations, Department of the Interior regulations, and BLM policy, when this report is incorporated by reference, the BLM must cite and summarize this report (see 40 CFR § 1501.12; 43 CFR § 46.135; and BLM

Handbook H-1790-1, "NEPA Handbook", chapter 5.2.1) and ensure it is available for inspection by potentially interested persons. In the course of incorporating this report by reference, the NEPA document should also explicitly incorporate all linked content and reference materials used in this report to provide for a complete record. **Note:** This report does not take the place of an analysis and disclosure of emissions at the project level that may be completed for NEPA analysis specific to a decision to lease or authorize development, but this report supplements that analysis by providing an evaluation of cumulative emissions from fossil fuel authorizations on a state and national level.

~~This report is available in two formats: a static report and a dynamic online tool. The static version is essentially any printed version of the dynamic web tool and should be used to support the administrative records for applicable federal decisions at the point in time that NEPA analysis is conducted. The web-based version is dynamic and allows for real-time data incorporation and transformations that are not easily replicated in a nondigital format. The web version is built to be interactive and allow readers to quickly explore and find various datasets such that the context and conclusions of the report can be easily understood. Dynamic content contained within the various report elements will load and render applicable datasets based on the user's interaction with the element's control(s). The interactive design means that readers will need to take care to ensure that any dynamic datasets of interest are rendered (i.e. visible) in the document prior to printing the report, as the browser will only print what is rendered. For example, most of the charts in this report allow users to explore multiple datasets; however, only the visible dataset is printed. The report will not print all of the available chart configurations for a particular dataset which could number in the hundreds. Users can save individual charts by right clicking and selecting "save image as. .." to download a copy, and in most case the data for a rendered chart can be downloaded as well.~~

This report was prepared by air quality, fluid minerals, and leasing specialists across the BLM, to make a broad but concerted effort to utilize and present the best data and statistics available for estimating emissions associated with BLM-authorized actions in a consistent manner. This data was analyzed using the best available science applicable to the onshore federal mineral estate. As new information and models become available, the BLM will continue to improve and revise its emission estimates, methodologies, and assumptions as appropriate. This report will be updated annually, and each annual version of the report will review the accuracy of the estimates and projections represented in previous versions and will incorporate actual data from the previous year, to calibrate assumptions used in the next year's emissions estimates and projections and thereby improve the accuracy of each iteration of the report.

1.3 Updates and Breaking Changes

There were no major changes to this year's report, beyond dropping support for the short-term coal statistics projections previously shown in table 6-7. We also note that the EIA did not update their Annual Energy Outlook report for 2024, and thus this report is still using the 2023 outlook for long-term forecasts.

1.4 Disclaimer

Much of the sourced information for this report has been obtained, summarized, or linked from the presentations of various governmental agencies, international institutions, and nongovernmental organizations. All information in this report is being provided "as is," and while the authors made every attempt to ensure that the information is timely, complete, accurate, and obtained from reliable sources, the BLM makes no guarantee that it is free of errors or omissions. ~~Hyperlinks contained within the report connect to other websites that are maintained by other Federal Government agencies or nonfederal entities over which the BLM exercises no control.~~ The BLM does not make any representation as to the accuracy or any other aspect of information contained in linked content or data obtained from external application programming interfaces. The projections and evaluations of the data developed and disclosed in this report are presented strictly to display assumptions for analysis and should not be interpreted as an exacting prediction or guarantee of future conditions, emission trends, or as an emissions cap or authorization limit. This report is not intended to, and does not create any right or benefit, substantive or procedural, enforceable at law or in equity by a party against the United States, its departments, agencies, or entities, its officers, employees, agents, or any other person.

The BLM reserves the right to modify this document at any time to address deficiencies, inadvertent omissions and errors, or to address changes in the evolution of climate science that warrant intra-annual document updates in order to elevate awareness and inform decision making.

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2.0 Relationships to Other Laws and Policies

This chapter outlines several laws and regulations that could affect sources of GHGs subject to review and disclosure under NEPA that are relative to federal mineral authorizations. **Note:** This section of the report is not a legal treatise, analysis, or opinion. The statutes and regulations governing the BLM and mineral operations on federal lands speak for themselves. Information about legal requirements summarized in this report is not intended to be comprehensive, but rather is included for convenience of analysis.

2.1 Federal Land Policy and Management Act

The Federal Land Policy and Management Act (FLPMA) of 1976 (43 USC §§ 1701-1785) provides the majority of the BLM's legislated authority, policy direction, and basic management guidance. This act outlines the BLM's role as a multiple use land management agency and provides for management of the public lands under principles of multiple use and sustained yield unless otherwise provided by law. The act states a policy that public lands are to be managed "in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values" (Sec. 102(a)(8)). To fulfill this responsibility, the BLM's land use plans ensure "compliance with applicable pollution control laws, including State and Federal air, water, noise, or other pollution standards or implementation plans" (Sec. 202(c)(8)). Accordingly, BLM leases and operating permits for fossil fuels require compliance with all state and federal air pollution requirements. FLPMA also gives the BLM authority to revoke or suspend any BLM-authorized activity that is found to be in violation of regulations applicable to public lands and/or noncompliance with applicable state or federal air quality standards or implementation plans, thus ensuring that the BLM can provide for compliance with applicable air quality standards, regulations, and implementation plans (Sec. 302(c)). Thus, for purposes of analysis, the BLM assumes full compliance with applicable state and federal air quality requirements, emissions standards, and related equipment and performance standards in effect at the time of the writing of the report.

2.2 Mineral Leasing Act

The Mineral Leasing Act (MLA) of 1920 (30 U.S.C. 181 et seq.), as amended, authorizes and governs leasing of public lands for development of deposits of coal, oil, gas and other hydrocarbons, sulfur, phosphate, potassium, and sodium. Section 185 of this title contains provisions relating to granting of rights-of-ways through Federal lands for pipelines. The MLA and the Mineral Leasing Act for Acquired Lands of 1947 give the BLM responsibility for oil and gas leasing of minerals underlying about 712 million acres of BLM-managed surface lands, National Forest System lands, other federal lands managed by other agencies, and state and private surface lands where the mineral rights underneath were retained by the Federal Government. The Federal Onshore Oil and Gas Leasing Reform Act of 1987 (Sec. 5102) amended the MLA (30 U.S.C. 226) and directs the BLM to conduct lease sales for each state where eligible lands are available at least quarterly. Leases are first offered for sale at competitive auctions and then are made available noncompetitively, for 2 years, if a qualified bid is not received at the competitive sale.

2.3 National Environmental Policy Act

The National Environmental Policy Act (NEPA) of 1969 (42 U.S.C § 4321 et seq.) ensures that information on the potential environmental and human impact of federal actions is available to public officials and citizens before decisions are made and before actions are taken. One of the purposes of the act is to "promote efforts which will prevent or eliminate damage to the environment and biosphere" and to promote human health and welfare (Section 2). This act requires that agencies prepare a detailed statement on the environmental impact of the proposed action for major federal actions expected to significantly affect the quality of the human environment (Section 102(C)). In addition, agencies are required, to the fullest extent possible, to use a "systematic, interdisciplinary approach" in planning and decision-making processes that may have an impact on the environment (Section 102(A)).

2.4 Council on Environmental Quality

The Council on Environmental Quality (CEO) is an entity within the executive office of the President that is responsible for coordinating federal efforts to improve, preserve, and protect America's public health and environment. The CEO oversees the implementation of NEPA by issuing guidance, interpreting regulations, and approving federal agency NEPA procedures.

~~On January 9th, 2023, CEO issued interim GHG guidance that updates CEQ's 2016 *Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews ("2076 GHG Guidance")*, that highlights best practices for analysis grounded in science and agency experience. A summary of key recommendations from the guidance agencies should implement is as follows~~

- ~~quantify a proposed action's projected GHG emissions or reductions for the expected lifetime of the action, considering available data and GHG quantification tools that are suitable for the proposed action;~~
- ~~discuss methods to appropriately analyze reasonably foreseeable direct, indirect, and cumulative GHG emissions;~~
- ~~use projected GHG emissions associated with proposed actions and their reasonable alternatives to help assess potential short- and long-term climate change effects;~~
- ~~monetize the effects of a project's GHG emissions using the social cost of GHGs;~~
- ~~use the best available science (including modeling) when assessing the potential future state of the affected environment in NEPA analyses and to help explain the real-world effects-including effects that will be experienced locally in relation to the proposed action-associated with an increase in GHG emissions that contribute to climate change;~~
- ~~explain how a proposed action and alternatives would help meet or detract from achieving climate action goals or commitments; and~~
- ~~consider implementing mitigation measures to the greatest extent possible and as early in project development as possible to avoid or reduce GHG emissions in accordance with the recommended standards to evaluate the verifiability, durability and enforceability of mitigation measures.~~

2.5 Executive Orders

Reserved.~~Executive orders (EOs) and memoranda were issued to address the climate crisis and focus on GHG emission reductions and increased renewable energy production. The orders rescind previous CEQ guidance on analysis of GHG emissions, with the goal of reviewing, revising/updating, and issuing new guidance on the consideration of GHGs and climate change in NEPA analysis. Finally, the methodologies for the calculation of the social cost of carbon, nitrous oxide, and methane, as well as the incorporation of this information in NEPA and other analyses are key subjects selected for review and potential revision. The following is a summary of two of the EOs:~~

~~*EO 13990 - Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis (January 25, 2027):* Directs all executive departments and agencies to immediately commence work to confront the climate crisis with the goal to improve public health and the environment. Two key directives in this EO are (7) the establishment of an Interagency Working Group on the Social Cost of Greenhouse Gases tasked with developing and promulgating costs for agencies to apply during cost-benefit analysis and (2) the recission of the CEQ draft guidance, entitled "Draft National Environmental Policy Act Guidance on Consideration of Greenhouse Gas Emissions," 84 FR 30097 (June 26, 2019). The EO also directs the Secretary of the Interior to place a temporary moratorium on all oil and gas activities in the Arctic National Wildlife Refuge, revokes the permit for the Keystone XL pipeline, and requires all agency heads to review any agency activity under the prior administration to ensure compliance with the current administration's environmental policies.~~

~~***EO 14008 - Tackling the Climate Crisis at Home and Abroad (January 27, 2027):*** Directs the executive branch to establish climate considerations as an element of U.S. foreign policy and national security and to take a government-side approach to the climate crisis. This EO reaffirms the decision to rejoin the Paris Agreement, commitments to environmental justice and new clean infrastructure projects, establishing a National Climate Task Force, and puts the U.S. on a path to achieve net-zero emissions by no later than 2050. Specific directives for the Department of the Interior and the BLM include increasing renewable energy production on public lands and waters, performing a comprehensive review of potential climate and other impacts from oil and natural gas development on public lands, establishing a civilian climate corps, and working with key stakeholders to achieve a goal of conserving at least 30 percent of the nation's lands and waters by 2030.~~

2.6 United States Global Change Research Program

The United States Global Change Research Program (USGCRP) is a federal program that was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act of 1990 (Public Law 107-606; 104 Stat 3096-37 04). The Global Change Research Act mandates that the USGCRP deliver a report, known as the National Climate Assessment (NCA) to Congress and the President no less than every 4 years. Fourteen federal agencies collaborate to advance understanding of the changing earth system and maximize efficiencies in federal global change research. The fourth, and most recent report, NCA4, was released in two volumes in 2017 and 2018, and elements of each volume have been summarized and incorporated into this report to describe the known effects of climate change. The Fifth National Climate Assessment (NCA5) is currently underway, with anticipated delivery in 2023.

2.7 Clean Air Act

GHGs are considered air pollutants and are regulated under the Clean Air Act (CAA) (42 U.S.C. § 7407 et seq.). The U.S. Supreme Court first ruled that GHGs are air pollutants in 2007 (Massachusetts v. Environmental Protection Agency, 549 U.S. 497 (2007)) and instructed the Environmental Protection Agency (EPA) to determine if GHG emissions endanger public health and welfare. In April 2009, the EPA issued its endangerment finding; in May 2070 issued its GHG Tailoring Rule (40 CFR Part 57, 52, 70, et al.); and in January 2071, the EPA began regulating GHGs under its Prevention of Significant Deterioration (PSD) and Title V permitting programs.

The EPA set initial emissions thresholds for PSD and Title V permitting applicable to stationary sources that emit greater than 100,000 tons of carbon dioxide equivalents (CO_2e) per year (e.g., some power plants, landfills, and other sources) or modifications of major sources with resulting emissions increases greater than 75,000 tons of CO_2e per year. However, in 2074, the U.S. Supreme Court (Utility Air Regulatory Group v. EPA, 573 US 302,134 (2014)) held that the EPA may not treat GHGs as an air pollutant for purposes of determining whether a source is a major source required to obtain a PSD or Title V operating permit under the CAA.

In 2009, the EPA published a rule for the mandatory reporting of GHGs (40 CFR Part 98, Subpart C), which is referred to as the Greenhouse Gas Reporting Program (GHGRP). This rule establishes mandatory GHG reporting requirements for owners and operators of certain facilities that directly emit GHGs as well as for certain indirect emitters, or suppliers. For suppliers, the GHGs reported are the quantity that would be emitted from combustion or use of the products supplied. The rule provides a basis for future EPA policy decisions and regulatory initiatives regarding GHGs. Facilities are generally required to submit annual reports under 40 CFR Part 98 if annual emissions exceed 25,000 metric tons of CO_2e per year.

2.8 Specific Regulatory Requirements

Various laws and regulations have been implemented by air quality regulatory agencies that limit GHG emissions from mining activities and oil and gas production, transmissions, and distribution facilities. Although many of the laws and regulations subsequently summarized focus on limiting criteria air pollutants or precursors such as volatile organic compounds, they also have a secondary benefit of limiting GHG emissions [2].

Federal Rules

Federal regulations require that GHG emissions related to coal be quantified and reported under 40 CFR 98. 40 CFR 98, Subpart FF, requires underground coal mines to report methane emissions. Coal-fired electric power plants are required to continuously monitor carbon dioxide emissions under 40 CFR 98, Subpart D, and submit quarterly emission reports to EPA under 40 CFR 75. Petroleum and natural gas systems are also required to report GHG emissions under 40 CFR 98, Subpart W.

The Mine Safety and Health Administration requires methane monitoring in underground mines and sets limits on methane concentrations to protect the life, health, and safety of the miners, but it does not limit methane emission amounts.

The EPA has established emissions control requirements in the New Source Performance Standards (NSPS) at 40 CFR Part 60 that apply to coal, oil, and natural gas production facilities. 40 CFR 60, Subparts 0000 thru OOOOc, for example, serve to control methane emissions from oil and natural gas industry sources by requiring reduced emissions completions ("green" completions) on new hydraulically fractured gas wells as well as emissions controls on pneumatic controllers, pumps, storage vessels, and compressors. EPA estimates the updated rules will avoid 58 million tons of methane emissions, 16 million tons of VOCs, and approximately 590,000 tons of air toxics from now until 2038. Other relevant NSPS requirements under 40 CFR Part 60 include:

- **Subpart GG** - Standards of Performance for Stationary Gas Turbines
- **Subpart IIII** - Standards of Performance for Stationary Compression Ignition Internal Combustion Engines
- **Subpart JJJJ** - Standards of Performance for Stationary Spark Ignition Internal Combustion Engines
- **Subpart K** - Standards of Performance for Storage Vessels for Petroleum Liquids for which Construction, Reconstruction, or Modification Commenced after June 11, 1973 and prior to May 19, 1978
- **Subpart Ka** - Standards of Performance for Storage Vessels for Petroleum Liquids for which Construction, Reconstruction, or Modification Commenced after May 18, 1978 and prior to July 23, 1984

- **Subpart Kb** - Standards of Performance for Storage Vessels for Petroleum Liquids for which Construction, Reconstruction, or Modification Commenced after July 23, 1984
- **Subpart KKK** - Standards of Performance for Equipment Leaks of VOe from Onshore Natural Gas Processing Plants for Which Construction, Reconstruction, or Modification Commenced After January 20, 1984, and on or Before August 23, 2011
- **Subpart KKKK** - Standards of Performance for Stationary Combustion Turbines
- **Subpart OOOO** - Standards of Performance for Crude Oil and Natural Gas Production, Transmission, and Distribution for which Construction, Modification, or Reconstruction Commenced after August 23, 2011
- **Subpart OOOOa** - Standards of Performance for Crude Oil and Natural Gas Production, Transmission, and Distribution for which Construction, Modification, or Reconstruction Commenced on or after September 18, 2015 and before December 6, 2022
- **Subpart OOOOb** - Standards of Performance for Crude Oil and Natural Gas Facilities for which Construction, Modification or Reconstruction Commenced after December 6, 2022
- **Subpart OOOOc** - Standards of Performance for Existing Crude Oil and Natural Gas Facilities Constructed on or before December 6, 2022
- **Subpart TTTT** - Standards of Performance for Greenhouse Gas Emissions for Electric Generating Units
- **Subpart V** - Standards of Performance for Coal Preparation and Processing Plants

In addition to the EPA's rules, the BLM finalized the Waste Prevention, Production Subject to Royalties, and Resource Conservation Rule - also known as the Waste Prevention Rule - in April 2024. The new version requires operators of oil and gas leases to take reasonable steps to avoid natural gas waste, as well as develop leak detection, repair and waste minimization plans. When natural gas loss could have been avoidable, the rule ensures public and Tribal mineral owners are properly compensated through royalty payments. The rule is expected to generate more than $50 million in additional natural gas royalty payments each year and conserve billions of cubic feet of gas that might have otherwise been vented, flared, or leaked.

The State of Alaska established administrative code 18 AAC 50 which describes air quality control for the state. Under 18 AAC 50.040, the state adopted emissions control standards established in 40 CFR Part 60 as they apply to a Title V source.

California

The California Air Resources Board regulation on "Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities" (17 CCR 95665 - 95677) sets equipment standards, testing requirements, and leak detection requirements for crude oil and gas production and storage facilities. Requirements are similar to federal standards under 40 CFR 60, Subpart OOOOa, but are more stringent, cover additional types of equipment and operations, and apply to existing as well as new sources. Although the rule is focused on controlling GHG emissions, the standards and monitoring employed also control volatile organic compound and hazard air pollutant emissions.

The California Code of Regulations, Title 17, sections 1700 - 1883, govern the siting, development, operation, monitoring, inspection, stimulation, and abandonment of oil and gas production wells and gas storage wells. The regulations are intended to protect the environment, preserve safety, and prevent loss or waste of produced oil and gas. Although they are not specifically designed to reduce GHG emissions, provisions limiting loss and waste of gas and requiring effective abandonment reduce methane emissions from wells in California.

California's "Mandatory Greenhouse Gas Emissions Reporting" (17 CCR 95100-95163) requires petroleum and natural gas system operators to report their annual GHG emissions to the California Air Resources Board.

California's cap-and-trade program, launched in 2013, is among a suite of major policies the state uses to lower its GHG emissions. In 2022, the California Air Resources Board issued the 2022 Scoping Plan for Achieving Carbon Neutrality. The Plan lays out a path to achieve targets for carbon neutrality and reduce anthropogenic greenhouse gas (GHG) emissions by 85 percent below 1990 levels no later than 2045. The state also has a goal of 100 percent carbon-free electricity by 2045. However, the Plan concludes that it is not feasible to phase out oil and gas production fully by 2045.

Colorado

The Colorado Energy and Carbon Management Commission (ECMC) regulates oil and gas related activities in Colorado. In addition, the Colorado Department of Public Health Environment (CDPHE) has regulations, reporting, and permitting requirements for oil and gas operations in Colorado. The BLM currently requires all federal oil and gas development and operations in Colorado to obtain the necessary permits and follow the applicable rules and regulations set forth by the ECMC and CDPHE.

Recent Colorado legislative actions have resulted in rules and regulations aimed at inventorying and reducing GHG emissions to meet Colorado's GHG emissions goals. Colorado Senate Bill 19-096 (SB 96), addressing GHG emissions data collection, and House Bill 19-1261 (HB 1261), addressing statewide GHG reduction goals, were signed into law on May 30, 2019. SB 96 directs the Air Quality Control Commission (AQCC) to update the state-wide GHG inventory at least every two years and to adopt rules requiring monitoring and public reporting of GHG emissions in support of state GHG reduction goals. The AQCC adopted GHG inventory and reporting requirements for oil and gas under Regulation 7 in December 2019 and September 2020 and adopted a comprehensive statewide GHG reporting rule under Regulation 22 in May 2020. In December 2023, the AQCC adopted the GHG intensity verification rule under Regulation 7. This rule defines how certain oil and gas facilities must calculate their GHG intensity, monitor operations to ensure compliance with intensity standards, and keep records to accurately account for emissions from their operations. Colorado House Bill 21-1266 (signed into law July 2021) required the AQCC to establish a fee for GHG emissions. In February 2024, the AQCC adopted a rule under Regulation 3 to establish fees for GHG emissions. The fees apply to Colorado's largest GHG emitters that release more than 25,000 metric tons of $C0_2e$ per year.

Future rules and regulations may further affect oil and gas development and operations on the federal mineral estate in Colorado. In January 2021, Colorado published its GHG Pollution Reduction Roadmap report to describe pathways and strategies for achieving goals described in HB 1261. Specifically, the Roadmap included near-term actions to reduce GHG emissions that progress towards Colorado's 2025 and 2030 GHG emissions reduction goals. Since being published, Colorado has tracked the implementation of an identified list of the near-term actions, and by December 2022 had begun work or completed over 90% of the identified actions. In February 2024, Colorado published an update to the Roadmap (Roadmap 2.0). Roadmap 2.0 includes an updated inventory of GHG emissions and a new set of near-term actions that will guide implementation in the state through 2026. Roadmap 2.0 shows that without any new rules or laws beyond what is already underway as of the fall 2023, Colorado is projected to be more than 80% of the way to meeting its statutory goal of a 50% emissions reduction in 2030 from 2005 levels. As a part of this Roadmap update, Colorado has committed to 49 additional near-term actions that will drive emissions reductions in every sector including oil and gas. The additional oil and gas actions include enforcing intensity requirements for operations, develop strategies for net GHG neutral oil and gas development and operations, well plugging, reducing truck emissions associated with oil and gas operations, and study alternative uses for oil and gas wells.

Under the Interest Rate Reduction Act (IRA), the Denver Regional Council of Governments (DRCOG) was awarded with an EPA Climate Pollution Reduction Grant for the Denver-Aurora-Lakewood Metropolitan Statistical Area and prepared a Priority Climate Action Plan consistent with the grant requirements. The plan describes eight near-term, high-priority, implementation-ready measures to reduce greenhouse gas emissions, improve air quality and drive equity in the Front Range of Colorado. DRCOG is scheduled to complete its Comprehensive Climate Action Plan by August 2025.

Montana

The Montana Board of Oil and Gas Conservation (MBOGC) regulates oil and gas exploration and production in the state. MBOGC regulations related to air impacts from oil and gas operations can be found in Title 36, Chapter 22 of the Administrative Rules of Montana (ARM) and include regulation 36.22.1207 which prohibits the storage of waste oil and oil sludge in pits and open vessels. The Montana Department of Environmental Quality (MDEQ) administers rules and regulations to implement the Montana Environmental Policy Act and the Montana Clean Air Act. MDEQ rules for air emissions from oil and gas operations can be found in Title 17, Chapter 8 of the ARM and include requirements for controlling volatile organic compound vapors at a 95% or greater control efficiency, loading and unloading of hydrocarbon liquids using submerged fill technology, and equipping internal combustion engines with nonselective catalytic reduction or oxidation catalytic reduction.

New Mexico

The New Mexico Environment Department (NMED) has developed the "Oil and Natural Gas Regulation for Ozone Precursors" (20.2.50.1 NMAC), which was published on July 26, 2022, with an effective date of August 5, 2022. Approximately 50,000 wells and associated equipment will be subject to this regulation. It is anticipated that the regulation will annually reduce volatile organic compound emissions by 106,420 tons, nitrogen oxide emissions by 23,148 tons, and methane emissions by 200,000 to 425,000 tons. The regulation includes emissions reduction requirements for compressors, engines and turbines, liquids unloading, dehydrators, heaters, pneumatics, storage tanks, and pipeline inspection gauge (PIG) launching and receiving. The regulation also encourages operators to stop venting and flaring and use fuel cells technology to convert CH_4 to electricity at the well site and incentivizes new technology for leak detection and repair [3].

The New Mexico Oil Conservation Division of the Energy, Minerals and Natural Resources Department (EMNRD) finalized its natural gas waste rules in March 2021. The rules went into effect in May 2021 and require 98% gas capture from oil and gas production and midstream operations by the end of 2026, as well as banning routine venting and flaring[4].

North Dakota

The North Dakota Department of Mineral Resources' Oil and Gas Division regulates the drilling and production of oil and gas and includes regulations that ban the venting of natural gas and require that vented casinghead gas be burned through a flare (North Dakota Administrative Code 43-02-03-45). The North Dakota Industrial Commission (NDIC) has jurisdiction over the volume of gas flared at a well site to conserve mineral resources and established Order No. 24665 for reducing gas flaring. The order requires producers to submit a gas capture plan with every drilling permit application. The North Dakota Department of Environmental Quality's Division of Air Quality has established permitting and reporting requirements for oil and gas facilities under North Dakota air pollution control rules, Chapter 33.1-15-20, and submerged fill and flare requirements in Chapter 33.1-15-07.

Utah

The Utah Department of Environmental Quality established administrative code R307-500 which applies to all oil and natural gas exploration, production, and transmission operations; well production facilities; natural gas compressor stations; and natural gas processing plants in Utah. These rules adopt emissions control standards established in 40 CFR Part 60, Subpart 0000. Controls are required for pneumatic controllers, venting and flaring, tank truck loading, storage vessels, dehydrators, VOC control devices, stationary natural gas engines, and leak detection and repair requirements.

Wyoming

The Wyoming Department of Environmental Quality established Wyoming Air Quality Standards and Regulations (WAQSR). Chapter 6 (Section 2) and Chapter 3 (Section 6) of those regulations apply to all oil and natural gas exploration, production, and transmission operations; well production facilities; natural gas compressor stations; and natural gas processing plants in Wyoming. These rules adopt emissions control standards established in 40 CFR Part 60, Subpart 0000. Controls are required for pneumatic controllers, venting and flaring, tank truck loading, storage vessels, dehydrators, VOC control devices, stationary natural gas engines, and leak detection and repair requirements.

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3.0 Greenhouse Gases

Gases that trap heat in the atmosphere are called greenhouse gases (GHGs). Current ongoing global climate change is caused, in part, by the atmospheric buildup of GHGs, which may persist for decades or even centuries. Since the start of the Industrial Revolution, human activities have increased GHG emissions substantially above historical background levels.

The primary GHGs emitted by natural and anthropogenic sources include water vapor, carbon dioxide, methane, ozone, nitrous oxide, and chlorofluorocarbons. Water vapor is the largest contributor to the natural greenhouse effect. On average, water accounts for about 60% of the warming effect. However, water vapor is fundamentally different from other GHGs in that it can condense and rain out when it reaches high concentrations, and the total amount of water vapor in the atmosphere is in part a function of the earth's temperature (EPA 2021). Water vapor has a short residence time of approximately 10 days in the atmosphere. While water vapor does have a warming effect on the earth, water vapor does not control the earth's temperature. Instead, water vapor concentrations in the atmosphere are controlled by the earth's temperature (ACS 2021) [5]. More water evaporates from the earth at higher temperatures, which increases the amount of moisture in the clouds that eventually falls as precipitation.

Anthropogenic GHGs are commonly emitted air pollutants that include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_20), and several fluorinated species of gases such as hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Carbon dioxide is by far the most abundant, and more than two-thirds of man-made CO_2 emissions in the U.S. come primarily from the transportation and electricity production sectors. Methane from human activities accounts for approximately 10% of total U.S. GHG emissions and results from primarily agriculture and natural gas and petroleum systems. Nitrous oxide emissions from agriculture, fuel combustion, and industrial sources account for approximately 7% of the total U.S. GHG emissions. Fluorinated gases are powerful GHGs that are emitted from a variety of industrial processes and are often used as substitutes for ozone-depleting substances (i.e., chlorofluorocarbons, hydrochlorofluorocarbons, and halons), but they are not typically associated with SLM-authorized activities and, as such, will not be discussed further in this report. This report will address the three major GHGs associated with BLM's fossil energy development authorizations, namely CO_2, CH_4, and N_20. **Note:** Not all of the emissions estimates contained in this report include separate values for each gas due to data limitations, particularly where some of the methodologies employed combine these gases into a single CO_2 equivalent output that the BLM cannot separate.

Each of these gases can remain in the atmosphere for different lifetimes, ranging from about a decade to thousands of years. As a result, these gases become well mixed such that their measurement in the atmosphere is roughly the same all over the earth, regardless of the source or origin of the emissions. For this reason, global GHG emissions are the most useful basis for the cumulative analysis of emissions related to BLM actions. Unlike other common air pollutants, the ecological impacts that are attributable to the GHGs are not the result of localized or even regional emissions but are entirely dependent on the collective behavior and emissions of the world's societies.

3.1 Carbon Dioxide (CO_2)

Of the primary GHGs, CO_2 is the most widely occurring. It is a major component of natural carbon cycling in the terrestrial biosphere including photosynthesis (CO_2 uptake by plants) and respiration (CO_2 release by plants, animals, and microorganisms), decomposition, and ocean releases. Carbon dioxide is emitted from human activities including the combustion of fossil fuels (ie., coal, oil, and natural gas), solid waste, deforestation and wood products manufacturing, and from certain chemical reactions such as steam reforming for the production of hydrogen and calcination for the production of cement clinker. Carbon dioxide emissions accounted for 81% of the total U.S. GHG emissions in 2018 (EPA 2021) [6]. Global ambient CO_2 concentrations increased to an average of 419.3 parts per million (ppm) in 2021. This average is estimated by the National Oceanic and Atmospheric Administration (NOAA) to be the highest average concentration of global CO_2 in the past 800,000 years (Lindsey 2020) [7]. This represents a nearly 50% increase since the beginning of the Industrial Age, when the concentration was near 280 ppm, and a 13 percent increase since 2000, when it was near 370 ppm.

The lifetime of CO_2 in the atmosphere varies between 20 and 1,000 years and is difficult to determine precisely because several processes remove it from the atmosphere. On average, approximately 50% of the CO_2 released into the atmosphere from the burning of fossil fuels remains in the atmosphere while the other 50% is absorbed by plants and trees and certain areas of the ocean (NOAA 2015) [8].

3.2 Methane (CH_4)

Methane is a powerful GHG that is more than 29 times more effective at trapping heat in the atmosphere than CO_2. According to the EPA, methane concentrations in the atmosphere have more than doubled in the last two centuries, largely due to human-related activities. Methane emissions accounted for 9.5% of U.S. GHG emissions in 2018. Methane is emitted during the production and transportation of coal, natural gas, and oil. It is also produced biologically under anaerobic conditions in ruminant animals, wetlands, landfills, and wastewater treatment facilities. In addition, fertilizer use, agriculture, and changes in land use (e.g., from forest to grazing) are major sources of CH_4 in the atmosphere.

3.3 Nitrous Oxide (N_2O)

Nitrous oxide is produced by biological processes that occur in soil and water and by a variety of anthropogenic activities in the agricultural, energy, industrial, and waste management fields. While total N_2O emissions are much lower than CO_2 emissions, N_2O is 273 times more powerful than CO_2 at trapping heat in the atmosphere. Since 1750, the global atmospheric concentration of N_2O has risen by approximately 22% (WMO 2018)[9]. The main anthropogenic activities producing N_2O in the United States are agricultural soil management, stationary fuel combustion, manure management, fuel combustion in motor vehicles, and adipic acid production.

3.4 Global Warming Potentials

The impact of a given GHG on global warming depends both on its radiative forcing and how long it lasts in the atmosphere. Each GHG varies with respect to its concentration in the atmosphere and the amount of outgoing radiation absorbed by the gas relative to the amount of incoming radiation it allows to pass through (i e., radiative forcing). Different GHGs also have different atmospheric lifetimes. Some, such as methane, react in the atmosphere relatively quickly (on the order of 12 years); others, such as carbon dioxide, typically last for hundreds of years or longer. Climate scientists have calculated a factor, known as the global warming potential (GWP), for each GHG that accounts for these effects.

The GWP is used as a conversion factor to convert a mixture of different GHG emissions into carbon dioxide equivalents (CO_2e). Specifically, GWP is a measure of how much energy the emissions of 1 ton of a GHG will absorb over a given period, relative to 1 ton of CO_2 in the same timeframe. The larger its GWP, the more the specific gas warms the earth as compared to CO_2. The GWP for CO_2 is defined as 1 regardless of the timeframe, because the gas is being used as the reference. The GWP values are updated periodically to account for changing concentrations in the atmosphere and as new estimates on energy absorption or atmospheric lifetime for each gas become available.

GWPs have been developed over different time horizons including 20-year, 100-year, and 500-year for several GHGs. The GWP for a relatively short-lived GHG, such as CH_4, is larger over short periods (for example, 20 years) than it is over longer periods (such as 100 years) because most of the CH_4 will have reacted away well before 100 years have passed. Conversely, very long-lived GHGs have a 20-year GWP that is lower than the 100-year GWP because the time-integrated radiative forcing is less (relative to CO_2) over the shorter time interval. As a result of various complex feedbacks in the earth-atmosphere system, GWPs can be only roughly estimated; according to the Intergovernmental Panel on Climate Change (IPCC), GWPs have a large uncertainty: ±26 percent and ±11 percent for the 20-year and 100-year CH_4 GWPs, respectively, and ±118 percent and ±130 percent for the 20-year and 100-year N_2O GWPs, respectively (IPCC 2021). 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. Also, no single metric adequately represents the global warming effects of GHGs due to their differing amounts of climate forcing, atmospheric lifetimes, and emissions profiles.

For the base year of this report (2020), the BLM used the IPCC Fifth Assessment Report (AR5) GWPs (shown in Table 3-1), as these values are commonly used by other entities in emissions inventories and reporting requirements and by the EPA in its climate science communications. The IPCC has now produced the Sixth Assessment Report (AR6) with contributions by its three working groups to provide a synthesis report, three special reports, and a refinement to its latest methodology report. In August of 2021, Working Group I released its report entitled, "Climate Change 2021: The Physical Science Basis," which includes updated GWPs. For the purposes of this report, the BLM is using the updated AR6 GWP values for CH_4 and N_2O (shown in Table 3-1). **Note:** There are references to emissions data or aggregated emissions in this report that are developed by entities that use different GWPs than those presented in this section. Any external emissions data (e.g., EPA's "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020," which uses AR4 GWP values) are being presented at face value, meaning that the BLM is not attempting to convert those emissions to the GWP basis presented in this report. The variability in GWPs used in various reports may introduce small numerical differences when comparing emissions on a relative basis. Readers are encouraged to investigate additional information provided by other agencies, such as Annex 6 of the EPA's "Inventory of U.S. Greenhouse Gas Emissions and Sinks," to understand the differences in total GWP-weighted emissions reported by these agencies. As the AR6 GWPs are adopted in other agency's reporting requirements, inventories, and communications, the BLM will update any incorporated data to allow for more accurate comparisons.

The BLM uses the 1DO-year time horizon for GWPs for the emissions calculated in this report and most of the report metrics, to be consistent with the scientific and regulatory communities that develop climate change assessments and policy. The 1DO-year GWP (GWPl 00) 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 by researchers and regulators. In addition, the EPA uses the 1OD-year time horizon in its annual inventory, GHGRP, and uses the GWPs and time horizon consistent with the IPCC Fifth Assessment Report (assume similar for AR6).

The 1DO-year time horizon allows the BLM to compare GHG emissions from its authorized coal, oil, and gas development to other available state and national emissions inventories which also use 1OD-year GWPs. This timeframe also more fully accounts for any climate feedbacks (discussed in chapter 8), where greater climate impacts are expected to occur further in time away from the point of initial perturbation (emissions) of the climate system. The 1DO-year timeframe provides a 1-to-1 basis of comparison for the metrics most often used to discuss climate change in the literature in terms of emissions, model results, impacts, and potential emission targets and is therefore more meaningful and understandable for the purposes of this analysis as compared to any other available GWP timeframe. **Note:** Unless otherwise noted, the BLM uses GWP emissions factors inclusive of climate feedbacks to calculate all of the CO_2e estimates in this report.

Table 3-1. Global Warming Potentials

GHG Species	Atmospheric Lifetime (years)	GWP 20-year (AR5)	GWP 20-year (AR6)	GWP 100-year (AR5)	GWP 100-year (AR6)
CO_2	20 - 1,000				
CH_4 (fossil)	11.8 ±1.8	88	82.5	36	29.8
N_2O	109 ±10	268	273	298	273

Data Sources: IPCC AR5 WGI, 2013[10], IPCC AR6 WGI, 2021[11]
Carbon dioxide's lifetime is shown as a range because the gas is not destroyed over time, but rather is transferred between the various reservoirs within the ocean-atmosphere-land system at varying rates. CO_2's GWP includes its own climate feedbacks.

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4.0 Climate Change Science and Trends

Climate refers to atmospheric conditions (e.g., temperature, humidity, pressure, precipitation, solar radiation, wind) at a particular location averaged over a long period of time. The American Meteorological Society defines climate change as "any systematic fluctuation in the long-term statistics of climate elements (e.g., temperature, pressure, or wind) that is sustained over several decades or longer" (AMS 2012) [12] Climatologists commonly use 30-year averages of variables, such as temperature and precipitation, as benchmarks for historical comparison and climate change assessment. While the climate has changed throughout earth's history due to natural forcing, recent climate change is almost entirely the result of increasing GHG concentrations resulting from human activity since the Industrial Revolution.

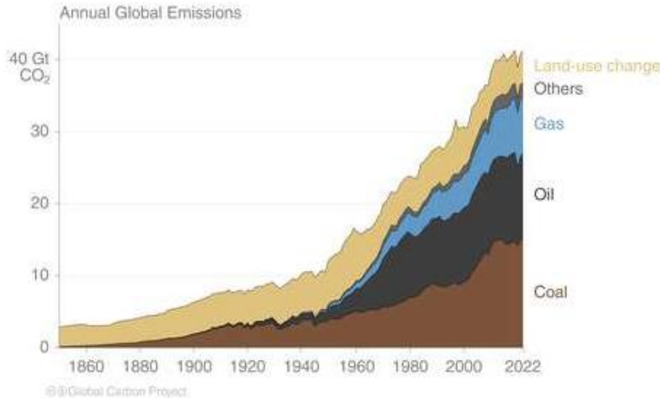
In addition to characterizing long-term weather, climate reflects the frequency, variability, and extreme ranges of atmospheric variables and phenomena. There are numerous sources of natural climate variability on scales ranging from years to millennia, including volcanic eruptions (e.g., Robock 2000) [13], fluctuating solar irradiance (e.g., Schmidt et al. 2012), [14] and changes to Earth's orbit (Milankovitch cycles). There are also many "teleconnections" such as the El Nino Southern Oscillation (ENSO), North Atlantic Oscillation, and Pacific Decadal Oscillation that shape interannual, interdecadal, and multidecadal climate variability. Each of these sources of natural climate variability occur on distinct time scales, some episodic like volcanic eruptions, while teleconnections are cyclical with varying periodicities. Moreover, each source of climate variability produces differing impacts based on region and time of year. For instance, ENSO impacts are more pronounced during winter in the United States, with a strong Pacific Northwest and southwestern United States signal, but no clear impact in the central Rocky Mountains. Teleconnections also do not necessarily produce similar impacts during each occurrence with climate anomalies that differ from typical patterns associated with specific phases of each teleconnection commonly observed. A notable example is the 2015-16 El Nino, which was exceptionally dry in California and relatively wet in the Pacific Northwest, counter to seasonal outlooks and typical El Nino conditions (Cash and Burls 2019) [15]. Multiple modes of atmospheric and oceanic variability introduce tremendous uncertainty in earth's climate on interannual to interdecadal time scales.

On longer time scales, GHG concentrations exert a larger influence on earth's climate than the higher frequency oscillations that produce natural interannual to multiyear variability. Because GHG emissions dominate other sources of climate variability on the multidecade to century time scale, climate change models can project future states of earth's climate based on GHG emissions scenarios.

4.1 Climate Forcing and Feedbacks

The driver for the buildup of heat within the climate system is best described in terms of radiative forcing (RF). The term describes the energy balance (i.e., equilibrium), or the difference between solar radiation absorbed by the earth and the energy radiated back to space that will occur given the heliophysics of the sun-earth system and the basic laws of thermodynamics. Radiative forcing, given in units of watts per square meter ($W\ m^{-2}$), has both positive (+ heating) and negative (- cooling) components, such that altering any of these components will likely cause the climate system to settle into a new equilibrium. GHGs help to contain solar energy loss by trapping longer wave (low energy) radiation emitted from earth's surface, and thus act as a positive forcing component for which the buildup of these gases has contributed to the current changing state of the climate equilibrium towards warming.

Current ongoing global climate change is caused, in large part, by the atmospheric buildup of GHGs, which may persist for decades or even centuries. The buildup of GHGs such as CO_2, CH_4, N_2O, and fluorinated gases since the Industrial Revolution (1760 to 1840) has substantially increased atmospheric concentrations of these compounds compared to background levels. Several types of activities contribute to the phenomenon of climate change, including emissions of GHGs from fossil fuels used as a primary energy source, large wildfires, changes to the natural carbon cycle, and changes to radiative forces and reflectivity (albedo). Between 1850 and 2019, cumulative anthropogenic CO_2 emissions emitted to the atmosphere were approximately 2,400 ± 240 $GtCO_2$. About 43% of these emissions have remained in the atmosphere, while the rest was removed from the atmosphere and stored in natural terrestrial ecosystems (plants and soils - 29%) and in the oceans (28%).



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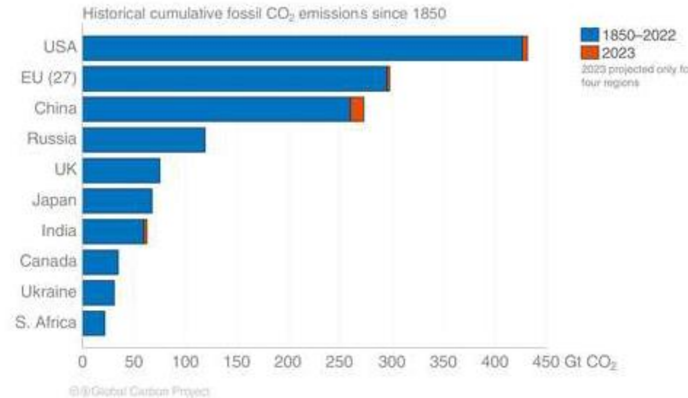
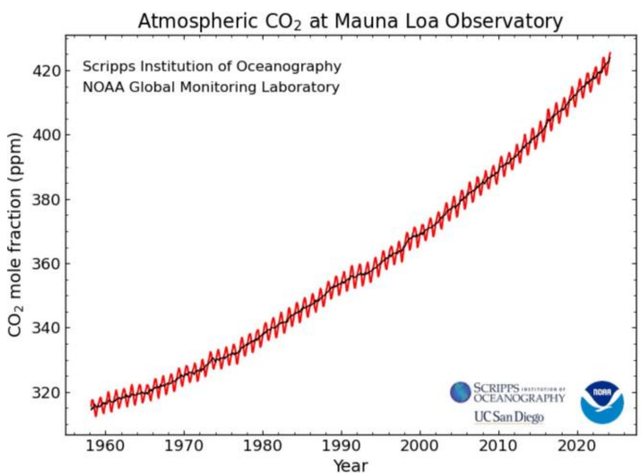


(2)

Figure 4-1. Cumulative Global Historical Emissions

Although CO_2 levels in the atmosphere have varied perpetually throughout earth's history along with corresponding variations in climatic conditions, industrialization and the burning of carbon-based fossil fuel sources have caused CO_2 concentrations to increase measurably, from approximately 280 ppm in 1750 to 425.4 ppm as of March 2024 (annual unadjusted). The rate of increase in CO_2 is unprecedented, at more than 250 times faster than from natural sources after the last Ice Age (NASA 2021) [16] This fact is demonstrated by data from the Mauna Loa CO_2 monitor in Hawaii that documents atmospheric concentrations of CO_2 going back to 1960, at which point the average annual concentration was recorded at approximately 317 ppm. The record shows that approximately 72% of the increase in atmospheric CO_2 concentration since pre-industrial times (1750) occurred within the last 60 years. The Mauna Loa site also contains updated trend data for CH_4 and N_2O (see Figure 4-2). The trends are the result of an increasing global population along with rising standards of living and modernization, all of which correspond with an increase in energy demand that has fueled emissions growth primarily from the use of fossil fuels.



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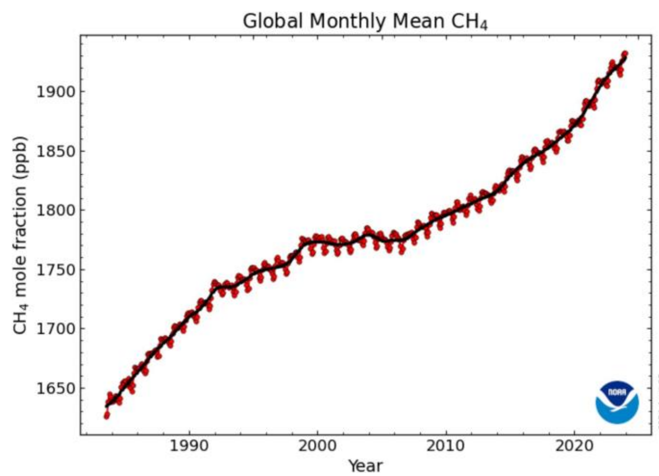

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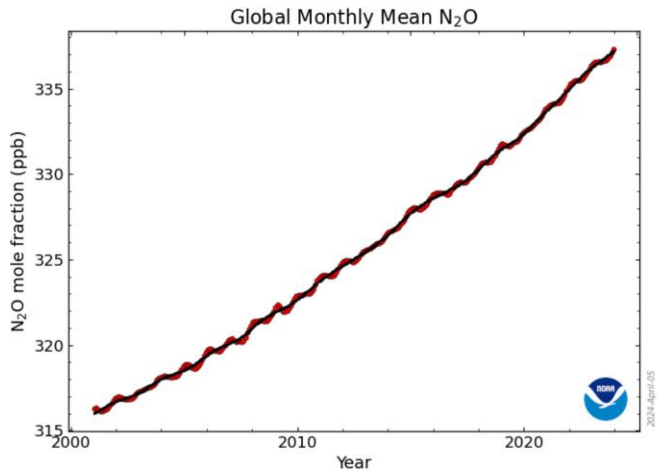

(3)

Figure 4-2. Mauna Loa GHG Monitoring Data

From pre-industrial times to present, emissions from fossil fuel combustion and cement production have released approximately 375 [345 to 405] GtC to the atmosphere (68%), while deforestation and other land use change are estimated to have released 180 [100 to 260] GtC (32%). Concentrations of CO_2, CH_4, and N_20 are now substantially higher than concentrations found in various ice cores dating back to the past 800,000 years. Table 4-1 shows a summary of the anthropogenic changes to atmospheric GHGs since pre-industrial times. The estimated concentrations of CH_4 have more than doubled (722 ppb to 1,932.2 ppb), while N_20 concentrations have increased by a fifth (270 ppb to 337.3 ppb). The National Oceanic and Atmospheric Administration (NOAA), whom operates the Mauna Loa monitors, estimates that 2023 was the 12th consecutive year CO_2 increased by more than 2 ppm; and that prior to 2013 only three consecutive years of CO_2 growth of 2 ppm or more had ever been recorded.

Table 4-1. Global Atmospheric Concentration and Rate of Change of Greenhouse Gases

GHG Metric	CO2 (ppm)	CH4 (ppb)	N20 (ppb)
Pre-Industrial Concentration	278	722	270
2023 Atmospheric Concentration	419.3	1,922.6	336.7
2023 Concentration Relative to Pre-Industrial	150%	260%	125%
Annual Rate of Change (ppmlppb/yr)	2.8	10.6	1.0

Source: https://research.noaa.gov/2024/04/05/no-sign-of-greenhouse-gases-increases-slowing-in-2023
ppm = parts per million, ppb = parts per billion.

Each year, NOAA publishes updates to its Annual Greenhouse Gas Index (AGGI). The AGGI was developed to provide an easily understood standard for expressing the climate-warming influence of long-lived GHGs. Specifically, the AGGI is the ratio of the total direct climate forcing from measured long-lived GHG concentrations compared to the 1990 baseline year (chosen because it is the baseline year for the Kyoto Protocol and the publication year of the first IPCC Scientific Assessment of Climate Change). The 1990 baseline year is given an AGGI value of 1.0, and the pre-industrial era is given a value of 0.0 (see Figure 4-3) (Lindsey 2020) [17] The AGGI for 2022 was 7.49 which corresponds to CO_2 equivalents atmospheric concentration of 523 ppm. This represents a 49% increase to climate forcing since 1990 and a 1.8% increase over 2021 levels. While the AGGI does not predict the amount the earth's climate has warmed, it does provide a measure of the effect of GHG emissions on the climate system.

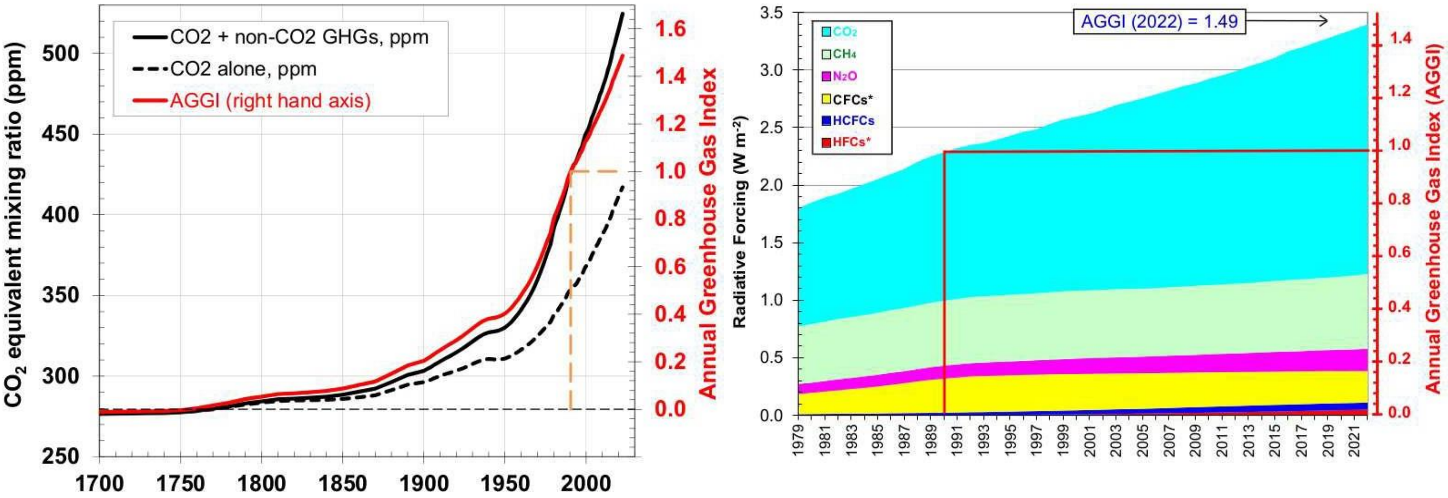

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Figure 4-3. 2022 Annual GHG Index

Note: 2023 AGGI data was not available at the time of report publishing.

The total anthropogenic RF for 2019 relative to 1750 (i.e., the pre-industrial era) was 2.72 ± 0.76 W m-^{2}, which includes both heating and cooling parameter estimates. For well-mixed GHGs, the total positive forcing component is equal to about 3.32 W m-^{2} The largest contribution to total RF since 1750 is caused by the increase in the atmospheric concentration of CO_2. Emissions of CO_2 alone caused an RF of 2.16 ± 0.26 W m^{-2} (65%), while CH_4 caused an RF of 0.54 ± 0.71 W m^{-2} (7 6%). The data highlights methane's important role as a potent greenhouse gas, given its RF value in relation to its atmospheric loading trend, approximately 556 Tg yr-1 (64% anthropogenic, 36% natural), and relatively short atmospheric lifetime (7 2 years). N_20 has the third largest forcing of the anthropogenic gases, at 0.27 ± 0.03 W m^{-2} (6%). Collectively, the three GHGs of concern account for approximately 87% of the positive forcing within the climate system.

The earth's climate system is complex and interwoven in ways that are not yet fully understood. There are several known climate feedback mechanisms that add uncertainty in terms of timing (fast and slow feedbacks) and overall sensitivity within the evaluation of the climate system. Sensitivity refers to the amount of positive or negative feedback that occurs in response to a given forcing. The feedbacks and processes connecting RF to a climate response can operate on a large range of time scales. Reaching temperature equilibrium in response to anthropogenic activities (emissions and land use changes) takes decades or longer because some of the climate components - in particular the oceans and cryosphere - are slow to respond due to their large thermal masses and the long-time scale of circulation between the ocean surface and the deep ocean. Some of the latest available climate feedback research indicates that relatively small changes in RF can initiate stronger responses in some feedback components. This suggests that some of these mechanisms, and the climate in general, may have a higher sensitivity than is currently understood. As with the forcing components, there are also positive and negative feedback mechanisms, and there is a relatively large range of uncertainty concerning estimates of the climate sensitivity that leaves the subject open to further investigation. To quote directly from Chapter 8 of the Working Group I contribution to AR5, "In a complex and interconnected system, feedbacks can become increasingly complex, and uncertainty of the magnitude and even direction of feedback increases the further one departs from the primary perturbation, resulting in a trade-off between completeness and robustness, and hence utility for decision-making." Figure 4-4 shows a conceptualized model of the climate and feedback mechanisms and how they interact.

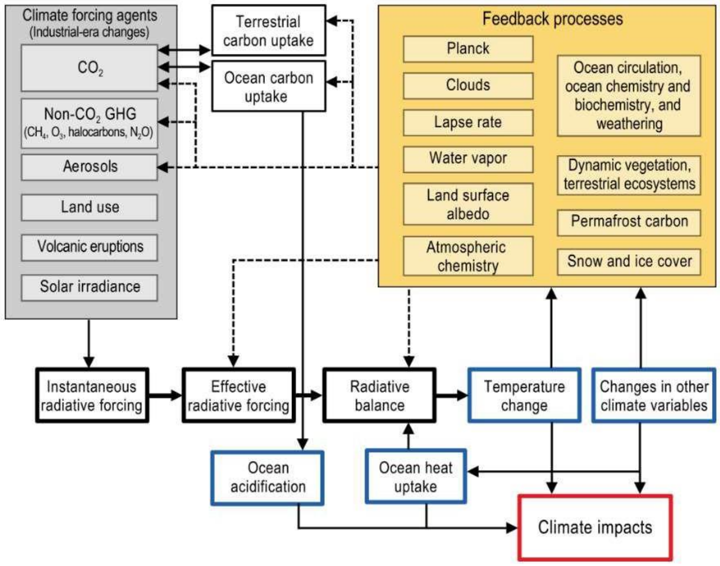


Figure 4-4. Conceptualized Climate System Diagram (Simplified)

4.2 Past and Present Climate Impacts

According to IPCC's 6th climate assessment report: "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over centuries to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentration of greenhouse gases have increased." The globally averaged combined land and ocean surface temperature data, as calculated by a linear trend, shows human caused warming of 1.07 ± 0.23°C over the period 1850 to 2019. A recent study suggests that modern global temperatures are the highest in the last 12,000 years (Bova et al. 2027) [18]

Ocean warming has dominated the increase in energy stored, accounting for 91% of the heating of the climate system, followed by land warming (5%), ice loss (3%), and atmospheric warming (1 %). Over the period 1901-2018, global mean sea level rose by 0.2 [0.15 to 0.25] meters, while the average rate of rise has tripled. **Note:** Rates of sea level rise over broad regions can be several times larger or smaller than the global mean sea level rise for periods of several decades, due to fluctuations in ocean circulation. IPCC's report further states that on a global scale, ocean surface temperatures increased by 0.88 [0.68 to 1.01] °C between approximately 1850 and 2020.

The IPCC report states that Arctic sea ice coverage reached its lowest level since 1850, and that late summer Arctic sea ice area was smaller than at any time in at least the past 1000 years. Interestingly, the report also states that the observed linear relationship between global surface temperatures and sea ice retreat indicates there is no tipping point in the system for a total collapse, such that the losses are potentially reversible. The global nature of glacier retreat since the 1950s, with almost all of the world's glaciers retreating synchronously, is unprecedented in at least the last 2000 years. Between 1992-2020, it is likely that Greenland lost approximately 4890 ± 460 Gt of ice, contributing 13.5 ± 1.3 mm to global mean sea level rise. Records of soil temperature increases in permafrost regions over the past few decades have been widespread, while snow cover in the Northern Hemisphere has been decreasing at a rate of -1.9 million km^2 per 1°C of temperature change during the snow season.

The following summary text provides an overview of the highlights from the 5^{th} iteration of the National Climate Assessment (NCA) report. The NCA provides region-specific impact assessments for climate change parameters that are anticipated to occur throughout this century. The report states that the observed warming that occurred since the industrial revolution is unequivocally caused by greenhouse gas emissions from human activities. The global climate continues to change rapidly compared to the pace of the natural variations in climate that have occurred throughout the earth's history. Rate of change trends for globally averaged temperature, sea level rise, upper-ocean heat content, land-based ice melt, Arctic sea ice, depth of seasonal permafrost thaw, regional drought persistence and other climate variables are unprecedented over time scales of thousands to hundreds of thousands of years based on multiple lines of evidence. The frequency and intensity of extreme heat and heavy precipitation events are increasing; a trend that is virtually certain to continue in the future as the global temperature increases (high confidence).

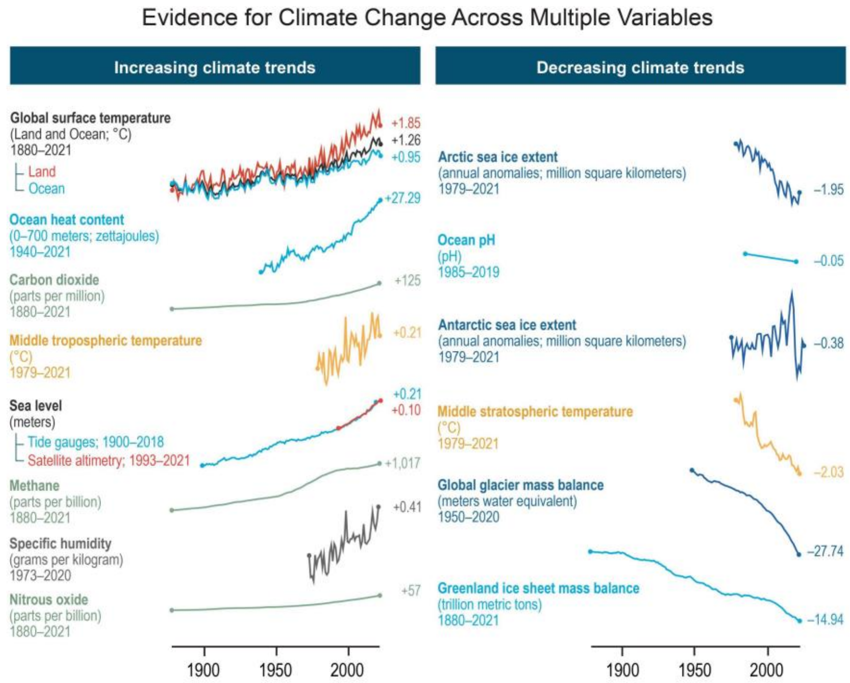


Figure 4-5. NCA Recent Rate of Change Trends Analysis

Source NCA5, Stripe Inc., NOAA NCEI, and CISESS NC.

The annual average temperature over the contiguous United States has increased by 2.5°F over the last half century, while Alaska has seen an average temperature increase of 4.2°F The data reflects the fact that the arctic regions are warming faster than the lower latitudes. Additionally, the data trends show that winter is warming almost twice as fast as the summer months. At the regional scale, each National Climate Assessment (NCA) region experienced increasing temperatures between 1901 - 1960 and 1986 - 2016. The largest changes (beyond Alaska) were in the western half of the United States, while the Southeast has had the least warming due to a combination of natural variations and human influences; since the early 1960s, however, the Southeast has been warming at an accelerated rate. Over the past two decades, the number of high temperature records recorded in the United States far exceeds the number of low temperature records. The length of the frost-free season has increased in each NCA region since the early 1900s. The frequency of cold waves has decreased since the early 1900s, and the frequency of heat waves has increased since the mid-1960s.

Precipitation patterns are changing across most of the country. Annual average precipitation in the central and eastern portions of the U.S. have increased between 5% and 15% relative to the averages recorded between 1901 and 1960. During this same time period the western portions of the U.S. have seen precipitation declines of between 10% and 15%. The timing of the precipitation is also changing, with the western portions of the country getting dryer in the summer and wetter in the winter, while the rest of the U.S. is generally recording more precipitation throughout the year. Regardless of locality, more precipitation is falling as rain rather than snow which is impacting snow pack levels in the heavily reliant west.

4.3 Global Climate Trends 2023

The following information is summarized from the World Meteorological Organization's (WMO) 2023 State of the Global Climate report. Last year was the hottest on record, with global average surface temperatures of 1.45 ± 0.12°C above the pre-industrial average being recorded. The year was also remarkable for the level of ocean warming, with heating levels reaching the highest ever observed. Arctic sea ice extent (maximum) was the fifth lowest on record, with continued long-term trends of reduced late-summer cover. Accumulated precipitation totals were mixed, but a majority of the Western Hemisphere saw reduced totals. Extreme weather events plagued all portions of the globe, with localized population displacement and continued food insecurity being primary outcomes. The loss of agricultural productivity from extreme weather is also contributing to the sustained rise in food costs. In the U.S. there were 28 incidences of billion-dollar disasters in 2023 relating to extreme weather events and climate change, totaling almost $93 billion in costs. [19]

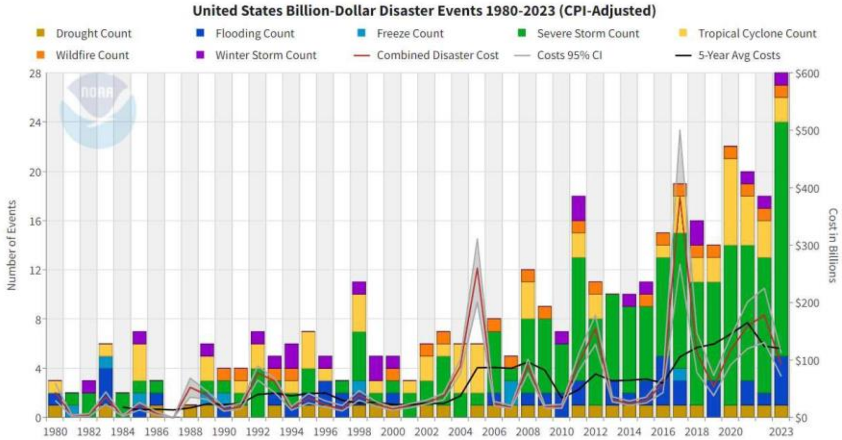


Figure 4-6. U.S. Extreme Weather Events Data

4.4 Climate Change Impacts in Select States with SLM-Authorized Fossil Fuels

The climate change indicators, impacts, and trends specific to states where the BLM conducts most of its fossil fuel authorizations are subsequently described. For each state, precipitation and temperature data from the NOAA's climate division dataset (Vose et al. 2014) [20] are presented to document climate trends. Data extending back to 1895 are available for each state in the contiguous United States while the period of record for Alaska begins in 1925. Detailed narratives for each state's current climate conditions can be found at NOAA with additional information provided by the Western Regional Climate Center.

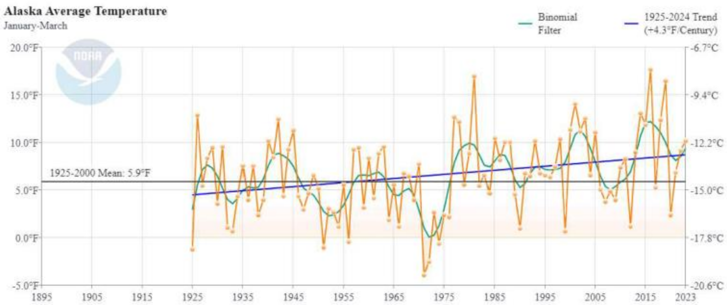
Alaska

From 1925 to the mid-1970s, the statewide annual average temperature decreased by about 1°C. A major climate shift in the Pacific Ocean during the 1976-77 winter season, detailed extensively by Miller et al. (1994) [21] produced many environmental impacts throughout the Pacific Basin including significant changes in Alaskan climatology as reported by Hartmann and Wendler (2005). [22] Since the Pacific Ocean shift of 1976-77, the statewide annual average temperature increased by 2.5°C to 3°C with the four warmest years on record in Alaska observed since 2014 (Figure 4-7). Most of the warming has occurred in the winter and spring seasons, and the least amount in fall. Summer temperatures have been well above average since 1990 and winter temperatures have been above average since 2002. Some recent warming has been linked to the Pacific Decadal Oscillation, which is a major control on Alaskan climate. However, the most recent 10-year period (2011-2020) was over 1°C warmer than any 10-year period in the 20th century. Starting in the 1990s, high temperature records occurred three times as often as record lows, and in 2015, nine times as frequently. However, temperature trends across the state vary considerably with the most warming observed in the North Coast, West Coast, Central Interior, and Bristol Bay climate divisions. Since the 1970s, Arctic and boreal regions in Alaska have experienced rapid rates of warming and thawing of permafrost.

There is no clear trend in statewide precipitation (Figure 4-7), though in the past three decades, precipitation in the West Coast, Northeast Interior, and Central Panhandle climate divisions averaged about 10% higher than the 1925-1999 mean. As with average precipitation, the occurrence of extreme precipitation events are highly variable and are both regionally and seasonally dependent. Most of Alaska has seen an increase in extreme precipitation events (the heaviest one percent of 3-day precipitation totals) since the mid-20th century. However, there is no statewide average trend in the number of days with precipitation exceeding 1 inch since 1950, and the highest values occurred in the 1930s.

Late summer Arctic sea ice extent and thickness has decreased substantially in the last several decades, and the ice volume is approximately half of that observed prior to satellite monitoring in 1979. Since the early 1980s, annual average Arctic sea ice extent has decreased between 3.5% and 4.1% per decade, and September sea ice extent, which is the annual minimum extent, has decreased between 10.7% and 15.9% per decade. The lowest minimum Arctic sea ice extent occurred in 2012. Arctic sea ice plays a vital role in the climate of Alaska, the lives of its inhabitants, and the functionality of its ecosystems. Warming linked to ice loss influences atmospheric circulation and precipitation patterns, both within and beyond the Arctic. With the late-summer ice edge located farther north than it used to be, storms produce larger waves and cause more coastal erosion. A significant increase in the number of coastal erosion events has been observed as the protective sea ice embankment is no longer present during the fall months. In response to the increased erosion, several coastal communities are seeking to relocate.

Glaciers continue to melt in Alaska, with an estimated loss of 75 ± 11 gigatons (Gt) of ice volume per year from 1994 to 2013, 70% of which is coming from land-terminating glaciers; this rate is nearly double the 1962-2006 rate. Melting glaciers are likely to produce uncertainties for hydrologic power generation, which is an important resource in Alaska.



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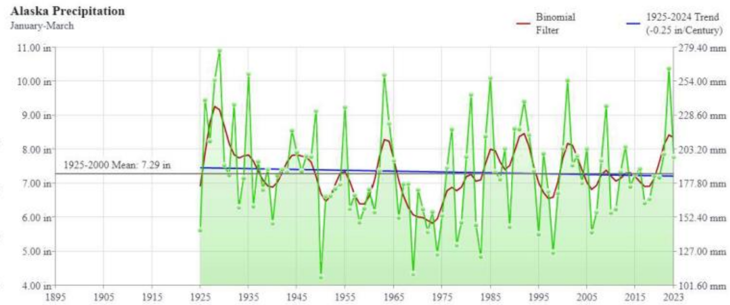

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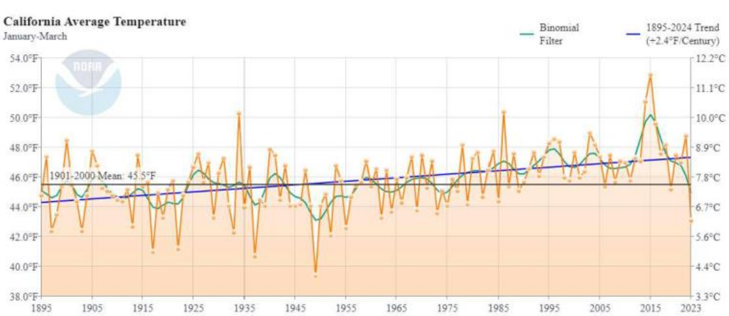
Figure 4-7. AK Temperature and Precipitation Records

California

The average annual temperatures in California have increased by nearly 3°F since the beginning of the 20th century (Figure 4-8). The years 2014 and 2015 were the first and second warmest, respectively, in the 126-year record, and the most recent 10-year period (2011-2020) was the warmest on record. Since 1995, California has experienced a below normal number of cold nights and its highest number of very warm nights over the historical record. The record warmth in 2014 and 2015, in combination with multiple years of below average precipitation including the driest year (Figure 4-7) led to the most severe drought of the past 1,200 years (Griffin and Anchukaitis 2014) [23]

While there is no long-term trend in statewide precipitation (Figure 4-8), 2013 and 2020 were the driest and third driest years, respectively, in the 126-year record. Like precipitation, the state's snowpack varies greatly from year to year. During the SNOTEL monitoring era, which begins around 1980, snowpack has decreased slightly in the state's major river basins. According to data provided by the USDA's Natural Resources Conservation Service (NRCS), statewide April 1 snowpack has averaged about 10% lower during the first two decades of the 21st century as compared to the last two decades of the 20th century, with 2015 likely featuring the lowest snowpack in the Sierra Nevada in the last 500 years (Belmecheri et al. 2015) [24]

Many coastal resources in the state have been affected by sea level rise, ocean warming, reduced ocean oxygen, and ocean acidification-all impacts of human-caused climate change. At the Golden Gate Bridge in San Francisco, sea level rose 9 inches (22 cm) between 1854 and 2016, and in San Diego, sea level rose 9.5 inches (24 cm) from 1906 to 2016.



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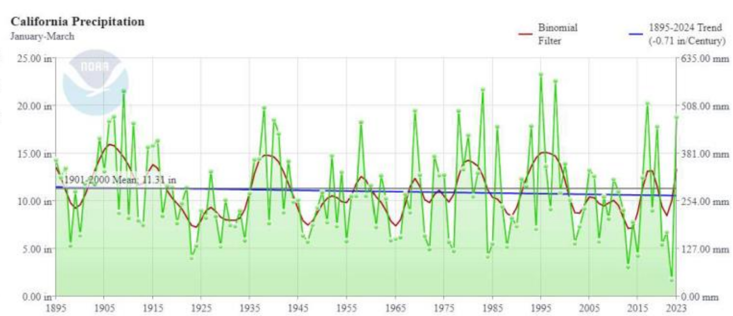

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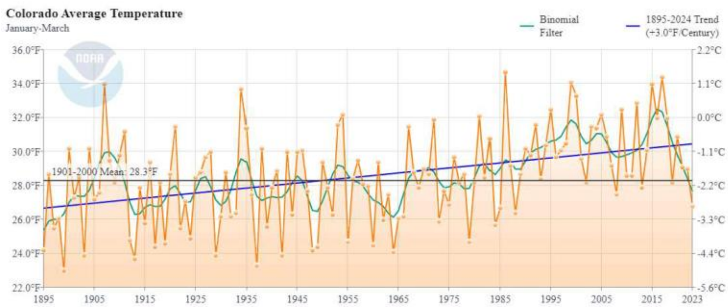
Figure 4-8. CA Temperature and Precipitation Records

Colorado

Since the start of the 20th century, the average annual temperature in Colorado increased by approximately 2.5°F (Figure 4-9). Six of the eight hottest years in the state's recorded history have occurred since 2012, and the most recent 10-year period (2011-2020) was the hottest yet observed. While temperatures have increased statewide, the Colorado Basin (Colorado Climate Division 2) has warmed by nearly twice as much as either the Arkansas Basin (Colorado Climate Division 1) or the Rio Grande Basin (Colorado Climate Division 5). In addition to the overall trend of higher average temperatures, the state has experienced an above average number of very hot days (days with a maximum temperature exceeding 95°F) and a decrease in the number of very cold nights (days with a minimum temperature below 0°F) since 1990. Warming has occurred in all seasons and has been observed throughout the state. Daily minimum temperatures increased more than daily maximum temperatures. Increased temperatures have contributed to earlier snowmelt and peak runoff timing during spring by 1 to 4 weeks. The growing season (i.e., frost-free days) has increased by nearly three weeks since 1991 relative to the 1901 to 1960 average.

Long-term average annual precipitation has been variable, though Colorado has generally experienced above average fall precipitation since 1980 and below average spring precipitation since 2000. Unlike many areas of the United States, Colorado has not experienced an upward trend in the frequency of extreme precipitation events. Drought reconstructions from tree rings indicate that droughts are a frequent occurrence in Colorado, and episodes more severe than any in the historical record have occurred in the more distant past.

Despite historically low snowpack in 2012, there is no long-term trend in April 1 snowpack water at Berthoud Pass, which has one of the state's longer snow course sampling histories. However, there is considerable site-specific variability among Colorado snow course locations, with some indicating no long-term trend while others show a significant decrease in April 1 snowpack. Snowpack data from the NRCS show that during the most recent 40 years covered by SNOTEL data, year-to-year variability in basin-specific and statewide April 1 snowpack is large, though in general, snowpack has been slightly lower in the most recent 20-year period



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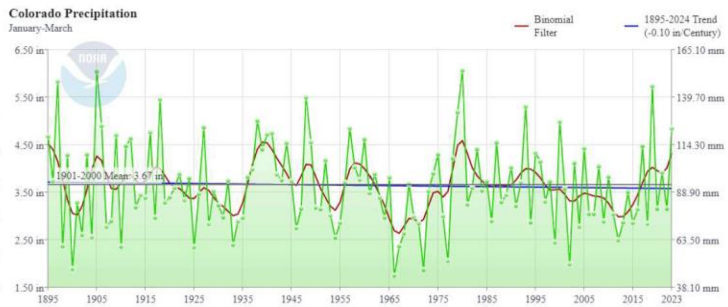

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Figure 4-9. CO Temperature and Precipitation Records

Northern Great Plains (Montana, North Dakota, and South Dakota)

Since the start of the 20th century, Montana and the Dakotas have warmed by about 2.5°F. Since 1981, 8 and 9 of the hottest years on record have occurred in the Dakotas and Montana, respectively. While temperatures have increased in all seasons, the largest increase has occurred in winter and spring. For example, over the past 130 years, winter temperatures in North Dakota have increased by 4.4°F per century, more than three times as much as the summer trend of 1.4°F per century. Warmer temperatures have extended the growing season by as much as 30 days in the northern Great Plains.

There is no clear long-term trend in Montana precipitation, but in the Dakotas, annual precipitation amounts have increased, and rainstorms are becoming more intense. Over the last 50 years in the Great Plains, the amount of rain falling during the wettest 4 days of the year increased by approximately 15%. Increasing rainfall could benefit some farms but also may increase the risk of flooding.

Despite warming temperatures, NRCS snowpack data show that average April 1 snow-water equivalents in Montana have not changed during the SNOTEL era. However, since 1955, longer term snow course data indicate a significant decrease in Montana's April 1 snowpack (Mote et al. 2018) [25]

Rising temperatures and recent droughts have killed many trees by drying out soils, increasing the risk of forest fires, or enabling outbreaks of forest insects. In the coming decades, the changing climate is likely to decrease the availability of water in Montana, affect agricultural yields, and further increase the risk of wildfires.

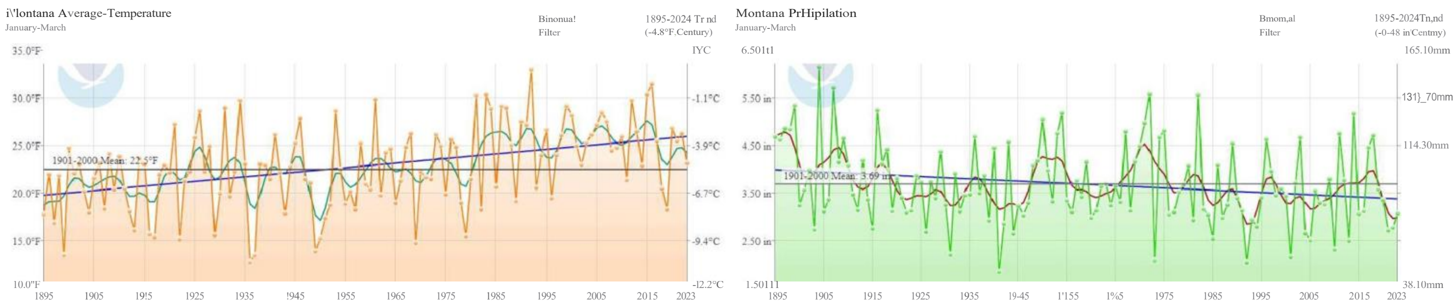

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Figure 4-10. MT Temperature and Precipitation Records

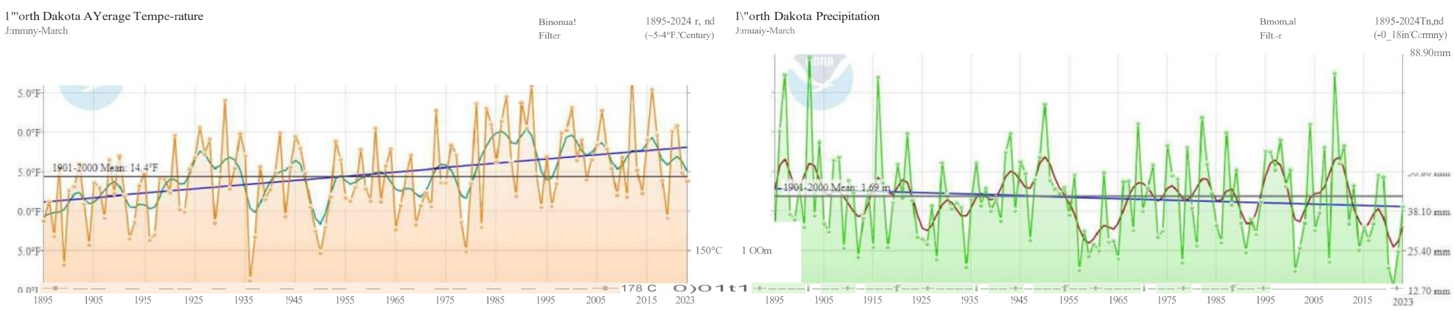

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Figure 4-11. ND Temperature and Precipitation Records

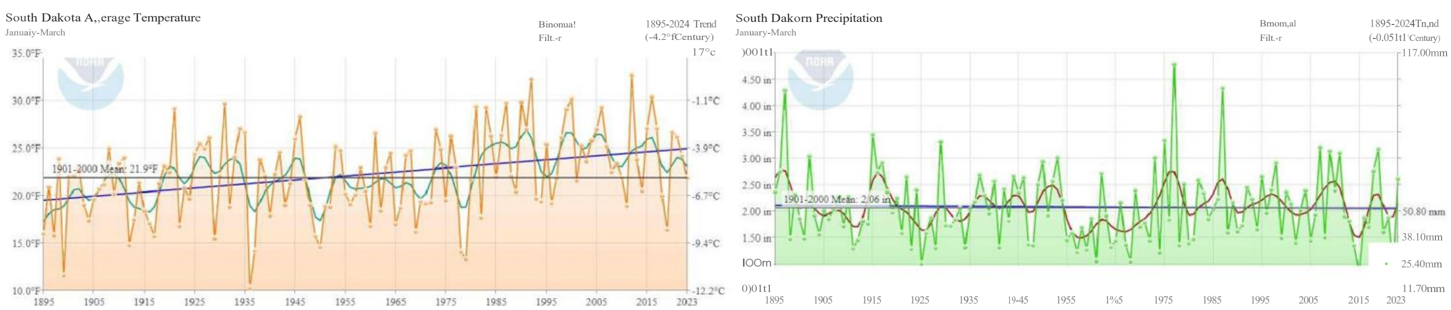

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Figure 4-12. SD Temperature and Precipitation Records

Nevada

The average annual temperature in Nevada has risen 5.7% over the last 120 years, from 49.0°F near the beginning of the 20th century to 57 .8°F over the past 10 years. Eight of the ten warmest years since 1895 have occurred since 2000. The rate of warming is not uniform across the state. Urban areas, for example, are getting hotter faster relative to rural areas, which is most likely being driven by the heat island effect. Nevada is the driest state in the nation in terms of annual average precipitation (combined rain and snowfall). Average annual precipitation has decreased 2.2% between the beginning of the 20th century and the past 10 years.

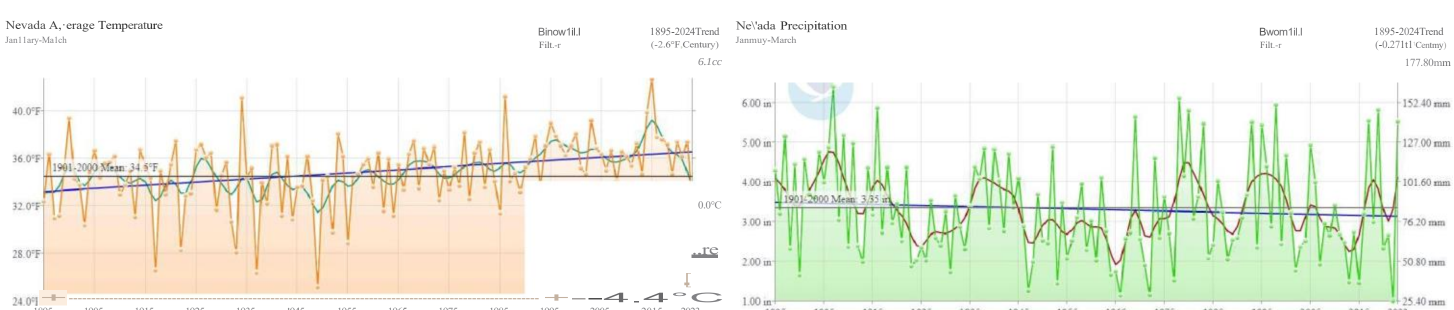

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Figure 4-13. NV Temperature and Precipitation Records

New Mexico

From 1895 to the end of the 1970s, there was no trend in New Mexico mean annual temperature, but since 1980, the mean annual temperature increased by approximately 2.7°F (Figure 4-74) and at a relatively linear rate of about 0.7°F per decade[26] The last decade (2011-2020) was the warmest on record for the state, and the 3 hottest years observed each occurred since 2012. Temperatures have increased the most in the central and southeastern portions of the state while the northeastern plains and Mogollon Rim have warmed by about half as much (Vose et al. 2017) [27] Along with higher mean temperatures, much of the state has seen increases in the number of extremely hot days (maximum temperature at or above 100°F), especially on the eastern plains. The number of warm nights (minimum temperature of 70°F or higher) has also increased, with the 2010-2020 period experiencing about double the long-term average

There is large interannual and interdecadal variability in New Mexico precipitation (Figure 4-14). While 2020 was the second driest year on record and the most recent decade (2011-2020) was the driest since 1955-1964, there is no long-term trend in mean annual precipitation. Statewide annual precipitation has ranged from a high of 26.57 inches in 1941 to a low of 6.58 inches in 1956. Unlike many areas of the United States, there has been no increase in the frequency of extreme precipitation events (days with an inch or more of precipitation) in New Mexico. While the average number of such events between 2015 and 2018 was the highest on record, it is too short a period to constitute a trend. Drought reconstructions from tree rings indicate that droughts are a frequent occurrence in New Mexico, and episodes more severe than any in the recent historical record have occurred in the more distant past.

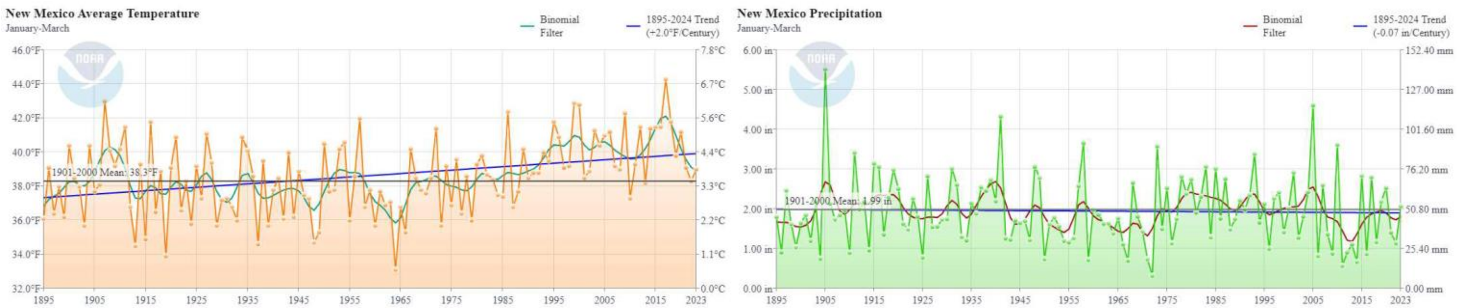

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Figure 4-14. NM Temperature and Precipitation Records

Utah

The early 21st century has been the warmest period on record for Utah (Figure 4-15). Since 1895, temperatures have been increasing 0.2°F to 0.3°F per decade in each of Utah's seven climate divisions. The period from 2000 to 2004 had the largest number of extremely hot days with maximum temperature at or above 100°F in the historical record. In addition to the overall trend of higher temperatures, the state has experienced a marked increase in the number of very warm nights (minimum temperature at or above 75°F) and a decrease in the number of very cold nights (minimum temperature at or below 0°F) since 1990. While 2020 was the driest year on record for Utah and 21st century precipitation has averaged a few percent below the long-term mean across Utah, there is no statistically significant trend in precipitation for the state or in any climate division with natural variability resulting in both wetter and drier periods than observed in the past two decades (Figure 4-15). As the state has warmed, the percentage of precipitation falling as snow during the winter has decreased, as has snow depth and snow cover.

April 1 snowpack across the state has gradually decreased in the past 40 years with 2011-2020 average statewide snowpack approximately 20% lower than that observed between 1987-1990. Utah frequently experiences droughts. Since snowmelt from the snowpack provides water for many river basins, abnormally low winter and spring precipitation is often the trigger for drought conditions. In 2012, Utah experienced one of its driest springs since records began in 1895, resulting in severe drought conditions in areas across the entire state. The historical record indicates periodic occurrences of extended wet and dry periods. Dry conditions since 2000 have resulted in near-record-low water levels in the Great Salt Lake.

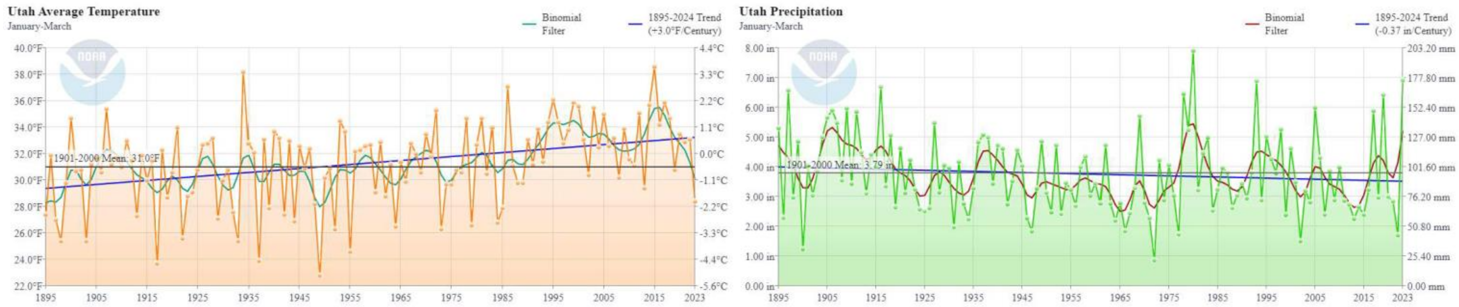

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Figure 4-15. UT Temperature and Precipitation Records

<u>Wyoming</u>

The 21st century has been the warmest period on record for Wyoming, with a net warming of 1.4°F since the beginning of the 20th century (Figure 4-16). Three of the four hottest years on record have occurred since 207 2, with that year the hottest in the 126-year observational period. Temperature increases have been observed in all seasons. Since 1995, winter and summer temperatures have averaged 1.9°F and 1.2°F above the historical average, respectively. The state has experienced an above average frequency of very hot days (days with maximum temperature above 95°F) since 2000. Wyoming rarely experiences warm nights (days with minimum temperatures above 70°F), but the early part of the 21st century has seen an above average number of such nights. In addition to the overall trend of higher average temperatures, the state has experienced a below average number of very cold days (days with maximum temperatures below 0°F) since 2000.

There is no long-term trend in statewide annual mean precipitation (Figure 4-16), though 2012 was the driest year on record and 2020 the fifth driest on record. The driest multiyear periods were in the 1930s, 1950s, and 2000s, and the wettest in the 1940s and 1990s. The driest 5-year period was 1931-1935 and the wettest was 1995-1999. Unlike many other areas of the Western United States, April 1 snowpack has remained relatively constant over the past 40 years. The median statewide April 1 snowpack between 1981-2000 is the same as that observed during the most recent 10-year period (2011-2020).

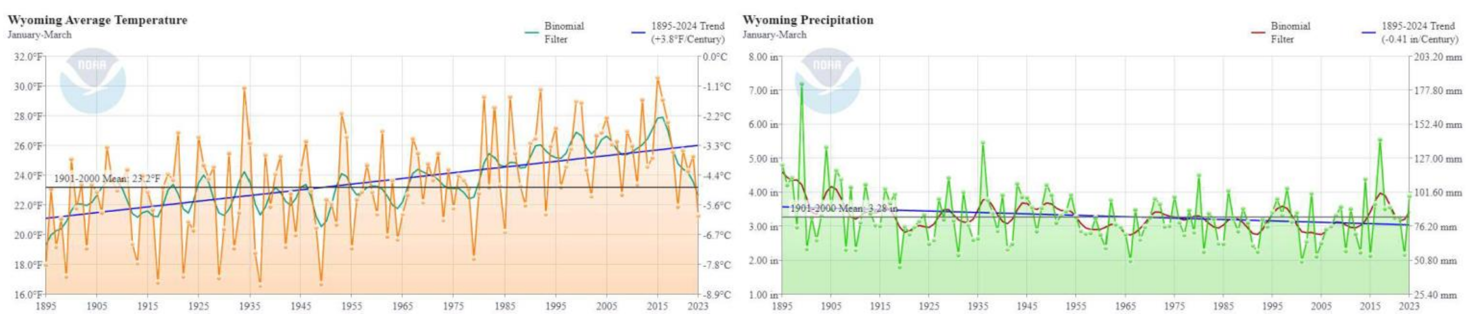

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Figure 4-16. WY Temperature and Precipitation Records

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5.0 Global, National, and State GHG Emissions

This chapter discusses present and projected cumulative GHG emissions at various scales. Emissions are summarized from the latest global and national inventories and provide explicit accounting for GHGs from all sources of fossil fuel combustion. State-level data is also provided for multiple sectors of emitters, including fossil fuels development. This information provides the cumulative context for describing the primary contributing factors to the present and projected (future baseline) affected environment relative to climate change, for which the GHG emissions from BLM's fossil fuel authorizations (past, present, and future) are a part.

5.1 Annual Global Emissions

According to preliminary data estimates provided by the Rhodium Group[28] (an independent research provider), cumulative global net GHG emissions increased approximately 1% in 2022. Figure 5-1 shows the global CO_2e emissions from GHGs for all sectors, including land-use and land-use changes, increase from 50.1 $GtCO_2e$ in 2021 to approximately 50.6 $GtCO_2e$ in 2022. Figure 5-1 also shows the percent of emissions from the largest emitters by country/region and the annual percent change in emissions relative to the recent previous years. The data shows that the top-emitters were responsible for approximately 63% of the total emissions, and that China alone was responsible for nearly half of that, although its emissions have slowed considerably due to recent economic headwinds.

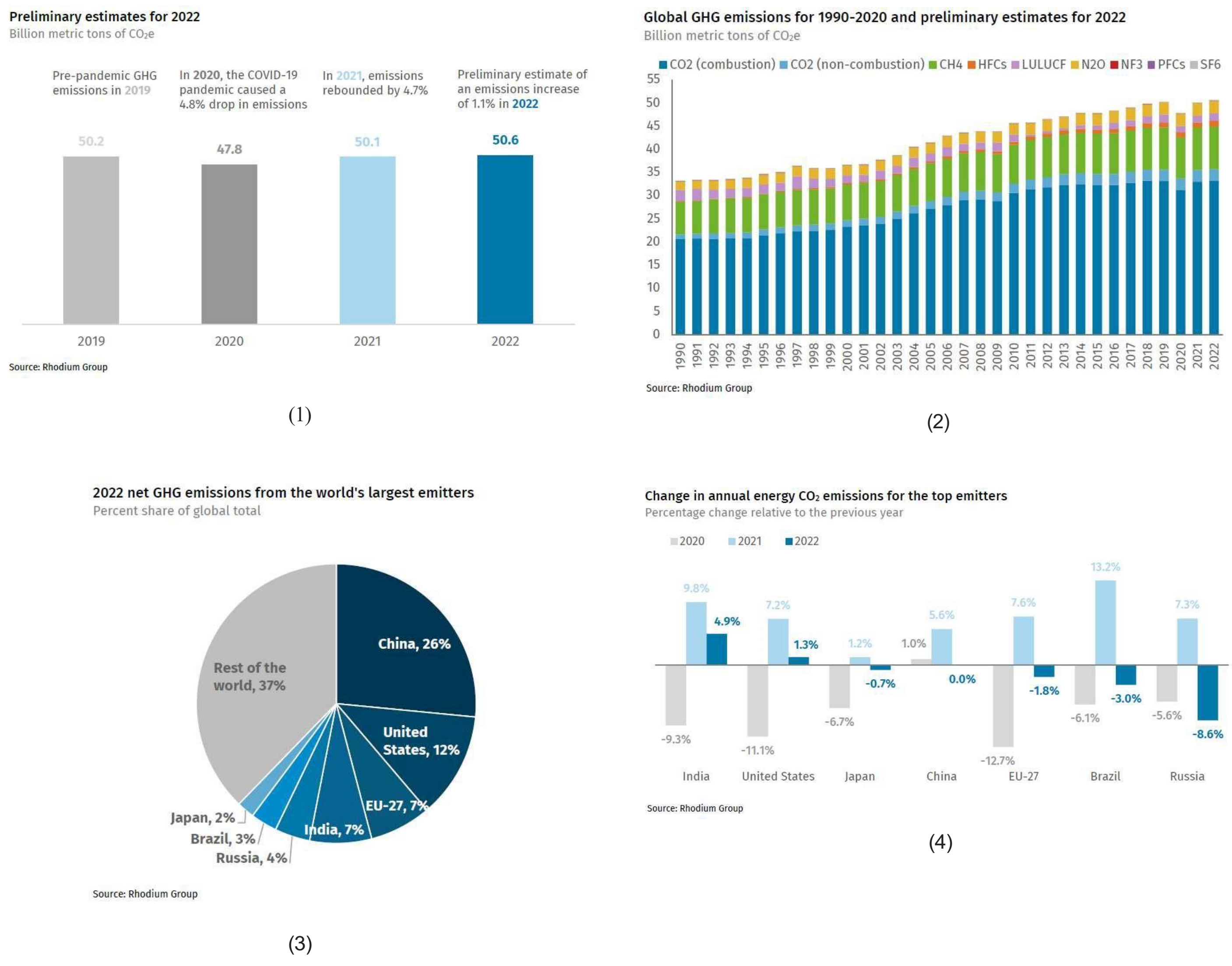


Figure 5-1. Global GHG Emissions and Top Contributors

Globally, the use of all fossil fuels and the CO_2 emissions associated with the combustion of these fuels continue to rise. Figure 5-2 shows global CO_2 emissions from total fossil fuel consumption, by fuel type, and region. The large increases in global coal emissions since 2000 can mostly be attributed to China, and more recently India's, increased use of coal-fired power plants.

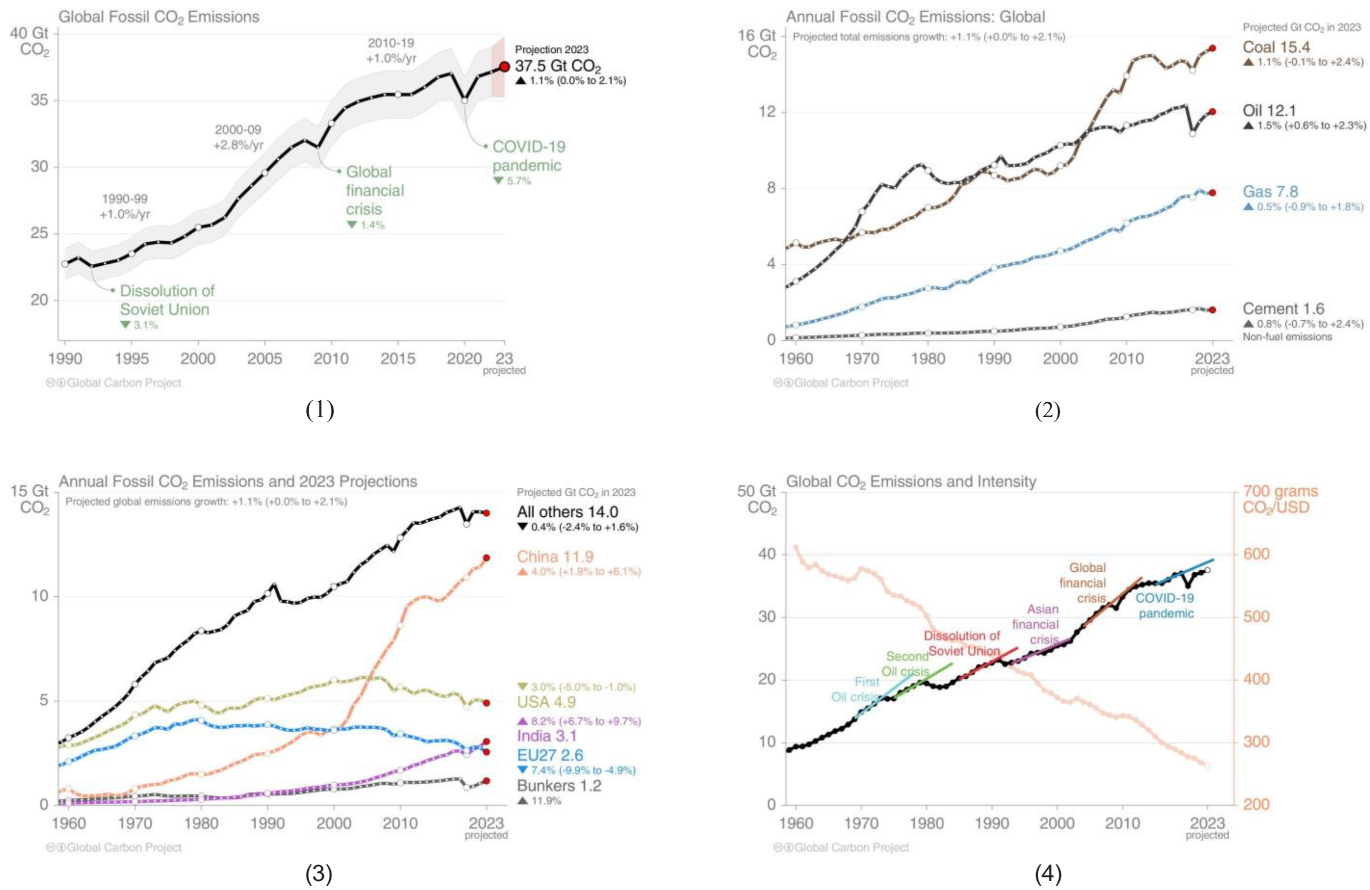
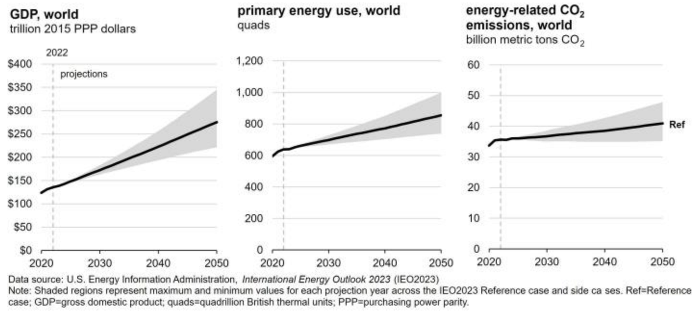


Figure 5-2. Global Fossil CO_2 Emissions

5.2 Projected Global Emissions

The U.S. Energy Information Administration (EIA) provides long-term (2020-2050) world energy and emissions projections in its International Energy Outlook (IEO). The most recent IEO that contains CO_2 emissions data is the IEO2023, released in October 2023. The IEO provides several different scenarios (cases) to forecast future energy needs and associated fossil fuel consumption. The reference case reflects current trends and relationships among supply, demand, and prices in the future and is a reasonable baseline case to compare with cases that include alternative assumptions about the future energy system. The IEO reference case assumes global energy consumption will rise nearly 38% between 2022 and 2050. According to the reference case projections, the use of all fossil fuels increases through 2050, with much of the increased demand coming from Asia. Natural gas consumption is projected to grow between 11% to 57% through 2050, which is limited by the projected growth in renewable energy sources (approximately 32% in 2050). Constant petroleum growth is forecast for the entire projection period, with almost all of the supply going towards meeting transportation demand and growth. Global energy-related CO_2 emissions are projected to increase by 15% from 2022 to 2050 from about 35.7 billion metric tons CO_2 to approximately 41 billion metric tons. Although aggregate CO_2 emissions from the energy sector are projected to continue to rise, the carbon intensity of future energy sources (i.e., the amount of CO_2 emissions produced per unit of energy used) is projected to decrease indicating that sources of energy that do not produce CO_2 emissions (e.g., renewables) will comprise a larger portion of meeting future energy demands. Figure 5-3 (EIA IEO graphs) shows some of the energy mix and emissions estimates derived from projected global energy use.



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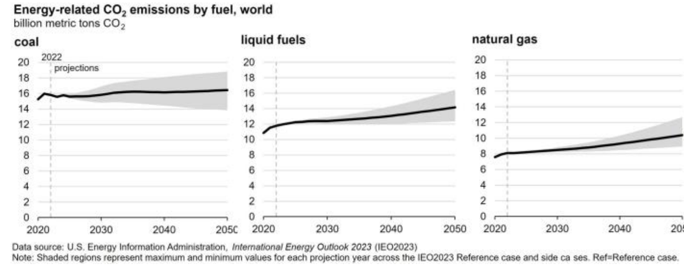

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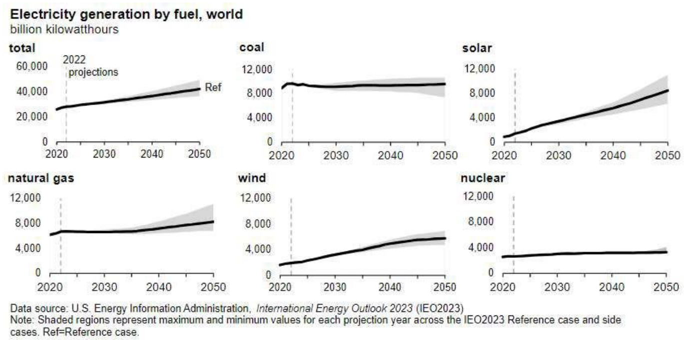

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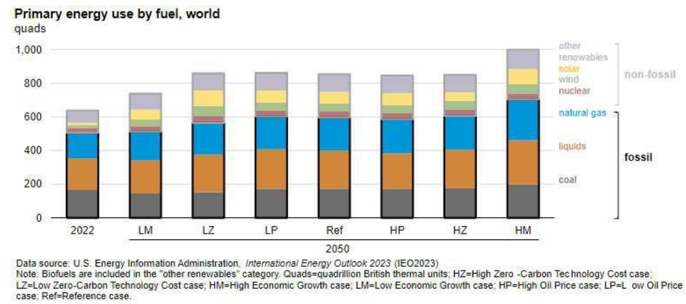

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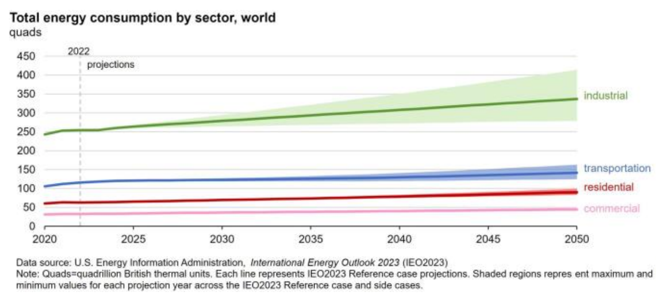

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Figure 5-3. IEO - Future Global Energy Related Projections

5.3 Annual U.S. Emissions

The U.S. EPA provides a comprehensive accounting of total GHG emissions for all man-made sources in the United States. The results of these tracking and quantification efforts are published in the annual "Inventory of U.S. Greenhouse Gas Emissions and Sinks." The inventory report is a top-down assessment of national annual GHG emissions and is prepared to comply with commitments under the United Nations Framework Convention on Climate Change (UNFCCC). The EPA generally uses national energy data, data on national agricultural activities, and other national statistics to provide a comprehensive accounting of total GHG emissions. The use of the aggregated national data results in total coverage of sources including small emitters but means that the national emissions estimates for most source categories are not broken down at the geographic or facility level.

According to the latest version of the " Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022 (EPA 2024)," total gross U.S. GHG emissions were 6,343.2 Mt of CO_2e in 2022, which represents an increase of approximately 1.3% from the previous year and a decrease of 16.7% from the peak emissions in 2005. The decrease in total GHG emissions between 2019 and 2020 was largely due to the impacts of the coronavirus (COVID-19) pandemic on travel and economic activity. The decline also reflects the combined impacts of many long-term trends, including population, economic growth, energy market trends, technological changes including energy efficiency, and the carbon intensity of energy fuel choices. Approximately 82% (5,199.8 Mt) of the total emissions were from the energy sector, primarily fossil fuel combustion for transportation and electricity generation. The tonnages presented in this paragraph were calculated by the EPA using GWPs from the IPCC's AR5 (shown in Table 5-1). The EPA also presents emissions estimates using GWPs from IPCC's AR6 in the annexes to the "Inventory of U.S. Greenhouse Gas Emissions and Sinks."

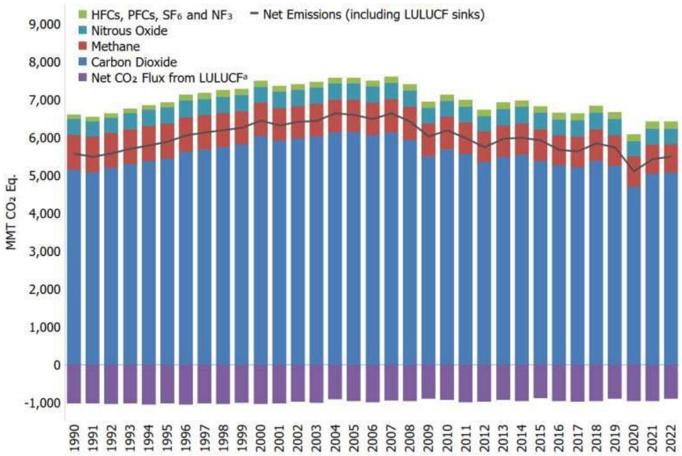
Table 5-1. Select U.S. Total GHG Emissions

IPCC Sector/ Category	1990	2005	2018	2019	2020	2021	2022
Energy	5,368	6,351.5	5,589.5	5,460.6	4,894	5,196.6	5,199.8
Fossil Fuel Combustion	4,728.2	5,747.3	4,989.8	4,855.9	4,344.9	4,639.1	4,699.4
Natural Gas Systems	247.3	228.3	227.1	232.2	221.8	217.5	209.7
Non-Energy Use of Fuels	112.4	128.9	129.4	127.6	119.2	140.2	102.8
Petroleum Systems	60.8	61.2	96.8	106.8	83.6	74.9	61.6
Coal Mining	112.7	76	62.2	56	48.3	47.1	46.1
Stationary Combustion	31.9	39.3	34.7	32	29.4	31.1	33.3
Mobile Combustion	45.6	41.4	20.4	21.9	18.7	19.3	19.3
Incineration of Waste	13.3	13.6	13.7	13.3	13.3	12.8	12.7
Abandoned Oil and Gas Wells	7.7	8.1	8.3	8.3	8.3	8.3	8.5
Abandoned Underground Coal Mines	8.1	7.4	6.9	6.6	6.5	6.4	6.3
Cement Production	33.5	46.2	39	40.9	40.7	41.3	41.9
Petrochemical Production	21.9	27.5	29.7	31.1	30.1	33.6	28.8
Field Burning of Agricultural Residues	0.6	0.7	0.6	0.6	0.6	0.6	0.8
Waste	236	192.1	173.7	176	171.5	169.2	166.9
Landfills	197.8	147.7	126.7	129	124.8	122.6	119.8
Wastewater Treatment	37.5	40.7	42.5	42.5	42.2	42	42.7
Composting	0.7	3.6	4.3	4.3	4.4	4.4	4.4
Total Gross Emissions (Sources)	6,487.3	7,477.4	6,754.8	6,617.9	6,026	6,340.2	6,343.2
LULUCF Sector Net Total	-881	-781.1	-765.1	-704	-776.2	-754.2	-854.2
Forest Land	-914.2	-793.9	-791.2	-736.3	-782.2	-768.7	-872
Cropland	31.6	25.6	39.7	41.7	33.4	37.6	3.4
Grassland	2.2	-28.4	-12.3	-8.7	-19.3	-14	39.6
Wetlands	44.8	44.4	42.6	42.6	42.4	42.4	38.8
Settlements	-45.3	-28.9	-44	-43.4	-50.5	-51.4	-64.1
Net Emission (Sources and Sinks)	5,606.4	6,696.3	5,989.7	5,913.9	5,249.8	5,586	5,489

The primary GHG emitted by human activities in the U.S. was CO_2, representing approximately 79.7% of total 2022 GHG emissions on a GWP-weighted basis. The largest source of CO_2, and of overall GHG emissions, was fossil fuel combustion (4,699 Mt). CH4 emissions from all sectors (760.8 Mt) accounted for 11.1% of U.S. emissions in 2022. The major sources of CH_4 include natural gas systems, enteric fermentation and manure management associated with domestic livestock, and decomposition of wastes in landfills. N_20 emissions accounted for 6.1% of total GHG emissions (398.8 Mt). The agricultural sector including fertilizers and soil management and manure management was the largest source of N_20 emissions. Figure 5-4 shows total U.S. GHG emissions by greenhouse gas and source sector.

The EPA GHG inventory report includes emissions data broken out by five different emissions sectors. The energy sector includes three different subcategories-coal mining, natural gas and petroleum systems, and fossil fuel combustion. The emissions itemized under the coal mining and natural gas and petroleum systems subcategories include emissions for all U.S. sources in each of these categories and are not differentiated by mineral ownership (i.e., federal, state, or private minerals). The coal mining sector includes emissions from underground and surface mining as well as post mining activities and abandoned underground mines. In 2021, GHG emissions from this subcategory were 53.6 Mt, a decrease of 2.4% from the previous year. The natural gas and petroleum systems subcategory includes emissions from oil and gas exploration, production, and processing as well as other sources. In 2021, GHG emissions from this subcategory were 300.7 Mt, a decrease of 6% from the previous year.

The fossil fuel combustion subcategory includes emissions from the use of fossil fuels in transportation, electricity generation, industry, and residential use. In 2021, the total GHG emissions from this subcategory were 4,689.4 Mt, up 6.3% from the previous year. Figure 5-4 shows the CO_2 emissions from fossil fuel combustion since 1990.



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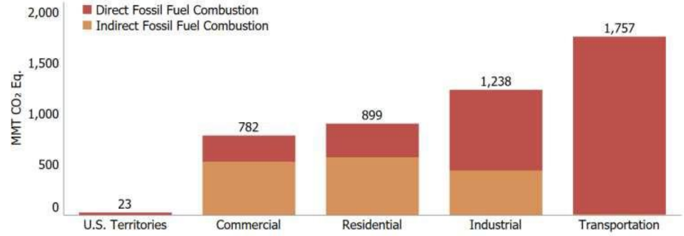

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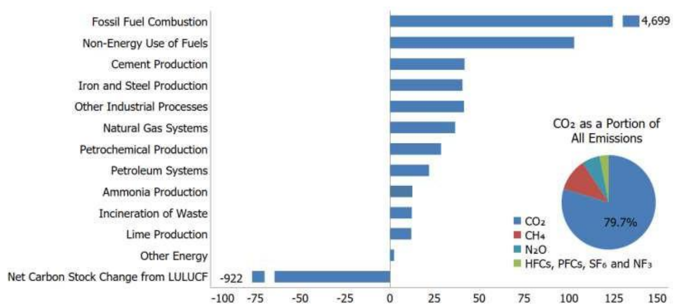

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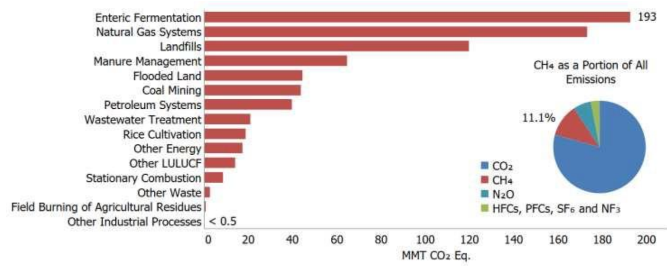

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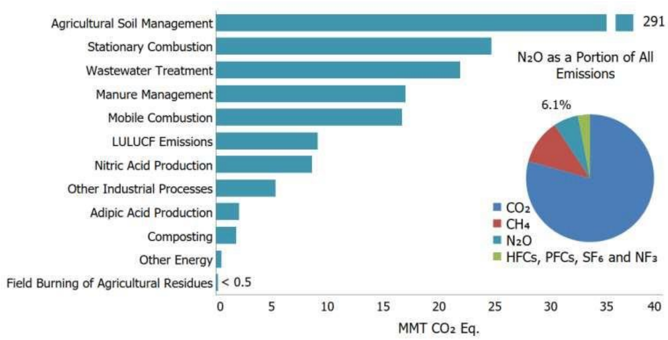

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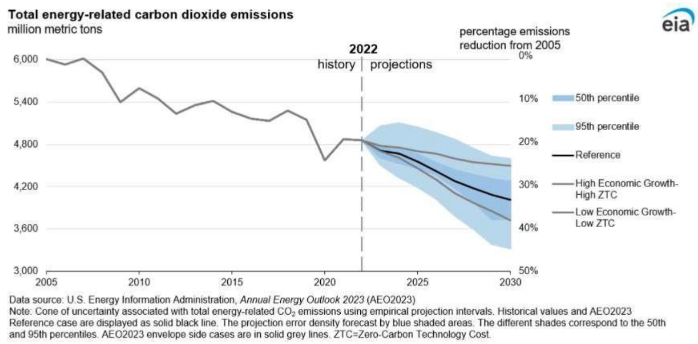
Figure 5-4. U.S. GHG Emissions

5.4 Projected U.S. Emissions

In addition to providing long-term projections for global energy demand and associated CO_2 emissions, the EIA produces an assessment of domestic energy and emissions trends through 2050 in its Annual Energy Outlook (AEO) report. According to the 2023 AEO there has been significant national and international energy market volatility as world economies emerge from the end of the global COVID-19 pandemic. Additionally, Russia's full-scale invasion of Ukraine has been very disruptive to normal or historical energy markets, such that a re-normalization is unlikely to occur. Based on the range of assumptions the EIA modeled (including the modifying assumptions incorporated under the Inflation Reduction Act (IRA)) projections for energy-related CO_2 emissions from fossil fuel consumption are projected to fall 25% to 38% by 2030. The U.S. market for electricity is forecast to be increasingly met by renewable sources of energy through 2050 while demand from transformation to electrification in many end-use sectors continues. Solar generating capacity in the AEO scenarios show growth between 325% to 1019% by 2050, while wind generating capacity is anticipated to grow by about 138% to 235%.

There are no major anticipated shifts in domestic oil and gas consumption through about 2040, but high international demand leads to continued growth in domestic production and allows the U.S to remain a net exporter of petroleum products and natural gas through 2050 in all AEO2023 cases. The domestic use of coal is projected to decline significantly through 2050, especially in terms of its use for electricity production. Coal exports are forecast to remain steady or grow slightly over the projection period. Figure 5-5 shows the projected changes in U S fossil fuel use and emissions through 2050.



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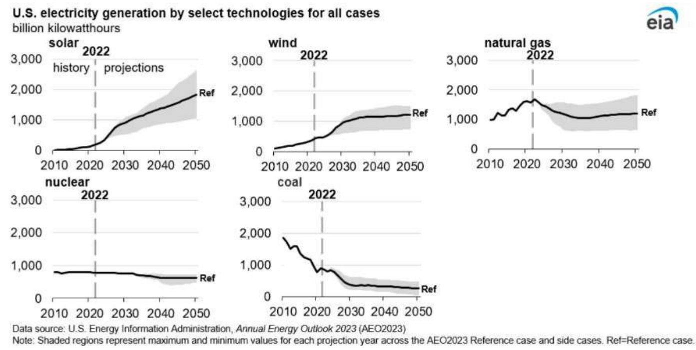

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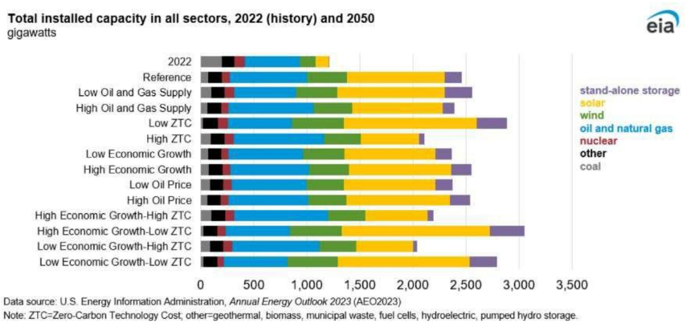

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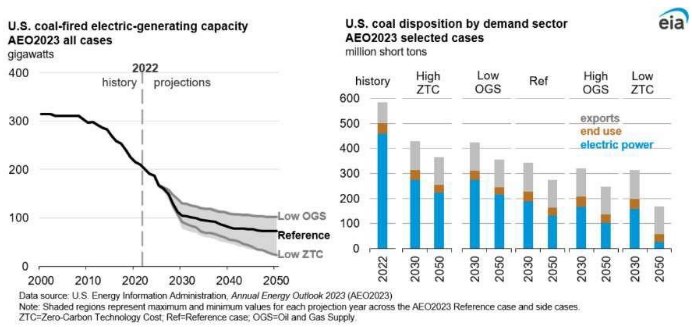

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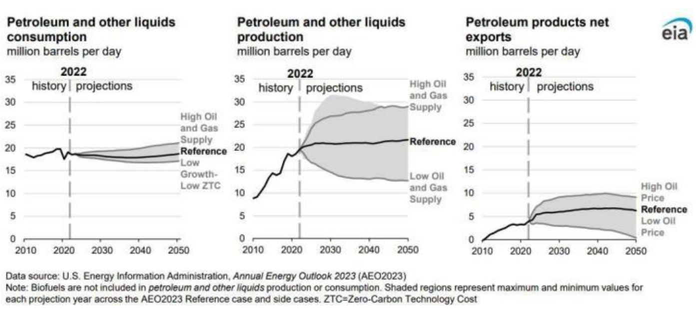

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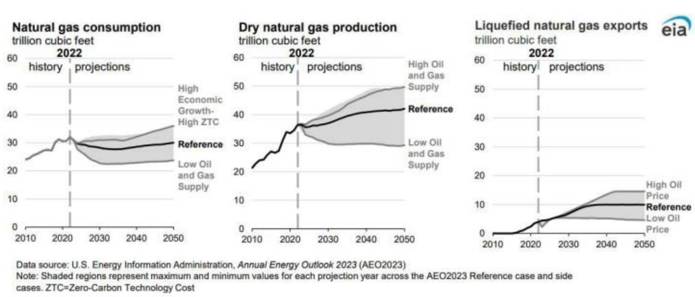

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Figure 5-5. U.S. Projected Emissions & Energy Mix (2023 AEO)

5.5 State Emissions

Each year, the U.S. EPA compiles disaggregated data on GHG emissions at both a state and facility level. The state-level emissions are derived from the national inventory report Detailed emissions data from the largest GHG-emitting facilities in the U S are collected through EPA's GHG Reporting Program (GHGRP). Large emitters of GHG emissions (> 25,000 tons/year) in each state are required to report their annual emissions along with other relevant facility data. Approximately 8,000 facilities report their emissions annually. The data is compiled by facility and by state and are available through EPA's Facility Level Information on Greenhouse gases Tool (FLIGHT). The GHGRP data are useful for understanding the major sources and types of GHG emissions within a state; however, it is not a comprehensive emissions inventory for each state as many sources of emissions (e.g., agriculture and land use sectors) are not required to report The EPA has estimated that GHGRP reporting covers approximately 85% of the total GHG emissions for sector-specific sources. Table 5-2 shows the most recent GHG emissions as estimated by the EPA for the states in which the BLM authorizes leasing and development of federal fossil fuel minerals. The information is broken down by sector, with detailed information being shown for the energy sector. The table also shows the estimates of net GHG emissions, which account for land use, land-use change, and forestry carbon sinks and sources. The emissions data for the petroleum and natural gas systems include offshore data (Alaska and Louisiana).

Table 5-2. State GHG Emissions (Mt $C0_2e$)

Sector	1990	2005	2017	2018	2019	2020	2021
Energy	68.8014	89.0143	80.2803	81.7997	75 0445	73.6246	72.0108
Fossil Fuel Combustion	56.4657	63.0576	61.5922	62.624	57.8053	54.4688	53.218
Natural Gas Systems	6.3499	14.5251	9.4494	8.9649	8.4064	11.6631	10.899
Non-Energy Use of Fuels	0.1688	0.1579	0.158	0.1745	0.156	0.1431	0.1521
Petroleum Systems	1.3401	2.2018	1.7677	1.811	2.0557	1.9887	2.1154
Coal Mining	3.7486	8.2523	6.448	7.3626	5.8369	4.5505	4.8534
Stationary Combustion	0.5264	0.6205	0.7302	0.7295	0.6465	0.6838	0.6438
Mobile Combustion	0.1416	0.1427	0.0747	0.0744	0.08	0.0712	0.0737
Incineration of Waste	0	0	0	0	0	0	0
Abandoned Oil and Gas Wells	0.0604	0.0564	0.0602	0.0589	0.0578	0.0554	0.0554
Abandoned Underground Coal Mines	0	0	0	0	0	0	0
Industrial Processes and Product Use	2.8864	3.5596	2.8922	2.9176	2.9917	2.7448	2.9562
Agriculture	7.4208	7.9511	8.9897	8.84	9 022	8.3616	8.5368
Waste	0.2376	0.1519	0.2689	0.2668	0.2602	0.2241	0.2236
Total Emissions (Sources)	79.3462	100.677	92.4312	93.8241	87.3183	84.9551	83.7274
Land Use, Land-Use Change, and Forestry	9.2551	7.616	20.61 59	5.5245	6.0592	4.9819	5.5049
Net Emission (Sources and Sinks)	88.6012	108.293	113.0471	99.3486	93.3776	89.937	89.2323

Source: State GHG Emissions and Removals I US EPA
NO = Not Occurring.
"+" Does not exceed 0.005 Mt $C0_2e$
Total Emissions (sources) = Emissions without Land Use, Land-Use Change, and Forestry (LULUCF).
Net Emission (sources and sinks) = Emissions with LULUCF.

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6.0 Methods and Assumptions

This report contains estimates of both direct and indirect (including downstream combustion) emissions from BLM-authorized fossil fuel development on the federal mineral estate for the three primary GHGs of concern (CO_2, CH_4, N_2O). In addition, the estimated emissions are aggregated at different scales for comparison to emissions reports and inventories completed by other entities at state, national, and global scales and for relevant industrial sectors. Estimated emissions from BLM-authorized activities are aggregated by BLM state administrative units for comparison to state emissions inventories and to put the scale of emissions into context.

The term direct is used to describe emissions from fossil fuel mineral development and production-related activities authorized by the BLM that typically take place on leased acres of the federal mineral estate. Direct emissions could result from a variety of activities, such as lease exploration, access road construction, well pad or coal mine development, well drilling and completions, recurring maintenance and production equipment operations, and site reclamation. Indirect emissions are those that result from activities outside of the BLM's oversight authority and for which the agency exercises no continuing program of responsibility, such as off-lease infrastructure development and maintenance, transportation and distribution, processing and refining, and the end use (including combustion) of any federal minerals produced. End use emissions make up the majority of GHG emissions related to federal energy resource development. The sum of the direct and indirect GHG emissions from fossil fuel mineral production is also known as a life-cycle assessment (LCA).

The emissions estimates are also presented at two cumulative scales: geographic and temporal. The geographic cumulative scale is the entire onshore federal mineral estate managed by the BLM. The temporal cumulative scales include estimated emissions from total federal onshore mineral production projected for the next 12 months, the life-of-project emission estimates associated with the 12-month projections, and the long-term emissions from the portion of energy demand estimated to be met from the federal mineral estate out to year 2050 using data from the Energy Information Administration. The estimates provide a baseline to compare emissions from BLM-authorized development with those of the broader economy (national and global) and illustrate the degree to which federal fossil fuel mineral development contributes to projected GHG emissions and therefore to climate change.

As part of the full life-cycle assessment, this report also includes estimates of projected emissions on both a short-term and long-term basis: in which the short-term estimates are based on reasonably foreseeable development trends derived from leasing and production statistics, and the long-range estimates are based on the analysis of energy market dynamics developed by the U.S. Energy Information Administration (EIA) in its Annual Energy Outlook (AEO) report. Together, the estimates are designed to provide relevant, well-supported, and factual information that is intended to fully account for GHG emissions from BLM authorizations to develop the federal mineral estate.

6.1 Emissions Factors and Production Data

To characterize direct and certain indirect GHG emission estimates in this report, the BLM is applying a combination of published LCA data, other studies and statistics, and assumptions for each fossil fuel type. The LCA data presented in this report are meant to broaden the analysis of the potential emissions that could result from BLM management of the onshore federal mineral estate. While this approach depicts the energy-in/energy-out emissions calculus, LCA accounting is not accurate in terms of the true GHG burden federal minerals represent. For example, adding all of the energy life cycle emissions inventories prepared for fossil fuel mineral development would result in totals greater than the levels reported at national scales (e.g., EPA's National Emissions Inventory Report). This is because LCA accounting for each mineral can lead to double-counting effects when the results of each separate mineral type are added (Lenzen 2008)[29] Ultimately, it is known that a portion of the mineral production will be used to obtain more minerals. For example, petroleum is used and accounted for throughout coal's life-cycle in the form of combustion from mining and transportation activities and has thus been double counted relative to estimating total petroleum in its own bin. For any accounting period, there can be no greater sum of emissions than that for which the supply of each mineral type can provide. In general, this means that the total federal GHG burden on the environment is best described by the end use, or downstream combustion portion of the disclosed accounting, plus any fugitive emissions that result from fossil mineral processes prior to end use. Some of the referenced LCA sources contain estimates for systemic losses of methane (i.e., fugitive emissions), such that when this data is available the BLM back-calculates the fugitive losses from the direct emissions to more fully provide transparency for emissions resulting from BLM-authorized development.

The end-use phase emissions for coal, oil, and gas (assumed combustion) are estimated using EPA emissions factors from Tables C-l and C-2 of 40 CFR Part 98, Subpart C, as shown in Tables 6-2, 4-7 and 4-9. The EPA factors were chosen to represent the downstream portion of these life-cycle emissions since they provide a relatively straightforward basis for estimating the consumption of each fuel for which the actual downstream transformation or use is relatively unknown compared to the assumptions and specificity used in the referenced LCA data.

Fossil fuel production is the primary input used in the LCA methodology, and generally in this report. The BLM is using data and statistics from the Energy Information Administration and the Office of Natural Resources Revenue (ONRR), both of which provide production accounting services for domestic fossil fuel minerals to estimate report year emissions on a fiscal year basis (when such data exists).

6.2 Coal

Virtually all coal produced in the U.S is classified as either thermal (steam coal) or metallurgical (met or coking coal). Steam coal has a variety of energy-related uses in several sectors of the economy, including as a primary fuel for baseload electrical generating plants. Met coal is used (indirectly, as coke) as a fuel and reactant in steel production blast furnaces. Regardless of classification, the BLM is unaware of any non-combustion or other *de minimis* uses for coal stocks and is thus assuming 100% combustion for all federal coal produced.

To estimate the LCA emissions associated with federal coal production, this report relies on data obtained from several sources to adequately capture the variability of mine activities occurring at regional scales. The estimates use production metrics representative of operational mines (underground and surface) in each state to evaluate the GHG emissions profiles for extraction. For Wyoming, Montana, and North Dakota, life-cycle emission factors developed by the Department of Energy's National Energy Technology Laboratory (NETL) [30] are used to evaluate emissions from production and the export transport of coal regardless of actual state origin. For New Mexico, Oklahoma, and Alabama, NETL life-cycle emission factors for U.S coal-fired power plants[31] were used for production emissions estimates. For Colorado and Utah, the BLM used detailed internal data from operational mines (both underground and surface) to evaluate LCA GHGs associated with production.

This year's report also incorporates data from a work product developed by the U.S. Geologic Survey (USGS) under an Interagency Agreement (IAA L21PG00l 34) [32] signed with BLM back in 2021. The agreement enlists USGS support for estimating GHG emissions from active and future coal mining operations, by specifically calculating the remaining federal coal resources and reserves at active mines, and updating projected future coal mining activities on federal lands. This work was pivotal for allowing the BLM to produce longer term estimates for the federal coal program based on existing and potential coal leases, limited market dynamics, coal plant closure forecasts, and the direct input from mine operators. The USGS projections provide estimates for fugitive methane emissions from mining (direct) and post mining (indirect) activities, transport emissions (indirect) for known coal delivery destinations and methodologies, and sector specific downstream (indirect) estimates for produced coal end-use, based on the type of coal mined (steam or metallurgic) The data shows a nearly 9-fold reduction in emissions resulting from declining coal production from Federal-lease mine plans as coal-burning power plants are retired, with a significant reduction projected around 2032 (assumes the abandonment of multiple Federal-lease mines following coal-fired power plant shutdowns). **Note:** The BLM is retaining our original methodology of using emissions factors from tables C-1 and C-2 of 40 CFR Part 98, Subpart C, for estimating coal combustion emissions. Calculating sector specific combustion emissions for coal adds little value for reporting purposes since BLM does not provide similar sector specific downstream oil and gas emissions estimates in this report at present. In general, the BLM is less concerned with where GHGs come from as compared to say EPA, which has regulatory authority over sector sources and the ability to fine tune regulations to combat climate change. The BLM's purpose in this report is to account for and disclose an overall carbon footprint from the federal mineral estate. However, we are incorporating the federal coal ranks from USGS's work (vs. the state level EIA coal ranks) to provide for refined emissions factor calculations. Additionally, we note that BLM's internal analysis of the report year data shows that the USGS and BLM methods deviate in total emissions by about 3.5% after subtracting the extraction emissions, which the USGS data does not account for, but before correcting for the AR6 GWP used in this report (the USGS data is based on AR4 GWPs). Here, BLMs methodology would be considered more conservative i.e., resulting in higher emissions estimates for the same volumes of coal combusted.

Table 6-1 presents a summary of coal production statistics and the estimated direct emissions factors for activities occurring at active mines for each state. Figure 6-1 shows a U.S Geological Survey map for coal rankings in the U.S that supports the statistics presented in Table 6-1. A summary of the downstream emissions factors derived for each coal type in states where the BLM authorizes coal leasing is presented in Table 6-3.

Table 6-1. Coal Production Emissions Factors and Statistics

State	Direct EF (kg $C0_2e$/ton)	Bituminous	Subbituminous	Lignite	Exported	Export Type	Underground	Surface
Alabama	259.27	100%	0%	0%	80.33%	Met	85.23%	14.78%
Colorado	65.1	100%	0%	0%	0.70%	Met	60.04%	39.96%
Montana	13.8	99.74%	0%	0.26%	0%	NA	25.36%	74.64%
New Mexico	259.27	100%	0%	0%	0%	NA	16.97%	83.03%
North Dakota	13.8	0%	0%	100%	0%	NA	0%	100%
Oklahoma	65.1	100%	0%	0%	0%	NA	0%	100%
Utah	27.5	100%	0%	0%	3.66%	Steam	96.51%	3.49%
Wyoming	138	0%	100%	0%	0.34%	Steam	1.34%	98.66%

Source USGS (IAA L21PG00734), EIA Annual Coal Report (Tables 2, 6, and 8).

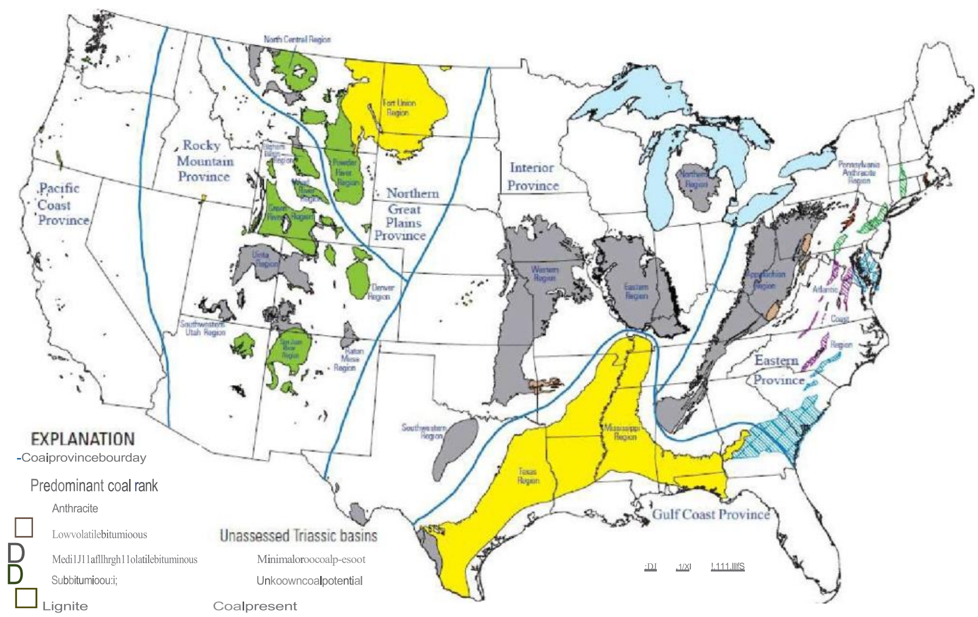


Figure 6-1. 2021 USGS Coal Field Ranks Map [33]

Table 6-2. EPA Coal Energy Content and Emissions Factors

Coal Rank	MMbtu/ ton	kg CO2/ MMbtu	kg CO2/ ton	kg CH4/ MMbtu	kg N20/ MMbtu	kg CH4/ ton	kg N20/ ton	kg C02e/ ton
Bituminous	24.93	93.28	2,325.47	0 011	0.0016	0.2742	0.0398	2,344.53
Subbituminous	17.25	97.17	1,676.18	0.011	0.0016	0.1897	0.0276	1,689.37
Lignite	14.21	97.72	1,388.6	0011	0.0016	0.1563	0.0227	1,399.46

Source Tables C-1 and C-2 of 40 CFR Part 98, Subpart C
Note: MMbtu is 1 million British thermal units. No anthracite coal is mined on the federal mineral estate.

Table 6-3. Derived Downstream Coal Emissions Factors

State	CO_2	CH_4	N_20	$C0_2e$ 100
Alabama	2,325	0.274	0.04	2,344
Colorado	2,325	0.274	0.04	2,344
Montana	2,323	0.274	0.04	2,342
North Dakota	1,388	0.156	0.023	1,399
Utah	2,325	0.274	0.04	2,344
Wyoming	1,676	0.19	0.028	1,689
National	1,948	0.225	0.033	1,963

To estimate non-export coal transport emissions where the delivery locations could not be ascertained, the BLM is relying on coal shipping data published by the EIA. The data shows the amount of coal shipped per method along with the origin and destination states for the latest available production (2022), which was assumed to be a proxy for the 2023 production data presented in this report. The raw data was scaled to account for the actual production shifts in federal coal producing states relative to the published data. The BLM's estimates assume that all federal coal was transported via rail or truck using the fraction of production shipping methodology obtained from USGS. Reasonable assumptions had to be made for the shipping distance since the actual point of origin, route, and destination data is unknown. Origin to destination state mileage was estimated to the center points of each state and then adding an additional 20% to the derived length. Intrastate trip length estimates were made using 75% of the square root of each state's total land area divided by two. For both inter- and in-state shipping, the trip lengths were doubled to account for the return trips. Total ton-miles were derived by using USGS supplied rail and truck revenue ton-miles per gallon of fuel (762 and 86, respectively) to estimate the total diesel required to ship the unknown destination quantities of coal. Emissions are calculated by multiplying the estimated fuel use by EPA diesel fuel emissions factors (Table 6-4) for the applicable shipping method. A summary of the analysis data is shown in Table 6-5.

Table 6-4. Coal Transport Emissions Factors

Method	Units	CO_2	CH_4	N_20	$C0_2e$
Railroad	grams/gal	10,210	0.8	0.26	10,304.82
Truck	grams/gal	10,210	0.0665	0.3017	10,294.37
Export	kg CO_2e/ton	NA	NA	NA	107.09

Source: U.S. EPA Emissions Factor Hub
Export: NETL LCA of Coal Exports from the Powder River Basin (cited above), corrected to AR6 GWP.

Table 6-5. Coal Transport Data

State	Production Destination Unknown	Truck Transport	Rail Transport	Truck Diesel (gal)	Rail Diesel (gal)	Export Volume (tons)	Total $C0_2e$ (Mt)
Alabama	100%	0%	100%	0	11,323	208,554	0.023
Colorado	42%	3.92%	38.14%	379,937	1,194,700	44,324	0.026
Montana	100%	0%	700%	0	40,598,436	0	0.478
North Dakota	0%	0%	0%	0	0	0	0.006
Utah	45%	24.05%	20.69%	3,060,870	777,188	8,528,624	2.879
Wyoming	94%	0%	94%	0	533,280,429	11	6.414

Report year emissions from BLM coal leasing authorizations are based on ONRR records of actual coal production. Table 6-6 shows a summary of the ONRR production data from states that reported federal coal production during the past 5 years. The table also shows total U.S. coal production (federal and nonfederal) to illustrate the percentage of federal coal relative to the U.S. total (% U.S. Total) and the percentage of federal coal that comes from the various federal coal producing states (% Federal). The percent total calculations are based on the 5-year average data column.

Table 6-6. Federal Coal Production (tons)

Area	2019	2020	2021	2022	2023	5-Year Average	% U.S. Total	% Federal
U.S Total	706,309,263	535,434,354	577,431,278	594,155,282	580,386,061	598,743,248	100%	NA
Federal Total	302,146,258	246,492,649	252,264,178	270,194,425	242,842,109	262,787,924	43.89%	100%
Onshore Total	302,146,258	246,492,649	252,264,178	270,194,425	242,842,109	262,787,924	43.89%	100%
Wyoming	251,903,536	206,625,803	217,807,957	232,982,333	217,134,087	225,290,743	37.63%	85.73%
Montana	78,067,706	13,407,510	10,614,886	12,759,947	9,207,466	12,811,503	2.14%	4.88%
Utah	12,964,773	12,242,432	11,295,467	10,290,260	6,600,105	10,678,607	1.78%	4 06%
Colorado	10,058,177	9,037,683	7,468,159	6,331,968	5,355,739	7,650,345	1.28%	2.91%
North Dakota	4,375,332	2,996,726	4,340,950	5,349,940	4,423,107	4,297,210	0.72%	1.64%
New Mexico	4,214,550	1,963,242	736,759	2,217,007	0	1,826,312	0.31%	0.69%
Alabama	399,098	145,052	0	259,622	121,611	185,077	0.03%	0.07%
Oklahoma	161,751	74,201	0	3,348	0	47,860	0.01%	0.02%

% U.S. Total and % Federal data are based on the 5-Year Average data column.

6.3 Short-Term Coal Projections

Most of the coal produced from BLM-managed lands comes from the Powder River Basin (PRB) in Wyoming and Montana. According to a recent analysis (Cohn 2021)[34], several PRB mines have closed or are scheduled to close in the next few years, and PRB production has dropped by 50% since its peak in 2010 This includes a nearly 20% decrease experienced between 2019 and 2020 as documented in Table 6-6 and in other reports (West 2021)[35] BLM data indicate that few new coal leases have been sold in recent years, while a somewhat larger number of leases have been terminated, and that less recent leases were purchased to provide reserves for future production at existing mines. The BLM does not project any major shifts in existing coal production and does not expect any additional coal production from new leases in the next 12 months. Table 6-7 presents federal coal statistics[36] that are useful to discern leasing trends and to potentially guide future emissions estimates. The data include the number of leases, leased acres, and lease sales held for each of the past 5 years broken down by leasing region.

Table 6-7. Federal Coal Leasing Statistics

Area	Statistic	2019	2020	2021	2022	2023
	Leases	299	287	287	284	283
Total Federal	Acres	458,636	437,039	435,535	433,264	427,425
	Sales I Term	0 I -5	3 I -2	2 I -14	1 I -1	0 I -2
	Leases	99	99	99	99	99
Wyoming	Acres	191,279	189,476	186,918	186,917	186,977
	Sales I Term	010	010	010	010	010
	Leases	50	49	50	47	47
Colorado	Acres	80,636	80,336	82,838	87,748	81,708
	Sales I Term	0 I -1	0 I -1	7 I 0	0 I -3	1 I -1
	Leases	71	58	58	58	58
Utah	Acres	82,800	62,985	62,985	64,250	64,250
	Sales I Term	0 I -1	0 I -13	0 I 0	0 I 0	1 I 0

Area	Statistic	2019	2020	2021	2022	2023
	Leases	51	52	52	54	54
Montana & North Dakota	Acres	47,935	48,095	48,095	49,045	49,045
	Sales I Term	3 I 0	1 I 0	0 I 0	2 I 0	0 I 0
	Leases	20	20	20	20	19
New Mexico & Oklahoma	Acres	42,716	42,716	41,413	41,056	35,257
	Sales I Term	0 I 0	0 I 0	0 I 0	0 I 0	0 I -1
	Leases	6	6	7	6	6
Remaining	Acres	13,270	13,431	13,286	10,248	10,248
	Sales I Term	0 I 0	1 I 0	0 I -1	0 I 0	0 I 0

Source BLM, Public Land Statistics, Volumes 203-207, FY 207 8-FY 2022. (2023 statistics pending) BLM Public Land Statistics

BLM's coal statistics and data are not nearly robust enough to form a short-term (12-month) estimate of potential production from which to estimate emissions. Previous annual reports simply used a two-year average of production as a projection. This year, the BLM is using the EIA's short-term energy outlook (STEO) for coal projections. The STEO forecast is for significantly less volume in 2024, as compared to 2023.

The short-term life-of-project emissions for this report year are calculated by applying the appropriate life-cycle emissions factors to the aggregated life-of-mine production data supplied by the USGS as noted above. This USGS data has allowed the BLM to extend our short-term emissions estimates for coal as shown in Table 7-3.

6.4 Crude Oil

According to Energy Information Administration (EIA) data (2022), approximately 95% of oil stocks in the U.S. are transformed into fuels, while the remainder is refined to produce a range of petrochemical products such as plastics and other consumables. Refining processes require additional feedstocks to meet regulatory requirements or yield the desired products. Because of these feedstocks and the fact that most of the products refineries produce are less dense than the crude oil stock, refined product volume is greater than that of the crude oil feed by approximately 5.9%. This gain, known in the industry as process gain, means that the percent of crude oil stocks used to produce combustible products is essentially equivalent to the original produced crude oil volumes; and so for the purposes of this report, the BLM is assuming a 100% combustion rate for crude oil production.

To account for the methods and infrastructure used to produce and market crude oil products, this report relies on published data produced in part by the DOE NETL, which updates its 2005 baseline well-to-wheels life-cycle GHG analysis of petroleum-based fuels consumed in the U.S. (Cooney et al. 2017).[37] The update focuses on three primary products derived from crude oil including gasoline, diesel, and jet fuel, which according to the EIA accounts for approximately 83% of the potential crude oil stock use in the U.S. To estimate crude oil life-cycle emissions from the reported production volumes, the BLM calculates a weighted average of NETL's updated modeled LCA emission factors as derived from the EIA product percentages. As part of this year's annual update, the BLM is providing speciated GHG estimates for all crude oil life-cycle stages. The speciated gas emissions factors are taken from NETL's 2005 Baseline Data and Analysis of Life Cycle Greenhouse Gas Emissions of Petroleum-Based Fuels report The baseline report also provides a CO_2e emissions factor, and here the BLM is just applying the GWP corrected ratio of the baseline and update CO_2e emissions to the speciated factors in the baseline to derive update based speciated factors. The speciated gases are then summed using AR6 GWPs to arrive at a final updated CO_2e factor. Table 6-8 shows the LCA emissions factors as applied in this report

Table 6-8. GHG Emissions Factors for Federal Oil Production (tonnes/bbl)

Life-Cycle Stage	Type	CO2	CH4	N20	C02e
Extraction / Production	Direct	4.60E-02	9.19E-04	1.26E-06	7.38E-02
Crude Transport	Indirect	4.73E-03	3.89E-06	8.0DE-08	4.87E-03
Refining	Indirect	4.SSE-02	5.97E-05	7.82E-07	5.0SE-02
Product Distribution	Indirect	5 OSE-03	3.14E-06	9.98E-08	5.20E-03
End Use	Indirect	4.32E-01	1.74E-05	3.48E-06	4.34E-01

End Use Source: 40 CFR Appendix Tables C-1 & C-2 to Subpart C of Part 98 - Default Combustion CO_2, CH_4, and N_20 Emission Factors and High Heat Values for Various Fuels.

I Emissions factors converted to AR6 GWPs from referenced sources.

Report year emissions and projected emissions from BLM crude oil leasing authorizations and permitting actions are based on ONRR records of actual oil production. Table 6-9 shows a summary of the ONRR production data from states that reported federal oil production during the past 5 years. The table also shows total U.S. oil production (federal and nonfederal) to illustrate the percentage of federal oil relative to the U.S. total (% U.S. Total) and the percentage of federal oil that comes from the various federal oil producing states (% Federal). The U.S. total data includes all oil produced from both onshore and offshore sources. The percent total calculations are based on the 5-year average data column (see example calculation in table notes).

Table 6-9. Federal Oil Production (bbl)

Area	2019	2020	2021	2022	2023	5-Year Average	% U.S. Total	% Federal
U.S. Total	4,493,544,000	4,142,504,000	4,112,721,000	4,347,377,000	4,719,402,000	4,363,109,600	100%	NA
Federal Total	987,032,983	977,941,822	1,005,768,076	1,116,395,993	1,231,811,623	1,062,590,099	24.35%	700%
Offshore	688,807,489	654,170,375	610,858,770	629,715,983	676,108,370	651,812,197	14.94%	67.34%
Onshore Total	292,225,494	323,771,447	394,909,306	487,280,010	555,703,253	410,777,902	9.47%	38.66%
New Mexico	167,258,895	203,860,456	270,575,368	362,239,643	434,729,597	287,732,792	6.59%	27.08%
Wyoming	48,533,379	51,227,005	44,935,189	48,941,865	48,497,880	48,427,064	1.11%	4.56%
North Dakota	45,477,304	39,229,118	49,615,244	44,705,399	42,226,255	44,250,664	1.01%	4.16%
Colorado	5,994,493	7,085,358	9,160,979	10,838,468	10,280,384	8,671,936	0.2%	0.82%
California	9,609,406	9,824,206	8,572,513	8,526,127	8,027,995	8,912,049	0.2%	0.84%
Utah	8,070,861	6,483,457	6,447,746	6,601,756	6,970,865	6,914,937	0.16%	0.65%
Montana	3,333,387	2,935,881	2,826,717	2,637,615	2,406,734	2,828,067	0.06%	0.27%
Alaska	1,341,860	946,878	873,808	853,722	844,836	972,221	0.02%	0.09%
Oklahoma	764,714	637,438	492,907	684,540	677,742	651,468	0.01%	0.06%
Louisiana	563,448	450,247	382,111	350,459	256,575	400,568	0.01%	0.04%
Nevada	267,670	237,927	219,674	233,631	226,504	237,080	0.01%	0.02%
Texas	371,194	321,714	303,324	191,944	128,622	263,360	0.01%	0.02%
Mississippi	301,090	243,814	211,928	184,966	177,116	223,783	0.01%	0.02%
South Dakota	110,551	103,203	123,025	121,701	107,304	113,157	0%	0.01%
Kansas	138,217	102,297	90,442	90,336	73,534	98,965	0%	0.01%
Nebraska	22,785	18,942	19,738	26,822	25,073	22,672	0%	0%
Alabama	18,967	18,108	17,095	17,358	16,278	17,561	0%	0%
Illinois	15,293	15,411	14,762	14,333	13,147	14,589	0%	0%
Michigan	13,372	10,333	9,614	7,972	7,352	9,729	0%	0%

	11,803	11,922	9,384	6,283	5,460	8,970	0%	0%
	5,967	7,003	6,710	4,459	3,400	5,508	0%	0%
	624	569	589	492	475	550	0%	0%
	213	164	437	117	123	211	0%	0%
Arkansas		2	2	2	2	2	0%	0%

Ex: % U.S. Total for ND (7 .03%) = (39,457,563 / 3,843,019,800 * 100) and% Federal ND (4.27%) = (39,457,563 / 923,755,471 * 100)

6.5 Natural Gas

Natural gas is used as a combustion energy source in almost every sector of the economy. According to EIA data, approximately 3% of natural gas stocks are used in the industrial sector as a raw material to produce chemicals, fertilizer, and hydrogen. The amount of natural gas diverted into each of the non-combustion product streams is not known. However, the processes [38] that support the chemical transformation of methane (natural gas) into hydrogen is known to generate a stoichiometric amount of CO_2 emissions from the feedstock gas. Thus for this report year, the BLM is conservatively assuming that any process or product using natural gas as a feedstock would release GHGs at the same rate as combustion.

To account for the LCA emissions associated with natural gas production, the BLM is relying on data published by the Department of Energy's National Energy Technology Laboratory (DOE NETL) in a 2019 report entitled "Life Cycle Analysis of Natural Gas Extraction and Power Generation" [39] The NETL report provides a detailed examination of the natural gas supply chain in the U.S. broken down by basin and resource type. The calculations in this report are based on the national averages published in the NETL report, as these values provide a reasonable estimation of emissions based on the fractions of production the representative federal basins contribute to total U.S. production (see Figure 6-2, which contains the applicable NETL report exhibits). The NETL report concludes that the average life-cycle GHG emissions from the U.S. natural gas supply chain are 18.53 grams (g) of carbon dioxide equivalent per megajoule (MJ) of delivered (i.e., combusted) natural gas. The report also concludes that total methane emissions throughout the supply chain are approximately 1.24% of the production volume (see Figure 6-2, NETL Exhibit 6-2). The loss of gas throughout the supply chain represents a reduction of the available gas that could be combusted by the same fraction, and so for accounting purposes the BLM is assuming a combustion rate of 98.76% of all production volumes. In terms of emissions speciation, methane alone accounts for 6.493 g CO_2e/MJ (0.218 g CH_4/MJ) of the total supply chain CO_2e factor. The BLM is assuming that 100% of the production emissions from the supply chain processes are part of the direct emissions scope from federal production. The direct emissions of CO_2 and CH_4 from the federal production supply chain are estimated to be 2.852 and 0.08 grams per megajoule, respectively. The BLM is using the published energy density of natural gas (1,026 Btu/cf) from Tables C-1 and C-2 at 40 CFR Part 98, Subpart C, to calculate LCA emissions in this report.

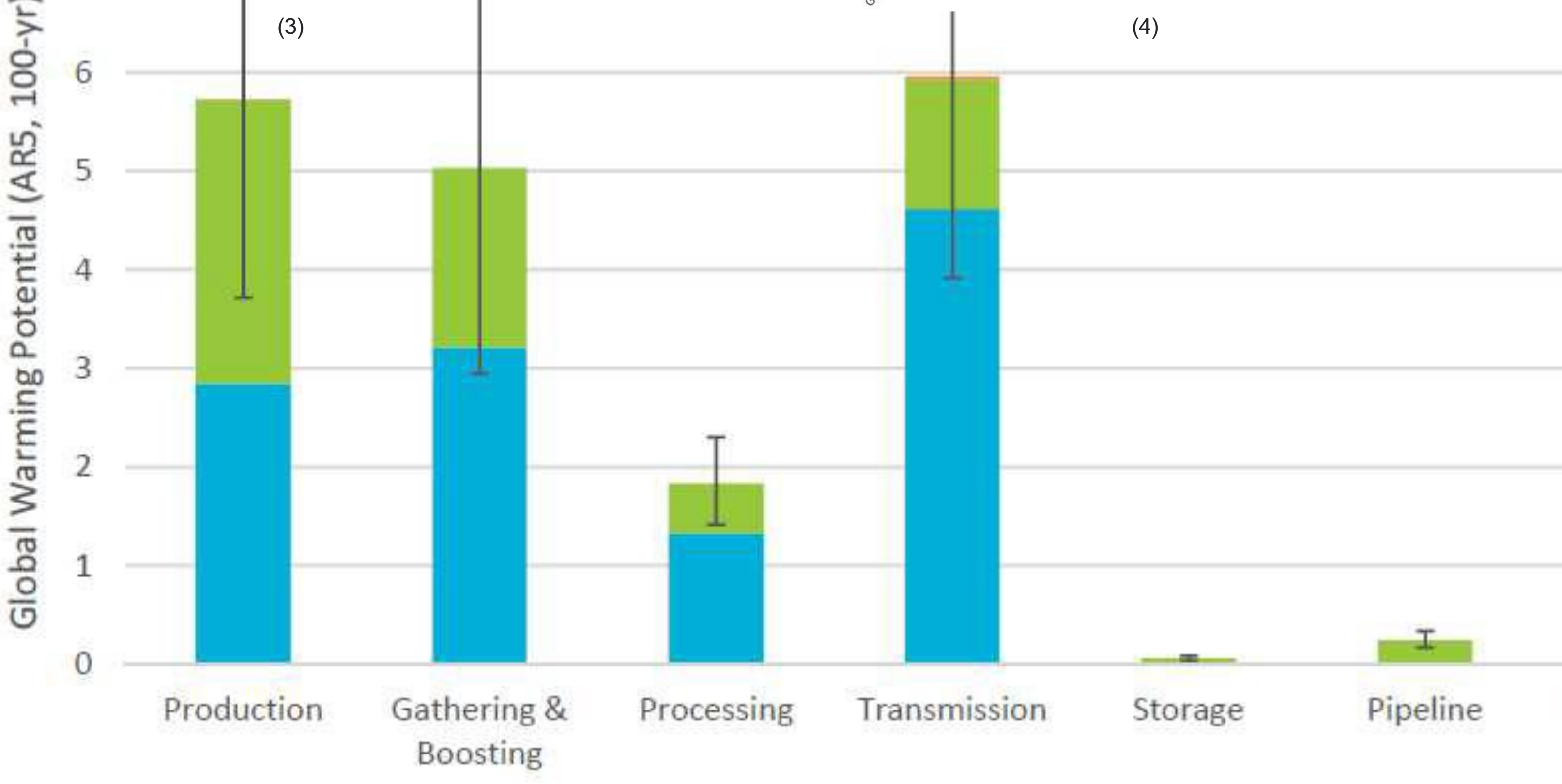
(1)

Exhibit 2-3. Natural Gas Production Shares by Well Type and Geography

Geography	Well Type						
	Conventional	Shale	Tight	CBM	Offshore	Associated	Total
Onshore Production							
Anadarko	2.2%	2.6%	1.7%				6.5%
Appalachian		29.0%					29.0%
Arkla	0.4%	4.2%	1.4%				6.0%
Arkoma	0.3%	0.9%					1.2%
East Texas	1.6%	1.3%	1.3%				4.2%
Fort Worth Syncline		1.8%	0.0%				1.8%
Green River	1.6%		3.9%				5.5%
Gulf Coast	0.8%	6.6%	1.3%				8.7%
Permian	2.3%	5.3%					7.6%
Piceance			0.3%				0.3%
San Juan	1.4%			1.9%			3.3%
South Oklahoma		1.0%					1.0%
Strawn		3.2%					3.2%
Uinta	0.5%		0.8%				1.3%
*Subtotal: Onshore**	*11.0%*	*56.0%*	*10.6%*	*1.9%*			*79.6%*
Offshore Production							
Offshore Gulf of					4.2%		4.2%
Offshore Alaska					0.1%		0.1%
Subtotal: Offshore					*4.3%*		*4.3%*
Associated Gas							
United States						16.1%	16.1%
Total							
*Total**	*11.0%*	*56.0%*	*10.6%*	*1.9%*	*4.3%*	*16.1%*	*100%*

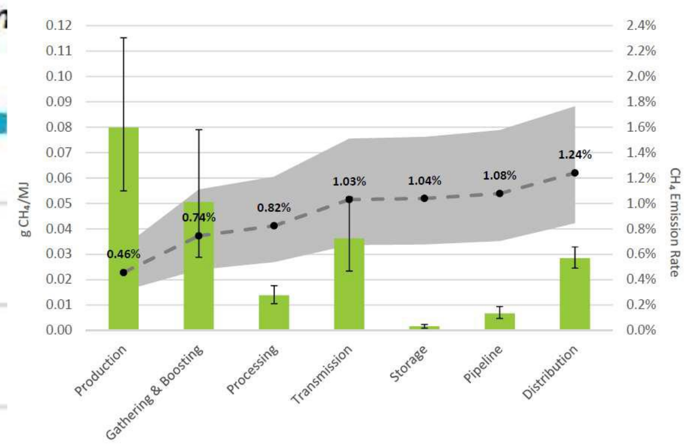
(2)

Exhibit 6-1. Life Cycle GHG Em ... **hain**

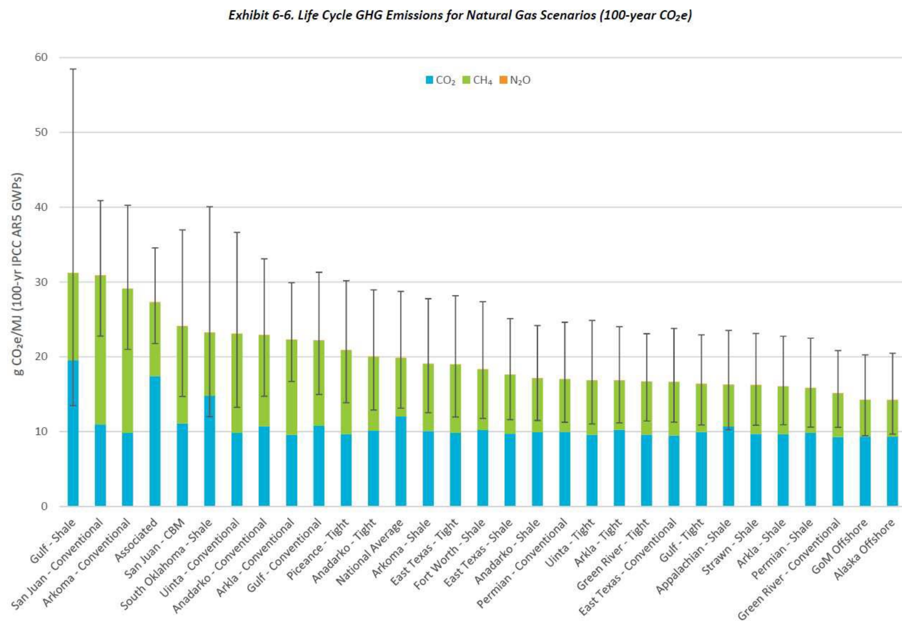


(3)

Exhibit 6-2. Life Cycle CH_4 Emissions for the U.S. Natural Gas Supply Chain



(4)



(5)

Figure 6-2. NETL Report Exhibits for LCA Estimates

Table 6-10. GHG Emissions Factors for Federal Gas Production (tonnes/Mcf)

Life-Cycle Stage	Type	CO2	CH4	N20	C02e
Extraction / Production	Direct	3.09E-03	8.66E-05	7 .55E-12	5.67E-03
Subtotal Transport	Indirect	847E-03	1 33E-04	1.31E-07	1 25E-02
Subtotal Process	Indirect	144E-03	1 66E-05	5 12E-09	1 94E-03
End Use	Indirect	544E-02	1.03E-06	1 03E-07	545E-02

Transport subtotal includes gather/goos!, station transmission, pipeline transmission, and product distribution emissions. Processing subtotal includes gas plant processing and storage.
Emissions factors converted to AR6 GWPs from referenced sources.

Report year emissions and projected emissions from BLM gas leasing authorizations and permitting actions are based on ONRR records of actual gas production. Table 6-11 shows a summary of the ONRR production data from states that reported federal gas production during the past 5 years. The table also shows total U.S. gas production (federal and nonfederal) to illustrate the percentage of federal gas relative to the U.S. total (% U.S. Total) and the percentage of federal gas that comes from the various federal gas producing states (% Federal). The U.S. total data includes all gas produced from both onshore and offshore sources. The percent total calculations are based on the 5-year average data column (see example calculation in table notes)

Table 6-11. Federal Gas Production (Mcf)

Area	2019	2020	2021	2022	2023	5-Year Average	% U.S. Total	% Feder
u S Total	40,780,210,000	40,729,927,000	41,676,743,000	43,802,269,000	45,637,380,000	42,525,305,800	100%	NA
Federal Tota l	4,435,264,808	4,241,927,465	4,170,641,717	4,490,685,283	4,767,849,011	4,421,273,657	104%	100j
Onshore Total	3,378,980,254	3,320,343,321	3,374,344,451	3,674,900,338	3,967,991,112	3,543,311,895	8.33%	80.14
New Mexico	1,050,380,249	1,152,119,760	1,375,746,281	1,690,687,502	2,051,843,940	1,464,155,546	344%	33.12
Wyoming	1,300,399,021	1,227,263,632	1,106,578,639	1,035,848,236	974,607,998	1,128,939,505	2.65%	25.53

Offshore	1,056,284,554	921,584,144	796,297,266	815,784,945	799,857,899	877,961,762	2.06%	19.86
Colorado	653,842,976	588,265,189	528,750,428	532,852,813	521,501,783	565,042,638	1.33%	12.78
Utah	158,031,635	141,214,642	125,480,792	138,671,914	120,276,047	136,735,006	0.32%	3.09'
North Dakota	87,716,596	82,793,573	117,708,437	122,399,190	127,586,503	107,640,860	0.25%	243'
Texas	27,304,091	25,299,385	32,789,608	44,355,895	41,973,260	34,344,448	0.08%	0.78'
Louisiana	17,115,734	24,788,203	18,957,681	44,026,919	67,843,624	34,546,432	0.08%	0.78'
Oklahoma	16,516,886	15,240,795	12,783,966	12,782,736	12,823,295	14,029,536	0.03%	0.32'
Alaska	17,782,527	17,985,636	14,745,716	11,756,599	10,566,814	14,567,458	0.03%	0.33'
Montana	11,217,428	10,533,070	9,857,071	9,390,726	8,713,604	9,942,380	0.02%	0.22'
Arkansas	8,937,651	8,128,106	7,744,737	7,470,207	8,080,724	8,072,285	0.02%	0.18'
Alabama	10,471,583	9,271,966	7,805,455	7,350,519	7,531,731	8,486,251	0.02%	0.19'
California	10,567,501	7,910,128	7,856,872	7,061,394	7,215,948	8,122,369	0.02%	0.18'
Ohio	2,239,070	3,712,978	2,544,033	5,486,638	3,198,865	3,436,317	0.01%	0.08'

3,568,045	3,249,474	2,904,133	2,877,040	2,555,544	3,030,847	0.01%	0.07'
1,238,164	1,108,381	934,647	877,321	747,830	981,269	0%	0.02'
949,527	836,796	625,804	492,962	473,405	675,699	0%	0.02'
269,000	231,728	167,722	168,514	140,880	195,569	0%	0%
132,545	129,765	125,251	119,647	115,250	124,492	0%	0%
107,057	98,203	93,717	88,822	78,762	93,312	0%	0%
84,325	69,616	52,101	63,917	57,043	65,400	0%	0%
71,444	61,437	53,644	51,038	45,061	56,525	0%	0%
7,564	6,926	6,838	6,679	3,746	6,351	0%	0%
25,151	11,465	23,139	5,529	1,264	13,310	0%	0%
1,891	10,293	5,399	5,220	6,048	5,770	0%	0%
2,587	2,170	2,337	2,361	2,143	2,320	0%	0%

Ex: % U.S. Total for CO (1.87%) = (614,714,989 / 32,835,395,600 * 100) and % Federal CO (14.26%) = (614,714,989 / 4,311,117,195 * 100)

6.6 Short-Term Oil and Gas Projections

The short-term projections for oil and gas emissions are based on analyses of three authorization scopes that exist for potential oil and gas production. These include (1) leased federal lands that are held-by-production, (2) approved applications for permit to drill (APDs), and (3) leased lands from competitive lease sales expected to occur over the next annual reporting cycle (7 2 months). As was the case for coal, here too the BLM is assuming that all oil and gas developed is consumed in the same year. When initiating a planning action in an area of potential oil and gas development, the BLM may produce an analysis of the fluid mineral potential known as a reasonably foreseeable development (RFD) scenario for oil and gas development for the specific geographic area. An RFD is typically constructed to support the management actions developed for a field or district office's resource management plan. The RFD provides an estimate of development potential and growth rates within the specified region based on several indicators, including the estimated hydrocarbon potential, operator surveys, existing development trends, various economics forecasts, and basin or geology factors, among others. These documents typically provide 20+ years of oil and gas development estimates and have traditionally been used to inform decisions on areas open and closed for leasing and the need for implementing stipulations, conditions of approval, or mitigation measures. The RFDs that are currently available, although useful for informing management actions and tracking limits of analysis for a particular region, are not useful for estimating GHG emissions across all BLM-managed mineral estate in a particular year because of their differing years of analysis, projection methodologies, and management objectives. The BLM does not currently have an up-to-date RFD that covers the entire federal onshore mineral estate. Due to the inconsistencies among available RFDs and a lack of an RFD for all federal mineral producing regions, the individual RFDs or a summation of all available RFDs may not be used to derive a single replicable methodology from which to make projections, which is one of the goals of this report. Thus, for the purposes of this report, a more representative and consistent approach for making projections that captures the implications of different levels of development and production across the entirety of the federal mineral estate was employed.

Each of the authorization scopes previously described relies in part on the most recent 5-year average dataset of federal mineral statistics[40] developed by the BLM in combination with the previously identified external sources of fossil fuel production data. The development statistics include both internal BLM tracking data, such as annual lease acres and held-by-production rates, APD approval counts, spud rates, and producible well counts, as well as an analysis of external well completion and production rates for individual wells in states reporting federal oil and gas production. Additional parameters are calculated from the internal statistics to aid in the projection calculations and to provide custom metrics for tracking purposes as shown in Table 6-12.

Table 6-12. 5-Year Federal Oil and Gas Statistics

Statistic	2019	2020	2021	2022	2023	5-Year Average
Acres Under Lease	26,287,326	26,604,169	24,932,645	23,771,097	23,796,348	24,958,318
Producing Acres	12,915,006	12,711,111	12,607,203	12,429,147	12,446,907	12,621,875
Acres Held by Production (%) *	49.13%	47.78%	50.57%	52.29%	53.66%	50.57%
New Lease Acres (sold)	2,245,906	1,871,962	249,732	74,758	97,712	906,693
Number of APDs Approved	3,181	4,226	4,974	2,852	3,519	3,789
Number of Wells Spud	1,995	1,486	1,630	2,063	2,106	1,857
Number of Producible Wells	96,356	96,710	88,887	89,350	90,298	92,202
Federal Wells per Acre *	0.372	0.313	0.284	0.284	0.276	0.294
Total Potential Wells*	186,776	192,279	164,357	160,997	146,884	170,249
Potential New Wells*	90,373	96,782	75,483	77,659	56,598	78,058
Potential Development Years*	1,172.7	1,090	881.3	734.7	1,604.3	7,097
Total C02e Emissions (Mt)*	309.45	313.64	465.63	447.77	611.54	429.62
C02e Emissions (tonnes/prod acre)*	439.91	407.76	522.35	520.55	479.17	473.93
Potential New Lease Wells*	6,294	2,897	1,202	252	358	2,259
Source: BLM Oil and Gas Statistics. "*" Denotes calculated parameter.						

The BLM analyzed 10 years (2013-2022) of external data from the S&P Global Enerdeq Browser database (commercial source) for oil and gas wells in federal mineral producing states. The analysis of the individual wells provided an estimate of the total potential mineral yield, or estimated ultimate recovery (EUR), and the associated decline rates that could be expected from any new wells developed within the authorization scopes analyzed in this report. Producing the EUR and decline estimates was necessary because life-of-project production is a reasonably foreseeable outcome from existing and future authorizations if economic quantities of federal minerals exist within any authorization scope.

Enerdeq provides subscription-based access to more than 5 million completions and 2.5 million production entities and provides an adequate sample size for most regions to apply statistical methods for determining the EUR. Initially, the BLM made queries to obtain the American Petroleum Institute (API) well identifiers for all new wells completed within the last 10 years. The 10-year timeframe was chosen to capture the changes in characteristics for wells developed before and after the advent and widespread adoption of horizontal drilling and hydraulic fracturing completion techniques. The queried data was scrubbed to eliminate nontarget wells (e.g., injection, water) and then organized by state to query 10 years of production data. This query provided the individual well production-by-age data that was necessary to develop the decline curve profiles and provide for cumulative production estimates over the life of a well. Oil and gas wells typically produce high quantities of minerals initially, followed by a period of rapid decline that settles into a very shallow decline over the remainder of their economic life. The BLM applied regression analysis techniques to the production data to generate a typical decline equation for wells in each state. The EUR for each state was calculated for an estimated life span of 30 years. These EUR volumes were then applied to the estimated number of new wells projected for the applicable authorization boundaries in each state to estimate cumulative or life-of-project GHG emissions. The decline curve formulas are also useful for estimating existing held-by-production projections as described later. Table 6-13 presents some of the

Enerdeq data highlights that went into the BLM's analysis, and Figure 6-3 shows the results of the decline analysis for the selected state.

Table 6-13. Enerdeq Data as Analyzed by BLM (2023)

State	New Wells	Oil Producers	Gas Producers	Counties	Basins	Play Types	Vertical	Directional	Horizontal	10 Yr Oil (bbls)	10 Yr Gas (Mcf)
Alabama	244	83	239	70	4	3	796	42	6	73,818,908	54,911,130
Alaska	602	525	602	10	2		8	130	464	441,830,777	6,289,990,679
Arkansas	1,421	149	1,359	18	2	4	147	59	1,215	5,773,220	2,112,694,264
California	9,729	9,706	7,025	17	5	2	3,546	4,982	1,201	372,870,387	227,212,097
Colorado	12,088	11,833	12,033	31	11	5	247	2,489	9,352	1,178,900,638	8,949,692,008
Florida	8	8	0	3	2	2		4	3	1,547,244	3,415,416
Idaho	12		11				5	7	0	433,480	15,820,120
Illinois	245	245	0	24			241	0	4	4,021,040	0
Indiana	30	30	0	6			25	0	5	425,525	0
Kansas	3,723	2,770	703	82	11	3	2,853	72	258	68,510,487	727,551,347
Kentucky	413	11	403	25	3	2	113		299	145,485	44,298,349
Louisiana	1,207	838	1,031	72		6	283	377	547	162,477,224	6,386,661,385
Michigan	113	112	42	20			28	37	48	8,747,640	6,275,207
Mississippi	277	276	166	28	2	3	124	84	69	36,468,599	79,397,855
Montana	440	434	379	21	10	3	79	4	357	60,178,985	73,710,723
Nebraska	201	201		16	6		200	0		5,994,033	1,575
Nevada	5	5	0	2			4	0		39,718	0
New Mexico	9,865	9,785	9,834	9	5	5	904	245	8,716	2,216,160,877	7,868,969,596
New York	683	663	620	7			681	0	2	751,031	1,010,953
North Dakota	11,582	11,576	11,524	14		2	33	6	11,543	3,000,558,278	6,160,597,262
Ohio	3,341	2,117	3,798	40	2	2	486	19	2,836	164,761,274	15,323,477,760
Oklahoma	11,672	11,201	11,215	64	11	5	899	118	10,655	1,026,032,605	14,044,489,681
Oregon		0						0	0	0	992,360
Pennsylvania	8,874	3,049	8,556	33		2	1,732	49	7,033	39,938,010	42,189,187,677
South Dakota	25	25	0		3		3	0	22	2,590,634	1,057,790
Texas	35,532	34,063	34,448	796	16	5	4,723	480	30,329	8,629,679,751	46,862,505,349
Utah	2,806	2,800	2,791	10	7	4	543	1,839	424	186,860,851	856,392,619
Virginia	897	0	897	5		3	754	126	17	0	144,174,602
West Virginia	3,103	2,416	3,095	29		3	254	30	2,818	99,369,096	13,844,985,994
Wyoming	5,290	5,107	4,986	19	11	5	731	2,124	2,435	457,018,451	4,470,390,812
Sums	**123,769**	**116,654**	**122,180**	**814**	**125**	**79**	**19,844**	**13,264**	**90,660**	**18,185,903,642**	**176,133,864,604**

Data is representative of all wells (federal and nonfederal) drilled and producing within the analyzed period.
Active development status (not shown) assigned to states with development rates of approximately 500 or more wells per year.

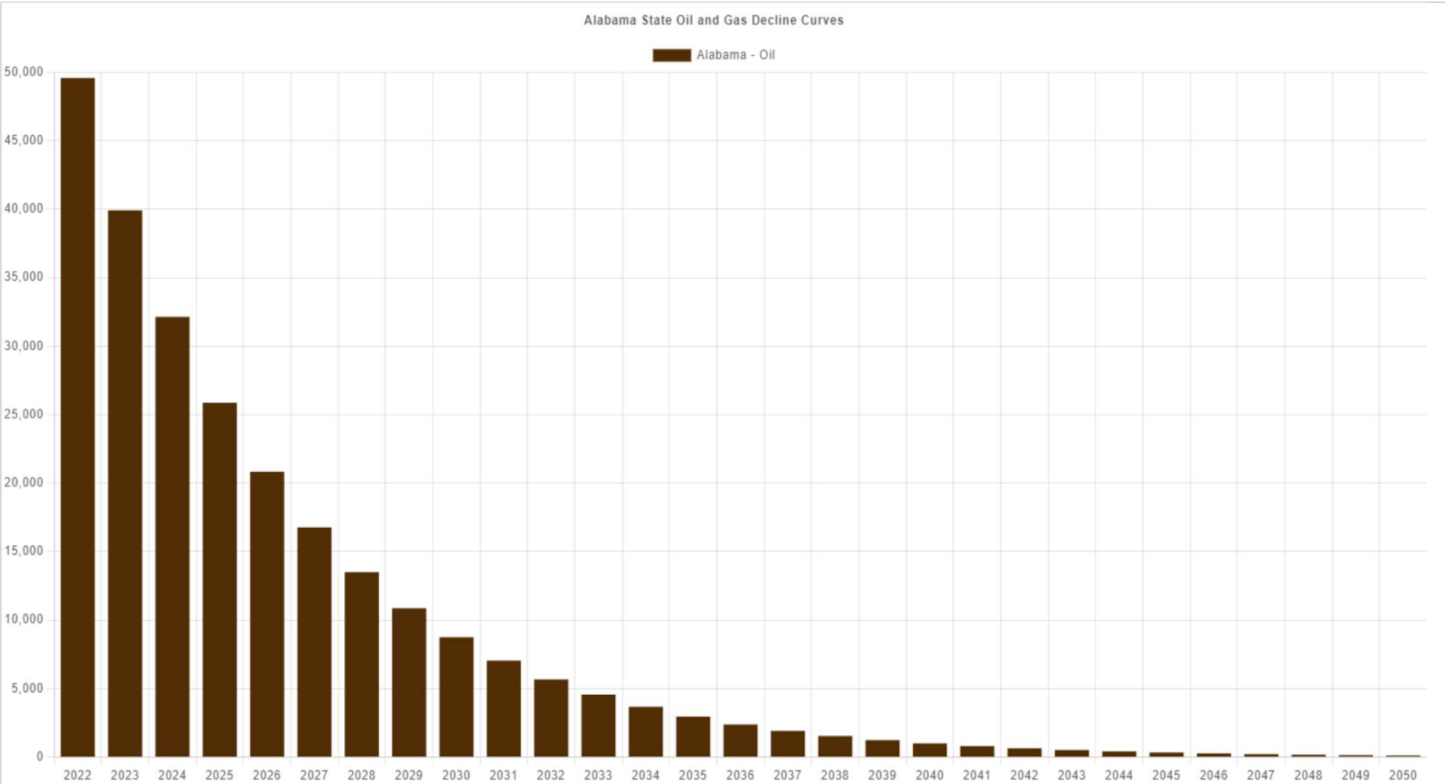


Figure 6-3. State Oil and Gas Decline Curves

Leased Lands

To estimate the potential GHG emissions resulting from leased lands held-by-production, the BLM applies the derived decline curves on a relative basis to the report year production levels and projects out for an additional 30 years (the assumed life-of-project period) for each applicable state. The decline curves for any state are statistically valid for an average "new" well; however, the held-by-production data is representative of wells at various ages. Thus applying the decline curve to existing field-wide production would most likely underrepresent future cumulative emissions. The decline data show that newer wells are far more productive in their first few years of life than over the entire life of the project period, and thus it is generally assumed that for any state with active development, the newer wells are driving production. For these states, the BLM assumed a field-wide decline age of 5 years. For a majority of the decline data, the 5-year mark lands squarely at the heel of the harmonic shaped curves (see Figure 6-3, year 5) and should correspond with a moderate gradual decline that could be expected at field-wide scales with active development. For all other states, the decline age was assumed to be 10 years (very shallow decline, leading to sustained production over the projection period). Additionally, this analysis conservatively assumes that all existing wells on leases held-by-production will continue to produce for another 30 years, even though it is highly likely that some will be plugged and abandoned. This fact can be clearly seen in the data contained in Table 6-12; even though the BLM recorded 1,857 well spuds per year on average over the 5-year period, the producible well counts are relatively flat over the entire 5-year period. It is likely that some of the recorded spuds came up dry leading to a smaller increment in the producible well counts, just as it is likely that some of the producible wells on record reached the end of their economic lives (i.e., no longer considered producible), and were thus subtracted from this count.

Approved Applications for Permit to Drill

To estimate the potential GHG emissions resulting from approved APDs, the BLM uses the last 2 years of approved APD counts minus the spuds recorded for the same period. Here the BLM is breaking from the general approach in this report of using 5-year average data for making projections in acknowledgement that APDs are only valid for 2 years (absent extensions that can be granted for an additional 2 years with appropriate justification). In general, the BLM statistics show that spud counts lag APD approvals across the states, and therefore it is reasonable to assume that the delta between the two metrics is enough to cover any potential extensions and subsequent development that may arise during the reporting period (i.e., the next 12 months). The remaining APD counts are multiplied by the corresponding decline curve equation that was derived for each state.

Potential Future Leasing

Estimates of potential GHG emissions resulting from any future leasing are relatively speculative. In terms of emissions, the BLM is assuming that full development of the leased parcels would occur concurrently within the same sale (report) year While this assumption does not reflect a typical timeline for oil and gas development, it is simplifying for projection purposes and allows the BLM to evaluate the potential emissions for any authorizations made. Here, the BLM relies on the 5-year average of the acres held by production, the annual total leased acres, and the calculated well density (wells per acre) on the federal mineral estate. Additionally, for some states with leased lands where the 5-year average statistics fall below a threshold minimum, the BLM assumes a minimum leased acreage to conservatively estimate potential emissions. The minimum thresholds are 100 acres leased for states with less than 4,000 acres currently leased, and 2,560 acres leased for states with more than 4,000 acres currently leased for which the 5-year leasing average is less than the minimum itself. The statistical annual lease acres data (5-year average) or the alternative minimum lease acres is used to estimate the number of wells for potentially leased lands which are then multiplied by the corresponding decline curve data for each state to obtain the estimated life-of-project production and emissions.

6.7 Long-Term Federal Fossil Fuel Mineral Emissions Projections

The emission estimates from the federal mineral estate authorization boundaries previously outlined present current emissions and projected emissions based on potential development and production volumes over the short term. As discussed at the beginning of this section, the BLM is using data from EIA's AEO report to estimate potential long-term emissions (to year 2050). The AEO is developed using the National Energy Modeling System (NEMS), an integrated model that captures interactions of economic changes and energy supply, demand, and prices. The AEO is published to satisfy the Department of Energy Organization Act of 1977, which requires EIA's Administrator to prepare annual reports on trends and projections for energy use and supply. The AEO explores several scenarios that capture alternative policy-based cases that can be compared to the reference case, which represents EIA's best assessment of how U.S. and world energy markets will operate through 2050. The reference case examines a future characterized by slower growth in energy consumption (due to energy efficiency increases) and by increasing energy supply due to technological progress in the renewable, oil, and natural gas energy sectors. The reference case is also the baseline scenario from which all other side-case estimates are made. The most current version of the AEO (2023) was used to supplement this report. **Note:** Projections in the AEO are not predictions of what will happen, but rather, they are modeled projections of what may happen given certain assumptions. The major underlying assumption for the application of any AEO scenario data is that the ratio of federal and nonfederal mineral production is fixed at the current annual average for each state going forward. For each year of AEO data, which is inclusive of total (federal and nonfederal) production, the BLM is applying the report year federal fraction for each mineral type to forecast long-term federal mineral production from which to estimate emissions. Overall, this forecast method is useful for analyzing long-term trends in GHG emissions and comparing the levels to specific climate change policy milestones to ascertain reasonable progress.

6.8 Uncertainties in Emissions Estimates

This report relies on life-cycle emissions estimates produced in part by the DOE NETL (as previously cited). The life-cycle estimates produced by the BLM cover broad activities used to represent recovery and processing of federal minerals, including lease exploration, construction, well drilling and completion, production, processing, transportation, and end use. The BLM acknowledges that operational diversity, product variations, and broad geographic distribution of the federal mineral estate introduces some uncertainty into the simplifying assumptions and approximation methodologies used to estimate emissions in this report. This acknowledgement is not intended to dispute the validity of the estimates but to help prioritize efforts to improve the accuracy of future iterations of this report. For some of the current estimates, such as CO_2 emissions from energy-related combustion activities, the impact of uncertainties on overall emission estimates is believed to be relatively small. For some other limited categories of emissions, including the assumptions used to estimate production and project future emissions, the following uncertainties could have a larger impact on the estimates.

- The uncertainties inherent to the sourced LCA data, which is unavoidably propagated in the BLM estimates.
- Uncertainty in global warming potential (GWP) factors, which may be up to+ or - 40% and may change often due to updated scientific understanding.
- Unknowable factors about actual or future development localities, methodologies, and production rates.
- The exact nature of energy sources and amounts used in production, transportation, and processing systems.
- How the produced federal minerals are ultimately transformed and used.
- The overall energy density of the produced federal mineral estate (used in emissions calculations).

- The exact nature of any control technology that may be utilized at direct or indirect activity locations.

The BLM is making a broad but concerted effort to utilize and present the best data available for the emissions estimates in this report. As new information becomes available, the BLM will continue to improve and revise its emission estimates, methodologies, and assumptions as appropriate. Ultimately, these estimates are subject to many influences that are largely beyond the BLM's practical control. Unforeseen changes in several factors such as geologic conditions, drilling technology, global and national economics, energy demand, geopolitical strife, and laws and policies enacted at the federal, state, and local level could result in different outcomes than those projected in this assessment.

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7.0 GHG Emissions and Projections from SLM-Authorized Actions

This chapter provides direct and indirect GHG emission estimates for both existing and projected federal fossil fuel production. Existing emissions estimates show the GHGs emitted from the assumed consumption of each fossil fuel based on production statistics from the previous fiscal year for all producing wells and mines. The projected emissions include both short- and long-term estimates based on the methodologies discussed in the previous chapter.

7.1 Short-Term Coal Emissions

Table 7-1 presents the emissions from coal production on the federal mineral estate in FY 2023, which result from multiplying the representative emission factors from Tables 6-1, 6-3, and 6-4 by the state-specific shipping and production data contained in Tables 6-5 and 6-6. The estimates presented here include emissions from the typical coal lifecycle, including emissions arising from activities outside of the BLM's jurisdiction (such as emissions associated with coal exports). Table 7-2 and 7-3 show the short-term emissions projections (7 2-month and life-of-project) from reasonably foreseeable coal production in the 8 states where federal coal is presently being produced.

Table 7-1. Federal Coal Emissions - 2023 (Mt)

Area	Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
US Total	580,386,061	11.4916	NA	25.2458	1,139.84	1,176.58
Federal Total	242,842,109	3.7462	1.1404	6.9986	422.89	434.78
Onshore Total	242,842,109	3.7462	1.1404	6.9986	422.89	434.78
Alabama	121,611	0.0315	0.0061	0.0114	0.29	0.33
Colorado	5,355,739	0.3487	0.1615	0.1476	12.56	13.21
Montana	9,207,466	0.1271	0.0344	0.4155	21.56	22.14
North Dakota	4,423,101	0.061	0.0046	0.0046	6.19	6.26
Utah	6,600,105	0.1815	0.1217	0.2438	15.47	16.02

Production units = short tons.
U.S. Total is both federal and nonfederal data, shown for illustration purposes.

Table 7-2. Federal Coal Emissions - Projected 12-Months (Mt)

Area	12-Month Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
BLM Total	202,530,320	7.8429	0.9511	5.8368	352.69	367.32
Wyoming	181,089,829	5.6236	0.6773	5.1504	305.93	317.38
Montana	7,679,027	0.2385	0.0287	0.3465	17.98	18.6
Utah	5,504,488	0.1026	0.1015	0.2033	12.91	13.31
Colorado	4,466,686	0.5036	0.1347	0.1231	10.47	11.23

Area	12-Month Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
North Dakota	3,688,866	1.3195	0.0039	0.0039	5.16	6.49
Alabama	101,424	0.0551	0.0051	0.0095	0.24	0.31

12-Month production units = short tons.
Projected emissions prepared from 2023 USGS IAA deliverable.

Table 7-3. Federal Coal Emissions - Projected Short-Term Life-of-Project (Mt)

Area	LOP Producion	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
BLM Total	3,625,086,464	111.7851	16.5136	103.5495	6,164.62	6,396.46
Wyoming	3,241,778,000	100.6708	12.1239	92.2002	5,476.57	5,681.56
Utah	145,949,040	2.7192	2.6922	5.397 3	342.18	352.98
Montana	104,800,024	3.2553	0.3918	4.7296	245.45	253.83
North Dakota	89,730,000	0	0	0	0	0
Colorado	42,108,500	4.7478	1.2698	1.1606	98.72	105.9
Alabama	720,900	0.3919	0.0359	0.0679	1.69	2.19

Life-of-Project {LOP) production units = short tons.
Projected emissions prepared from 2023 USGS IAA deliverable.

7.2 Short-Term Oil Emissions

Tables 7-4 through 7-10 show the FY 2023 held-by-production emissions from oil production on the federal mineral estate, as well as the emissions from projected APD approvals and leasing within the next 12-months on both a maximum annual and life-of-project basis. The emissions are calculated by multiplying the emission factors from Tables 6-8 by the state-specific production amounts from Table 6-9, or by the projection metrics (APO or lease wells and the associated production). The estimates presented here include emissions from the full oil lifecycle, including emissions arising from activities outside of the BLM's jurisdiction (such as emissions associated with refining and processing).

Table 7-4. Federal Oil Emissions - Held-By-Production Lands 2023 (Mt)

Area	Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
U.S Total	4,719,402,000	348.1367	239.7319	47.4913	2,045.87	2,681.23
Federal Total	1,231,811,623	63.001	62.5724	12.3957	533.99	671.96
Onshore Total	555,703,253	40.9926	28.2281	5.592	240.9	315.71
Alabama	16,278	0.0012	0.0008	0.0002	0.01	0.01
Alaska	844,836	0.0623	0.0429	0.0085	0.37	0.48
Arkansas	2	0	0	0	0	0
California	8,027,995	0.5922	0.4078	0.0808	3.48	4.56
Colorado	10,280,384	0.7584	0.5222	0.7035	4.46	5.84
Idaho	123	0	0	0	0	0
Illinois	13,147	0.001	0.0007	0.0001	0.01	0.01
Kansas	73,534	0.0054	0.0037	0.0007	0.03	0.04
Kentucky	3,400	0.0003	0.0002	0	0	0
Louisiana	256,575	0.0189	0.013	0.0026	0.11	0.15
Michigan	7,352	0.0005	0.0004	0.0001	0	0
Mississippi	177,116	0.0131	0.009	0.0078	0.08	0.1
Montana	2,406,734	0.1775	0.1223	0.0242	1.04	1.37
Nebraska	25,073	0.0018	0.0013	0.0003	0.01	0.01
Nevada	226,504	0.0167	0.0115	0.0023	0.1	0.13
New Mexico	434,729,597	32.0687	22.083	4.3747	188.46	246.98
North Dakota	42,226,255	3.1149	2.145	0.4249	18.31	23.99
Offshore	676,108,370	22.0084	34.3443	6.8037	293.09	356.25
Ohio	5,460	0.0004	0.0003	0.0001	0	0
Oklahoma	677,742	0.05	0.0344	0.0068	0.29	0.39
Pennsylvania	475	0	0	0	0	0
South Dakota	107,304	0.0079	0.0055	0.0071	0.05	0.06
Texas	128,622	0.0095	0.0065	0.0013	0.06	0.07
Utah	6,970,865	0.5142	0.3541	0.0701	3.02	3.96
Wyoming	48,497,880	3.5775	2.4636	0.488	27.02	27.55

Production units (bbl).
U.S. Total is both federal and nonfederal data, shown for illustration purposes.
"0" values are the result of rounding to a defined number of significant digits (Ex: 0.0000), which are then truncated. These values are actually less than the significant digits provide for (Ex: 0 00004)

Table 7-5. Federal Oil Emissions - Held-By-Production Lands Projected 12-Months (Mt)

Area	12-Month Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
BLM Total	451,275,406	33.2893	22.9235	4.5412	195.63	256.38
New Mexico	350,618,029	25.8641	17.8104	3.5283	151.99	199.2
Wyoming	39,589,724	2.9204	2.011	0.3984	17.16	22.49
North Dakota	35,170,191	2.5944	1.7865	0.3539	15.25	19.98
Colorado	8,204,798	0.6052	0.4168	0.0826	3.56	4.66
California	7,205,529	0.531 5	0.366	00725	3.12	4.09
Utah	6,132,363	0.4524	0.3115	0.0617	2.66	3.48
Montana	2,061,924	0.1521	0.7047	0.0207	0.89	1.17
Alaska	769,938	0.0568	0.0391	00077	0.33	0.44
Oklahoma	574,784	0.0424	0.0292	0.0058	0.25	0.33
Louisiana	247,546	0.0183	0.0126	0.0025	0.11	0.14
Nevada	189,676	0.014	0.0096	0.0019	0.08	0.11
Mississippi	160,686	0.0119	0.0082	0.0016	0.07	0.09
Texas	116,754	0.0086	0.0059	0.0012	0.05	0.07
South Dakota	101,149	0.0075	0.0051	0.001	0.04	0.06
Kansas	67,009	0.0049	0.0034	0.0007	0.03	0.04
Nebraska	23,033	0.0017	0.0012	0.0002	0.01	0.01
Alabama	14,993	0.0011	0.0008	0.0002	0.01	0.01
Illinois	11,963	0.0009	0.0006	0.0001	0.01	0.01
Michigan	7,007	0.0005	0.0004	0.0001	0	0
Ohio	4,678	0.0003	0.0002	0	0	0
Kentucky	3,092	0.0002	0.0002	0	0	0
Pennsylvania	433	0	0	0	0	0
Idaho	105	0	0	0	0	0
Arkansas	2	0	0	0	0	0

Production units (bbl).
"0" values are the result of rounding to a defined number of significant digits (Ex: 0.0000), which are then truncated. These values are actually less than the

significant digits provide for (Ex: 0.00004).

Table 7-6. Federal Oil Emissions - Held-By-Production Lands Projected Life-of-Project **(Mt)**

Area	LOP Producion	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
BLM Total	3,998,006,971	294.9214	203.0871	40.2319	1,733.14	2,271.38
New Mexico	2,987,004,381	220.3427	151.7311	30.0582	1,294.87	1,697
Wyoming	356,768,995	26.3178	18.1228	3.5902	154.66	202.69
North Dakota	349,339,737	25.7698	17.7454	3.5154	151.44	198.47
California	107,215,124	7.909	5.4462	1.0789	46.48	60.91
Utah	73,957,008	5.4556	3.7568	0.7442	3206	42.02
Colorado	66,658,983	4.9172	3.3861	0.6708	28.9	37.87
Montana	23,667,900	1.7459	1.2023	0.2382	10.26	13.45
Alaska	11,618,919	0.8571	0.5902	0.1169	5.04	6.6
Oklahoma	6,256,611	0.4615	0.3178	0.063	2.71	3.55
Louisiana	5,603,351	0.4133	0.2846	0.0564	2.43	3.18
Mississippi	2,353,569	0.1736	0.1196	0.0237	1 02	1.34
South Dakota	1,928,227	0.1422	0.0979	0.0194	0.84	1.1
Texas	1,857,234	0.137	0.0943	0.0187	0.81	1.06
Nevada	1,731,242	0.1277	0.0879	0.0174	0.75	0.98
Kansas	1,010,571	0.0745	0.0513	0.0102	0.44	0.57
Nebraska	366,659	0.027	0.0186	0.0037	0.16	0.21
Alabama	242,943	0.0179	0.0123	0.0024	0.11	0.14
Illinois	178,734	0.0132	0.0091	0.0018	0.08	0.1
Michigan	144,739	0.0107	0.0074	0.0015	0.06	0.08
Ohio	48,382	0.0036	0.0025	0.0005	0.02	0.03
Kentucky	46,001	0.0034	0.0023	0.0005	0.02	0.03
Pennsylvania	6,567	0.0005	0.0003	0.0001	0	0
Idaho	1,058	0.0001	0.0001	0	0	0
Arkansas	36	0	0	0	0	0

Production units (bbl).
"O" values are the result of rounding to a defined number of significant digits (Ex: 0.0000). which are then truncated. These values are actually less than the significant digits provide for (Ex: 0.00004).

Table 7-7. Federal Oil Emissions - Approved APDs Projected 12-Months (Mt)

Area	12-Month Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
BLM Total	345,522,920	25.4882	17.5516	3.477	149.78	196.3
New Mexico	283,907,548	20.943	14.4217	2.857	123.07	161.3
Wyoming	23,822,725	1.7573	1.2101	0.2397	10.33	13.53
North Dakota	15,287,988	1.1278	0.7766	0.1538	6.63	8.69
Colorado	6,272,706	0.4627	0.3186	0.0637	2.72	3.56
Utah	5,669,730	0.4182	0.288	0.0571	2.46	3.22
Texas	2,975,855	0.2195	0.1512	0.0299	1.29	1.69
Alaska	2,906,469	0.2144	0.1476	0.0292	1.26	1.65
Louisiana	2,244,153	0.1655	0.114	0.0226	0.97	1.27
California	1,304,520	0.0962	0.0663	0.0131	0.57	0.74
Montana	688,028	0.0508	0.0349	0.0069	0.3	0.39
Oklahoma	283,128	0.0209	0.0144	0.0028	0.12	0.16
Mississippi	100,402	0.0074	0.0051	0.001	0.04	0.06
South Dakota	25,714	0.0019	0.0013	0.0003	0.01	0.01
Nevada	23,814	0.0018	0.0012	0.0002	0.01	0.01
Arkansas	10,140	0.0007	0.0005	0.0001	0	0.01

Production units (bbl).
"0" values are the result of rounding to a defined number of significant digits (Ex: 0.0000), which are then truncated. These values are actually less than the significant digits provide for (Ex: 0.00004).

Table 7-8. Federal Oil Emissions - Approved APDs Projected Life-of-Project (Mt)

Area	LOP Producion	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
BLM Total	1,078,792,702	79.5794	54.7995	10.8559	467.66	612.89
New Mexico	870,939,942	64.2467	44.2412	8.7643	377.55	494.81
Wyoming	76,577,692	5.6489	3.8899	0.7706	33.2	43.57
North Dakota	38,905,992	2.87	1.9763	0.397 5	76.87	22.1
Louisiana	23,787,013	1.7104	1.1778	0.2333	7005	13.17
Texas	18,534,820	1.3673	0.9415	0.1865	8.03	10.53
Utah	14,796,883	1.0975	0.7516	0.1489	6.41	8.41
Alaska	12,843,596	0.9474	0.6524	0.1292	5.57	7.3
Colorado	12,161,473	0.8971	0.6178	0.1224	5.27	6.91
California	7,055,586	0.5205	0.3584	0.071	3.06	4.01
Montana	2,221,931	0.1639	0.1129	0.0224	0.96	1.26
Oklahoma	834,373	0.061 5	0.0424	0.0084	0.36	047
Mississippi	435,687	0.0321	0.0221	0.0044	0.79	0.25
South Dakota	173,262	0.0728	0.0088	0.007 7	0.08	0.1
Arkansas	78,930	0.0058	0.004	0.0008	0.03	0.04
Nevada	45,522	0.0034	0.0023	0.0005	0.02	0.03

Production units (bbl).
"0" values are the result of rounding to a defined number of significant digits (Ex: 0.0000), which are then truncated. These values are actually less than the significant digits provide for (Ex: 0.00004).

Table 7-9. Federal Oil Emissions - Potential Lease Projected 12-Months (Mt)

Area	12-Month Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
BLM Total	137,051,854	10.1099	6.9618	1.3792	59.41	77.86
Wyoming	60,219,825	4.4422	3 059	0.606	26.11	34.21
New Mexico	44,040,687	3.2488	2.2371	0.4432	19 09	2502
Utah	11,783,475	0.8692	0.5986	0.1186	5.11	6.69
Colorado	6,210,600	0.4581	0.3155	0.0625	2.69	3.53
Alaska	6,135,879	0.4526	0.3117	0.0617	2.66	3.49
North Dakota	3,426,618	0.2528	0.1741	0.0345	1.49	1.95
Montana	2,439,372	0.1799	0.1239	0.0245	1 06	1.39
Louisiana	1,056,072	0.0779	0.0536	0.0106	0.46	0.6
California	596,352	0.044	0.0303	0.006	0.26	0.34
Texas	258,770	0.0191	0.0131	0.0026	0.11	0.15
Oklahoma	235,940	0.0174	0.012	0.0024	0.1	0.13
Ohio	190,308	0.014	0.0097	0.0019	0.08	0.11
Mississippi	100,402	0.0074	0.0051	0.001	0.04	0.06
Nevada	95,256	0.007	0.0048	0.001	0.04	0.05
Alabama	49,578	0.0037	0.0025	0.0005	0.02	0.03
Kansas	44,412	0.0033	0.0023	0.0004	0.02	0.03
Michigan	42,582	0.0031	0.0022	0.0004	0.02	0.02
Idaho	27,996	0.0021	0.0014	0.0003	0.01	0.02
West Virginia	27,815	0.0021	0.0014	0.0003	0.01	0.02
South Dakota	25,714	0.0019	0.0013	0.0003	0.01	0.01
Nebraska	11,368	0.0008	0.0006	0.0001	0	0.01
Arkansas	10,140	0.0007	0.0005	0.0001	0	0.01
Illinois	6,590	0.0005	0.0003	0.0001	0	0
Pennsylvania	5,737	0.0004	0.0003	0.0001	0	0
Kentucky	5,357	0.0004	0.0003	0.0001	0	0
Indiana	4,368	0.0003	0.0002	0	0	0
New York	641	0	0	0	0	0

Area	12-Month Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
Arizona	0	0	0	0	0	0
Maryland	0	0	0	0	0	0
Oregon	0	0	0	0	0	0
Tennessee	0	0	0	0	0	0
Virginia	0	0	0	0	0	0

Production units (bbl)
"O" values are the result of rounding to a defined number of significant digits (Ex: 0.0000), which are then truncated. These values are actually less than the significant digits provide for (Ex: 0.00004).

Table 7-10. Federal Oil Emissions - Potential Lease Projected Life-of-Project (Mt)

Area	LOP Producion	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
BLM Total	434,071,883	32.07 58	22.0465	4.3675	788.74	246.57
Wyoming	193,575,471	14.2795	9.8337	7.9479	83.92	109.98
New Mexico	135,703,113	9.9662	6.8628	1.3595	58.57	76.76
Utah	30,752,558	2.2685	1.5621	0.3095	13.33	17.47
Alaska	27,114,258	2 0001	1.3773	0.2729	11.75	15.4
Colorado	12,041,063	0.8882	0.6117	0.1212	5.22	6.84
Louisiana	10,911,536	0.8049	0.5543	0.1098	4.73	6.2
North Dakota	8,720,309	0.6433	0.443	0.0878	3.78	4.95
Montana	7,877,755	0.5811	0.4002	0.0793	3.42	4.48
California	3,225,411	0.2379	0.1638	0.0325	1.4	1.83
Texas	7,617,723	0.7189	0.087 9	0.0162	0.7	0.92
Oklahoma	695,317	0.0513	0.0353	0.007	0.3	0.4
Mississippi	435,687	0.0321	0.0221	0.0044	0.19	0.25
Michigan	404,647	0.0298	0.0206	0.0041	0.18	0.23
Ohio	387,864	0.0286	0.0197	0.0039	0.17	0.22
Alabama	254,046	0.0187	0.0129	0.0026	0.11	0.14
Kansas	184,016	0.0136	0.0093	0.0019	0.08	0.1
Nevada	182,088	0.0134	0.0092	0.0018	0.08	0.1
South Dakota	173,262	0.0128	0.0088	0.007 7	0.08	0.1
Arkansas	78,930	0.0058	0.004	0.0008	0.03	0.04

Area	LOP Producion	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
Idaho	75,664	0.0056	0.0038	0.0008	0.03	0.04
Nebraska	53,599	0.004	0.0027	0.0005	0.02	0.03
West Virginia	49,315	0.0036	0.0025	0.0005	0.02	0.03
Indiana	29,873	0.0022	0.0015	0.0003	0.01	0.02
Illinois	26,716	0.002	0.0014	0.0003	0.01	0.02
Pennsylvania	24,062	0.0018	0.0012	0.0002	0.01	0.01
Kentucky	21,509	0.0016	0.0011	0.0002	0.01	0.01
New York	2,097	0.0002	0.0001	0	0	0
Arizona	0	0	0	0	0	0
Maryland	0	0	0	0	0	0
Oregon	0	0	0	0	0	0
Tennessee	0	0	0	0	0	0
Virginia	0	0	0	0	0	0

Production units (bbl).
"O" values are the result of rounding to a defined number of significant digits (Ex: 0.0000), which are then truncated. These values are actually less than the significant digits provide for (Ex: 0.00004).

7.3 Short-Term Gas Emissions

Tables 7-11 through 7-17 show the FY 2023 held-by-production emissions from gas production on the federal mineral estate, as well as the emissions from projected APD approvals and leasing within the next 12-months on both a maximum annual and life-of-project basis. The emissions are calculated by multiplying the emission factors from Tables 6-10 by the state-specific production amounts from Table 6-11, or by the projection metrics (APD or lease wells and the associated production). The estimates presented here include emissions from the full gas lifecycle, including emissions arising from activities outside of the BLM's jurisdiction (such as emissions associated with refining and processing).

Table 7-11. Federal Gas Emissions - Held-By-Production Lands 2023 (Mt)

Area	Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
US Total	45,637,380,000	258.6683	88.4027	568.3278	2,487.15	3,402.55
Federal Total	4,767,849,011	27 0992	9 2356	59.3746	259.84	355.55
Onshore Total	3,967,991,112	22.4902	7.6863	49.4139	216.25	295.84
Alabama	7,531,731	0.0427	0.0146	0.0938	0.41	0.56
Alaska	10,566,814	0.0599	0.0205	0.1316	0.58	0.79
Arkansas	8,080,724	0.0458	0.0157	01006	0.44	0.6
California	7,215,948	0.0409	0.014	0.0899	0.39	0.54
Colorado	521,501,783	2.9558	1 0102	6.4943	28.42	38.88
Idaho	1,264	0	0	0	0	0
Illinois	2,143	0	0	0	0	0
Kansas	2,555,544	0.0145	0.005	0.0318	0.14	0.19
Kentucky	78,762	0.0004	0.0002	0.001	0	0.01
Louisiana	67,843,624	0.3845	0.1314	0.8449	3.7	5 06
Michigan	747,830	0.0042	0.0014	0.0093	0.04	0.06
Mississippi	140,880	0.0008	0.0003	0.0018	0.01	0.01
Montana	8,713,604	0.0494	0.0169	0.1085	0.47	0.65
Nevada	6,048	0	0	0.0001	0	0
New Mexico	2,051,843,940	11.6297	3.9746	25.5519	111.82	152.98
New York	3,746	0	0	0	0	0
North Dakota	127,586,503	0.7231	0.2471	1.5889	6.95	9 51
Offshore	799,857,899	4.609	1.5494	9 9607	43.59	59.71
Ohio	3,198,865	0.0181	0.0062	0.0398	0.17	0.24
Oklahoma	12,823,295	0.0727	0.0248	01597	0.7	0.96
Pennsylvania	45,061	0.0003	0.0001	0.0006	0	0
South Dakota	473,405	0.0027	0.0009	0.0059	0.03	0.04
Texas	41,973,260	0.2379	0.0813	0.5227	2.29	3.13
Utah	120,276,047	0.6817	0.233	1.4978	6.55	8.97
Virginia	115,250	0.0007	0.0002	0.0014	0.01	0.01

Area	Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
West Virginia	57,043	0.0003	0.0001	0.0007	0	0
Wyoming	974,607,998	5.524	1.8879	12.1369	53.11	72.66

Production units (Mcf).
U.S. Total is both federal and nonfederal data, shown for illustration purposes.
"O" values are the result of rounding to a defined number of significant digits (Ex: 0.0000), which are then truncated. These values are actually less than the significant digits provide for (Ex: 0.00004).

Table 7-12. Federal Gas Emissions - Held-By-Production Lands Projected 12-Months (Mt)

Area	12-Month Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
BLM Total	3,321,327,999	18.825	6.4336	41.3609	181.01	247.63
New Mexico	1,680,736,903	9.5263	3.2557	20.9304	91.6	125.31
Wyoming	830,297,920	4.706	1.6083	10.3398	45.25	61.9
Colorado	440,421,280	2.4963	0.8531	5.4846	24	32.84
Utah	109,176,117	0.6188	0.2115	1.3596	5.95	8.14
North Dakota	107,056,495	0.6068	0.2074	1.3332	5.83	7.98
Louisiana	60,804,894	0.3446	0.1178	0.7572	3.31	4.53
Texas	36,556,696	0.2072	0.0708	0.4552	1.99	2.73
Oklahoma	11,032,383	0.0625	0.0214	0.1374	0.6	0.82
Alaska	9,788,142	0.0555	0.019	0.1219	0.53	0.73
Montana	7,602,986	0.0431	0.0147	0.0947	0.41	0.57
Arkansas	7,496,763	0.0425	0.0145	0.0934	0.41	0.56
Alabama	6,936,891	0.0393	0.0134	0.0864	0.38	0.52
California	6,743,609	0.0382	0.0131	0.084	0.37	0.5
Ohio	2,768,226	0.0157	0.0054	0.0345	0.15	0.21
Kansas	2,355,562	0.0134	0.0046	0.0293	0.13	0.18
Michigan	711,872	0.004	0.0014	0.0089	0.04	0.05
South Dakota	434,505	0.0025	0.0008	0.0054	0.02	0.03
Mississippi	130,543	0.0007	0.0003	0.0016	0.01	0.01
Virginia	106,721	0.0006	0.0002	0.0013	0.01	0.01
Kentucky	64,527	0.0004	00001	0.0008	0	0
West Virginia	51,574	0.0003	0.0001	0.0006	0	0
Pennsylvania	41,015	0.0002	0.0001	0.0005	0	0

Area	12-Month Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
Nevada	5,763	0	0	0.0001	0	0
New York	3,556	0	0	0	0	0
Illinois	2,042	0	0	0	0	0
Idaho	1,014	0	0	0	0	0

Production units (Mcf).
"0" values are the result of rounding to a defined number of significant digits (Ex: 0.0000), which are then truncated. These values are actually less than the significant digits provide for (Ex: 0.00004).

Table 7-13. Federal Gas Emissions - Held-By-Production Lands Projected Life-of-Project (Mt)

Area	LOP Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
BLM Total	34,185,200,781	193.7584	66.2191	425.7124	1,863.03	2,548.72
New Mexico	15,395,655,522	87.2611	29.8224	191.724	839.03	1,147.84
Wyoming	9,252,924,462	52.4447	17.9235	115.2278	504.27	689.86
Colorado	4,691,265,139	26.5896	9.0873	58.4209	255.67	349.76
Utah	1,604,642,866	9.095	3.1083	19.9828	87.45	119.64
North Dakota	1,103,507,550	6.2546	2.1376	13.7421	60.14	82.27
Louisiana	823,181,724	4.6657	1.5946	10.2512	44.86	61.37
Texas	458,586,085	2.5992	0.8883	5.7108	24.99	34.19
Alaska	164,943,012	0.9349	0.3195	2.0541	8.99	12.3
Oklahoma	129,499,016	0.734	0.2508	1.6127	7.06	9.65
California	128,355,062	0.7275	0.2486	1.5984	7	9.57
Arkansas	127,681,371	0.7237	0.2473	1.59	6.96	9.52
Alabama	112,392,016	0.637	0.2177	1.3996	6.13	8.38
Montana	96,338,166	0.546	0.1866	1.1997	5.25	7.18
Kansas	38,370,022	0.2175	0.0743	0.4778	2.09	2.86
Ohio	30,291,591	0.1717	0.0587	0.3772	1.65	2.26
Michigan	14,573,057	0.0826	0.0282	0.1815	0.79	1.09
South Dakota	6,875,864	0.039	0.0133	0.0856	0.37	0.51
Mississippi	2,204,984	0.0125	0.0043	0.0275	0.72	0.16
Virginia	1,794,224	0.0102	0.0035	0.0223	0.7	0.13
West Virginia	738,638	0.0042	0.007 4	0.0092	0.04	0.06
Pennsylvania	613,856	0.0035	0.007 2	0.0076	0.03	0.05
Kentucky	526,818	0.003	0.001	0.0066	0.03	0.04
Nevada	118,805	0.0007	0.0002	0.0015	0.01	0.01
New York	71,339	0.0004	0.0001	0.0009	0	0.01
Illinois	42,097	0.0002	0.0001	0.0005	0	0
Idaho	7,495	0	0	0.0001	0	0

Production units (Mcf).
"O" values are the result of rounding to a defined number of significant digits (Ex: 0.0000), which are then truncated. These values are actually less than the significant digits provide for (Ex: 0.00004).

Table 7-14. Federal Gas Emissions - Approved APDs Projected 12-Months (Mt)

Area	12-Month Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
BLM Total	1,389,678,097	7.8766	2.6919	17.3058	75.73	103.61
New Mexico	992,016,368	5.6227	1.9216	12.3537	54.06	73.96
Wyoming	799,131,410	1.1287	0.3857	2.4798	10.85	14.85
Louisiana	61,620,172	0.3493	0.7194	0.7674	3.36	4.59
Colorado	35,096,389	0.1989	0.068	0.4371	1.91	2.62
Alaska	33,356,232	0.1891	0.0646	0.4154	1.82	2.49
North Dakota	28,349,588	0.1607	0.0549	0.353	1.54	2.11
Utah	20,656,044	0.1171	0.04	0.2572	1.13	1.54
Texas	13,676,697	0.0775	0.0265	0.1703	0.75	1 02
Oklahoma	3,095,736	0.0175	0.006	0.0386	0.17	0.23
California	1,058,925	0.006	0.0021	0.0132	0.06	0.08
Montana	811,987	0.0046	0.0016	0.0101	0.04	0.06
Arkansas	459,642	0.0026	0.0009	0.0057	0.03	0.03
Mississippi	326,596	0.0019	0.0006	0.0041	0.02	0.02
South Dakota	22,311	0.0001	0	0.0003	0	0
Nevada	0	0	0	0	0	0

Production units (Mcf).
"0" values are the result of rounding to a defined number of significant digits (Ex: 0.0000), which are then truncated. These values are actually less than the significant digits provide for (Ex: 0.00004).

Table 7-15. Federal Gas Emissions - Approved APDs Projected Life-of-Project (Mt)

Area	LOP Producion	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
BLM Total	4,748,865,896	26.9161	9.1989	59.1382	258.8	354.06
New Mexico	3,154,261,330	17.8781	6.11	39.2804	171.9	235.17
Wyoming	762,369,198	4.321	1.4768	9.4939	41.55	56.84
Louisiana	250,400,368	1.4192	0.485	3.1183	13.65	18.67
Alaska	181,394,589	1.0281	0.3514	2.2589	9.89	13.52
Colorado	128,067,592	0.7259	0.2481	1.5948	6.98	9.55
North Dakota	100,222,604	0.5681	0.1941	1.2481	5.46	7.47
Utah	80,658,713	0.4572	0.1562	1.0045	4.4	6.01
Texas	60,840,473	0.3448	0.1179	0.7577	3.32	4.54
Oklahoma	12,689,609	0.0719	0.0246	0.158	0.69	0.95
California	10,006,394	0.0567	0.0194	0.1246	0.55	0.75
Montana	3,553,363	0.0201	0.0069	0.0443	0.19	0.26
Arkansas	2,568,979	0.0146	0.005	0.032	0.14	0.19
Mississippi	1,729,005	0.0098	0.0033	0.0215	0.09	0.13
South Dakota	103,679	0.0006	0.0002	0.0013	0.01	0.01
Nevada	0	0	0	0	0	0

Production units (Mcf).
"0" values are the result of rounding to a defined number of significant digits (Ex: 0.0000), which are then truncated. These values are actually less than the significant digits provide for (Ex: 0.00004).

Table 7-16. Federal Gas Emissions - Potential Lease Projected 12-Months (Mt)

Area	12-Month Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
BLM Total	865,879,690	4.9077	1.6773	10.7829	47.19	64.56
Wyoming	503,370,570	2.8531	0.9751	6.2685	27.43	37.53
New Mexico	153,884,892	0.8722	0.2981	1.9163	8.39	11.47
Alaska	70,418,712	0.3991	0.1364	0.8769	3.84	5.25
Utah	42,929,730	0.2433	0.0832	0.5346	2.34	3.2
Colorado	34,748,900	0.197	0.0673	0.4327	1.89	2.59
Louisiana	28,997,728	0.1644	0.0562	0.3611	1.58	2.16
Ohio	10,092,112	0.0572	0.0195	0.1257	0.55	0.75
North Dakota	6,354,218	0.036	0.0123	0.0791	0.35	0.47
Montana	2,878,863	0.0163	0.0056	0.0359	0.16	0.21
Oklahoma	2,579,780	0.0146	0.005	0.0321	0.14	0.19
Pennsylvania	2,154,202	0.0122	0.0042	0.0268	0.12	0.16
West Virginia	2,043,655	0.0116	0.004	0.0254	0.11	0.15
Idaho	1,603,346	0.0091	0.0031	0.02	0.09	0.12
Texas	1,189,278	0.0067	00023	0.0148	0.06	0.09
Oregon	665,954	0.0038	00013	0.0083	0.04	0.05
California	484,080	0.0027	0.0009	0.006	0.03	0.04
Arkansas	459,642	0.0026	0.0009	0.0057	0.03	0.03
Mississippi	326,596	0.0019	0.0006	0.0041	0.02	0.02
Kansas	301,964	00017	0.0006	0.0038	0.02	0.02
Kentucky	109,826	0.0006	0.0002	0.0014	0.01	0.07
Michigan	106,277	0.0006	0.0002	0.0013	0.01	0.01
Alabama	94,002	0.0005	0.0002	0.0012	0.01	0.01
Virginia	62,370	0.0004	0.0001	0.0008	0	0
South Dakota	22,311	0.0001	0	0.0003	0	0
New York	682	0	0	0	0	0
Arizona	0	0	0	0	0	0
Illinois	0	0	0	0	0	0

Area	12-Month Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
Indiana	0	0	0	0	0	0
Maryland	0	0	0	0	0	0
Nebraska	0	0	0	0	0	0
Nevada	0	0	0	0	0	0
Tennessee	0	0	0	0	0	0

Production units (Mcf).
"0" values are the result of rounding to a defined number of significant digits (Ex: 0.0000), which are then truncated. These values are actually less than the significant digits provide for (Ex: 0.00004).

Table 7-17. Federal Gas Emissions - Potential Lease Projected Life-of-Project (Mt)

Area	LOP Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
BLM Total	3,328,879,065	18.8678	6.4483	47.4549	787.42	248.79
Wyoming	1,927,140,563	10.9228	3.733	23.9989	105 03	743.68
New Mexico	489,299,552	2.7733	0.9478	6.0933	26.67	36.48
Alaska	382,944,132	2.1705	0.7418	4.7688	20.87	28.55
Utah	167,634,072	0.9501	0.3247	2 0876	9.14	12.5
Colorado	126,799,596	0.7187	0.2456	1.5791	6.91	9.45
Louisiana	117,835,467	0.6679	0.2283	1.4674	6.42	8.79
Ohio	32,634,202	0.185	0.0632	0.4064	1.78	2.43
North Dakota	22,463,687	0.1273	0.0435	0.2797	1.22	1.67
Montana	12,598,286	0.0714	0.0244	0.1569	0.69	0.94
Oklahoma	10,574,674	0.0599	0.0205	0.1317	0.58	0.79
Pennsylvania	8,768,943	0.0497	0.017	01092	0.48	0.65
West Virginia	7,529,708	0.0427	0.0146	0.0938	0.47	0.56
Texas	5,290,476	0.03	0.0102	0.0659	0.29	0.39
California	4,574,351	0.0259	0.0089	0.057	0.25	0.34
Idaho	3,375,274	0.0191	0.0065	0.042	0.18	0.25
Arkansas	2,568,979	0.0146	0.005	0.032	0.14	0.19
Mississippi	1,729,005	0.0098	0.0033	0.0215	0.09	0.13
Oregon	1,675,879	0.0095	0.0032	0.0209	0.09	0.12
Kansas	1,507,005	0.0085	0.0029	0.0188	0.08	0.11

Area	LOP Production	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
Michigan	776,819	0.0044	0.0015	0.0097	0.04	0.06
Alabama	462,915	0.0026	0.0009	0.0058	0.03	0.03
Virginia	337,163	0.0019	0.0007	0.0042	0.02	0.03
Kentucky	248,680	0.0014	0.0005	0.0031	0.01	0.02
South Dakota	103,679	0.0006	0.0002	0.0013	0.01	0.01
New York	5,958	0	0	0.0001	0	0
Arizona	0	0	0	0	0	0
Illinois	0	0	0	0	0	0
Indiana	0	0	0	0	0	0
Maryland	0	0	0	0	0	0
Nebraska	0	0	0	0	0	0
Nevada	0	0	0	0	0	0
Tennessee	0	0	0	0	0	0

Production units (Mcf).
"0" values are the result of rounding to a defined number of significant digits (Ex: 0.0000), which are then truncated. These values are actually less than the significant digits provide for (Ex: 0.00004).

Figure 7-1 shows an annualized timeline of the projected short-term life-of-project C0$_2$e emissions from the previous tables (existing producing wells and projected wells from new APDs and Leasing (12-months)) for the selected state. The cumulative sum of all the state series (i.e., the federal sum) is displayed in Table 7-18.

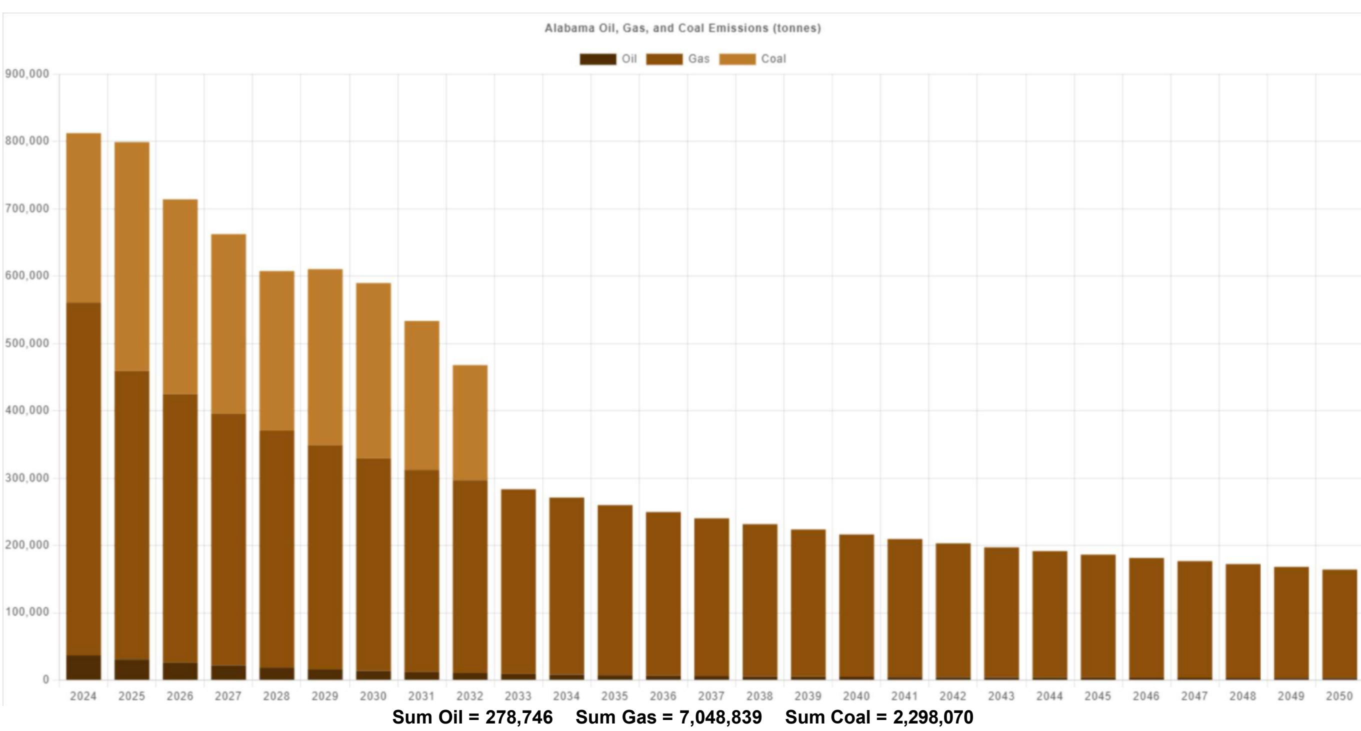


Figure 7-1. Projected State Oil, Gas, and Coal CO_2e Emissions (tonnes)

Note: Oil and gas data differs from the LOP estimates in the tables above, which are a based on a 30 projection, while the chart data only extends to 2050 in order to maintain consistency with the long-term projects shown in Figure 7-2.

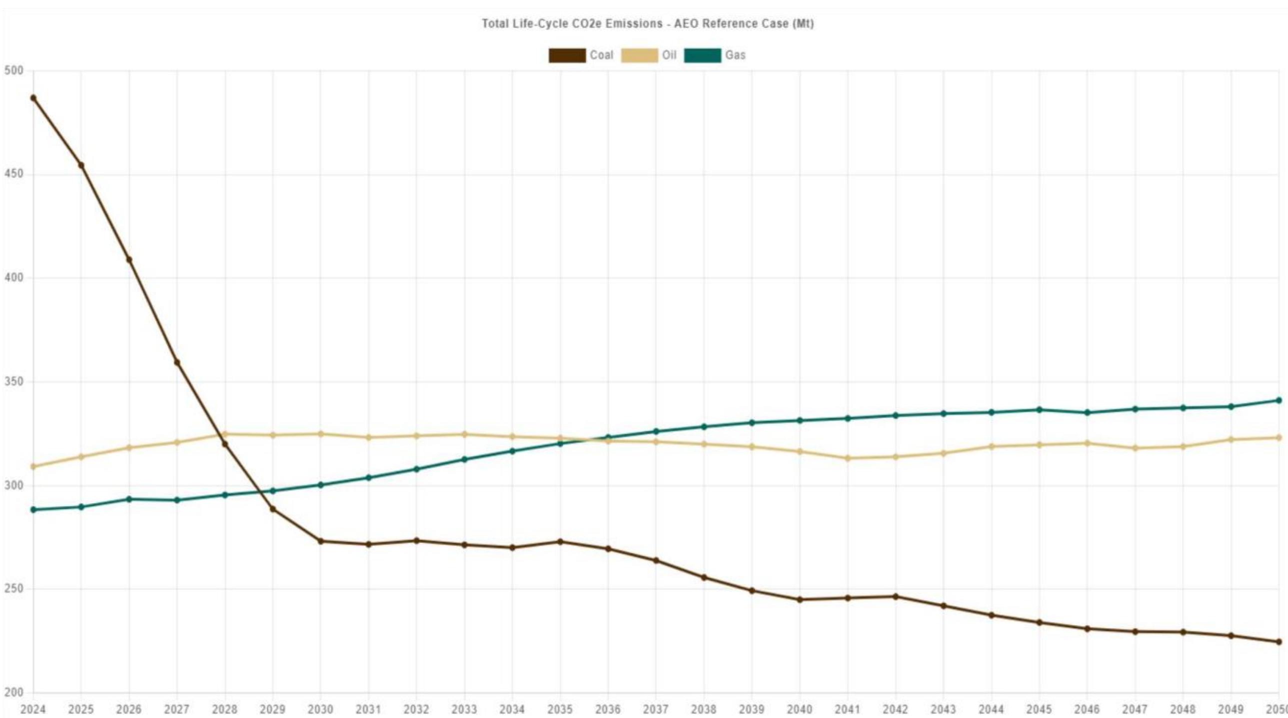
Note: Data may contain rounding discrepancies.

Table 7-18. Federal Summary - Projected Short-Term Life-of-Project Emissions (Mt)

Mineral	Extraction C02e	Processing C02e	Transport C02e	Combustion C02e	Total C02e
Coal	128.3	19.3	152.7	6,873.4	7,173.7
Oil	383.1	263.8	52.3	2,251.4	2,950.5
Gas	234.3	80.1	514.9	2,253.2	3,082.5
Totals	**746**	**363**	**720**	**11,378**	**13,207**

7.3 Long-Term Federal Fossil Fuel Mineral Emissions Projections

The long-term emissions estimates presented in Figure 7-2 and Table 7-18 are based on EIA's Annual Energy Outlook (AEO) reference case data. For the 2023 AEO, the high oil price scenario produces the highest emissions. This should also be true at subnational scales depending on the production resource mix of the individual region. The low oil and gas supply case produces the lowest projected emissions, which is slightly counterintuitive considering that the low renewables cost case would be expected to produce fewer emissions overall (second lowest scenario). Areas with higher levels of coal production could see higher emissions in a low oil and gas supply scenario, as increased coal production takes up the energy slack from lower available oil and gas supplies.



Series Sums: Coal = 7,582 Oil = 8,636 Gas = 8,620 Totals = 24,838

Figure 7-2. Long-Term Onshore Federal Mineral Emissions (Mt CO_2e)

Note: Rounding and data conversions, or updated API data may introduce small discrepancies in the series sums.

Table 7-19. Long-Term Federal Mineral Projections - AEO Reference Case

Federal Minerals	Production	Energy (Quads)	Emissions (Mt $C0_2e$)
Coal (MM short tons)	4,799	7.57E+0l	7,582

Oil (MM bbl)	15,207	8.81E+0l	8,640
Gas (Bcf)	115,674	1.19E+02	8,624
Projected Totals	**NA**	**2.83E+02**	**24,845**

The projections made from the 2023 data show that fossil fuel mineral development from the federal onshore mineral estate could account for approximately 14.41% of total U.S. GHG emissions by 2050. The difference in federal emissions on an absolute basis between the high (high oil price) and low (low oil and gas supply) AEO projection scenarios is approximately 7,717 Mt of CO_2e over the entirety of the projection period, or about 296.8 Mt of CO_2e on an annual average basis. The difference (or delta) between the cumulative short-term emissions previously described and the long-term emissions estimates can be thought of as the level of additional development that could be authorized to sustain the existing federal fraction of production over the longer term. Similarly, if the short-term emissions exceed a longer-term scenario, then the delta can be thought of as the amount of reduction required to attain the outlook forecast. In all cases, the EIA clearly explains that the AEO scenario projections are not predictions of what will happen, but rather, they are modeled projections of what may happen given certain assumptions. **Note:** The EIA recently announced it would suspend production of the AEO in 2024 to update the National Energy Modeling System (NEMS) in order to provide enhanced modeling of hydrogen, carbon capture, and other emerging technologies. As such, this iteration of the report continues to rely on the 2023 AEO data.

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8.0 Projected Climate Change

The current understanding of the climate system comes from the cumulative results of observations, experimental research, theoretical studies, and model simulations conducted by thousands of scientists from all over the world. Climate change is fundamentally a cumulative phenomenon, global in scope, and all GHGs contribute incrementally to climate change regardless of scale or origin. The future climate equilibrium is dependent upon warming caused by past and future anthropogenic emissions, and natural variability. The multitude of interwoven natural systems and feedback mechanisms that contribute to climate variability over the entirety of Earth further complicate analysis.

8.1 Representative Concentration Pathways

Climate scientists provide projection analyses by modeling changes to earth's systems in response to a range of global emissions scenarios known as Representative Concentration Pathways (RCPs). The RCPs are not fully integrated scenarios of climate feedback, policy, emissions limits, thresholds, or socioeconomic projections, but rather a consistent set of cumulative emissions projections out to year 27 00 of only the components of radiative forcing that are meant to serve as input for climate and atmospheric chemistry modeling. There are four scenarios that climate scientists have used for assessment in the Coupled Model Intercomparison Project Phase 5 (CMIP5) (Figure 8-1).

- ***RCP2.6*** - A low emissions pathway that is representative of scenarios that lead to very low atmospheric GHG concentrations. Radiative forcing levels reach a peak around 3.7 W/m^2 by mid-century, returning to 2.6 W/m^2 by 2100. To reach these radiative forcing levels, global GHG emissions are reduced substantially over time. This scenario also assumes there will be "negative emissions" starting in 2080, with more carbon being removed from the atmosphere than is emitted. The aggregate global emissions of this pathway is approximately 1 ,715.7 $GtC0_2e$ (2018 - 2100). CO_2 alone represents 54.2% of the total contributing emissions, and 81 .5% of the total CO_2 emissions are attributable to fossil fuel use.
- ***RCP4.5-*** Stabilization scenario where total radiative forcing stabilizes at 4.5 W/m^2 before 2100 by employment of a range of technologies and strategies for reducing GHG emissions. This pathway forecasts global emissions increasing until about 2040 and then declining starting in 2050. The aggregate emissions of this pathway is approximately 3,728.6 $GtC0_2e$ (2018 - 2100). CO_2 alone represents 67% of the total contributing emissions, and 98.2% of the total CO_2 emissions are attributable to fossil fuel use.
- ***RCP6.0-*** Stabilization scenario where total radiative forcing stabilizes at of 6.0 W/m^2 after 2100 by employment of a range of technologies and strategies for reducing GHG emissions. Emissions of CO_2 grow steadily until 2080 before declining. The cumulative emissions of this pathway are approximately 5,380.2 $GtC0_2e$ (2018 - 2100). CO_2 alone represents 74.3% of the total contributing emissions, and 101 .1% of the total CO_2 emissions are attributable to fossil fuel use. Please note, the Land Use Change (LUC) CO_2 emissions in this scenario are negative at about the mid-century mark, which produces data showing fossil fuel emissions that are greater than the total emissions (which include the negative LUC values).
- ***RCPB.5-*** Pathway scenario with increasing emissions over time that leads to very high GHG concentration levels and radiative forcing of 8.5 W/m^2 in 2100. This pathway assumes emissions trajectories follow historical growth and assumes no climate policies are enacted to reduce emissions. The aggregate emissions of this pathway are approximately 9,227.7 $GtC0_2e$ (2018 - 2100) CO_2 alone represents 72.3% of the total contributing emissions, and 97.8% of the total CO_2 emissions are attributable to fossil fuel use.

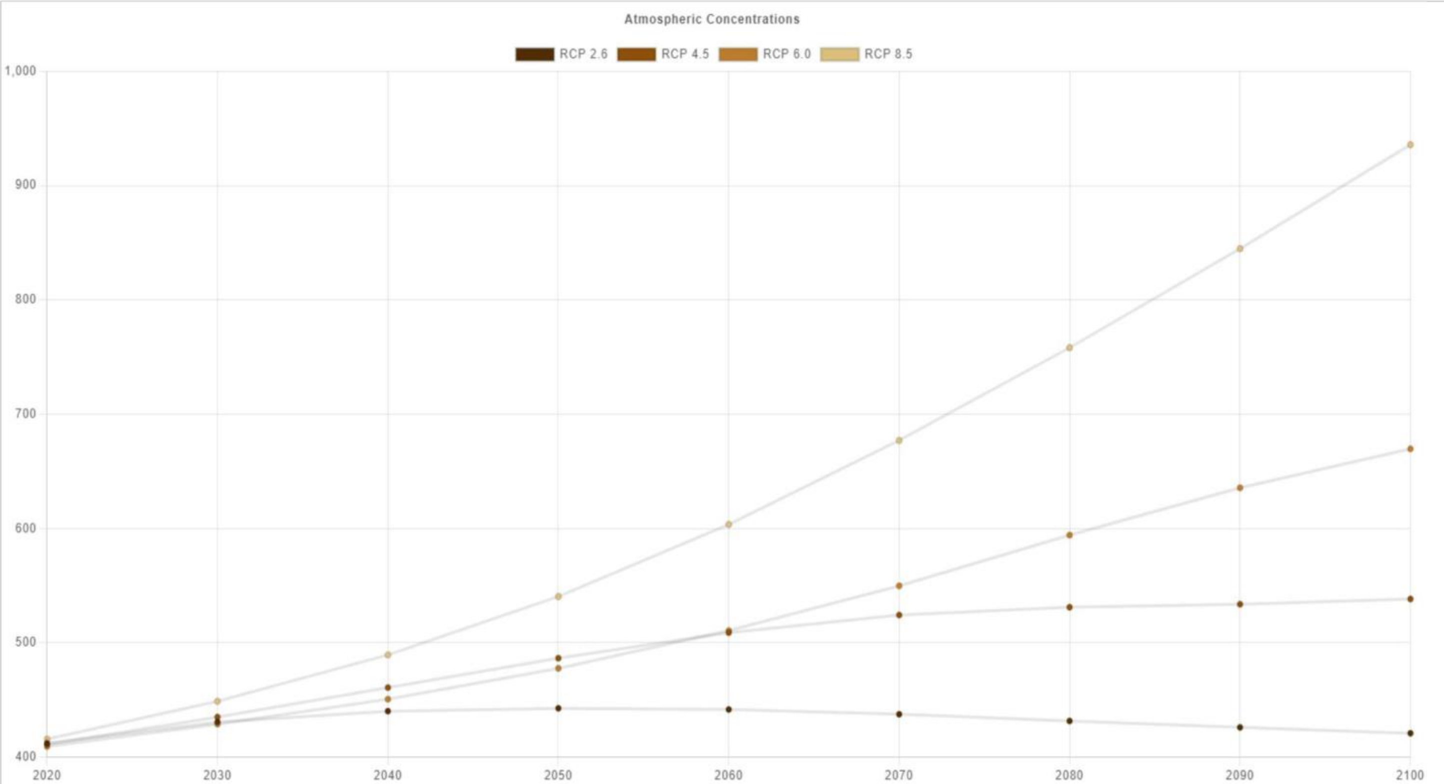


Figure 8-1. RCP Emissions and Attributes Data

Source: [RCP Database]()
Units Concentrations CO_2 (ppm), CH_4 and N_2O (ppb), Forcing All (W/m^2), Emissions CO_2 (PgC/yr), CH_4 and N_2O (Tg/yr)

By 2050, the magnitude of projected climate change is substantially affected by the overall emissions path along which the world is tracking. It should be noted that according to the IPCC, only emissions projections following the lowest concentration pathway (RCP2.6) result in an estimated mean increase in global average temperatures below 2°C. Equally important, IPCC scientists project warming will continue beyond 2100 under all RCP scenarios except for RCP2.6.

The projected increase of global mean surface temperature by the end of the 21st century (2081-2100) relative to 1986-2005 is likely to be 0.3°C to 1.7°C under RCP2.6, 1.1°C to 2.6°C under RCP4.5, 1.4°C to 3.1°C under RCP6.0, and 2.6°C to 4.8°C under RCP8.5. As global mean surface temperature increases, it is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales. It is also very likely that heat waves will occur with a higher frequency and longer duration. Occasional cold winter extremes will continue to occur due to the inherent variability within the climate system. Changes in precipitation patterns will not be uniform, but in general, scientists expect arid regions to become drier and wetter areas to experience frequent exceptional precipitation events. Oceans will continue to warm, with the greatest impacts occurring at the surface of tropical and northern hemisphere subtropical regions. Models also predict ocean acidification will increase for all RCP scenarios, where surface pH can be expected to decrease by 0.06 to 0.07 (7 5 to 17%) for RCP2.6 and 0.14 to 0.15 (38 to 41%) for RCP4.5. Year-round reductions in Arctic Sea ice are projected for all RCP scenarios, and it is virtually certain that near-surface (upper 3.5 m) permafrost extent at high northern latitudes will be reduced (37% - RCP2.6 to 87 % - RCP8.5) as the global mean surface temperature increases. Global mean sea level rise will very likely continue at a faster rate than observed from 1977 to 207 0 For the period 2081-2100 relative to 1986-2005, the rise will likely be in the range of 0.26 to 0.55 m for RCP2.6 and of 045 to 0.82 m for RCP8.5. It is very likely that the sea level will rise in more than 95% of the ocean area, where about 70% of coastlines worldwide would experience a sea level change within ±20% of the global mean.

8.2 Shared Socioeconomic Pathways

In preparation for the IPCC's Sixth Assessment Report (AR6), the climate science research community, economists, and energy systems modelers developed a new range of "pathways" that examine how global society, demographics, and economics might influence future climate impacts, vulnerabilities, adaptation, and mitigation over the next century. The scenarios are collectively known as the Shared Socioeconomic Pathways (SSPs). These new scenarios were used to inform the latest round of climate modeling that was incorporated into AR6. The RCPs and SSPs are meant to complement each other. The RCPs set pathways for GHG concentrations and the potential amount of radiative forcing and warming the world may experience by the end of the century.

The SSPs explore how reductions in emissions will, or will not, be achieved and can therefore be thought of as potential mitigation alternatives.

There are five basic SSP narratives [41] that were developed. The SSP scenarios provide a range of plausible trends (Figure 9-2) that could shape future society and include the following

- ***SSP1 (Low challenges to mitigation and adaptation)*** - The world shifts gradually, but pervasively, toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries. Management of the global commons slowly improves, educational and health investments accelerate the demographic transition, and the emphasis on economic growth shifts toward a broader emphasis on human well-being. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Consumption is oriented toward low material growth and lower resource and energy intensity.
- *SSP2 (Medium challenges to mitigation and adaptation)* - The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. Development and income growth proceeds unevenly, with some countries making relatively good progress and others falling short of expectations. Global and national institutions work toward but make slow progress in achieving sustainable development goals. Environmental systems experience degradation, although there are some improvements, and overall the intensity of resource and energy use declines. Global population growth is moderate and levels off in the second half of the century. Income inequality persists or improves only slowly, and challenges to reducing vulnerability to societal and environmental changes remain.
- ***SSP3 (High challenges to mitigation and adaptation)*** - A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues. Policies shift over time to become increasingly oriented toward national and regional security issues. Countries focus on achieving energy and food security goals within their own regions at the expense of broader-based development. Investments in education and technological development decline. Economic development is slow, consumption is material-intensive, and inequalities persist or worsen over time. Population growth is low in industrialized and high in developing countries. A low international priority for addressing environmental concerns leads to strong environmental degradation in some regions.
- ***SSP4 (Low challenges to mitigation, high challenges to adaptation)***- Highly unequal investments in human capital, combined with increasing disparities in economic opportunity and political power, lead to increasing inequalities and stratification both across and within countries. Over time, a gap widens between an internationally-connected society that contributes to knowledge- and capital-intensive sectors of the global economy, and a fragmented collection of lower-income, poorly educated societies that work in a labor intensive, low-tech economy. Social cohesion degrades and conflict and unrest become increasingly common. Technology development is high in the high-tech economy and sectors. The globally connected energy sector diversifies, with investments in both carbon-intensive fuels like coal and unconventional oil, but also low-carbon energy sources. Environmental policies focus on local issues around middle and high income areas.
- ***SSP5 (High challenges to mitigation, low challenges to adaptation)*** - This world places increasing faith in competitive markets, innovation, and participatory societies to produce rapid technological progress and development of human capital as the path to institutions to enhance human and social capital. At the same time, the push for economic and social development is coupled with the exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles around the world. All these factors lead to rapid growth of the global economy, while global population peaks and declines in the 27 st century. Local environmental problems like air pollution are successfully managed. There is faith in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary.

Both SSP1 and SSP5 consider optimistic scenarios for human development with substantial investments in education, rapid economic growth, and technology. They differ in that SSP5 assumes that development is driven by fossil fuel energy, while in SSP7 there is a shift towards sustainable practices and sustainable development. Global markets are increasingly integrated. There are also strong investments in health, education, and renewable energy sources. The SSP2 scenario represents a "middle of the road" path that follows historical development trends throughout the 21st century. While SSP3 and SSP4 present less optimistic economic and social development scenarios, with little investment in education or health in poorer countries coupled with a fast-growing population and increasing inequalities. Each SSP has a baseline scenario that describes future developments in the absence of new climate policies, beyond those already in place today. The SSPs can then be combined with various emission mitigation objectives to identify how each of the different RCPs can be achieved.

To understand how the SSPs relate to different levels of warming under the RCP scenarios, six different integrated assessment models (IAMs) were used. The IAMs produce an estimate of the GHG emissions that would occur based on socioeconomic factors outlined in the SSPs. The resulting emissions were then used as inputs for the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC) to provide estimates of atmospheric GHG concentrations and future warming. In addition to the four RCPs analyzed in AR5, three additional RCPs representing radiative forcing of 1.9, 3.4, and 7.0 W/m^2 were evaluated to expand the range of emissions mitigation targets. The RCP1.9 represents a pathway that limits warming to 1.5°C. The combination of five SSPs and six of the RCPs is shown in Figure 8-2 (a). Each box in the slide shows the number of models that were able to successfully reach the RCP target, out of the total number of models available for a given SSP. For example, the "3/4" in the SSP5/RCP2.6 cell means that four IAMs tried to achieve RCP2.6 in an SSP5 world, but only three of the models could find a solution. The other model could not either reduce emissions fast enough or generate sufficient negative emissions. Similarly, only SSP5 could generate scenarios that reached RCP8.5 levels of radiative forcing, while emissions were too low in other SSP baselines. This research shows that some mitigation and adaptation to climate change is much easier under some SSP scenarios than others and not all SSPs are compatible with RCPs that limit warming to 1.5°C or 2°C above pre-industrial levels. However, even though not all the IAMs find a viable solution for scenarios that limit warming below 1.5°C or 2°C, it does not necessarily mean that these scenarios are impossible. Models are imperfect and cannot foresee all changes that will happen over the next century.

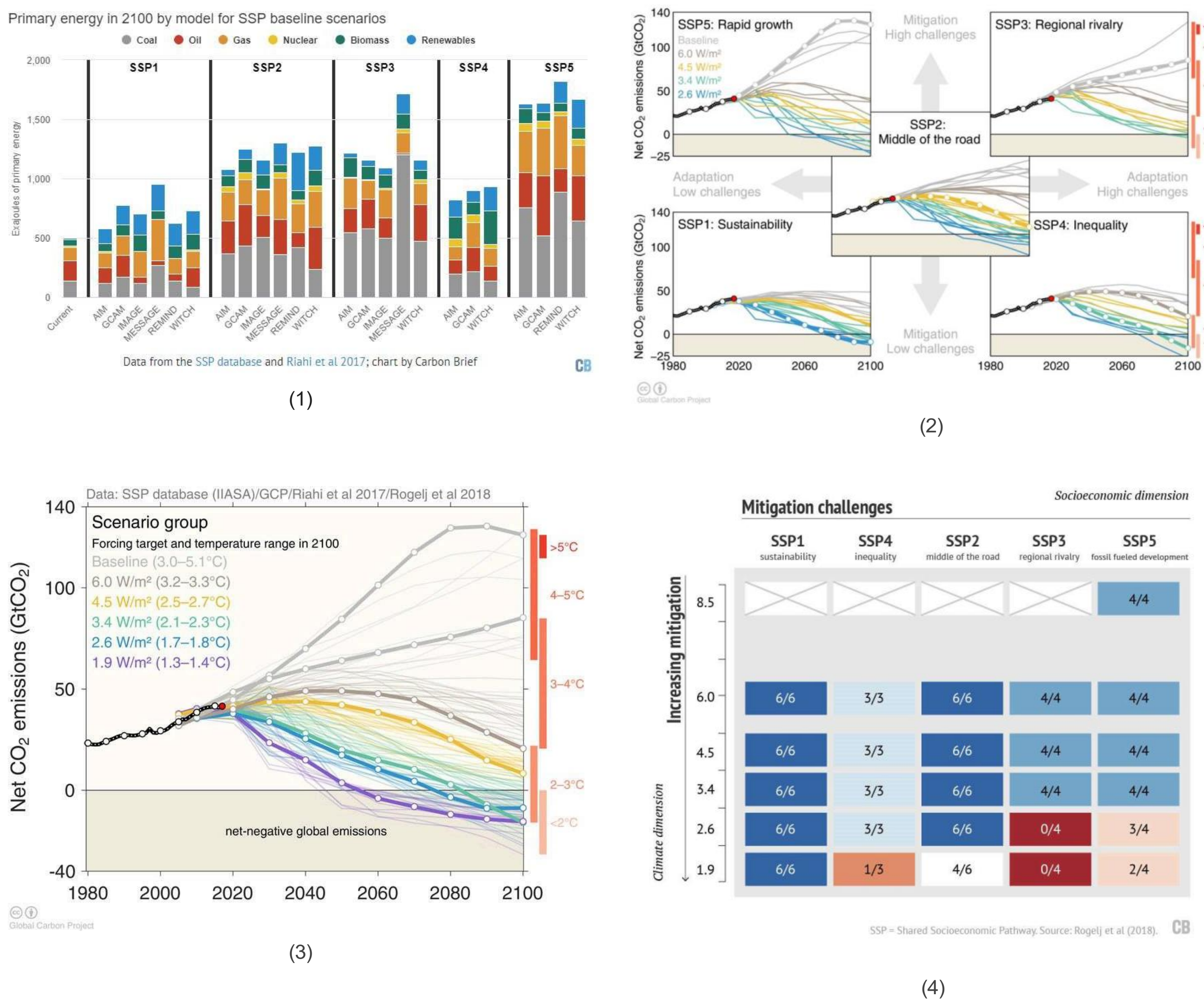


Figure 8-2. Shared Socioeconomic Pathways

1 - Global primary energy use by fuel type in 2100 in exajoules (EJ) for baseline scenarios in each 1AM and SSP. Current energy use (as of 2010) is shown for reference in the far left bar. Data from the SSP database and Riahi et al 2017;
2 - Global CO2 emissions (GtC02) for all 1AM runs in the SSP database separated out by SSP. Chart via Glen Peters and Robbie Andrews and the Global Carbon Project.
3 - Global CO2 emissions (gigatonnes, GtC02) for all 1AM runs in the SSP database. SSP no-climate-policy baseline scenarios are shown grey, while various mitigation targets are shown in color. Bold lines indicate the subset of scenarios chosen as a focus for running CMIP6 climate model simulations. Chart produced for Carbon Brief by Glen Peters and Robbie Andrews from the Global Carbon Project.
4 - Combination of SSP and RCP model runs in the SSP database, with RCPs listed in order of increasing mitigation and SSPs in the (rough) order of increasing

mitigation difficulty. Ratios in cells indicate the number of models that succeeded in making the scenario "work" out of the total number of models available for the SSP. Chart by Carbon Brief, adapted from Figure SI in Rogelj et al (207 8).

8.3 AR6 and NCAS Summary

Earlier this year the IPCC released their synthesis report for the sixth assessment report (AR6), titled "Climate Change 2023". [42] It is ssentially more of the same relative to AR5, but with an enhanced sense of climate understanding and deeper urgency. In short, human activities that release GHGs to the atmosphere are the problem. The attribution and effects of these emissions on climate change are well documented, and the predictions of most changes and the rates of change are starting to emerge or manifest. The solution is to reduce emissions as quickly as possible, understanding that some level of future climate change has already been committed to, for potentially hundreds to thousands of years. Adaptation measures will be required, but may have effective limits on both a short-term and long-term basis. The following is a brief highlight of the future climate change analysis presented in IPCC's Sixth Assessment Report.

Human activities are estimated to have caused approximately I .0°C of global warming above pre-industrial levels, with a likely range being 0.8°C to 1 .2°C. Global surface temperatures are likely to reach 1.5°C in the near-term even under the very low GHG emission scenario (SSP 1 -1.9). Discernible differences in global surface temperature trends between contrasting SSPs would begin to emerge from natural variability within around 20 years. Continued emissions will further affect all major climate system components, and with every additional increment of global warming, changes in the extremes become larger. Continued warming is projected to further intensify the global water cycle, including variability and overall rates of precipitation, which in turn will affect very wet and very dry weather, episodic climate events, and the seasons in general. In scenarios with increasing emissions, natural land and ocean carbon sinks are projected to take up less CO_2 emissions. The extents and volumes of almost all cryosphere elements (permafrost, ice sheets, glaciers, etc.) will be reduced, and will contribute to global mean sea level rise. An increase in ocean acidification and deoxygenation is also virtually certain, along with compounding heatwaves and droughts that are projected to become more frequent, with concurrent events sustained in multiple locations.

Further warming will make climate change risks become increasingly complex and more difficult to manage. As compared to the AR5, global aggregated risk levels are assessed to become higher even at lower levels of global warming due to recent evidence of observed impacts, improved process understanding, and new knowledge on exposure and vulnerability of human and natural systems, including limits to adaptation. Projected exposure to climatic hazards will increase globally due to socio-economic development trends such as migration, and growing inequality and urbanization. Ecosystem vulnerability will become strongly influenced by cumulative (past, present, and future) patterns of land, ocean, and freshwater management.

According to the 5th NCA, projections show that for every 1 °C of global warming the U.S. will have a corresponding average temperature increase of 2.5°F, where northern and western portion of the country will be disproportionately affected. Additional increases in annual average temperature of about 2.5°F are expected over the next few decades regardless of the future emissions, and increases ranging from 3°F to 12°F (1.6°-6.6°C) are expected by the end of century depending on whether the world follows a lower or higher future emissions scenario. There is a good deal of uncertainty in terms of both the potential emissions trajectories implied by current policies and the sensitivity of the climate with respect to additional emissions and carbon cycle feedbacks that may affect the portion of emissions that accumulate in the atmosphere. Additionally, the potential for a worse-than-current-policy outcome is not zero (i.e., higher emissions than presently forecast). These uncertainties combined with current projections for sustained fossil fuel use through 2050 made by the EIA and others, suggests that attaining net zero could be extremely difficult.

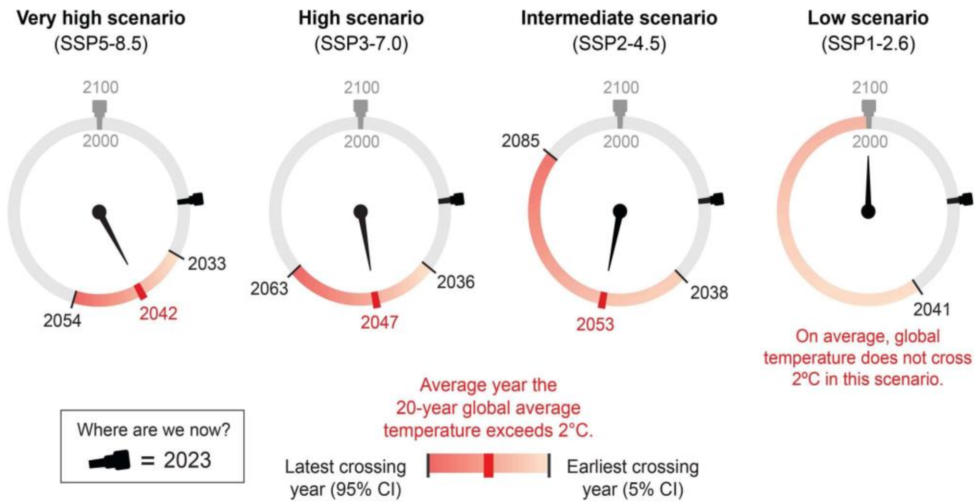


Figure 8-3. Projected Target Temperature Acquisition Times

Source: NCA5.

8.4 State Climate Change Projections

The following climate change discussion summarizes information from NCA5 and NOAA's state climate summaries. Figure 8-4 provides projected temperature and precipitation changes for the U.S relative to several global warming scenarios.

Alaska

Alaska is on the front lines of climate change and is among the fastest warming regions on Earth. It is warming faster than any other state, and it faces a myriad of issues associated with a changing climate. Global climate models project more warming in the Arctic and interior areas than in the southern areas of Alaska. In the RCP8.5 scenario, interior and northern areas of the state are projected to warm by 10°- 16°F, southern portions by 2.5°- 8°F Climate models suggest that Arctic waters will be virtually ice-free by late summer before 2050 and near-surface permafrost will likely disappear on 16% to 24% of the landscape by the end of the 21st century.

Average precipitation is projected to increase in all seasons during the 21st century, with the greatest increases expected in winter and spring. By the middle of the 21st century, annual precipitation increases are projected to exceed 10% over most of the state, with greater increases in the Arctic and interior and the largest increases in the northeastern interior.

Climatic extremes are expected to change with the changing climate. Under a higher scenario (RCP8.5), by mid-century (2046-2065) the highest daily maximum temperature (the hottest temperature one might expect on a given summer day) is projected to increase 4°- 8°F compared to the average for 1987 - 2000. For the same future period (2046-2065), the lowest daily maximum temperature (the highest temperature of the coldest day of the year) throughout most of the state is projected to increase by more than 10°F, with smaller projected changes in the Aleutian Islands and southeastern Alaska. Additionally, the lowest daily minimum temperatures (the coldest nights of the year) are projected to increase by more than 12°F. The number of nights below freezing would likely decrease by at least 20 nights per year statewide, and by greater than 45 nights annually in coastal areas of the North Slope, Seward Peninsula, Yukon-Kuskokwim Delta, Alaska Peninsula, and Southcentral Alaska. Annual maximum one-day precipitation is projected to increase by 5%-10% in southeastern Alaska and by more than 15% in the rest of the state, although the longest dry and wet spells are not expected to change over most of the state. Growing season length (the time between last and first frosts in a given year) is expected to increase by at least 20 days and perhaps more than 40 days compared to the 1982-2010 average. Whether or not this increased growing potential is realized will largely depend on soil conditions and precipitation.

The area burned by wildfires may increase further under a warming climate. Projections of burned area for 2006-2100 are 98 million acres under a lower scenario (RCP4.5) and 120 million acres under a higher scenario (RCP8.5).

California

Under a higher emissions pathway, historically unprecedented warming is projected by the end of the 21st century. Even under a pathway of lower GHG emissions, average annual temperatures are projected to most likely exceed historical record levels by the middle of the 21st century. However, there is a large range of temperature increases under both pathways, and under the lower pathway a few projections are only slightly warmer than historical records. Overall, any warming will lead to increased heat wave intensity but decreased cold wave intensity. Future heat waves could particularly stress coastal communities, such as San Francisco, that are rarely exposed to extreme temperatures and therefore are not well adapted to such events. More intense, longer-lasting heat waves will result in increasing peak demands for electricity for air conditioning, depleting electrical generation and distribution capacities, resulting in increased risks of brownouts and blackouts. The EPA projects that climate change could increase the need for additional electric generating capacity by 10 to 20% by 2050 as a result. Conversely, demand for natural gas, oil, and wood for heating will decrease. Electricity supply also will be affected by changes in the timing of river flows and where hydroelectric systems have limited storage capacity, since increased year-to-year variability of precipitation is expected.

Winter precipitation projections range from slight decreases in southern California to increases in northern California, but these changes are smaller than natural variations. Increasing temperatures are projected to increase the average snowfall elevation, which would reduce water storage in the snowpack, particularly at lower mountain elevations on the margins of snow accumulation. Under the higher scenario (RCP8.5), much of the mountainous area in California with winters currently dominated by snow would begin to receive more precipitation as rain and then only rain by 2050. Higher spring temperatures will also result in earlier melting of the snowpack. The shift in snow melt to earlier in the season is critical for California's water supply because flood control rules require that water be allowed to flow downstream, and that water cannot be stored in reservoirs for use in the dry season.

Climate models project an increase in the frequency of heavy downpours, especially through atmospheric rivers, which are narrow bands of highly concentrated storms that move in from the Pacific Ocean. A series of strong atmospheric rivers caused extreme flooding in California in 2016 and 2017. Under the higher scenario (RCP8.5), models project increases in the frequency and intensity of atmospheric rivers.

Droughts are expected to become more intense due to climate change. Even if precipitation increases in the future, temperature rises will increase the rate of soil moisture loss during dry spells, further reducing streamflow, soil moisture, and water supplies. As a result, wildfires are projected to become more frequent and severe.

Increasing temperatures raise concerns for sea level rise in coastal areas. Since 1880, global sea level has risen by about 8 inches. It is projected to rise another 1 to 4 feet by 2100 as a result of both past and future emissions due to human activities. Continued sea level rise will present major challenges to California's water management system. The Sacramento-San Joaquin Delta is the hub of California's water supply system. Water from reservoirs in northern California flows through the Delta where it is then pumped into aqueducts to central and southern California. Sea level rise will cause salty ocean water to intrude into the Delta through San Francisco Bay. This would require increased releases of water from upstream reservoirs to keep the salty water out of the Delta. Water that is used to push salt flows out into the ocean is no longer available for water supply.

Colorado

All climate model projections indicate future warming in Colorado. Statewide average annual temperatures are projected to warm by 2.5'F to 5'F by 2050 relative to a 1971-2000 baseline under RCP4.5. Under the high emissions scenario (RCP8.5), the projected warming is 3.5'F to 6.5'F and would occur later in the century as the two referenced scenarios diverge. Summer temperatures are projected to warm slightly more than winter temperatures, where average temperatures would be similar to the hottest summers that have occurred in the past 100 years. Increases in heat wave intensity are projected, but the intensity of cold waves is projected to decrease continuing recent trends.

Colorado precipitation projections are less clear, with individual models showing a range of changes by 2050 of -5% to +6% for RCP 4.5, and -3% to +8% under RCP8.5. Nearly all models predict an increase in winter precipitation by 2050, although most projections of April 1 snowpack show declines by mid-century due to projected warming. Although heavier winter precipitation could provide important water for the water-scarce Southwest, projected rising temperatures will increase the average lowest elevation at which snow falls (the snow line), with more precipitation falling as rain instead of snow, reducing water storage in the snowpack, particularly at those lower elevations which are now on the margins of reliable snowpack accumulation. Warmer temperatures will also result in earlier melting of the snowpack and increased evaporation of soil moisture, further decreasing water availability during the already dry summer months. Extreme precipitation events are also projected to increase because of increases in the atmospheric water vapor in the oceanic water vapor source regions (due to rising sea surface temperatures) for Colorado's extreme events.

Late-summer river flows are projected to decrease as peak runoff shifts earlier in the season, although the changes in the timing of runoff are more certain than changes in the amount of runoff. In general, most published research indicates a tendency towards future decreases in annual streamflow for all of Colorado's river basins. Projected hotter temperatures increase probabilities of decadal to multidecadal megadroughts, which are persistent droughts lasting longer than a decade, even when precipitation increases. Increased warming, drought, and insect outbreaks, all caused by or linked to climate change, will continue to increase wildfire risks and impacts to people and ecosystems.

Northern Great Plains (Montana, North Dakota, and South Dakota)

The "Fourth National Climate Assessment Impacts, Risks, and Adaptation in the United States" discusses projected climate change in the Northern Great Plains (consisting of Montana, Wyoming, North Dakota, South Dakota, and Nebraska) in Chapter 22. The impacts of climate change throughout the Northern Great Plains include changes in flooding and drought, rising temperatures, and the spread of invasive species.

Climate projections suggest temperatures will increase throughout the 27 st century across the region under all emission scenarios. Temperature increases of 2°- 4°F projected by 2050 for the Northern Great Plains under the lower scenario (RCP4 5) are expected to result in an increase in the occurrence of both drought and heat waves. Under a higher emissions pathway (RCPB.5), historically unprecedented warming is projected by the end of the 21st century. The warmest climate model projections indicate average temperatures may increase by over 10°F above the hottest temperatures observed during the 20th century. Temperature increases are projected for all seasons with the most warming indicated during summer. This warming is predicted to occur along with less snowpack and a mix of increases and reductions in average annual water availability.

The "Fourth National Climate Assessment" notes that the amount, distribution, and variability of annual precipitation in the Northern Great Plains are anticipated to change, with increases in winter and spring precipitation of 10%-30% by the end of this century and a decrease in the amount of precipitation falling as snow under a higher scenario (RCPB.5). Summer precipitation is expected to vary across the Northern Great Plains, ranging from no change under a lower scenario (RCP4.5) to 1 0%-20% reductions under a higher scenario (RCPB.5). The number of heavy precipitation events (events with greater than 1 inch per day) for much of the region is expected to increase. Although fewer hail days are expected, a 40% increase in damage potential from hail due to more frequent occurrence of larger hail is predicted for the spring months by mid-century under a higher scenario (RCPB.5). Even with increases in precipitation, warmer temperatures are expected to increase evaporative demand, leading to more frequent and severe droughts.

Nevada

Under a higher emissions pathway, historically unprecedented warming is projected to continue through this century. Even under a lower emissions pathway, annual average temperatures are projected to most likely exceed historical record levels by the middle of this century. However, a large range of temperature increases is projected under both pathways, and under the lower pathway, a few projections are only slightly warmer than historical records. Extreme high temperatures are projected to increase substantially, with potentially large impacts in the very hot southern deserts, particularly the Las Vegas metro area, where 70% of the state's population resides. Extreme heat, combined with the urban heat island effect, will result in poor air quality and an increased risk of chronic respiratory conditions and heat stress.

Projected rising temperatures in Nevada will raise the snow line-the average lowest elevation at which snow falls. This will increase the likelihood that precipitation will fall as rain rather than snow, reducing water storage in the snowpack, particularly at those lower mountain elevations that are now on the margins of reliable snowpack accumulation. Higher spring temperatures will also result in earlier melting of the snowpack, further decreasing water availability during the already dry summer months.

Warmer temperatures are likely to decrease the amount of water in the mountain snowpack and increase the demand for water. Higher temperatures will also increase the evaporation rate, which will reduce streamflow and soil moisture. Thus, the intensity of future droughts is likely to increase, as will the risk of wildfires in some ecosystems. Increases in population and potentially decreased water flow from the Colorado River may lead to future water security issues across the state.

New Mexico

Climate models suggest that annual average temperatures in this region may rise by 4°F to as much as 12°F above current levels by the end of the 21st century depending on the emissions scenario. More warming is projected to occur in the northern part of the state. While projections of annual precipitation are uncertain, more precipitation falling as rain is very likely to occur as temperatures increase. Spring precipitation, which is already light in the mountains of New Mexico, is projected to decrease across the state. A decrease in spring precipitation, coupled with higher temperatures, would have negative impacts on mountain snowpack. Even if snowpack accumulation remained similar to current levels, the projected higher temperatures will lead to an earlier start and end to the snowmelt season, potentially necessitating changes in water management.

A Bureau of Reclamation report[43] 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 would be decreases in overall water availability by one-quarter to one-third.
- The seasonality of stream and river flows would change, with summertime flows decreasing.
- Stream and river flow variability would increase. The frequency, intensity, and duration of both droughts and floods would increase.
- The tendency for reduced environmental flows in the Upper Rio Grande system will make it more difficult to maintain and result in decreased reservoir storage.

Observed temperatures are generally within the envelope of model simulations of the historical period (gray shading graphs - Figure 9-3). Historically unprecedented warming is projected during the 21st century. Less warming is expected under a lower emissions future, where the average daily maximum temperature could rise by as much as 6°F, in contrast to the higher emissions scenario that could lead to average daily maximums that are 11°F warmer than the historical record.

<u>Utah</u>

Climate projections under a higher emissions scenario (RCPS.5) indicate that Utah could warm by as much as 15°F above current levels by the end of the century, though the mean RCPS.5 increase for the state is about 7°F hotter than recent temperatures. Under a lower emissions scenario, warming is projected to be about 2°F to 5°F above the 1991-2020 mean. There is a large range of temperature increases under both pathways, and under the lower pathway, a few projections are only slightly warmer than historical records. Increases in average temperatures will be accompanied by increases in heat wave intensity and decreases in cold wave intensity.

Climate models are not consistent in their projections of precipitation for Utah, including winter precipitation. However, projected rising temperatures will increase the average lowest elevation at which snow falls (the snow line). Continuing recent trends, this will increase the likelihood that precipitation will fall as rain instead of snow, reducing water storage in the snowpack, particularly at lower elevations that are currently on the margins of reliable snowpack accumulation. In addition, extreme precipitation is projected to increase, potentially increasing the frequency and intensity of floods.

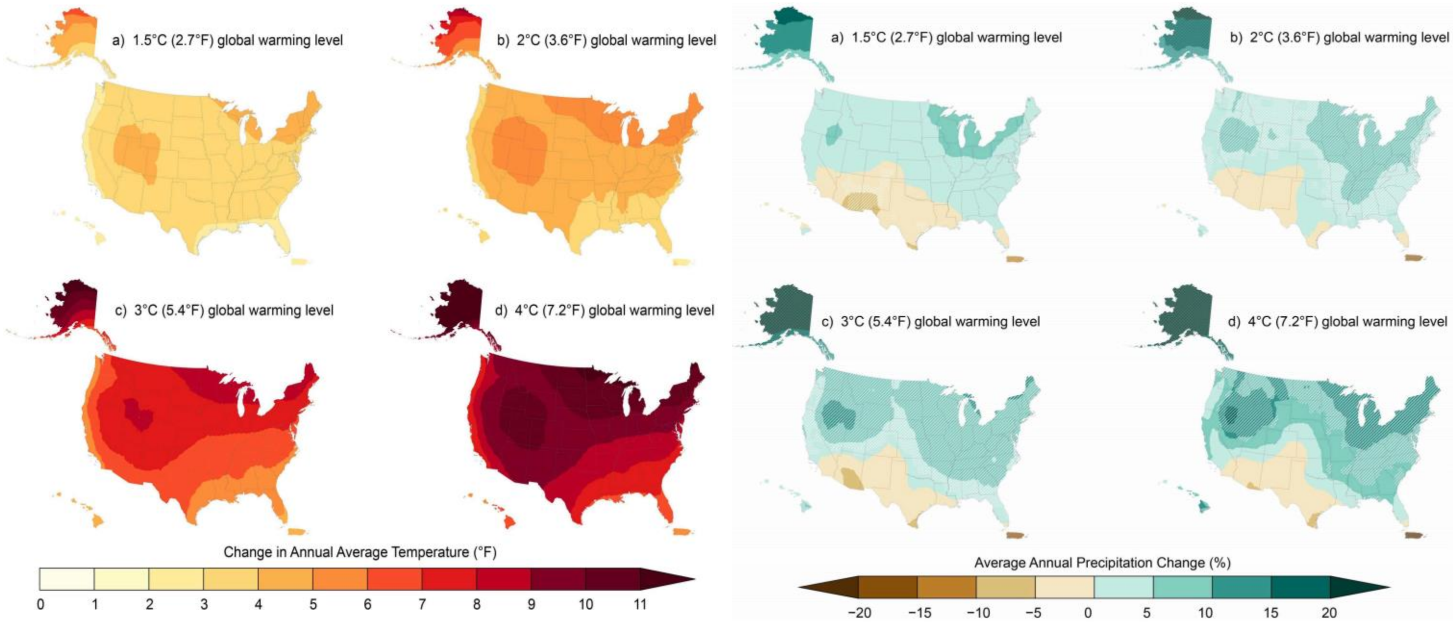
Droughts, a natural part of Utah's climate, are expected to become more intense. Higher temperatures will amplify the effects of naturally occurring dry spells by increasing the rate of loss of soil moisture. Most of Utah's water is supplied by the snowpack, and changes to the snow/rain ratio could result in less water storage. Additionally, higher spring temperatures can cause early melting of the snowpack, decreasing water availability during the already dry summer months. The projected increase in the intensity of naturally occurring droughts will increase the occurrence and severity of wildfires.

<u>Wyoming</u>

Under a higher emissions pathway (RCPS.5), historically unprecedented warming is projected by the end of the 21st century. The mean temperature is projected to increase by about 10°F with hottest projections indicating an increase up to 15°F. Even under a pathway of lower GHG emissions, average annual temperatures are projected to most likely exceed historical record levels by the middle of the 21st century. However, there is a large range of temperature increases under both pathways, and under the lower pathway, a few projections are only slightly warmer than historical records. Increases in heat wave intensity are projected, but the intensity of cold waves is projected to decrease.

Climate models suggest that winter and spring precipitation will increase, which combined with rising temperatures will increase the average lowest elevation at which snow falls. This will increase the likelihood that some of the precipitation events now occurring as snow will fall as rain instead, reducing water storage in the snowpack, particularly at lower elevations. Higher spring temperatures will also result in earlier melting of the snowpack, further decreasing water availability during the drier summer months. Heavier spring precipitation, combined with a shift from snow to rain, could also increase the potential for flooding.

The intensity of future droughts is projected to increase. Even if precipitation amounts increase in the future, temperature increases will intensify evaporation rates, resulting in lower soil moisture during dry spells. Thus, future summer droughts, a natural part of the Wyoming climate, are likely to become more intense. This in turn will increase the risk of wildfires, which are projected to become more frequent and severe. Decreasing snowpack and earlier melt will have regional impacts as the state's abundant snowfall feeds major river systems in the United States.



(1) (2)

Figure 8-4. Projected Temperature and Precipitation Changes

8.5 Effects on Public Health and Safety

The following data have been summarized from the Centers for Disease Control and Prevention, Climate and Health website. Climate change and other natural and human-made health stressors influence human health and disease in numerous ways. Some existing health threats will intensify, and new health threats will emerge as a result of climate change. Key weather and climate drivers of health impacts include increasingly frequent, intense, and longer lasting extreme heat, which worsen drought, wildfire, and air pollution risks; increasingly frequent extreme precipitation, intense storms, and changes in precipitation patterns that lead to drought and ecosystem changes; and rising sea levels that intensify coastal flooding and storm surges. Key drivers of vulnerability include the attributes of certain groups (e.g., age, socioeconomic status, race, current level of health) and of place (e.g., floodplains, coastal zones, urban areas), as well as the resilience of critical public health infrastructure. Health effects of these disruptions include increased respiratory and cardiovascular disease, injuries, and premature deaths related to extreme weather events, changes in the prevalence and geographical distribution of foodborne and waterborne illnesses and other infectious diseases, and threats to mental health.

Climate change is projected to affect human health by contributing to degrading air quality in many regions. Increases in dust, pollen and allergens, wildfire smoke, and ground level ozone associated with changes in climate are already being realized in the U.S. Atmospheric warming can increase the formation of ground-level ozone which is a GHG and adds to the heat trapping effect. Ground-level ozone (a key component of smog) is associated with many health problems, such as diminished lung function, increases in cardiovascular disease, and increases in premature deaths. Climate change effects including drought, heat waves, and stagnation events can impact air quality causing increased concentrations of particulate matter. Increases in wildfires and associated smoke, drier conditions that create more airborne dust, and changes in vegetation that result in increases in pollen and allergens all contribute to increases in particulate matter in the air. Health effects of particulate matter include asthma, heart disease, lung cancer, and other disease.

Climate change is currently increasing the vulnerability of many forests to wildfire. Climate change is projected to increase the frequency of wildfires in certain regions of the United States. Long periods of record high temperatures are associated with droughts that contribute to dry conditions and drive wildfires in some areas. Wildfire smoke contains particulate matter, carbon monoxide, nitrogen oxides, and various volatile organic compounds (i.e., ozone precursors) and can significantly reduce air quality locally and in areas downwind of fires. Smoke exposure increases respiratory and cardiovascular hospitalizations, emergency department visits, medical visits for lung illnesses, and medication dispensations for asthma, bronchitis, chest pain, chronic obstructive pulmonary disease (COPD), and respiratory infections.

Drought conditions may increase environmental exposure to dust storms, extreme heat events, flash flooding, degraded water quality, and reduced water quantity. Dust storms associated with drought conditions contribute to degraded air quality. Extreme heat events have long threatened public health in the United States. Heat waves are also associated with increased hospital admissions for cardiovascular, kidney, and respiratory disorders. Extreme summer heat is increasing in the United States, and climate projections indicate that extreme heat events will be more frequent and intense in coming decades.

Milder winters resulting from a warming climate can reduce illness, injuries, and deaths associated with cold and snow. Vulnerability to winter weather depends on many non-climate factors, including housing, age, and baseline health. Although deaths and injuries related to extreme cold events are projected to decline due to climate change, these reductions are not expected to compensate for the increase in heat-related deaths.

The frequency of heavy precipitation events has already increased for the nation as a whole and is projected to increase in all U.S. regions. Increases in both extreme precipitation and total precipitation have contributed to increases in severe flooding events in certain regions. In addition to the immediate health hazards associated with extreme precipitation events when flooding occurs, other hazards can often appear once a storm event has passed. Elevated waterborne disease outbreaks have been reported in the weeks following heavy rainfall, although other variables may also affect these associations. Water intrusion into buildings can result in mold contamination that manifests later, leading to indoor air quality problems. Buildings damaged during hurricanes are especially susceptible to water intrusion. Populations living in damp indoor environments experience increased prevalence of asthma and other upper respiratory tract symptoms, such as coughing and wheezing, as well as lower respiratory tract infections such as pneumonia, respiratory syncytial virus (RSV), and RSV pneumonia.

Climate is one of the factors that influences the distribution of diseases borne by vectors such as fleas, ticks, and mosquitoes, which spread pathogens that cause illness. The geographic and seasonal distribution of vector populations, and the diseases they can carry, depend not only on climate but also on land use, socioeconomic and cultural factors, pest control, access to health care, and human responses to disease risk, among other factors. Daily, seasonal, or year-to-year climate variability can sometimes result in vector/pathogen adaptation and shifts or expansions in their geographic ranges. North Americans are currently at risk from numerous vector-borne diseases, including Lyme, dengue fever, West Nile virus, Rocky Mountain spotted fever, plague, and tularemia. Vector-borne pathogens not currently found in the United States, such as chikungunya, Chagas disease, and Rift Valley fever viruses, are also potential threats.

Mental illness is a major concern in the United States, and extreme weather events can affect mental health in several ways. For example, research demonstrated high levels of anxiety and post-traumatic stress disorder among people affected by Hurricane Katrina, and similar observations have followed floods and heat waves. Some evidence suggests wildfires have similar effects. All of these events are increasingly fueled by climate change. Additional potential mental health impacts, less well understood, include the possible distress associated with environmental degradation and displacement, and the anxiety and despair that knowledge of climate change might elicit in some people.

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9.0 Emissions Analysis

According to IPCC, a large emissions gap exists between global GHG emissions associated with the implementation of the Nationally Determined Contributions (NDCs) in 2030 and those associated with modelled mitigation pathways that limit warming to 1 .5°C (>50%) or 2°C (>67%). Modelled pathways that are consistent with the NDCs and assume no additional emissions reductions lead to median global warming of 2.8 [2.1 to 3.4] °C by 2100 Many countries have signaled their intent to achieve net zero emissions around 2050, but limited policies to date do not appear to be inline with that goal Policies implemented at the end of 2020 are projected to result in higher global GHG emissions in 2030 than emissions implied by NDCs (implementation gap), that without strengthened policies will lead to projected global warming of 3.2 [2.2 to 3.5] °C by 2100.

The United States has set an economy-wide target of reducing net GHG emissions by 50-52 percent below 2005 levels in 2030 as part of it's 2021 NDC[44] In practice, that means the U.S. would have economy-wide net CO_2e emissions of less than 3,348.15 Mt in 2030. As stated in the NDC, the primary means for mitigating GHGs or obtaining the emissions reduction goals is via the electrification of end-use sources that currently burn fossil fuels, while switching to a carbon-free energy supply. **Note:** Nothing in the United States' NDC places limits on domestic fossil fuel production (federal or otherwise).

Annually, the United Nations (UN) publishes an emissions gap report which provides an assessment of how actions and pledges of countries affect global GHG emissions trends and how these trends compare to emissions trajectories that are consistent with long-term goals for limiting global warming (UN 2021). Specifically, the emissions gap is the difference between GHG emissions levels consistent with limiting global warming to 1.5°C or 2.0°C and the emissions levels consistent with current reduction commitments by member nations. The latest report is in line with the latest IPCC assessment and basically states that urgent system-wide transformation of energy systems are needed to limit greenhouse gas emissions by 2030 (approximately 45% compared with projections based on policies currently in place to get on track to 1.5°C and 30% for 2°C).

For the purposes of NEPA analyses, the BLM uses the decision scope emissions (i.e., reasonably foreseeable GHG emissions) of a proposed federal action as a proxy for assessing climate impacts. Published climate impact predictions associated with various global emissions scenarios are described in the NEPA analysis and are compared to the decision scope emissions levels to provide a basis for considering the magnitude, or range of impacts, that could follow from the proposed action. This methodology for assessing climate-related impacts is in line with previously issued guidance [45] and has obvious benefits in that emissions calculations are relatively straightforward and can be clearly explained if properly documented. More specifically, the proxy approach was adopted because of the lack of climate analysis tools and techniques that lend themselves to describing the physical climate or earth system responses, such as changes to sea level, average surface temperatures, or regional precipitation rates, that could be attributable to emissions associated with any single action or decision.

Comparing proxy emissions at various scales relative to a quantity of emissions known to have a definitive climate impact (i.e., modelled emissions) allows the BLM to provide a clearly understandable sense of the intensity for an action relative to the magnitude of the issue. Further, there are no established emissions thresholds for NEPA analysis to contextualize the quantifiable GHG emissions of an action or decision in terms of environmental effects. Although future policy may prescribe an emissions threshold for analysis, the implications of such a limit (physical or otherwise) are beyond the scope of this report to contemplate presently

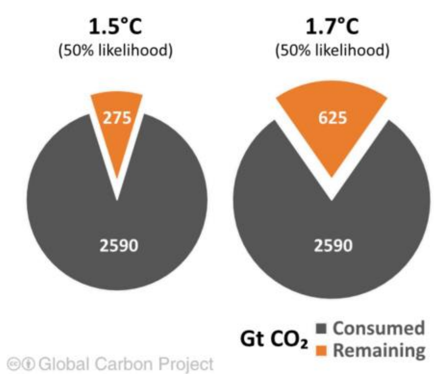
One of the drawbacks of the proxy emissions method is the difficulty in downscaling the published climate impacts (predicted or observed) relative to the federal action emissions, which are typically several orders of magnitude smaller than the emissions levels associated with the published impacts. Still, comparing emissions levels between proposed actions, current emissions and conditions, and published predictions based on forecasted emission scenarios allows decision makers to form a qualitative Judgment about the potential for climate impacts from a proposed action.

9.1 Carbon Neutrality and Carbon Budgets

Carbon neutrality, or net zero emissions, is maintaining a balance between emitting and absorbing GHGs from the atmosphere. On a global scale, carbon neutrality would result in atmospheric concentrations of GHGs reaching an equilibrium, which could stabilize climate change and limit global warming. Under the 207 5 Paris Agreement, countries agreed to cut GHG emissions with the goal of holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 7 .5°C above pre-industrial levels in order to avoid some of the more dire consequences associated with climate change. Carbon budgets are an estimate of the amount of additional GHGs that could be emitted into the atmosphere over time to reach carbon neutrality while still limiting global temperatures to no more than 1.5°C or 2°C above pre-industrial levels. At the time of this draft, the IPCC Special Report on Global Warming of 1.5°C (2018) is the most widely accepted authority on the development of a carbon budget to meet the goals of the Paris Agreement. Other organizations have also developed carbon budgets for specific sectors and emissions and temperature targets. For example, the International Energy Agency (IEA) developed its carbon budget focused on the energy sector in its report on achieving Net Zero by 2050. The International Renewable Energy Agency (IRENA) developed a carbon budget focused on rapid transition from fossil fuels for its Renewables Energy Outlook and its World Energy Transitions Outlook.

Carbon budgets are dependent on the key assumptions and parameters used to develop the budget such as source sectors for emissions, GHGs included, temperature targets, climate sensitivity, and estimates of cumulative carbon emissions that have already occurred. For example, scientists recently revised the IPCC budget to account for problems associated with the Earth System Models used in the AR5 budget estimates[46] These models underestimated historical cumulative CO_2 emissions and were projecting temperatures warmer than have been observed. The new estimates rely on observational constraints to make the budget calculations, which have been widely accepted by climate scientists as being more accurate. According to IPCC AR6, global surface temperature are projected to rise by 0.45°C [0.27°C to 0.63°C] for every 1000 $GtCO_2$ emitted by human activity.

Carbon budget estimates are expressed as the remaining cumulative CO_2 emissions from a base year until the time when net zero global emissions can be achieved. The latest budget estimates made by the Global Carbon Project suggests that at current emissions rates the world has a 50% change of exceeding the 1.5°C temperature target in roughly 5 years. Analysis by IPCC scientists in AR6 suggest the 1.5°C temperature target is likely to be exceeded by 2030, which is in line with the carbon budget estimates. These estimates contain uncertainties that are characteristic of scientists' current understanding of the earth's climate-influencing systems, such as feedbacks and the forcing and response associated with the non-CO_2 GHG species, and historical emissions accounting. The uncertainty range associated with the latest estimates is approximately ±400 Gt CO_2 Staying within the 1.5°C carbon budget implies that CO_2 emissions need to start declining this decade to maintain reasonable progress to reach net zero by about 2050, or 2100 for the 2°C budget. Figure 9-1 outlines what an emissions reduction curve under either scenario might look like. **Note:** The 1.5°C pathway to neutrality assumes a higher degree of emissions reduction than pledges made under the Paris Agreement.



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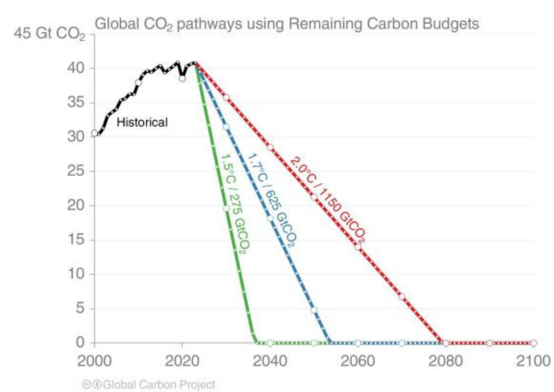

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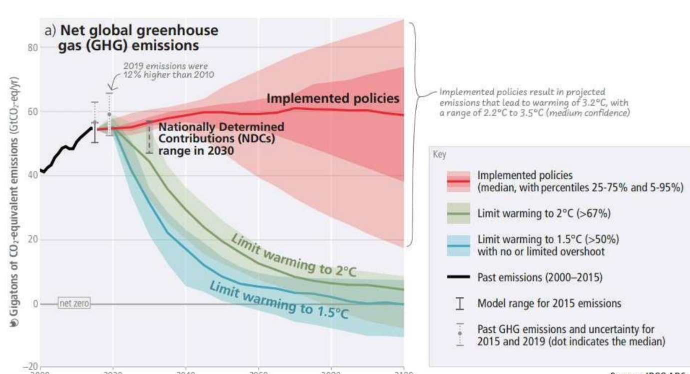

(3)

Figure 9-1. Remaining Carbon Budgets and Mitigation Pathways

None of the global carbon budgets are a hard line that countries have committed to stay within as part of the Paris Agreement or otherwise. Carbon budgets were originally envisioned as being a convenient tool to simplify communication of a complex issue and to assist policymakers considering options for reducing GHG emissions on a national and global scale. Carbon budgets have not yet been established on a national or subnational scale, primarily due to the lack of consensus on how to allocate the global budget to each nation. As such, the global budgets that limit warming to 1.5°C or 2.0°C are not useful for BLM decision making as it is unclear what portion of the budget applies to emissions occurring in the United States, or how to account for BLM's authorized portion of projected U.S. emissions, and whether or not to account/ deduct any fraction of federal minerals that are consumed in other countries via exports.

However, stakeholders and members of the public have requested that the BLM consider comparing its predicted emissions in the context of global carbon budgets. Table 9-1 provides an estimate of the potential emissions associated with BLM fossil fuel authorizations in relation to IPCC carbon budgets. The BLM uses the long-term estimates of federal fossil fuel (oil, gas, and coal) emissions (see Chapter 7) that were developed from AEO data. The projected annual emissions are added over the remaining timeframe until the global emissions budget is estimated to be exhausted in order to show the portion of the budget that is consumed by federal emissions. The BLM-estimated emissions include direct emissions as well as transport and downstream combustion emissions. It is important to note that this comparison of BLMs-estimated emissions from fossil fuel authorizations to global carbon budgets does not portray the full picture of carbon flux (amount emitted vs. amount stored/sequestered/offset) on public lands. Results of the carbon budget analysis are presented as the percent of the budget consumed by federal fossil fuel emissions and the additional time (days) it takes to consume the budget without federal fossil fuel emissions. The results in the table reflect only the emissions side of the equation and may overestimate actual consumption of global carbon budgets resulting from BLM leases and authorizations due to the aforementioned double counting that life-cycle accounting generates. The U.S. Geological Survey estimated that sequestration on federal lands offset approximately 15% of CO_2 emissions resulting from the extraction and end-use combustion emissions of fossil fuels on federal lands. In future annual iterations of this report, the BLM may refine this carbon budget evaluation based on new or improved emissions and sequestration information on public lands, and on potential future U.S. policies establishing carbon neutral emissions pathways.

Table 9-1. Evaluation of Potential Federal Fossil Fuel GHG Emissions with Respect to Global Carbon Budgets

Metric	1.5 Deg C (50%)	2.0 Deg C (50%)
Remaining Carbon Budget (Mt CO_2)	275,000	1,150,000
Time to Exhaust Remaining Budget (years)	5.11	21.38
Federal Coal Emissions During Budget Timeframe Long-term (Mt CO_2)	2,990	7,201
Federal Coal Fraction of Carbon Budget (%)	1.09%	0.63%
Time to Exhaust Budget without Federal Coal Emissions (years)	5.17	21.51
Additional Time to Exhaust Budget without Federal Coal Emissions (days)	20	49
Federal Oil and Gas Emissions During Budget Timeframe Long-term (Mt CO_2)	2,355	7,903
Federal Oil and Gas Fraction of Carbon Budget(%)	0.86%	0.69%
Time to Exhaust Budget without Federal Oil and Gas Emissions (years)	5.16	21.53
Additional Time to Exhaust Budget without Federal Oil and Gas Emissions (days)	16	54
Estimated Global Surface Warming Attributable to Federal Minerals (°C)	0.0024	0.0068

Latest global emissions estimates from the Rhodium Group, as cited in chapter 5.1
Long-term Onshore Federal Mineral Emissions estimated from the EIA AEO reference case energy projection scenario. Does not include sequestration by federal lands or other federal emissions offsets.
Surface warming calculations are simplified to consider all federal emissions CO_2e as CO_2.

9.2 Emissions Comparisons

The annual global and U.S. emissions data presented in chapter 6 can be compared with the estimated report year GHG emissions from BLM fossil fuel production in chapter 7 to provide context around the scale and potential impact of the onshore federal mineral estate. Evaluating the magnitude of estimated emissions from a particular category in the context of other categories or total geographic emissions is one way to evaluate their relative potential impact on climate change. A comparative analysis is also useful for informing policy and planning decisions and to identify options for maximizing the effectiveness of mitigation and emissions reduction strategies. Table 9-2 compares the magnitude of the BLM's estimated emissions to global and U.S. emissions at different scales. For example, the table shows that the emissions associated with the BLM's authorizing of leasing and extraction of onshore federal minerals on public lands, (i.e., direct emissions from coal, oil, and gas) comprise 0.12% of global emissions and 1.06% of U.S. emissions. The total emissions from onshore coal, oil, and gas development and end use comprise 1.95% of global emissions and 16.5% of U.S. emissions. It is important to note that the U.S. emissions shown in the table (U.S. total, energy production, fossil fuel combustion, coal mining, and natural gas and petroleum systems) are derived using GWPs from IPCC AR5 to convert to CO_2 equivalents, whereas BLM emissions are derived using GWPs from IPCC AR6 (see Table 3-1). This may result in a slight overestimation of the BLM's share of U.S. emissions in the table. Additionally, comparing BLM's life-cycle accounting to other forms of sector specific accounting (EPA, IPCC, etc.) is conservative since the life-cycle method introduces a double count of emissions not present in other inventories (as described in Chapter 6.1).

Table 9-2. BLM Annual Share of Select Global and U.S. GHG Emissions

Emission Category	Emissions (Mt C02e)	BLM Share				
		Total Emissions All fuels	Indirect Emissions All Fuels	Direct Emissions All Fuels	Direct Emissions Oil and Gas	Direct Emissions Coal
Global - Total GHG emissions	53,786	1.95%	1.82%	0.12%	0.12%	0.01%
Global - Fossil Fuel Combustion	38,522	2.72%	2.54%	0.17%	0.16%	0.01%
US Total GHG emissions	6,341	16.5%	15.44%	1.06%	1%	0.06%
U.S. Fossil Fuel Combustion	5,200	20.12%	18.83%	1.29%	1.22%	0.07%
US Coal Mining	46	NA	NA	NA	NA	8.13%
US Natural Gas and Petroleum Systems	300	NA	NA	NA	21.16%	NA
NOC 2030 Target	3,348	31.25%	29.24%	2 01%	1.9%	0.11%
Carbon Budget 1.5 (50% - remaining)	275,000	0.38%	0.36%	0.02%	0.02%	0%
Carbon Budget 2.0 (50% - remaining)	1,150,000	0.09%	0.09%	0.07%	0.07%	0%

Not applicable "NA" cells are irrelevant to calculated data columns.

9.3 Climate Impact Modeling

Coupled Earth System Models (ESMs) are the primary climate research tools used by the IPCC. ESMs are the state of the science in coupled Earth system modeling. However, these classes of climate models are computationally intensive, making such models infeasible to assess hundreds to thousands of emissions scenarios.[47]

To move beyond the emissions as a proxy approach for ascribing climate impact attribution as a result of BLM-authorized emissions, the Bureau has been investigating the use of reduced complexity climate models (RCMs) to analyze such emissions for the purposes of obtaining potential gross scale (e.g. perturbations from global climatic means) earth system responses that could be attributable to the federal decision scope over which the BLM has purview. RCMs are essential tools in policy and decision making as they are computationally efficient allowing for quick analysis of a myriad of emissions scenarios. BLM's use of RCMs is consistent with the intended application of this class of models, to assess potential basic earth system responses that could be attributable to BLM authorized GHG increases. While this application is consistent with the policy analysis nature of this class of climate models, RCMs do not produce sufficiently resolved temporal or spatial information that would be necessary to project earth system responses for specific sub annual temporal ranges and specific geographic areas for a given emissions scenario.

Most simple climate models are based in part on global average energy-balance equations, and a few incorporate additional processing modules to better account for some of the more complex feedback mechanics. The Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC) stands out as a potential resource due to its ease of use (online access), flexibility, robustness, and overall transparency (the model maintainers and collaborators are working towards an open-source release in 2023). As described on the model's wiki page, "MAGICC is designed to provide maximum flexibility in order to match different types of responses seen in more sophisticated models, the approach in MAGICC's model development has always been to derive the simple equations as much as possible from key physical and biological processes." This process-based approach has a strong conceptual advantage in comparison to simple statistical fits that are more likely to quickly degrade when emulating scenarios outside the original calibration space of the sophisticated models. From a user's perspective, the platform offers detailed documentation and baseline scenario emissions input files that are easily modified to suit the BLM's needs. Figure 8-2 shows MAGICC's conceptual model workflow.

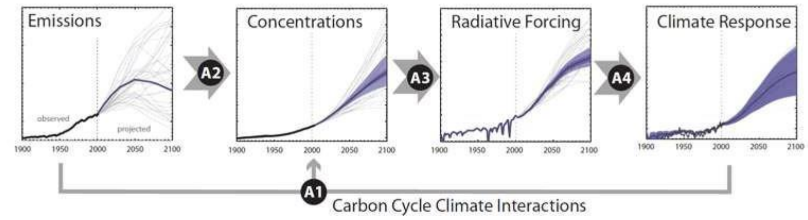

Figure 9-2. MAGICC Model Calculation Workflow[48]

Figure 7-2 presents the long-term onshore federal mineral emissions for 12 AEO scenarios. Using the projected emissions for each of these AEO cases, the BLM conducted MAGICC runs evaluating potential contributions to global climate change and related values for the SSP119 and SSP245 climate change projection scenarios. These two scenarios were chosen because they most closely approximate or frame the desired outcomes of the Paris Climate Accord, and would also reflect the greatest contribution as a percent of BLM's authorized cumulative emissions relative to the global emissions levels contained in the SSP scenarios (should provide for a conservative contribution analysis) MAGICC modeling was completed for two federal mineral emissions source groups separately, oil and gas, and oil, gas and coal. The SSPs are explained in Section 8.2 of this report and the following provides additional information regarding the SSP119 and SSP245 base scenarios used for the MAGICC modeling.

- **SSP 1 - 1.9:** IPCC's most optimistic scenario describing a world where global CO_2 emissions are cut to net zero around 2050. This is the only scenario that meets the Paris Agreement's goal of keeping global warming to around 1.5 degrees Celsius above preindustrial temperatures, with warming hitting 1.5C but then dipping back down and stabilizing around 1.4C by the end of the century. The total CO_2 emissions (fossil and industrial) for this scenario in 2050 are 2,865.45 Mt.
- **SSP 2 - 4.5:** This is a "middle of the road" scenario where global CO_2 emissions hover around current levels before starting to fall mid-century, but do not reach net-zero by 2100. In this scenario, temperatures rise 2.7C by the end of the century. The total CO_2 emissions (fossil and industrial) for this scenario in 2050 are 42,961.30 Mt.

The MAGICC modeling emissions inputs were prepared assuming that the projected federal mineral GHG emissions levels (as shown in Figure 7-2) would be included in the baseline SSP119 and SSP245 global GHG emissions levels since they are cumulative in nature. To determine the potential climate change contributions, the projected federal fossil fuel CO2, CH4 and N2O emissions for each AEO scenario were subtracted from the baseline scenario emissions levels. The MAGICC results for the modified scenarios were then subtracted from the baseline scenarios results to determine the overall federal contribution to the modeled parameters from each AEO scenario run. The "high oil price" and "low oil and gas supply" form the bookends of the potential impacts, and thus are the only runs presented in detail below.

For the SSP119 scenario, the projected federal minerals emissions under each AEO scenario would make up a larger portion of the SSP119 global levels by year 2050 as compared to early years (e.g. 2030) because they would not follow the same global trends of reductions towards net-zero. Under the AEO "high oil price" scenario, federal mineral (oil, gas, and coal) CO_2 emissions are projected to make up approximately 30% of the total global CO_2 levels in year 2050. Whereas in the SSP245 scenario, projected federal mineral (oil, gas and coal) CO_2 emissions under the AEO "high oil price" scenario are projected to make up around only 2% of the total global CO_2 emissions level in 2050. For the SSP245 scenario, projected federal minerals emissions under each AEO scenario would constitute a similar percentage of the global emissions levels for all future years through 2050. The AEO "low oil and gas supply" scenario has the lowest projected federal fossil fuel GHG emissions levels and under this scenario would constitute approximately 22% and 1.5% of the SSP119 and SSP245 year 2050 global CO_2 emissions levels, respectively.

The following tables present the MAGICC modeling results for each baseline scenario (SSPl 19 and SSP245 - no changes to the modeling inputs) and for the modified AEO "high oil price" case (scenario with the highest predicted federal mineral emissions and global climate change impacts), and the AEO "low oil and gas supply" case (scenario with lowest predicted federal fossil fuel emissions and global climate change impacts). Because the projected federal mineral CO_2 emissions constitute a larger portion of the global levels in the modified SSP119 scenario, the modeled impacts are generally higher relative to the baseline as compared to the SSP245 scenario. As shown in the Table 9-3, the "paired" (in time) global average temperature differences are small overall, but larger than the impacts predicted for the modified SSP245 scenario shown in Table 9-4. One noticeable difference among the scenarios is that in the modified SSP119 scenario (i.e., without federal mineral GHG emissions), the global average temperature change would return to 1.5 degrees K/C (above preindustrial temperature level) one or two years sooner, depending on the federal minerals emissions scenario. Regardless of the modeling scenario, the predicted earliest future year above 1.5 degree K/C change is 2033. Not shown in the tables are the modeling results for future projected federal minerals emissions following the AEO "no inflation reduction act" scenario. Future climate change impacts for this scenario ranked third highest among the 12 scenarios modeled and are comparable to those shown for the AEO "high oil price" scenario. The model results show that regardless of the global climate change projection scenario (SSP119 or SSP245) and the pathway that federal fossil fuels emissions follow, federal minerals emissions are predicted to have minimal impacts to future global climate change through the end of the century.

Table 9-3. MAGGIC Model Results for SSP119

Model Run		**BLM Oil and Gas**		**BLM Oil, Gas, and Coal**	
Emissions Scenario	**Base SSP 119**	**AEO High Oil Price**	**AEO Low Oil and Gas Supply**	**AEO High Oil Price**	**AEO Low Oil and Gas Supply**
Atmospheric CH4 (ppb)	1,886.8	1,886.7	1,886.7	1,886.6	1,886.7
Atmospheric CO2 (ppm)	435.4	434.4	434.9	434.19	434.5
Atmospheric N2O (ppb)	353.9	353.9	353.9	353.9	353.9
Effective Radiative Forcing (wm·^{7})	3.224	3.211	3.217	3.208	3.212
Surface Temperature (°C)	1.616	1.606	1.611	1.604	1608
Max Surf Temp Year	2049	2049	2049	2049	2049
Absolute Peak Max Differences (°C)	NA	0.009	0.005	0.012	0.008
Paired Max Differences (°C)	NA	0.012	0.006	0.015	0.01
Paired Max Difference Year	NA	2060	2060	2060	2060

Not applicable "NA" cells are irrelevant to data rows.

Table 9-4. MAGGIC Model Results for SSP245

Model Run		**BLM Oil and Gas**		**BLM Oil, Gas, and Coal**	
Emissions Scenario	**Base SSP 245**	**AEO High Oil Price**	**AEO Low Oil and Gas Supply**	**AEO High Oil Price**	**AEO Low Oil and Gas Supply**
Atmospheric CH4 (ppb)	2,057.8	2,045.9	2,048.5	2,045.6	2,048.7
Atmospheric CO2 (ppm)	578.3	576.8	577.5	576.3	576.9
Atmospheric N2O (ppb)	377.2	377.2	377.2	377.2	377.2
Effective Radiative Forcing (wm·^{1})	4.966	4.95	4.958	4.946	4.951
Surface Temperature (°C)	2.715	2.706	2.711	2.704	2.707
Max Surf Temp Year	2100	2100	2100	2100	2700
Absolute Peak Max Differences (°C)	NA	0.009	0.005	0.012	0.008
Paired Max Differences (°C)	NA	0.017	0.006	0.07 3	0.07
Paired Max Difference Year	NA	2060	2060	2060	2060

Not applicable "NA" cells are irrelevant to data rows.

9.4 Goal Alignment

At present, the BLM's short-term projections of potential emissions from existing and near-term authorizations are consistent with the nation's net zero by 2050 goal and the shorter-term 2030 commitments made for the NDCs under the Paris Agreement. This is primarily due to a decline in projected production of oil, gas, and coal through mid-century (see Figure 7-1) from existing and foreseeable Federal fossil fuel leases, and increases in Federal renewable energy right of ways (see Table 10-4). The longer-term estimates that include the modeled effects of the Inflation Reduction Act also show progress towards meeting national goals, such that the economy-wide influences of the law are likely to shape additional federal fossil fuel development in the years to come. Many of the energy projections made by the EIA in their AEO Report conclude that the U.S. will be a leading energy exporter through 2050. This would undoubtedly include exports of federal minerals to some extent, and there could exist a situation where the U.S. is showing significant declines in domestic emissions while maintaining production levels consistent with higher emissions. Such a scenario would still be consistent with the US achieving its climate action goals, and given the geo-political dynamics in the international energy markets (e.g. Russia's war with Ukraine), it may also become strategically important for the U.S. to maintain energy exports. Future iterations of this report may explicitly account for exports of oil and gas as warranted.

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10.0 Mitigation

Much of the current policy on mitigating emissions in the U.S. comes from individual states and municipalities as well as market forcing that results when institutions move assets and future investments away from fossil fuel projects. More recently, the passage of the Bipartisan Infrastructure Law and the Inflation Reduction Act (IRA) have been projected to have positive influence on abating climate change impacts by helping the U.S achieve emissions reductions that were committed to under the Paris Agreement. These laws are examples of economy-wide mitigation measures that are necessary to influence supply-side energy economics to transition towards low or no carbon sources. Additionally, increasing the economy-scale supply of low or no carbon alternatives will provide consumers with real choices relative to the current status quo, which over time should drive energy markets toward demand driven dynamics, and accelerate the pace of change transition to net zero emissions.

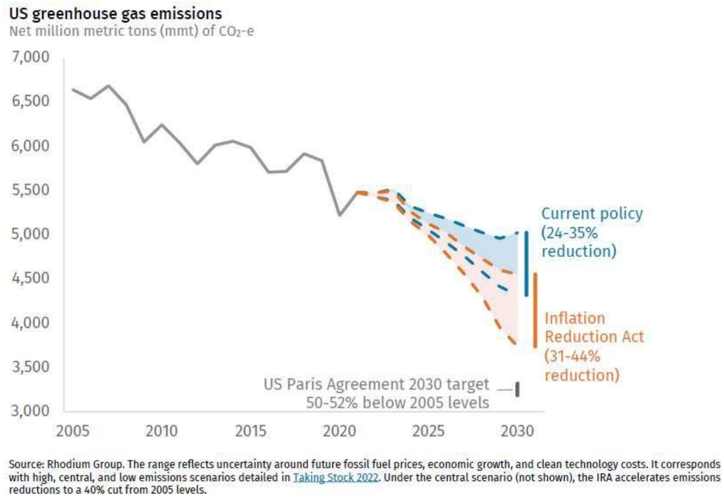

Figure 10-1. Projected Short-Term Emissions Reductions Associated with the IRA

10.1 Emissions Reduction Potential

The BLM has developed best management practices (BMPs) designed to reduce emissions from field production and operations for on-lease activities. BMPs may include limiting emissions on stationary combustion sources, mobile combustion sources, fugitive sources, and process emissions occurring on a lease parcel. Analysis and approval of future development on the lease parcels may include application of BMPs within the BLM's authority, as conditions of approval, or controls, to reduce or mitigate GHG emissions. Additional design features developed during project analysis may also be incorporated as applicant-committed measures by the project proponent or added in from necessary air quality permits.

Mitigation measures to reduce direct GHG emissions from oil and gas operations may include the following

- Flare hydrocarbon and gases at high temperatures in order to reduce emissions of incomplete combustion through the use of multichambered combustors.
- Require that vapor recovery systems be maintained and functional in areas where petroleum liquids are stored.
- Installment of liquids gathering facilities or central production facilities to reduce the total number of sources and minimize truck traffic.
- Use natural gas fired or electric drill rig engines.
- Use selective catalytic reducers and low-sulfur fuel for diesel-fired drill rig engines.
- Implement directional and horizontal drilling technologies whereby one well provides access to petroleum resources that would normally require drilling several vertical wellbores.
- Require that produced and associated gas be gathered and compressed for transportation in areas where long-distance gas pipelines are available.

Additionally, the BLM encourages oil and 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. The EPA reports that 89% of the CH_4 reductions came from the oil and gas production sector. By utilizing a variety of technologies, including reduced blow down frequency, installing vapor recovery units, and converting gas-driven pumps to electric, mechanical, or solar driven pumps, operators can develop innovative project design features to self-limit their emissions. 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.

The majority of GHG emissions resulting from federal fossil fuel authorizations occur outside of the BLM's authority and control. These emissions are referred to as indirect emissions and generally occur off-lease during the transport, distribution, refining, and end use of the produced federal minerals. The BLM's decision space for the downstream emissions is limited to either selecting the no action alternative (i.e., not authorizing lands for fossil fuel development during land-use planning), limiting the pace of development (consistent with current laws for leasing and within the confines of valid and existing rights), or choosing alternatives with offsets for portions of the emissions. The various strategies available to the BLM for offsetting emissions are subsequently described.

10.2 Offsetting Emissions

In addition to controlling or preventing emissions, strategies to offset emissions could be utilized to align BLM decision making with the goal of achieving net-zero emissions by 2050. The following are various strategies available to the BLM for offsetting emissions. These strategies may or may not be useful for offsetting emissions from individual leases, and other carbon offset strategies may exist beyond those listed here.

Carbon Sequestration

In 2018, the U.S. Geological Survey (USGS) produced a report estimating GHG emissions and sequestration on federal lands from 2005 to 2014. The report provides net ecosystem productivity (NEP) factors for all federal lands in the United States. NEP is the amount of CO_2 converted to fixed carbon by the terrestrial ecosystem and is the product of CO_2 converted to carbon through photosynthesis minus the release of CO_2 back into the atmosphere from plant respiration and the decomposition of dead organic matter. The report also provided details on land use changes and land cover changes (LULC) which are typically brought on by wildfires, harvest, and general land development. LULC reduces the effective rate of NEP and is reported as net biome productivity (NBP). NBP is the final figure used in the USGS report to calculate the net emissions between federal fossil fuel emissions and the sequestration capacity of the federal lands. Here the BLM is attempting to do the same type of calculation for the report year emissions. Although the NBP data is a few years old and conditions on the ground may have changed in some regions of the U.S, it is the best data available to show region-by-region sequestration and net emissions estimates. As atmospheric concentrations of GHGs increase in the future, terrestrial ecosystems will generally sequester a smaller percentage of emissions. Table 10-1 shows the average annual NEP and NBP from 2005 to 2014 and average NEP and NBP per acre of land in different states and the nation. Averages of the datasets are presented because factors such as wildfires can be highly variable between years. The negative values indicate the sequestration capacity for the areas shown. At the national level, the USGS estimates that terrestrial ecosystems (forests, grasslands, and shrublands) on federal lands sequestered an average of 195 Mt CO_2/yr between 2005 and 2014, offsetting approximately 15% of the CO_2 emissions resulting from the extraction of fossil fuels on federal lands and their end-use combustion. In the absence of site-specific data, the average values per acre could be used to provide an estimate of sequestration for individual lease parcels.

Table 10-1. Carbon Sequestration Capacity of Federal Lands (Mt $C0_2e$)

State	Federal Owned Acreage	Mean NEP	NEP per acre	Mean NBP	NBP per acre
Alaska	222,666,580	-63.7	-0.28608	-18	-0.08084
California	45,493,133	-30.67	-0.67417	-14.51	-0.31895
Colorado	24,100,247	-16.57	-0.68754	-13.84	-0.57427
Montana	27,082,401	-23.47	-0.86661	-18.85	-0.69602
New Mexico	24,665,774	-3.73	-0.15122	-2.15	-0.08717
North Dakota	1,733,641	-2.85	-1.64394	-7 .82	-7 .04981
Utah	33,267,621	-10.76	-0.32344	-8.58	-0.25791
Wyoming	29,137,722	-12.11	-0.41561	-10.39	-0.35658

State	Federal Owned Acreage	Mean NEP	NEP per acre	Mean NBP	NBP per acre
Nationally	615,301,953	-342.93	-0.55734	-194.76	-0.31653

Federal Acres Source: Congressional Research Service 2020 report on Federal Land Ownership: Overview and Data 1±2.1

Historically, natural carbon sequestration in plants and soils has been able to lock up about 29% of all anthropogenic emissions on a global scale. Natural sequestration is important because it offers a potential path forward to help mitigate the impact of CO_2 emissions and may play a long-term role in fighting climate change. The Trillion Trees initiative is an example of an enhanced natural sequestration effort. This multinational initiative seeks to reverse deforestation by planting and protecting one trillion trees by 2050. The campaign claims that conserving intact forests, ending deforestation, and restoring trees and natural ecosystems can provide about one-third of the solution to climate change by removing excess CO_2 from the atmosphere. Nationally, restoring forests and ecosystems devastated by wildfires could aid in this effort. What remains unclear is how climate change will impact regional environments and their ability to sustain historical or enhanced sequestration levels going forward.

Plugging Orphaned and Abandoned Wells

The EPA, in its "Inventory of U.S. Greenhouse Gas Emissions and Sinks" annual report, estimates that abandoned oil and gas wells emitted 284,000 tonnes of CH_4 and 7,000 tonnes of CO_2 in 2020. Using AR6 GWPs, abandoned wells emitted 8.46 Mt CO_2e in 2020. However, not all the wells classified as abandoned by the EPA are at the end of their operational life. Some wells may be idled or shut-in and will return to production status, and others may be turned into disposal wells. Plugging abandoned wells that are not expected to be used again could reduce the overall emissions from federal lands.

The Infrastructure Investment and Jobs Act was signed into law on November 15, 2021, and established the Orphaned Well Site Plugging, Remediation, and Restoration program (Section 40601 of the act). The program has been established to address orphaned wells on federal lands and create a grant program for states and tribes to establish or grow and manage their own orphaned well plugging, remediation, and restoration programs. Orphaned wells, either unplugged or improperly plugged, can leak methane and other harmful air pollutants into the atmosphere, leach contaminants into surrounding lands and waters, create safety hazards on the ground, and prevent lands from being used for recreation or other productive purposes. In order to address the environmental harms associated with orphaned wells, a memorandum of understanding (MOU) was signed on January 14, 2022, by the Department of the Interior, the Department of Agriculture, the Department of Energy, the Environmental Protection Agency; and the Interstate Oil and Gas Compact Commission to implement the federal program for the plugging, remediating, and reclaiming orphaned wells and associated facilities on federal lands. The MOU established an executive group to provide executive-level oversight and ensure the successful implementation of the program and a technical working group (TWG) led by the BLM that includes representatives from each of the other federal land management agencies. The TWG provides input and recommendations to the executive group, coordinates funding and overarching program objectives, and shares best practices and technical expertise for implementing the program. The BLM will play a role in administering the program on behalf of the DOI. As part of the rule requirements, the emissions avoidance of plugging methane leaks from federal wells is to be reported to Congress. As such, it is likely that the BLM will be able to report out the findings as part of this report in the future.

There is limited emissions data from orphaned wells to support emissions factors by oil and gas basin or production type. The EPA uses information from the Townsend-Small et al. 2016 [50] study which measured emissions from 138 abandoned wells in the Powder River Basin in Wyoming, Denver-Julesburg Basin in Colorado, Uintah Basin in Utah, and Appalachian Basin in Ohio. The study authors developed emissions factors for well categories observed to exhibit significantly different emissions levels: plugged versus unplugged (including inactive, temporarily abandoned, shut in, dormant, orphaned, and abandoned), in Eastern and Western U.S. regions. The authors used statistical bootstrapping on the data (sampled emissions rates) to provide factors with a 95% upper confidence limit. Table 10-2 shows the emissions factors from the study. The unplugged wells with the highest GHG emissions are found in the Eastern U.S. with a mean emissions rate of 6.87 tonnes (t) CO_2e/yr/well. Wells on federal land which are predominately in the Western U.S. have a mean emissions rate of 0.42 tonnes CO_2e/yr/well, which is 6% of the emissions of an unplugged well in the Eastern U.S.

Table 10-2. Potential GHG Emissions from Orphaned and Abandoned Wells

Well Category	Mean (g/hr/well)	95% Upper Confidence Limit (g/hr/well)	Mean (t COze/yr/well)	95% Upper Confidence Limit (t $C0_2e$/yr/well)
All wells (entire U.S.)	1.38	3.17	0.34	0.78
All wells (Eastern U.S.)	14	32.87	3.43	8.06
All wells (Western U.S.)	0.18	0.41	0.04	0.10
Plugged wells (entire U.S.)	0.00	0.07	0.00	0.00
Unplugged wells (entire U.S.)	10.02	22.47	2.46	5.51
Plugged (Eastern U.S.)	0	NA	0	NA
Unplugged (Eastern U.S.)	28.01	64	6.87	15.7
Plugged (Western U.S.)	0 00	0.07	0 00	0 00
Unplugged (Western U.S.)	1.71	3.83	0.42	0.94

Source: Townsend-Small et al. (2016).

Energy Substitution

Overall, GHG emissions could be reduced if production and consumption of energy from fossil fuels were displaced by lower emitting forms of energy. Energy markets are complex, and the net effects of production changes in one location or one sector are affected by multiple factors in the broader energy market. In general, reductions in oil and natural gas produced from Federal leases may be partially offset by non-Federal production (state and private) in the United States, in which the indirect GHG emissions would be similar, or by overseas production, in which case the GHG emissions would likely be higher, as there are generally less regulatory requirements for production and the produced fuels would need to be physically transported into the United States. There may also be substitution of other energy resources to meet energy demand. These substitution patterns will be different for different fuel types. Oil is primarily used for transportation, while natural gas is primarily used for electricity production and manufacturing, and to a lesser degree by residential and commercial users (AEO, 2023). Coal and renewable energy sources are stronger substitutes for natural gas in electricity generation. The effect of substitution between different fuel sources on indirect GHG emissions depends on the replacement energy source. For example, coal is a relatively more carbon intense fuel than natural gas and hydroelectricity is the least carbon intense fuel. In the transportation sector, alternatives to oil are likely to be less carbon intensive. A comparison of GHG emissions across fuel type is discussed in the next section. Finally, substitution across energy sources or oil and gas production from other locations may not fully meet the energy needs that would otherwise have been realized through production from the Federal mineral estate. Price effects may lower the market equilibrium quantity demanded for some fuel sources. This would lead to a reduction in indirect GHG emissions. These three effects are likely to occur in some combination when considering substitution away from Federal fossil fuels, but the relative contribution of each depends on many factors. Models have been developed to estimate energy market substitution effects under certain scenarios (e.g. BOEM's MarketSim, and BLM's EnergySub). However, these models are subject to limitations which diminish their ability to model some energy substitution scenarios. This is an active area of research.

The National Renewable Energy Laboratory (NREL) reviewed and summarized life cycle assessment (LCA) emissions of different electricity generating technologies to reduce uncertainties around estimates of environmental impacts and increase the value of the LCAs in decision making. The LCAs provided in Table 10-3 show the amount of GHG emissions from different types of electrical grid energy sources. Even renewable energy sources, referred to as carbon neutral, emit some GHGs during facility construction, maintenance, decommissioning, and from transportation and distribution of energy. Of these energy sources, the BLM offers leases for coal, oil and gas, geothermal, wind, and solar.

Table 10-3. GHG Emission Factors for Comparison of Electrical System Energy Sources

Units	Coal	Natural Gas	Biopower	Geothermal	Wind	Solar	Hydro	Nuclear
grams CO_2e/kWh Source:NREL	980	465	40	11 - 47	11	27- 44	7	12

The BLM keeps statistics on the designed electric generating capacity of existing and pending wind, solar, and geothermal projects on BLM-managed lands. A summary of the generating capacity for each renewable is provided in Table 10-4. If the renewable projects replace existing fossil fuel energy production and reduce the demand for federal fossil fuels, the potential foreseeable emissions reductions would range from 97 .6 Mt CO_2e for replacing natural gas energy production to 202.5 Mt CO_2e for replacing coal energy production (approximately a 40% reduction relative to report year coal emissions). Relative to last years data, the pending capacity of renewables has increased by approximately 400%. NREL found that in the Western United States energy grid there would be a 25-45% reduction in carbon emissions, equivalent to taking 22-36 million cars off the road, with a 35% integration of wind and solar energy into the electric power system.

Table 10-4. Electric Generating Capacity of Federal Lands

Renewable Source	Existing Capacity (Mega Watts)	Pending Capacity (Mega Watts)	Potential GHG Reduction Compared to Coal (Mt $C0_2e$)	Potential GHG Reduction Compared to Natural Gas (Mt $C0_2e$)
Geothermal	1,235	597	4.88	2.19
Solar	3,147	20,751	170.14	76.53
Wind	1,440	3,240	27.50	12.89
Total	5,822	24,588	202.53	91.60

Source: https://www blm.gov/prog rams/ energy-and-minerals/renewable-energy.
Pending capacity includes approved but not constructed or currently operating projects.

Carbon Capture

In addition to efforts to better respond and adapt to climate change, other federal initiatives are also 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. Some research has shown that coal-fired power plants using carbon capture and sequestration (CCS) technology can reduce GHG emissions by approximately 80% compared to coal-fired power plants without CCS technology. While CCS technology is still in the early adoption stage, it does show potential for reducing GHG emissions.

The BLM recently issued policy regarding geologic carbon storage on public lands, as part of a comprehensive strategy to combat climate change and reduce carbon dioxide levels in the atmosphere. Additionally, the BLM is presently processing a right-of-way grant for a project with a design capacity to sequester approximately 409.5 Mt of CO_2. Other projects will likely follow.

Another form of carbon capture includes recovering and using coal mine methane (CMM). The main idea behind capturing CMM is to recover methane that would otherwise be released from a coal seam and leak into the atmosphere. The recovered methane would then be combusted which converts the methane to carbon dioxide and water, less potent GHGs. Technology is readily available to recover and use CMM. Specific CMM end uses depend on the gas quality, especially the concentration of methane and the presence of contaminants. Worldwide, CMM is most often used for power generation, district heating, boiler fuel, or town gas, or it is sold to natural gas pipeline systems.

Compensatory Mitigation

Compensatory mitigation is the process of offsetting adverse impacts by replacing or substituting the affected resource or environment through a proponent's offsite actions, monetary payments, or in-kind contributions. Some examples of compensatory mitigation for GHG emissions include plugging orphaned and abandoned wells, purchasing carbon offsets, or supporting land improvement projects that maximize carbon sequestration. Prior BLM policy stated that compensatory mitigation could only be applied at the development stage if the project proponent offered it as a component of a development plan or if it was required by state or federal laws other than FLPMA (BLM Instruction Memorandum (IM) 2019-018, "Compensatory Mitigation"). ~~However, Secretarial Order (SO) 3398, "Revocation of Secretary's Orders Inconsistent with Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis" (April 16, 2027), rescinded SO 3349, "American Energy Independence" (March 29, 207 7), and SO 3360, "Rescinding Authorities Inconsistent with Secretary's Order 3349" (December 22, 207 7), which IM 207 9-07 8 was based. The BLM issued IM 2027-038 on July 14, 2027, rescinding the previous IM 2079-078. The BLM expects to establish policies that are aligned with EO 13990, SO 3398, and the priorities of the Department. During this interim period, offices should consider and implement compensatory mitigation on a case-by-case basis, in consultation with state office and national office program specialists and the Office of the Solicitor as needed.~~

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Glossary

abandoned- An oil or gas well is considered abandoned when it has been permanently taken out of production.

actual fossil fuel production - federal oil and gas lease that is considered to be in an "actual production" status whenever it contains one or more wells drilled on a lease or agreement (communitization or unitization) basis which are producing oil and/or gas in paying quantities. A lease is also considered to be in "actual production" status whenever it contains one or more wells drilled on a lease or agreement basis, which are capable of producing oil and/or gas in paying quantities even though production is not then occurring (BLM Handbook H-3100-1, "Oil and Gas Leasing").

albedo - The fraction of light that is reflected by a body or surface. It is commonly used in astronomy to describe the reflective properties of planets, satellites, and asteroids. It is also an important consideration in climatology since recent albedo decreases in the Arctic have increased heat absorption at the surface.

anthropogenic - relating to, or resulting from, the influence of human beings on nature.

applications for permit to drill (APDs) - A revocable authorization to use public land for a specified purpose.

carbon dioxide equivalents (C02e) - A method to express the impact of each different greenhouse gas (methane, nitrous oxide, etc.) in terms of the equivalent amount of CO_2 emissions that would create the same amount of warming of the atmosphere.

climate feedbacks - Feedback in general is the process in which changing one quantity changes a second quantity, and the change in the second quantity in turn changes the first. For example, a positive feedback in global warming is the tendency of warming to increase the amount of water vapor in the atmosphere, which in turn leads to further warming.

completions - Well completion is the process of making a well ready for production (or injection) after drilling operations are completed. This may include hydraulic fracturing.

confidence limit- In statistics, a confidence interval is a type of estimate computed from the observed data. This gives a range of values for an unknown parameter. The interval has an associated confidence level that gives the probability with which an estimated interval will contain the true value of the parameter.

cryosphere - The part of the earth's surface characterized by the presence of frozen water, including mountain glaciers and continental ice sheets, seasonal snow and ice cover on land, and sea ice.

decline - Once an oil and gas well has been completed (the process of making a well ready for production), its maximum production level can be attained within days or weeks. After this level has been reached (transient flow period), there is a decline in production usually caused by loss of reservoir pressure or changing volumes of produced fluid. The rate of production decline is depicted by a decline curve. Decline curves generally show the amount of oil or gas produced per unit of time, for many successive periods.

direct emissions - GHG emissions that are emitted from the development of coal, oil, and gas on the federal mineral estate (ie., onsite mining or upstream operations).

downstream - Includes GHG emissions from refining, distributing, and retail of extracted minerals. This includes oil refineries, gas processing plants, products distributors, and natural gas distribution companies. Downstream emissions also include end uses such as combustion of fuels (gasoline, diesel, etc.), plastics, pharmaceuticals, natural gas, and propane.

estimated ultimate recovery (EUR) - The estimated quantity of expected total production from an oil or gas reserve or well. The EUR for a well is calculated as the sum of the observed monthly production values plus the sum of the monthly production values estimated using the decline curve, starting the month after the last observed production month through month 360 (30 years in total).

federal lands - All lands and interests in lands owned by the United States which are subject to the mineral leasing laws, including mineral resources or mineral estates reserved to the United States in the conveyance of a surface or nonmineral estate (43 CFR §3160.0-5).

federal mineral estate - The onshore subsurface mineral estate owned by the Federal Government and managed by the BLM, regardless of surface ownership.

fiscal year- A one-year period that companies and governments use for financial reporting and budgeting. The Federal Government defines a fiscal year as the period between October 1st to September 30th.

fugitive emissions - Emissions of greenhouse gases that are not produced intentionally by a stack or vent and may include leaks from industrial sources and pipelines (IPCC 2006).

held-by-production - A provision in an oil or natural gas property lease that allows the lessee, generally an energy company, to continue drilling activities on the property as long as it is economically producing a minimum amount of oil or gas. The held-by-production provision thereby extends the lessee's right to operate the property beyond the initial lease term.

indirect emissions - GHG emissions that are a consequence of the produced fossil fuels but occur downstream from the point of production on federal lands and/or are outside of BLM's approval authority.

leases - An authorization to possess and use public land for a period of time sufficient to amortize capital investments in the land.

life-cycle assessment- A methodology for assessing environmental impacts associated with all the stages of the life cycle of a commercial product, process, or service. For instance, in the case of a manufactured product, environmental impacts are assessed from raw material extraction and processing (cradle), through the product's manufacture, distribution and use, to the recycling or final disposal of the materials composing it (grave).

megatonnes- A tonne (symbol t) is a metric unit of mass equal to 1,000 kilograms. It is also referred to as a metric ton. It is equivalent to approximately 2,204.6 pounds, or 1.102 short tons (US). Mega is a multiple of 7 QA6, and thus a Megatonne (symbol Mt), is equal to one million metric tons.

multiple use and sustained yield- A combination of balanced and diverse resource uses that takes into account the long-term needs of future generations for renewable and nonrenewable resources, including recreation, range, timber, minerals, watershed, and wildlife and fish, along with natural scenic, scientific, and historical values.

operators - Any person or entity including but not limited to the lessee or operating rights owner, who has stated in writing to the authorized officer that it is responsible under the terms and conditions of the lease for the operations conducted on the leased lands or a portion thereof (43 CFR §37 60.0-5).

parcels - The name given to an area of land made available for competitive or noncompetitive leasing (BLM Handbook H-3100-1, "Oil and Gas Leasing").

plugged- A well is plugged by setting mechanical or cement plugs in the wellbore at specific intervals to prevent fluid flow.

producible well- A well producing oil or gas, or if not producing oil or gas, a well either declared or capable of being declared producing.

public lands - Any land and interest in land owned by the United States within the several States and administered by the Secretary of the Interior through the Bureau of Land Management, without regard to how the United States acquired ownership, except (7) lands located on the Outer Continental Shelf; and (2) lands held for the benefit of Indians, Aleuts, and Eskimos (43 U.S.C §1702, Federal Land Policy and Management Act of 1976, Sec. 103(e)).

reasonably foreseeable development (RFD)- **A** technical report containing a long-term projection (scenario) of a particular use of the public lands, in this case oil and gas exploration, development, production, and reclamation activity (BLM Handbook H-1624-1, "Planning for Fluid Mineral Resources").

snow-water equivalents - April 1 snow-water equivalents (SWEs) are used as a surrogate for the total seasonal precipitation accumulation and for the maximum seasonal snowpack on the ground.

spud- Spudding is the process of beginning to drill a well in the oil and gas industry.

stoichiometric - Stoichiometry is the study of the quantitative relationships or ratios between two or more substances undergoing a physical change or chemical change (chemical reaction).

teleconnections - A weather pattern that refers to a recurring and persistent, large-scale pattern of pressure and circulation anomalies that spans vast geographical areas. Thus, they are often the culprit responsible for abnormal weather patterns occurring simultaneously over seemingly vast distances.

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Appendix

2023 Report Year Database (spreadsheet)

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