U.S. Department of ENERGY | Office of Fossil Energy and Carbon Management

# APPENDIX C: CONSEQUENTIAL GREENHOUSE GAS ANALYSIS OF U.S. LNG EXPORTS

December 2024

# Consequential Analysis Appendix

**December 2024**

**Prepared for:**

U.S. Department of Energy, Office of Fossil Energy and Carbon Management,
Office of Resource Sustainability

**Prepared by:**

National Energy Technology Laboratory
3610 Collins Ferry Road
Morgantown, WV 26505

# CONTENTS

## FIGURES



## *TABLES*

## Acronyms and Abbreviations

| | |
|---|---|
| **°C** | Degrees Celsius |
| **AEO** | Annual Energy Outlook |
| **AgLanduse** | Agricultural land use |
| **AR5** | Fifth Assessment Report |
| **AR6** | Sixth Assessment Report |
| **AR6, 100-yr** | Sixth Assessment Report, 100-year basis |
| **AR6, 20-yr** | Sixth Assessment Report, 20-year basis |
| **Bcf, BCF** | Billion cubic feet |
| **Bcf/d** | Billion cubic feet per day |
| **BECCS** | Bioenergy with carbon capture and storage |
| **BIL** | Bipartisan Infrastructure Law |
| **BP** | British Petroleum |
| **Btu** | British thermal unit |
| **$C_2F_6$** | Hexafluoroethane |
| **C Asia + East Eur** | Central Asia and Eastern Europe |
| **ccf** | Climate–carbon cycle Feedback |
| **CCS** | Carbon capture and storage |
| **CCUS** | Carbon capture, utilization, and storage |
| **CDR** | Carbon dioxide removal |
| **$CF_4$** | Tetrafluoromethane |
| **$CH_4$** | Methane |
| **$CO_2$** | Carbon dioxide |
| **$CO_2e$** | Carbon dioxide equivalent |
| **DAC** | Direct air capture |
| **DACCS** | Direct air carbon capture and storage |
| **DOE** | Department of Energy |
| **EIA** | Energy Information Administration |
| **EJ** | Exajoule ($10^{18}$ joules) |
| **EPA** | Environmental Protection Agency |
| **EU** | European Union |
| **F-gases** | Fluorinated gases |
| **FECM** | Office of Fossil Energy and Carbon Management |
| **g** | Gram |
| **GCAM** | Global Change Analysis Model |
| **GDP** | Gross domestic product |
| **GHG** | Greenhouse gas |
| **GoM, GOM** | Gulf of Mexico |
| **Gt** | Gigaton |
| **GWP** | Global warming potential |
| **$H_2$** | Hydrogen |
| **HFC** | Hydrofluorocarbons |
| **HHV** | Higher heating value |
| **HMM** | Hydrogen Market Module |
| **IEA** | International Energy Agency |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **IRA** | Inflation Reduction Act |
| **ITC** | Investment tax credit |
| **LAC** | Latin American countries |
| **LCA** | Life cycle analysis |
| **LHV** | Lower heating value |
| **LNG** | Liquefied natural gas |
| **LUC** | Land use change |
| **LULUCF** | Land use, land use change, and forestry |
| **LC-GHG** | Market adjustment factor |
| **MAM** | Macroeconomic Activity Module |
| **Mcf** | Million cubic feet |
| **MJ** | Megajoule |

| | |
|---|---|
| **MMBtu** | Million British thermal units |
| **MMscf** | Million standard cubic feet |
| **$N_2O$** | Nitrous oxide |
| **NA** | Not available/applicable |
| **NEMS** | National Energy Modeling System |
| **NERA** | NERA Economic Consulting |
| **NETL** | National Energy Technology Laboratory |
| **NG** | Natural gas |
| **NGA** | Natural Gas Act |
| **NGP** | Natural gas processing |
| **NZ** | New Zealand |
| **O&M** | Operating and Maintenance |
| **OGSM** | Oil and Gas Supply Module |
| **PNNL** | Pacific Northwest National Laboratory |
| **PTC** | Production tax credit |
| **ROW** | Rest of the World |
| **SC-GHG** | Social cost of greenhouse gas emissions |
| **$SF_6$** | Sulfur hexafluoride |
| **Tcf, TCF** | Trillion cubic feet |
| **Tg** | Teragram ($10^{12}$ grams) |
| **U.S., USA** | United States |
| **yr** | Year |

## FOREWORD

This multi-volume study of U.S. LNG exports serves to provide an updated understanding of the potential effects of U.S. LNG exports on the domestic economy, U.S. households and consumers; communities that live near locations where natural gas is produced or exported; domestic and international energy security, including effects on U.S. trading partners; and the environment and climate. Prior to this study, Department of Energy's (DOE's) most recent economic and environmental analyses of U.S. LNG exports were published in 2018 and 2019, respectively. At that time, U.S. LNG exports were just getting underway and our export capacity was 4 billion cubic feet per day (Bcf/d), less than one-third of what it is today. Since then, our world and the global natural gas sector have changed significantly: the U.S. has become the top global exporter of LNG; Russia has invaded Ukraine and used energy as a weapon to undermine European and global security; the impacts and costs of extreme weather and natural disasters fueled by climate change have increased dramatically; and the pace of the energy transition and technological innovation has itself accelerated.

These developments and others factor into a global energy system that is changing rapidly. The pace of change creates inherent uncertainty in projecting the potential pathways for U.S. LNG through 2050. Accordingly, several considerations should be borne in mind when interpreting this study and its results.

- Given the global scope and timeframe examined in this study, there should be recognition of the inherent uncertainty in conclusions, especially given their size relative to the overall global economy and energy system.
- This study is not intended to serve as a forecast of U.S. LNG exports and impacts. Rather, it is an exercise exploring alternative conditional scenarios of future U.S. LNG exports and examining their implications for global and U.S. energy systems, economic systems, and greenhouse gas (GHG) emissions. This type of scenario analysis is a well-established analytical approach for exploring complex relationships across a range of variables.
- The scenarios explored in this study span a range of U.S. LNG export outcomes. Each scenario relies on input assumptions regarding many domestic, international, economic, and non-economic factors, such as future socioeconomic development, technology and resource availability, technological advancement, and institutional change. A full uncertainty analysis encompassing all underlying factors is beyond the scope of this study.
- For the portions of this study that have modeled results, the study does not attach probabilities to any of the scenarios examined.

## EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE) is responsible for authorizing exports of domestically produced natural gas, including liquefied natural gas (LNG), to foreign countries under section 3 of the Natural Gas Act (NGA), 15 U.S.C. § 717b. An application to export domestically produced natural gas to countries that have a free trade agreement (FTA) with the United States must be granted without delay or modification and is deemed to be consistent with the public interest by statute. For applications to export domestic natural gas to non-FTA countries, DOE must grant the application unless it finds that the proposed exportation will not be consistent with the public interest.

Since 2012, to inform its public interest determination, DOE's Office of Fossil Energy and Carbon Management (FECM) has commissioned multiple studies to help assess the various facets of the public interest that are affected by U.S. LNG exports. The purpose of the current study is to provide a comprehensive update to our understanding of how varying levels of U.S. LNG exports impact all these facets.

This appendix provides a consequential analysis and focuses on i) the current baseline GHG intensity of U.S. upstream natural gas and liquefaction processes, and ii) the global emissions impacts from changes in U.S. LNG exports through 2050 as provided in the Global Analysis (Appendix A). This analysis uses results from the Global Change Analysis Model (GCAM) and explores scenario comparisons of GHG emissions, level of U.S. LNG exports, and levels of global services provided. Global services are defined as those products of the global economy that provide services to consumers, such as energy, commodities, fertilizers, etc.

Key findings of this Appendix are:

1. Differences in volumes of U.S. LNG exports lead to different levels both of GHG emissions and of global services provided. When compared to scenarios that assume export levels based on existing and under construction facilities (*Existing/FID*), higher levels of U.S. LNG exports lead to higher global GHG emissions (ranging from 21 Tg $CO_2$e to 1,452 Tg $CO_2$e or about 0.002% to 0.1%), as well as higher levels of global services provided (ranging from 0.006% to about 0.1%).
2. The GCAM upstream GHG intensity values for all scenarios are within 1% of the values in the latest NETL Natural Gas baseline study (representative of the base year of this study, 2020) on an IPCC AR6, 100-yr basis.
    a. Per MJ of natural gas scaled to account for liquefaction losses, the production through transmission (upstream) GHG intensity is 9.2 g $CO_2$e/MJ exported on an IPCC AR6, 100-yr GWP, LHV basis and 15.7 g $CO_2$e/MJ exported on an IPCC AR6, 20-yr GWP, LHV basis.
    b. Overall, adjustments to align to NETL national average performance data for GHG intensity added about 20 Tg $CO_2$e emissions per model year, an increase of less than 0.05% on an AR6, 100-yr basis, and subtracted about 100 Tg $CO_2$e emissions per model year, a decrease of less than 0.2% on an AR6, 20-yr basis.
3. The national average GHG intensity for liquefaction operations in the base year is modeled using government reported data and expanded to provide representative life cycle system boundaries, resulting in a GHG emissions intensity of 5.3 g $CO_2$e/MJ of natural gas ready for export, reported on an IPCC AR6, 100-yr lower heating value (LHV) basis, and 5.6 g $CO_2$e/MJ on an IPCC AR6, 20-yr lower heating value (LHV) basis.
4. This analysis defines the upstream natural gas and liquefaction processes as project direct emissions, the direct emissions from export and use of the natural gas and direct and indirect market effects as project non-direct emissions, and the sum of them to be the consequential GHG intensity of U.S. LNG exports. Given the upstream natural gas and

liquefaction values estimated above, the average U.S. project direct emissions for 2020, the baseline year for this study, is 9.2 + 5.3 = 14.5 g $CO_2$e/MJ (AR6, 100-yr), and 21.3 g $CO_2$e/MJ (AR6, 20-yr).

5. The consequential GHG intensity is the effect (inclusive of both direct and indirect emissions) of U.S. LNG on global emissions per unit of U.S. LNG exported. The consequential GHG intensity is defined as the difference in GHG emissions between the scenarios divided by the difference in U.S. LNG exports. For instance, for one of the scenario comparisons assessed (*Defined Polices: Model Resolved*) the consequential GHG intensity is +6.3 g $CO_2$e/MJ (on both an AR6, 100-yr and AR6, 20-yr basis), indicating that the overall global effect of producing and exporting U.S. LNG leads to an increase in global GHG emissions resulting from consequential market effects.
    a. Analysis of the results shows that direct and indirect market substitutions result in a decrease in global GHG emissions intensity when compared on an equivalent global services basis. The increased availability of U.S. LNG on the global market enables increased demand for energy to be met with a lower cost energy supply option that often displaces more or equally GHG emissions-intensive fuels (e.g., coal and oil) within the model over the thirty-year study period.
    b. Results also show that increasing the availability of U.S. LNG on the global market (increased global energy supply) results in increased consumption of global services when compared to the baseline scenario (e.g., *Defined Policies: Existing/FID*). The consequential effect of increased global consumption of energy and services directly contributes to increased global GHG emissions.
    c. The net result of these two market effects is an increase in global GHG emissions of +6.3 g $CO_2$e/MJ of NG exported from the U.S. Across all scenarios, this GHG intensity figure ranges from 1.2 g $CO_2$e/MJ to 12.6 g $CO_2$e/MJ (AR6, 100-yr basis), and from -1.4 g $CO_2$e/MJ to 11.2 g $CO_2$e/MJ (AR6, 20-yr basis).
    d. The increase in global GHG emissions between the *Defined Policies: Model Resolved* and *Defined Policies: Existing/FID* scenarios is estimated to result in a cumulative SC-GHG impact of $74 billion using a discount rate of 2.5%, $130 billion using a discount rate of 2.0%, and $220 billion using a discount rate of 1.5% (all 2020$). Per MJ, this equates to a range of 0.02 cents/MJ to 0.15 cents/MJ (2.5%). The cumulative SC-GHG of the increase in global emissions across the study scenarios ranged from $3 billion to $150 billion (2.5%) to $12 billion to $450 billion (1.5%) in 2020$.
6. Estimated consequential GHG impacts and SC-GHG values for an individual U.S. export project can be calculated by using individual project values in place of the default of U.S. average values modeled in the study.
    a. For example, on an AR6, 100-yr basis, given the NETL average liquefaction emissions for a project of 5.3 g $CO_2$e/MJ, if an individual project has a liquefaction process with emissions that are half of the average (2.65 g $CO_2$e /MJ), the individual project consequential GHG intensity could be adjusted down by 2.65 g $CO_2$e/MJ (calculated as the difference between the average of 5.3 g $CO_2$e/MJ and the individual project emissions intensity of 2.65 g $CO_2$e/MJ). If the average U.S. consequential GHG intensity is 6.3 g $CO_2$e /MJ, the individual project consequential intensity would be 3.65 g $CO_2$e /MJ.
    b. Total lifetime social costs of the project direct and project non-direct greenhouse gas emissions from a 1 Bcf/d facility operating for 30 years are estimated to be $8 billion to $23 billion ($2020) for a facility with default average intensity values (varying across assumed discount rates). A similar facility with half the liquefaction emissions would have social costs of greenhouse gases estimated to be $4.6 billion to $13 billion ($2020).

## BACKGROUND

This portion of the study utilizes the global greenhouse gas (GHG) emissions and U.S. liquefied natural gas (LNG) export volumes determined from the Global Change Analysis Model (GCAM) (detailed in Appendix A with a description of its application to this analysis in Appendix C-2) for each scenario considered within the study to determine the consequential life cycle GHG emissions on a per unit (Megajoule [MJ]) of U.S LNG exported. The life cycle analysis (LCA) modeling approach used in this study is referred to as a "consequential LCA".[1,2,3] This type of LCA accounts for the direct emissions from production, delivery, and use of the U.S. exported natural gas and the indirect emissions from changes in market behavior. Market behavior includes consequences from the decision to use U.S. exported natural gas to meet demands for provision of global services (e.g., energy, commodities, fertilizers, etc.), including fuel substitution and changes in demand for services.

The consequential LCA approach used in this study differs from past DOE LNG LCA modeling approaches. Prior DOE LNG LCA studies conducted by the National Energy Technology Laboratory (NETL)[4] and used to evaluate LNG project applications[5] directly compared the life cycle GHG emissions for producing and consuming a megawatt-hour (MWh) of baseload electricity in European and Asian markets using: (1) U.S. LNG exported from the Gulf Coast of the U.S.; (2) LNG exported from Oran, Algeria; (3) pipeline natural gas from Yamal, Russia; and (4) regionally-sourced coal. This type of LCA is referred to as an "attributional LCA".

An attributional LCA directly compares the environmental performance of each supply chain (e.g., LNG, pipeline natural gas, coal) to produce an equivalent service to society (e.g., 1 MWh of electricity)[6]. An attributional LCA modeling approach does not account for changes in market behavior in response to fuel availability. Comparing attributional LCA results provides information about the difference in environmental performance to provide an equivalent service to society. The comparative difference is the result of one form of energy completely replacing another form in the market, often referred to as direct market substitution. Attributional LCA results do not seek to provide information about the potential indirect market effects from changes in supply and price resulting from a decision to use one form of energy over the other, nor do they provide information

[1] Ekvall, T. (2002). Cleaner production tools: LCA and beyond. Integrating Greener Product Development Perspectives, 10(5), 403–406. https://doi.org/10.1016/S0959-6526(02)00026-4

[2] Brandão, M., Weidema, B. P., Martin, M., Cowie, A., Hamelin, L., & Zamagni, A. (2024). Consequential Life Cycle Assessment: What, Why and How? In M. A. Abraham (Ed.), Encyclopedia of Sustainable Technologies (Second Edition) (pp. 181–189). Elsevier. https://doi.org/10.1016/B978-0-323-90386-8.00001-2

[3] UNEP SETAC. (2011). Global guidance principles for life cycle assessment databases: a basis for greener processes and products. United Nations Environment Programme. https://www.lifecycle initiative.org/ wp-content/ uploads/2012/12/2011%20-%20Global%20Guidance%20Principles.pdf

[4] Khutal, H., et al. Life Cycle Analysis of Natural Gas Extraction and Power Generation: U.S. 2020 Emissions Profile. National Energy Technology Laboratory, Pittsburgh, December 2024. https://www.netl.doe.gov/energy-analysis/details?id=546d4009-c43b-43f5-bcc9-64d5e63fc8d5

[5] Roman-White, S., Rai, S., Littlefield, J., Cooney, G., & Skone, T. J. (2019). Life cycle greenhouse gas perspective on exporting liquefied natural gas from the Unites States: 2019 update. NETL, Pittsburgh, September 12, 2019.

[6] An attributional Life Cycle Assessment (LCA) comparison is done for systems that provide equivalent services to society, i.e., an equivalent function (e.g., the 1 MWh mentioned above). In this study, the boundary is far larger than that of a typical LCA, and thus the total of all services provided globally, and annually over a 30-year study period, is considered. This study will show how the level of global services change across scenarios to help to assess whether equivalent services are being provided.

about how supply or demand for global services could change resulting from changes in supply and price.

DOE has acknowledged that prior attributional LNG LCA results did not account for potential direct or indirect market effects. This study, by contrast, does consider reasonably foreseeable market effects using an integrated multisector model, GCAM, to better understand the market substitution (both direct and indirect) and changes in levels of global services provided (e.g., change in global energy or commodity consumption) that results from the increased availability of U.S. LNG on the global market. The GCAM model includes all GHG emissions from extraction, liquefaction, and use of the LNG, as well as all GHG emissions associated with global services produced. Consequential LCA results are reported with information about the change in global services to illuminate these differences when comparing results.

A trade-off of the consequential modeling approach used in this study is a reduction in attribution for specific source-to-consumption pathways, as previously modeled and used by DOE. Therefore, as a result of the consequential life cycle modeling approach, this study does not present comparative results of natural gas compared to coal for production of a MWh of electricity, or other direct source-to-consumption pathways.

## CONSEQUENTIAL LCA MODELING APPROACH FOR ASSESSING GHG EMISSIONS FROM INCREASED U.S. LNG EXPORTS

The objective of the consequential LCA component of this study is to estimate the direct and indirect market effects of additional U.S. LNG exports to better understand their effect on global GHG emissions.

Two metrics are used to assess the consequential GHG emissions effects of increased U.S. LNG exports: (1) GHG intensity in carbon dioxide equivalents ($CO_2e$) using International Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) global warming potentials (GWPs) - on 100-year (AR6, 100-yr) and 20-year (AR6, 20-yr) time frames; and (2) social cost of greenhouse gas emissions (SC-GHG) using the estimates and methodology developed by the U.S. Environmental Protection Agency (EPA) in the regulatory analysis of its December 2023 Final Rule, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review," (2023 SC-GHG estimates).[7]

This analysis establishes a GHG intensity performance of U.S. natural gas production and delivery to liquefaction plants and U.S. average liquefaction plant GHG emissions intensity performance in 2020 as a reference benchmark. The reference year of 2020 aligns with the start of the study period for market consequences derived from the GCAM model.

A second objective of the LCA study is to determine the market drivers of the change in global GHG emissions with respect to changes in U.S. LNG export GHG intensity when providing an equivalent service to society (excluding increases in global services).

The consequential LCA modeling approach consists of ten data conversion and interpretation steps, each of which is described in more detail below:

1. Obtain study scenario GHG emissions and U.S. LNG export volumes from GCAM.
2. Obtain national average life cycle GHG performance data for U.S. natural gas (from NETL natural gas baseline).
3. Model national average life cycle GHG performance for U.S. liquefaction plants (developed as part of this study).
4. Align GCAM natural gas production and pipeline transport to U.S. national average GHG performance in the baseline year.
5. Calculate GCAM-NETL-aligned global GHG emissions results (for modeled years 2020-2050)
6. Interpolate GCAM-aligned global GHG emissions and U.S. LNG export volumes from 5-year GCAM modeled time steps to annual values for the study period of 2020 to 2050.
7. Calculate GCAM-NETL-aligned consequential GHG intensity per unit of U.S. LNG export (normalized over the study period of 2020 to 2050).
8. Subtract the U.S. national average upstream natural gas and liquefaction plant performance to determine the project non-direct emissions intensity.

[7] DOE has preliminarily determined that the updated 2023 SC-GHG estimates, including the approach to discounting, represent a significant improvement in estimating the SC-GHG through incorporating the most recent advancements in the scientific literature and by addressing recommendations on prior methodologies. DOE explained the basis for its determination and made it available for public comment in a July 2024 NODA for consumer gas-fired instantaneous water heaters, 89 FR 59693, 59700. As DOE explained in the July 2024 NODA, the 2023 SC-GHG estimates represent a significant improvement because the 2023 SC-GHG estimates implement the key recommendations of the National Academies, and they incorporate the extensive scientific findings and methodological advances that have occurred since the last IWG substantive updates in 2013, 2015, and 2016.

9. Add the project direct emissions intensity (U.S. LNG project upstream natural gas supply and liquefaction plant GHG performance) to the project non-direct emissions intensity to determine individual project GHG emissions intensity inclusive of consequential market effects.
10. Demonstrate estimation of consequential GHG intensity and SC-GHG for an individual U.S. LNG project.

The sections below describe one potential modeling approach that shows initial example results using a consistent and specific set of scenarios within one global climate policy generated by the GCAM model for this study. Complete results for each scenario comparison are provided in the Results section and detailed tables in Appendix C-4.

### Step 1: Obtain Study Scenario GCAM GHG Emissions and U.S. LNG Export Results from GCAM

This consequential analysis considers scenarios designed for this study with varying assumptions about future climate policy ambition, technology availability, and level of U.S. LNG exports (summarized in Table 1 and further defined in Appendix A). This study does not attach probabilities to any of the scenarios, and no inference about the relative likelihood of these scenarios occurring should be made.

*Table 1. Scenario design and summary*

| Key Assumptions | | | Scenario full name | Scenario abbreviation |
|---|---|---|---|---|
| **Global climate policies** | **Technology availability[a]** | **U.S. LNG export levels** | | |
| Defined Policies | | Model Resolved | *Defined Policies: Model Resolved* | *DP: MR* |
| | | Existing/FID Exports[c] | *Defined Policies: Existing/FID Exports* | *DP: ExFID* |
| | | High Exports | *Defined Policies: High Exports* | *DP: Hi Exp* |
| Commitments | High CCS | Model Resolved | *Commitments (High CCS): Model Resolved* | *C (High CCS): MR* |
| | | Existing/FID Exports | *Commitments (High CCS): Existing/FID Exports* | *C (High CCS): ExFID* |
| | | High Exports | *Commitments (High CCS): High Exports* | *C (High CCS): Hi Exp* |
| | Moderate CCS | Model Resolved | *Commitments (Moderate CCS): Model Resolved* | *C (Mod CCS): MR* |
| | | Existing/FID Exports | *Commitments (Moderate CCS): Existing/FID Exports* | *C (Mod CCS): ExFID* |
| | | High Exports | *Commitments (Moderate CCS): High Exports* | *C (Mod CCS): Hi Exp* |
| Net Zero 2050 | High CCS | Model Resolved | *Net Zero 2050 (High CCS): Model Resolved* | *NZ (High CCS): MR* |
| | | Existing/FID Exports | *Net Zero 2050 (High CCS): Existing/FID Exports* | *NZ (High CCS): ExFID* |
| | | High Exports | *Net Zero 2050 (High CCS): High Exports* | *NZ (High CCS): Hi Exp* |
| | Moderate CCS[b] | Model Resolved | *Net Zero 2050 (Moderate CCS): Model Resolved* | *NZ (Mod CCS): MR* |
| | | High Exports | *Net Zero 2050 (Moderate CCS): High Exports* | *NZ (Mod CCS): Hi Exp* |

Notes:

[a] Technology availability assumptions (*High CCS* and *Moderate CCS*) are combined only with *Commitments* and *Net Zero 2050* climate policy ambition assumptions.

[b] In the *Net Zero 2050 (Moderate CCS): Model Resolved* scenario, U.S. LNG exports fall below the existing/FID exports level. Thus, a *Net Zero 2050 (Moderate CCS): Existing/FID Exports* scenario would resolve to the same outcomes as the *Net Zero 2050 (Moderate CCS): Model Resolved* scenario and is therefore not shown (and not used in this consequential analysis).

[c] Existing/FID exports refer to LNG capacity of currently operational LNG projects or LNG projects with export authorizations from DOE that have reached final investment decisions (FID) on their projects.

In the broader study, the NEMS and GCAM models were used to represent economic and environmental changes associated with the defined changes in U.S. LNG exports. The NEMS modeling focused on domestic changes that would be expected to occur in the scenarios modeled, but results from NEMS were not used as a part of this consequential analysis.[8]

Additional sensitivity scenarios on levels of domestic and rest of world natural gas production for the *Defined Policies* scenarios are listed in Table 2.

*Table 2. Additional sensitivity scenarios in this study*

| Global climate policies | Natural gas resources | U.S. LNG export levels | Sensitivity scenarios full name | Sensitivity scenario abbreviation |
|---|---|---|---|---|
| Defined Policies | High U.S. Supply | Model Resolved | *DP High U.S. Supply: Model Resolved* | *DP Hi US Sup: MR* |
| | High U.S. Supply | Existing/FID Exports | *DP High U.S. Supply: Existing/FID Exports* | *DP Hi US Sup: ExFID* |
| | Low U.S. Supply | Model Resolved | *DP Low U.S. Supply: Model Resolved* | *DP Lo US Sup: MR* |
| | Low U.S. Supply | Existing/FID Exports | *DP Low U.S. Supply: Existing/FID Exports* | *DP Lo US Sup: ExFID* |
| | High Middle East Supply | Model Resolved | *DP High Middle East Supply: Model Resolved* | *DP Hi ME Sup: MR* |
| | High Middle East Supply | Existing/FID Exports | *DP High Middle East Supply: Existing/FID Exports* | *DP Hi ME Sup: ExFID* |

Results from all scenarios in Table 1 and Table 2 were provided to NETL as output files with results for each model year (i.e., in five-year increments from 2020-2050). Across all years and scenarios, GCAM has about 100 discrete sectors, hundreds of discrete technologies, and many sector-technology pairs that can vary depending on the model configuration. However, only a subset of these sectors is relevant to this analysis (i.e., to the natural gas sectors). Detailed discussion of the formats and structures of received GCAM files is included in Appendix C-2.

Table 3 summarizes cumulative data for model year (2020-2050) including GHG emissions, U.S. LNG export volumes, and summary measures of global services from GCAM for the scenarios in Table 1. By default, GHG values in this study are shown using IPCC AR6, 100-year GWP values.

[8] NETL reviewed the NEMS data to evaluate the magnitude of changes to the regional production mix of natural gas over time to assess whether the GHG intensity of U.S. natural gas produced would change as a result of production mix changes. No significant change in intensity was found (see Appendix C-1 for details).

Where noted, IPCC AR6, 20-yr GWP values are also provided.[9] Shown here are GHG emissions in Teragrams of $CO_2$-equivalents (Tg $CO_2$e). The global services index is an aggregate weighted metric that summarizes the total services provided to global society as a result of the economic activity modeled in the scenarios over the 2020-2050 period where, by assumption, the *ExFID* scenario has a value of 1.00 within each Global Climate Policy set of scenarios (see Appendix C-2 for details).

*Table 3. Summary of cumulative model year (every five years, 2020-2050) U.S. LNG exports, GHG emissions, and global services from GCAM*

| Scenario | Geographical Scope / Global Service Type | | | | | | | Global Weighted Index |
|---|---|---|---|---|---|---|---|---|
| | Global | U.S. | Global | Global Industrial | | Global Transportation | | |
| | GHG Emissions (AR6, 100-yr) (Tg $CO_2$e) | LNG Export Volumes (EJ) | Energy Services (EJ) | Commodity Products (Mt) | Nitrogen Fertilizer (Mt) | Freight, Million Ton-Kilometers (Mt-km) | Passenger, Million Passenger-Kilometers (Mp-km) | |
| *DP: Hi Exp* | 351,607 | 95 | 2,376 | 39,752 | 1,144 | 1.53E+09 | 1.78E+09 | 1.0015 |
| *DP: MR* | 351,444 | 77 | 2,374 | 39,740 | 1,144 | 1.53E+09 | 1.78E+09 | 1.0008 |
| *DP: ExFID* | 351,286 | 50 | 2,372 | 39,725 | 1,145 | 1.52E+09 | 1.78E+09 | 1.0000 |
| | | | | | | | | |
| *DP: Hi ME Sup: MR* | 352,433 | 74 | 2,382 | 39,801 | 1,143 | 1.53E+09 | 1.78E+09 | 1.00047 |
| *DP: Hi ME Sup: ExFID* | 352,356 | 50 | 2,381 | 39,792 | 1,143 | 1.53E+09 | 1.78E+09 | 1.0000 |
| | | | | | | | | |
| *DP Hi US Sup: MR* | 351,649 | 88 | 2,376 | 39,750 | 1,144 | 1.53E+09 | 1.78E+09 | 1.00127 |
| *DP Hi US Sup: ExFID* | 351,377 | 50 | 2,372 | 39,727 | 1,145 | 1.53E+09 | 1.78E+09 | 1.0000 |
| | | | | | | | | |
| *DP Lo US Sup: MR* | 350,692 | 53 | 2,370 | 39,720 | 1,145 | 1.52E+09 | 1.77E+09 | 1.00010 |
| *DP Lo US Sup: ExFID* | 350,683 | 49 | 2,369 | 39,717 | 1,145 | 1.52E+09 | 1.77E+09 | 1.0000 |
| | | | | | | | | |
| *C (High CCS): Hi Exp* | 283,821 | 74 | 2,289 | 37,152 | 1,157 | 1.43E+09 | 1.76E+09 | 1.0009 |
| *C (High CCS): MR* | 283,677 | 56 | 2,287 | 37,137 | 1,157 | 1.43E+09 | 1.76E+09 | 1.0002 |
| *C (High CCS): ExFID* | 283,657 | 49 | 2,287 | 37,133 | 1,158 | 1.43E+09 | 1.76E+09 | 1.0000 |
| | | | | | | | | |
| *C (Mod CCS): Hi Exp* | 270,432 | 69 | 2,254 | 35,460 | 1,131 | 1.38E+09 | 1.76E+09 | 1.0008 |
| *C (Mod CCS): MR* | 270,432 | 51 | 2,252 | 35,454 | 1,131 | 1.38E+09 | 1.76E+09 | 1.0001 |
| *C (Mod CCS): ExFID* | 270,189 | 48 | 2,252 | 35,453 | 1,131 | 1.38E+09 | 1.76E+09 | 1.0000 |
| | | | | | | | | |
| *NZ (High CCS): Hi Exp* | 240,973 | 70 | 2,237 | 35,611 | 1,158 | 1.37E+09 | 1.76E+09 | 1.0008 |
| *NZ (High CCS): MR* | 240,923 | 52 | 2,236 | 35,594 | 1,158 | 1.37E+09 | 1.76E+09 | 1.0001 |
| *NZ (High CCS): ExFID* | 240,919 | 48 | 2,235 | 35,592 | 1,158 | 1.37E+09 | 1.76E+09 | 1.0000 |

[9] The use of GWP values converts emissions of distinct greenhouse gases into a single index of carbon dioxide equivalents to represent the global warming impact of the varied gases. The IPCC AR6, 100-yr GWP values (units kg $CO_2$e/kg gas) used are: fossil $CH_4$ (29.8), non-fossil $CH_4$ (27.2), and $N_2O$ (273). See Appendix C-2 for GWP values used for other greenhouse gases (e.g., F-gases) and IPCC reports.

| Scenario | Geographical Scope / Global Service Type | | | | | | | Global Weighted Index |
|---|---|---|---|---|---|---|---|---|
| | Global | U.S. | Global | Global Industrial | | Global Transportation | | |
| | GHG Emissions (AR6, 100-yr) (Tg $CO_2e$) | LNG Export Volumes (EJ) | Energy Services (EJ) | Commodity Products (Mt) | Nitrogen Fertilizer (Mt) | Freight, Million Ton-Kilometers (Mt-km) | Passenger, Million Passenger-Kilometers (Mp-km) | |
| | | | | | | | | |
| *NZ (Mod CCS): Hi Exp* | 224,035 | 61 | 2,195 | 33,244 | 1,119 | 1.30E+09 | 1.76E+09 | 1.0005 |
| *NZ (Mod CCS): MR* | 224,035 | 43 | 2,194 | 33,244 | 1,119 | 1.30E+09 | 1.76E+09 | 1.0000 |
| *NZ (Mod CCS): ExFID* | 223,831 | 43 | 2,194 | 33,244 | 1,119 | 1.30E+09 | 1.76E+09 | 1.0000 |

Notes:

- The values in this table reflect the sums of the 5-year interval data provided by the GCAM output for the years 2020-2050.
- Global energy services include: agricultural energy use, commercial cooking, commercial cooling, commercial heating, commercial hot water, commercial non-building, commercial office, commercial other, commercial others, commercial refrigeration, residential computers, residential cooking, residential cooling, residential freezers, residential furnace fans, residential heating, residential hot water, residential other, residential others, residential refrigerators, residential televisions, chemical energy use, chemical feedstocks, construction energy use, construction feedstocks, mining energy use, other industrial energy use, other industrial feedstocks, process heat cement
- Conversion of annual values from EJ/year to Bcf/d is 1:2.7759
- Global commodities products include production of aluminum, alumina, cement, and iron & steel.
- Freight transportation includes freight and international shipping.
- Passenger transportation includes ground and aviation.
- The weighted index is not provided in the GCAM results but was created in collaboration with the GCAM modeling team and is included here to summarize the global services results.

### Step 2: Obtain U.S. Natural Gas National Average Life Cycle GHG Performance (from NETL Natural Gas Baseline)

The 2024 NETL natural gas baseline study[10] describes the GHG emissions due to production, gathering and boosting, processing, transmission, storage, and distribution of domestic U.S. natural gas to consumers and is representative of the year 2020, which aligns with the temporal representation of upstream natural gas processes of this study period (2020-2050). These natural gas supply chain stages (or industry segments) generally align with categories used in other federal efforts, such as EPA's Greenhouse Gas Reporting Program (GHGRP)[11] and Greenhouse Gas Inventory.[12] Results of this study are provided for two main scopes: production through transmission (end users after transmission typically include industrial and power sectors that receive natural gas via transmission pipeline directly), and production through distribution (end users after distribution typically include a combination of residential, commercial, industrial, and power sectors, where natural gas is delivered through the distribution pipeline network).

Quantitatively, the NETL natural gas baseline reports estimated ranges of GHG emissions intensities for each species (i.e., type of gas molecule) of GHG emission and for each stage of the domestic natural gas supply chain following the principles of attributional LCA. For the scope

[10] Khutal, H., et al. Life Cycle Analysis of Natural Gas Extraction and Power Generation: U.S. 2020 Emissions Profile. National Energy Technology Laboratory, Pittsburgh, December 2024. https://www.netl.doe.gov/energy-analysis/details?id=546d4009-c43b-43f5-bcc9-64d5e63fc8d5

[11] U.S. EPA, Greenhouse Gas Reporting Program, https://www.epa.gov/ghgreporting, last accessed Sept 1, 2023.

[12] U.S. EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks, last accessed Sept 1, 2023.

of domestic natural gas production through the transmission stage, the U.S. average GHG emissions intensity is estimated at 7.79 grams (g) $CO_2$e/megajoule (MJ) (with a 95 percent mean confidence interval of 4.6–11.1 g $CO_2$e/MJ, using IPCC AR6, 100-yr GWP values, higher heating value [HHV] basis) or about 8.63 g $CO_2$e/MJ (with a 95 percent mean confidence interval of 5.4 g $CO_2$e/MJ –12.8 g $CO_2$e/MJ, using the IPCC AR6, 100-yr GWP values, lower heating value [LHV] basis).[13,14]

The production through transmission boundary represents emissions associated with natural gas delivered to liquefaction plants (plant input). However, due to natural gas consumption and losses at the liquefaction stage, the amount of natural gas delivered to a liquefaction plant is higher than the amount of natural gas throughput/exported (plant output). Adjusting from a "per MJ of NG delivered to liquefaction plant" (plant input) to "per MJ of NG through liquefaction plant" (plant output) basis, results in a higher upstream GHG emissions intensity value. As a result, the production through transmission (upstream) GHG intensity on a per MJ NG throughput from liquefaction plant basis is 9.2 g $CO_2$e/MJ Exported (IPCC AR6, 100-yr GWP, LHV basis).[15]

### Step 3: Model U.S. Liquefaction Plant National Average Life Cycle GHG Performance

As part of this study, a new national average life cycle GHG performance for U.S. liquefaction operations in the year 2020 was modeled to align the temporal representation of the liquefication data to the study period (2020-2050) and the U.S. national average for upstream natural gas production and delivery described in Step 2. U.S. Environmental Protection Agency's GHGRP data representative of year 2020 emissions were used as the basis with adjustments to account for certain missing emission sources in GHGRP that are discussed in more detail below, while ensuring alignment with combustion emission factors modeled in the NETL natural gas baseline LCA.

The resulting national average liquefaction process GHG emissions intensity for the year 2020 is 5.27 (or 5.3) g $CO_2$e/MJ (LHV) and is referred to as the 2024 NETL estimate throughout the rest of this section.

Six facilities reported to GHGRP for the 2020 data year and exported natural gas, as shown in Table 4. For the data tables and calculations shown for calculating the 2024 NETL estimate, only data from these six export facilities are used. These export volumes were also used to weight the calculated or reported facility-level GHG emissions.

[13] The rest of this report expresses GHG emissions intensity values on a lower heating value (LHV) basis (unless explicitly specified otherwise) to ensure alignment with the energy content basis used by the Global Change Analysis Model (GCAM).

[14] The higher heating value (HHV) of a fuel includes the heat released if all of the water vapor in the combustion products were condensed, while the lower heating value (LHV) is the heat released if all of the water vapor remained as vapor. A conversion factor of 1.108 MJ higher (HHV) basis per MJ lower (LHV) basis was used throughout the steps of this analysis.

[15] As per the updated NETL liquefaction stage modeling, around 1.07 kg of NG is delivered to the liquefaction plant per 1 kg of NG throughput from the plant.

*Table 4. 2020 LNG facility export volumes as reported in GHGRP Subpart W*[16]

| LNG Facility Name | Quantity Exported (MMcf) |
|---|---|
| SLNG Elba Island Terminal | 36,272 |
| Sabine Pass LNG Terminal | 926,901 |
| Cove Point LNG Facility | 233,227 |
| Freeport | 421,381 |
| Corpus Christi Liquefaction | 395,716 |
| Cameron LNG LLC | 385,662 |

Facility-level GHG emissions are summarized by GHGRP, allowing a direct calculation of carbon intensity for all facilities, shown in Table 5.

The speciated, summary emissions for each facility reported by GHGRP are shown in the AR4, 100-yr columns in the table. These are then converted to AR6, 100-yr to match this study (see Appendix C-2 for GWP values). LNG production is reported to GHGRP in terms of thousand cubic feet of gas, which is converted here to mass of LNG. The annual emissions and LNG production are used to calculate the speciated, AR6, 100-yr emission intensities, followed by the total in the last column. The production-weighted intensities are calculated in the bottom row based on the facility-specific information.

GHGRP data have known data gaps with regards to natural gas liquefaction facilities, including not accounting for GHG emissions from acid gas removal units (AGRU) and electricity consumption for compressors (as indicated by the low 2020 GHGRP GHG emissions intensity of the electric-driven Freeport LNG plant in Table 5).

*Table 5. 2020 LNG facility GHG emissions as summarized in GHGRP*[17]

| | AR4, 100-yr, as-reported (Mt $CO_2$e/yr) | | | AR6, 100-yr, converted (Mt $CO_2$e/yr) | | | LNG Production, converted (Mt) | Emission Intensity, calculated AR6, 100-yr (kg $CO_2$e/kg LNG) | | | AR6, 100-yr Emissions Intensity (kg $CO_2$e/ kg LNG) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| U.S. LNG Facility Name | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2$ | $CH_4$ | $N_2O$ | | $CO_2$ | $CH_4$ | $N_2O$ | Total |
| SLNG Elba Island Terminal | 77,054 | 4,471 | 41 | 77,054 | 5,329 | 38 | 730,500 | 0.105 | 7.29E-03 | 5.19E-05 | 0.113 |
| Sabine Pass LNG Terminal | 4,127,013 | 29,905 | 2,314 | 4,127,013 | 35,647 | 2,120 | 18,667,328 | 0.221 | 1.91E-03 | 1.14E-04 | 0.223 |
| Cove Point LNG Facility | 1,120,158 | 4,616 | 614 | 1,120,158 | 5,502 | 562 | 4,697,068 | 0.238 | 1.17E-03 | 1.20E-04 | 0.240 |
| Freeport | 52,688 | 5,664 | 27 | 52,688 | 6,752 | 25 | 8,486,405 | 0.006 | 7.96E-04 | 2.90E-06 | 0.007 |
| Corpus Christi Liquefaction | 1,774,907 | 20,083 | 997 | 1,774,907 | 23,938 | 913 | 7,969,529 | 0.223 | 3.00E-03 | 1.15E-04 | 0.226 |
| Cameron LNG LLC | 3,092,913 | 46,931 | 1,729 | 3,092,913 | 55,942 | 1,584 | 7,767,049 | 0.398 | 7.20E-03 | 2.04E-04 | 0.406 |
| | | | | | | | Production Weighted Avg | 0.212 | 9.24E-05 | 3.97E-07 | 0.215 |

[16] U.S. EPA Greenhouse Gas Reporting Program (2021). Subpart W Reporting Year 2020. Available at www.epa.gov/ghgreporting. Date accessed: October 15, 2024.
[17] U.S. EPA Greenhouse Gas Reporting Program (2023). Summary GHG Data 2020. https://www.epa.gov/system/files/other-files/2023-12/ghgp_data_2020.xlsx. Date accessed: October 15, 2024.

Additionally, there are minor differences in the combustion factors used in the calculation of emissions from GHGRP Subpart C[18] data and those used by NETL in its LNG modeling. To address these limitations, the following steps were taken:

- When natural gas arrives at the LNG facility, it often contains some small amount of carbon dioxide that needs to be removed using acid gas removal before the low-temperature liquefaction process. In general, the $CO_2$ from acid gas removal (AGR) is simply vented to the atmosphere after being removed. These AGR $CO_2$ venting emissions have been estimated and incorporated within the GHG emissions profile of each liquefaction facility using the appropriate regional post-processing NG compositions reported in the natural gas baseline report and assuming that all $CO_2$ is removed from the pipeline gas and vented. The facilities are first aligned to an appropriate production region (either southeast or southwest) from the 2024 NETL natural gas baseline study, and then the post-processing natural gas composition is used to assign the mass fraction of $CO_2$ in the natural gas entering AGR (southeast – 0.261 kg $CO_2$/kg NG and southwest – 0.405 kg $CO_2$/kg NG[19]). The mass of $CO_2$ removed is then calculated as:

$$mass\ CO_2\ removed = \frac{mass\ fraction_{CO_2} \cdot mass\ fraction_{LNG\ export}}{1 - mass\ fraction_{CO_2}}$$

These data are summarized in Table 6, where the mass values are in metric tons (equal to Mg).

*Table 6. 2020 LNG facility calculated $CO_2$ emissions from acid gas removal units[20]*

| U.S. LNG Facility Name | 2024 NETL Natural Gas Baseline Study Production Region | Mass Fraction $CO_2$ in Gas Entering AGU Facility | LNG Mass Exported (Mt) | Mass $CO_2$ Removed (Mt/yr) |
|---|---|---|---|---|
| SLNG Elba Island Terminal | Southeast | 0.26% | 730,500 | 1,911 |
| Sabine Pass LNG Terminal | Southeast | 0.26% | 18,667,328 | 48,827 |
| Cove Point LNG Facility | Southeast | 0.26% | 4,697,068 | 12,286 |
| Freeport | Southwest | 0.40% | 8,486,405 | 34,500 |
| Corpus Christi Liquefaction | Southwest | 0.40% | 7,969,529 | 32,399 |
| Cameron LNG LLC | Southeast | 0.26% | 7,767,049 | 20,316 |

- Emissions from electricity consumption for Freeport LNG terminal's electric drive turbines (the only operating U.S. export facility using this configuration) are incorporated using the Electric Reliability Council of Texas (ERCOT) electricity generation mix for 2020. The amount of electricity used by the Freeport LNG terminal is available in the company's

[18] Subpart C of the GHGRP is for General Stationary Fuel Combustion Sources. The EPA website summarizes these as "Stationary fuel combustion sources are devices that combust any solid, liquid, or gaseous fuel generally to produce electricity, steam, useful heat, or energy for industrial, commercial, or institutional use or reduce the volume of waste by removing combustible matter." For this work, the subpart C data from only the LNG facilities are considered.
[19] Khutal, H., et al. Life Cycle Analysis of Natural Gas Extraction and Power Generation: U.S. 2020 Emissions Profile. National Energy Technology Laboratory, Pittsburgh, December 2024. https://www.netl.doe.gov/energy-analysis/details?id=546d4009-c43b-43f5-bcc9-64d5e63fc8d5
[20] U.S. EPA Greenhouse Gas Reporting Program (2021). Subpart W Reporting Year 2020. Available at www.epa.gov/ghgreporting. Date accessed: October 15, 2024.

sustainability report: 3,469,942 MWh[21]. The ERCOT greenhouse gas emissions intensity (kg $CO_2$e/MWh, AR6, 100-yr) is calculated using a custom generation mix in the NETL Grid Mix Explorer.[22] The generation mix was derived from the ERCOT Fuel Mix Report[23] as shown in Table 7. The end result is an additional 0.204 kg $CO_2$/kg LNG (AR6, 100-yr) exported for the Freeport facility.

*Table 7. 2020 ERCOT generation mix[24]*

| Fuel type | Percent Mix | $CO_2$ (kg/MWh) | $CH_4$ (kg/MWh) | $N_2O$ (kg/MWh) | GWP, AR6, 100-yr (kg $CO_2$e/MWh) |
|---|---|---|---|---|---|
| Biomass | 0.09% | 1.11 | 2.7E-04 | 3.4E-05 | 1.1 |
| Coal | 18.00% | 203.57 | 9.3E-02 | 3.3E-03 | 207.2 |
| Natural gas | 45.66% | 259.07 | 7.8E-01 | 9.9E-04 | 282.5 |
| Hydro | 0.17% | 0.02 | 8.1E-05 | 1.0E-09 | 0.0 |
| Nuclear | 10.89% | 1.48 | 1.7E-02 | 9.0E-05 | 2.0 |
| Solar | 2.30% | 0.47 | 1.1E-03 | 1.6E-06 | 0.5 |
| Wind | 22.88% | 6.23 | 1.4E-02 | 2.3E-05 | 6.7 |
| | | | | Total | 500.1 |

- The reported facility-level emissions are separated by Subpart W[25] (Table 8 and Table 9) and Subpart C (Table 10) to allow the incorporation of the NETL combustion factors. The fuel quantities in Table 10 are multiplied by the NETL combustion factors listed in
- Table 11 to calculate the emissions for each combustion source. Combustion emissions for GHGRP are calculated using fuel use by the facility (e.g., gallons of diesel) and emissions factors (e.g., kg $CO_2$ per gallon diesel combusted) specified for reporting to GHGRP. NETL has developed its own emissions factors from open data sources that are used in its models. In order to make sure the liquefaction emissions used in this study would match future implementations in NETL products, NETL combustion factors are used to calculate the combustion emissions. Additionally, life cycle emissions for diesel production are included for completeness.
- Flaring $CO_2$ emissions are calculated from the amounts of natural gas sent to flaring reported in Table 8 by assuming a 98% mass conversion efficiency from $CH_4$ to $CO_2$ with the remaining 2% emitted as $CH_4$. If only these combustion-specific changes were

[21] Freeport LNG Sustainability and Community Investment Report 2020. https://freeportlng.com/files/docs/2020-Freeport-LNG-SCIR.PDF
[22] NETL Grid Mix Explorer v4.2. https://netl.doe.gov/energy-analysis/details?id=f0f94954-3627-4e9b-a5c0-c29cfe419d1c.
[23] ERCOT Fuel Mix Report: 2007-2020. https://www.ercot.com/files/docs/2021/03/10/FuelMixReport_PreviousYears.zip
[24] U.S. EPA Greenhouse Gas Reporting Program (2021). Subpart W Reporting Year 2020. Available at www.epa.gov/ghgreporting. Date accessed: October 15, 2024.
[25] Subpart W of the GHGRP is for emissions from petroleum and natural gas systems, and more specifically non-combustion emissions. The EPA website summarizes these as "Owners or operators of facilities that contain petroleum and natural gas systems and emit 25,000 metric tons or more of GHGs per year (expressed as carbon dioxide equivalents) report GHG data to EPA. Owners or operators collect GHG data; calculate GHG emissions; and follow the specified procedures for quality assurance, missing data, recordkeeping, and reporting. Subpart W consists of emission sources in ten segments of the petroleum and natural gas industry."

implemented, the 0.215 kg $CO_2e$/kg LNG value in Table 5 would become 0.219 kg $CO_2e$/kg LNG, a 2 percent increase.

*Table 8. 2020 LNG facility GHGRP Subpart W LNG import and export equipment emission sources*[26]

| U.S. LNG Facility Name | NG Sent to Flare (MMscf) | Feed Gas Sent to Flare - $CH_4$ Mass Fraction | Feed Gas Sent to Flare - $CO_2$ Mass Fraction | Blowdown Vent Stack (tons $CO_2$) | Blowdown Vent Stack (tons $CH_4$) | Blowdown Vent Stack (tons $N_2O$) |
|---|---|---|---|---|---|---|
| SLNG Elba Island Terminal | 770 | 0.3392 | 0.0234 | 0.1 | 5.1 | 0 |
| Sabine Pass LNG Terminal | 3,741 | 0.8045 | 0.0771 | 0.0 | 258.6 | 0 |
| Cove Point LNG Facility | 1,454 | 0.4538 | 0.2749 | 0.6 | 22.4 | 0 |
| Freeport | 854 | 0.9750 | 0.0100 | 0.0 | 0.0 | 0 |
| Corpus Christi Liquefaction | 4,338 | 0.8549 | 0.0039 | 0.0 | 0.0 | 0 |
| Cameron LNG LLC | 22,041 | 0.8254 | 0.0079 | 0.0 | 0.0 | 0 |

*Table 9. 2020 LNG facility GHGRP Subpart W LNG import and export equipment emission sources (cont'd)*[26]

| U.S. LNG Facility Name | Equipment Leaks (tons $CO_2$) | Equipment Leaks (tons $CH_4$) | Equipment Leaks (tons $N_2O$) | Reciprocating Compressors (tons $CO_2$) | Reciprocating Compressors (tons $CH_4$) | Reciprocating Compressors (tons $N_2O$) |
|---|---|---|---|---|---|---|
| SLNG Elba Island Terminal | 0 | 48.37 | 0 | 0.7 | 23.97 | 0 |
| Sabine Pass LNG Terminal | 0 | 224.73 | 0 | 0 | 0 | 0 |
| Cove Point LNG Facility | 0 | 19.88 | 0 | 2.7 | 93.09 | 0 |
| Freeport | 0 | 9.39 | 0 | 0 | 0 | 0 |
| Corpus Christi Liquefaction | 0 | 58.38 | 0 | 0 | 0 | 0 |
| Cameron LNG LLC | 1.8 | 68.97 | 0 | 0 | 0 | 0 |

[26] U.S. EPA Greenhouse Gas Reporting Program (2021). Subpart W Reporting Year 2020. Available at www.epa.gov/ghgreporting. Date accessed: October 15, 2024.

*Table 10. 2020 LNG facility GHGRP Subpart C general stationary fuel combustion[26]*

| U.S. LNG Facility Name | Simple Cycle Combustion Turbines - NG Combusted (MMscf/yr) | Other Combustion Sources - NG Combusted (MMscf/yr) | Thermal Oxidizer Direct Fired (MMscf/yr) | Combined Cycle Combustion Turbines - NG Combusted (MMscf/yr) | Other Boiler - NG Combusted (MMscf/yr) | Process Heater - NG Combusted (MMscf/yr) | Process Heater - Propane Combusted (MMscf/yr) | Recipro-cating Internal Combustion Engine - Distillate Fuel Oil No. 2 (gal/yr) |
|---|---|---|---|---|---|---|---|---|
| SLNG Elba Island Terminal | 0 | 1,050 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sabine Pass LNG Terminal | 74,721 | 0 | 1,587 | 0 | 0 | 0 | 0 | 0 |
| Cove Point LNG Facility | 2,897 | 0 | 0 | 14,492 | 2,516 | 290 | 0.358 | 0 |
| Freeport | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Corpus Christi Liquefaction | 25,805 | 798 | 0 | 2,084 | 0 | 0 | 0 | 25,856 |
| Cameron LNG LLC | 0 | 33,009 | 641 | 639 | 0 | 0 | 0 | 0 |

*Table 11. NETL stationary combustion emission factors and distillate fuel life cycle emissions*

| Fuel | $CO_2$ | $CH_4$ | $N_2O$ | Units |
|---|---|---|---|---|
| Distillate Fuel Oil No. 2[1] | 3.20 | 1.28E-04 | 2.51E-05 | kg/kg diesel |
| Distillate Fuel Oil No. 2 (Upstream)[2] | 0.638 | 4.82E-03 | 2.82E-05 | kg/kg diesel production |
| Natural Gas Reciprocating Compressor[3] | 2.83 | 3.31E-02 | 0 | kg/kg natural gas |
| Natural Gas Centrifugal Compressor[3] | 2.66 | 2.08E-04 | 7.24E-05 | kg/kg natural gas |
| Natural Gas Combustion[2] | 2.83 | 5.42E-05 | 0 | kg/kg natural gas |
| Propane[4] | 0.155 | 0 | 0 | kg/scf |

Notes:

[1] NETL (2014). NETL Life Cycle Inventory Data – Unit Process: Combustion of Diesel. U.S. Department of Energy, National Energy Technology Laboratory. Last Updated: January 2015 (version 02). www.netl.doe.gov/LCA

[2] NETL (2008). Development of Baseline Data and Analysis of Life Cycle Greenhouse Gas Emissions of Petroleum-Based Fuels.

[3] NETL (2015). NETL Life Cycle Inventory Data – Unit Process: Combustion of Natural Gas. U.S. Department of Energy, National Energy Technology Laboratory. Last Updated: January 2015 (version 01). www.netl.doe.gov/LCA

[4] Propane emission factor is from Table C-1 to Subpart C – Default $CO_2$ Emission Factors and High Heat Values for Various Types of Fuel. https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98/subpart-C/appendix-Table%20C-1%20to%20Subpart%20C%20of%20Part%2098

Table 12 summarizes the total for each species of GHG emissions (i.e., “speciated emissions”) as calculated after the above adjustments and re-calculates the GHG intensity for each LNG facility (following the same columns/steps as used to create Table 5). These results show that accounting for the additional emissions increases the production-weighted average emissions intensity from 0.215 (Table 5) to 0.258 kg $CO_2$e/kg LNG. Additional unit conversion present results on a g $CO_2$e/MJ basis, including a conversion to LHV to align with GCAM.[27]

[27] The higher heating and lower heating values for these conversions are 54.3 MJ/kg LNG and 49.0 MJ/kg LNG, respectively, and are multiplied by the mass-based Facility GHG intensity (in kg $CO_2$e/kg LNG).

*Table 12. NETL liquefaction estimate - speciated emissions*

| U.S. LNG Facility Name | $CO_2$ (Mg $CO_2e$) | $CH_4$ (Mg $CO_2e$) | $N_2O$ (Mg $CO_2e$) | GWP, AR6, 100-yr (Mg $CO_2e$) | LNG Mass Exported (Mg) | Facility GHG Intensity (kg $CO_2e$/kg LNG) | Facility GHG Intensity (g $CO_2e$/MJ LNG HHV) | Facility GHG Intensity (g $CO_2e$/MJ LNG LHV) |
|---|---|---|---|---|---|---|---|---|
| SLNG Elba Island Terminal | 76,214 | 5,477 | 0 | 81,691 | 730,500 | 0.112 | 2.06 | 2.28 |
| Sabine Pass LNG Terminal | 4,304,382 | 59,889 | 29,753 | 4,394,024 | 18,667,328 | 0.235 | 4.33 | 4.80 |
| Cove Point LNG Facility | 1,145,880 | 14,215 | 6,924 | 1,167,019 | 4,697,068 | 0.248 | 4.57 | 5.07 |
| Freeport | 1,717,497 | 103,843 | 4,169 | 1,825,509 | 8,486,405 | 0.215 | 3.96 | 4.39 |
| Corpus Christi Liquefaction | 1,770,920 | 49,755 | 11,105 | 1,831,780 | 7,969,529 | 0.230 | 4.23 | 4.69 |
| Cameron LNG LLC | 2,960,706 | 221,601 | 254 | 3,182,562 | 7,767,049 | 0.410 | 7.54 | 8.36 |
| | | | | | Production Weighted Average | 0.258 | 4.76 | 5.27 |

Below, the updated 2024 NETL liquefaction stage (2020 data year) GHG intensity estimates are compared to:

- U.S. EPA Greenhouse Gas Reporting Program (GHGRP) data[28,29]
- A 2021 paper that included liquefaction emissions as part of supplier-specific LCA for LNG supply chains (Roman-White et al., 2021)[30]
- An August 2024 pre-print of a paper reporting greenhouse gas emissions estimates of two liquefaction facilities based on measured emissions (Zhu et al., 2024)[31]

[28] U.S. EPA Greenhouse Gas Reporting Program (2023). Summary GHG Data 2020. https://www.epa.gov/system/files/other-files/2023-12/ghgp_data_2020.xlsx. Date accessed: October 15, 2024.
[29] U.S. EPA Greenhouse Gas Reporting Program (2023). Summary GHG Data 2022. http://www.epa.gov/ghgreporting. Date accessed: October 15, 2024. Calculations are based on emissions and exports from seven facilities for 2022.
[30] Roman-White, S. A., Littlefield, J. A., Fleury, K. G., Allen, D. T., Balcombe, P., Konschnik, K. E., Ewing, J., Ross, G. B., & George, F. (2021). LNG Supply Chains: A Supplier-Specific Life-Cycle Assessment for Improved Emission Accounting. ACS Sustainable Chemistry & Engineering, 9(32), 10857–10867. https://doi.org/10.1021/acssuschemeng.1c03307
[31] Zhu Y, Ross G, Khaliukova O, Roman-White S, George F, Hammerling D, et al. Multi-scale Measurements of Greenhouse Gas Emissions at U.S. Natural Gas Liquefaction Terminals. ChemRxiv. 2024; doi:10.26434/chemrxiv-2024-h4flq (This content is a preprint and has not been peer-reviewed).

*Table 13. Comparison of NETL liquefaction stage GHG emissions intensity with other literature*

| Source | | Liquefaction Stage Emissions Intensity | | | | |
|---|---|---|---|---|---|---|
| | | **$CO_2$ (kg $CO_2$/kg LNG)** | **$CH_4$ (kg $CH_4$/kg LNG)** | **$N_2O$ (kg $N_2O$/kg LNG)** | **$CO_2e$, AR6, 100-yr GWP (kg $CO_2e$/kg LNG)** | **$CO_2e$, AR6, 100-yr GWP (g $CO_2e$/MJ LHV)** |
| **NETL 2024 – National Average** | | **0.248** | **3.16E-04** | **3.96E-06** | **0.258** | **5.27** |
| GHGRP Reporting Year 2020 | | 0.212 | 9.24E-05 | 3.97E-07 | 0.215 | 4.39 |
| GHGRP Reporting Year 2022 | | 0.202 | 4.79E-05 | 3.82E-07 | 0.204 | 4.16 |
| Roman-White et al., 2021 | Sabine Pass, 2018 data | - | 5.00E-05 | - | 0.26 | 5.31 |
| Zhu et al., 2024 | Site 1 | 0.220 | 1.82E-04 | - | 0.225 | 4.59 |
| | Site 2 | 0.243 | 2.22E-04 | - | 0.250 (0.211 – 0.281) | 5.10 |

Notes:
- The 2024 NETL estimate uses 2020 GHGRP data as the reference data source and incorporates acid gas removal emissions for each facility and electricity consumption emissions for the Freeport LNG facility, while ensuring alignment with combustion emission factors modeled in the NETL natural gas baseline LCA to generate a representative national average liquefaction stage GHG intensity profile.
- Upon accounting for emissions from electricity consumption for the Freeport LNG terminal (represents 18% of NG exports in 2020), the GHG intensity of the facility rises from 0.011 kg $CO_2e$/kg LNG to 0.22 kg $CO_2e$/kg LNG (AR6, 100-year). Emissions from electricity consumption represent ~95% of the GHG emissions profile of the Freeport LNG terminal based on available data.

The higher GHG emissions intensity for the 2024 NETL liquefaction result compared to the 2020 and 2022 (20% and 26% higher, respectively) reporting year GHGRP estimates is driven by the additional AGRU $CO_2$ emissions, carbon intensity of the ERCOT grid to support on site electricity use and ensuring consistency with NETL modeling emissions factors. On an AR6, 100-yr basis, the 2024 NETL attributional GHG emissions intensity estimate for liquefaction generally aligns with estimates from other sources as noted below and provided in Table 13.

- Roman-White et al., 2021: 2024 NETL liquefaction stage emissions intensity is equivalent (<1% difference) to the liquefaction stage estimate reported in the Roman-White et al. study.

- Zhu et al., 2024: 2024 NETL estimate is around 3-15% higher than estimates reported by Zhu et al. However, NETL estimates are within the reported uncertainty range for site 2 as reported by Zhu et al. Also, the 2024 NETL estimate represents a national average liquefaction stage GHG emissions intensity profile for the year 2020, whereas the Zhu et al. study focuses on two specific liquefaction terminals – Sabine Pass, LA and Corpus Christi, TX.

### Step 4: Align GCAM Natural Gas Production and Pipeline Transport to U.S. National Average GHG Performance

NETL compared the GCAM model results to the year 2020 national average for upstream natural gas production through delivery to a large end user as reported in the NETL Baseline Study (as described in Step 2). This was done to align the representation of U.S. natural gas production and

pipeline transport GHG emissions representation to the study start period (Year 2020) based on U.S. industry average data.

Specifically, NETL assessed and aligned the emissions estimates per unit of gas produced and delivered to large end users (e.g., LNG export facilities) in the U.S. from GCAM to the NETL life cycle GHG intensity for U.S. average natural gas production and delivery to large end users (from Step 2), using a ratio of the NETL and GCAM results. Since GCAM uses lower heating value (LHV) to express energy content, the NETL model output figures were adjusted from HHV to LHV basis, resulting in a value of 8.63 g $CO_2$e/MJ (AR6, 100-yr, LHV basis). This comparison aggregated data only from three GCAM sectors in the USA region: *natural gas, gas pipelines,* and *other industrial energy use*[32].

The intensity values of upstream natural gas in GCAM and the 2024 NETL study were found to differ by 1.17% (with the NETL intensity of 8.63 g $CO_2$e/MJ being slightly higher than the GCAM value found to be 8.53 g $CO_2$e/MJ on an AR6, 100-yr LHV basis). See Appendix C-2 for additional details, including the alternate development of the adjustment factor on an AR6, 20-yr basis.

### Step 5: Calculate GCAM-NETL-aligned Global GHG Emissions Results

Using the 1.17% adjustment factor calculated in Step 4, results for the three GCAM sectors listed in Step 4 were adjusted (increased by 1.17%) to align with NETL GHG intensity values. Non-U.S. region natural gas production and delivery GHG emissions intensity values for these same sectors were also adjusted up by 1.17% to align with NETL life cycle GHG intensity values. Note that the comparison and adjustment was done only to maintain the total $CO_2$e intensity value and not on a speciated emission basis. This adjustment was applied to all model years and regions for these three sectors reported by GCAM (i.e., every fifth year from 2020-2050). The *Defined Policies: Existing/FID Exports* scenario is shown in Table 14 as an example of the overall unadjusted and adjusted GCAM GHG emissions results (across all sectors) and for the three aligned sectors. The majority of the increase in adjusted emissions are in the GCAM *natural gas* sector. Overall, the adjustments to align to NETL 2020 national average performance data for GHG intensity (AR6, 100-yr basis) added about 20 Tg $CO_2$e emissions per model year, a net increase in overall global emissions of less than 0.05%.

*Table 14. GCAM unadjusted and NETL aligned sector emissions for Defined Policies: Existing/FID Scenario (AR6, 100-yr basis)*

| Year | GHG Emissions (Tg $CO_2$e) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | GCAM Unadjusted | | | | | GCAM-NETL Aligned | | | | |
| | Natural Gas | Gas Pipeline | Other Industrial Energy Use | All Other Sectors | Total Across All GCAM Sectors | Natural Gas | Gas Pipeline | Other Industrial Energy Use | All Other Sectors | Total Across All GCAM Sectors |
| **2020** | 957 | 185 | 5,146 | 47,463 | 53,751 | 968 | 188 | 5,152 | 47,462 | 53,770 |
| **2025** | 827 | 171 | 5,855 | 44,145 | 50,998 | 836 | 173 | 5,862 | 44,146 | 51,017 |
| **2030** | 868 | 182 | 6,670 | 41,417 | 49,137 | 878 | 184 | 6,677 | 41,417 | 49,156 |
| **2035** | 888 | 184 | 7,310 | 41,792 | 50,174 | 899 | 187 | 7,318 | 41,790 | 50,194 |
| **2040** | 894 | 189 | 7,856 | 40,428 | 49,367 | 904 | 191 | 7,864 | 40,429 | 49,388 |

[32] The adjustment for the other industrial energy use sector was focused only on natural gas relevant technologies, which comprises a small part of the overall sector. As such the resulting adjustment factor for that sector was about 0.1%. Appendix C-2 shows details of the adjustment for that sector.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **2045** | 955 | 193 | 8,445 | 39,651 | 49,244 | 966 | 195 | 8,454 | 39,652 | 49,267 |
| **2050** | 1,013 | 195 | 8,936 | 38,471 | 48,615 | 1,025 | 197 | 8,945 | 38,472 | 48,639 |

Note: As detailed above, only a subset of emissions in the other industrial energy use were adjusted.

Table 15 shows how speciated emissions of $CO_2$ and $CH_4$ changed with the adjustments described above for the *Defined Policies: Existing/FID Exports* scenario. This shows that of the approximately 20 Tg $CO_2$e adjusted per year, it is generally evenly split between $CO_2$ and $CH_4$ on a $CO_2$e basis. The table also provides perspective on the contribution of the speciated emissions to the total global emissions profile.

*Table 15. Model-year GCAM-NETL-aligned GHG emissions for DP: ExFID Scenario*

| Year | GHG Emissions (Tg $CO_2$e) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | GCAM Unadjusted | | | | | GCAM-NETL Aligned | | | | |
| | $CO_2$ Energy | $CO_2$ LUC[a] | $CH_4$ Energy | Other GHGs | Total | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | Other GHGs | Total |
| **2020** | 38,399 | 398 | 6,666 | 8,288 | 53,751 | 38,407 | 398 | 6,677 | 8,288 | 53,770 |
| **2025** | 36,091 | 754 | 5,588 | 8,566 | 50,998 | 36,099 | 754 | 5,598 | 8,566 | 51,017 |
| **2030** | 36,605 | -2,679 | 5,785 | 9,425 | 49,137 | 36,615 | -2,679 | 5,795 | 9,425 | 49,156 |
| **2035** | 35,737 | -1,233 | 5,763 | 9,906 | 50,174 | 35,748 | -1,233 | 5,773 | 9,906 | 50,194 |
| **2040** | 34,906 | 1,328 | 5,584 | 10,204 | 49,367 | 34,917 | -1,328 | 5,595 | 10,204 | 49,388 |
| **2045** | 34,047 | -992 | 5,617 | 10,573 | 49,244 | 34,058 | -992 | 5,628 | 10,573 | 49,267 |
| **2050** | 32,900 | -874 | 5,629 | 10,961 | 48,615 | 32,912 | -874 | 5,641 | 10,961 | 48,639 |

Note: In the global analysis, $CO_2$ emissions from energy are subject to uncertainties in regional emission intensities of natural gas and other fossil fuels. The negative result for land use change $CO_2$ emissions demonstrates that more $CO_2$ is removed from the atmosphere than released from changes in land use systems in the modeled timeframe. In the global analysis, emissions from land-use changes are driven in part by changes in energy production, including those driven by changes in demand (e.g., global demand or LNG). These emissions are also subject to greater uncertainties largely due to uncertainties in data. A detailed exploration of these uncertainties is beyond the scope of this study.

### Step 6: Interpolate GCAM-aligned Results from 5-year Time Steps to Annual Results

The results from Step 5 of every fifth-year model output (2020-2050) were interpolated to all intervening years via simple linear interpolation methods (e.g., the difference in five-year values divided by five and added as 1/5$^{th}$ shares to subsequent years). This interpolation was done for both GHG emissions as well as for U.S. LNG exports, with an example for *Defined Policies: Existing/FID Exports* shown in Table 16. These annual results are also summed as cumulative values over the period 2020-2050. Interpolated U.S. LNG export values are provided in Table 16.

*Table 16. Modeled, interpolated, and cumulative GCAM-NETL-aligned GHG emissions for DP: ExFID Scenario*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | Other GHGs | Total | U.S. LNG Exports | |
|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 100-yr) | | | | | EJ | Bcf/d |
| **2020** | 38,407 | 398 | 6,677 | 8,288 | 53,770 | 2.44 | 6.8 |
| **2021** | 37,946 | 469 | 6,461 | 8,344 | 53,220 | 3.22 | 8.9 |
| **2022** | 37,484 | 540 | 6,245 | 8,399 | 52,669 | 4.00 | 11.1 |
| **2023** | 37,023 | 611 | 6,029 | 8,455 | 52,118 | 4.78 | 13.3 |
| **2024** | 36,561 | 683 | 5,814 | 8,511 | 51,567 | 5.55 | 15.4 |

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | Other GHGs | Total | U.S. LNG Exports | |
|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 100-yr) | | | | | EJ | Bcf/d |
| **2025** | 36,099 | 754 | 5,598 | 8,566 | 51,017 | 6.33 | 17.6 |
| **2026** | 36,202 | 67 | 5,637 | 8,738 | 50,645 | 6.45 | 17.9 |
| **2027** | 36,305 | -619 | 5,677 | 8,910 | 50,273 | 6.58 | 18.3 |
| **2028** | 36,409 | -1,306 | 5,716 | 9,082 | 49,901 | 6.70 | 18.6 |
| **2029** | 36,512 | -1,992 | 5,755 | 9,254 | 49,529 | 6.83 | 19.0 |
| **2030** | 36,615 | -2,679 | 5,795 | 9,425 | 49,157 | 6.95 | 19.3 |
| **2031** | 36,441 | -2,389 | 5,791 | 9,522 | 49,364 | 7.27 | 20.2 |
| **2032** | 36,268 | -2,100 | 5,786 | 9,618 | 49,572 | 7.59 | 21.1 |
| **2033** | 36,095 | -1,811 | 5,782 | 9,714 | 49,779 | 7.90 | 21.9 |
| **2034** | 35,921 | -1,522 | 5,777 | 9,810 | 49,987 | 8.22 | 22.8 |
| **2035** | 35,748 | -1,233 | 5,773 | 9,906 | 50,194 | 8.54 | 23.7 |
| **2036** | 35,582 | -1,252 | 5,738 | 9,966 | 50,033 | 8.54 | 23.7 |
| **2037** | 35,416 | -1,271 | 5,702 | 10,025 | 49,872 | 8.54 | 23.7 |
| **2038** | 35,249 | -1,290 | 5,666 | 10,085 | 49,711 | 8.54 | 23.7 |
| **2039** | 35,083 | -1,309 | 5,631 | 10,144 | 49,550 | 8.54 | 23.7 |
| **2040** | 34,917 | -1,328 | 5,595 | 10,204 | 49,388 | 8.54 | 23.7 |
| **2041** | 34,745 | -1,261 | 5,602 | 10,278 | 49,364 | 8.54 | 23.7 |
| **2042** | 34,574 | -1,194 | 5,608 | 10,352 | 49,340 | 8.54 | 23.7 |
| **2043** | 34,402 | -1,127 | 5,615 | 10,425 | 49,315 | 8.54 | 23.7 |
| **2044** | 34,230 | -1,059 | 5,621 | 10,499 | 49,291 | 8.54 | 23.7 |
| **2045** | 34,058 | -992 | 5,628 | 10,573 | 49,267 | 8.54 | 23.7 |
| **2046** | 33,829 | -969 | 5,631 | 10,651 | 49,141 | 8.54 | 23.7 |
| **2047** | 33,600 | -945 | 5,633 | 10,728 | 49,016 | 8.54 | 23.7 |
| **2048** | 33,370 | -922 | 5,636 | 10,806 | 48,890 | 8.54 | 23.7 |
| **2049** | 33,141 | -898 | 5,638 | 10,883 | 48,765 | 8.54 | 23.7 |
| **2050** | 32,912 | -874 | 5,641 | 10,961 | 48,639 | 8.54 | 23.7 |
| **Total** | **1,101,142** | **-28,818** | **178,896** | **301,120** | **1,552,340** | **227** | **-** |

Using the interpolated data for *Defined Policies: Model Resolved* and *Defined Policies: Existing/FID Exports*, Speciated emissions for all years 2020-2050, as well as total GHG emissions and U.S. LNG export volumes for all modeled scenarios are provided as data tables in Appendix C-4.

shows that while U.S. LNG export volumes (expressed as the dotted orange and blue lines) begin to appreciably change around 2030, and more than double in the modeled scenario by 2050, total global GHG emissions (shown as the solid orange and blue lines) do not begin to differ until 2040, and then by only 0.1 percent. The time effect of when the emissions differ is important and will be revisited in the discussion of subsequent steps.

Speciated emissions for all years 2020-2050, as well as total GHG emissions and U.S. LNG export volumes for all modeled scenarios are provided as data tables in Appendix C-4.

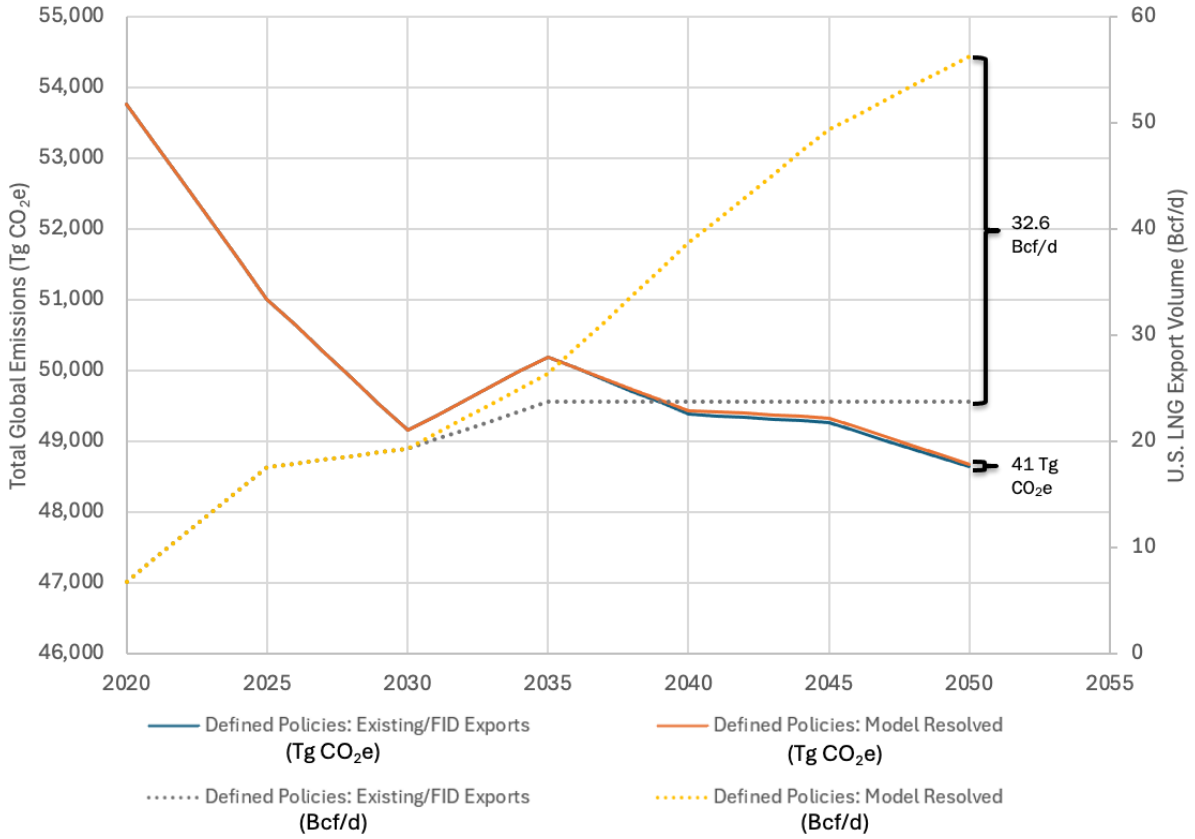


*Figure 1. GHG emissions and U.S. LNG export trends for the Defined Policies: Existing/FID and Defined Policies: Model Resolved Scenarios*

### Step 7: Calculate GCAM-NETL-aligned Consequential GHG Intensity and SC-GHG per Unit of U.S. LNG Exports

The emissions results provided by GCAM are total global emissions, including upstream and downstream emissions (accounting for direct emissions and direct and indirect market effects, and including use/combustion of fuels). The consequential GHG intensity is the effect (inclusive of both direct and indirect emissions) of U.S. LNG on global emissions per unit of U.S. LNG exported. To quantify the consequential GHG intensity of U.S. LNG, the GCAM-NETL-aligned results were used to estimate the change in global GHG emissions per unit of U.S. LNG exported between scenarios within a global climate policy. The consequential GHG intensity of increased U.S. LNG Exports is defined as shown in Equation 1:

$$\underset{scenario\ n}{Consequential\ GHG\ Intensity\ of\ U.S.\ Exports} = \frac{Global\ Emissions_{scenario\ n} - Global\ Emissions_{scenario\ base}}{U.S.\ LNG\ Exports_{scenario\ n} - U.S.\ LNG\ Exports_{scenario\ base}} \quad (1)$$

This intensity value in all scenarios was estimated in comparison to the *Existing/FID* scenario baseline within a policy scenario (e.g., *Defined Policies: Model Resolved* would be compared to the *Defined Policies: Existing/FID* baseline, and this specific pairwise comparison will be used throughout this section of the report as an example). The consequential GHG intensity of increased U.S. LNG exports under this scenario can be calculated for every year (2020–2050), and with cumulative values of GHG emissions and U.S. LNG exports over the time horizon of the model.

For *Defined Policies: Model Resolved* versus *Defined Policies: Existing/FID Exports*[33] the consequential GHG intensity is the total difference in annually estimated global GHG emissions over the 2020-2050 period (711 Tg $CO_2e$) divided by the total difference in exported U.S. LNG over the same period (113 EJ)[34], or 6.3 g $CO_2e$/MJ. The consequential GHG intensity of U.S. LNG exports is estimated for all scenarios (versus their *ExFID* baseline). Cumulative consequential GHG intensity results for all scenarios are provided in Table 22. Annual consequential GHG intensity results for each scenario are provided in Appendix C-4.

Note that the study assumes that the difference in emissions between scenarios within a global climate policy is the total difference in life cycle emissions (and that the reason for the difference in emissions is the difference in U.S. LNG exported). By normalizing to the difference in U.S. LNG exports, the study assumes that the consequential GHG intensity result is showing the difference in total global emissions associated with an additional unit of U.S. LNG exported, inclusive of direct emissions and direct and indirect market effects. This leads to results on a g $CO_2e$/MJ of LNG exported basis (amount of GHGs emitted per unit of energy contained in LNG).[35]

The speciated GHG emissions inputs to the consequential GHG intensity can also be used with the 2023 SC-GHG methodology to monetize the impacts of the changes in GHG emissions associated with increased U.S. LNG exports. The SC-GHG, as described by the Interagency Working Group (IWG) on SC-GHG, is "the monetary value of the net harm to society associated with adding a small amount of greenhouse gases to the atmosphere in a given year."[36] Estimates of the SC-GHG "allow analysts to incorporate the net social benefits of reducing emissions of greenhouse gases, or the net social costs of increasing such emissions, in benefit-cost analysis, and when appropriate, in decision making and other contexts."[37] In short, the SC-GHG monetizes the net harm to society caused by the release of an additional ton of GHGs into the atmosphere in a given year.

The 2023 SC-GHG method uses a trio of discount rates (1.5%, 2.0% and 2.5%) to provide values of the SC-GHG for a particular base year (assumed in this study as 2024) and dollar year. The base year (which can also be considered the present value year) was chosen to be 2024 to align with the time of the study, consistent with the suggested choice aligning with a regulatory impact assessment time. The study used 2020 as the dollar year, consistent with the default year of damages provided in the framework. The monetized SC-GHG values for each of the three greenhouse gases for each of the three discount rates for each year of the study period (in year 2020 dollars) used by the method are summarized in Appendix C-3.

---

[33] Recall that from Table 1, the *Defined Policies: Existing/FID Exports* scenario in GCAM represents expected future trajectories of U.S. LNG exports and GHG emissions where U.S. LNG production is constrained to volumes equal to 90% of the capacity up to or past the point of final investment decision, while the *Defined Policies: Model Resolved* scenario calculates what economically-driven levels of U.S. LNG might be supplied into the global market without that constraint. Yet, this scenario comparison is just one of the many scenarios modeled and should not be considered the primary result.

[34] Results for each year 2020-2050 and IPCC AR6 20-year time horizons are shown in Appendix C-4.

[35] The underlying GCAM data is in Tg of GHG Emissions and EJ of LNG used, a Tg/EJ is equivalent to g/MJ.

[36] Interagency Working Group on Social Cost of Greenhouse Gases, U.S. Government. (February 2021). "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide. Interim Estimates under Executive Order 13990". https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf

[37] U.S. EPA (November 2023). Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances. https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf

For *Defined Policies: Model Resolved* versus *Defined Policies: Existing/FID Exports*, the cumulative difference in emissions from 2020-2050 is estimated to have a cumulative SC-GHG impact of $70 billion using a discount rate of 2.5%, $130 billion using a discount rate of 2.0%, and $220 billion using a discount rate of 1.5% (all 2020$). SC-GHG estimates for all scenarios are provided in Table 23.

Normalizing SC-GHG results per MJ of change in natural gas exported leads to estimated intensities ranging from $0.0007/MJ (2.5% discount rate) to $0.002/MJ (1.5% discount rate). In other words, for this scenario, the social costs of the additional GHG emissions associated with increased U.S. LNG exports range from 0.07 cents/MJ (2.5% discount rate) to 0.2 cents/MJ (1.5% discount rate). SC-GHG estimates per unit of change in energy exported for all scenarios are provided in

Table 24. SC-GHG estimates per unit of change in energy exported for all scenarios are provided in Appendix C-2.

### Step 8: Subtract National Average Upstream Natural Gas and Liquefaction Plant GHG Performance to Determine Project Non-Direct Emissions Intensity

The overall consequential GHG intensity values include all emissions from direct emissions as well as direct and indirect market effects. To facilitate an approach to evaluating environmental GHG performance of individual LNG projects that accounts for consequential market effects, these overall consequential values need to be broken down into component parts. Overall, the consequential GHG intensity of U.S. exports can be split into two primary categories, project direct emissions and project non-direct emissions, expressed in Equation 2.

*Consequential GHG Intensity of US Exports = Project Direct Emissions + Project Non-Direct Emissions* (2)

where:

Project direct emissions include liquefaction emissions and all upstream emissions of producing and processing the natural gas before liquefaction.

Project non-direct emissions include emissions not included in the definition of project direct emissions. This includes direct emissions from ocean shipping, regasification, importing country transport of the gas, and use (unspecified) of the exported gas, plus the direct and indirect market effects.

The project non-direct emissions factor is estimated by taking the consequential GHG intensity and subtracting the estimated project direct emissions intensity, as shown in Equation 3 (just a re-arranged version of Equation 2).

*Project Non-Direct Emissions = Consequential GHG Intensity of US Exports - Project Direct Emissions.* (3)

For the purposes of this study, project direct emissions values were assumed to be equal to the sum of Year 2020 U.S. average GHG emission intensity estimates for upstream natural gas production and delivery and liquefaction operations as described in Steps 2 and 3 (i.e., 9.2 and 5.3 g $CO_2$e/MJ, respectively, for upstream natural gas and liquefaction). The sum of project direct emissions is thus 14.5 g $CO_2$e/MJ.

Applying Equation 3 and the project direct emissions factor above, the project non-direct emissions factor for *Defined Policies: Model Resolved* would be +6.3 – (9.2 + 5.3), or a net of -8.2 g $CO_2$e/MJ. Since the project direct emissions are substantially higher than the consequential GHG intensity, it follows that the project non-direct emissions would be negative given Equations 2 and 3.

The project non-direct emissions value, which includes LNG usages across all technologies and options in global markets, represents the overall expected net global effect from ocean transport through use of the LNG plus direct and indirect market effects. The project non-direct emissions value is an interim value that enables comparison to GHG emissions from the U.S. default natural gas upstream and liquefaction values used in this study and should not be used as the basis for interpreting study findings. Table 25 summarizes the resulting project non-direct emissions values for all scenarios.

### Step 9: Add Project Direct Emissions to Project Non-Direct Emissions to Determine Individual Project GHG Emissions Intensity Inclusive of Consequential Market Effects

To understand how an individual U.S. export project may differ from the U.S. average liquefaction facility values modeled in the study, the various speciated emissions values, consequential GHG intensity, and project non-direct emissions can be compared.

The default values used for individual project analyses would be the average U.S. values described in Steps 2 and 3 (9.2 g $CO_2$e/MJ for upstream U.S. natural gas and 5.3 g $CO_2$e/MJ for liquefaction).

Equations 2 and 3, defined above, are repeated here and used to help organize the consequential GHG intensities of the default facility.

*Consequential GHG Intensity of US Exports = Project Direct Emissions + Project Non-Direct Emissions* (2)

*Project Non-Direct Emissions = Consequential GHG Intensity of US Exports - Project Direct Emissions* (3)

For a default project, using the example of *Defined Policies: Model Resolved* compared against *Defined Policies: Existing/FID Exports*, the consequential GHG intensity can be organized into speciated components as shown in Table 17, with a total default U.S. average consequential GHG intensity of +6.3 g $CO_2$e/MJ. The values in Table 17, and its project non-direct emissions and consequential GHG intensity rows, could be used to subsequently compare individual project data.[38]

*Table 17. Default values for natural gas upstream and liquefaction facility operations (example DP:MR vs. DP:ExFID)*

| Stage | Average Default GHG Intensity, (g $CO_2$e/MJ) | | |
|---|---|---|---|
| | $CO_2$ | $CH_4$ | Total |
| NG Upstream | 5.6 | 3.6 | 9.2 |
| Liquefaction | 5.1 | 0.2 | 5.3 |
| Project Non-Direct Emissions (Estimated) | **-4.8** | **-3.4** | **-8.2** |
| Consequential Global GHG Emissions Intensity | 5.8 | 0.5 | **+6.3** |

### Step 10: Demonstrate Estimation of Consequential GHG Intensity and SC-GHG for an Individual U.S. LNG Project

This step demonstrates how the study results can be used, starting with the default U.S. average LNG export results (from Step 9) and hypothetical project data, to estimate the consequential GHG intensity and SC-GHG for an individual U.S. LNG project. This methodology could be used

[38] Note that for the sake of this simple demonstration, all speciated GHG emissions in the consequential model have been aligned to just $CO_2$ and $CH_4$ emissions (this includes all species of emissions shown in Step 5). $CO_2$ emissions have been combined with $N_2O$ emissions, and $CH_4$ emissions have been combined with F-gases.

to support a side-by-side comparison of the estimated consequential GHG intensity of an individual project against the U.S. default values.

Two hypothetical projects are described below: one with higher liquefaction emissions than the U.S. default value (example 1) and one with lower liquefaction emissions than the U.S. default (example 2). Two metrics are used for comparing the GHG performance: (1) GHG intensity in $CO_2e$ using IPCC AR6, 100-yr GWPs and (2) SC-GHG estimates.

### Metric #1: Comparative Environmental GHG Performance: Consequential GHG Intensity

Table 18 represents a hypothetical LNG export project side by side with the default values from Step 9. In this hypothetical scenario, the facility liquefaction emissions are double those of the default facility; values different from the default facility are bolded.

The consequential GHG intensity per unit of LNG exported (in Table 18) is increased by 5.3 (the amount of 'doubled' liquefaction emissions estimated in Step 3) and is now +11.5 g $CO_2e$/MJ, which is 84% higher than the default facility (6.3 g $CO_2e$/MJ) from Step 9.

The second hypothetical project case assumes a project with 50% lower GHG intensity for the liquefaction stage, as shown in Table 19.

The consequential GHG intensity per unit of LNG exported (as shown in Table 19) is +3.6 g $CO_2e$/MJ (down 42% from +6.3 g $CO_2e$/MJ for the default). While both hypothetical scenarios focused on liquefaction information, the same framework could be used to evaluate emissions differences resulting from the upstream source of gas.

*Table 18. Hypothetical example 1: High GHG intensity liquefaction project example (based on difference in defined policies scenarios, Market-Resolved vs. Existing/FID Exports)*

| Stage | Average Default GHG Intensity (g $CO_2e$/MJ) | | | Project GHG Intensity (g $CO_2e$/MJ) | | |
|---|---|---|---|---|---|---|
| | **$CO_2$** | **$CH_4$** | **Total** | **$CO_2$** | **$CH_4$** | **Total** |
| NG Upstream | 5.6 | 3.6 | 9.2 | 5.6 | 3.6 | 9.2 (Avg Default) |
| Liquefaction | 5.1 | 0.2 | 5.3 | **10.1** | **0.4** | **10.5 (Project)** |
| Project Non-Direct Emissions | -4.8 | -3.4 | -8.2 | -4.8 | -3.4 | -8.2 |
| Total Consequential Global GHG Emissions Intensity | 5.8 | 0.4 | +6.3 | **10.9** | **0.6** | **+11.5** |

*Table 19. Hypothetical example 2: Low GHG intensity liquefaction project example (based on difference in current policies scenarios, Market-Resolved vs. Existing/FID Exports)*

| Stage | Average Default GHG Intensity (g $CO_2e$/MJ) | | | Project GHG Intensity (g $CO_2e$/MJ) | | |
|---|---|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | Total | $CO_2$ | $CH_4$ | Total |
| NG Upstream | 5.6 | 3.6 | 9.2 | 5.6 | 3.6 | 9.2 (Avg Default) |
| Liquefaction | 5.1 | 0.2 | 5.3 | **2.6** | **0.1** | **2.6 (Project)** |
| Project Non-direct Emissions | -4.8 | -3.4 | -8.2 | -4.8 | -3.4 | -8.2 |
| Total Consequential Global LC GHG Emissions Intensity | 5.8 | 0.4 | +6.3 | **3.3** | **0.3** | **+3.6** |

### Metric #2: Comparative Environmental Performance: Consequential Social Costs of Greenhouse Gases

The second metric uses the 2023 SC-GHG as introduced in Step 7 to identify and compare the monetized values of the damages associated with a project's direct and non-direct emissions. The "Difference" between the U.S. average (Default Facility) and the hypothetical example (Project Specific) data shows the net change in social cost of greenhouse gases when liquefaction emissions are doubled (high GHG intensity liquefaction example) and when liquefaction emissions are reduced by 50% (low GHG intensity liquefaction example). The project direct emissions associated with the default facility and this illustrative project-specific example were estimated using annual emissions estimates to calculate the SC-GHG results.

In Metric #1, the metric is in g $CO_2e$ per MJ exported natural gas. To assess how liquefaction emissions could affect the SC-GHG, the GHG intensity in Metric #1 is used to determine the annual emissions, by species, for a hypothetical facility that exports 1 Bcf/d every year from 2020 through 2050 (equivalent to 0.36 EJ/year or 360 billion MJ/yr). These annual export volumes are multiplied by the GHG intensities in Table 18 to generate the yearly speciated greenhouse gas emissions that are used in the SC-GHG calculations.

Table 20 summarizes the SC-GHG results across the three discount rates for the first hypothetical project facility (high liquefaction) inclusive of market consequences.

*Table 20. Social cost of greenhouse gases for hypothetical example 1: High GHG intensity liquefaction [base year 2024, dollar year 2020]*

| | Social Cost of Greenhouse Gases ($billion) for a Facility Exporting 1 Bcf/d from 2020 through 2050 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2.5% Discount Rate | | | | 2% Discount Rate | | | | 1.5% Discount Rate | | | |
| | $CO_2$ | $CH_4$ | $N_2O$ | Total | $CO_2$ | $CH_4$ | $N_2O$ | Total | $CO_2$ | $CH_4$ | $N_2O$ | Total |
| Default Facility | $7.8 | $0.28 | $0.00 | $8.1 | $13 | $0.37 | $0.00 | $13 | $22 | $0.51 | $0.00 | $23 |
| Project-Specific | $15 | $0.40 | $0.03 | $15 | $24 | $0.53 | $0.05 | $25 | $42 | $0.73 | $0.08 | $43 |
| Difference | $6.8 | $0.12 | $0.03 | $6.9 | $11 | $0.16 | $0.05 | $11 | $19 | $0.22 | $0.08 | $19 |
| Percent Difference | 87% | 44% | -0% | 86% | 87% | 44% | -0% | 86% | 87% | 44% | -0% | 86% |

The results suggest that the total lifetime social costs of the project direct and project non-direct greenhouse gas emissions from a 1 Bcf/d facility are about $8 billion to $23 billion for a facility with default average intensity values (varying across discount rates), with the large majority of social costs related to GHG emissions being attributed to emissions of $CO_2$. A 1 Bcf/d facility with double liquefaction emissions has a social cost of greenhouse gases that are about $15 billion to $43 billion, $7 billion to $20 billion higher than the average 1 Bcf/d facility, a difference of about 86%.

Table 21 summarizes the SC-GHG results under each of the three discount rates for the second hypothetical project facility, also assuming 1 Bcf/d capacity for the years 2020-2050, based on Table 19.

The SC-GHG results of this second example show that a hypothetical 1 Bcf/d facility with 50% lower liquefaction emissions has a SC-GHG of about $4.6 to $13 billion, $3.5 billion to $10 billion lower than the average 1 Bcf/d facility, a difference of -43%.

*Table 21. Social cost of greenhouse gases for hypothetical example 2: Low GHG intensity liquefaction [base year 2024, dollar year 2020]*

| | **Social Cost of Greenhouse Gases ($billion) for a Facility Exporting 1 Bcf/d from 2020 through 2050** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2.5% Discount Rate** | | | | **2% Discount Rate** | | | | **1.5% Discount Rate** | | | |
| | **$CO_2$** | **$CH_4$** | **$N_2O$** | **Total** | **$CO_2$** | **$CH_4$** | **$N_2O$** | **Total** | **$CO_2$** | **$CH_4$** | **$N_2O$** | **Total** |
| Default Facility | $7.8 | $0.28 | $0.00 | $8.1 | $13 | $0.37 | $0.00 | $13 | $22 | $0.51 | $0.00 | $23 |
| Project-Specific | $4.4 | $0.22 | -$0.02 | $4.6 | $7.3 | $0.29 | -$0.03 | $7.6 | $13 | $0.39 | -$0.04 | $13 |
| Difference | -$3.4 | -$0.06 | -$0.02 | -$3.5 | -$5.6 | -$0.08 | -$0.03 | -$5.7 | -$9.7 | -$0.11 | -$0.04 | -$10 |
| Percent Difference | -43% | -22% | -0% | -43% | -43% | -22% | -0% | -43% | -43% | -22% | -0% | -43% |

## CONSEQUENTIAL LCA MODELING RESULTS FOR ALL SCENARIO COMPARISONS

The sections above detailed the steps of the consequential analysis and used a single comparison set (*Defined Policies: Model Resolved* versus *Defined Policies: Existing/FID Exports*) to demonstrate example results. This section summarizes the results for all other scenarios included in the broader study. Note that due to adjustments made to the GCAM data and described in Steps 4 and 5, these results differ slightly from the GHG emissions values shown in Appendix A of the broader study.

Following the approach in Step 7, Table 22 shows the cumulative change in GHG emissions, changes in U.S. LNG Exported, and consequential GHG intensities of U.S. exports for all scenarios (baseline scenario is *Existing/FID* within each scenario). Also included is the weighted index summary change in cumulative global services, as shown in Table 3. Differences in global services are included to provide the full picture of changes resulting from the change in U.S. LNG exports. Increased U.S. LNG exports are leading to higher emissions in the non-*ExFID* scenarios as well as increased global services.

*Table 22. Cumulative consequential GHG intensities of U.S. exports, LHV, AR6, 100-yr basis*

| Scenario | Cumulative Change in GHG Emissions, 2020-2050 (Tg $CO_2e$)[a] | Cumulative Change in U.S. LNG Exported, 2020-2050 (EJ)[a] | Change in Cumulative Global Services[a,b] | Consequential GHG Intensity of U.S. LNG Exports (g $CO_2e$/MJ)[a] |
|---|---|---|---|---|
| ***Defined Policies*** | | | | |
| *DP: Hi Exp* | 1,452 | 189 | 1.0015 | 7.7 |
| *DP: MR* | 711 | 113 | 1.0008 | 6.3 |
| *DP: Hi ME Sup: MR* | 363 | 100 | 1.0005 | 3.6 |
| *DP: Hi US Sup: MR* | 1,186 | 156 | 1.0013 | 7.6 |
| *DP: Lo US Sup: MR* | 32 | 18 | 1.0001 | 1.8 |
| ***Commitments*** | | | | |
| *C (Hi CCS): Hi Exp* | 787 | 107 | 1.0009 | 7.3 |
| *C (Hi CCS): MR* | 97 | 31 | 1.0002 | 3.1 |
| *C (Mod CCS): Hi Exp* | 1,055 | 87 | 1.0008 | 12.1 |
| *C (Mod CCS): MR* | 67 | 11 | 1.0001 | 5.9 |
| ***Net Zero 2050*** | | | | |
| *NZ (Hi CCS): Hi Exp* | 324 | 93 | 1.0008 | 3.5 |
| *NZ (Hi CCS): MR* | 21 | 17 | 1.0001 | 1.2 |
| *NZ (Mod CCS): Hi Exp* | 955 | 76 | 1.0005 | 12.6 |
| *NZ (Mod CCS): MR*[39] | 0 | 0 | 1.0000 | - |

Notes:
[a] Changes for all scenarios found vs. Existing/FID within each scenario.
[b] Scenarios modeled provide different levels of global services in response to changes in U.S. LNG exports. Values are indexed to the Existing/FID results within each scenario.

For the Defined Policies scenarios, the cumulative differences in U.S. LNG exported from the *Existing/FID* to other scenarios range from 18 EJ to 189 EJ over the study period. The consequential GHG intensity per unit of U.S. LNG exported values range from 1.8 to 7.7. The *Defined Policies: Model Resolved* and *Defined Policies: High Exports* scenarios provide 0.08% to 0.15% more cumulative global services than the *Defined Policies: Existing/FID Exports* scenario baseline.

For the Commitments scenarios, the cumulative differences in U.S. LNG exported from the *Existing/FID* to other scenarios range from 11 EJ to 107 EJ over the study period. As a result, the consequential GHG intensity per unit of U.S. LNG exported values range from 3.1 to 12.1. The *High CCS* and *Mod CCS* scenarios provide 0.01% to 0.09% more cumulative global services than the *Commitments Existing/FID Exports* scenario baselines.

Finally, for the Net Zero 2050 scenario, the cumulative differences in U.S. LNG exported from the *Existing/FID Exports* to other scenarios range from 0 EJ to 93 EJ. As a result, the consequential GHG intensity per unit of U.S. LNG exported values range from 1.2 to 12.6 (not including the scenario where there is no difference in exports). The *High CCS* and *Mod CCS* scenarios provide 0.01% to 0.08% more cumulative global services than the *Net Zero 2050 Existing/FID Exports* scenario baselines.

The speciated GHG emissions inputs to the consequential GHG intensity can also be used with the 2023 SC-GHG methodology to monetize the impacts of the changes in GHG emissions associated with increased U.S. LNG exports. The base year (which can also be considered the

[39] Note that the results for the Net Zero 2050 market response scenario for moderate CCS adoption leads to an extraneous result due to the GCAM model estimation of negligible changes in LNG exports and emissions.

present value year) was chosen to be 2024 to align with the time of the study, consistent with the suggested choice aligning with a regulatory impact assessment time. The study used 2020 as the dollar year, consistent with the default year of damages provided in the framework. The SC-GHG values (in year 2020 dollars) used by the method are summarized in Appendix C-3.

Cumulative results are included in Table 23. The SC-GHG values are generally highest for the High Export scenarios within a set of scenarios, and also generally highest for *Defined Policies* scenarios, followed by *Commitments* scenarios, followed by *Net Zero 2050* scenarios.

*Table 23. Changes in cumulative social cost of greenhouse gases (SC-GHG), 2020$*

| Scenario[a] | Cumulative Change in Emissions, 2020-2050 (Tg $CO_2$e)[a,b] | | | | Cumulative Change in U.S. LNG Exported, 2020-2050 (EJ)[a] | Cumulative Change in Global Services[a,c] | Cumulative Change in SC-GHG ($billion 2020)[a] | | |
|---|---|---|---|---|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ | Total | | | 2.5% | 2.0% | 1.5 % |
| ***Defined Policies*** | | | | | | | | | |
| *DP: Hi Exp* | 1,401 | 79 | -88 | 1,452 | 189 | 1.0015 | $150 | $250 | $450 |
| *DP: MR* | 709 | 17 | -47 | 711 | 113 | 1.0008 | $74 | $130 | $220 |
| *DP: Hi ME Sup: MR* | 436 | -68 | -25 | 363 | 100 | 1.0005 | $42 | $72 | $130 |
| *DP: Hi US Sup: MR* | 1,135 | 72 | -71 | 1,186 | 156 | 1.0013 | $120 | $210 | $360 |
| *DP: Lo US Sup: MR* | 42 | -8 | -6 | 32 | 18 | 1.0001 | $3 | $6 | $11 |
| ***Commitments*** | | | | | | | | | |
| *C (Hi CCS): Hi Exp* | 870 | -95 | -25 | 787 | 107 | 1.0009 | $89 | $150 | $270 |
| *C (Hi CCS): MR* | 143 | -50 | -4 | 97 | 31 | 1.0002 | $12 | $22 | $40 |
| *C (Mod CCS): Hi Exp* | 1,088 | -60 | 0 | 1,055 | 87 | 1.0008 | $120 | $200 | $360 |
| *C (Mod CCS): MR* | 83 | -18 | 0 | 67 | 11 | 1.0001 | $8 | $14 | $25 |
| ***Net Zero 2050*** | | | | | | | | | |
| *NZ (Hi CCS): Hi Exp* | 402 | -85 | -22 | 324 | 93 | 1.0008 | $36 | $63 | $120 |
| *NZ (Hi CCS): MR* | 49 | -29 | -3 | 21 | 17 | 1.0001 | $3 | $6 | $12 |
| *NZ (Mod CCS): Hi Exp* | 1,007 | -59 | -11 | 955 | 76 | 1.0005 | $110 | $190 | $330 |
| *NZ (Mod CCS): MR* | 0 | 0 | 0 | 0 | 0 | 1.0000 | $0 | $0 | $0 |

[a] Changes for all scenarios found vs. Existing/FID within each global climate policy scenario.
[b] Values shown on IPCC AR6, 100-yr basis. Total also includes F-gases (not shown in table).
[c] Scenarios modeled provide different levels of global services in response to changes in U.S. LNG exports. Values are indexed to the Existing/FID results within each scenario.

As shown in Table 23, in the Defined Policies scenarios, increasing U.S. LNG exports are generally leading to higher cumulative $CO_2$ and $CH_4$ emissions and lower $N_2O$ emissions globally, whereas, in the Commitments and Net Zero 2050 scenarios, cumulative $CO_2$ emissions are generally increasing, while $CH_4$ and $N_2O$ emissions are generally decreasing. Similarly, the change in methane emissions are generally a small part of the total change in GHG emissions.

The changes in SC-GHG between scenarios summarized in Table 23 were also normalized per change in MJ of U.S. LNG exported. Normalized results are included in Table 24. Overall, the normalized SC-GHG ranges between 0.02 and 0.24 cents per MJ for *Defined Policies* Scenarios, 0.04 cents per MJ and 0.41 cents per MJ for *Commitments* Scenarios, and 0.02 cents per MJ and 0.43 cents per MJ in *Net Zero 2050* Scenarios.

*Table 24. Normalized changes per MJ exported in cumulative social cost of greenhouse gases*

| Scenario | Cumulative Change GHG Emissions 2020-2050 (Tg $CO_2e$)[a] | Cumulative Change in U.S. LNG Exported, 2020-2050 (EJ)[a] | Cumulative Change in Global Services[a,b] | Cumulative Change in SC-GHG per MJ (cents/MJ)[a] | | |
|---|---|---|---|---|---|---|
| | | | | Discount Rate | | |
| | | | | 2.5% | 2.0% | 1.5% |
| ***Defined Policies*** | | | | | | |
| *DP: Hi Exp* | 1,452 | 189 | 1.0015 | 0.08 | 0.14 | 0.24 |
| *DP: MR* | 711 | 113 | 1.0008 | 0.07 | 0.11 | 0.20 |
| *DP: Hi ME Sup: MR* | 363 | 100 | 1.0005 | 0.04 | 0.07 | 0.12 |
| *DP: Hi US Sup: MR* | 1,186 | 156 | 1.0013 | 0.08 | 0.13 | 0.23 |
| *DP: Lo US Sup: MR* | 32 | 18 | 1.0001 | 0.02 | 0.03 | 0.06 |
| ***Commitments*** | | | | | | |
| *C (Hi CCS): Hi Exp* | 787 | 107 | 1.0009 | 0.08 | 0.14 | 0.25 |
| *C (Hi CCS): MR* | 97 | 31 | 1.0002 | 0.04 | 0.07 | 0.13 |
| *C (Mod CCS): Hi Exp* | 1,055 | 87 | 1.0008 | 0.14 | 0.23 | 0.41 |
| *C (Mod CCS): MR* | 67 | 11 | 1.0001 | 0.07 | 0.13 | 0.23 |
| ***Net Zero 2050*** | | | | | | |
| *NZ (Hi CCS): Hi Exp* | 324 | 93 | 1.0008 | 0.04 | 0.07 | 0.12 |
| *NZ (Hi CCS): MR* | 21 | 17 | 1.0001 | 0.02 | 0.04 | 0.07 |
| *NZ (Mod CCS): Hi Exp* | 955 | 76 | 1.0005 | 0.15 | 0.24 | 0.43 |
| *NZ (Mod CCS): MR* | 0 | 0 | 1.0000 | N/A | N/A | N/A |

Notes:

[a] Changes for all scenarios found vs. Existing/FID within each global climate policy scenario.

[b] Scenarios modeled provide different levels of global services in response to changes in U.S. LNG exports. Values are indexed to the Existing/FID results within each scenario.

Following Step 8, Table 25 summarizes the consequential GHG intensities of U.S. LNG exports and project non-direct emissions values for all scenarios in this study (compared to a baseline of the *Existing/FID Exports* scenario within their global climate policy).

*Table 25. Summary of consequential GHG intensities and project non-direct emissions values for all scenarios (versus ExFID), AR6, 100-yr basis*

| Scenario | Cumulative Change in GHG Emissions 2020-2050 (Tg $CO_2e$)[a] | Cumulative Change in U.S. LNG Exported, 2020-2050 (EJ)[a] | Change in Cumulative Global Services[a,b] | Consequential GHG Intensity of U.S. LNG Exports | Project Non-Direct Emissions Factor (PNDE)[c] |
|---|---|---|---|---|---|
| | | | | Grams of Carbon Dioxide Equivalents per Megajoule of U.S. LNG Exported[a] (g $CO_2e$/MJ) | |
| *DP: Hi Exp* | 1,452 | 189 | 1.0015 | 7.7 | -6.8 |
| *DP: MR* | 711 | 113 | 1.0008 | 6.3 | -8.2 |
| *DP: Hi ME Sup: MR* | 363 | 100 | 1.0005 | 3.6 | -10.9 |
| *DP: Hi US Sup: MR* | 1,186 | 156 | 1.0013 | 7.6 | -6.9 |
| *DP: Lo US Sup: MR* | 32 | 18 | 1.0001 | 1.8 | -12.7 |
| *C (Hi CCS): Hi Exp* | 787 | 107 | 1.0009 | 7.3 | -7.2 |
| *C (Hi CCS): MR* | 97 | 31 | 1.0002 | 3.1 | -11.4 |
| *C (Mod CCS): Hi Exp* | 1,055 | 87 | 1.0008 | 12.1 | -2.4 |
| *C (Mod CCS): MR* | 67 | 11 | 1.0001 | 5.9 | -8.6 |
| *NZ (Hi CCS): Hi Exp* | 324 | 93 | 1.0008 | 3.5 | -11 |
| *NZ (Hi CCS): MR* | 21 | 17 | 1.0001 | 1.2 | -13.3 |
| *NZ (Mod CCS): Hi Exp* | 955 | 76 | 1.0005 | 12.6 | -1.9 |
| *NZ (Mod CCS): MR* | 0 | 0 | 1.0000 | - | - |

Notes:
[a] Changes for all scenarios found vs. Existing/FID within each global climate policy scenario
[b] Scenarios modeled provide different levels of global services in response to changes in U.S. LNG exports. Values are indexed to the Existing/FID results within each scenario.
[c] Assumes project direct emissions defined as including Natural Gas Upstream and Liquefaction of 14.5 g $CO_2e$/MJ.

The project non-direct emissions values are not specific to a receiving region and represent a result across all potential landing locations for LNG. Note that the consequential GHG intensity and project non-direct emissions results were aggregated in relation to estimated future volumes of exported LNG from the U.S. in the context of a global model. Project non-direct emissions results represent overall expected effects and not those of individual shipments of LNG. As shown in Table 25, the consequential GHG intensity and corresponding project non-direct emissions values are different for each scenario pairing. This study does not prescribe likelihood of one scenario pairing over another, but rather, presents the range of derived results for a set of potential future scenarios modeled by the study, see Table 1 and Appendix A for description of study scenarios.

Consequential analysis results using the IPCC AR6, 20-yr GWP values are summarized in Table 26. As further described in Appendix C-2, this required converting all initially received GCAM values to the AR6, 20-yr basis, and aligning them with the NETL natural gas baseline study values on an AR6, 20-yr basis. The project direct emissions, comprised of natural gas upstream and liquefaction emissions, was also recalculated on an AR6, 20-yr basis, and found to be 21.3 g $CO_2e$/MJ.

*Table 26. Summary of consequential GHG intensities and project non-direct emissions values for all scenarios (versus ExFID), AR6, 20-yr basis*

| Scenario | Cumulative Change in GHG Emissions 2020-2050 (Tg $CO_2e$)[a] | Cumulative Change in U.S. LNG Exported, 2020-2050 (EJ)[a] | Change in Cumulative Global Services[a,b] | Consequential GHG Intensity of U.S. LNG Exports | Project Non-Direct Emissions Factor (PNDE)[c] |
|---|---|---|---|---|---|
| | | | | Grams of Carbon Dioxide Equivalents per Megajoule of U.S. LNG Exported[a] (g $CO_2e$/MJ) | |
| *DP: Hi Exp* | 1,533 | 189 | 1.0015 | 8.1 | -13.1 |
| *DP: MR* | 718 | 113 | 1.0008 | 6.3 | -14.9 |
| *DP: Hi ME Sup: MR* | 252 | 100 | 1.0005 | 2.5 | -18.8 |
| *DP: Hi US Sup: MR* | 1,262 | 156 | 1.0013 | 8.1 | -13.2 |
| *DP: Lo US Sup: MR* | 18 | 18 | 1.0001 | 1.0 | -20.2 |
| *C (Hi CCS): Hi Exp* | 626 | 107 | 1.0009 | 5.8 | -15.4 |
| *C (Hi CCS): MR* | 17 | 31 | 1.0002 | 0.6 | -20.7 |
| *C (Mod CCS): Hi Exp* | 943 | 87 | 1.0008 | 10.8 | -10.4 |
| *C (Mod CCS): MR* | 38 | 11 | 1.0001 | 3.4 | -17.9 |
| *NZ (Hi CCS): Hi Exp* | 176 | 93 | 1.0008 | 1.9 | -19.4 |
| *NZ (Hi CCS): MR* | -24 | 17 | 1.0001 | -1.4 | -22.7 |
| *NZ (Mod CCS): Hi Exp* | 845 | 11.2 | 1.0005 | 11.2 | -10.1 |
| *NZ (Mod CCS): MR* | 0 | 0 | 1.0000 | - | - |

Notes:
[a] Changes for all scenarios found vs. Existing/FID within each global climate policy scenario
[b] Scenarios modeled provide different levels of global services in response to changes in U.S. LNG exports. Values are indexed to the Existing/FID results within each scenario.
[c] Assumes project direct emissions defined as including Natural Gas Upstream and Liquefaction of 14.5 g $CO_2e$/MJ.

In the *Defined Policies* scenarios, higher LNG exports generally lead to net higher cumulative $CH_4$ emissions, while in Commitments and Net Zero 2050 scenarios, cumulative $CH_4$ emissions are decreasing. As the GWP value for $CH_4$ is roughly 2.7 times higher for AR6, 20-yr than AR6, 100-yr, scenarios with significant $CH_4$ emissions increases or decreases (as compared to their *Existing/FID* baseline) have their cumulative $CH_4$differences amplified as a result. In one scenario (*Net Zero 2050 (High CCS): Model Resolved*), the effect is that the amplified value of $CH_4$ emissions results in a net change in GHG emissions that goes from positive (in AR6, 100-yr) to negative (in AR6, 20-yr), making the consequential GHG intensity negative (-1.4 g $CO_2e$/MJ) instead of the previous +1.2 g $CO_2e$/MJ. Likewise, the project non-direct emissions values on the AR6, 20-yr basis are more negative than those in AR6, 100-yr, because the project direct emissions value is increased from the 14.5 g $CO_2e$/MJ used in the AR6, 100-yr basis to 21.3 g $CO_2e$/MJ on an AR6, 20-yr basis.

## A. Individual Project Direct Emissions Breakeven GHG Performance

The project direct emissions and project non-direct emissions can be used to calculate a breakeven rate, which would be the percent change difference between an individual project's emissions and the default factors that would result in a global consequential intensity of zero (i.e., 0 g $CO_2e$/MJ). As defined above, the U.S. average performance values are the 9.2 g $CO_2e$/MJ for upstream and 5.3 g $CO_2e$/MJ for liquefaction (the sum of which result in an average U.S. project direct emissions of 14.5). The project non-direct emissions values from Table 25 can be used with the average project direct emissions values to estimate the breakeven percent as shown here:

$$Breakeven\ (\%) = \frac{Absolute\ Value\ of\ Project\ Nondirect\ Emissions - Average\ Project\ Direct\ Emissions}{Average\ Project\ Direct\ Emissions} \times 100$$

Table 27 shows the resulting breakeven percent changes in project direct emissions needed for all scenarios modeled (versus ExFID) on an AR6,100-yr basis.

*Table 27. Breakeven percent changes (versus ExFID), AR6, 100-yr basis*

| Scenario[a] | Cumulative Change in GHG Emissions, 2020-2050 (Tg $CO_2$e)[b] | Cumulative Change in U.S. LNG Exported, 2020-2050 (EJ)[b] | Change in Global Services[b,c] | Breakeven GHG Emissions Change in Project Direct Emissions[b] |
|---|---|---|---|---|
| *DP: Hi Exp* | 1,452 | 189 | 1.0015 | -53% |
| *DP: MR* | 711 | 113 | 1.0008 | -43% |
| *DP: Hi ME Sup: MR* | 363 | 100 | 1.0005 | -25% |
| *DP: Hi US Sup: MR* | 1,186 | 156 | 1.0013 | -53% |
| *DP: Lo US Sup: MR* | 32 | 18 | 1.0001 | -13% |
| *C (Hi CCS): Hi Exp* | 787 | 107 | 1.0009 | -51% |
| *C (Hi CCS): MR* | 97 | 31 | 1.0002 | -21% |
| *C (Mod CCS): Hi Exp* | 1,055 | 87 | 1.0008 | -84% |
| *C (Mod CCS): MR* | 67 | 11 | 1.0001 | -40% |
| *NZ (Hi CCS): Hi Exp* | 324 | 93 | 1.0008 | -24% |
| *NZ (Hi CCS): MR* | 21 | 17 | 1.0001 | -8% |
| *NZ (Mod CCS): Hi Exp* | 955 | 11.2 | 1.0005 | -87% |

Notes:

[a] Scenario *NZ (Mod CCS): MR* is not presented here because model-resolved LNG exports do not exceed existing/FID levels in this scenario.

[b] Changes for all scenarios found vs. Existing/FID within each global climate policy scenario.

[c] Scenarios modeled provide different levels of global services in response to changes in U.S. LNG exports. Values are indexed to the Existing/FID results within each scenario.

To illustrate a specific example for the AR6, 100-yr results, for *Defined Policies: Model Resolved*, the project direct emissions would need to be 43% lower to breakeven (the project direct emissions would have to decrease from 14.5 g $CO_2$e/MJ to 8.2 g $CO_2$e/MJ). In that scenario the project direct emissions would be 8.2 g $CO_2$e/MJ and would offset the project non-direct emissions of -8.2 g $CO_2$e/MJ, so the consequential GHG intensity would be zero. These results show that, depending on the assumed scenario, the project direct emissions would need to be reduced by at least 8% and up to 87% for U.S. LNG exports to have a zero consequential GHG intensity (i.e., to result in no net increase in global GHG emissions, holding all else equal).

Building on the breakeven analysis for *Defined Policies: Model Resolved* and its focus on the tradeoff between project direct and project non-direct emissions, the project direct upstream emissions of 9.2 g $CO_2$e/MJ (production through transmission) include 3.6 g $CO_2$e/MJ associated with methane emissions. The methane emissions correspond to an upstream methane emission rate of 0.56% (production through transmission). For example, if the upstream methane emission rate for a specific project was reported as 1.4%, the upstream methane emissions contribution to the project direct upstream emissions would increase by 5.4 g $CO_2$e /MJ to 9.0 g $CO_2$e/MJ, resulting in project direct upstream emissions of 14.6 g $CO_2$e/MJ. Combined with the average project direct liquefaction emissions (5.3 g $CO_2$e/MJ), the project direct emissions would be 19.9 g $CO_2$e/MJ. In order to breakeven, the project direct emissions would have to be lowered from 19.9 g $CO_2$e/MJ to 8.2 g $CO_2$e/MJ. The required project direct emission reductions (11.7 g $CO_2$e/MJ) are greater than the average project direct liquefaction emissions. The implication is that a project with upstream emissions of 1.4% would not breakeven even if its liquefaction

process had no emissions while the upstream natural gas methane emission rate was 1.4%. In such a case, a completely carbon neutral liquefaction facility would result in a consequential GHG emissions intensity of 6.4 g $CO_2$e/MJ, a 0.1 g $CO_2$e/MJ increase in GHG emissions per MJ of natural gas exported (i.e., Upstream Project Direct Emissions + Liquefaction Project Direct Emissions + Project Non-Direct Emissions = Consequential GHG Emissions Intensity; or 14.6 + 0 – 8.2 = 6.4).

Table 28 summarizes the breakeven analysis on an AR6, 20-yr GHG emissions basis.

*Table 28 Breakeven percent changes (versus ExFID), AR6, 20-yr basis*

| Scenario[a] | Cumulative Change in GHG Emissions, 2020-2050 (Tg $CO_2$e)[b] | Cumulative Change in U.S. LNG Exported, 2020-2050 (EJ)[b] | Change in Global Services[b,c] | Breakeven GHG Emissions Change in Project Direct Emissions[b] |
|---|---|---|---|---|
| *DP: Hi Exp* | 1,533 | 189 | 1.0015 | -38% |
| *DP: MR* | 718 | 113 | 1.0008 | -30% |
| *DP: Hi ME Sup: MR* | 252 | 100 | 1.0005 | -12% |
| *DP: Hi US Sup: MR* | 1,262 | 156 | 1.0013 | -38% |
| *DP: Lo US Sup: MR* | 18 | 18 | 1.0001 | -5% |
| *C (Hi CCS): Hi Exp* | 626 | 107 | 1.0009 | -27% |
| *C (Hi CCS): MR* | 17 | 31 | 1.0002 | -3% |
| *C (Mod CCS): Hi Exp* | 943 | 87 | 1.0008 | -51% |
| *C (Mod CCS): MR* | 38 | 11 | 1.0001 | -16% |
| *NZ (Hi CCS): Hi Exp* | 176 | 93 | 1.0008 | -9% |
| *NZ (Hi CCS): MR* | -24 | 17 | 1.0001 | +7% |
| *NZ (Mod CCS): Hi Exp* | 845 | 11.2 | 1.0005 | -53% |

Notes:

[a] Scenario *NZ (Mod CCS): MR* is not presented here because model-resolved LNG exports do not exceed existing/FID levels in this scenario.

[b] Changes for all scenarios found vs. Existing/FID within each global climate policy scenario.

[c] Scenarios modeled provide different levels of global services in response to changes in U.S. LNG exports. Values are indexed to the Existing/FID results within each scenario.

To illustrate a specific example for the AR6, 20-yr results, for *Defined Policies: Model Resolved*, the project direct emissions would need to be 30% lower to breakeven (the project direct emissions would have to decrease from 21.3 g $CO_2$e/MJ to 14.9 g $CO_2$e/MJ). In that scenario the decreased project direct emissions would be 14.9 g $CO_2$e/MJ and would offset the project non-direct emissions of -14.9 g $CO_2$e/MJ, so the consequential GHG intensity would be zero. These results show that, depending on the assumed scenario, the project direct emissions would need to be reduced by up to 53%, or in one scenario increase by 7%, for U.S. LNG exports to have a zero consequential GHG.

## B. Evaluation of Model Sensitivity to Key Performance Attributes

Sensitivity analyses were also conducted to evaluate the potential impact on the scenario results if key model aspects were underrepresented in the analysis. Specifically, upstream methane intensity of global natural gas production and representation of global liquefaction facility operating emissions were evaluated. In each sensitivity analysis case, GCAM results have been modified exogenously, as opposed to doing additional model runs in GCAM.

## 1. Sensitivity Analysis 1: Upstream Methane Emissions Intensity

This analysis considers the sensitivity of the consequential results to the assumed upstream natural gas methane emissions rates in GCAM. To accomplish this, methane emissions rates for the U.S. and the other natural gas producing regions in GCAM were adjusted using an index based on the relative change in the U.S. methane emissions rate.

To accomplish this, the GCAM-NETL-aligned U.S. upstream emissions estimates were aligned with the 2024 NETL Natural Gas Baseline on a speciated basis. As part of the alignment, U.S. upstream $CH_4$ emissions were scaled to match the 0.56% NETL methane emissions rate while keeping total $CO_2e$ emissions of the natural gas sector consistent with the GCAM results. This provides a distinct and aligned estimate of upstream NG sector emissions for the sensitivity analysis.

The range of U.S. upstream natural gas sector methane emission rates in this analysis is from 0.2% (about one third of the NETL estimated rate) to 2.8% (a value at the high end of recently completed studies) and is done at increments of 0.2%. Table 29 includes the assumed U.S. methane emissions rate for the sensitivity cases and the relative level of upstream methane. The relative level of methane is the percentage applied to non-U.S. methane emissions rates to scale them for this sensitivity analysis. This approach preserves the unique country/regional methane emission rate differences within GCAM.

Table 29 summarizes the consequential GHG intensity resulting from the assumed changes in the upstream natural gas production methane emissions rates applied globally for *Defined Policies: Model Resolved* versus *Defined Policies: Existing/FID Exports*. In all other scenario pairings, the contribution of methane emissions are lower (or are decreasing with respect to increased U.S. exports) and therefore exhibit less sensitivity to changes in methane intensity of natural gas production.

Note that in this comparison while the increase in methane emissions increases overall global GHG emissions, the increase is happening in both scenarios. Since the consequential intensity is calculated based on the difference between the scenarios, the increased methane emissions have limited impact on the intensity (e.g., if the same number is added to two different linear equations, the difference between the two equations remains the same). To the extent methane emissions associated with increased U.S. LNG exports are increasing, there would be offsetting changes in the global energy system as a result of substitution of the U.S. LNG for natural gas and other sources of energy.

*Table 29. Sensitivity analysis for upstream methane emissions rate (U.S. base is 0.56%), DP:MR versus DP: ExFID*

| U.S. Methane Emission Rate | Relative Level of Upstream Methane | Consequential GHG Intensity (g $CO_2e$/MJ) | Percent Change in Consequential GHG Intensity from Base |
|---|---|---|---|
| 0.20% | 35.7% | 6.3 | 0% |
| 0.40% | 71.4% | 6.3 | 0% |
| 0.60% | 107.1% | 6.3 | 0% |
| 0.80% | 142.9% | 6.3 | 0% |
| 1.00% | 178.6% | 6.3 | 0% |
| 1.20% | 214.3% | 6.3 | 0% |
| 1.40% | 250.0% | 6.3 | 0% |
| 1.60% | 285.7% | 6.3 | 0% |
| 1.80% | 321.4% | 6.3 | 0% |

| | | | |
|---|---|---|---|
| 2.00% | 357.1% | 6.3 | 0% |
| 2.20% | 392.9% | 6.3 | 0% |
| 2.40% | 428.6% | 6.4 | 2% |
| 2.60% | 464.3% | 6.4 | 2% |
| 2.80% | 500.0% | 6.4 | 2% |

Note: Baseline U.S. Methane Emissions Rate is 0.56%.

## 2. Sensitivity Analysis 2: Liquefaction Plant Emissions Representation within GCAM

Within GCAM, GHG emissions from liquefaction are modeled in an aggregate *other industrial energy use* sector that comprises many activities. LNG-relevant processes and activities are only one of many modeled in each sector. Unlike other sectors in GCAM where activities are modeled from interactions with other sectors, growth in this sector is generally modeled as a function of exogenously defined GDP (i.e., if GDP goes up then activity and associated emissions increase comparably). As part of this study, the connections between GHG emissions and GDP growth in GCAM were compared for several regions expected to provide significant LNG supplies over time, to assess how well the sectoral results from GCAM might be modeling expected increases in LNG activities. However, this analysis was unable to estimate a specific amount by which the values are under (or over) estimated in a particular region. As a result, instead of adjusting GCAM sectoral values (e.g., as done above for upstream natural gas methane intensity), a sensitivity analysis was conducted to show the effects on model results associated with liquefaction processes.

In this sensitivity case, the U.S. average performance values referenced above for liquefaction (5.3 g $CO_2$e/MJ) are added exogenously for all global LNG exports for all regions, not just those exported by the U.S. This is done because the GCAM model is otherwise representing global emissions of all LNG produced, not just those exported by the U.S. While emissions are added for all LNG, the denominator for the consequential GHG intensity remains per additional unit of U.S. LNG exported. This case adds these liquefaction emissions on top of the existing baseline emissions of the modeled scenario.

Table 30 summarizes the original results from Table 22 (referred to as the base case) as well as those from the sensitivity case (accounting for additional emissions for liquefaction). While it might be expected that the consequential results simply would shift by the intensity of emissions added, (i.e., by 5.3 g $CO_2$e/MJ), this is not the case because while all global LNG has its emissions intensity increased, the new result is divided only by the U.S. LNG exported. As a result, the net differences are smaller than the 5.3 g $CO_2$e/MJ value. For example, the values for the *Defined Policies: Model Resolved* scenario are 6.3 g $CO_2$e/MJ in the base case, and 10 g $CO_2$e/MJ in the Sensitivity Case, a difference of 3.7 g $CO_2$e/MJ as opposed to the 5.3 g $CO_2$e/MJ that were added per unit of global LNG produced.

Generally, even in a worst case of adding additional full liquefaction emissions to the base case GHG emissions, the project non-direct emissions values remain negative. There are only two exceptions – the *Commitments (Moderate CCS): High Exports* and the *Net Zero 2050 (Moderate CCS): High Exports* scenarios.

*Table 30. Sensitivity analysis results for additional liquefaction emissions*

| Scenario[a] | Cumulative Change in U.S. LNG Exported, 2020-2050 (EJ)[b] | Change in Global Services[b,c] | Base Case | Sensitivity Case: Added Liquefaction | Base Case | Sensitivity Case: Added Liquefaction |
|---|---|---|---|---|---|---|
| | | | Consequential GHG Intensity per Unit U.S. LNG Exported (g $CO_2e$/MJ)[b] | | Project Non-Direct Emissions (g $CO_2e$/MJ)[b] | |
| ***Defined Policies*** | | | | | | |
| *DP: Hi Exp* | 189 | 1.0015 | 7.7 | 11.8 | -6.8 | -2.7 |
| *DP: MR* | 113 | 1.0008 | 6.3 | 9.9 | -8.2 | -4.6 |
| *DP: Hi ME Sup: MR* | 100 | 1.0005 | 3.6 | 6.1 | -10.9 | -8.5 |
| *DP: Hi US Sup: MR* | 156 | 1.0013 | 7.6 | 11.6 | -6.9 | -2.9 |
| *DP: Lo US Sup: MR* | 18 | 1.0001 | 1.8 | 4.1 | -12.7 | -10.4 |
| ***Commitments*** | | | | | | |
| *C (Hi CCS): Hi Exp* | 107 | 1.0009 | 7.3 | 11.2 | -7.2 | -3.3 |
| *C (Hi CCS): MR* | 31 | 1.0002 | 3.1 | 5.9 | -11.4 | -8.6 |
| *C (Mod CCS): Hi Exp* | 87 | 1.0008 | 12.1 | 16.4 | -2.4 | +1.9 |
| *C (Mod CCS): MR* | 11 | 1.0001 | 5.9 | 8.4 | -8.6 | -6.1 |
| ***Net Zero 2050*** | | | | | | |
| *NZ (Hi CCS): Hi Exp* | 324 | 1.0008 | 3.5 | 7.5 | -11 | -7.1 |
| *NZ (Hi CCS): MR* | 21 | 1.0001 | 1.2 | 3.7 | -13.3 | -10.8 |
| *NZ (Mod CCS): Hi Exp* | 955 | 1.0005 | 12.6 | 18.1 | -1.9 | +3.6 |

Notes:

[a] Scenario *NZ (Mod CCS): MR* is not presented here because model-resolved LNG exports do not exceed existing/FID levels in this scenario.

[b] Changes for all scenarios found vs. Existing/FID within each global climate policy scenario.

[c] Scenarios modeled provide different levels of global services in response to changes in U.S. LNG exports. Values are indexed to the Existing/FID results within each scenario.

## C. Market Drivers for Changes in GHG Intensity of U.S. LNG Exports

NETL completed an additional analysis to evaluate the market drivers of the change in global GHG emissions in GCAM with respect to changes in U.S. LNG export GHG intensity when providing an equivalent service to society.

### 1. Change in Global Services

As summarized in Table 3, in addition to volumes of LNG exported and GHG emissions for each scenario, the GCAM model also provides estimated outputs of various services including energy, transportation, commodity materials, and fertilizers. The results from GCAM show that as higher levels of U.S. LNG are exported, global services increase. An abridged summary of some of the aggregated service categories (now cumulative for all years 2020-2050, not just model years) is provided in Table 31. The first row shows that the *Defined Policies: Existing/FID Exports* scenario provides 10,158 EJ of energy services globally, and the *Defined Policies: Model Resolved* and *DP:HighExp* scenarios provide higher levels of energy services, commensurate with more U.S. LNG being put into the global market.

*Table 31. Summary of GCAM modeled services provided in selected defined policies scenarios*

| Aggregate Economic Sector | Type of Service Output (Unit) | *DP: ExFID* | *DP: MR* | *DP: High Exp* |
|---|---|---|---|---|
| Energy | Energy Services (EJ) | 10,158 | 10,168 | 10,176 |
| Industrial | Commodity Products Million Metric Tons (MT) | 175,861 | 175,926 | 175,979 |
| | Nitrogen Fertilizer Million Metric Tons (MT) | 5,079 | 5,077 | 5,076 |
| Transportation | Freight Transportation (Billion-Ton-Kilometers) | 6,742,516 | 6,745,127 | 6,747,250 |
| | Passenger Transportation (Billion-Passenger-Kilometers) | 7,863,606 | 7,863,998 | 7,864,321 |
| Weighted Index | | 1.0000 | 1.0008 | 1.001 |

The results presented for the consequential LCA part of the study were estimated with the values in Table 31, i.e., those that show that increased LNG leads to increased levels of services provided (and will now be referred to as "increased services" results).

## 2. GHG Intensity of U.S. LNG Exports per Unit of Global Services (Equivalent Unit of Service)

As a result of the identified difference in services provided between scenarios within global climate policies, an additional analysis was performed to quantify the effect of this difference on the model results. A consequential LCA, unlike an attributional LCA, does not have to maintain functional equivalence but must report the difference in the function (in this case, the services provided). In this additional analysis, the GHG emissions are compared based on the same level of global services provided. This helps explore how replacing one product or service with another affects emissions, both directly and indirectly, to offer the same service to society.

In this additional analysis, the results of the increased services scenario models were adjusted to provide equivalent levels of global services. Table 32 expands the summarized results for *Defined Policies: Model Resolved* and *Defined Policies: Existing/FID Exports*. The consequential GHG emissions per unit of U.S. LNG as derived above (for the case of increased services provided) would be +6.3 g $CO_2$e/MJ, due to a 113 EJ difference in cumulative LNG exported and a cumulative difference of 711 Tg $CO_2$e of GHG emissions between the cases. However, there is also a cumulative difference of 9.7 EJ more global energy services provided in the *Defined Policies: Model Resolved* scenario versus *Defined Policies: Existing/FID Exports*. This means that the *Defined Policies: Model Resolved* scenario is providing more global services to society as compared to the *Defined Policies: Existing/FID Exports* scenario. This was a general finding across all scenarios when compared to the ExFID scenario, and not just *Defined Policies: Model Resolved* versus *Defined Policies: Existing/FID Exports*.

*Table 32. Cumulative (2020-2050) GCAM results for DP:ExFID and DP:MR (with increased services)*

| Scenario | U.S. LNG Exports (EJ) | Change in U.S. LNG Exports (EJ) | Global Energy Services (EJ) | Change in Global Energy Services (EJ) | GHG Emissions (Tg $CO_2$e) | Change in GHG Emissions (Tg $CO_2$e) | Consequential GHG Intensity (g $CO_2$e/MJ) |
|---|---|---|---|---|---|---|---|
| *DP: ExFID* | 227.4 | - | 10,158 | - | 1,552,340 | - | - |
| *DP: MR* | 340.6 | 113.2 | 10,168 | **9.7** | 1,553,051 | 710.8 | **6.3** |

To make these two scenarios "equivalent on a functional unit basis of services delivered", since the *Defined Policies: Model Resolved* scenario provides a higher level of global services (9.7 EJ), its U.S. LNG export volume and GHG emissions values are linearly scaled to meet the lower energy service levels of *Defined Policies: Existing/FID Exports*. In doing so, the difference across all service levels is found, and by assumption, the GHG emissions were scaled down by the same difference.[40]

Using the derived weighted index value from Table 31 of 1.0008 as a scaling factor for changes in global services, results for *Defined Policies: Model Resolved* were scaled down for all service categories to meet the assumed weighted average level for *Defined Policies: Existing/FID Exports*. Global EJ of service supplied are scaled from 10,168 to 10,158 (making them equal), leading to updated estimates for *Defined Policies: Model Resolved* of 112.9 EJ of U.S. LNG exported, and 1,551,825 Tg of $CO_2$e emissions, as shown in Table 33.

In making these adjustments, both the numerator and denominator of the consequential GHG intensity per unit U.S. LNG are changed. The cumulative GHG emissions difference is now negative (-515 Tg, was positive before), since emissions of *Defined Policies: Model Resolved* are now less than *Defined Policies: Existing/FID Exports*, and the cumulative U.S. LNG Exported is slightly lower than before (112.9 EJ instead of 113.2 EJ). Overall, for this example, the equivalent services-adjusted consequential GHG intensity per unit of LNG is now -4.6 g $CO_2$e/MJ for *Defined Policies: Model Resolved*.

The most prominent effect of this scaling down of GHG emissions is that the GHG emissions of the *Defined Policies: Model Resolved* scenario is lower than the *Defined Policies: Existing/FID Exports* scenario, suggesting that when excluding increases in global services, U.S. LNG substitutions for other energy services results in a net decrease in GHG intensity. In other words, U.S. LNG substitution in foreign markets results in lower global GHG emissions when accounting for all changes in energy services.

*Table 33. Summary of GCAM results for DP:ExFID and DP:MR (with equivalent services)*

| Scenario | U.S. LNG Exports (EJ) | Change in U.S. LNG Exports (EJ) | Global Energy Services (EJ) | Change in Global Energy Services (EJ) | GHG Emissions (Tg $CO_2$e) | Change in GHG Emissions (Tg $CO_2$e) | Consequential GHG Intensity (g $CO_2$e/MJ) |
|---|---|---|---|---|---|---|---|
| *DP: ExFID* | 227.4 | - | 10,158 | - | 1,552,340 | - | - |
| *DP: MR* | **340.4** | **112.9** | **10,158** | **0** | **1,551,825** | **-515.4** | **-4.6** |

Table 34 shows a summary of equivalent services-adjusted consequential GHG intensity values per unit of LNG exported for all scenarios, following the method presented above.

[40] The GCAM model provides outputs of various services including energy, transportation, commodity materials, and a weighted-average metric was provided by PNNL to help consider an appropriate scaling factor encompassing all services provided, not just those provided by energy (see Appendix C-2 for details).

*Table 34. Cumulative consequential GHG intensities of U.S. exports (LHV, AR6, 100-yr, equivalent services basis)*

| Scenario[a] | Cumulative Change in GHG Emissions, 2020-2050 (Tg $CO_2e$)[b] | Cumulative Change in U.S. LNG Exported, 2020-2050 (EJ)[b] | Change in Global Services[b,c] | Consequential GHG Intensity per Unit U.S. LNG Exported (g $CO_2e$/MJ)[b] |
|---|---|---|---|---|
| ***Defined Policies*** | | | | |
| *DP: Hi Exp* | -838 | 188 | 0 | -4.5 |
| *DP: MR* | -515 | 113 | 0 | -4.6 |
| *DP: Hi ME Sup: MR* | -364 | 100 | 0 | -3.6 |
| *DP: Hi US Sup: MR* | -778 | 115 | 0 | -5.0 |
| *DP: Lo US Sup: MR* | -119 | 18 | 0 | -6.8 |
| | | | | |
| ***Commitments*** | | | | |
| *C (Hi CCS): Hi Exp* | -379 | 107 | 0 | -3.6 |
| *C (Hi CCS): MR* | -156 | 31 | 0 | -5.0 |
| *C (Mod CCS): Hi Exp* | 114 | 86 | 0 | +1.7 |
| *C (Mod CCS): MR* | -3 | 11 | 0 | -0.3 |
| | | | | |
| ***Net Zero 2050*** | | | | |
| *NZ (Hi CCS): Hi Exp* | -489 | 93 | 0 | -5.3 |
| *NZ (Hi CCS): MR* | -75 | 17 | 0 | -4.4 |
| *NZ (Mod CCS): Hi Exp* | 496 | 76 | 0 | +6.6 |

Notes:
[a] Scenario *NZ (Mod CCS): MR* is not presented here because model-resolved LNG exports do not exceed existing/FID levels in this scenario.
[b] Changes for all scenarios found vs. Existing/FID within each global climate policy scenario.
[c] Scenarios modeled provide different levels of global services in response to changes in U.S. LNG exports. Values are indexed to the Existing/FID results within each scenario.

The consequential GHG intensity per unit LNG generally switches from positive to negative for equivalent service adjusted scenarios (except for two of them). This occurs because the GCAM model results between scenarios, especially for GHG emissions, are very similar (within 1%) and tend to only vary by small amounts, even when cumulative over the 2020-2050 period. By making the scaling adjustment, what were small positive changes in emissions values become negative change emissions values when compared to the *ExFID* baselines.

By revisiting the results for the *Defined Policies: Model Resolved* versus *Defined Policies: Existing/FID Exports* scenario analysis above, the original (increased services) results were based on a cumulative difference of 711 Tg $CO_2e$ (*Defined Policies: Model Resolved* higher than *Defined Policies: Existing/FID Exports*). In scaling the scenario results to an equivalent services basis, it is revealed that 515 Tg of emissions were substituted for providing energy services and thus the difference (1,226 Tg) was associated with providing additional energy to society.

## 3. Summary of Market Drivers of Total Consequential GHG Intensity of U.S. LNG Exports

For additional comparative context, Tables 35 and 36 provide direct attributional life cycle GHG emissions and direct and indirect emissions from market effects from increased U.S. LNG exports. Attributional life cycle GHG emissions from production, export, and end use of the fuel in an Asian destination market is presented in Table 35 assuming 100% combustion of U.S. LNG exports with unabated emissions at the point of end use (i.e., no carbon capture and storage (CCS) installed at point of end use). The illustrative attributional life cycle GHG emissions profile has 76 g

$CO_2$e/MJ of LNG exported.[41] This attributional GHG emission profile would represent the expected contribution to global emissions if 100% of U.S. LNG exports resulted in an equivalent increase in global services, without any market substitution. To put this in the terms of exports, for 1 Bcf/d of LNG exported to an Asian destination market, the annual unabated direct life cycle GHG emissions would total up to 27 Tg $CO_2$e.

Multiplying the total increase in U.S. LNG export by the attributional profile from production through end use equals the total direct GHG emissions from increased U.S. LNG exports when market effects are not accounted for (i.e., an approach similar to those of past studies).[42] For example, comparing *Model Resolved* to *Existing/FID Exports* levels in the *Defined Policies* scenario, the direct life cycle GHG emissions from production, export, and end use (assuming 100% combustion without CCS) of increased U.S. LNG exports would cumulatively (2020-2050) contribute 8,588 Tg $CO_2$e before accounting for market effects. In 2050, direct life cycle GHG emissions from all modeled U.S. LNG exports (56.3 Bcf/d) would be approximately 1,500 Tg $CO_2$e before accounting for market effects.

Consequential modeling of direct and indirect market effects provided by the GCAM model determined that both market substitution and increased global services occur when the supply of U.S. LNG is increased to the global market, compared to the *Existing/FID* levels for each scenario. The section above, *GHG Intensity of U.S. LNG Exports per Unit of Global Services (Equivalent Unit of Service)*, summarized the net market effects from market substitution only (excluding increased global services). The market substitution effect is larger when representing the direct life cycle GHG emissions from increased exports and accounting for the resulting change from direct and indirect market effects. This value is reported in Tables 35 and 36 as the *Cumulative Change in Direct Attributional Emissions of Direct and Indirect Market Substitution Effects only, 2020 – 2050* and is obtained by determining the difference between the cumulative change in direct GHG emissions and the cumulative change in GHG emissions from Table 34 on an equivalent services basis (also reproduced in Table 35 and Table 36 below).

Combining the net market substitution effects with the change in GHG emissions from increased global services, the result equals the cumulative change in GHG emissions as determined in Step 7 above and reported in Table 22.

Table 36 summarizes the direct and indirect life cycle GHG emissions contributions if 100% of U.S. LNG exports were consumed at end use facilities equipped with 90% carbon capture equipment and permanent sequestration of the captured carbon dioxide to prevent release to the atmosphere. The illustrative attributional life cycle GHG emissions profile of U.S. LNG consumed in an Asian market with 90% carbon capture on end use combustion is modeled as 30 g $CO_2$e/MJ of LNG exported.

Tables 35 and 36 provide bounding perspectives based on the end use of U.S.LNG exported fuel being combusted without or with CCS. The consequential result determined from the GCAM model accounts for the variations in both end use destinations and end use applications. These tables are intended to help facilitate an understanding of consequential market effects in context of the attributional GHG emissions that result from production, export, and use of increased U.S. LNG exports for each scenario pairing.

---

[41] The attributional values found for use in this section were calculated using the natural gas upstream and liquefaction values updated in this study for the year 2020, the end use combustion values from the 2020 NETL Natural Gas Report (Khutal et al, 2024), and the use and losses of gas and GHG emissions for ocean shipping through regasification values from the 2019 NETL LNG Update (Roman-White et al, 2019). The combustion cases are representative of F and H-class NGCC plants (without CCS and with 90% CCS) from the 2020 (Khutal et al, 2024) study. The 90% CCS case was selected to match those of the GCAM model.
[42] See, for example, Roman-White et al, 2019.

*Table 35. Summary of market drivers of total consequential GHG intensity of increased U.S. LNG exports, cumulative change, 2020 - 2050 (LHV, AR6, 100-yr), direct emissions end use of U.S. LNG represented as unabated combustion (no CCS)*

| Scenario[a] | Cumulative Change in U.S. LNG Exported, 2020-2050 (EJ)[b,c] | Cumulative Change in Direct Attributional Emissions from Increased U.S. LNG Exports if 100% Combusted w/o CCS End Use, 2020-2050 (Tg $CO_2e$)[b,d] | Cumulative Change in Direct Attributional Emissions of Direct and Indirect Market Substitutions, 2020-2050 (Tg $CO_2e$)[b,e] | Cumulative Change in Direct and Indirect GHG Emissions Market Substitution Effects Only, 2020-2050 (Tg $CO_2e$)[b,f] | Cumulative Change in Indirect GHG Emissions from Increased Global Services Effects Only, 2020-2050 (Tg $CO_2e$)[b,g] | Cumulative Change in GHG Emissions, 2020-2050 (Tg $CO_2e$)[b,h,i] |
|---|---|---|---|---|---|---|
| ***Defined Policies*** | | | | | | |
| *DP: Hi Exp* | 188 | 14,288 | -15,126 | -838 | 2,290 | 1,452 |
| *DP: MR* | 113 | 8,588 | -9,103 | -515 | 1,226 | 711 |
| *DP: Hi ME Sup: MR* | 100 | 7,600 | -7,964 | -364 | 727 | 363 |
| *DP: Hi US Sup: MR* | 115 | 8,740 | -9,518 | -778 | 1,964 | 1,186 |
| *DP: Lo US Sup: MR* | 18 | 1,368 | -1,487 | -119 | 151 | 32 |
| ***Commitments*** | | | | | | |
| *C (Hi CCS): Hi Exp* | 107 | 8,132 | -8,511 | -379 | 1,166 | 787 |
| *C (Hi CCS): MR* | 31 | 2,356 | -2,512 | -156 | 253 | 97 |
| *C (Mod CCS): Hi Exp* | 86 | 6,536 | -6,422 | 114 | 1,169 | 1,055 |
| *C (Mod CCS): MR* | 11 | 836 | -839 | -3 | 70 | 67 |
| ***Net Zero 2050*** | | | | | | |
| *NZ (Hi CCS): Hi Exp* | 93 | 7,068 | -7,557 | -489 | 813 | 324 |
| *NZ (Hi CCS): MR* | 17 | 1,292 | -1,367 | -75 | 96 | 21 |
| *NZ (Mod CCS): Hi Exp* | 76 | 5,776 | -5,280 | 496 | 459 | 955 |

Notes:

[a] Scenario *NZ (Mod CCS): MR* is not presented here because model-resolved LNG exports do not exceed existing/FID levels in this scenario.

[b] Changes for all scenarios found vs. *Existing/FID* within each global climate policy scenario.

[c] Conversion of annual values from EJ/year to Bcf/d is 1:2.7759

[d] Assumes every EJ of U.S. LNG exported is combusted at end use and released to the atmosphere (no CCS). Oceans shipping was modeled as 100% to Asian Market (27,500 nautical miles, round trip). Attributional life cycle result (76 g $CO_2e$/MJ LHV, AR6, 100-yr) is provided to illustrate the absolute cumulative emissions to the environment from 2020 - 2050 for one example end destination and use. Consequential modeling results account for a range of end destinations and end uses with varying degrees of CCS deployment depending on the scenario.

[e] Total direct emissions from increased U.S. LNG exports plus the indirect GHG emissions from market substitution effects, excludes GHG emissions from increases in global services. Direct emissions are estimated for illustrative purposes based on direct emissions from U.S. LNG exports if 100% combusted w/o CCS end use.

[f] Results from Table 34, Cumulative Consequential GHG Intensities for U.S. Exports (LHV, AR6, 100-yr, equivalent services basis).

[g] Derived from the absolute difference between the cumulative change in GHG emissions from Table 22 (all consequences) and Table 34 (excludes change in global services).

[h] Results from Table 22. Cumulative Consequential GHG Intensities of U.S. Exports, LV, AR6,100-yr Basis.

[i] Consequential GHG Intensity of U.S. LNG Exports (g $CO_2e$/MJ), as reported in Table 22, can be obtained by dividing the Cumulative change in GHG Emissions, 2020 - 2050 (this column) by the Cumulative Change in U.S. LNG Exported, 2020 – 2050 (second column in the table).

*Table 36. Summary of market drivers of total consequential GHG intensity of increased U.S. LNG exports, cumulative change, 2020 - 2050 (LHV, AR6, 100-yr), direct emissions end use of U.S. LNG represented as 90% CCS at end use*

| Scenario[a] | Cumulative Change in U.S. LNG Exported, 2020-2050 (EJ)[b,c] | Cumulative Change in Direct GHG Emissions from Increased U.S. LNG Exports if 100% Combusted with 90% CCS End Use, 2020-2050 (Tg $CO_2e$)[b,d] | Cumulative Change in Direct Attributional Emissions of Direct and Indirect Market Substitutions, 2020-2050 (Tg $CO_2e$)[b,e] | Cumulative Change in Direct and Indirect GHG Emissions Market Substitution Effects Only, 2020-2050 (Tg $CO_2e$)[b,f] | Cumulative Change in Indirect GHG Emissions from Increased Global Services Effects Only, 2020-2050 (Tg $CO_2e$)[b,g] | Cumulative Change in GHG Emissions, 2020-2050 (Tg $CO_2e$)[b,h,i] |
|---|---|---|---|---|---|---|
| ***Defined Policies*** | | | | | | |
| *DP: Hi Exp* | 188 | 5,640 | -6,478 | -838 | 2,290 | 1,452 |
| *DP: MR* | 113 | 3,390 | -3,905 | -515 | 1,226 | 711 |
| *DP: Hi ME Sup: MR* | 100 | 3,000 | -3,364 | -364 | 727 | 363 |
| *DP: Hi US Sup: MR* | 115 | 3,450 | -4,228 | -778 | 1,964 | 1,186 |
| *DP: Lo US Sup: MR* | 18 | 540 | -659 | -119 | 151 | 32 |
| ***Commitments*** | | | | | | |
| *C (Hi CCS): Hi Exp* | 107 | 3,210 | -3,589 | -379 | 1,166 | 787 |
| *C (Hi CCS): MR* | 31 | 930 | -1,086 | -156 | 253 | 97 |
| *C (Mod CCS): Hi Exp* | 86 | 2,580 | -2,466 | 114 | 1,169 | 1,055 |
| *C (Mod CCS): MR* | 11 | 330 | -333 | -3 | 70 | 67 |
| ***Net Zero 2050*** | | | | | | |
| *NZ (Hi CCS): Hi Exp* | 93 | 2,790 | -3,279 | -489 | 813 | 324 |
| *NZ (Hi CCS): MR* | 17 | 510 | -585 | -75 | 96 | 21 |
| *NZ (Mod CCS): Hi Exp* | 76 | 2,280 | -1,784 | 496 | 459 | 955 |

Notes:

[a] Scenario *NZ (Mod CCS): MR* is not presented here because model-resolved LNG exports do not exceed existing/FID levels in this scenario.

[b] Changes for all scenarios found vs. Existing/FID within each global climate policy scenario.

[c] Conversion of annual values from EJ/year to Bcf/d is 1:2.7759

[d] Assumes every EJ of U.S. LNG exported is combusted at end use and 90% of the end use carbon dioxide emissions are captured and sequestered from being released to the atmosphere. Oceans shipping was modeled as 100% to Asian Market (27,500 nautical miles, round trip). Attributional life cycle result (30 g $CO_2e$/MJ LHV, AR6, 100-yr) is provided to illustrate the absolute cumulative emissions to the environment from 2020 - 2050 for one example end destination and use. Consequential modeling results account for a range of end destinations and end uses with varying degrees of CCS deployment depending on the scenario.

[e] Total direct emissions from increased U.S. LNG exports plus the indirect GHG emissions from market substitution effects, excludes GHG emissions from increases in global services. Direct emissions are estimated for illustrative purposes based on direct emissions from U.S. LNG exports with 90% CCS at end use combustion.

[f] Results from Table 34, Cumulative Consequential GHG Intensities for U.S. Exports (LHV, AR6, 100-yr, equivalent services basis).

[g] Derived from the absolute difference between the cumulative change in GHG emissions from Table 22 (all consequences) and Table 34 (excludes change in global services).

[h] Results from Table 22. Cumulative Consequential GHG Intensities of U.S. Exports, LV, AR6,100-yr Basis.

[i] Consequential GHG Intensity of U.S. LNG Exports (g $CO_2e$/MJ), as reported in Table 22, can be obtained by dividing the Cumulative change in GHG Emissions, 2020 - 2050 (this column) by the Cumulative Change in U.S. LNG Exported, 2020 – 2050 (second column in the table).

## D. Modeling Caveats and Limitations

The results of this study are dependent on various data sources, models, and assumptions that are highly connected. Important caveats and limitations of this analysis include:

1. For the estimation of liquefaction emissions of projects, the basis of the NETL GHG intensity estimates are current practice and data. This affects the primary result as well as the framework for the individual project analysis. As modeled within this study, the U.S.

average performance for liquefaction facilities used as the default value is a static reference aligned to year 2020 industry performance. This liquefaction facility value is not adjusted in future modeling years for potential unknown industry changes, such as implementation of carbon capture and storage, electrification, etc.

2. The upstream natural gas GHG intensity profile is currently based on the 2024 NETL Natural Gas baseline study. Measurement studies of the combined oil and gas sectors suggest methane emission rates could be higher for natural gas production than are represented in the NETL natural gas model. Sensitivity to upstream methane emissions is evaluated in the Results, Sensitivity Analysis section of this study.
3. Changes in the quantity of natural gas liquefied globally result in direct changes in emissions from liquefaction operations represented in the GCAM model. Liquefaction operations are modeled as a component of other industrial emissions within GCAM and are responsive to changes in country GDP and not directly connected to changes in country-level LNG export volumes. Therefore, sensitivity to liquefaction operating emissions representation in the GCAM model is evaluated in the Results, Sensitivity Analysis section of this study.

## STUDY SUMMARY

The purpose of this study was to examine the potential global GHG emissions implications of a wide range of levels of U.S. LNG exports. Key conclusions include:

1. Differences in volumes of U.S. LNG exports lead to different levels both of GHG emissions and of global services provided. When compared to scenarios that assume export levels based on existing and under construction facilities (*Existing/FID*), higher levels of U.S. LNG exports lead to higher global GHG emissions (ranging from 21 Tg $CO_2$e to 1,452 Tg $CO_2$e or about 0.002% to 0.1%), as well as higher levels of global services provided (ranging from 0.006% to about 0.1%).
2. The GCAM upstream GHG intensity values for all scenarios are within 1% of the values in the latest NETL Natural Gas baseline study (representative of the base year of this study, 2020) on an IPCC AR6, 100-yr basis.
    a. Per MJ of natural gas scaled to account for liquefaction losses, the production through transmission (upstream) GHG intensity is 9.2 g $CO_2$e/MJ exported on an IPCC AR6, 100-yr GWP, LHV basis and 15.7 g $CO_2$e/MJ exported on an IPCC AR6, 20-yr GWP, LHV basis.
    b. Overall, adjustments to align to NETL national average performance data for GHG intensity added about 20 Tg $CO_2$e emissions per model year, an increase of less than 0.05% on an AR6, 100-yr basis, and subtracted about 100 Tg $CO_2$e emissions per model year, a decrease of less than 0.2% (AR6, 20-yr basis).
3. The national average GHG intensity for liquefaction operations in the base year is modeled using government reported data and expanded to provide representative life cycle system boundaries, resulting in a GHG emissions intensity of 5.3 g $CO_2$e/MJ of natural gas ready for export, reported on an IPCC AR6, 100-yr lower heating value (LHV) basis, and 5.6 g $CO_2$e/MJ on an IPCC AR6, 20-yr lower heating value (LHV) basis.
4. This analysis defines the upstream natural gas and liquefaction processes as project direct emissions, the direct emissions from export and use of the natural gas and direct and indirect market effects as project non-direct emissions and the sum of them to be the consequential GHG intensity of U.S. LNG Exports. Given the upstream natural gas and liquefaction values estimated above, the average U.S. project direct emissions for 2020, the baseline year for this study, is 9.2 + 5.3 = 14.5 g $CO_2$e/MJ (AR6, 100-yr), and 21.3 g $CO_2$e/MJ (AR6, 20-yr).

5. The consequential GHG intensity is the effect (inclusive of both direct and indirect emissions) of U.S. LNG on global emissions per unit of U.S. LNG exported. The consequential GHG intensity is defined as the difference in GHG emissions between the scenarios divided by the difference in U.S. LNG exports. For instance, for one of the scenario comparisons assessed (*Defined Polices: Model Resolved*) the consequential GHG intensity is +6.3 g $CO_2$e/MJ (on both an AR6, 100-yr and AR6, 20-yr basis), indicating that the overall global effect of producing and exporting U.S. LNG leads to an increase in global GHG emissions resulting from consequential market effects.
    a. Analysis of the results shows that direct and indirect market substitutions result in a decrease in global GHG emissions intensity when compared on an equivalent global services basis. The increased availability of U.S. LNG on the global market enables increased demand for energy to be met with a lower cost energy supply option that often displaces more or equally GHG emissions-intensive fuels (e.g., coal and oil) within the model over the thirty-year study period.
    b. Results also show that increasing the availability of U.S. LNG on the global market (increased global energy supply) results in increased consumption of global services when compared to the baseline scenario (e.g., *Defined Policies: Existing/FID*). The consequential effect of increased global consumption of energy and services directly contributes to increased global GHG emissions.
    c. The net result of these two market effects is an increase in global GHG emissions of +6.3 g $CO_2$e/MJ of NG exported from the U.S. Across all scenarios, this GHG intensity figure ranges from 1.2 g $CO_2$e/MJ to 12.6 g $CO_2$e/MJ (AR6, 100-yr basis), and -1.4 g $CO_2$e/MJ to 11.2 g $CO_2$e/MJ (AR6, 20-yr basis).
    d. The increase in global GHG emissions between the *Defined Policies: Model Resolved* and *Defined Policies: Existing/FID* scenarios is estimated to result in a cumulative SC-GHG impact of $74 billion using a discount rate of 2.5%, $130 billion using a discount rate of 2.0%, and $220 billion using a discount rate of 1.5% (all 2020$). Per MJ, this equates to a range of 0.02 cents/MJ to 0.15 cents/MJ (2.5%). The cumulative SC-GHG of the increase in global emissions across the study scenarios ranged from $3 billion to $150 billion (2.5%) to $12 billion to $450 billion (1.5%) in 2020$.
6. Estimated consequential GHG impacts and SC-GHG values for an individual U.S. export project can be calculated by using individual project values in place of the default of U.S. average values modeled in the study.
    a. For example, on an AR6, 100-yr basis, given the NETL average liquefaction emissions for a project of 5.3 g $CO_2$e/MJ, if an individual project has a liquefaction process with emissions that are half of the average (2.65 g $CO_2$e /MJ), the individual project consequential GHG intensity could be adjusted down by 2.65 g $CO_2$e/MJ (calculated as the difference between the average of 5.3 g $CO_2$e/MJ and the individual project emissions intensity of 2.65 g $CO_2$e/MJ). If the average U.S. consequential GHG intensity is 6.3 g $CO_2$e /MJ, the individual project consequential intensity would be 3.65 g $CO_2$e /MJ.
    b. Total lifetime social costs of the project direct and project non-direct greenhouse gas emissions from a 1 Bcf/d facility operating for 30 years are estimated to be $8 billion to $23 billion ($2020) for a facility with default average intensity values (varying across assumed discount rates). A similar facility with half the liquefaction emissions would have social costs of greenhouse gases estimated to be $4.6 billion to $13 billion ($2020).

## APPENDICES TO THIS REPORT

Appendix C-1: NEMS and NETL LCA Model Results Comparison

Appendix C-2: Incorporation, Assessment, and Adjustments to the Global Change Analysis Model (GCAM) Results

Appendix C-3: Social Cost of Greenhouse Gases Modeling and Additional Results

Appendix C-4: Detailed Data Tables for Values Summarized in this Report

## APPENDIX C-1: NEMS AND NETL LCA MODEL RESULTS COMPARISON

The NEMS modeling done in this project focused on domestic changes that would be expected to occur in the scenarios modeled. NETL reviewed the NEMS data to evaluate if the regional production mix of natural gas would be expected to change over time. If the NEMS results suggested that production would be expected to shift significantly from the current mix of regions, and especially if to distinctly higher or lower intensity regions, then NETL would have recommended adjustments to the assumed GHG intensity for U.S. natural gas in the results.

For *all scenarios*, NEMS-modeled data of dry natural gas production of "Production by OGSM District" were mapped to a state and then to an NETL natural gas model region as shown in Table C-1.1. Note that several "states" are offshore regions.

*Table C-1.1. Matching NEMS (Oil and Gas Methane Partnership states) to NETL states and regions*

| Production by OGSM District | State | Region |
|---|---|---|
| Alabama, North | Alabama | Southeast |
| Alabama, South | Alabama | Southeast |
| Arizona | Arizona | Southwest |
| Arkansas | Arkansas | Southeast |
| California | California | Pacific |
| Colorado | Colorado | Rocky Mountain |
| Connecticut | Connecticut | Northeast |
| Delaware | Delaware | Northeast |
| Florida | Florida | Southeast |
| Georgia | Georgia | Southeast |
| Idaho | Idaho | Rocky Mountain |
| Illinois | Illinois | Midwest |
| Indiana | Indiana | Midwest |
| Iowa | Iowa | Midwest |
| Kansas | Kansas | Midwest |
| Kentucky | Kentucky | Southeast |
| Louisiana, North | Louisiana | Southeast |
| Louisiana, South | Louisiana | Southeast |
| Maryland | Maryland | Northeast |
| Massachusetts | Massachusetts | Northeast |
| Michigan | Michigan | Midwest |
| Minnesota | Minnesota | Midwest |
| Mississippi, North | Mississippi | Southeast |
| Mississippi, South | Mississippi | Southeast |
| Missouri | Missouri | Midwest |
| Montana | Montana | Rocky Mountain |
| Nebraska | Nebraska | Midwest |
| Nevada | Nevada | Rocky Mountain |
| New Hampshire | New Hampshire | Northeast |

| | | |
|---|---|---|
| New Jersey | New Jersey | Northeast |
| New Mexico, East | New Mexico | Southwest |
| New Mexico, West | New Mexico | Southwest |
| New York | New York | Northeast |
| North Carolina | North Carolina | Southeast |
| North Dakota | North Dakota | Midwest |
| Ohio | Ohio | Midwest |
| Oklahoma | Oklahoma | Southwest |
| Oregon | Oregon | Pacific |
| Pennsylvania | Pennsylvania | Northeast |
| Rhode Island | Rhode Island | Northeast |
| South Carolina | South Carolina | Southeast |
| South Dakota | South Dakota | Midwest |
| Tennessee | Tennessee | Southeast |
| Texas RRC 1 | Texas | Southwest |
| Texas RRC 2 | Texas | Southwest |
| Texas RRC 3 | Texas | Southwest |
| Texas RRC 4 | Texas | Southwest |
| Texas RRC 5 | Texas | Southwest |
| Texas RRC 6 | Texas | Southwest |
| Texas RRC 7B | Texas | Southwest |
| Texas RRC 7C | Texas | Southwest |
| Texas RRC 8 | Texas | Southwest |
| Texas RRC 8A | Texas | Southwest |
| Texas RRC 9 | Texas | Southwest |
| Texas RRC 10 | Texas | Southwest |
| Utah | Utah | Rocky Mountain |
| Virginia | Virginia | Northeast |
| Washington | Washington | Pacific |
| West Virginia | West Virginia | Northeast |
| Wisconsin | Wisconsin | Midwest |
| Wyoming | Wyoming | Rocky Mountain |
| Alabama State Offshore | Alabama | Southeast |
| Louisiana State Offshore | Louisiana | Southeast |
| Texas State Offshore | Texas | Southwest |
| California State Offshore | California | Pacific |
| North Atlantic Federal Offshore | North Carolina | Southeast |
| Mid Atlantic Federal Offshore | Federal Offshore - GoM | Southeast |
| South Atlantic Federal Offshore | South Carolina | Southeast |
| Eastern GOM Federal Offshore | Federal Offshore - GoM | Southeast |
| Central GOM Federal Offshore | Federal Offshore - GoM | Southeast |

| | | |
|---|---|---|
| Western GOM Federal Offshore | Federal Offshore - GoM | Southeast |
| California Federal Offshore | California | Pacific |
| Northern Pacific Federal Offshore | Federal Offshore - GoM | Southeast |
| Alaska Federal Offshore | Federal Offshore - GoM | Southeast |

This classification enables the aggregation of dry production data (excluding extraction losses) by region for each respective year, as summarized with every 10 years of data in Table C-1.2.

*Table C-1.2. Regional dry production (Tcf) between 2020 and 2050, DP:MR*

| Region | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| Southeast | 4.59 | 6.64 | 6.01 | 6.28 | 7.21 | 8.01 | 8.11 |
| Southwest | 11.26 | 13.08 | 13.38 | 14.00 | 16.43 | 19.38 | 21.18 |
| Pacific | 2.69 | 2.08 | 2.09 | 1.98 | 2.19 | 2.61 | 2.78 |
| Rocky Mountain | 3.32 | 2.92 | 2.88 | 2.57 | 2.65 | 2.66 | 2.67 |
| Northeast | 10.33 | 11.80 | 11.93 | 12.94 | 14.49 | 15.21 | 15.31 |
| Midwest | 0.97 | 0.95 | 0.96 | 0.95 | 0.92 | 0.91 | 0.91 |

From this aggregated data, the production share is calculated by dividing the region-specific production by the total U.S. production for each year and is summarized in Table C-1.3.

*Table C-1.3. Regional NG dry production shares, DP:MR*

| Region | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| Midwest | 0.139 | 0.177 | 0.161 | 0.162 | 0.164 | 0.164 | 0.159 |
| Northeast | 0.339 | 0.349 | 0.359 | 0.362 | 0.374 | 0.397 | 0.416 |
| Pacific | 0.081 | 0.056 | 0.056 | 0.050 | 0.050 | 0.054 | 0.055 |
| Rocky Mountain | 0.100 | 0.078 | 0.077 | 0.067 | 0.060 | 0.055 | 0.052 |
| Southeast | 0.311 | 0.315 | 0.320 | 0.335 | 0.330 | 0.312 | 0.300 |
| Southwest | 0.029 | 0.025 | 0.026 | 0.024 | 0.021 | 0.019 | 0.018 |

The regional production shares estimated based on NEMS data are disaggregated to a techno-basin level based on the proportion of regional natural gas production shares in the 2020 NETL Natural Gas model. Based on the 2020 NETL Natural Gas model, Table C-1.4 provides the techno-basin to region mapping details and Table C-1.5 reports the GHG emissions intensity results for natural gas production from all techno-basins, for the production through transmission network life cycle boundary, using U.S. average transmission network data.

*Table C-1.4. Regional NG dry production shares, DP:MR*

| Techno-basin | Region |
|---|---|
| Alaska Offshore | Pacific |
| Anadarko Conventional | Southwest |
| Anadarko Shale | Southwest |
| Anadarko Tight | Southwest |
| Appalachian Shale | Northeast |
| Arkla Conventional | Southeast |
| Arkla Shale | Southeast |
| Arkla Tight | Southeast |

| | |
|---|---|
| Arkoma Conventional | Southwest |
| Arkoma Shale | Southwest |
| East Texas Conventional | Southwest |
| East Texas Shale | Southwest |
| East Texas Tight | Southwest |
| Fort Worth Shale | Southwest |
| GoM Offshore | Southeast |
| Green River Conventional | Rocky Mountain |
| Green River Tight | Rocky Mountain |
| Gulf Conventional | Southwest |
| Gulf Shale | Southwest |
| Gulf Tight | Southwest |
| Permian Conventional | Southwest |
| Permian Shale | Southwest |
| Piceance Tight | Rocky Mountain |
| San Juan Coalbed Methane | Southwest |
| San Juan Shale | Southwest |
| South Oklahoma Shale | Southwest |
| Strawn Shale | Southwest |
| Uinta Conventional | Rocky Mountain |
| Uinta Tight | Rocky Mountain |

*Table C-1.5. GHG emissions intensity by techno-basin, production through transmission network boundary using U.S. average transmission data (g $CO_2$e/MJ, IPCC AR6, 100-yr GWP)*

| Techno-basin | GHG Emissions Intensity (g $CO_2$e/MJ) |
|---|---|
| Alaska Offshore | 6.99E+00 |
| Anadarko Conv | 1.62E+01 |
| Anadarko Shale | 9.68E+00 |
| Anadarko Tight | 1.17E+01 |
| Appalachian Shale | 6.41E+00 |
| Arkla Conv | 6.40E+00 |
| Arkla Shale | 6.39E+00 |
| Arkla Tight | 1.16E+01 |
| Arkoma Conv | 1.54E+01 |
| Arkoma Shale | 1.22E+01 |
| East Texas Conv | 7.70E+00 |
| East Texas Shale | 8.01E+00 |
| East Texas Tight | 7.74E+00 |
| Fort Worth Shale | 1.32E+01 |
| GoM Offshore | 6.20E+00 |
| Green River Conv | 1.28E+01 |
| Green River Tight | 1.32E+01 |
| Gulf Conv | 8.51E+00 |

| | |
|---|---|
| Gulf Shale | 7.44E+00 |
| Gulf Tight | 9.38E+00 |
| Permian Conv | 9.61E+00 |
| Permian Shale | 1.03E+01 |
| Piceance Tight | 8.55E+00 |
| San Juan Coalbed Methane | 1.77E+01 |
| San Juan Shale | 2.72E+01 |
| South Oklahoma Shale | 8.64E+00 |
| Strawn Shale | 1.34E+01 |
| Uinta Conv | 3.44E+01 |
| Uinta Tight | 1.84E+01 |

Note: The GHG emissions intensity results are provided on a per MJ NG delivered, LHV basis. Results from the 2020 NETL Natural Gas Model were converted from HHV to LHV basis for this work.

Overall, Table C-1.6 suggests that the NEMS-modeled changes in domestic natural gas production by region across the scenarios are not expected to significantly affect the projected GHG emissions intensities over time as evidenced by the 0 to 0.004 variance across the time horizon and scenarios.

*Table C-1.6. Estimated U.S. average GHG intensity (g $CO_2$e/MJ) across NEMS scenarios, production through transmission (2020-2050)*

| **Scenario** | ***2020*** | ***2025*** | ***2030*** | ***2035*** | ***2040*** | ***2045*** | ***2050*** |
|---|---|---|---|---|---|---|---|
| *DP: MR* | *0.083* | *0.082* | *0.082* | *0.082* | *0.082* | *0.083* | *0.084* |
| *DP: ExFID* | *0.083* | *0.082* | *0.082* | *0.082* | *0.082* | *0.082* | *0.082* |
| *DP Hi US Sup: MR* | *0.083* | *0.083* | *0.084* | *0.083* | *0.084* | *0.084* | *0.084* |
| *DP Hi US Sup: ExFID* | *0.083* | *0.083* | *0.084* | *0.084* | *0.083* | *0.083* | *0.083* |
| *DP Lo US Sup: MR* | *0.083* | *0.081* | *0.081* | *0.080* | *0.080* | *0.081* | *0.081* |
| *DP Lo US Sup: ExFID* | *0.083* | *0.081* | *0.081* | *0.080* | *0.080* | *0.080* | *0.081* |

# APPENDIX C-2: INCORPORATION, ASSESSMENT, AND ADJUSTMENTS TO THE GLOBAL CHANGE ANALYSIS MODEL (GCAM) RESULTS

Across all years and scenarios, GCAM has over 100 discrete sectors, hundreds of discrete technologies, and many sector-technology pairs that can vary depending on the model configuration. However, only a subset of these factors is relevant to this analysis (i.e., with a focus on the natural gas sector).

Results provided by PNNL for the various scenarios and years modeled were provided as described in Table C-2.1 and were processed accordingly.

*Table C-2.1. Provided set of GCAM data documentation*

| File | Data Represented |
|---|---|
| co2_em_tech | Provides data showing $CO_2$ emissions in megatons per year for various sectors, energy sources or "technology" for different scenarios across each of 32 regions. |
| non_co2_em_tech | Provides data showing non-$CO_2$ emissions in gigagrams, equivalent to metric kilotons or 1,000 metric tons, for various sectors, energy sources or "technology" and different scenarios across each of 37 regions. |
| inputs.by.tech | Provides detailed information about energy consumption in different regions and sectors along with specific technologies and years. |
| outputs.by.tech | Reports the energy production within the various regions, by sectors (sub-sector is not applicable in this dataset) along with specific technologies and years. |
| **Columns** | **Description** |
| scenario | Scenario or context for which the data is provided such as "Defined Policies: Existing/FID," which suggests that the data corresponds to the existing capacity or infrastructure in the region. |
| region | This column specifies the geo-political region under consideration. |
| sector | This column categorizes the different sectors or areas of activity for which $CO_2$ emissions are being measured, e.g., "*agricultural energy use*," "*cement*," etc. |
| sub-sector | Within a sector, there may be further divisions or subcategories to specify the specific aspect of the sector being measured, e.g., by type of fuel or "mobile," "stationary," etc., indicating different types of energy use within a single sector. |
| technology | This column identifies the specific technology or energy source being utilized within the subsector. For example, "gas CC" and "gas steam/CT." |
| year | The specific year or period for which the $CO_2$ emissions values are provided; this ranges from 2020 to 2050. |
| value | Numerical values for the activity being described given combination of scenario, region, sector, subsector, technology, and year. |
| ghg | Refers to the GHG that is being emitted (for non-$CO_2$ data). It identifies the specific type of gas responsible for the emissions, e.g., $CH_4$, $N_2O$, HFC125, $C_2F_6$, etc. |
| input | The energy or other input into sector/subsector/technology. |
| output | The commodity or service provided by the sector/subsector/technology. |

## A. GCAM and NETL (2020) Emissions Intensity Comparison and Adjustment

The GCAM model represents economic activity (and associated GHG emissions) by sectors and technologies, and their respective inputs and outputs, for regions, years, and scenarios. However, only three sectors in GCAM include GHG emissions relevant to the natural gas sector: *natural*

*gas*, *gas pipeline*, and *other industrial energy use*. In this document, these GCAM sectors are *italicized* when referred to given their colloquial use in other ways such as in describing stages of the natural gas life cycle.

Using the basis of process stages as represented in the NETL Natural Gas model, Figure C-2.1 shows the relevant GCAM sectors that have associated $CO_2$ and non-$CO_2$ emissions. While, overall, GCAM has 16 species of GHG emissions, for the three GCAM sectors above relevant to the upstream natural gas sector, only emissions of $CO_2$, $CH_4$, and $N_2O$ were represented. Most stages of the NETL Natural Gas model framework are accounted for in these three GCAM sectors, but not all are explicitly scaled to production amounts of natural gas or derivative products. Also, the Ocean Shipping stage is included as part of *trn_shipping_intl* but the effects could not be separated out for this analysis. As a result, the comparison in this report was focused on a comparison of emissions from production of natural gas in the U.S. through delivery to a large end user rather than LNG delivered around the world.

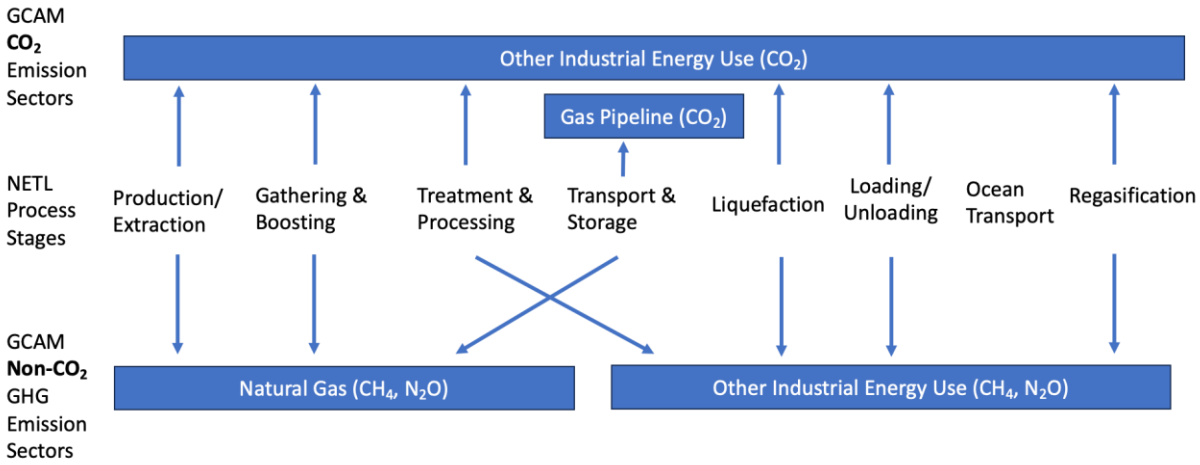


*Figure C-2.1. Mapping of NETL natural gas stages to GCAM sectors*

To assess the alignment of the modeling of natural gas upstream emissions in GCAM against the NETL Natural Gas model, quantitative values of emissions intensities in the year 2020 of the various GCAM sectors for the "USA" region for the three natural gas-relevant sectors were listed and compared to NETL natural gas model results. Note, in order to compare NETL and GCAM results, NETL model results were regenerated using an LHV basis as shown below and differ from those published (as HHV by default) and listed in Step 2 of the report.

However, the *other industrial energy use* sector contains a diverse set of activities without explicitly representing emissions related to natural gas. GCAM incorporates a variety of data sources to represent activity in this sector. Relevant to natural gas activities for this sector, 2015 International Energy Agency (IEA) data on energy use by oil and gas production activities used by the GCAM modeling team were provided and utilized to apportion GHG emissions associated with natural gas activity, as in Table C-2.2.

*Table C-2.2. LCA stage cross-mapping*

| NETL LCA Stage | IEA Energy Flow | GCAM Sector – Energy & $CO_2$ |
|---|---|---|
| Extraction | Oil and Gas Extraction | other industrial energy use |
| Gathering and Boosting | Oil and Gas Extraction | other industrial energy use |
| Processing | Gas Works | other industrial energy use |
| Domestic Pipeline Transport | Pipeline Transport | gas pipeline |
| Liquefaction | LNG/Regasification Plants | other industrial energy use |

| | | |
|---|---|---|
| Ocean Transport | International Marine Bunkers | trn_shipping_intl |
| Regasification | LNG/Regasification Plants | other industrial energy use |
| Pipeline Transport (at destination) | Pipeline Transport | gas pipeline |

The IEA data is aggregated into oil and gas activities such as “Extraction, Gathering and Boosting,” “Processing,” and “Liquefaction and Regasification.” However, a challenge is that the IEA data represents aggregated activities of extraction of both oil and gas resources. Given the lack of data on liquefaction and regasification in the 2015 IEA data (including for the United States), emissions from those activities are excluded from the analysis, consistent with the focus on upstream natural gas effects.

Overall, only four subsector/technology pair values of the other industrial energy use sector in GCAM were considered: gas/gas, gas/gas cogen, refined liquids/refined liquids, and refined liquids/refined liquids cogen (and are shown as aggregated to the subsector level).

The emissions intensity cells in Table C-2.3 show the underlying equation used to generate values on an AR6, 100-yr basis, where the numerator is the total emissions from GCAM for the USA region for the Defined Policies: Model Resolved scenario for the year 2020 for each of the three GHGs (if available), normalized by the total production of U.S. natural gas and oil from GCAM in 2020 (32.29 EJ and 22.32 EJ, respectively). Note that GCAM reports “production” of resources but actually maps more appropriately to “delivered product”. As such the basis of the GCAM and NETL boundaries match (all are in terms of NG delivered). Units of emissions intensity follow those internal to GCAM, which are Tg $CO_2$ equivalent/EJ, which conveniently are equal to g $CO_2$e/MJ, the same units as used in the NETL model. Thus, the bottom rows in Table C-2.3 show comparisons to those of the NETL model.

*Table C-2.3. GCAM emissions intensities for sectors (DP:MR, 2020, USA region, AR6, 100-yr basis)*

| | | | **Estimated GCAM Emissions Intensity (LHV) (Tg $CO_2$e/EJ, g $CO_2$e/MJ) [IPCC AR6, 100-yr]** | | |
|---|---|---|---|---|---|
| **GCAM Sector** | **NETL LCA Stage** | **Comments/Potential Mapping Inaccuracy** | **$CO_2$** | **$CH_4$** | **$N_2O$** |
| *gas pipeline* | Transmission and Storage | Have assumed this fully represents the Transmission sector equivalent to the NETL Natural Gas model. | 38.0/32.3 = 1.18 | - | - |
| *natural gas* | Production + Gathering & Boosting + Processing | From discussions with GCAM team, this sector represents all other natural gas related activities, thus the mapping to all other NETL stages other than transmission. | - | 138.3/32.3 = 4.28 | .014/32.3 = 4.5 E-4 |
| *other industrial energy use (technology = gas or gas cogen)*[a] | **For 2015**, Extraction, Gathering & Boosting | Estimates from IEA energy shares.<br><br>For technology = gas or gas cogen, all GHG emissions allocated to the natural gas product.<br><br>For technology = refined liquids or refined liquids cogen, GHG emissions are allocated to the natural gas and crude oil products on an energy (EJ) produced basis from GCAM output data. | 92.9/32.3 = 2.88 | 0.06/32.3 = 0.002 | 0.04/32.3 = 0.001 |
| *other industrial energy use (technology = refined liquids and refined liquids cogen)*[a] | | | 10.3/(32.3+ 22.3) = 0.2 | 0.07/(32.3+ 22.3) = 0.001 | 0.39/(32.3+ 22.3) = 0.007 |
| *other industrial energy use (electricity)*[a] | | | - | - | - |
| **Total GCAM by gas (LHV)** | | | **= 1.18 + 2.88 + .2 = 4.24** | **4.28** | **0.009** |
| **Total GCAM (LHV)** | | | | | **8.53** |
| **Subtotal from NETL Model, Processing through Transmission boundary – LHV basis** | | | | | **8.63** |
| **Adjustment factor (LHV)** | | | | | **8.63/8.53 = 1.0117** |

Overall, the estimated upstream emissions intensity for the USA region in GCAM in the year 2020 for *Defined Policies: Model Resolved* was about 8.53 g $CO_2$e/MJ (AR6, 100-yr, LHV basis), which is slightly lower than the GHG emissions intensity estimated by the NETL model for the production through transmission boundary (8.63 g $CO_2$e/MJ, AR6, 100-yr, LHV basis). Using the relationship between those estimates, emissions results in the three GCAM natural gas sectors identified above were adjusted by a factor of 8.63/8.53, or 1.0117 (a 1.17% increase) to maintain consistency with past NETL studies of the natural gas sector. This adjustment factor was used for all regions and for all years in the model, and is directly applied to GHG emissions in all regions of the GCAM model results for the *natural gas* and *gas pipeline* sectors as they wholly related to natural gas activities. By linearly scaling all regional values in this way, the existing and diverse

$CH_4$ mitigation trends for each region in the underlying GCAM emissions factors for the *natural gas* sector were preserved by using this adjustment method.

For the *other industrial energy use* sector, the adjustment is complicated by the fact that the sector includes many activities beyond those associated with natural gas, such as use of biomass and coal. If the adjustment factor were wholly applied to the GHG emissions of the sector, then the total emissions in GCAM would be reduced for both natural gas and non-natural gas activities. A compromise was made to estimate the total needed reductions in emissions associated with only natural gas activity for each region, and to reduce the emissions of the other industrial energy use sector by that amount. While this does not achieve a full alignment of these associated emissions (i.e., it does not lead to a 1.17% increase in emissions intensity for the sector), it avoids the outcome where that sector's emissions are reduced for all of the other activities. Specifically, as delineated above only the emissions of the gas/gas cogen and refined liquids/refined liquids cogen subsectors were increased by 1.17%, and only for the share of activity within those subsectors associated with Extraction and Gathering/Boosting activities.

These adjustments to emissions from all regions, all scenarios, and all years were applied to existing GCAM results (i.e., GCAM was not re-run based on these adjustments). As 99.5% of GHG emissions in the *other industrial energy use* sector are $CO_2$, only $CO_2$ emissions for that sector were adjusted. The net global adjustment of GHG emissions in this sector (an increase of 0.11% in 2020) has negligible effects on GHG emissions.

Table C-2.4 shows the GWP of GHG emissions estimates from GCAM that were used in conjunction with the emissions factors to derive the overall life cycle GHG intensity values.

*Table C-2.4. GWP values used in this analysis*

| GHG | AR6, 100-yr | AR6, 20-yr |
|---|---|---|
| $CH_4$ (fossil) | 29.8 | 82.5 |
| $CH_4$ (non-fossil) | 27.2 | 80.8 |
| $N_2O$ (fossil) | 273 | 273 |
| $N_2O$ (non-fossil) | 273 | 273 |
| HFC125 | 3740 | 6740 |
| HFC134a | 1530 | 4140 |
| HFC143a | 5810 | 7840 |
| HFC23 | 14600 | 12400 |
| HFC32 | 771 | 2690 |
| $SF_6$ | 24300 | 18200 |
| HFC245fa | 962 | 3170 |
| HFC365mfc | 914 | 2920 |
| $C_2F_6$ | 12400 | 8940 |
| $CF_4$ | 7380 | 5300 |
| HFC43 | 1600 | 3960 |
| HFC152a | 164 | 591 |
| HFC227ea | 3600 | 5850 |
| HFC236fa | 8690 | 7450 |

Note that unlike the natural gas system-specific emission comparisons and adjustments discussed above, which focus on $CO_2$, $CH_4$, and $N_2O$, GCAM estimates emissions of 16 GHGs and all are included in this study.

Using the same detailed approach as detailed in Table C-2.3, Table C-2.5 more succinctly summarizes the provided GCAM values and adjustments identified for the IPCC AR6, 20-yr values.

*Table C-2.5. GCAM emissions intensities for sectors (S1, 2020, U.S. region, AR6, 20-yr basis)*

| GCAM Sector | Estimated GCAM Emissions Intensity (Tg $CO_2$e/EJ, g $CO_2$e/MJ) [IPCC AR6, 20-yr] | | |
|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ |
| *gas pipeline* | 1.18 | - | - |
| *natural gas* | - | 11.86 | 4.5 E-4 |
| *other industrial energy use (technology = gas or gas cogen)* | 2.88 | 0.005 | 0.001 |
| *other industrial energy use (technology = refined liquids and refined liquids cogen)* | 0.2 | 0.006 | 0.007 |
| Total GCAM by gas (LHV) | = 1.18 + 2.88 + .2 = 4.24 | 11.87 | 0.009 |
| Total GCAM (LHV) | | | 16.1 |
| NETL (LHV basis) | | | 14.6 |
| Adjustment Factor (LHV) | | | 0.907 |

In addition to the adjustment of GCAM results, the liquefaction and upstream natural gas GHG intensity values produced in Steps 2 and 3 were also updated to the AR6, 20-yr basis. The resulting values are 15.7 g $CO_2$e/MJ and 5.6 g $CO_2$e/MJ for the for the upstream natural gas GHG intensity and liquefaction GHG intensity, respectively. The sum of these is 21.3 g $CO_2$e/MJ and is the estimate of project direct emissions for analysis on an AR6, 20-yr basis.

## B. Method and Scaling Factors Used for Service-Equivalent Analysis

An additional analysis was done from the base set of scenarios that estimated results with increased services provided. The additional analysis normalized services delivered on an equivalent basis, as described in this section.

An output file from GCAM provided aggregated summaries of domestic and global services provided from GCAM, which include end-use energy services (e.g., space heating and cooling, passenger and freight transportation, industrial energy) and output of some major commodities (e.g., cement). Originally provided estimates of about 50 services are aggregated into about 15 categories.

A method was derived to compare and normalize the greenhouse gas emissions and U.S. LNG exports based on the changes in services provided between scenarios across the entire set of services provided.

The “outputs” data is an export of GCAM modeling that shows the quantities of outputs for various services. These account for energy services that can be quantified using appropriate exajoule units, material production (e.g., cement and iron/steel) that are more appropriately quantified by mass, and transportation that can be for materials or people with appropriate units. For any scenario pair where the end, cumulative result is an increase in U.S. LNG exports, these cumulative global services increase by different amounts along with their GHG emissions. In order to compare the carbon intensity of two scenarios, the GHG emissions and U.S. LNG exports need

to be adjusted to account for those changes in services. This is done by calculating a ratio of the service between two scenarios – for example scenario 1 cement production in million tonnes divided scenario 2 cement production in million tons. This is done for all services, resulting in a vector of multiple (50 into 15) ratios. These ratios are weighted by the amount of energy input for that service, and then summed together to provide a single weighting factor to apply to the both the global GHG emissions and U.S. LNG production.

In general, when adjusting scenarios to reach service-equivalence, the GHG intensity per unit of U.S. LNG is negative, suggesting that the global GHG intensity of services in general slightly decreases as a result of U.S. LNG exports. This is largely due to removals of enough coal, oil, and more GHG-intense natural gas from energy use globally to offset the reductions in any renewable energy use that also occur. As a result, weighted average scaling factors for the service-equivalent analysis were developed for all scenarios relative overall to the *Defined Policies: Existing/FID Exports* scenario and within each set of scenarios to the specific *ExFID* scenario, as shown in Table C-2.6.

*Table C-2.6. Scaling factors used for service adjustment calculation relative to the existing/fid levels of LNG export*

| Scenario | Service Adjustment Scaling Factor |
|---|---|
| *Defined Policies: High Exports* | 1.001476 |
| *Defined Policies: Model Resolved* | 1.00079 |
| *Defined Policies: Existing/FID Exports* | 1 |
| *Defined Policies: High Middle East Supply: Model Resolved* | 1.000467 |
| *Defined Policies: High Middle East Supply: Existing/FID Exports* | 1 |
| *Defined Policies: High US Supply: Model Resolved* | 1.001265 |
| *Defined Policies: High US Supply: Existing/FID Exports* | 1 |
| *Defined Policies: Low US Supply: Model Resolved* | 1.000098 |
| *Defined Policies: Low US Supply: Existing/FID Exports* | 1 |
| *Commitments (High CCS): High Exports* | 1.00092 |
| *Commitments (High CCS): Model Resolved* | 1.000199 |
| *Commitments (High CCS): Existing/FID Exports* | 1 |
| *Commitments (Mod CCS): High Exports* | 1.000755 |
| *Commitments (Mod CCS): Model Resolved* | 1.000058 |
| *Commitments (Mod CCS): Existing/FID Exports* | 1 |
| *Net Zero 2050 (High CCS): High Exports* | 1.000759 |
| *Net Zero 2050 (High CCS): Model Resolved* | 1.000089 |
| *Net Zero 2050 (High CCS): Existing/FID Exports* | 1 |
| *Net Zero 2050 (Mod CCS): High Exports* | 1.000464 |
| *Net Zero 2050 (Mod CCS): Model Resolved* | 1 |
| *Net Zero 2050 (Mod CCS): Existing/FID Exports* | 1 |

## APPENDIX C-3: SOCIAL COST OF GREENHOUSE GASES MODELING AND ADDITIONAL RESULTS

The speciated GHG emissions inputs to the consequential GHG intensity can also be used with the 2023 SC-GHG methodology to monetize the impacts of the changes in GHG emissions associated with increased U.S. LNG exports. The social cost of greenhouse gases (SC-GHG), as described by the Interagency Working Group (IWG) on SC-GHG, is "the monetary value of the net harm to society associated with adding a small amount of greenhouse gases to the atmosphere in a given year." In short, the SC-GHG monetizes the net harm to society caused by the release of an additional ton of GHGs into the atmosphere in a given year.

The 2023 SC-GHG method uses a trio of constant discount rates (1.5%, 2.0% and 2.5%) to provide estimate the SC-GHG for a particular base year (assumed in this study as 2024) and dollar year. The base year (which can also be considered the present value year) was chosen to be 2024 to align with the time of the study, consistent with the suggested choice aligning with a regulatory impact assessment time. The study used 2020 and 2022 as the dollar year, consistent with the default year of damages provided in the framework[43]. The SC-GHG for a given quantity of emissions estimate the net social benefits in dollar values of reducing those emissions, or the net social costs of increasing emissions by that quantity. It also provides a common metric (social costs, in dollars) for identifying the effects of changes in inputs or assumptions on the final result.

Using the 2023 SC-GHG guidance and analysis documents in this study requires only the input of annual speciated GHG emissions of carbon dioxide, methane, and nitrous oxide, which came from the NETL-aligned GCAM results. Table C-3.1 summarizes the monetized SC-GHG estimates in the 2023 SC-GHG method used in the study in 2020 dollars per metric ton of emissions by species, which are defined as having been set using near-term Ramsey discount rates. A GDP deflator is used to convert these values as needed for the 2022-dollar year basis.

*Table C-3.1. Annual Unrounded Values in 2023 SC-GHG Estimates, 2020-2080 (2020$ per metric ton of emissions)*

| Gas | $CO_2$ | $CO_2$ | $CO_2$ | $CH_4$ | $CH_4$ | $CH_4$ | $N_2O$ | $N_2O$ | $N_2O$ |
|---|---|---|---|---|---|---|---|---|---|
| **Near-term Ramsey Discount Rate** | **2.50%** | **2.00%** | **1.50%** | **2.50%** | **2.00%** | **1.50%** | **2.50%** | **2.00%** | **1.50%** |
| 2020 | 117 | 193 | 337 | 1,257 | 1,648 | 2,305 | 35,232 | 54,139 | 87,284 |
| 2021 | 119 | 197 | 341 | 1,324 | 1,723 | 2,391 | 36,180 | 55,364 | 88,869 |
| 2022 | 122 | 200 | 346 | 1,390 | 1,799 | 2,478 | 37,128 | 56,590 | 90,454 |
| 2023 | 125 | 204 | 351 | 1,457 | 1,874 | 2,564 | 38,076 | 57,816 | 92,040 |
| 2024 | 128 | 208 | 356 | 1,524 | 1,950 | 2,650 | 39,024 | 59,041 | 93,625 |
| 2025 | 130 | 212 | 360 | 1,590 | 2,025 | 2,737 | 39,972 | 60,267 | 95,210 |
| 2026 | 133 | 215 | 365 | 1,657 | 2,101 | 2,823 | 40,920 | 61,492 | 96,796 |
| 2027 | 136 | 219 | 370 | 1,724 | 2,176 | 2,910 | 41,868 | 62,718 | 98,381 |
| 2028 | 139 | 223 | 375 | 1,791 | 2,252 | 2,996 | 42,816 | 63,944 | 99,966 |
| 2029 | 141 | 226 | 380 | 1,857 | 2,327 | 3,083 | 43,764 | 65,169 | 101,552 |
| 2030 | 144 | 230 | 384 | 1,924 | 2,403 | 3,169 | 44,712 | 66,395 | 103,137 |

[43] Generally, this Appendix refers to 2020-dollar year results, while the Summary report refers to 2022 dollar year results.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2031 | 147 | 234 | 389 | 2,002 | 2,490 | 3,270 | 45,693 | 67,645 | 104,727 |
| 2032 | 150 | 237 | 394 | 2,080 | 2,578 | 3,371 | 46,674 | 68,895 | 106,316 |
| 2033 | 153 | 241 | 398 | 2,157 | 2,666 | 3,471 | 47,655 | 70,145 | 107,906 |
| 2034 | 155 | 245 | 403 | 2,235 | 2,754 | 3,572 | 48,636 | 71,394 | 109,495 |
| 2035 | 158 | 248 | 408 | 2,313 | 2,842 | 3,673 | 49,617 | 72,644 | 111,085 |
| 2036 | 161 | 252 | 412 | 2,391 | 2,929 | 3,774 | 50,598 | 73,894 | 112,674 |
| 2037 | 164 | 256 | 417 | 2,468 | 3,017 | 3,875 | 51,578 | 75,144 | 114,264 |
| 2038 | 167 | 259 | 422 | 2,546 | 3,105 | 3,975 | 52,559 | 76,394 | 115,853 |
| 2039 | 170 | 263 | 426 | 2,624 | 3,193 | 4,076 | 53,540 | 77,644 | 117,443 |
| 2040 | 173 | 267 | 431 | 2,702 | 3,280 | 4,177 | 54,521 | 78,894 | 119,032 |
| 2041 | 176 | 271 | 436 | 2,786 | 3,375 | 4,285 | 55,632 | 80,304 | 120,809 |
| 2042 | 179 | 275 | 441 | 2,871 | 3,471 | 4,394 | 56,744 | 81,714 | 122,586 |
| 2043 | 182 | 279 | 446 | 2,955 | 3,566 | 4,502 | 57,855 | 83,124 | 124,362 |
| 2044 | 186 | 283 | 451 | 3,040 | 3,661 | 4,610 | 58,966 | 84,535 | 126,139 |
| 2045 | 189 | 287 | 456 | 3,124 | 3,756 | 4,718 | 60,078 | 85,945 | 127,916 |
| 2046 | 192 | 291 | 462 | 3,209 | 3,851 | 4,827 | 61,189 | 87,355 | 129,693 |
| 2047 | 195 | 296 | 467 | 3,293 | 3,946 | 4,935 | 62,301 | 88,765 | 131,469 |
| 2048 | 199 | 300 | 472 | 3,378 | 4,041 | 5,043 | 63,412 | 90,176 | 133,246 |
| 2049 | 202 | 304 | 477 | 3,462 | 4,136 | 5,151 | 64,523 | 91,586 | 135,023 |
| 2050 | 205 | 308 | 482 | 3,547 | 4,231 | 5,260 | 65,635 | 92,996 | 136,799 |

Results from the SC-GHG analyses for the 2020-dollar year basis are summarized in Table C-3.2 through Table C-3.4. Note that unlike the consequential intensity and project non-direct emissions results shown earlier, these social costs of greenhouse gases are those associated with all global emissions over the 2020-2050 period for the scenarios, and not just those associated with U.S. LNG exports.

*Table C-3.2. Social cost of greenhouse gases results for Defined Policies (base year 2024, trillion 2020$)*

| | | **Discount Rate** | | |
|---|---|---|---|---|
| **Scenario** | **Gas** | **2.50%** | **2.00%** | **1.50%** |
| *Defined Policies: High Exports* | $CO_2$ | $129.06 | $213.68 | $370.63 |
| | $CH_4$ | $19.39 | $25.34 | $34.86 |
| | $N_2O$ | $14.31 | $22.18 | $35.93 |
| | **Total** | **$162.76** | **$261.20** | **$441.42** |
| *Defined Policies: Model Resolved* | $CO_2$ | $128.98 | $213.54 | $370.40 |
| | $CH_4$ | $19.38 | $25.34 | $34.85 |
| | $N_2O$ | $14.31 | $22.19 | $35.94 |
| | **Total** | **$162.68** | **$261.07** | **$441.19** |
| *Defined Policies: Existing/FID Exports* | $CO_2$ | $128.90 | $213.41 | $370.16 |
| | $CH_4$ | $19.38 | $25.33 | $34.85 |
| | $N_2O$ | $14.32 | $22.20 | $35.96 |
| | **Total** | **$162.60** | **$260.95** | **$440.97** |
| | | | | |

| | | | | |
|---|---|---|---|---|
| *Defined Policies: High Middle East Supply: Model Resolved* | $CO_2$ | $129.36 | $214.19 | $371.52 |
| | $CH_4$ | $19.44 | $25.41 | $34.96 |
| | $N_2O$ | $14.30 | $22.17 | $35.90 |
| | **Total** | **$163.11** | **$261.77** | **$442.39** |
| *Defined Policies: High Middle East Supply: Existing/FID Exports* | $CO_2$ | $129.31 | $214.10 | $371.38 |
| | $CH_4$ | $19.45 | $25.42 | $34.97 |
| | $N_2O$ | $14.30 | $22.17 | $35.91 |
| | **Total** | **$163.06** | **$261.70** | **$442.26** |
| | | | | |
| *Defined Policies: High US Supply: Model Resolved* | $CO_2$ | $129.07 | $213.69 | $370.66 |
| | $CH_4$ | $19.39 | $25.34 | $34.86 |
| | $N_2O$ | $14.31 | $22.19 | $35.93 |
| | **Total** | **$162.77** | **$261.22** | **$441.45** |
| *Defined Policies: High US Supply: Existing/FID Exports* | $CO_2$ | $128.94 | $213.48 | $370.28 |
| | $CH_4$ | $19.39 | $25.34 | $34.86 |
| | $N_2O$ | $14.32 | $22.20 | $35.96 |
| | **Total** | **$162.65** | **$261.01** | **$441.09** |
| | | | | |
| *Defined Policies: Low US Supply: Model Resolved* | $CO_2$ | $128.63 | $212.95 | $369.36 |
| | $CH_4$ | $19.37 | $25.32 | $34.83 |
| | $N_2O$ | $14.32 | $22.20 | $35.95 |
| | **Total** | **$162.32** | **$260.47** | **$440.14** |
| *Defined Policies: Low US Supply: Existing/FID Exports* | $CO_2$ | $128.62 | $212.94 | $369.35 |
| | $CH_4$ | $19.37 | $25.32 | $34.83 |
| | $N_2O$ | $14.32 | $22.20 | $35.95 |
| | **Total** | **$162.31** | **$260.46** | **$440.13** |

*Table C-3.3. Social cost of greenhouse gases results for Commitments (base year 2024, trillion 2020$)*

| | | **Discount Rate** | | |
|---|---|---|---|---|
| **Scenario** | **Gas** | **2.50%** | **2.00%** | **1.50%** |
| *Commitments (High CCS): High Exports* | $CO_2$ | $100.51 | $165.67 | $286.26 |
| | $CH_4$ | $17.98 | $23.47 | $32.26 |
| | $N_2O$ | $13.68 | $21.19 | $34.29 |
| | **Total** | **$132.16** | **$210.33** | **$352.81** |
| *Commitments (High CCS): Model Resolved* | $CO_2$ | $100.43 | $165.53 | $286.02 |
| | $CH_4$ | $17.98 | $23.47 | $32.27 |
| | $N_2O$ | $13.68 | $21.19 | $34.30 |
| | **Total** | **$132.09** | **$210.20** | **$352.58** |
| *Commitments (High CCS): Existing/FID Exports* | $CO_2$ | $100.41 | $165.51 | $285.97 |
| | $CH_4$ | $17.98 | $23.48 | $32.27 |
| | $N_2O$ | $13.68 | $21.19 | $34.30 |
| | **Total** | **$132.07** | **$210.17** | **$352.54** |
| | | | | |
| | $CO_2$ | $95.51 | $157.29 | $271.59 |

| | | | | |
|---|---|---|---|---|
| *Commitments (Mod CCS): High Exports* | $CH_4$ | $17.14 | $22.37 | $30.74 |
| | $N_2O$ | $13.29 | $20.58 | $33.30 |
| | **Total** | **$125.94** | **$200.24** | **$335.64** |
| *Commitments (Mod CCS): Model Resolved* | $CO_2$ | $95.39 | $157.10 | $271.25 |
| | $CH_4$ | $17.14 | $22.37 | $30.75 |
| | $N_2O$ | $13.29 | $20.58 | $33.30 |
| | **Total** | **$125.82** | **$200.05** | **$335.30** |
| *Commitments (Mod CCS): Existing/FID Exports* | $CO_2$ | $95.38 | $157.08 | $271.22 |
| | $CH_4$ | $17.14 | $22.37 | $30.75 |
| | $N_2O$ | $13.29 | $20.58 | $33.30 |
| | **Total** | **$125.82** | **$200.04** | **$335.28** |

*Table C-3.4. Social cost of greenhouse gases results for Net Zero 2050 (base year 2024, trillion 2020$)*

| | | Discount Rate | | |
|---|---|---|---|---|
| **Scenario** | **Gas** | **2.50%** | **2.00%** | **1.50%** |
| *Net Zero 2050 (High CCS): High Exports* | $CO_2$ | $79.78 | $131.11 | $225.96 |
| | $CH_4$ | $17.06 | $22.26 | $30.60 |
| | $N_2O$ | $13.30 | $20.60 | $33.33 |
| | **Total** | **$110.14** | **$173.97** | **$289.90** |
| *Net Zero 2050 (High CCS): Model Resolved* | $CO_2$ | $79.75 | $131.04 | $225.85 |
| | $CH_4$ | $17.06 | $22.27 | $30.61 |
| | $N_2O$ | $13.30 | $20.60 | $33.34 |
| | **Total** | **$110.11** | **$173.91** | **$289.79** |
| *Net Zero 2050 (High CCS): Existing/FID Exports* | $CO_2$ | $79.74 | $131.03 | $225.83 |
| | $CH_4$ | $17.06 | $22.27 | $30.61 |
| | $N_2O$ | $13.30 | $20.60 | $33.34 |
| | **Total** | **$110.11** | **$173.91** | **$289.78** |
| | | | | |
| *Net Zero 2050 (Mod CCS): High Exports* | $CO_2$ | $72.93 | $119.68 | $206.02 |
| | $CH_4$ | $16.01 | $20.89 | $28.70 |
| | $N_2O$ | $12.80 | $19.82 | $32.06 |
| | **Total** | **$101.74** | **$160.38** | **$266.78** |
| *Net Zero 2050 (Mod CCS): Model Resolved* | $CO_2$ | $72.82 | $119.48 | $205.68 |
| | $CH_4$ | $16.01 | $20.89 | $28.71 |
| | $N_2O$ | $12.80 | $19.82 | $32.06 |
| | **Total** | **$101.63** | **$160.19** | **$266.45** |
| *Net Zero 2050 (Mod CCS): Existing/FID Exports* | $CO_2$ | $72.82 | $119.48 | $205.68 |
| | $CH_4$ | $16.01 | $20.89 | $28.71 |
| | $N_2O$ | $12.80 | $19.82 | $32.06 |
| | **Total** | **$101.63** | **$160.19** | **$266.45** |

Similarly, Table C-3.5 through Table C-3.7 show SC-GHG results for all scenarios for the 2022-dollar year basis.

*Table C-3.5. Social cost of greenhouse gases results for Defined Policies (base year 2024, trillion 2022$)*

| | | Discount Rate | | |
|---|---|---|---|---|
| **Scenario** | **Gas** | **2.50%** | **2.00%** | **1.50%** |
| *Defined Policies: High Exports* | $CO_2$ | $144.48 | $239.21 | $414.92 |
| | $CH_4$ | $21.71 | $28.37 | $39.03 |
| | $N_2O$ | $16.02 | $24.83 | $40.22 |
| | **Total** | **$182.20** | **$292.41** | **$494.16** |
| *Defined Policies: Model Resolved* | $CO_2$ | $144.39 | $239.06 | $414.66 |
| | $CH_4$ | $21.70 | $28.36 | $39.02 |
| | $N_2O$ | $16.02 | $24.84 | $40.23 |
| | **Total** | **$182.12** | **$292.27** | **$493.91** |
| *Defined Policies: Existing/FID Exports* | $CO_2$ | $144.30 | $238.91 | $414.39 |
| | $CH_4$ | $21.70 | $28.36 | $39.02 |
| | $N_2O$ | $16.03 | $24.85 | $40.25 |
| | **Total** | **$182.03** | **$292.13** | **$493.66** |
| | | | | |
| *Defined Policies: High Middle East Supply: Model Resolved* | $CO_2$ | $144.82 | $239.78 | $415.92 |
| | $CH_4$ | $21.77 | $28.45 | $39.14 |
| | $N_2O$ | $16.01 | $24.82 | $40.19 |
| | **Total** | **$182.60** | **$293.05** | **$495.25** |
| *Defined Policies: High Middle East Supply: Existing/FID Exports* | $CO_2$ | $144.77 | $239.69 | $415.75 |
| | $CH_4$ | $21.77 | $28.46 | $39.15 |
| | $N_2O$ | $16.01 | $24.82 | $40.20 |
| | **Total** | **$182.55** | **$292.97** | **$495.10** |
| | | | | |
| *Defined Policies: High US Supply: Model Resolved* | $CO_2$ | $144.49 | $239.23 | $414.95 |
| | $CH_4$ | $21.71 | $28.37 | $39.03 |
| | $N_2O$ | $16.02 | $24.84 | $40.23 |
| | **Total** | **$182.22** | **$292.43** | **$494.20** |
| *Defined Policies: High US Supply: Existing/FID Exports* | $CO_2$ | $144.35 | $238.98 | $414.52 |
| | $CH_4$ | $21.70 | $28.36 | $39.02 |
| | $N_2O$ | $16.03 | $24.85 | $40.25 |
| | **Total** | **$182.08** | **$292.20** | **$493.79** |
| | | | | |
| *Defined Policies: Low US Supply: Model Resolved* | $CO_2$ | $144.00 | $238.40 | $413.49 |
| | $CH_4$ | $21.69 | $28.34 | $38.99 |
| | $N_2O$ | $16.03 | $24.85 | $40.25 |
| | **Total** | **$181.71** | **$291.59** | **$492.73** |
| *Defined Policies: Low US Supply: Existing/FID Exports* | $CO_2$ | $143.99 | $238.39 | $413.48 |
| | $CH_4$ | $21.69 | $28.34 | $38.99 |
| | $N_2O$ | $16.03 | $24.85 | $40.25 |
| | **Total** | **$181.71** | **$291.59** | **$492.72** |

*Table C-3.6. Social cost of greenhouse gases results for Commitments (base year 2024, trillion 2022$)*

| | | Discount Rate | | |
|---|---|---|---|---|
| **Scenario** | **Gas** | **2.50%** | **2.00%** | **1.50%** |
| *Commitments (High CCS): High Exports* | $CO_2$ | $112.52 | $185.47 | $320.47 |
| | $CH_4$ | $20.12 | $26.27 | $36.12 |
| | $N_2O$ | $15.31 | $23.72 | $38.39 |
| | **Total** | **$147.96** | **$235.46** | **$394.97** |
| *Commitments (High CCS): Model Resolved* | $CO_2$ | $112.43 | $185.31 | $320.19 |
| | $CH_4$ | $20.13 | $26.28 | $36.12 |
| | $N_2O$ | $15.31 | $23.72 | $38.39 |
| | **Total** | **$147.87** | **$235.31** | **$394.71** |
| *Commitments (High CCS): Existing/FID Exports* | $CO_2$ | $112.41 | $185.28 | $320.14 |
| | $CH_4$ | $20.13 | $26.28 | $36.13 |
| | $N_2O$ | $15.31 | $23.72 | $38.40 |
| | **Total** | **$147.86** | **$235.29** | **$394.67** |
| | | | | |
| *Commitments (Mod CCS): High Exports* | $CO_2$ | $106.92 | $176.09 | $304.04 |
| | $CH_4$ | $19.19 | $25.04 | $34.42 |
| | $N_2O$ | $14.88 | $23.04 | $37.28 |
| | **Total** | **$140.99** | **$224.17** | **$375.74** |
| *Commitments (Mod CCS): Model Resolved* | $CO_2$ | $106.79 | $175.87 | $303.66 |
| | $CH_4$ | $19.19 | $25.04 | $34.42 |
| | $N_2O$ | $14.88 | $23.04 | $37.28 |
| | **Total** | **$140.86** | **$223.96** | **$375.37** |
| *Commitments (Mod CCS): Existing/FID Exports* | $CO_2$ | $106.78 | $175.85 | $303.63 |
| | $CH_4$ | $19.19 | $25.05 | $34.42 |
| | $N_2O$ | $14.88 | $23.04 | $37.28 |
| | **Total** | **$140.85** | **$223.94** | **$375.34** |

*Table C-3.7. Social cost of greenhouse gases results for Net Zero 2050 (base year 2024, trillion 2022$)*

| | | Discount Rate | | |
|---|---|---|---|---|
| **Scenario** | **Gas** | **2.50%** | **2.00%** | **1.50%** |
| *Net Zero 2050 (High CCS): High Exports* | $CO_2$ | $89.32 | $146.77 | $252.96 |
| | $CH_4$ | $19.09 | $24.92 | $34.26 |
| | $N_2O$ | $14.89 | $23.06 | $37.32 |
| | **Total** | **$123.30** | **$194.76** | **$324.54** |
| *Net Zero 2050 (High CCS): Model Resolved* | $CO_2$ | $89.27 | $146.70 | $252.83 |
| | $CH_4$ | $19.10 | $24.93 | $34.27 |
| | $N_2O$ | $14.89 | $23.07 | $37.32 |
| | **Total** | **$123.27** | **$194.69** | **$324.42** |
| | $CO_2$ | $89.27 | $146.69 | $252.81 |

| | | | | |
|---|---|---|---|---|
| *Net Zero 2050 (High CCS): Existing/FID Exports* | $CH_4$ | $19.10 | $24.93 | $34.27 |
| | $N_2O$ | $14.89 | $23.07 | $37.32 |
| | **Total** | **$123.26** | **$194.69** | **$324.41** |
| | | | | |
| *Net Zero 2050 (Mod CCS): High Exports* | $CO_2$ | $81.65 | $133.98 | $230.63 |
| | $CH_4$ | $17.92 | $23.38 | $32.13 |
| | $N_2O$ | $14.33 | $22.19 | $35.89 |
| | **Total** | **$113.90** | **$179.54** | **$298.65** |
| *Net Zero 2050 (Mod CCS): Model Resolved* | $CO_2$ | $81.52 | $133.76 | $230.25 |
| | $CH_4$ | $17.92 | $23.39 | $32.14 |
| | $N_2O$ | $14.33 | $22.19 | $35.89 |
| | **Total** | **$113.77** | **$179.34** | **$298.29** |
| *Net Zero 2050 (Mod CCS): Existing/FID Exports* | $CO_2$ | $81.52 | $133.76 | $230.25 |
| | $CH_4$ | $17.92 | $23.39 | $32.14 |
| | $N_2O$ | $14.33 | $22.19 | $35.89 |
| | **Total** | **$113.77** | **$179.34** | **$298.29** |

## APPENDIX C-4: DETAILED DATA TABLES FOR VALUES SUMMARIZED IN THIS REPORT

The first set of tables provided in this Appendix are archives of the speciated GHG emissions data for all scenarios used in the analysis, representing the GCAM-NETL-aligned values described in the Consequential Appendix. Values are provided on both AR6-100 and AR6-20 basis.

The second set of tables provided in this Appendix summarize annual and cumulative values of GHG emissions, U.S. LNG exports, and the consequential GHG intensity and project non-direct emissions, for all scenarios.

*Table C-4.1. Global Emissions Summary for Defined Policies: Model Resolved (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 100-year) | | | | | | | |
| **2020** | 38,407 | 398 | 6,677 | 3,929 | 887 | 2,123 | 1,349 | 53,770 |
| **2021** | 37,946 | 469 | 6,461 | 3,946 | 877 | 2,151 | 1,370 | 53,219 |
| **2022** | 37,484 | 540 | 6,245 | 3,964 | 867 | 2,179 | 1,390 | 52,669 |
| **2023** | 37,022 | 611 | 6,029 | 3,981 | 857 | 2,206 | 1,410 | 52,118 |
| **2024** | 36,561 | 683 | 5,813 | 3,999 | 847 | 2,234 | 1,431 | 51,567 |
| **2025** | 36,099 | 754 | 5,598 | 4,016 | 837 | 2,262 | 1,451 | 51,017 |
| **2026** | 36,202 | 67 | 5,637 | 4,081 | 845 | 2,294 | 1,518 | 50,645 |
| **2027** | 36,305 | -619 | 5,677 | 4,145 | 853 | 2,326 | 1,586 | 50,273 |
| **2028** | 36,409 | -1,306 | 5,716 | 4,210 | 860 | 2,358 | 1,653 | 49,901 |
| **2029** | 36,512 | -1,992 | 5,755 | 4,274 | 868 | 2,390 | 1,721 | 49,529 |
| **2030** | 36,615 | -2,679 | 5,795 | 4,339 | 876 | 2,423 | 1,788 | 49,156 |
| **2031** | 36,441 | -2,389 | 5,791 | 4,399 | 869 | 2,448 | 1,806 | 49,364 |
| **2032** | 36,268 | -2,100 | 5,786 | 4,460 | 863 | 2,472 | 1,823 | 49,572 |
| **2033** | 36,094 | -1,811 | 5,782 | 4,520 | 857 | 2,497 | 1,840 | 49,779 |
| **2034** | 35,921 | -1,522 | 5,777 | 4,580 | 851 | 2,522 | 1,857 | 49,987 |
| **2035** | 35,748 | -1,233 | 5,773 | 4,640 | 844 | 2,547 | 1,874 | 50,194 |
| **2036** | 35,582 | -1,252 | 5,737 | 4,694 | 833 | 2,571 | 1,868 | 50,033 |
| **2037** | 35,415 | -1,271 | 5,702 | 4,747 | 822 | 2,595 | 1,861 | 49,872 |
| **2038** | 35,249 | -1,290 | 5,666 | 4,800 | 812 | 2,619 | 1,855 | 49,711 |
| **2039** | 35,083 | -1,309 | 5,631 | 4,853 | 801 | 2,643 | 1,848 | 49,549 |
| **2040** | 34,917 | -1,328 | 5,595 | 4,906 | 790 | 2,667 | 1,841 | 49,388 |
| **2041** | 34,745 | -1,261 | 5,602 | 4,962 | 791 | 2,698 | 1,827 | 49,364 |
| **2042** | 34,574 | -1,194 | 5,608 | 5,017 | 792 | 2,730 | 1,812 | 49,340 |
| **2043** | 34,402 | -1,127 | 5,615 | 5,073 | 793 | 2,761 | 1,797 | 49,315 |
| **2044** | 34,230 | -1,059 | 5,621 | 5,129 | 794 | 2,793 | 1,783 | 49,291 |
| **2045** | 34,058 | -992 | 5,628 | 5,185 | 796 | 2,824 | 1,768 | 49,267 |
| **2046** | 33,829 | -969 | 5,630 | 5,235 | 796 | 2,855 | 1,764 | 49,141 |
| **2047** | 33,600 | -945 | 5,633 | 5,286 | 797 | 2,885 | 1,759 | 49,016 |
| **2048** | 33,370 | -922 | 5,636 | 5,337 | 798 | 2,916 | 1,755 | 48,890 |
| **2049** | 33,141 | -898 | 5,638 | 5,388 | 798 | 2,946 | 1,751 | 48,765 |
| **2050** | 32,912 | -874 | 5,641 | 5,439 | 799 | 2,977 | 1,746 | 48,639 |
| **Total** | **1,101,142** | **-28,818** | **178,895** | **143,533** | **25,770** | **78,914** | **52,903** | **1,552,340** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.2. Global Emissions Summary for Defined Policies: Model Resolved (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,407 | 398 | 6,677 | 3,929 | 887 | 2,123 | 1,349 | 53,770 |
| **2021** | 37,946 | 469 | 6,461 | 3,946 | 877 | 2,151 | 1,370 | 53,219 |
| **2022** | 37,484 | 540 | 6,245 | 3,964 | 867 | 2,179 | 1,390 | 52,669 |
| **2023** | 37,022 | 611 | 6,029 | 3,981 | 857 | 2,206 | 1,410 | 52,118 |
| **2024** | 36,561 | 683 | 5,813 | 3,999 | 847 | 2,234 | 1,431 | 51,567 |
| **2025** | 36,099 | 754 | 5,598 | 4,016 | 837 | 2,262 | 1,451 | 51,017 |
| **2026** | 36,202 | 67 | 5,637 | 4,081 | 845 | 2,294 | 1,518 | 50,645 |
| **2027** | 36,305 | -619 | 5,677 | 4,145 | 853 | 2,326 | 1,586 | 50,273 |
| **2028** | 36,409 | -1,306 | 5,716 | 4,210 | 860 | 2,358 | 1,653 | 49,901 |
| **2029** | 36,512 | -1,992 | 5,755 | 4,274 | 868 | 2,390 | 1,721 | 49,529 |
| **2030** | 36,615 | -2,679 | 5,795 | 4,339 | 876 | 2,423 | 1,788 | 49,156 |
| **2031** | 36,449 | -2,397 | 5,791 | 4,399 | 869 | 2,447 | 1,806 | 49,365 |
| **2032** | 36,282 | -2,115 | 5,788 | 4,460 | 863 | 2,472 | 1,823 | 49,573 |
| **2033** | 36,116 | -1,833 | 5,784 | 4,520 | 857 | 2,497 | 1,840 | 49,781 |
| **2034** | 35,950 | -1,551 | 5,780 | 4,580 | 850 | 2,522 | 1,858 | 49,989 |
| **2035** | 35,783 | -1,269 | 5,777 | 4,640 | 844 | 2,546 | 1,875 | 50,197 |
| **2036** | 35,631 | -1,293 | 5,742 | 4,694 | 833 | 2,570 | 1,869 | 50,046 |
| **2037** | 35,479 | -1,317 | 5,707 | 4,747 | 822 | 2,594 | 1,863 | 49,894 |
| **2038** | 35,327 | -1,341 | 5,672 | 4,800 | 811 | 2,618 | 1,856 | 49,743 |
| **2039** | 35,175 | -1,364 | 5,637 | 4,853 | 800 | 2,641 | 1,850 | 49,592 |
| **2040** | 35,023 | -1,388 | 5,602 | 4,906 | 789 | 2,665 | 1,844 | 49,440 |
| **2041** | 34,849 | -1,315 | 5,607 | 4,962 | 790 | 2,696 | 1,829 | 49,418 |
| **2042** | 34,674 | -1,241 | 5,612 | 5,017 | 791 | 2,728 | 1,814 | 49,396 |
| **2043** | 34,500 | -1,167 | 5,617 | 5,073 | 792 | 2,759 | 1,800 | 49,374 |
| **2044** | 34,325 | -1,093 | 5,621 | 5,129 | 794 | 2,791 | 1,785 | 49,352 |
| **2045** | 34,151 | -1,020 | 5,626 | 5,185 | 795 | 2,822 | 1,770 | 49,329 |
| **2046** | 33,913 | -990 | 5,627 | 5,235 | 795 | 2,853 | 1,766 | 49,200 |
| **2047** | 33,675 | -960 | 5,628 | 5,286 | 796 | 2,883 | 1,761 | 49,070 |
| **2048** | 33,437 | -930 | 5,629 | 5,337 | 797 | 2,914 | 1,757 | 48,940 |
| **2049** | 33,198 | -900 | 5,630 | 5,388 | 797 | 2,944 | 1,752 | 48,810 |
| **2050** | 32,960 | -871 | 5,631 | 5,439 | 798 | 2,975 | 1,748 | 48,680 |
| **Total** | **1,102,460** | **-29,427** | **178,912** | **143,533** | **25,756** | **78,881** | **52,936** | **1,553,051** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.3. Global Emissions Summary for Defined Policies: High Exports (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,407 | 398 | 6,677 | 3,929 | 887 | 2,123 | 1,349 | 53,770 |
| **2021** | 37,946 | 469 | 6,461 | 3,946 | 877 | 2,151 | 1,370 | 53,219 |
| **2022** | 37,484 | 540 | 6,245 | 3,964 | 867 | 2,179 | 1,390 | 52,669 |
| **2023** | 37,022 | 611 | 6,029 | 3,981 | 857 | 2,206 | 1,410 | 52,118 |
| **2024** | 36,561 | 683 | 5,813 | 3,999 | 847 | 2,234 | 1,431 | 51,567 |
| **2025** | 36,099 | 754 | 5,598 | 4,016 | 837 | 2,262 | 1,451 | 51,017 |
| **2026** | 36,202 | 67 | 5,637 | 4,081 | 845 | 2,294 | 1,518 | 50,645 |
| **2027** | 36,305 | -619 | 5,677 | 4,145 | 853 | 2,326 | 1,586 | 50,273 |
| **2028** | 36,409 | -1,306 | 5,716 | 4,210 | 860 | 2,358 | 1,653 | 49,901 |
| **2029** | 36,512 | -1,992 | 5,755 | 4,274 | 868 | 2,390 | 1,721 | 49,529 |
| **2030** | 36,615 | -2,679 | 5,795 | 4,339 | 876 | 2,423 | 1,788 | 49,156 |
| **2031** | 36,462 | -2,410 | 5,792 | 4,399 | 869 | 2,447 | 1,806 | 49,365 |
| **2032** | 36,309 | -2,142 | 5,790 | 4,460 | 863 | 2,472 | 1,824 | 49,574 |
| **2033** | 36,156 | -1,873 | 5,788 | 4,520 | 856 | 2,496 | 1,841 | 49,783 |
| **2034** | 36,003 | -1,605 | 5,785 | 4,580 | 850 | 2,520 | 1,859 | 49,992 |
| **2035** | 35,850 | -1,337 | 5,783 | 4,640 | 843 | 2,545 | 1,876 | 50,201 |
| **2036** | 35,699 | -1,349 | 5,748 | 4,694 | 832 | 2,569 | 1,870 | 50,062 |
| **2037** | 35,549 | -1,362 | 5,713 | 4,747 | 821 | 2,592 | 1,864 | 49,924 |
| **2038** | 35,398 | -1,375 | 5,678 | 4,800 | 810 | 2,616 | 1,858 | 49,785 |
| **2039** | 35,248 | -1,388 | 5,643 | 4,853 | 799 | 2,640 | 1,852 | 49,647 |
| **2040** | 35,097 | -1,400 | 5,608 | 4,906 | 788 | 2,663 | 1,846 | 49,508 |
| **2041** | 34,921 | -1,326 | 5,612 | 4,962 | 789 | 2,695 | 1,831 | 49,483 |
| **2042** | 34,745 | -1,252 | 5,616 | 5,017 | 791 | 2,726 | 1,816 | 49,458 |
| **2043** | 34,568 | -1,179 | 5,620 | 5,073 | 792 | 2,758 | 1,801 | 49,433 |
| **2044** | 34,392 | -1,105 | 5,624 | 5,129 | 793 | 2,789 | 1,787 | 49,409 |
| **2045** | 34,215 | -1,031 | 5,628 | 5,185 | 794 | 2,820 | 1,772 | 49,384 |
| **2046** | 33,972 | -999 | 5,628 | 5,235 | 795 | 2,851 | 1,767 | 49,250 |
| **2047** | 33,730 | -967 | 5,629 | 5,286 | 795 | 2,881 | 1,763 | 49,117 |
| **2048** | 33,487 | -935 | 5,629 | 5,337 | 796 | 2,912 | 1,758 | 48,984 |
| **2049** | 33,244 | -903 | 5,629 | 5,388 | 796 | 2,942 | 1,754 | 48,851 |
| **2050** | 33,001 | -872 | 5,629 | 5,439 | 797 | 2,973 | 1,749 | 48,717 |
| **Total** | **1,103,609** | **-29,883** | **178,974** | **143,533** | **25,744** | **78,852** | **52,963** | **1,553,792** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.4. Global Emissions Summary for Defined Policies: High Middle East Supply: Existing/FID Exports (GCAM_NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,416 | 397 | 6,678 | 3,929 | 887 | 2,123 | 1,350 | 53,780 |
| **2021** | 37,955 | 468 | 6,462 | 3,946 | 877 | 2,151 | 1,370 | 53,230 |
| **2022** | 37,495 | 540 | 6,247 | 3,964 | 867 | 2,179 | 1,390 | 52,681 |
| **2023** | 37,035 | 611 | 6,031 | 3,981 | 857 | 2,206 | 1,411 | 52,131 |
| **2024** | 36,574 | 682 | 5,815 | 3,999 | 847 | 2,234 | 1,431 | 51,582 |
| **2025** | 36,114 | 753 | 5,599 | 4,016 | 837 | 2,262 | 1,451 | 51,032 |
| **2026** | 36,227 | 56 | 5,640 | 4,081 | 845 | 2,294 | 1,519 | 50,662 |
| **2027** | 36,340 | -640 | 5,681 | 4,145 | 853 | 2,326 | 1,586 | 50,291 |
| **2028** | 36,454 | -1,336 | 5,722 | 4,210 | 860 | 2,358 | 1,654 | 49,921 |
| **2029** | 36,567 | -2,033 | 5,763 | 4,274 | 868 | 2,390 | 1,722 | 49,551 |
| **2030** | 36,680 | -2,729 | 5,804 | 4,339 | 875 | 2,422 | 1,789 | 49,180 |
| **2031** | 36,529 | -2,452 | 5,803 | 4,399 | 869 | 2,446 | 1,807 | 49,401 |
| **2032** | 36,378 | -2,175 | 5,803 | 4,460 | 863 | 2,471 | 1,825 | 49,623 |
| **2033** | 36,227 | -1,898 | 5,802 | 4,520 | 856 | 2,495 | 1,842 | 49,844 |
| **2034** | 36,075 | -1,621 | 5,802 | 4,580 | 850 | 2,520 | 1,860 | 50,065 |
| **2035** | 35,924 | -1,345 | 5,801 | 4,640 | 843 | 2,544 | 1,878 | 50,286 |
| **2036** | 35,786 | -1,363 | 5,771 | 4,694 | 832 | 2,568 | 1,872 | 50,158 |
| **2037** | 35,647 | -1,382 | 5,740 | 4,747 | 821 | 2,591 | 1,866 | 50,030 |
| **2038** | 35,509 | -1,400 | 5,710 | 4,800 | 810 | 2,615 | 1,860 | 49,903 |
| **2039** | 35,370 | -1,419 | 5,680 | 4,853 | 799 | 2,638 | 1,854 | 49,775 |
| **2040** | 35,232 | -1,438 | 5,650 | 4,906 | 788 | 2,662 | 1,848 | 49,647 |
| **2041** | 35,073 | -1,374 | 5,659 | 4,962 | 789 | 2,693 | 1,833 | 49,635 |
| **2042** | 34,915 | -1,311 | 5,668 | 5,017 | 790 | 2,724 | 1,818 | 49,623 |
| **2043** | 34,757 | -1,248 | 5,678 | 5,073 | 792 | 2,755 | 1,804 | 49,610 |
| **2044** | 34,598 | -1,184 | 5,687 | 5,129 | 793 | 2,786 | 1,789 | 49,598 |
| **2045** | 34,440 | -1,121 | 5,696 | 5,185 | 794 | 2,817 | 1,775 | 49,586 |
| **2046** | 34,218 | -1,100 | 5,702 | 5,236 | 794 | 2,847 | 1,771 | 49,468 |
| **2047** | 33,997 | -1,078 | 5,707 | 5,286 | 795 | 2,877 | 1,766 | 49,350 |
| **2048** | 33,775 | -1,057 | 5,712 | 5,337 | 796 | 2,907 | 1,762 | 49,232 |
| **2049** | 33,553 | -1,035 | 5,717 | 5,388 | 796 | 2,937 | 1,758 | 49,114 |
| **2050** | 33,331 | -1,014 | 5,722 | 5,439 | 797 | 2,967 | 1,753 | 48,996 |
| **Total** | **1,107,190** | **-31,246** | **179,951** | **143,534** | **25,741** | **78,803** | **53,012** | **1,556,984** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.5. Global Emissions Summary for Defined Policies: High Middle East Supply: Model Resolved (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,416 | 397 | 6,678 | 3,929 | 887 | 2,123 | 1,350 | 53,780 |
| **2021** | 37,955 | 468 | 6,462 | 3,946 | 877 | 2,151 | 1,370 | 53,230 |
| **2022** | 37,495 | 540 | 6,247 | 3,964 | 867 | 2,179 | 1,390 | 52,681 |
| **2023** | 37,035 | 611 | 6,031 | 3,981 | 857 | 2,206 | 1,411 | 52,131 |
| **2024** | 36,574 | 682 | 5,815 | 3,999 | 847 | 2,234 | 1,431 | 51,582 |
| **2025** | 36,114 | 753 | 5,599 | 4,016 | 837 | 2,262 | 1,451 | 51,032 |
| **2026** | 36,227 | 56 | 5,640 | 4,081 | 845 | 2,294 | 1,519 | 50,662 |
| **2027** | 36,340 | -640 | 5,681 | 4,145 | 853 | 2,326 | 1,586 | 50,291 |
| **2028** | 36,454 | -1,336 | 5,722 | 4,210 | 860 | 2,358 | 1,654 | 49,921 |
| **2029** | 36,567 | -2,033 | 5,763 | 4,274 | 868 | 2,390 | 1,722 | 49,551 |
| **2030** | 36,680 | -2,729 | 5,804 | 4,339 | 875 | 2,422 | 1,789 | 49,180 |
| **2031** | 36,535 | -2,458 | 5,804 | 4,399 | 869 | 2,446 | 1,807 | 49,402 |
| **2032** | 36,389 | -2,186 | 5,803 | 4,460 | 862 | 2,470 | 1,825 | 49,624 |
| **2033** | 36,243 | -1,915 | 5,803 | 4,520 | 856 | 2,495 | 1,843 | 49,845 |
| **2034** | 36,098 | -1,643 | 5,803 | 4,580 | 850 | 2,519 | 1,861 | 50,067 |
| **2035** | 35,952 | -1,372 | 5,803 | 4,640 | 843 | 2,543 | 1,878 | 50,288 |
| **2036** | 35,819 | -1,390 | 5,772 | 4,694 | 832 | 2,567 | 1,872 | 50,166 |
| **2037** | 35,686 | -1,408 | 5,741 | 4,747 | 821 | 2,590 | 1,867 | 50,044 |
| **2038** | 35,553 | -1,426 | 5,710 | 4,800 | 810 | 2,614 | 1,861 | 49,922 |
| **2039** | 35,420 | -1,444 | 5,680 | 4,853 | 799 | 2,637 | 1,855 | 49,799 |
| **2040** | 35,287 | -1,462 | 5,649 | 4,906 | 788 | 2,661 | 1,849 | 49,677 |
| **2041** | 35,126 | -1,394 | 5,657 | 4,962 | 789 | 2,692 | 1,834 | 49,666 |
| **2042** | 34,966 | -1,327 | 5,665 | 5,017 | 790 | 2,723 | 1,820 | 49,654 |
| **2043** | 34,806 | -1,259 | 5,673 | 5,073 | 791 | 2,754 | 1,805 | 49,643 |
| **2044** | 34,645 | -1,192 | 5,681 | 5,129 | 792 | 2,785 | 1,791 | 49,632 |
| **2045** | 34,485 | -1,124 | 5,689 | 5,185 | 793 | 2,816 | 1,776 | 49,620 |
| **2046** | 34,260 | -1,103 | 5,693 | 5,236 | 794 | 2,846 | 1,772 | 49,497 |
| **2047** | 34,035 | -1,082 | 5,697 | 5,286 | 795 | 2,876 | 1,767 | 49,375 |
| **2048** | 33,810 | -1,061 | 5,701 | 5,337 | 795 | 2,906 | 1,763 | 49,252 |
| **2049** | 33,585 | -1,040 | 5,706 | 5,388 | 796 | 2,936 | 1,759 | 49,129 |
| **2050** | 33,360 | -1,019 | 5,710 | 5,439 | 797 | 2,966 | 1,754 | 49,006 |
| **Total** | **1,107,917** | **-31,537** | **179,882** | **143,534** | **25,734** | **78,785** | **53,032** | **1,557,347** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.6. Global Emissions Summary for Defined Policies: High U.S. Supply: Existing/FID Exports (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,403 | 398 | 6,677 | 3,929 | 887 | 2,123 | 1,349 | 53,766 |
| **2021** | 37,943 | 469 | 6,461 | 3,946 | 877 | 2,151 | 1,370 | 53,216 |
| **2022** | 37,483 | 539 | 6,245 | 3,964 | 867 | 2,179 | 1,390 | 52,667 |
| **2023** | 37,023 | 610 | 6,029 | 3,981 | 857 | 2,206 | 1,410 | 52,117 |
| **2024** | 36,563 | 681 | 5,814 | 3,999 | 847 | 2,234 | 1,431 | 51,568 |
| **2025** | 36,103 | 751 | 5,598 | 4,016 | 837 | 2,262 | 1,451 | 51,019 |
| **2026** | 36,207 | 64 | 5,637 | 4,081 | 845 | 2,294 | 1,519 | 50,647 |
| **2027** | 36,312 | -623 | 5,677 | 4,145 | 853 | 2,326 | 1,586 | 50,276 |
| **2028** | 36,416 | -1,310 | 5,717 | 4,210 | 860 | 2,358 | 1,653 | 49,905 |
| **2029** | 36,520 | -1,997 | 5,756 | 4,274 | 868 | 2,390 | 1,721 | 49,534 |
| **2030** | 36,625 | -2,684 | 5,796 | 4,339 | 876 | 2,423 | 1,788 | 49,162 |
| **2031** | 36,451 | -2,393 | 5,791 | 4,399 | 869 | 2,447 | 1,806 | 49,371 |
| **2032** | 36,276 | -2,102 | 5,787 | 4,460 | 863 | 2,472 | 1,823 | 49,580 |
| **2033** | 36,102 | -1,811 | 5,782 | 4,520 | 857 | 2,497 | 1,840 | 49,788 |
| **2034** | 35,928 | -1,520 | 5,778 | 4,580 | 851 | 2,522 | 1,857 | 49,997 |
| **2035** | 35,754 | -1,229 | 5,773 | 4,640 | 844 | 2,547 | 1,874 | 50,205 |
| **2036** | 35,589 | -1,249 | 5,738 | 4,694 | 833 | 2,571 | 1,868 | 50,044 |
| **2037** | 35,425 | -1,270 | 5,702 | 4,747 | 823 | 2,595 | 1,861 | 49,883 |
| **2038** | 35,260 | -1,290 | 5,667 | 4,800 | 812 | 2,619 | 1,855 | 49,722 |
| **2039** | 35,095 | -1,311 | 5,631 | 4,853 | 801 | 2,643 | 1,848 | 49,560 |
| **2040** | 34,931 | -1,331 | 5,596 | 4,906 | 790 | 2,667 | 1,841 | 49,399 |
| **2041** | 34,763 | -1,266 | 5,602 | 4,962 | 791 | 2,698 | 1,827 | 49,377 |
| **2042** | 34,595 | -1,200 | 5,609 | 5,017 | 792 | 2,730 | 1,812 | 49,356 |
| **2043** | 34,427 | -1,135 | 5,616 | 5,073 | 793 | 2,761 | 1,798 | 49,334 |
| **2044** | 34,259 | -1,069 | 5,623 | 5,129 | 795 | 2,793 | 1,783 | 49,312 |
| **2045** | 34,091 | -1,004 | 5,630 | 5,185 | 796 | 2,824 | 1,768 | 49,290 |
| **2046** | 33,866 | -981 | 5,633 | 5,235 | 797 | 2,855 | 1,764 | 49,168 |
| **2047** | 33,642 | -959 | 5,635 | 5,286 | 797 | 2,885 | 1,760 | 49,047 |
| **2048** | 33,417 | -937 | 5,638 | 5,337 | 798 | 2,916 | 1,755 | 48,925 |
| **2049** | 33,193 | -914 | 5,641 | 5,388 | 799 | 2,946 | 1,751 | 48,803 |
| **2050** | 32,968 | -892 | 5,644 | 5,439 | 800 | 2,977 | 1,747 | 48,681 |
| **Total** | **1,101,631** | **-28,959** | **178,923** | **143,533** | **25,773** | **78,913** | **52,906** | **1,552,720** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.7. Global Emissions Summary for Defined Policies: High U.S. Supply: Model Resolved (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,403 | 398 | 6,677 | 3,929 | 887 | 2,123 | 1,349 | 53,766 |
| **2021** | 37,943 | 469 | 6,461 | 3,946 | 877 | 2,151 | 1,370 | 53,216 |
| **2022** | 37,483 | 539 | 6,245 | 3,964 | 867 | 2,179 | 1,390 | 52,667 |
| **2023** | 37,023 | 610 | 6,029 | 3,981 | 857 | 2,206 | 1,410 | 52,117 |
| **2024** | 36,563 | 681 | 5,814 | 3,999 | 847 | 2,234 | 1,431 | 51,568 |
| **2025** | 36,103 | 751 | 5,598 | 4,016 | 837 | 2,262 | 1,451 | 51,019 |
| **2026** | 36,207 | 64 | 5,637 | 4,081 | 845 | 2,294 | 1,519 | 50,647 |
| **2027** | 36,312 | -623 | 5,677 | 4,145 | 853 | 2,326 | 1,586 | 50,276 |
| **2028** | 36,416 | -1,310 | 5,717 | 4,210 | 860 | 2,358 | 1,653 | 49,905 |
| **2029** | 36,520 | -1,997 | 5,756 | 4,274 | 868 | 2,390 | 1,721 | 49,534 |
| **2030** | 36,625 | -2,684 | 5,796 | 4,339 | 876 | 2,423 | 1,788 | 49,162 |
| **2031** | 36,462 | -2,404 | 5,792 | 4,399 | 869 | 2,447 | 1,806 | 49,372 |
| **2032** | 36,299 | -2,125 | 5,789 | 4,460 | 863 | 2,472 | 1,823 | 49,581 |
| **2033** | 36,137 | -1,846 | 5,786 | 4,520 | 857 | 2,497 | 1,841 | 49,791 |
| **2034** | 35,974 | -1,566 | 5,782 | 4,580 | 850 | 2,521 | 1,858 | 50,000 |
| **2035** | 35,812 | -1,287 | 5,779 | 4,640 | 844 | 2,546 | 1,876 | 50,209 |
| **2036** | 35,665 | -1,312 | 5,745 | 4,694 | 833 | 2,570 | 1,869 | 50,064 |
| **2037** | 35,519 | -1,336 | 5,710 | 4,747 | 822 | 2,593 | 1,863 | 49,918 |
| **2038** | 35,373 | -1,361 | 5,675 | 4,800 | 811 | 2,617 | 1,857 | 49,772 |
| **2039** | 35,227 | -1,385 | 5,641 | 4,853 | 800 | 2,641 | 1,851 | 49,627 |
| **2040** | 35,081 | -1,410 | 5,606 | 4,906 | 789 | 2,664 | 1,845 | 49,481 |
| **2041** | 34,915 | -1,341 | 5,611 | 4,962 | 790 | 2,696 | 1,830 | 49,463 |
| **2042** | 34,749 | -1,272 | 5,616 | 5,017 | 791 | 2,727 | 1,816 | 49,444 |
| **2043** | 34,582 | -1,203 | 5,622 | 5,073 | 792 | 2,758 | 1,801 | 49,425 |
| **2044** | 34,416 | -1,134 | 5,627 | 5,129 | 793 | 2,789 | 1,786 | 49,407 |
| **2045** | 34,250 | -1,065 | 5,632 | 5,185 | 794 | 2,821 | 1,772 | 49,388 |
| **2046** | 34,020 | -1,037 | 5,633 | 5,235 | 795 | 2,851 | 1,767 | 49,265 |
| **2047** | 33,790 | -1,009 | 5,634 | 5,286 | 796 | 2,881 | 1,763 | 49,141 |
| **2048** | 33,559 | -981 | 5,635 | 5,337 | 797 | 2,912 | 1,758 | 49,017 |
| **2049** | 33,329 | -953 | 5,636 | 5,388 | 797 | 2,942 | 1,754 | 48,894 |
| **2050** | 33,099 | -925 | 5,637 | 5,439 | 798 | 2,972 | 1,750 | 48,770 |
| **Total** | **1,103,858** | **-30,051** | **178,994** | **143,533** | **25,753** | **78,862** | **52,956** | **1,553,906** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.8. Global Emissions Summary for Defined Policies: Low U.S. Supply: Existing/FID Exports (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,431 | 396 | 6,678 | 3,929 | 887 | 2,123 | 1,350 | 53,794 |
| **2021** | 37,958 | 472 | 6,462 | 3,946 | 877 | 2,151 | 1,370 | 53,236 |
| **2022** | 37,484 | 548 | 6,245 | 3,964 | 867 | 2,179 | 1,390 | 52,678 |
| **2023** | 37,011 | 625 | 6,029 | 3,981 | 857 | 2,206 | 1,410 | 52,119 |
| **2024** | 36,538 | 701 | 5,812 | 3,999 | 847 | 2,234 | 1,431 | 51,561 |
| **2025** | 36,065 | 777 | 5,595 | 4,016 | 837 | 2,261 | 1,451 | 51,003 |
| **2026** | 36,159 | 93 | 5,634 | 4,081 | 845 | 2,294 | 1,518 | 50,624 |
| **2027** | 36,254 | -591 | 5,673 | 4,145 | 852 | 2,326 | 1,586 | 50,245 |
| **2028** | 36,348 | -1,275 | 5,712 | 4,210 | 860 | 2,358 | 1,653 | 49,866 |
| **2029** | 36,443 | -1,959 | 5,751 | 4,274 | 868 | 2,391 | 1,720 | 49,487 |
| **2030** | 36,537 | -2,643 | 5,790 | 4,339 | 875 | 2,423 | 1,788 | 49,108 |
| **2031** | 36,359 | -2,357 | 5,785 | 4,399 | 869 | 2,448 | 1,805 | 49,308 |
| **2032** | 36,181 | -2,071 | 5,780 | 4,460 | 863 | 2,473 | 1,822 | 49,508 |
| **2033** | 36,004 | -1,785 | 5,775 | 4,520 | 856 | 2,498 | 1,839 | 49,708 |
| **2034** | 35,826 | -1,498 | 5,770 | 4,580 | 850 | 2,523 | 1,856 | 49,907 |
| **2035** | 35,648 | -1,212 | 5,766 | 4,640 | 844 | 2,548 | 1,873 | 50,107 |
| **2036** | 35,477 | -1,232 | 5,730 | 4,694 | 833 | 2,571 | 1,867 | 49,940 |
| **2037** | 35,306 | -1,251 | 5,695 | 4,747 | 822 | 2,595 | 1,860 | 49,773 |
| **2038** | 35,134 | -1,271 | 5,659 | 4,800 | 811 | 2,619 | 1,854 | 49,606 |
| **2039** | 34,963 | -1,290 | 5,624 | 4,853 | 800 | 2,643 | 1,847 | 49,439 |
| **2040** | 34,791 | -1,310 | 5,588 | 4,906 | 789 | 2,667 | 1,841 | 49,273 |
| **2041** | 34,602 | -1,230 | 5,594 | 4,962 | 790 | 2,699 | 1,826 | 49,243 |
| **2042** | 34,412 | -1,149 | 5,600 | 5,017 | 791 | 2,730 | 1,811 | 49,213 |
| **2043** | 34,222 | -1,068 | 5,605 | 5,073 | 792 | 2,762 | 1,797 | 49,183 |
| **2044** | 34,032 | -988 | 5,611 | 5,129 | 794 | 2,793 | 1,782 | 49,153 |
| **2045** | 33,842 | -907 | 5,616 | 5,185 | 795 | 2,825 | 1,767 | 49,123 |
| **2046** | 33,618 | -904 | 5,619 | 5,235 | 795 | 2,856 | 1,763 | 48,982 |
| **2047** | 33,394 | -901 | 5,621 | 5,286 | 796 | 2,886 | 1,759 | 48,841 |
| **2048** | 33,171 | -898 | 5,624 | 5,337 | 796 | 2,917 | 1,754 | 48,701 |
| **2049** | 32,947 | -895 | 5,627 | 5,388 | 797 | 2,947 | 1,750 | 48,560 |
| **2050** | 32,723 | -892 | 5,629 | 5,438 | 798 | 2,978 | 1,746 | 48,419 |
| **Total** | **1,097,878** | **-27,967** | **178,699** | **143,533** | **25,755** | **78,923** | **52,887** | **1,549,708** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.9. Global Emissions Summary for Defined Policies: Low U.S. Supply: Model Resolved (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,431 | 396 | 6,678 | 3,929 | 887 | 2,123 | 1,350 | 53,794 |
| **2021** | 37,958 | 472 | 6,462 | 3,946 | 877 | 2,151 | 1,370 | 53,236 |
| **2022** | 37,484 | 548 | 6,245 | 3,964 | 867 | 2,179 | 1,390 | 52,678 |
| **2023** | 37,011 | 625 | 6,029 | 3,981 | 857 | 2,206 | 1,410 | 52,119 |
| **2024** | 36,538 | 701 | 5,812 | 3,999 | 847 | 2,234 | 1,431 | 51,561 |
| **2025** | 36,065 | 777 | 5,595 | 4,016 | 837 | 2,261 | 1,451 | 51,003 |
| **2026** | 36,159 | 93 | 5,634 | 4,081 | 845 | 2,294 | 1,518 | 50,624 |
| **2027** | 36,254 | -591 | 5,673 | 4,145 | 852 | 2,326 | 1,586 | 50,245 |
| **2028** | 36,348 | -1,275 | 5,712 | 4,210 | 860 | 2,358 | 1,653 | 49,866 |
| **2029** | 36,443 | -1,959 | 5,751 | 4,274 | 868 | 2,391 | 1,720 | 49,487 |
| **2030** | 36,537 | -2,643 | 5,790 | 4,339 | 875 | 2,423 | 1,788 | 49,108 |
| **2031** | 36,359 | -2,357 | 5,785 | 4,399 | 869 | 2,448 | 1,805 | 49,308 |
| **2032** | 36,181 | -2,071 | 5,780 | 4,460 | 863 | 2,473 | 1,822 | 49,508 |
| **2033** | 36,004 | -1,785 | 5,775 | 4,520 | 856 | 2,498 | 1,839 | 49,708 |
| **2034** | 35,826 | -1,498 | 5,770 | 4,580 | 850 | 2,523 | 1,856 | 49,907 |
| **2035** | 35,648 | -1,212 | 5,766 | 4,640 | 844 | 2,548 | 1,873 | 50,107 |
| **2036** | 35,478 | -1,232 | 5,730 | 4,694 | 833 | 2,571 | 1,867 | 49,940 |
| **2037** | 35,307 | -1,252 | 5,695 | 4,747 | 822 | 2,595 | 1,860 | 49,774 |
| **2038** | 35,136 | -1,273 | 5,659 | 4,800 | 811 | 2,619 | 1,854 | 49,607 |
| **2039** | 34,966 | -1,293 | 5,624 | 4,853 | 800 | 2,643 | 1,847 | 49,440 |
| **2040** | 34,795 | -1,313 | 5,589 | 4,906 | 789 | 2,667 | 1,841 | 49,274 |
| **2041** | 34,607 | -1,234 | 5,594 | 4,962 | 790 | 2,698 | 1,826 | 49,244 |
| **2042** | 34,420 | -1,156 | 5,599 | 5,017 | 791 | 2,730 | 1,812 | 49,214 |
| **2043** | 34,232 | -1,077 | 5,605 | 5,073 | 792 | 2,762 | 1,797 | 49,184 |
| **2044** | 34,045 | -999 | 5,610 | 5,129 | 794 | 2,793 | 1,782 | 49,154 |
| **2045** | 33,857 | -920 | 5,615 | 5,185 | 795 | 2,825 | 1,768 | 49,124 |
| **2046** | 33,636 | -918 | 5,618 | 5,235 | 795 | 2,855 | 1,763 | 48,984 |
| **2047** | 33,414 | -916 | 5,620 | 5,286 | 796 | 2,886 | 1,759 | 48,845 |
| **2048** | 33,193 | -914 | 5,623 | 5,337 | 796 | 2,916 | 1,755 | 48,705 |
| **2049** | 32,971 | -912 | 5,625 | 5,388 | 797 | 2,947 | 1,751 | 48,566 |
| **2050** | 32,750 | -910 | 5,627 | 5,438 | 797 | 2,977 | 1,746 | 48,426 |
| **Total** | **1,098,051** | **-28,098** | **178,691** | **143,533** | **25,753** | **78,919** | **52,891** | **1,549,740** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.10. Global Emissions Summary for Commitments (High CCS): Existing/FID Exports (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,407 | 532 | 6,674 | 3,928 | 886 | 2,126 | 1,349 | 53,903 |
| **2021** | 37,781 | 616 | 6,430 | 3,944 | 872 | 2,151 | 1,366 | 53,160 |
| **2022** | 37,155 | 700 | 6,185 | 3,959 | 857 | 2,177 | 1,384 | 52,417 |
| **2023** | 36,529 | 784 | 5,940 | 3,975 | 843 | 2,202 | 1,401 | 51,674 |
| **2024** | 35,903 | 868 | 5,696 | 3,990 | 829 | 2,227 | 1,418 | 50,931 |
| **2025** | 35,278 | 952 | 5,451 | 4,005 | 815 | 2,252 | 1,435 | 50,188 |
| **2026** | 35,132 | 732 | 5,483 | 4,071 | 825 | 2,277 | 1,497 | 50,016 |
| **2027** | 34,987 | 511 | 5,515 | 4,137 | 834 | 2,301 | 1,560 | 49,845 |
| **2028** | 34,841 | 291 | 5,548 | 4,202 | 844 | 2,326 | 1,622 | 49,674 |
| **2029** | 34,696 | 70 | 5,580 | 4,268 | 853 | 2,350 | 1,685 | 49,502 |
| **2030** | 34,550 | -150 | 5,612 | 4,334 | 863 | 2,374 | 1,747 | 49,331 |
| **2031** | 33,222 | -124 | 5,524 | 4,381 | 842 | 2,401 | 1,744 | 47,989 |
| **2032** | 31,893 | -98 | 5,435 | 4,428 | 820 | 2,428 | 1,741 | 46,648 |
| **2033** | 30,565 | -72 | 5,346 | 4,476 | 799 | 2,455 | 1,738 | 45,306 |
| **2034** | 29,237 | -46 | 5,257 | 4,523 | 777 | 2,482 | 1,735 | 43,965 |
| **2035** | 27,908 | -20 | 5,169 | 4,570 | 756 | 2,509 | 1,732 | 42,623 |
| **2036** | 26,604 | 180 | 5,107 | 4,618 | 747 | 2,530 | 1,723 | 41,510 |
| **2037** | 25,300 | 380 | 5,046 | 4,666 | 738 | 2,551 | 1,715 | 40,396 |
| **2038** | 23,995 | 580 | 4,985 | 4,714 | 729 | 2,572 | 1,706 | 39,282 |
| **2039** | 22,691 | 781 | 4,923 | 4,762 | 720 | 2,594 | 1,698 | 38,168 |
| **2040** | 21,387 | 981 | 4,862 | 4,810 | 711 | 2,615 | 1,689 | 37,054 |
| **2041** | 20,078 | 871 | 4,749 | 4,851 | 694 | 2,627 | 1,623 | 35,492 |
| **2042** | 18,769 | 762 | 4,636 | 4,891 | 677 | 2,638 | 1,556 | 33,930 |
| **2043** | 17,460 | 652 | 4,523 | 4,932 | 660 | 2,650 | 1,490 | 32,368 |
| **2044** | 16,152 | 542 | 4,411 | 4,972 | 643 | 2,662 | 1,424 | 30,805 |
| **2045** | 14,843 | 433 | 4,298 | 5,013 | 626 | 2,674 | 1,357 | 29,243 |
| **2046** | 13,554 | 250 | 4,208 | 5,058 | 610 | 2,686 | 1,317 | 27,683 |
| **2047** | 12,265 | 67 | 4,119 | 5,104 | 594 | 2,698 | 1,276 | 26,122 |
| **2048** | 10,976 | -116 | 4,029 | 5,149 | 578 | 2,710 | 1,236 | 24,561 |
| **2049** | 9,687 | -299 | 3,940 | 5,194 | 562 | 2,722 | 1,196 | 23,001 |
| **2050** | 8,397 | -481 | 3,850 | 5,240 | 545 | 2,734 | 1,155 | 21,440 |
| **Total** | **810,240** | **11,127** | **158,531** | **141,167** | **23,148** | **76,699** | **47,315** | **1,268,227** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.11. Global Emissions Summary for Commitments (High CCS): Model Resolved (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,407 | 532 | 6,674 | 3,928 | 886 | 2,126 | 1,349 | 53,903 |
| **2021** | 37,781 | 616 | 6,430 | 3,944 | 872 | 2,151 | 1,366 | 53,160 |
| **2022** | 37,155 | 700 | 6,185 | 3,959 | 857 | 2,177 | 1,384 | 52,417 |
| **2023** | 36,529 | 784 | 5,940 | 3,975 | 843 | 2,202 | 1,401 | 51,674 |
| **2024** | 35,903 | 868 | 5,696 | 3,990 | 829 | 2,227 | 1,418 | 50,931 |
| **2025** | 35,278 | 952 | 5,451 | 4,005 | 815 | 2,252 | 1,435 | 50,188 |
| **2026** | 35,132 | 732 | 5,483 | 4,071 | 825 | 2,277 | 1,497 | 50,016 |
| **2027** | 34,987 | 511 | 5,515 | 4,137 | 834 | 2,301 | 1,560 | 49,845 |
| **2028** | 34,841 | 291 | 5,548 | 4,202 | 844 | 2,326 | 1,622 | 49,674 |
| **2029** | 34,696 | 70 | 5,580 | 4,268 | 853 | 2,350 | 1,685 | 49,502 |
| **2030** | 34,550 | -150 | 5,612 | 4,334 | 863 | 2,374 | 1,747 | 49,331 |
| **2031** | 33,222 | -124 | 5,524 | 4,381 | 842 | 2,401 | 1,744 | 47,989 |
| **2032** | 31,893 | -98 | 5,435 | 4,428 | 820 | 2,428 | 1,741 | 46,648 |
| **2033** | 30,565 | -72 | 5,346 | 4,476 | 799 | 2,455 | 1,738 | 45,306 |
| **2034** | 29,237 | -46 | 5,257 | 4,523 | 777 | 2,482 | 1,735 | 43,965 |
| **2035** | 27,908 | -20 | 5,169 | 4,570 | 756 | 2,509 | 1,732 | 42,623 |
| **2036** | 26,609 | 172 | 5,107 | 4,618 | 747 | 2,530 | 1,724 | 41,507 |
| **2037** | 25,309 | 365 | 5,046 | 4,666 | 738 | 2,551 | 1,715 | 40,390 |
| **2038** | 24,010 | 557 | 4,985 | 4,714 | 729 | 2,572 | 1,707 | 39,273 |
| **2039** | 22,710 | 750 | 4,923 | 4,762 | 719 | 2,594 | 1,698 | 38,157 |
| **2040** | 21,411 | 942 | 4,862 | 4,810 | 710 | 2,615 | 1,690 | 37,040 |
| **2041** | 20,100 | 845 | 4,748 | 4,851 | 693 | 2,626 | 1,624 | 35,487 |
| **2042** | 18,789 | 747 | 4,634 | 4,891 | 677 | 2,638 | 1,557 | 33,934 |
| **2043** | 17,478 | 650 | 4,520 | 4,932 | 660 | 2,650 | 1,491 | 32,381 |
| **2044** | 16,168 | 552 | 4,407 | 4,972 | 643 | 2,662 | 1,424 | 30,828 |
| **2045** | 14,857 | 455 | 4,293 | 5,013 | 626 | 2,673 | 1,358 | 29,274 |
| **2046** | 13,566 | 269 | 4,202 | 5,058 | 610 | 2,685 | 1,317 | 27,708 |
| **2047** | 12,275 | 84 | 4,112 | 5,104 | 594 | 2,697 | 1,277 | 26,142 |
| **2048** | 10,984 | -102 | 4,022 | 5,149 | 578 | 2,709 | 1,236 | 24,576 |
| **2049** | 9,693 | -287 | 3,932 | 5,194 | 562 | 2,721 | 1,196 | 23,010 |
| **2050** | 8,402 | -473 | 3,842 | 5,240 | 545 | 2,733 | 1,155 | 21,444 |
| **Total** | **810,441** | **11,069** | **158,481** | **141,167** | **23,147** | **76,696** | **47,323** | **1,268,324** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.12. Global Emissions Summary for Commitments (High CCS): High Exports (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,407 | 532 | 6,674 | 3,928 | 886 | 2,126 | 1,349 | 53,903 |
| **2021** | 37,781 | 616 | 6,430 | 3,944 | 872 | 2,151 | 1,366 | 53,160 |
| **2022** | 37,155 | 700 | 6,185 | 3,959 | 857 | 2,177 | 1,384 | 52,417 |
| **2023** | 36,529 | 784 | 5,940 | 3,975 | 843 | 2,202 | 1,401 | 51,674 |
| **2024** | 35,903 | 868 | 5,696 | 3,990 | 829 | 2,227 | 1,418 | 50,931 |
| **2025** | 35,278 | 952 | 5,451 | 4,005 | 815 | 2,252 | 1,435 | 50,188 |
| **2026** | 35,132 | 732 | 5,483 | 4,071 | 825 | 2,277 | 1,497 | 50,016 |
| **2027** | 34,987 | 511 | 5,515 | 4,137 | 834 | 2,301 | 1,560 | 49,845 |
| **2028** | 34,841 | 291 | 5,548 | 4,202 | 844 | 2,326 | 1,622 | 49,674 |
| **2029** | 34,696 | 70 | 5,580 | 4,268 | 853 | 2,350 | 1,685 | 49,502 |
| **2030** | 34,550 | -150 | 5,612 | 4,334 | 863 | 2,374 | 1,747 | 49,331 |
| **2031** | 33,239 | -141 | 5,525 | 4,381 | 842 | 2,401 | 1,745 | 47,991 |
| **2032** | 31,928 | -132 | 5,438 | 4,428 | 820 | 2,428 | 1,742 | 46,651 |
| **2033** | 30,617 | -123 | 5,350 | 4,476 | 799 | 2,454 | 1,739 | 45,311 |
| **2034** | 29,306 | -114 | 5,263 | 4,523 | 777 | 2,481 | 1,737 | 43,971 |
| **2035** | 27,994 | -105 | 5,175 | 4,570 | 755 | 2,507 | 1,734 | 42,631 |
| **2036** | 26,688 | 104 | 5,113 | 4,618 | 746 | 2,529 | 1,725 | 41,524 |
| **2037** | 25,382 | 313 | 5,050 | 4,666 | 737 | 2,550 | 1,717 | 40,416 |
| **2038** | 24,076 | 522 | 4,987 | 4,714 | 728 | 2,571 | 1,709 | 39,308 |
| **2039** | 22,770 | 731 | 4,925 | 4,762 | 719 | 2,592 | 1,700 | 38,201 |
| **2040** | 21,465 | 941 | 4,862 | 4,810 | 710 | 2,614 | 1,692 | 37,093 |
| **2041** | 20,149 | 852 | 4,747 | 4,851 | 693 | 2,626 | 1,625 | 35,543 |
| **2042** | 18,834 | 764 | 4,631 | 4,891 | 677 | 2,637 | 1,559 | 33,993 |
| **2043** | 17,518 | 675 | 4,516 | 4,932 | 660 | 2,649 | 1,492 | 32,443 |
| **2044** | 16,203 | 587 | 4,401 | 4,972 | 643 | 2,661 | 1,426 | 30,893 |
| **2045** | 14,888 | 499 | 4,285 | 5,013 | 626 | 2,673 | 1,359 | 29,343 |
| **2046** | 13,595 | 305 | 4,194 | 5,058 | 610 | 2,685 | 1,319 | 27,766 |
| **2047** | 12,303 | 112 | 4,102 | 5,104 | 594 | 2,697 | 1,278 | 26,189 |
| **2048** | 11,010 | -81 | 4,011 | 5,149 | 578 | 2,709 | 1,237 | 24,612 |
| **2049** | 9,718 | -275 | 3,919 | 5,195 | 561 | 2,721 | 1,197 | 23,036 |
| **2050** | 8,425 | -468 | 3,828 | 5,240 | 545 | 2,733 | 1,156 | 21,459 |
| **Total** | **811,367** | **10,870** | **158,436** | **141,167** | **23,143** | **76,678** | **47,352** | **1,269,014** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.13. Global Emissions Summary for Commitments (Moderate CCS): Existing/FID Exports (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,407 | 532 | 6,674 | 3,928 | 886 | 2,126 | 1,349 | 53,903 |
| **2021** | 37,778 | 571 | 6,397 | 3,937 | 867 | 2,149 | 1,361 | 53,061 |
| **2022** | 37,150 | 610 | 6,120 | 3,946 | 848 | 2,172 | 1,373 | 52,220 |
| **2023** | 36,522 | 650 | 5,842 | 3,955 | 829 | 2,195 | 1,385 | 51,378 |
| **2024** | 35,894 | 689 | 5,565 | 3,963 | 811 | 2,218 | 1,397 | 50,536 |
| **2025** | 35,266 | 728 | 5,287 | 3,972 | 792 | 2,241 | 1,408 | 49,694 |
| **2026** | 35,123 | 503 | 5,319 | 4,040 | 804 | 2,266 | 1,472 | 49,527 |
| **2027** | 34,980 | 279 | 5,350 | 4,108 | 815 | 2,291 | 1,535 | 49,359 |
| **2028** | 34,838 | 55 | 5,381 | 4,175 | 827 | 2,317 | 1,598 | 49,191 |
| **2029** | 34,695 | -169 | 5,412 | 4,243 | 838 | 2,342 | 1,662 | 49,024 |
| **2030** | 34,552 | -393 | 5,444 | 4,311 | 850 | 2,367 | 1,725 | 48,856 |
| **2031** | 33,267 | -563 | 5,299 | 4,347 | 824 | 2,385 | 1,706 | 47,265 |
| **2032** | 31,982 | -732 | 5,155 | 4,383 | 797 | 2,402 | 1,687 | 45,674 |
| **2033** | 30,696 | -902 | 5,011 | 4,419 | 771 | 2,420 | 1,668 | 44,084 |
| **2034** | 29,411 | -1,071 | 4,867 | 4,456 | 745 | 2,438 | 1,648 | 42,493 |
| **2035** | 28,126 | -1,241 | 4,723 | 4,492 | 718 | 2,455 | 1,629 | 40,902 |
| **2036** | 26,822 | -1,576 | 4,617 | 4,532 | 702 | 2,466 | 1,607 | 39,170 |
| **2037** | 25,518 | -1,911 | 4,512 | 4,572 | 685 | 2,477 | 1,584 | 37,437 |
| **2038** | 24,214 | -2,246 | 4,406 | 4,611 | 669 | 2,488 | 1,562 | 35,704 |
| **2039** | 22,910 | -2,582 | 4,301 | 4,651 | 653 | 2,499 | 1,539 | 33,971 |
| **2040** | 21,606 | -2,917 | 4,196 | 4,691 | 636 | 2,511 | 1,517 | 32,239 |
| **2041** | 20,283 | -2,775 | 4,094 | 4,739 | 621 | 2,520 | 1,471 | 30,953 |
| **2042** | 18,960 | -2,633 | 3,993 | 4,786 | 606 | 2,530 | 1,425 | 29,668 |
| **2043** | 17,638 | -2,491 | 3,891 | 4,834 | 591 | 2,540 | 1,379 | 28,382 |
| **2044** | 16,315 | -2,349 | 3,789 | 4,881 | 576 | 2,550 | 1,333 | 27,097 |
| **2045** | 14,992 | -2,206 | 3,688 | 4,929 | 561 | 2,560 | 1,287 | 25,811 |
| **2046** | 13,678 | -2,224 | 3,612 | 4,979 | 553 | 2,575 | 1,256 | 24,429 |
| **2047** | 12,364 | -2,241 | 3,536 | 5,029 | 545 | 2,589 | 1,224 | 23,047 |
| **2048** | 11,051 | -2,258 | 3,460 | 5,079 | 536 | 2,603 | 1,193 | 21,664 |
| **2049** | 9,737 | -2,275 | 3,384 | 5,129 | 528 | 2,618 | 1,162 | 20,282 |
| **2050** | 8,423 | -2,293 | 3,308 | 5,180 | 520 | 2,632 | 1,131 | 18,900 |
| **Total** | **813,197** | **-35,428** | **146,632** | **139,298** | **22,005** | **74,944** | **45,271** | **1,205,919** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.14. Global Emissions Summary for Commitments (Moderate CCS): Model Resolved (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,407 | 532 | 6,674 | 3,928 | 886 | 2,126 | 1,349 | 53,903 |
| **2021** | 37,778 | 571 | 6,397 | 3,937 | 867 | 2,149 | 1,361 | 53,061 |
| **2022** | 37,150 | 610 | 6,120 | 3,946 | 848 | 2,172 | 1,373 | 52,220 |
| **2023** | 36,522 | 650 | 5,842 | 3,955 | 829 | 2,195 | 1,385 | 51,378 |
| **2024** | 35,894 | 689 | 5,565 | 3,963 | 811 | 2,218 | 1,397 | 50,536 |
| **2025** | 35,266 | 728 | 5,287 | 3,972 | 792 | 2,241 | 1,408 | 49,694 |
| **2026** | 35,123 | 503 | 5,319 | 4,040 | 804 | 2,266 | 1,472 | 49,527 |
| **2027** | 34,980 | 279 | 5,350 | 4,108 | 815 | 2,291 | 1,535 | 49,359 |
| **2028** | 34,838 | 55 | 5,381 | 4,175 | 827 | 2,317 | 1,598 | 49,191 |
| **2029** | 34,695 | -169 | 5,412 | 4,243 | 838 | 2,342 | 1,662 | 49,024 |
| **2030** | 34,552 | -393 | 5,444 | 4,311 | 850 | 2,367 | 1,725 | 48,856 |
| **2031** | 33,267 | -563 | 5,299 | 4,347 | 824 | 2,385 | 1,706 | 47,265 |
| **2032** | 31,982 | -732 | 5,155 | 4,383 | 797 | 2,402 | 1,687 | 45,674 |
| **2033** | 30,696 | -902 | 5,011 | 4,419 | 771 | 2,420 | 1,668 | 44,084 |
| **2034** | 29,411 | -1,071 | 4,867 | 4,456 | 745 | 2,438 | 1,648 | 42,493 |
| **2035** | 28,126 | -1,241 | 4,723 | 4,492 | 718 | 2,455 | 1,629 | 40,902 |
| **2036** | 26,823 | -1,576 | 4,617 | 4,532 | 702 | 2,466 | 1,607 | 39,171 |
| **2037** | 25,520 | -1,911 | 4,512 | 4,572 | 685 | 2,477 | 1,584 | 37,440 |
| **2038** | 24,217 | -2,246 | 4,406 | 4,611 | 669 | 2,488 | 1,562 | 35,709 |
| **2039** | 22,914 | -2,581 | 4,301 | 4,651 | 653 | 2,500 | 1,539 | 33,978 |
| **2040** | 21,612 | -2,916 | 4,196 | 4,691 | 636 | 2,511 | 1,517 | 32,246 |
| **2041** | 20,289 | -2,774 | 4,094 | 4,739 | 621 | 2,520 | 1,471 | 30,960 |
| **2042** | 18,967 | -2,632 | 3,992 | 4,786 | 606 | 2,530 | 1,425 | 29,675 |
| **2043** | 17,644 | -2,489 | 3,890 | 4,834 | 591 | 2,540 | 1,379 | 28,389 |
| **2044** | 16,321 | -2,347 | 3,788 | 4,881 | 576 | 2,550 | 1,333 | 27,103 |
| **2045** | 14,999 | -2,205 | 3,686 | 4,929 | 561 | 2,560 | 1,287 | 25,817 |
| **2046** | 13,684 | -2,223 | 3,610 | 4,979 | 553 | 2,575 | 1,256 | 24,433 |
| **2047** | 12,370 | -2,241 | 3,533 | 5,029 | 545 | 2,589 | 1,224 | 23,050 |
| **2048** | 11,055 | -2,258 | 3,457 | 5,079 | 536 | 2,603 | 1,193 | 21,666 |
| **2049** | 9,741 | -2,276 | 3,381 | 5,129 | 528 | 2,618 | 1,162 | 20,283 |
| **2050** | 8,426 | -2,294 | 3,305 | 5,180 | 520 | 2,632 | 1,131 | 18,899 |
| **Total** | **813,270** | **-35,419** | **146,614** | **139,299** | **22,005** | **74,944** | **45,273** | **1,205,985** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.15. Global Emissions Summary for Commitments (Moderate CCS): High Exports (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,407 | 532 | 6,674 | 3,928 | 886 | 2,126 | 1,349 | 53,903 |
| **2021** | 37,778 | 571 | 6,397 | 3,937 | 867 | 2,149 | 1,361 | 53,061 |
| **2022** | 37,150 | 610 | 6,120 | 3,946 | 848 | 2,172 | 1,373 | 52,220 |
| **2023** | 36,522 | 650 | 5,842 | 3,955 | 829 | 2,195 | 1,385 | 51,378 |
| **2024** | 35,894 | 689 | 5,565 | 3,963 | 811 | 2,218 | 1,397 | 50,536 |
| **2025** | 35,266 | 728 | 5,287 | 3,972 | 792 | 2,241 | 1,408 | 49,694 |
| **2026** | 35,123 | 503 | 5,319 | 4,040 | 804 | 2,266 | 1,472 | 49,527 |
| **2027** | 34,980 | 279 | 5,350 | 4,108 | 815 | 2,291 | 1,535 | 49,359 |
| **2028** | 34,838 | 55 | 5,381 | 4,175 | 827 | 2,317 | 1,598 | 49,191 |
| **2029** | 34,695 | -169 | 5,412 | 4,243 | 838 | 2,342 | 1,662 | 49,024 |
| **2030** | 34,552 | -393 | 5,444 | 4,311 | 850 | 2,367 | 1,725 | 48,856 |
| **2031** | 33,276 | -560 | 5,301 | 4,347 | 824 | 2,385 | 1,706 | 47,278 |
| **2032** | 32,000 | -728 | 5,157 | 4,383 | 797 | 2,402 | 1,687 | 45,700 |
| **2033** | 30,724 | -895 | 5,014 | 4,419 | 771 | 2,420 | 1,669 | 44,122 |
| **2034** | 29,448 | -1,063 | 4,871 | 4,456 | 745 | 2,438 | 1,650 | 42,545 |
| **2035** | 28,172 | -1,230 | 4,728 | 4,492 | 719 | 2,455 | 1,631 | 40,967 |
| **2036** | 26,866 | -1,566 | 4,621 | 4,532 | 702 | 2,467 | 1,609 | 39,230 |
| **2037** | 25,561 | -1,903 | 4,514 | 4,572 | 686 | 2,478 | 1,586 | 37,493 |
| **2038** | 24,255 | -2,239 | 4,407 | 4,611 | 669 | 2,489 | 1,563 | 35,756 |
| **2039** | 22,950 | -2,575 | 4,300 | 4,651 | 653 | 2,500 | 1,541 | 34,019 |
| **2040** | 21,644 | -2,912 | 4,193 | 4,691 | 636 | 2,511 | 1,518 | 32,282 |
| **2041** | 20,325 | -2,770 | 4,091 | 4,739 | 621 | 2,520 | 1,472 | 30,999 |
| **2042** | 19,007 | -2,628 | 3,988 | 4,786 | 606 | 2,530 | 1,426 | 29,716 |
| **2043** | 17,688 | -2,486 | 3,885 | 4,834 | 591 | 2,540 | 1,380 | 28,433 |
| **2044** | 16,369 | -2,344 | 3,782 | 4,882 | 576 | 2,550 | 1,334 | 27,149 |
| **2045** | 15,050 | -2,201 | 3,679 | 4,929 | 561 | 2,560 | 1,288 | 25,866 |
| **2046** | 13,743 | -2,220 | 3,602 | 4,979 | 553 | 2,574 | 1,257 | 24,489 |
| **2047** | 12,436 | -2,239 | 3,526 | 5,029 | 545 | 2,589 | 1,226 | 23,111 |
| **2048** | 11,129 | -2,257 | 3,449 | 5,080 | 536 | 2,603 | 1,194 | 21,734 |
| **2049** | 9,822 | -2,276 | 3,373 | 5,130 | 528 | 2,617 | 1,163 | 20,357 |
| **2050** | 8,515 | -2,295 | 3,296 | 5,180 | 519 | 2,632 | 1,132 | 18,979 |
| **Total** | **814,186** | **-35,330** | **146,569** | **139,301** | **22,006** | **74,943** | **45,298** | **1,206,973** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.16. Global Emissions Summary for Net Zero 2050 (High CCS): Existing/FID Exports (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,407 | 532 | 6,674 | 3,928 | 886 | 2,126 | 1,349 | 53,903 |
| **2021** | 37,781 | 616 | 6,430 | 3,944 | 872 | 2,151 | 1,366 | 53,160 |
| **2022** | 37,155 | 700 | 6,185 | 3,959 | 857 | 2,177 | 1,384 | 52,417 |
| **2023** | 36,529 | 784 | 5,940 | 3,975 | 843 | 2,202 | 1,401 | 51,674 |
| **2024** | 35,903 | 868 | 5,696 | 3,990 | 829 | 2,227 | 1,418 | 50,931 |
| **2025** | 35,278 | 952 | 5,451 | 4,005 | 815 | 2,252 | 1,435 | 50,188 |
| **2026** | 33,803 | 423 | 5,351 | 4,051 | 798 | 2,275 | 1,471 | 48,171 |
| **2027** | 32,329 | -107 | 5,251 | 4,096 | 781 | 2,297 | 1,508 | 46,155 |
| **2028** | 30,854 | -636 | 5,151 | 4,141 | 764 | 2,319 | 1,545 | 44,138 |
| **2029** | 29,380 | -1,166 | 5,051 | 4,187 | 746 | 2,341 | 1,582 | 42,121 |
| **2030** | 27,905 | -1,695 | 4,951 | 4,232 | 729 | 2,364 | 1,618 | 40,105 |
| **2031** | 26,454 | -1,180 | 4,903 | 4,284 | 723 | 2,391 | 1,619 | 39,193 |
| **2032** | 25,003 | -666 | 4,854 | 4,336 | 717 | 2,418 | 1,619 | 38,281 |
| **2033** | 23,552 | -151 | 4,806 | 4,388 | 710 | 2,445 | 1,619 | 37,370 |
| **2034** | 22,101 | 364 | 4,758 | 4,440 | 704 | 2,472 | 1,619 | 36,458 |
| **2035** | 20,649 | 878 | 4,709 | 4,492 | 698 | 2,499 | 1,620 | 35,546 |
| **2036** | 19,293 | 727 | 4,597 | 4,532 | 679 | 2,512 | 1,593 | 33,933 |
| **2037** | 17,936 | 577 | 4,485 | 4,572 | 660 | 2,524 | 1,567 | 32,321 |
| **2038** | 16,580 | 426 | 4,373 | 4,612 | 640 | 2,537 | 1,541 | 30,708 |
| **2039** | 15,223 | 275 | 4,261 | 4,651 | 621 | 2,549 | 1,514 | 29,095 |
| **2040** | 13,866 | 125 | 4,149 | 4,691 | 602 | 2,562 | 1,488 | 27,483 |
| **2041** | 12,508 | 178 | 4,077 | 4,743 | 591 | 2,574 | 1,444 | 26,115 |
| **2042** | 11,150 | 231 | 4,005 | 4,795 | 581 | 2,586 | 1,400 | 24,746 |
| **2043** | 9,792 | 284 | 3,933 | 4,846 | 570 | 2,598 | 1,355 | 23,378 |
| **2044** | 8,434 | 337 | 3,861 | 4,898 | 559 | 2,610 | 1,311 | 22,010 |
| **2045** | 7,076 | 389 | 3,789 | 4,950 | 549 | 2,622 | 1,267 | 20,642 |
| **2046** | 5,680 | 360 | 3,693 | 5,004 | 541 | 2,633 | 1,236 | 19,147 |
| **2047** | 4,283 | 330 | 3,597 | 5,058 | 533 | 2,645 | 1,206 | 17,653 |
| **2048** | 2,887 | 301 | 3,501 | 5,112 | 526 | 2,657 | 1,175 | 16,158 |
| **2049** | 1,490 | 271 | 3,405 | 5,167 | 518 | 2,669 | 1,144 | 14,664 |
| **2050** | 94 | 242 | 3,308 | 5,221 | 510 | 2,680 | 1,114 | 13,169 |
| **Total** | **639,377** | **5,568** | **145,193** | **139,301** | **21,153** | **75,913** | **44,528** | **1,071,033** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.17. Global Emissions Summary for Net Zero 2050 (High CCS): Model Resolved (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,407 | 532 | 6,674 | 3,928 | 886 | 2,126 | 1,349 | 53,903 |
| **2021** | 37,781 | 616 | 6,430 | 3,944 | 872 | 2,151 | 1,366 | 53,160 |
| **2022** | 37,155 | 700 | 6,185 | 3,959 | 857 | 2,177 | 1,384 | 52,417 |
| **2023** | 36,529 | 784 | 5,940 | 3,975 | 843 | 2,202 | 1,401 | 51,674 |
| **2024** | 35,903 | 868 | 5,696 | 3,990 | 829 | 2,227 | 1,418 | 50,931 |
| **2025** | 35,278 | 952 | 5,451 | 4,005 | 815 | 2,252 | 1,435 | 50,188 |
| **2026** | 33,803 | 423 | 5,351 | 4,051 | 798 | 2,275 | 1,471 | 48,171 |
| **2027** | 32,329 | -107 | 5,251 | 4,096 | 781 | 2,297 | 1,508 | 46,155 |
| **2028** | 30,854 | -636 | 5,151 | 4,141 | 764 | 2,319 | 1,545 | 44,138 |
| **2029** | 29,380 | -1,166 | 5,051 | 4,187 | 746 | 2,341 | 1,582 | 42,121 |
| **2030** | 27,905 | -1,695 | 4,951 | 4,232 | 729 | 2,364 | 1,618 | 40,105 |
| **2031** | 26,454 | -1,181 | 4,903 | 4,284 | 723 | 2,391 | 1,619 | 39,193 |
| **2032** | 25,003 | -666 | 4,854 | 4,336 | 717 | 2,418 | 1,619 | 38,281 |
| **2033** | 23,551 | -151 | 4,806 | 4,388 | 710 | 2,445 | 1,619 | 37,369 |
| **2034** | 22,100 | 363 | 4,758 | 4,440 | 704 | 2,472 | 1,619 | 36,457 |
| **2035** | 20,649 | 878 | 4,709 | 4,492 | 698 | 2,499 | 1,620 | 35,546 |
| **2036** | 19,295 | 723 | 4,597 | 4,532 | 679 | 2,512 | 1,593 | 33,931 |
| **2037** | 17,941 | 567 | 4,485 | 4,572 | 660 | 2,524 | 1,567 | 32,316 |
| **2038** | 16,586 | 412 | 4,373 | 4,612 | 640 | 2,537 | 1,541 | 30,701 |
| **2039** | 15,232 | 257 | 4,261 | 4,651 | 621 | 2,549 | 1,515 | 29,086 |
| **2040** | 13,878 | 101 | 4,148 | 4,691 | 602 | 2,561 | 1,488 | 27,471 |
| **2041** | 12,518 | 162 | 4,076 | 4,743 | 591 | 2,573 | 1,444 | 26,108 |
| **2042** | 11,159 | 224 | 4,003 | 4,794 | 581 | 2,585 | 1,400 | 24,746 |
| **2043** | 9,799 | 285 | 3,931 | 4,846 | 570 | 2,597 | 1,356 | 23,384 |
| **2044** | 8,439 | 346 | 3,858 | 4,898 | 559 | 2,609 | 1,311 | 22,022 |
| **2045** | 7,080 | 407 | 3,786 | 4,950 | 549 | 2,621 | 1,267 | 20,660 |
| **2046** | 5,683 | 374 | 3,690 | 5,004 | 541 | 2,633 | 1,237 | 19,161 |
| **2047** | 4,286 | 341 | 3,593 | 5,058 | 533 | 2,645 | 1,206 | 17,663 |
| **2048** | 2,889 | 308 | 3,497 | 5,112 | 526 | 2,657 | 1,175 | 16,164 |
| **2049** | 1,492 | 275 | 3,401 | 5,167 | 518 | 2,668 | 1,144 | 14,666 |
| **2050** | 95 | 242 | 3,305 | 5,221 | 510 | 2,680 | 1,114 | 13,167 |
| **Total** | **639,453** | **5,540** | **145,165** | **139,301** | **21,152** | **75,911** | **44,531** | **1,071,054** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.18. Global Emissions Summary for Net Zero 2050 (High CCS): High Exports (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,407 | 532 | 6,674 | 3,928 | 886 | 2,126 | 1,349 | 53,903 |
| **2021** | 37,781 | 616 | 6,430 | 3,944 | 872 | 2,151 | 1,366 | 53,160 |
| **2022** | 37,155 | 700 | 6,185 | 3,959 | 857 | 2,177 | 1,384 | 52,417 |
| **2023** | 36,529 | 784 | 5,940 | 3,975 | 843 | 2,202 | 1,401 | 51,674 |
| **2024** | 35,903 | 868 | 5,696 | 3,990 | 829 | 2,227 | 1,418 | 50,931 |
| **2025** | 35,278 | 952 | 5,451 | 4,005 | 815 | 2,252 | 1,435 | 50,188 |
| **2026** | 33,803 | 423 | 5,351 | 4,051 | 798 | 2,275 | 1,471 | 48,171 |
| **2027** | 32,329 | -107 | 5,251 | 4,096 | 781 | 2,297 | 1,508 | 46,155 |
| **2028** | 30,854 | -636 | 5,151 | 4,141 | 764 | 2,319 | 1,545 | 44,138 |
| **2029** | 29,380 | -1,166 | 5,051 | 4,187 | 746 | 2,341 | 1,582 | 42,121 |
| **2030** | 27,905 | -1,695 | 4,951 | 4,232 | 729 | 2,364 | 1,618 | 40,105 |
| **2031** | 26,462 | -1,196 | 4,904 | 4,284 | 723 | 2,391 | 1,619 | 39,187 |
| **2032** | 25,020 | -697 | 4,856 | 4,336 | 716 | 2,418 | 1,620 | 38,270 |
| **2033** | 23,577 | -197 | 4,809 | 4,388 | 710 | 2,445 | 1,620 | 37,352 |
| **2034** | 22,134 | 302 | 4,761 | 4,440 | 704 | 2,472 | 1,621 | 36,434 |
| **2035** | 20,692 | 801 | 4,714 | 4,492 | 697 | 2,499 | 1,622 | 35,517 |
| **2036** | 19,337 | 662 | 4,601 | 4,532 | 678 | 2,511 | 1,595 | 33,916 |
| **2037** | 17,982 | 522 | 4,487 | 4,572 | 659 | 2,523 | 1,569 | 32,315 |
| **2038** | 16,628 | 382 | 4,374 | 4,611 | 640 | 2,536 | 1,543 | 30,714 |
| **2039** | 15,273 | 243 | 4,261 | 4,651 | 621 | 2,548 | 1,516 | 29,113 |
| **2040** | 13,919 | 103 | 4,147 | 4,691 | 602 | 2,560 | 1,490 | 27,512 |
| **2041** | 12,556 | 173 | 4,073 | 4,743 | 591 | 2,573 | 1,446 | 26,154 |
| **2042** | 11,193 | 243 | 3,999 | 4,794 | 581 | 2,585 | 1,401 | 24,796 |
| **2043** | 9,830 | 313 | 3,926 | 4,846 | 570 | 2,597 | 1,357 | 23,438 |
| **2044** | 8,467 | 383 | 3,852 | 4,898 | 560 | 2,609 | 1,313 | 22,080 |
| **2045** | 7,104 | 453 | 3,778 | 4,950 | 549 | 2,621 | 1,268 | 20,722 |
| **2046** | 5,704 | 407 | 3,681 | 5,004 | 541 | 2,632 | 1,237 | 19,207 |
| **2047** | 4,304 | 360 | 3,584 | 5,058 | 533 | 2,644 | 1,207 | 17,691 |
| **2048** | 2,904 | 313 | 3,487 | 5,113 | 525 | 2,656 | 1,176 | 16,175 |
| **2049** | 1,504 | 267 | 3,390 | 5,167 | 518 | 2,668 | 1,145 | 14,659 |
| **2050** | 104 | 220 | 3,293 | 5,221 | 510 | 2,679 | 1,114 | 13,143 |
| **Total** | **640,017** | **5,330** | **145,109** | **139,300** | **21,148** | **75,896** | **44,556** | **1,071,356** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.19. Global Emissions Summary for Net Zero 2050 (Moderate CCS): Existing/FID Exports (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,407 | 532 | 6,674 | 3,928 | 886 | 2,126 | 1,349 | 53,903 |
| **2021** | 37,778 | 571 | 6,397 | 3,937 | 867 | 2,149 | 1,361 | 53,061 |
| **2022** | 37,150 | 610 | 6,120 | 3,946 | 848 | 2,172 | 1,373 | 52,220 |
| **2023** | 36,522 | 650 | 5,842 | 3,955 | 829 | 2,195 | 1,385 | 51,378 |
| **2024** | 35,894 | 689 | 5,565 | 3,963 | 811 | 2,218 | 1,397 | 50,536 |
| **2025** | 35,266 | 728 | 5,287 | 3,972 | 792 | 2,241 | 1,408 | 49,694 |
| **2026** | 33,806 | 76 | 5,140 | 4,007 | 774 | 2,258 | 1,436 | 47,497 |
| **2027** | 32,347 | -576 | 4,992 | 4,042 | 757 | 2,276 | 1,463 | 45,300 |
| **2028** | 30,888 | -1,227 | 4,844 | 4,077 | 739 | 2,293 | 1,491 | 43,103 |
| **2029** | 29,428 | -1,879 | 4,696 | 4,112 | 721 | 2,310 | 1,518 | 40,906 |
| **2030** | 27,969 | -2,531 | 4,548 | 4,147 | 703 | 2,328 | 1,546 | 38,710 |
| **2031** | 26,585 | -2,788 | 4,429 | 4,189 | 685 | 2,338 | 1,535 | 36,973 |
| **2032** | 25,201 | -3,046 | 4,309 | 4,232 | 668 | 2,348 | 1,525 | 35,236 |
| **2033** | 23,817 | -3,304 | 4,189 | 4,275 | 650 | 2,358 | 1,514 | 33,499 |
| **2034** | 22,433 | -3,561 | 4,070 | 4,317 | 632 | 2,368 | 1,504 | 31,763 |
| **2035** | 21,049 | -3,819 | 3,950 | 4,360 | 614 | 2,378 | 1,493 | 30,026 |
| **2036** | 19,668 | -3,575 | 3,875 | 4,412 | 601 | 2,391 | 1,481 | 28,853 |
| **2037** | 18,286 | -3,331 | 3,799 | 4,463 | 588 | 2,404 | 1,470 | 27,679 |
| **2038** | 16,904 | -3,088 | 3,724 | 4,515 | 575 | 2,417 | 1,458 | 26,505 |
| **2039** | 15,522 | -2,844 | 3,649 | 4,567 | 562 | 2,430 | 1,446 | 25,332 |
| **2040** | 14,140 | -2,600 | 3,573 | 4,619 | 549 | 2,442 | 1,435 | 24,158 |
| **2041** | 12,778 | -2,738 | 3,468 | 4,670 | 541 | 2,449 | 1,396 | 22,563 |
| **2042** | 11,416 | -2,876 | 3,362 | 4,720 | 533 | 2,456 | 1,356 | 20,968 |
| **2043** | 10,054 | -3,014 | 3,256 | 4,771 | 524 | 2,463 | 1,317 | 19,372 |
| **2044** | 8,692 | -3,152 | 3,150 | 4,822 | 516 | 2,470 | 1,278 | 17,777 |
| **2045** | 7,330 | -3,290 | 3,044 | 4,873 | 508 | 2,477 | 1,239 | 16,181 |
| **2046** | 5,916 | -2,831 | 2,967 | 4,930 | 504 | 2,494 | 1,218 | 15,196 |
| **2047** | 4,501 | -2,373 | 2,890 | 4,987 | 500 | 2,510 | 1,196 | 14,212 |
| **2048** | 3,086 | -1,914 | 2,813 | 5,044 | 496 | 2,527 | 1,175 | 13,227 |
| **2049** | 1,672 | -1,455 | 2,735 | 5,101 | 492 | 2,544 | 1,154 | 12,242 |
| **2050** | 257 | -996 | 2,658 | 5,158 | 488 | 2,561 | 1,132 | 11,257 |
| **Total** | **644,762** | **-58,952** | **130,012** | **137,111** | **19,953** | **73,393** | **43,049** | **989,329** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.20. Global Emissions Summary for Net Zero 2050 (Moderate CCS): Model Resolved (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,407 | 532 | 6,674 | 3,928 | 886 | 2,126 | 1,349 | 53,903 |
| **2021** | 37,778 | 571 | 6,397 | 3,937 | 867 | 2,149 | 1,361 | 53,061 |
| **2022** | 37,150 | 610 | 6,120 | 3,946 | 848 | 2,172 | 1,373 | 52,220 |
| **2023** | 36,522 | 650 | 5,842 | 3,955 | 829 | 2,195 | 1,385 | 51,378 |
| **2024** | 35,894 | 689 | 5,565 | 3,963 | 811 | 2,218 | 1,397 | 50,536 |
| **2025** | 35,266 | 728 | 5,287 | 3,972 | 792 | 2,241 | 1,408 | 49,694 |
| **2026** | 33,806 | 76 | 5,140 | 4,007 | 774 | 2,258 | 1,436 | 47,497 |
| **2027** | 32,347 | -576 | 4,992 | 4,042 | 757 | 2,276 | 1,463 | 45,300 |
| **2028** | 30,888 | -1,227 | 4,844 | 4,077 | 739 | 2,293 | 1,491 | 43,103 |
| **2029** | 29,428 | -1,879 | 4,696 | 4,112 | 721 | 2,310 | 1,518 | 40,906 |
| **2030** | 27,969 | -2,531 | 4,548 | 4,147 | 703 | 2,328 | 1,546 | 38,710 |
| **2031** | 26,585 | -2,788 | 4,429 | 4,189 | 685 | 2,338 | 1,535 | 36,973 |
| **2032** | 25,201 | -3,046 | 4,309 | 4,232 | 668 | 2,348 | 1,525 | 35,236 |
| **2033** | 23,817 | -3,304 | 4,189 | 4,275 | 650 | 2,358 | 1,514 | 33,499 |
| **2034** | 22,433 | -3,561 | 4,070 | 4,317 | 632 | 2,368 | 1,504 | 31,763 |
| **2035** | 21,049 | -3,819 | 3,950 | 4,360 | 614 | 2,378 | 1,493 | 30,026 |
| **2036** | 19,668 | -3,575 | 3,875 | 4,412 | 601 | 2,391 | 1,481 | 28,853 |
| **2037** | 18,286 | -3,331 | 3,799 | 4,463 | 588 | 2,404 | 1,470 | 27,679 |
| **2038** | 16,904 | -3,088 | 3,724 | 4,515 | 575 | 2,417 | 1,458 | 26,505 |
| **2039** | 15,522 | -2,844 | 3,649 | 4,567 | 562 | 2,430 | 1,446 | 25,332 |
| **2040** | 14,140 | -2,600 | 3,573 | 4,619 | 549 | 2,442 | 1,435 | 24,158 |
| **2041** | 12,778 | -2,738 | 3,468 | 4,670 | 541 | 2,449 | 1,396 | 22,563 |
| **2042** | 11,416 | -2,876 | 3,362 | 4,720 | 533 | 2,456 | 1,356 | 20,968 |
| **2043** | 10,054 | -3,014 | 3,256 | 4,771 | 524 | 2,463 | 1,317 | 19,372 |
| **2044** | 8,692 | -3,152 | 3,150 | 4,822 | 516 | 2,470 | 1,278 | 17,777 |
| **2045** | 7,330 | -3,290 | 3,044 | 4,873 | 508 | 2,477 | 1,239 | 16,181 |
| **2046** | 5,916 | -2,831 | 2,967 | 4,930 | 504 | 2,494 | 1,218 | 15,196 |
| **2047** | 4,501 | -2,373 | 2,890 | 4,987 | 500 | 2,510 | 1,196 | 14,212 |
| **2048** | 3,086 | -1,914 | 2,813 | 5,044 | 496 | 2,527 | 1,175 | 13,227 |
| **2049** | 1,672 | -1,455 | 2,735 | 5,101 | 492 | 2,544 | 1,154 | 12,242 |
| **2050** | 257 | -996 | 2,658 | 5,158 | 488 | 2,561 | 1,132 | 11,257 |
| **Total** | **644,762** | **-58,952** | **130,012** | **137,111** | **19,953** | **73,393** | **43,049** | **989,329** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.21.Global Emissions Summary for Net Zero 2050 (Moderate CCS): High Exports (GCAM-NETL-Aligned, AR6-100 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,407 | 532 | 6,674 | 3,928 | 886 | 2,126 | 1,349 | 53,903 |
| **2021** | 37,778 | 571 | 6,397 | 3,937 | 867 | 2,149 | 1,361 | 53,061 |
| **2022** | 37,150 | 610 | 6,120 | 3,946 | 848 | 2,172 | 1,373 | 52,220 |
| **2023** | 36,522 | 650 | 5,842 | 3,955 | 829 | 2,195 | 1,385 | 51,378 |
| **2024** | 35,894 | 689 | 5,565 | 3,963 | 811 | 2,218 | 1,397 | 50,536 |
| **2025** | 35,266 | 728 | 5,287 | 3,972 | 792 | 2,241 | 1,408 | 49,694 |
| **2026** | 33,806 | 76 | 5,140 | 4,007 | 774 | 2,258 | 1,436 | 47,497 |
| **2027** | 32,347 | -576 | 4,992 | 4,042 | 757 | 2,276 | 1,463 | 45,300 |
| **2028** | 30,888 | -1,227 | 4,844 | 4,077 | 739 | 2,293 | 1,491 | 43,103 |
| **2029** | 29,428 | -1,879 | 4,696 | 4,112 | 721 | 2,310 | 1,518 | 40,906 |
| **2030** | 27,969 | -2,531 | 4,548 | 4,147 | 703 | 2,328 | 1,546 | 38,710 |
| **2031** | 26,596 | -2,796 | 4,429 | 4,189 | 685 | 2,338 | 1,535 | 36,978 |
| **2032** | 25,223 | -3,060 | 4,311 | 4,232 | 668 | 2,348 | 1,525 | 35,245 |
| **2033** | 23,850 | -3,325 | 4,192 | 4,275 | 650 | 2,358 | 1,515 | 33,513 |
| **2034** | 22,477 | -3,590 | 4,073 | 4,317 | 632 | 2,368 | 1,505 | 31,781 |
| **2035** | 21,104 | -3,855 | 3,954 | 4,360 | 614 | 2,378 | 1,495 | 30,049 |
| **2036** | 19,727 | -3,604 | 3,878 | 4,412 | 601 | 2,391 | 1,483 | 28,887 |
| **2037** | 18,349 | -3,354 | 3,802 | 4,463 | 588 | 2,404 | 1,471 | 27,724 |
| **2038** | 16,972 | -3,103 | 3,726 | 4,515 | 575 | 2,416 | 1,460 | 26,561 |
| **2039** | 15,594 | -2,852 | 3,650 | 4,567 | 562 | 2,429 | 1,448 | 25,399 |
| **2040** | 14,217 | -2,601 | 3,574 | 4,618 | 549 | 2,442 | 1,436 | 24,236 |
| **2041** | 12,857 | -2,740 | 3,467 | 4,669 | 541 | 2,449 | 1,397 | 22,639 |
| **2042** | 11,497 | -2,879 | 3,359 | 4,720 | 532 | 2,456 | 1,358 | 21,043 |
| **2043** | 10,137 | -3,018 | 3,251 | 4,771 | 524 | 2,463 | 1,318 | 19,446 |
| **2044** | 8,777 | -3,158 | 3,144 | 4,822 | 516 | 2,470 | 1,279 | 17,849 |
| **2045** | 7,417 | -3,297 | 3,036 | 4,873 | 508 | 2,477 | 1,239 | 16,253 |
| **2046** | 6,010 | -2,853 | 2,958 | 4,930 | 504 | 2,493 | 1,218 | 15,260 |
| **2047** | 4,604 | -2,410 | 2,880 | 4,987 | 500 | 2,510 | 1,197 | 14,267 |
| **2048** | 3,198 | -1,966 | 2,802 | 5,043 | 496 | 2,527 | 1,175 | 13,274 |
| **2049** | 1,792 | -1,523 | 2,723 | 5,100 | 491 | 2,543 | 1,154 | 12,282 |
| **2050** | 386 | -1,079 | 2,645 | 5,157 | 487 | 2,560 | 1,132 | 11,289 |
| **Total** | **646,236** | **-59,419** | **129,959** | **137,105** | **19,949** | **73,386** | **43,066** | **990,283** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.22. Global Emissions Summary for Defined Policies: Existing/FID Exports (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,334 | 398 | 18,207 | 11,671 | 887 | 2,123 | 2,244 | 73,863 |
| **2021** | 37,872 | 469 | 17,617 | 11,723 | 877 | 2,151 | 2,265 | 72,973 |
| **2022** | 37,409 | 540 | 17,027 | 11,775 | 867 | 2,179 | 2,287 | 72,083 |
| **2023** | 36,947 | 611 | 16,437 | 11,827 | 857 | 2,206 | 2,308 | 71,193 |
| **2024** | 36,484 | 683 | 15,847 | 11,879 | 847 | 2,234 | 2,330 | 70,303 |
| **2025** | 36,022 | 754 | 15,257 | 11,930 | 837 | 2,262 | 2,351 | 69,413 |
| **2026** | 36,123 | 67 | 15,363 | 12,122 | 845 | 2,294 | 2,456 | 69,271 |
| **2027** | 36,225 | -619 | 15,470 | 12,314 | 853 | 2,326 | 2,561 | 69,129 |
| **2028** | 36,326 | -1,306 | 15,577 | 12,506 | 860 | 2,358 | 2,665 | 68,987 |
| **2029** | 36,428 | -1,992 | 15,684 | 12,697 | 868 | 2,390 | 2,770 | 68,845 |
| **2030** | 36,529 | -2,679 | 15,791 | 12,889 | 876 | 2,423 | 2,875 | 68,703 |
| **2031** | 36,355 | -2,389 | 15,778 | 13,068 | 869 | 2,448 | 2,898 | 69,025 |
| **2032** | 36,180 | -2,100 | 15,764 | 13,248 | 863 | 2,472 | 2,921 | 69,348 |
| **2033** | 36,005 | -1,811 | 15,751 | 13,427 | 857 | 2,497 | 2,944 | 69,670 |
| **2034** | 35,831 | -1,522 | 15,738 | 13,606 | 851 | 2,522 | 2,967 | 69,992 |
| **2035** | 35,656 | -1,233 | 15,725 | 13,785 | 844 | 2,547 | 2,990 | 70,314 |
| **2036** | 35,489 | -1,252 | 15,626 | 13,943 | 833 | 2,571 | 2,975 | 70,185 |
| **2037** | 35,322 | -1,271 | 15,527 | 14,100 | 822 | 2,595 | 2,960 | 70,056 |
| **2038** | 35,155 | -1,290 | 15,428 | 14,258 | 811 | 2,619 | 2,945 | 69,927 |
| **2039** | 34,988 | -1,309 | 15,329 | 14,416 | 801 | 2,643 | 2,931 | 69,798 |
| **2040** | 34,821 | -1,328 | 15,230 | 14,574 | 790 | 2,667 | 2,916 | 69,669 |
| **2041** | 34,648 | -1,261 | 15,245 | 14,739 | 791 | 2,698 | 2,884 | 69,744 |
| **2042** | 34,475 | -1,194 | 15,259 | 14,905 | 792 | 2,730 | 2,853 | 69,820 |
| **2043** | 34,302 | -1,127 | 15,274 | 15,070 | 793 | 2,761 | 2,821 | 69,896 |
| **2044** | 34,130 | -1,059 | 15,289 | 15,236 | 794 | 2,793 | 2,789 | 69,971 |
| **2045** | 33,957 | -992 | 15,303 | 15,401 | 796 | 2,824 | 2,758 | 70,047 |
| **2046** | 33,727 | -969 | 15,307 | 15,552 | 796 | 2,855 | 2,747 | 70,016 |
| **2047** | 33,497 | -945 | 15,311 | 15,703 | 797 | 2,885 | 2,737 | 69,985 |
| **2048** | 33,267 | -922 | 15,315 | 15,854 | 798 | 2,916 | 2,726 | 69,954 |
| **2049** | 33,037 | -898 | 15,318 | 16,005 | 798 | 2,946 | 2,716 | 69,923 |
| **2050** | 32,807 | -874 | 15,322 | 16,156 | 799 | 2,977 | 2,705 | 69,892 |
| **Total** | **1,098,346** | **-28,818** | **487,115** | **426,377** | **25,770** | **78,914** | **84,293** | **2,171,997** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.23. Global Emissions Summary for Defined Policies: Model Resolved (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 100-year) | | | | | | | |
| **2020** | 38,334 | 398 | 18,207 | 11,671 | 887 | 2,123 | 2,244 | 73,863 |
| **2021** | 37,872 | 469 | 17,617 | 11,723 | 877 | 2,151 | 2,265 | 72,973 |
| **2022** | 37,409 | 540 | 17,027 | 11,775 | 867 | 2,179 | 2,287 | 72,083 |
| **2023** | 36,947 | 611 | 16,437 | 11,827 | 857 | 2,206 | 2,308 | 71,193 |
| **2024** | 36,484 | 683 | 15,847 | 11,879 | 847 | 2,234 | 2,330 | 70,303 |
| **2025** | 36,022 | 754 | 15,257 | 11,930 | 837 | 2,262 | 2,351 | 69,413 |
| **2026** | 36,123 | 67 | 15,363 | 12,122 | 845 | 2,294 | 2,456 | 69,271 |
| **2027** | 36,225 | -619 | 15,470 | 12,314 | 853 | 2,326 | 2,561 | 69,129 |
| **2028** | 36,326 | -1,306 | 15,577 | 12,506 | 860 | 2,358 | 2,665 | 68,987 |
| **2029** | 36,428 | -1,992 | 15,684 | 12,697 | 868 | 2,390 | 2,770 | 68,845 |
| **2030** | 36,529 | -2,679 | 15,791 | 12,889 | 876 | 2,423 | 2,875 | 68,703 |
| **2031** | 36,362 | -2,397 | 15,779 | 13,068 | 869 | 2,447 | 2,898 | 69,027 |
| **2032** | 36,194 | -2,115 | 15,768 | 13,247 | 863 | 2,472 | 2,921 | 69,351 |
| **2033** | 36,027 | -1,833 | 15,757 | 13,427 | 857 | 2,497 | 2,944 | 69,675 |
| **2034** | 35,859 | -1,551 | 15,745 | 13,606 | 850 | 2,522 | 2,968 | 69,999 |
| **2035** | 35,692 | -1,269 | 15,734 | 13,785 | 844 | 2,546 | 2,991 | 70,323 |
| **2036** | 35,538 | -1,293 | 15,636 | 13,943 | 833 | 2,570 | 2,977 | 70,204 |
| **2037** | 35,385 | -1,317 | 15,539 | 14,100 | 822 | 2,594 | 2,962 | 70,086 |
| **2038** | 35,232 | -1,341 | 15,442 | 14,258 | 811 | 2,618 | 2,948 | 69,967 |
| **2039** | 35,079 | -1,364 | 15,344 | 14,416 | 800 | 2,641 | 2,934 | 69,849 |
| **2040** | 34,925 | -1,388 | 15,247 | 14,574 | 789 | 2,665 | 2,919 | 69,731 |
| **2041** | 34,750 | -1,315 | 15,257 | 14,739 | 790 | 2,696 | 2,888 | 69,806 |
| **2042** | 34,575 | -1,241 | 15,267 | 14,905 | 791 | 2,728 | 2,856 | 69,881 |
| **2043** | 34,399 | -1,167 | 15,278 | 15,070 | 792 | 2,759 | 2,824 | 69,956 |
| **2044** | 34,224 | -1,093 | 15,288 | 15,236 | 794 | 2,791 | 2,793 | 70,031 |
| **2045** | 34,048 | -1,020 | 15,298 | 15,402 | 795 | 2,822 | 2,761 | 70,106 |
| **2046** | 33,810 | -990 | 15,298 | 15,552 | 795 | 2,853 | 2,750 | 70,068 |
| **2047** | 33,571 | -960 | 15,297 | 15,703 | 796 | 2,883 | 2,740 | 70,030 |
| **2048** | 33,332 | -930 | 15,297 | 15,854 | 797 | 2,914 | 2,729 | 69,992 |
| **2049** | 33,093 | -900 | 15,296 | 16,005 | 797 | 2,944 | 2,718 | 69,954 |
| **2050** | 32,855 | -871 | 15,296 | 16,156 | 798 | 2,975 | 2,708 | 69,916 |
| **Total** | **1,099,646** | **-29,427** | **487,141** | **426,378** | **25,755** | **78,881** | **84,340** | **2,172,715** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.24. Global Emissions Summary for Defined Policies: High Exports (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,334 | 398 | 18,207 | 11,671 | 887 | 2,123 | 2,244 | 73,863 |
| **2021** | 37,872 | 469 | 17,617 | 11,723 | 877 | 2,151 | 2,265 | 72,973 |
| **2022** | 37,409 | 540 | 17,027 | 11,775 | 867 | 2,179 | 2,287 | 72,083 |
| **2023** | 36,947 | 611 | 16,437 | 11,827 | 857 | 2,206 | 2,308 | 71,193 |
| **2024** | 36,484 | 683 | 15,847 | 11,879 | 847 | 2,234 | 2,330 | 70,303 |
| **2025** | 36,022 | 754 | 15,257 | 11,930 | 837 | 2,262 | 2,351 | 69,413 |
| **2026** | 36,123 | 67 | 15,363 | 12,122 | 845 | 2,294 | 2,456 | 69,271 |
| **2027** | 36,225 | -619 | 15,470 | 12,314 | 853 | 2,326 | 2,561 | 69,129 |
| **2028** | 36,326 | -1,306 | 15,577 | 12,506 | 860 | 2,358 | 2,665 | 68,987 |
| **2029** | 36,428 | -1,992 | 15,684 | 12,697 | 868 | 2,390 | 2,770 | 68,845 |
| **2030** | 36,529 | -2,679 | 15,791 | 12,889 | 876 | 2,423 | 2,875 | 68,703 |
| **2031** | 36,375 | -2,410 | 15,782 | 13,068 | 869 | 2,447 | 2,898 | 69,029 |
| **2032** | 36,220 | -2,142 | 15,773 | 13,247 | 863 | 2,472 | 2,922 | 69,356 |
| **2033** | 36,066 | -1,873 | 15,765 | 13,427 | 856 | 2,496 | 2,946 | 69,682 |
| **2034** | 35,912 | -1,605 | 15,756 | 13,606 | 850 | 2,520 | 2,969 | 70,008 |
| **2035** | 35,757 | -1,337 | 15,747 | 13,785 | 843 | 2,545 | 2,993 | 70,334 |
| **2036** | 35,606 | -1,349 | 15,650 | 13,943 | 832 | 2,569 | 2,979 | 70,228 |
| **2037** | 35,454 | -1,362 | 15,552 | 14,100 | 821 | 2,592 | 2,965 | 70,123 |
| **2038** | 35,302 | -1,375 | 15,455 | 14,258 | 810 | 2,616 | 2,950 | 70,017 |
| **2039** | 35,151 | -1,388 | 15,357 | 14,416 | 799 | 2,640 | 2,936 | 69,911 |
| **2040** | 34,999 | -1,400 | 15,260 | 14,574 | 788 | 2,663 | 2,922 | 69,806 |
| **2041** | 34,821 | -1,326 | 15,268 | 14,739 | 789 | 2,695 | 2,890 | 69,877 |
| **2042** | 34,644 | -1,252 | 15,277 | 14,905 | 791 | 2,726 | 2,858 | 69,948 |
| **2043** | 34,466 | -1,179 | 15,285 | 15,070 | 792 | 2,758 | 2,827 | 70,020 |
| **2044** | 34,289 | -1,105 | 15,294 | 15,236 | 793 | 2,789 | 2,795 | 70,091 |
| **2045** | 34,111 | -1,031 | 15,302 | 15,402 | 794 | 2,820 | 2,763 | 70,162 |
| **2046** | 33,868 | -999 | 15,300 | 15,552 | 795 | 2,851 | 2,753 | 70,120 |
| **2047** | 33,625 | -967 | 15,298 | 15,703 | 795 | 2,881 | 2,742 | 70,077 |
| **2048** | 33,381 | -935 | 15,296 | 15,854 | 796 | 2,912 | 2,731 | 70,035 |
| **2049** | 33,138 | -903 | 15,294 | 16,005 | 796 | 2,942 | 2,720 | 69,993 |
| **2050** | 32,894 | -872 | 15,292 | 16,156 | 797 | 2,973 | 2,710 | 69,950 |
| **Total** | **1,100,779** | **-29,883** | **487,281** | **426,378** | **25,744** | **78,852** | **84,380** | **2,173,530** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.25. Global Emissions Summary for Defined Policies: High Middle East Supply: Existing/FID Exports (GCAM_NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,342 | 397 | 18,209 | 11,671 | 887 | 2,123 | 2,244 | 73,874 |
| **2021** | 37,881 | 468 | 17,620 | 11,723 | 877 | 2,151 | 2,266 | 72,985 |
| **2022** | 37,420 | 540 | 17,030 | 11,775 | 867 | 2,179 | 2,287 | 72,097 |
| **2023** | 36,959 | 611 | 16,440 | 11,827 | 857 | 2,206 | 2,309 | 71,208 |
| **2024** | 36,497 | 682 | 15,850 | 11,879 | 847 | 2,234 | 2,330 | 70,319 |
| **2025** | 36,036 | 753 | 15,261 | 11,930 | 837 | 2,262 | 2,351 | 69,431 |
| **2026** | 36,148 | 56 | 15,371 | 12,122 | 845 | 2,294 | 2,456 | 69,292 |
| **2027** | 36,259 | -640 | 15,481 | 12,314 | 853 | 2,326 | 2,561 | 69,154 |
| **2028** | 36,371 | -1,336 | 15,591 | 12,506 | 860 | 2,358 | 2,666 | 69,016 |
| **2029** | 36,483 | -2,033 | 15,701 | 12,697 | 868 | 2,390 | 2,771 | 68,877 |
| **2030** | 36,594 | -2,729 | 15,812 | 12,889 | 875 | 2,422 | 2,876 | 68,739 |
| **2031** | 36,442 | -2,452 | 15,808 | 13,068 | 869 | 2,446 | 2,900 | 69,080 |
| **2032** | 36,289 | -2,175 | 15,804 | 13,247 | 863 | 2,471 | 2,923 | 69,421 |
| **2033** | 36,136 | -1,898 | 15,800 | 13,427 | 856 | 2,495 | 2,947 | 69,762 |
| **2034** | 35,984 | -1,621 | 15,796 | 13,606 | 850 | 2,520 | 2,971 | 70,104 |
| **2035** | 35,831 | -1,345 | 15,792 | 13,785 | 843 | 2,544 | 2,995 | 70,445 |
| **2036** | 35,691 | -1,363 | 15,706 | 13,943 | 832 | 2,568 | 2,981 | 70,357 |
| **2037** | 35,551 | -1,382 | 15,620 | 14,100 | 821 | 2,591 | 2,967 | 70,269 |
| **2038** | 35,411 | -1,400 | 15,534 | 14,258 | 810 | 2,615 | 2,953 | 70,181 |
| **2039** | 35,272 | -1,419 | 15,448 | 14,416 | 799 | 2,638 | 2,938 | 70,093 |
| **2040** | 35,132 | -1,438 | 15,362 | 14,574 | 788 | 2,662 | 2,924 | 70,005 |
| **2041** | 34,972 | -1,374 | 15,384 | 14,739 | 789 | 2,693 | 2,893 | 70,096 |
| **2042** | 34,813 | -1,311 | 15,405 | 14,905 | 790 | 2,724 | 2,862 | 70,188 |
| **2043** | 34,653 | -1,248 | 15,426 | 15,070 | 791 | 2,755 | 2,830 | 70,279 |
| **2044** | 34,493 | -1,184 | 15,448 | 15,236 | 793 | 2,786 | 2,799 | 70,370 |
| **2045** | 34,334 | -1,121 | 15,469 | 15,402 | 794 | 2,817 | 2,767 | 70,462 |
| **2046** | 34,111 | -1,100 | 15,479 | 15,553 | 794 | 2,847 | 2,757 | 70,442 |
| **2047** | 33,889 | -1,078 | 15,489 | 15,703 | 795 | 2,877 | 2,746 | 70,422 |
| **2048** | 33,666 | -1,057 | 15,499 | 15,854 | 796 | 2,907 | 2,736 | 70,402 |
| **2049** | 33,444 | -1,035 | 15,509 | 16,005 | 796 | 2,937 | 2,726 | 70,382 |
| **2050** | 33,221 | -1,014 | 15,519 | 16,156 | 797 | 2,967 | 2,715 | 70,362 |
| **Total** | **1,104,327** | **-31,246** | **489,663** | **426,379** | **25,741** | **78,803** | **84,447** | **2,178,114** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.26. Global Emissions Summary for Defined Policies: High Middle East Supply: Model Resolved (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,342 | 397 | 18,209 | 11,671 | 887 | 2,123 | 2,244 | 73,874 |
| **2021** | 37,881 | 468 | 17,620 | 11,723 | 877 | 2,151 | 2,266 | 72,985 |
| **2022** | 37,420 | 540 | 17,030 | 11,775 | 867 | 2,179 | 2,287 | 72,097 |
| **2023** | 36,959 | 611 | 16,440 | 11,827 | 857 | 2,206 | 2,309 | 71,208 |
| **2024** | 36,497 | 682 | 15,850 | 11,879 | 847 | 2,234 | 2,330 | 70,319 |
| **2025** | 36,036 | 753 | 15,261 | 11,930 | 837 | 2,262 | 2,351 | 69,431 |
| **2026** | 36,148 | 56 | 15,371 | 12,122 | 845 | 2,294 | 2,456 | 69,292 |
| **2027** | 36,259 | -640 | 15,481 | 12,314 | 853 | 2,326 | 2,561 | 69,154 |
| **2028** | 36,371 | -1,336 | 15,591 | 12,506 | 860 | 2,358 | 2,666 | 69,016 |
| **2029** | 36,483 | -2,033 | 15,701 | 12,697 | 868 | 2,390 | 2,771 | 68,877 |
| **2030** | 36,594 | -2,729 | 15,812 | 12,889 | 875 | 2,422 | 2,876 | 68,739 |
| **2031** | 36,447 | -2,458 | 15,809 | 13,068 | 869 | 2,446 | 2,900 | 69,081 |
| **2032** | 36,300 | -2,186 | 15,806 | 13,247 | 862 | 2,470 | 2,924 | 69,423 |
| **2033** | 36,153 | -1,915 | 15,802 | 13,426 | 856 | 2,495 | 2,948 | 69,766 |
| **2034** | 36,006 | -1,643 | 15,799 | 13,606 | 850 | 2,519 | 2,972 | 70,108 |
| **2035** | 35,859 | -1,372 | 15,796 | 13,785 | 843 | 2,543 | 2,996 | 70,450 |
| **2036** | 35,724 | -1,390 | 15,709 | 13,943 | 832 | 2,567 | 2,982 | 70,367 |
| **2037** | 35,590 | -1,408 | 15,622 | 14,100 | 821 | 2,590 | 2,968 | 70,283 |
| **2038** | 35,455 | -1,426 | 15,535 | 14,258 | 810 | 2,614 | 2,954 | 70,200 |
| **2039** | 35,321 | -1,444 | 15,447 | 14,416 | 799 | 2,637 | 2,940 | 70,116 |
| **2040** | 35,186 | -1,462 | 15,360 | 14,574 | 788 | 2,661 | 2,927 | 70,033 |
| **2041** | 35,025 | -1,394 | 15,378 | 14,739 | 789 | 2,692 | 2,895 | 70,123 |
| **2042** | 34,863 | -1,327 | 15,396 | 14,905 | 790 | 2,723 | 2,864 | 70,214 |
| **2043** | 34,701 | -1,259 | 15,414 | 15,070 | 791 | 2,754 | 2,832 | 70,304 |
| **2044** | 34,540 | -1,192 | 15,433 | 15,236 | 792 | 2,785 | 2,801 | 70,395 |
| **2045** | 34,378 | -1,124 | 15,451 | 15,402 | 793 | 2,816 | 2,769 | 70,485 |
| **2046** | 34,152 | -1,103 | 15,458 | 15,553 | 794 | 2,846 | 2,759 | 70,458 |
| **2047** | 33,926 | -1,082 | 15,465 | 15,704 | 795 | 2,876 | 2,748 | 70,432 |
| **2048** | 33,700 | -1,061 | 15,473 | 15,854 | 795 | 2,906 | 2,738 | 70,405 |
| **2049** | 33,475 | -1,040 | 15,480 | 16,005 | 796 | 2,936 | 2,727 | 70,379 |
| **2050** | 33,249 | -1,019 | 15,487 | 16,156 | 797 | 2,966 | 2,717 | 70,352 |
| **Total** | **1,105,043** | **-31,537** | **489,486** | **426,379** | **25,734** | **78,785** | **84,476** | **2,178,366** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.27. Global Emissions Summary for Defined Policies: High U.S. Supply: Existing/FID Exports (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,330 | 398 | 18,207 | 11,671 | 887 | 2,123 | 2,243 | 73,858 |
| **2021** | 37,869 | 469 | 17,617 | 11,723 | 877 | 2,151 | 2,265 | 72,970 |
| **2022** | 37,408 | 539 | 17,027 | 11,775 | 867 | 2,179 | 2,287 | 72,081 |
| **2023** | 36,947 | 610 | 16,437 | 11,827 | 857 | 2,206 | 2,308 | 71,192 |
| **2024** | 36,486 | 681 | 15,847 | 11,879 | 847 | 2,234 | 2,330 | 70,304 |
| **2025** | 36,026 | 751 | 15,257 | 11,930 | 837 | 2,262 | 2,351 | 69,415 |
| **2026** | 36,128 | 64 | 15,364 | 12,122 | 845 | 2,294 | 2,456 | 69,274 |
| **2027** | 36,231 | -623 | 15,471 | 12,314 | 853 | 2,326 | 2,561 | 69,133 |
| **2028** | 36,334 | -1,310 | 15,578 | 12,506 | 860 | 2,358 | 2,665 | 68,992 |
| **2029** | 36,436 | -1,997 | 15,686 | 12,697 | 868 | 2,390 | 2,770 | 68,851 |
| **2030** | 36,539 | -2,684 | 15,793 | 12,889 | 876 | 2,423 | 2,875 | 68,710 |
| **2031** | 36,364 | -2,393 | 15,779 | 13,068 | 869 | 2,447 | 2,898 | 69,033 |
| **2032** | 36,188 | -2,102 | 15,766 | 13,248 | 863 | 2,472 | 2,921 | 69,356 |
| **2033** | 36,013 | -1,811 | 15,752 | 13,427 | 857 | 2,497 | 2,944 | 69,680 |
| **2034** | 35,838 | -1,520 | 15,739 | 13,606 | 851 | 2,522 | 2,967 | 70,003 |
| **2035** | 35,662 | -1,229 | 15,725 | 13,785 | 844 | 2,547 | 2,990 | 70,326 |
| **2036** | 35,497 | -1,249 | 15,627 | 13,943 | 833 | 2,571 | 2,975 | 70,197 |
| **2037** | 35,331 | -1,270 | 15,528 | 14,100 | 823 | 2,595 | 2,960 | 70,068 |
| **2038** | 35,165 | -1,290 | 15,429 | 14,258 | 812 | 2,619 | 2,946 | 69,939 |
| **2039** | 35,000 | -1,311 | 15,330 | 14,416 | 801 | 2,643 | 2,931 | 69,810 |
| **2040** | 34,834 | -1,331 | 15,232 | 14,574 | 790 | 2,667 | 2,916 | 69,681 |
| **2041** | 34,665 | -1,266 | 15,247 | 14,739 | 791 | 2,698 | 2,884 | 69,759 |
| **2042** | 34,496 | -1,200 | 15,262 | 14,905 | 792 | 2,730 | 2,853 | 69,837 |
| **2043** | 34,327 | -1,135 | 15,277 | 15,070 | 793 | 2,761 | 2,821 | 69,916 |
| **2044** | 34,158 | -1,069 | 15,292 | 15,236 | 795 | 2,793 | 2,790 | 69,994 |
| **2045** | 33,989 | -1,004 | 15,307 | 15,401 | 796 | 2,824 | 2,758 | 70,073 |
| **2046** | 33,764 | -981 | 15,312 | 15,552 | 797 | 2,855 | 2,748 | 70,046 |
| **2047** | 33,539 | -959 | 15,316 | 15,703 | 797 | 2,885 | 2,737 | 70,019 |
| **2048** | 33,313 | -937 | 15,321 | 15,854 | 798 | 2,916 | 2,726 | 69,992 |
| **2049** | 33,088 | -914 | 15,325 | 16,005 | 799 | 2,946 | 2,716 | 69,965 |
| **2050** | 32,863 | -892 | 15,330 | 16,156 | 800 | 2,977 | 2,705 | 69,938 |
| **Total** | **1,098,830** | **-28,959** | **487,179** | **426,377** | **25,773** | **78,913** | **84,297** | **2,172,411** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.28. Global Emissions Summary for Defined Policies: High U.S. Supply: Model Resolved (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,330 | 398 | 18,207 | 11,671 | 887 | 2,123 | 2,243 | 73,858 |
| **2021** | 37,869 | 469 | 17,617 | 11,723 | 877 | 2,151 | 2,265 | 72,970 |
| **2022** | 37,408 | 539 | 17,027 | 11,775 | 867 | 2,179 | 2,287 | 72,081 |
| **2023** | 36,947 | 610 | 16,437 | 11,827 | 857 | 2,206 | 2,308 | 71,192 |
| **2024** | 36,486 | 681 | 15,847 | 11,879 | 847 | 2,234 | 2,330 | 70,304 |
| **2025** | 36,026 | 751 | 15,257 | 11,930 | 837 | 2,262 | 2,351 | 69,415 |
| **2026** | 36,128 | 64 | 15,364 | 12,122 | 845 | 2,294 | 2,456 | 69,274 |
| **2027** | 36,231 | -623 | 15,471 | 12,314 | 853 | 2,326 | 2,561 | 69,133 |
| **2028** | 36,334 | -1,310 | 15,578 | 12,506 | 860 | 2,358 | 2,665 | 68,992 |
| **2029** | 36,436 | -1,997 | 15,686 | 12,697 | 868 | 2,390 | 2,770 | 68,851 |
| **2030** | 36,539 | -2,684 | 15,793 | 12,889 | 876 | 2,423 | 2,875 | 68,710 |
| **2031** | 36,375 | -2,404 | 15,782 | 13,068 | 869 | 2,447 | 2,898 | 69,036 |
| **2032** | 36,211 | -2,125 | 15,771 | 13,247 | 863 | 2,472 | 2,922 | 69,361 |
| **2033** | 36,047 | -1,846 | 15,760 | 13,427 | 857 | 2,497 | 2,945 | 69,687 |
| **2034** | 35,883 | -1,566 | 15,750 | 13,606 | 850 | 2,521 | 2,968 | 70,012 |
| **2035** | 35,719 | -1,287 | 15,739 | 13,785 | 844 | 2,546 | 2,992 | 70,338 |
| **2036** | 35,572 | -1,312 | 15,642 | 13,943 | 833 | 2,570 | 2,978 | 70,226 |
| **2037** | 35,425 | -1,336 | 15,546 | 14,100 | 822 | 2,593 | 2,963 | 70,113 |
| **2038** | 35,277 | -1,361 | 15,450 | 14,258 | 811 | 2,617 | 2,949 | 70,001 |
| **2039** | 35,130 | -1,385 | 15,353 | 14,416 | 800 | 2,641 | 2,935 | 69,889 |
| **2040** | 34,983 | -1,410 | 15,257 | 14,574 | 789 | 2,664 | 2,921 | 69,777 |
| **2041** | 34,815 | -1,341 | 15,268 | 14,739 | 790 | 2,696 | 2,889 | 69,856 |
| **2042** | 34,648 | -1,272 | 15,278 | 14,905 | 791 | 2,727 | 2,858 | 69,935 |
| **2043** | 34,481 | -1,203 | 15,289 | 15,070 | 792 | 2,758 | 2,826 | 70,014 |
| **2044** | 34,314 | -1,134 | 15,300 | 15,236 | 793 | 2,789 | 2,795 | 70,093 |
| **2045** | 34,146 | -1,065 | 15,311 | 15,402 | 794 | 2,821 | 2,763 | 70,172 |
| **2046** | 33,915 | -1,037 | 15,311 | 15,552 | 795 | 2,851 | 2,752 | 70,140 |
| **2047** | 33,684 | -1,009 | 15,310 | 15,703 | 796 | 2,881 | 2,742 | 70,108 |
| **2048** | 33,453 | -981 | 15,310 | 15,854 | 797 | 2,912 | 2,731 | 70,077 |
| **2049** | 33,222 | -953 | 15,310 | 16,005 | 797 | 2,942 | 2,721 | 70,045 |
| **2050** | 32,991 | -925 | 15,310 | 16,156 | 798 | 2,972 | 2,710 | 70,013 |
| **Total** | **1,101,029** | **-30,051** | **487,331** | **426,379** | **25,753** | **78,862** | **84,370** | **2,173,673** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.29. Global Emissions Summary for Defined Policies: Low U.S. Supply: Existing/FID Exports (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,357 | 396 | 18,210 | 11,671 | 887 | 2,123 | 2,244 | 73,889 |
| **2021** | 37,883 | 472 | 17,618 | 11,723 | 877 | 2,151 | 2,266 | 72,990 |
| **2022** | 37,409 | 548 | 17,027 | 11,775 | 867 | 2,179 | 2,287 | 72,092 |
| **2023** | 36,935 | 625 | 16,435 | 11,827 | 857 | 2,206 | 2,308 | 71,193 |
| **2024** | 36,461 | 701 | 15,843 | 11,878 | 847 | 2,234 | 2,330 | 70,295 |
| **2025** | 35,987 | 777 | 15,252 | 11,930 | 837 | 2,261 | 2,351 | 69,396 |
| **2026** | 36,080 | 93 | 15,357 | 12,122 | 845 | 2,294 | 2,456 | 69,246 |
| **2027** | 36,173 | -591 | 15,462 | 12,314 | 852 | 2,326 | 2,560 | 69,097 |
| **2028** | 36,266 | -1,275 | 15,568 | 12,506 | 860 | 2,358 | 2,665 | 68,947 |
| **2029** | 36,359 | -1,959 | 15,673 | 12,697 | 868 | 2,391 | 2,769 | 68,797 |
| **2030** | 36,452 | -2,643 | 15,778 | 12,889 | 875 | 2,423 | 2,873 | 68,648 |
| **2031** | 36,273 | -2,357 | 15,764 | 13,068 | 869 | 2,448 | 2,896 | 68,962 |
| **2032** | 36,094 | -2,071 | 15,750 | 13,248 | 863 | 2,473 | 2,919 | 69,276 |
| **2033** | 35,915 | -1,785 | 15,736 | 13,427 | 856 | 2,498 | 2,943 | 69,590 |
| **2034** | 35,736 | -1,498 | 15,722 | 13,606 | 850 | 2,523 | 2,966 | 69,904 |
| **2035** | 35,557 | -1,212 | 15,707 | 13,785 | 844 | 2,548 | 2,989 | 70,218 |
| **2036** | 35,385 | -1,232 | 15,609 | 13,943 | 833 | 2,571 | 2,974 | 70,083 |
| **2037** | 35,213 | -1,251 | 15,510 | 14,100 | 822 | 2,595 | 2,959 | 69,949 |
| **2038** | 35,041 | -1,271 | 15,412 | 14,258 | 811 | 2,619 | 2,944 | 69,814 |
| **2039** | 34,869 | -1,290 | 15,313 | 14,416 | 800 | 2,643 | 2,930 | 69,680 |
| **2040** | 34,696 | -1,310 | 15,215 | 14,574 | 789 | 2,667 | 2,915 | 69,546 |
| **2041** | 34,506 | -1,230 | 15,227 | 14,739 | 790 | 2,699 | 2,883 | 69,615 |
| **2042** | 34,315 | -1,149 | 15,240 | 14,905 | 791 | 2,730 | 2,851 | 69,683 |
| **2043** | 34,124 | -1,068 | 15,252 | 15,070 | 792 | 2,762 | 2,820 | 69,752 |
| **2044** | 33,934 | -988 | 15,265 | 15,236 | 794 | 2,793 | 2,788 | 69,821 |
| **2045** | 33,743 | -907 | 15,277 | 15,401 | 795 | 2,825 | 2,756 | 69,890 |
| **2046** | 33,518 | -904 | 15,281 | 15,552 | 795 | 2,856 | 2,746 | 69,844 |
| **2047** | 33,294 | -901 | 15,284 | 15,703 | 796 | 2,886 | 2,735 | 69,798 |
| **2048** | 33,070 | -898 | 15,288 | 15,854 | 796 | 2,917 | 2,725 | 69,751 |
| **2049** | 32,845 | -895 | 15,292 | 16,005 | 797 | 2,947 | 2,715 | 69,705 |
| **2050** | 32,621 | -892 | 15,295 | 16,155 | 798 | 2,978 | 2,704 | 69,659 |
| **Total** | **1,095,112** | **-27,967** | **486,663** | **426,377** | **25,755** | **78,923** | **84,267** | **2,169,129** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.30. Global Emissions Summary for Defined Policies: Low U.S. Supply: Model Resolved (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,357 | 396 | 18,210 | 11,671 | 887 | 2,123 | 2,244 | 73,889 |
| **2021** | 37,883 | 472 | 17,618 | 11,723 | 877 | 2,151 | 2,266 | 72,990 |
| **2022** | 37,409 | 548 | 17,027 | 11,775 | 867 | 2,179 | 2,287 | 72,092 |
| **2023** | 36,935 | 625 | 16,435 | 11,827 | 857 | 2,206 | 2,308 | 71,193 |
| **2024** | 36,461 | 701 | 15,843 | 11,878 | 847 | 2,234 | 2,330 | 70,295 |
| **2025** | 35,987 | 777 | 15,252 | 11,930 | 837 | 2,261 | 2,351 | 69,396 |
| **2026** | 36,080 | 93 | 15,357 | 12,122 | 845 | 2,294 | 2,456 | 69,246 |
| **2027** | 36,173 | -591 | 15,462 | 12,314 | 852 | 2,326 | 2,560 | 69,097 |
| **2028** | 36,266 | -1,275 | 15,568 | 12,506 | 860 | 2,358 | 2,665 | 68,947 |
| **2029** | 36,359 | -1,959 | 15,673 | 12,697 | 868 | 2,391 | 2,769 | 68,797 |
| **2030** | 36,452 | -2,643 | 15,778 | 12,889 | 875 | 2,423 | 2,873 | 68,648 |
| **2031** | 36,273 | -2,357 | 15,764 | 13,068 | 869 | 2,448 | 2,896 | 68,962 |
| **2032** | 36,094 | -2,071 | 15,750 | 13,248 | 863 | 2,473 | 2,919 | 69,276 |
| **2033** | 35,915 | -1,785 | 15,736 | 13,427 | 856 | 2,498 | 2,943 | 69,590 |
| **2034** | 35,736 | -1,498 | 15,722 | 13,606 | 850 | 2,523 | 2,966 | 69,904 |
| **2035** | 35,557 | -1,212 | 15,707 | 13,785 | 844 | 2,548 | 2,989 | 70,218 |
| **2036** | 35,386 | -1,232 | 15,609 | 13,943 | 833 | 2,571 | 2,974 | 70,084 |
| **2037** | 35,214 | -1,252 | 15,511 | 14,100 | 822 | 2,595 | 2,959 | 69,949 |
| **2038** | 35,043 | -1,273 | 15,412 | 14,258 | 811 | 2,619 | 2,944 | 69,815 |
| **2039** | 34,871 | -1,293 | 15,314 | 14,416 | 800 | 2,643 | 2,930 | 69,681 |
| **2040** | 34,700 | -1,313 | 15,216 | 14,574 | 789 | 2,667 | 2,915 | 69,547 |
| **2041** | 34,511 | -1,234 | 15,227 | 14,739 | 790 | 2,698 | 2,883 | 69,616 |
| **2042** | 34,323 | -1,156 | 15,239 | 14,905 | 791 | 2,730 | 2,852 | 69,684 |
| **2043** | 34,135 | -1,077 | 15,251 | 15,070 | 792 | 2,762 | 2,820 | 69,753 |
| **2044** | 33,946 | -999 | 15,263 | 15,236 | 794 | 2,793 | 2,788 | 69,821 |
| **2045** | 33,758 | -920 | 15,275 | 15,401 | 795 | 2,825 | 2,757 | 69,890 |
| **2046** | 33,536 | -918 | 15,278 | 15,552 | 795 | 2,855 | 2,746 | 69,844 |
| **2047** | 33,314 | -916 | 15,281 | 15,703 | 796 | 2,886 | 2,736 | 69,799 |
| **2048** | 33,091 | -914 | 15,284 | 15,854 | 796 | 2,916 | 2,726 | 69,754 |
| **2049** | 32,869 | -912 | 15,288 | 16,005 | 797 | 2,947 | 2,715 | 69,708 |
| **2050** | 32,647 | -910 | 15,291 | 16,156 | 797 | 2,977 | 2,705 | 69,663 |
| **Total** | **1,095,283** | **-28,098** | **486,640** | **426,377** | **25,753** | **78,919** | **84,273** | **2,169,147** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.31. Global Emissions Summary for Commitments (High CCS): Existing/FID Exports (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,333 | 532 | 18,199 | 11,670 | 886 | 2,126 | 2,244 | 73,991 |
| **2021** | 37,707 | 616 | 17,531 | 11,716 | 872 | 2,151 | 2,260 | 72,853 |
| **2022** | 37,080 | 700 | 16,863 | 11,761 | 857 | 2,177 | 2,277 | 71,716 |
| **2023** | 36,454 | 784 | 16,195 | 11,807 | 843 | 2,202 | 2,294 | 70,579 |
| **2024** | 35,827 | 868 | 15,527 | 11,852 | 829 | 2,227 | 2,311 | 69,441 |
| **2025** | 35,200 | 952 | 14,859 | 11,898 | 815 | 2,252 | 2,327 | 68,304 |
| **2026** | 35,054 | 732 | 14,948 | 12,093 | 825 | 2,277 | 2,424 | 68,351 |
| **2027** | 34,907 | 511 | 15,036 | 12,288 | 834 | 2,301 | 2,521 | 68,399 |
| **2028** | 34,760 | 291 | 15,125 | 12,484 | 844 | 2,326 | 2,618 | 68,446 |
| **2029** | 34,613 | 70 | 15,214 | 12,679 | 853 | 2,350 | 2,714 | 68,493 |
| **2030** | 34,466 | -150 | 15,303 | 12,874 | 863 | 2,374 | 2,811 | 68,541 |
| **2031** | 33,137 | -124 | 15,060 | 13,014 | 842 | 2,401 | 2,802 | 67,133 |
| **2032** | 31,809 | -98 | 14,817 | 13,155 | 820 | 2,428 | 2,794 | 65,725 |
| **2033** | 30,480 | -72 | 14,575 | 13,295 | 799 | 2,455 | 2,786 | 64,317 |
| **2034** | 29,152 | -46 | 14,332 | 13,436 | 777 | 2,482 | 2,777 | 62,909 |
| **2035** | 27,823 | -20 | 14,089 | 13,576 | 756 | 2,509 | 2,769 | 61,501 |
| **2036** | 26,519 | 180 | 13,921 | 13,719 | 747 | 2,530 | 2,749 | 60,365 |
| **2037** | 25,215 | 380 | 13,753 | 13,862 | 738 | 2,551 | 2,730 | 59,228 |
| **2038** | 23,910 | 580 | 13,584 | 14,004 | 729 | 2,572 | 2,711 | 58,091 |
| **2039** | 22,606 | 781 | 13,416 | 14,147 | 720 | 2,594 | 2,691 | 56,954 |
| **2040** | 21,302 | 981 | 13,248 | 14,289 | 711 | 2,615 | 2,672 | 55,817 |
| **2041** | 19,994 | 871 | 12,937 | 14,410 | 694 | 2,627 | 2,547 | 54,079 |
| **2042** | 18,685 | 762 | 12,626 | 14,530 | 677 | 2,638 | 2,422 | 52,340 |
| **2043** | 17,377 | 652 | 12,315 | 14,650 | 660 | 2,650 | 2,297 | 50,601 |
| **2044** | 16,069 | 542 | 12,004 | 14,771 | 643 | 2,662 | 2,172 | 48,863 |
| **2045** | 14,760 | 433 | 11,693 | 14,891 | 626 | 2,674 | 2,047 | 47,124 |
| **2046** | 13,473 | 250 | 11,448 | 15,026 | 610 | 2,686 | 1,971 | 45,463 |
| **2047** | 12,186 | 67 | 11,202 | 15,161 | 594 | 2,698 | 1,894 | 43,802 |
| **2048** | 10,898 | -116 | 10,957 | 15,296 | 578 | 2,710 | 1,818 | 42,141 |
| **2049** | 9,611 | -299 | 10,712 | 15,430 | 562 | 2,722 | 1,742 | 40,479 |
| **2050** | 8,324 | -481 | 10,466 | 15,565 | 545 | 2,734 | 1,665 | 38,818 |
| **Total** | **807,730** | **11,127** | **431,956** | **419,349** | **23,148** | **76,699** | **74,856** | **1,844,865** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.32. Global Emissions Summary for Commitments (High CCS): Model Resolved (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,333 | 532 | 18,199 | 11,670 | 886 | 2,126 | 2,244 | 73,991 |
| **2021** | 37,707 | 616 | 17,531 | 11,716 | 872 | 2,151 | 2,260 | 72,853 |
| **2022** | 37,080 | 700 | 16,863 | 11,761 | 857 | 2,177 | 2,277 | 71,716 |
| **2023** | 36,454 | 784 | 16,195 | 11,807 | 843 | 2,202 | 2,294 | 70,579 |
| **2024** | 35,827 | 868 | 15,527 | 11,852 | 829 | 2,227 | 2,311 | 69,441 |
| **2025** | 35,200 | 952 | 14,859 | 11,898 | 815 | 2,252 | 2,327 | 68,304 |
| **2026** | 35,054 | 732 | 14,948 | 12,093 | 825 | 2,277 | 2,424 | 68,351 |
| **2027** | 34,907 | 511 | 15,036 | 12,288 | 834 | 2,301 | 2,521 | 68,399 |
| **2028** | 34,760 | 291 | 15,125 | 12,484 | 844 | 2,326 | 2,618 | 68,446 |
| **2029** | 34,613 | 70 | 15,214 | 12,679 | 853 | 2,350 | 2,714 | 68,493 |
| **2030** | 34,466 | -150 | 15,303 | 12,874 | 863 | 2,374 | 2,811 | 68,541 |
| **2031** | 33,137 | -124 | 15,060 | 13,014 | 842 | 2,401 | 2,802 | 67,133 |
| **2032** | 31,809 | -98 | 14,817 | 13,155 | 820 | 2,428 | 2,794 | 65,725 |
| **2033** | 30,480 | -72 | 14,575 | 13,295 | 799 | 2,455 | 2,786 | 64,317 |
| **2034** | 29,152 | -46 | 14,332 | 13,436 | 777 | 2,482 | 2,777 | 62,909 |
| **2035** | 27,823 | -20 | 14,089 | 13,576 | 756 | 2,509 | 2,769 | 61,501 |
| **2036** | 26,524 | 172 | 13,921 | 13,719 | 747 | 2,530 | 2,750 | 60,362 |
| **2037** | 25,224 | 365 | 13,753 | 13,861 | 738 | 2,551 | 2,730 | 59,222 |
| **2038** | 23,925 | 557 | 13,584 | 14,004 | 729 | 2,572 | 2,711 | 58,082 |
| **2039** | 22,625 | 750 | 13,416 | 14,147 | 719 | 2,594 | 2,692 | 56,943 |
| **2040** | 21,326 | 942 | 13,248 | 14,289 | 710 | 2,615 | 2,673 | 55,803 |
| **2041** | 20,015 | 845 | 12,935 | 14,410 | 693 | 2,626 | 2,548 | 54,072 |
| **2042** | 18,705 | 747 | 12,621 | 14,530 | 677 | 2,638 | 2,423 | 52,341 |
| **2043** | 17,395 | 650 | 12,307 | 14,650 | 660 | 2,650 | 2,298 | 50,610 |
| **2044** | 16,084 | 552 | 11,994 | 14,771 | 643 | 2,662 | 2,173 | 48,879 |
| **2045** | 14,774 | 455 | 11,680 | 14,891 | 626 | 2,673 | 2,048 | 47,147 |
| **2046** | 13,485 | 269 | 11,433 | 15,026 | 610 | 2,685 | 1,971 | 45,480 |
| **2047** | 12,195 | 84 | 11,186 | 15,161 | 594 | 2,697 | 1,895 | 43,812 |
| **2048** | 10,906 | -102 | 10,939 | 15,296 | 578 | 2,709 | 1,818 | 42,144 |
| **2049** | 9,617 | -287 | 10,692 | 15,431 | 562 | 2,721 | 1,742 | 40,477 |
| **2050** | 8,328 | -473 | 10,445 | 15,565 | 545 | 2,733 | 1,666 | 38,809 |
| **Total** | **807,928** | **11,069** | **431,827** | **419,349** | **23,147** | **76,696** | **74,867** | **1,844,882** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.33. Global Emissions Summary for Commitments (High CCS): High Exports (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,333 | 532 | 18,199 | 11,670 | 886 | 2,126 | 2,244 | 73,991 |
| **2021** | 37,707 | 616 | 17,531 | 11,716 | 872 | 2,151 | 2,260 | 72,853 |
| **2022** | 37,080 | 700 | 16,863 | 11,761 | 857 | 2,177 | 2,277 | 71,716 |
| **2023** | 36,454 | 784 | 16,195 | 11,807 | 843 | 2,202 | 2,294 | 70,579 |
| **2024** | 35,827 | 868 | 15,527 | 11,852 | 829 | 2,227 | 2,311 | 69,441 |
| **2025** | 35,200 | 952 | 14,859 | 11,898 | 815 | 2,252 | 2,327 | 68,304 |
| **2026** | 35,054 | 732 | 14,948 | 12,093 | 825 | 2,277 | 2,424 | 68,351 |
| **2027** | 34,907 | 511 | 15,036 | 12,288 | 834 | 2,301 | 2,521 | 68,399 |
| **2028** | 34,760 | 291 | 15,125 | 12,484 | 844 | 2,326 | 2,618 | 68,446 |
| **2029** | 34,613 | 70 | 15,214 | 12,679 | 853 | 2,350 | 2,714 | 68,493 |
| **2030** | 34,466 | -150 | 15,303 | 12,874 | 863 | 2,374 | 2,811 | 68,541 |
| **2031** | 33,155 | -141 | 15,063 | 13,014 | 842 | 2,401 | 2,803 | 67,136 |
| **2032** | 31,843 | -132 | 14,824 | 13,155 | 820 | 2,428 | 2,795 | 65,732 |
| **2033** | 30,532 | -123 | 14,584 | 13,295 | 799 | 2,454 | 2,787 | 64,327 |
| **2034** | 29,220 | -114 | 14,345 | 13,436 | 777 | 2,481 | 2,779 | 62,923 |
| **2035** | 27,909 | -105 | 14,105 | 13,576 | 755 | 2,507 | 2,771 | 61,518 |
| **2036** | 26,603 | 104 | 13,934 | 13,719 | 746 | 2,529 | 2,752 | 60,386 |
| **2037** | 25,297 | 313 | 13,762 | 13,861 | 737 | 2,550 | 2,733 | 59,253 |
| **2038** | 23,991 | 522 | 13,591 | 14,004 | 728 | 2,571 | 2,714 | 58,121 |
| **2039** | 22,685 | 731 | 13,420 | 14,146 | 719 | 2,592 | 2,695 | 56,988 |
| **2040** | 21,379 | 941 | 13,248 | 14,289 | 710 | 2,614 | 2,676 | 55,856 |
| **2041** | 20,064 | 852 | 12,931 | 14,409 | 693 | 2,626 | 2,550 | 54,125 |
| **2042** | 18,749 | 764 | 12,614 | 14,530 | 677 | 2,637 | 2,425 | 52,395 |
| **2043** | 17,434 | 675 | 12,296 | 14,650 | 660 | 2,649 | 2,300 | 50,665 |
| **2044** | 16,119 | 587 | 11,979 | 14,771 | 643 | 2,661 | 2,175 | 48,934 |
| **2045** | 14,804 | 499 | 11,662 | 14,891 | 626 | 2,673 | 2,049 | 47,204 |
| **2046** | 13,513 | 305 | 11,411 | 15,026 | 610 | 2,685 | 1,973 | 45,523 |
| **2047** | 12,222 | 112 | 11,161 | 15,161 | 594 | 2,697 | 1,896 | 43,843 |
| **2048** | 10,932 | -81 | 10,910 | 15,296 | 578 | 2,709 | 1,820 | 42,162 |
| **2049** | 9,641 | -275 | 10,659 | 15,431 | 561 | 2,721 | 1,743 | 40,482 |
| **2050** | 8,350 | -468 | 10,409 | 15,566 | 545 | 2,733 | 1,667 | 38,801 |
| **Total** | **808,839** | **10,870** | **431,707** | **419,348** | **23,143** | **76,678** | **74,905** | **1,845,490** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.34. Global Emissions Summary for Commitments (Moderate CCS): Existing/FID Exports (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,333 | 532 | 18,199 | 11,670 | 886 | 2,126 | 2,244 | 73,991 |
| **2021** | 37,705 | 571 | 17,443 | 11,696 | 867 | 2,149 | 2,252 | 72,682 |
| **2022** | 37,076 | 610 | 16,686 | 11,722 | 848 | 2,172 | 2,260 | 71,374 |
| **2023** | 36,447 | 650 | 15,929 | 11,747 | 829 | 2,195 | 2,268 | 70,065 |
| **2024** | 35,818 | 689 | 15,172 | 11,773 | 811 | 2,218 | 2,276 | 68,756 |
| **2025** | 35,190 | 728 | 14,415 | 11,799 | 792 | 2,241 | 2,284 | 67,448 |
| **2026** | 35,046 | 503 | 14,501 | 12,000 | 804 | 2,266 | 2,381 | 67,501 |
| **2027** | 34,902 | 279 | 14,587 | 12,202 | 815 | 2,291 | 2,478 | 67,554 |
| **2028** | 34,758 | 55 | 14,673 | 12,403 | 827 | 2,317 | 2,575 | 67,608 |
| **2029** | 34,613 | -169 | 14,759 | 12,605 | 838 | 2,342 | 2,673 | 67,661 |
| **2030** | 34,469 | -393 | 14,845 | 12,806 | 850 | 2,367 | 2,770 | 67,714 |
| **2031** | 33,184 | -563 | 14,451 | 12,914 | 824 | 2,385 | 2,734 | 65,928 |
| **2032** | 31,899 | -732 | 14,058 | 13,021 | 797 | 2,402 | 2,697 | 64,143 |
| **2033** | 30,614 | -902 | 13,664 | 13,128 | 771 | 2,420 | 2,661 | 62,357 |
| **2034** | 29,328 | -1,071 | 13,271 | 13,236 | 745 | 2,438 | 2,625 | 60,571 |
| **2035** | 28,043 | -1,241 | 12,877 | 13,343 | 718 | 2,455 | 2,589 | 58,785 |
| **2036** | 26,739 | -1,576 | 12,588 | 13,462 | 702 | 2,466 | 2,545 | 56,926 |
| **2037** | 25,436 | -1,911 | 12,299 | 13,580 | 685 | 2,477 | 2,501 | 55,068 |
| **2038** | 24,132 | -2,246 | 12,010 | 13,699 | 669 | 2,488 | 2,457 | 53,209 |
| **2039** | 22,829 | -2,582 | 11,721 | 13,817 | 653 | 2,499 | 2,413 | 51,350 |
| **2040** | 21,525 | -2,917 | 11,432 | 13,935 | 636 | 2,511 | 2,369 | 49,492 |
| **2041** | 20,204 | -2,775 | 11,156 | 14,077 | 621 | 2,520 | 2,281 | 48,084 |
| **2042** | 18,882 | -2,633 | 10,880 | 14,218 | 606 | 2,530 | 2,192 | 46,676 |
| **2043** | 17,561 | -2,491 | 10,603 | 14,359 | 591 | 2,540 | 2,104 | 45,269 |
| **2044** | 16,240 | -2,349 | 10,327 | 14,501 | 576 | 2,550 | 2,015 | 43,861 |
| **2045** | 14,918 | -2,206 | 10,051 | 14,642 | 561 | 2,560 | 1,927 | 42,453 |
| **2046** | 13,607 | -2,224 | 9,846 | 14,791 | 553 | 2,575 | 1,869 | 41,017 |
| **2047** | 12,295 | -2,241 | 9,642 | 14,940 | 545 | 2,589 | 1,812 | 39,581 |
| **2048** | 10,984 | -2,258 | 9,437 | 15,089 | 536 | 2,603 | 1,754 | 38,145 |
| **2049** | 9,673 | -2,275 | 9,232 | 15,237 | 528 | 2,618 | 1,697 | 36,709 |
| **2050** | 8,361 | -2,293 | 9,027 | 15,386 | 520 | 2,632 | 1,639 | 35,273 |
| **Total** | **810,811** | **-35,428** | **399,778** | **413,798** | **22,005** | **74,944** | **71,342** | **1,757,251** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.35. Global Emissions Summary for Commitments (Moderate CCS): Model Resolved (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,333 | 532 | 18,199 | 11,670 | 886 | 2,126 | 2,244 | 73,991 |
| **2021** | 37,705 | 571 | 17,443 | 11,696 | 867 | 2,149 | 2,252 | 72,682 |
| **2022** | 37,076 | 610 | 16,686 | 11,722 | 848 | 2,172 | 2,260 | 71,374 |
| **2023** | 36,447 | 650 | 15,929 | 11,747 | 829 | 2,195 | 2,268 | 70,065 |
| **2024** | 35,818 | 689 | 15,172 | 11,773 | 811 | 2,218 | 2,276 | 68,756 |
| **2025** | 35,190 | 728 | 14,415 | 11,799 | 792 | 2,241 | 2,284 | 67,448 |
| **2026** | 35,046 | 503 | 14,501 | 12,000 | 804 | 2,266 | 2,381 | 67,501 |
| **2027** | 34,902 | 279 | 14,587 | 12,202 | 815 | 2,291 | 2,478 | 67,554 |
| **2028** | 34,758 | 55 | 14,673 | 12,403 | 827 | 2,317 | 2,575 | 67,608 |
| **2029** | 34,613 | -169 | 14,759 | 12,605 | 838 | 2,342 | 2,673 | 67,661 |
| **2030** | 34,469 | -393 | 14,845 | 12,806 | 850 | 2,367 | 2,770 | 67,714 |
| **2031** | 33,184 | -563 | 14,451 | 12,914 | 824 | 2,385 | 2,734 | 65,928 |
| **2032** | 31,899 | -732 | 14,058 | 13,021 | 797 | 2,402 | 2,697 | 64,143 |
| **2033** | 30,614 | -902 | 13,664 | 13,128 | 771 | 2,420 | 2,661 | 62,357 |
| **2034** | 29,328 | -1,071 | 13,271 | 13,236 | 745 | 2,438 | 2,625 | 60,571 |
| **2035** | 28,043 | -1,241 | 12,877 | 13,343 | 718 | 2,455 | 2,589 | 58,785 |
| **2036** | 26,741 | -1,576 | 12,588 | 13,462 | 702 | 2,466 | 2,545 | 56,928 |
| **2037** | 25,438 | -1,911 | 12,299 | 13,580 | 685 | 2,477 | 2,501 | 55,071 |
| **2038** | 24,136 | -2,246 | 12,010 | 13,699 | 669 | 2,488 | 2,457 | 53,214 |
| **2039** | 22,834 | -2,581 | 11,721 | 13,817 | 653 | 2,500 | 2,414 | 51,357 |
| **2040** | 21,531 | -2,916 | 11,432 | 13,936 | 636 | 2,511 | 2,370 | 49,500 |
| **2041** | 20,210 | -2,774 | 11,155 | 14,077 | 621 | 2,520 | 2,281 | 48,091 |
| **2042** | 18,889 | -2,632 | 10,878 | 14,218 | 606 | 2,530 | 2,193 | 46,682 |
| **2043** | 17,567 | -2,489 | 10,600 | 14,359 | 591 | 2,540 | 2,104 | 45,273 |
| **2044** | 16,246 | -2,347 | 10,323 | 14,501 | 576 | 2,550 | 2,016 | 43,864 |
| **2045** | 14,925 | -2,205 | 10,046 | 14,642 | 561 | 2,560 | 1,927 | 42,456 |
| **2046** | 13,613 | -2,223 | 9,841 | 14,791 | 553 | 2,575 | 1,870 | 41,018 |
| **2047** | 12,301 | -2,241 | 9,636 | 14,940 | 545 | 2,589 | 1,812 | 39,581 |
| **2048** | 10,989 | -2,258 | 9,430 | 15,089 | 536 | 2,603 | 1,754 | 38,143 |
| **2049** | 9,677 | -2,276 | 9,225 | 15,238 | 528 | 2,618 | 1,697 | 36,706 |
| **2050** | 8,365 | -2,294 | 9,020 | 15,386 | 520 | 2,632 | 1,639 | 35,268 |
| **Total** | **810,883** | **-35,419** | **399,732** | **413,799** | **22,005** | **74,944** | **71,345** | **1,757,289** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.36. Global Emissions Summary for Commitments (Moderate CCS): High Exports (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,333 | 532 | 18,199 | 11,670 | 886 | 2,126 | 2,244 | 73,991 |
| **2021** | 37,705 | 571 | 17,443 | 11,696 | 867 | 2,149 | 2,252 | 72,682 |
| **2022** | 37,076 | 610 | 16,686 | 11,722 | 848 | 2,172 | 2,260 | 71,374 |
| **2023** | 36,447 | 650 | 15,929 | 11,747 | 829 | 2,195 | 2,268 | 70,065 |
| **2024** | 35,818 | 689 | 15,172 | 11,773 | 811 | 2,218 | 2,276 | 68,756 |
| **2025** | 35,190 | 728 | 14,415 | 11,799 | 792 | 2,241 | 2,284 | 67,448 |
| **2026** | 35,046 | 503 | 14,501 | 12,000 | 804 | 2,266 | 2,381 | 67,501 |
| **2027** | 34,902 | 279 | 14,587 | 12,202 | 815 | 2,291 | 2,478 | 67,554 |
| **2028** | 34,758 | 55 | 14,673 | 12,403 | 827 | 2,317 | 2,575 | 67,608 |
| **2029** | 34,613 | -169 | 14,759 | 12,605 | 838 | 2,342 | 2,673 | 67,661 |
| **2030** | 34,469 | -393 | 14,845 | 12,806 | 850 | 2,367 | 2,770 | 67,714 |
| **2031** | 33,193 | -560 | 14,454 | 12,914 | 824 | 2,385 | 2,734 | 65,943 |
| **2032** | 31,917 | -728 | 14,063 | 13,021 | 797 | 2,402 | 2,698 | 64,171 |
| **2033** | 30,641 | -895 | 13,672 | 13,128 | 771 | 2,420 | 2,662 | 62,400 |
| **2034** | 29,365 | -1,063 | 13,282 | 13,236 | 745 | 2,438 | 2,627 | 60,629 |
| **2035** | 28,088 | -1,230 | 12,891 | 13,343 | 719 | 2,455 | 2,591 | 58,857 |
| **2036** | 26,783 | -1,566 | 12,598 | 13,462 | 702 | 2,467 | 2,547 | 56,992 |
| **2037** | 25,478 | -1,903 | 12,305 | 13,580 | 686 | 2,478 | 2,503 | 55,127 |
| **2038** | 24,173 | -2,239 | 12,012 | 13,699 | 669 | 2,489 | 2,459 | 53,262 |
| **2039** | 22,868 | -2,575 | 11,719 | 13,817 | 653 | 2,500 | 2,415 | 51,396 |
| **2040** | 21,563 | -2,912 | 11,426 | 13,936 | 636 | 2,511 | 2,372 | 49,531 |
| **2041** | 20,245 | -2,770 | 11,146 | 14,077 | 621 | 2,520 | 2,283 | 48,124 |
| **2042** | 18,928 | -2,628 | 10,866 | 14,218 | 606 | 2,530 | 2,194 | 46,716 |
| **2043** | 17,610 | -2,486 | 10,587 | 14,360 | 591 | 2,540 | 2,106 | 45,308 |
| **2044** | 16,293 | -2,344 | 10,307 | 14,501 | 576 | 2,550 | 2,017 | 43,901 |
| **2045** | 14,975 | -2,201 | 10,028 | 14,642 | 561 | 2,560 | 1,928 | 42,493 |
| **2046** | 13,670 | -2,220 | 9,822 | 14,791 | 553 | 2,574 | 1,871 | 41,061 |
| **2047** | 12,366 | -2,239 | 9,616 | 14,940 | 544 | 2,589 | 1,813 | 39,630 |
| **2048** | 11,061 | -2,257 | 9,410 | 15,089 | 536 | 2,603 | 1,756 | 38,198 |
| **2049** | 9,757 | -2,276 | 9,204 | 15,238 | 528 | 2,617 | 1,698 | 36,766 |
| **2050** | 8,452 | -2,295 | 8,998 | 15,387 | 519 | 2,632 | 1,641 | 35,334 |
| **Total** | **811,784** | **-35,330** | **399,610** | **413,805** | **22,006** | **74,943** | **71,375** | **1,758,194** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.37. Global Emissions Summary for Net Zero 2050 (High CCS): Existing/FID Exports (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,333 | 532 | 18,199 | 11,670 | 886 | 2,126 | 2,244 | 73,991 |
| **2021** | 37,707 | 616 | 17,531 | 11,716 | 872 | 2,151 | 2,260 | 72,853 |
| **2022** | 37,080 | 700 | 16,863 | 11,761 | 857 | 2,177 | 2,277 | 71,716 |
| **2023** | 36,454 | 784 | 16,195 | 11,807 | 843 | 2,202 | 2,294 | 70,579 |
| **2024** | 35,827 | 868 | 15,527 | 11,852 | 829 | 2,227 | 2,311 | 69,441 |
| **2025** | 35,200 | 952 | 14,859 | 11,898 | 815 | 2,252 | 2,327 | 68,304 |
| **2026** | 33,725 | 423 | 14,586 | 12,033 | 798 | 2,275 | 2,384 | 66,223 |
| **2027** | 32,250 | -107 | 14,313 | 12,168 | 781 | 2,297 | 2,441 | 64,143 |
| **2028** | 30,775 | -636 | 14,041 | 12,303 | 764 | 2,319 | 2,498 | 62,063 |
| **2029** | 29,300 | -1,166 | 13,768 | 12,437 | 746 | 2,341 | 2,555 | 59,982 |
| **2030** | 27,825 | -1,695 | 13,495 | 12,572 | 729 | 2,364 | 2,611 | 57,902 |
| **2031** | 26,373 | -1,180 | 13,363 | 12,727 | 723 | 2,391 | 2,606 | 57,002 |
| **2032** | 24,922 | -666 | 13,231 | 12,881 | 717 | 2,418 | 2,600 | 56,103 |
| **2033** | 23,471 | -151 | 13,099 | 13,036 | 710 | 2,445 | 2,594 | 55,204 |
| **2034** | 22,020 | 364 | 12,967 | 13,190 | 704 | 2,472 | 2,588 | 54,305 |
| **2035** | 20,568 | 878 | 12,835 | 13,344 | 698 | 2,499 | 2,582 | 53,405 |
| **2036** | 19,212 | 727 | 12,527 | 13,463 | 679 | 2,512 | 2,530 | 51,650 |
| **2037** | 17,856 | 577 | 12,218 | 13,581 | 660 | 2,524 | 2,479 | 49,895 |
| **2038** | 16,500 | 426 | 11,910 | 13,699 | 640 | 2,537 | 2,427 | 48,139 |
| **2039** | 15,143 | 275 | 11,602 | 13,817 | 621 | 2,549 | 2,375 | 46,384 |
| **2040** | 13,787 | 125 | 11,294 | 13,936 | 602 | 2,562 | 2,323 | 44,629 |
| **2041** | 12,431 | 178 | 11,098 | 14,089 | 591 | 2,574 | 2,240 | 43,200 |
| **2042** | 11,074 | 231 | 10,902 | 14,243 | 581 | 2,586 | 2,156 | 41,772 |
| **2043** | 9,717 | 284 | 10,707 | 14,396 | 570 | 2,598 | 2,073 | 40,344 |
| **2044** | 8,360 | 337 | 10,511 | 14,550 | 559 | 2,610 | 1,989 | 38,916 |
| **2045** | 7,004 | 389 | 10,315 | 14,703 | 549 | 2,622 | 1,906 | 37,488 |
| **2046** | 5,611 | 360 | 10,054 | 14,864 | 541 | 2,633 | 1,848 | 35,912 |
| **2047** | 4,218 | 330 | 9,793 | 15,026 | 533 | 2,645 | 1,791 | 34,336 |
| **2048** | 2,824 | 301 | 9,532 | 15,187 | 526 | 2,657 | 1,733 | 32,760 |
| **2049** | 1,431 | 271 | 9,271 | 15,348 | 518 | 2,669 | 1,676 | 31,184 |
| **2050** | 38 | 242 | 9,010 | 15,510 | 510 | 2,680 | 1,619 | 29,609 |
| **Total** | **637,037** | **5,568** | **395,621** | **413,805** | **21,153** | **75,913** | **70,336** | **1,619,433** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.38. Global Emissions Summary for Net Zero 2050 (High CCS): Model Resolved (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,333 | 532 | 18,199 | 11,670 | 886 | 2,126 | 2,244 | 73,991 |
| **2021** | 37,707 | 616 | 17,531 | 11,716 | 872 | 2,151 | 2,260 | 72,853 |
| **2022** | 37,080 | 700 | 16,863 | 11,761 | 857 | 2,177 | 2,277 | 71,716 |
| **2023** | 36,454 | 784 | 16,195 | 11,807 | 843 | 2,202 | 2,294 | 70,579 |
| **2024** | 35,827 | 868 | 15,527 | 11,852 | 829 | 2,227 | 2,311 | 69,441 |
| **2025** | 35,200 | 952 | 14,859 | 11,898 | 815 | 2,252 | 2,327 | 68,304 |
| **2026** | 33,725 | 423 | 14,586 | 12,033 | 798 | 2,275 | 2,384 | 66,223 |
| **2027** | 32,250 | -107 | 14,313 | 12,168 | 781 | 2,297 | 2,441 | 64,143 |
| **2028** | 30,775 | -636 | 14,041 | 12,303 | 764 | 2,319 | 2,498 | 62,063 |
| **2029** | 29,300 | -1,166 | 13,768 | 12,437 | 746 | 2,341 | 2,555 | 59,982 |
| **2030** | 27,825 | -1,695 | 13,495 | 12,572 | 729 | 2,364 | 2,611 | 57,902 |
| **2031** | 26,373 | -1,181 | 13,363 | 12,727 | 723 | 2,391 | 2,606 | 57,002 |
| **2032** | 24,922 | -666 | 13,231 | 12,881 | 717 | 2,418 | 2,600 | 56,103 |
| **2033** | 23,471 | -151 | 13,099 | 13,036 | 710 | 2,445 | 2,594 | 55,204 |
| **2034** | 22,019 | 363 | 12,967 | 13,190 | 704 | 2,472 | 2,588 | 54,304 |
| **2035** | 20,568 | 878 | 12,835 | 13,344 | 698 | 2,499 | 2,582 | 53,405 |
| **2036** | 19,214 | 723 | 12,526 | 13,463 | 679 | 2,512 | 2,531 | 51,647 |
| **2037** | 17,860 | 567 | 12,218 | 13,581 | 660 | 2,524 | 2,479 | 49,889 |
| **2038** | 16,506 | 412 | 11,910 | 13,699 | 640 | 2,537 | 2,427 | 48,131 |
| **2039** | 15,152 | 257 | 11,601 | 13,817 | 621 | 2,549 | 2,376 | 46,373 |
| **2040** | 13,799 | 101 | 11,293 | 13,935 | 602 | 2,561 | 2,324 | 44,615 |
| **2041** | 12,440 | 162 | 11,096 | 14,089 | 591 | 2,573 | 2,240 | 43,193 |
| **2042** | 11,082 | 224 | 10,899 | 14,242 | 581 | 2,585 | 2,157 | 41,770 |
| **2043** | 9,724 | 285 | 10,702 | 14,396 | 570 | 2,597 | 2,073 | 40,347 |
| **2044** | 8,365 | 346 | 10,505 | 14,550 | 559 | 2,609 | 1,989 | 38,924 |
| **2045** | 7,007 | 407 | 10,308 | 14,703 | 549 | 2,621 | 1,906 | 37,501 |
| **2046** | 5,614 | 374 | 10,046 | 14,864 | 541 | 2,633 | 1,848 | 35,921 |
| **2047** | 4,220 | 341 | 9,785 | 15,026 | 533 | 2,645 | 1,791 | 34,341 |
| **2048** | 2,826 | 308 | 9,523 | 15,187 | 526 | 2,657 | 1,734 | 32,761 |
| **2049** | 1,433 | 275 | 9,262 | 15,348 | 518 | 2,668 | 1,676 | 31,181 |
| **2050** | 39 | 242 | 9,000 | 15,510 | 510 | 2,680 | 1,619 | 29,601 |
| **Total** | **637,113** | **5,540** | **395,547** | **413,805** | **21,152** | **75,911** | **70,340** | **1,619,408** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.39. Global Emissions Summary for Net Zero 2050 (High CCS): High Exports (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,333 | 532 | 18,199 | 11,670 | 886 | 2,126 | 2,244 | 73,991 |
| **2021** | 37,707 | 616 | 17,531 | 11,716 | 872 | 2,151 | 2,260 | 72,853 |
| **2022** | 37,080 | 700 | 16,863 | 11,761 | 857 | 2,177 | 2,277 | 71,716 |
| **2023** | 36,454 | 784 | 16,195 | 11,807 | 843 | 2,202 | 2,294 | 70,579 |
| **2024** | 35,827 | 868 | 15,527 | 11,852 | 829 | 2,227 | 2,311 | 69,441 |
| **2025** | 35,200 | 952 | 14,859 | 11,898 | 815 | 2,252 | 2,327 | 68,304 |
| **2026** | 33,725 | 423 | 14,586 | 12,033 | 798 | 2,275 | 2,384 | 66,223 |
| **2027** | 32,250 | -107 | 14,313 | 12,168 | 781 | 2,297 | 2,441 | 64,143 |
| **2028** | 30,775 | -636 | 14,041 | 12,303 | 764 | 2,319 | 2,498 | 62,063 |
| **2029** | 29,300 | -1,166 | 13,768 | 12,437 | 746 | 2,341 | 2,555 | 59,982 |
| **2030** | 27,825 | -1,695 | 13,495 | 12,572 | 729 | 2,364 | 2,611 | 57,902 |
| **2031** | 26,382 | -1,196 | 13,366 | 12,727 | 723 | 2,391 | 2,606 | 56,998 |
| **2032** | 24,939 | -697 | 13,236 | 12,881 | 716 | 2,418 | 2,601 | 56,094 |
| **2033** | 23,496 | -197 | 13,106 | 13,035 | 710 | 2,445 | 2,595 | 55,190 |
| **2034** | 22,053 | 302 | 12,976 | 13,190 | 704 | 2,472 | 2,590 | 54,286 |
| **2035** | 20,610 | 801 | 12,846 | 13,344 | 697 | 2,499 | 2,585 | 53,382 |
| **2036** | 19,256 | 662 | 12,535 | 13,462 | 678 | 2,511 | 2,533 | 51,636 |
| **2037** | 17,901 | 522 | 12,223 | 13,580 | 659 | 2,523 | 2,481 | 49,891 |
| **2038** | 16,547 | 382 | 11,912 | 13,699 | 640 | 2,536 | 2,430 | 48,145 |
| **2039** | 15,193 | 243 | 11,601 | 13,817 | 621 | 2,548 | 2,378 | 46,400 |
| **2040** | 13,839 | 103 | 11,289 | 13,935 | 602 | 2,560 | 2,326 | 44,654 |
| **2041** | 12,477 | 173 | 11,089 | 14,089 | 591 | 2,573 | 2,242 | 43,234 |
| **2042** | 11,115 | 243 | 10,888 | 14,242 | 581 | 2,585 | 2,159 | 41,813 |
| **2043** | 9,754 | 313 | 10,688 | 14,396 | 570 | 2,597 | 2,075 | 40,392 |
| **2044** | 8,392 | 383 | 10,487 | 14,550 | 560 | 2,609 | 1,991 | 38,971 |
| **2045** | 7,030 | 453 | 10,287 | 14,703 | 549 | 2,621 | 1,907 | 37,551 |
| **2046** | 5,634 | 407 | 10,024 | 14,865 | 541 | 2,632 | 1,850 | 35,952 |
| **2047** | 4,237 | 360 | 9,761 | 15,026 | 533 | 2,644 | 1,792 | 34,354 |
| **2048** | 2,841 | 313 | 9,497 | 15,187 | 525 | 2,656 | 1,735 | 32,755 |
| **2049** | 1,444 | 267 | 9,234 | 15,349 | 518 | 2,668 | 1,677 | 31,157 |
| **2050** | 48 | 220 | 8,971 | 15,510 | 510 | 2,679 | 1,620 | 29,558 |
| **Total** | **637,664** | **5,330** | **395,394** | **413,802** | **21,148** | **75,896** | **70,374** | **1,619,609** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.40. Global Emissions Summary for Net Zero 2050 (Moderate CCS): Existing/FID Exports (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,333 | 532 | 18,199 | 11,670 | 886 | 2,126 | 2,244 | 73,991 |
| **2021** | 37,705 | 571 | 17,443 | 11,696 | 867 | 2,149 | 2,252 | 72,682 |
| **2022** | 37,076 | 610 | 16,686 | 11,722 | 848 | 2,172 | 2,260 | 71,374 |
| **2023** | 36,447 | 650 | 15,929 | 11,747 | 829 | 2,195 | 2,268 | 70,065 |
| **2024** | 35,818 | 689 | 15,172 | 11,773 | 811 | 2,218 | 2,276 | 68,756 |
| **2025** | 35,190 | 728 | 14,415 | 11,799 | 792 | 2,241 | 2,284 | 67,448 |
| **2026** | 33,730 | 76 | 14,012 | 11,903 | 774 | 2,258 | 2,324 | 65,077 |
| **2027** | 32,270 | -576 | 13,609 | 12,007 | 757 | 2,276 | 2,364 | 62,706 |
| **2028** | 30,810 | -1,227 | 13,206 | 12,110 | 739 | 2,293 | 2,404 | 60,335 |
| **2029** | 29,350 | -1,879 | 12,802 | 12,214 | 721 | 2,310 | 2,444 | 57,963 |
| **2030** | 27,890 | -2,531 | 12,399 | 12,318 | 703 | 2,328 | 2,484 | 55,592 |
| **2031** | 26,507 | -2,788 | 12,074 | 12,445 | 685 | 2,338 | 2,461 | 53,721 |
| **2032** | 25,124 | -3,046 | 11,748 | 12,572 | 668 | 2,348 | 2,437 | 51,850 |
| **2033** | 23,741 | -3,304 | 11,422 | 12,698 | 650 | 2,358 | 2,414 | 49,979 |
| **2034** | 22,357 | -3,561 | 11,097 | 12,825 | 632 | 2,368 | 2,390 | 48,108 |
| **2035** | 20,974 | -3,819 | 10,771 | 12,952 | 614 | 2,378 | 2,367 | 46,237 |
| **2036** | 19,593 | -3,575 | 10,567 | 13,106 | 601 | 2,391 | 2,341 | 45,024 |
| **2037** | 18,213 | -3,331 | 10,362 | 13,259 | 588 | 2,404 | 2,316 | 43,811 |
| **2038** | 16,832 | -3,088 | 10,158 | 13,413 | 575 | 2,417 | 2,290 | 42,597 |
| **2039** | 15,451 | -2,844 | 9,954 | 13,566 | 562 | 2,430 | 2,264 | 41,384 |
| **2040** | 14,071 | -2,600 | 9,750 | 13,720 | 549 | 2,442 | 2,239 | 40,171 |
| **2041** | 12,712 | -2,738 | 9,466 | 13,871 | 541 | 2,449 | 2,165 | 38,466 |
| **2042** | 11,352 | -2,876 | 9,182 | 14,022 | 533 | 2,456 | 2,091 | 36,760 |
| **2043** | 9,993 | -3,014 | 8,898 | 14,174 | 524 | 2,463 | 2,017 | 35,055 |
| **2044** | 8,634 | -3,152 | 8,614 | 14,325 | 516 | 2,470 | 1,943 | 33,350 |
| **2045** | 7,275 | -3,290 | 8,330 | 14,476 | 508 | 2,477 | 1,869 | 31,645 |
| **2046** | 5,865 | -2,831 | 8,122 | 14,645 | 504 | 2,494 | 1,823 | 30,621 |
| **2047** | 4,455 | -2,373 | 7,914 | 14,814 | 500 | 2,510 | 1,776 | 29,597 |
| **2048** | 3,045 | -1,914 | 7,706 | 14,984 | 496 | 2,527 | 1,730 | 28,573 |
| **2049** | 1,635 | -1,455 | 7,498 | 15,153 | 492 | 2,544 | 1,683 | 27,549 |
| **2050** | 225 | -996 | 7,290 | 15,322 | 488 | 2,561 | 1,636 | 26,525 |
| **Total** | **642,673** | **-58,952** | **354,789** | **407,301** | **19,953** | **73,393** | **67,855** | **1,507,012** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.41. Global Emissions Summary for Net Zero 2050 (Moderate CCS): Model Resolved (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2e$/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,333 | 532 | 18,199 | 11,670 | 886 | 2,126 | 2,244 | 73,991 |
| **2021** | 37,705 | 571 | 17,443 | 11,696 | 867 | 2,149 | 2,252 | 72,682 |
| **2022** | 37,076 | 610 | 16,686 | 11,722 | 848 | 2,172 | 2,260 | 71,374 |
| **2023** | 36,447 | 650 | 15,929 | 11,747 | 829 | 2,195 | 2,268 | 70,065 |
| **2024** | 35,818 | 689 | 15,172 | 11,773 | 811 | 2,218 | 2,276 | 68,756 |
| **2025** | 35,190 | 728 | 14,415 | 11,799 | 792 | 2,241 | 2,284 | 67,448 |
| **2026** | 33,730 | 76 | 14,012 | 11,903 | 774 | 2,258 | 2,324 | 65,077 |
| **2027** | 32,270 | -576 | 13,609 | 12,007 | 757 | 2,276 | 2,364 | 62,706 |
| **2028** | 30,810 | -1,227 | 13,206 | 12,110 | 739 | 2,293 | 2,404 | 60,335 |
| **2029** | 29,350 | -1,879 | 12,802 | 12,214 | 721 | 2,310 | 2,444 | 57,963 |
| **2030** | 27,890 | -2,531 | 12,399 | 12,318 | 703 | 2,328 | 2,484 | 55,592 |
| **2031** | 26,507 | -2,788 | 12,074 | 12,445 | 685 | 2,338 | 2,461 | 53,721 |
| **2032** | 25,124 | -3,046 | 11,748 | 12,572 | 668 | 2,348 | 2,437 | 51,850 |
| **2033** | 23,741 | -3,304 | 11,422 | 12,698 | 650 | 2,358 | 2,414 | 49,979 |
| **2034** | 22,357 | -3,561 | 11,097 | 12,825 | 632 | 2,368 | 2,390 | 48,108 |
| **2035** | 20,974 | -3,819 | 10,771 | 12,952 | 614 | 2,378 | 2,367 | 46,237 |
| **2036** | 19,593 | -3,575 | 10,567 | 13,106 | 601 | 2,391 | 2,341 | 45,024 |
| **2037** | 18,213 | -3,331 | 10,362 | 13,259 | 588 | 2,404 | 2,316 | 43,811 |
| **2038** | 16,832 | -3,088 | 10,158 | 13,413 | 575 | 2,417 | 2,290 | 42,597 |
| **2039** | 15,451 | -2,844 | 9,954 | 13,566 | 562 | 2,430 | 2,264 | 41,384 |
| **2040** | 14,071 | -2,600 | 9,750 | 13,720 | 549 | 2,442 | 2,239 | 40,171 |
| **2041** | 12,712 | -2,738 | 9,466 | 13,871 | 541 | 2,449 | 2,165 | 38,466 |
| **2042** | 11,352 | -2,876 | 9,182 | 14,022 | 533 | 2,456 | 2,091 | 36,760 |
| **2043** | 9,993 | -3,014 | 8,898 | 14,174 | 524 | 2,463 | 2,017 | 35,055 |
| **2044** | 8,634 | -3,152 | 8,614 | 14,325 | 516 | 2,470 | 1,943 | 33,350 |
| **2045** | 7,275 | -3,290 | 8,330 | 14,476 | 508 | 2,477 | 1,869 | 31,645 |
| **2046** | 5,865 | -2,831 | 8,122 | 14,645 | 504 | 2,494 | 1,823 | 30,621 |
| **2047** | 4,455 | -2,373 | 7,914 | 14,814 | 500 | 2,510 | 1,776 | 29,597 |
| **2048** | 3,045 | -1,914 | 7,706 | 14,984 | 496 | 2,527 | 1,730 | 28,573 |
| **2049** | 1,635 | -1,455 | 7,498 | 15,153 | 492 | 2,544 | 1,683 | 27,549 |
| **2050** | 225 | -996 | 7,290 | 15,322 | 488 | 2,561 | 1,636 | 26,525 |
| **Total** | **642,673** | **-58,952** | **354,789** | **407,301** | **19,953** | **73,393** | **67,855** | **1,507,012** |

Note: Emissions shown have been interpolated for non-model years.

*Table C-4.42. Global Emissions Summary for Net Zero 2050 (Moderate CCS): High Exports (GCAM-NETL-Aligned, AR6-20 Basis)*

| Year | $CO_2$ Energy | $CO_2$ LUC | $CH_4$ Energy | $CH_4$ Ag | $N_2O$ Energy | $N_2O$ Ag | F Gases | Total |
|---|---|---|---|---|---|---|---|---|
| | Units (Tg $CO_2$e/year) (AR6, 20-year) | | | | | | | |
| **2020** | 38,333 | 532 | 18,199 | 11,670 | 886 | 2,126 | 2,244 | 73,991 |
| **2021** | 37,705 | 571 | 17,443 | 11,696 | 867 | 2,149 | 2,252 | 72,682 |
| **2022** | 37,076 | 610 | 16,686 | 11,722 | 848 | 2,172 | 2,260 | 71,374 |
| **2023** | 36,447 | 650 | 15,929 | 11,747 | 829 | 2,195 | 2,268 | 70,065 |
| **2024** | 35,818 | 689 | 15,172 | 11,773 | 811 | 2,218 | 2,276 | 68,756 |
| **2025** | 35,190 | 728 | 14,415 | 11,799 | 792 | 2,241 | 2,284 | 67,448 |
| **2026** | 33,730 | 76 | 14,012 | 11,903 | 774 | 2,258 | 2,324 | 65,077 |
| **2027** | 32,270 | -576 | 13,609 | 12,007 | 757 | 2,276 | 2,364 | 62,706 |
| **2028** | 30,810 | -1,227 | 13,206 | 12,110 | 739 | 2,293 | 2,404 | 60,335 |
| **2029** | 29,350 | -1,879 | 12,802 | 12,214 | 721 | 2,310 | 2,444 | 57,963 |
| **2030** | 27,890 | -2,531 | 12,399 | 12,318 | 703 | 2,328 | 2,484 | 55,592 |
| **2031** | 26,518 | -2,796 | 12,076 | 12,445 | 685 | 2,338 | 2,461 | 53,727 |
| **2032** | 25,145 | -3,060 | 11,752 | 12,571 | 668 | 2,348 | 2,438 | 51,862 |
| **2033** | 23,773 | -3,325 | 11,428 | 12,698 | 650 | 2,358 | 2,415 | 49,996 |
| **2034** | 22,401 | -3,590 | 11,105 | 12,825 | 632 | 2,368 | 2,392 | 48,131 |
| **2035** | 21,028 | -3,855 | 10,781 | 12,951 | 614 | 2,378 | 2,369 | 46,266 |
| **2036** | 19,652 | -3,604 | 10,575 | 13,105 | 601 | 2,391 | 2,343 | 45,062 |
| **2037** | 18,275 | -3,354 | 10,369 | 13,259 | 588 | 2,404 | 2,317 | 43,859 |
| **2038** | 16,899 | -3,103 | 10,164 | 13,412 | 575 | 2,416 | 2,292 | 42,656 |
| **2039** | 15,523 | -2,852 | 9,958 | 13,566 | 562 | 2,429 | 2,266 | 41,452 |
| **2040** | 14,146 | -2,601 | 9,752 | 13,720 | 549 | 2,442 | 2,241 | 40,249 |
| **2041** | 12,789 | -2,740 | 9,464 | 13,871 | 541 | 2,449 | 2,167 | 38,539 |
| **2042** | 11,432 | -2,879 | 9,175 | 14,022 | 532 | 2,456 | 2,092 | 36,830 |
| **2043** | 10,075 | -3,018 | 8,887 | 14,173 | 524 | 2,463 | 2,018 | 35,121 |
| **2044** | 8,717 | -3,158 | 8,598 | 14,324 | 516 | 2,470 | 1,944 | 33,412 |
| **2045** | 7,360 | -3,297 | 8,310 | 14,475 | 508 | 2,477 | 1,870 | 31,702 |
| **2046** | 5,959 | -2,853 | 8,099 | 14,644 | 504 | 2,493 | 1,823 | 30,669 |
| **2047** | 4,557 | -2,410 | 7,888 | 14,813 | 500 | 2,510 | 1,776 | 29,635 |
| **2048** | 3,156 | -1,966 | 7,678 | 14,982 | 496 | 2,527 | 1,730 | 28,601 |
| **2049** | 1,754 | -1,523 | 7,467 | 15,151 | 491 | 2,543 | 1,683 | 27,567 |
| **2050** | 353 | -1,079 | 7,256 | 15,320 | 487 | 2,560 | 1,636 | 26,534 |
| **Total** | **644,132** | **-59,419** | **354,650** | **407,283** | **19,949** | **73,386** | **67,876** | **1,507,858** |

Note: Emissions shown have been interpolated for non-model years.

## C. Summary Consequential Result Tables

The remaining tables summarize values of U.S. LNG Exports and GHG emissions used for calculating the consequential GHG intensity and PNDE factors on an annual and cumulative basis for all scenarios (including sensitivity scenarios) in the Consequential Analysis Appendix.

Note: U.S. LNG export and GHG emissions values were interpolated for non-model years. Also, consequential and PNDE results have been removed from these tables for years with zero or near-zero changes in GHG emissions or U.S. LNG exports that lead to extraneous annual results.

Table C-4.43. Annual and Cumulative Emissions, U.S. LNG Exports, and Consequential Analysis of Defined Policies Scenarios (AR6-100 Basis)

| Year | *DP: ExFID* | | *DP: MR* | | *DP: MR vs ExFID* | | | | *DP: Hi Exp* | | *DP: Hi Exp vs ExFID* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | US LNG EJ | GHG Tg $CO_2e$ | US LNG EJ | GHG Tg $CO_2e$ | Δ LNG EJ | Δ GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ | US LNG EJ | GHG Tg $CO_2e$ | Δ LNG EJ | Δ GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ |
| **2020** | 2.4 | 53,770 | 2.4 | 53,770 | 0.0 | 0.0 | | | 2.4 | 53,770 | 0.0 | 0.0 | | |
| **2021** | 3.2 | 53,219 | 3.2 | 53,219 | 0.0 | 0.0 | | | 3.2 | 53,219 | 0.0 | 0.0 | | |
| **2022** | 4.0 | 52,669 | 4.0 | 52,669 | 0.0 | 0.0 | | | 4.0 | 52,669 | 0.0 | 0.0 | | |
| **2023** | 4.8 | 52,118 | 4.8 | 52,118 | 0.0 | 0.0 | | | 4.8 | 52,118 | 0.0 | 0.0 | | |
| **2024** | 5.6 | 51,567 | 5.6 | 51,567 | 0.0 | 0.0 | | | 5.6 | 51,567 | 0.0 | 0.0 | | |
| **2025** | 6.3 | 51,017 | 6.3 | 51,017 | 0.0 | 0.0 | | | 6.3 | 51,017 | 0.0 | 0.0 | | |
| **2026** | 6.5 | 50,645 | 6.5 | 50,645 | 0.0 | 0.0 | | | 6.5 | 50,645 | 0.0 | 0.0 | | |
| **2027** | 6.6 | 50,273 | 6.6 | 50,273 | 0.0 | 0.0 | | | 6.6 | 50,273 | 0.0 | 0.0 | | |
| **2028** | 6.7 | 49,901 | 6.7 | 49,901 | 0.0 | 0.0 | | | 6.7 | 49,901 | 0.0 | 0.0 | | |
| **2029** | 6.8 | 49,529 | 6.8 | 49,529 | 0.0 | 0.0 | | | 6.8 | 49,529 | 0.0 | 0.0 | | |
| **2030** | 7.0 | 49,156 | 7.0 | 49,156 | 0.0 | 0.0 | | | 7.0 | 49,156 | 0.0 | 0.0 | | |
| **2031** | 7.3 | 49,364 | 7.5 | 49,365 | 0.2 | 0.6 | 3.1 | -11.4 | 7.8 | 49,365 | 0.6 | 1.3 | 2.4 | -12.1 |
| **2032** | 7.6 | 49,572 | 8.0 | 49,573 | 0.4 | 1.2 | 3.1 | -11.4 | 8.7 | 49,574 | 1.1 | 2.7 | 2.4 | -12.1 |
| **2033** | 7.9 | 49,779 | 8.5 | 49,781 | 0.6 | 1.8 | 3.1 | -11.4 | 9.6 | 49,783 | 1.7 | 4.0 | 2.4 | -12.1 |
| **2034** | 8.2 | 49,987 | 9.0 | 49,989 | 0.8 | 2.3 | 3.1 | -11.4 | 10.4 | 49,992 | 2.2 | 5.3 | 2.4 | -12.1 |
| **2035** | 8.5 | 50,194 | 9.5 | 50,197 | 1.0 | 2.9 | 3.1 | -11.4 | 11.3 | 50,201 | 2.8 | 6.7 | 2.4 | -12.1 |
| **2036** | 8.5 | 50,033 | 10.4 | 50,046 | 1.8 | 12.7 | 6.9 | -7.6 | 12.5 | 50,062 | 4.0 | 29.3 | 7.3 | -7.2 |
| **2037** | 8.5 | 49,872 | 11.3 | 49,894 | 2.7 | 22.6 | 8.3 | -6.3 | 13.8 | 49,924 | 5.3 | 51.8 | 9.9 | -4.6 |
| **2038** | 8.5 | 49,711 | 12.2 | 49,743 | 3.6 | 32.4 | 8.9 | -5.6 | 15.0 | 49,785 | 6.5 | 74.4 | 11.5 | -3.1 |
| **2039** | 8.5 | 49,549 | 13.0 | 49,592 | 4.5 | 42.2 | 9.4 | -5.2 | 16.3 | 49,647 | 7.7 | 97.0 | 12.5 | -2.0 |
| **2040** | 8.5 | 49,388 | 13.9 | 49,440 | 5.4 | 52.0 | 9.6 | -4.9 | 17.5 | 49,508 | 9.0 | 119.6 | 13.3 | -1.2 |
| **2041** | 8.5 | 49,364 | 14.7 | 49,418 | 6.2 | 54.1 | 8.8 | -5.7 | 18.7 | 49,483 | 10.1 | 119.1 | 11.8 | -2.8 |
| **2042** | 8.5 | 49,340 | 15.5 | 49,396 | 6.9 | 56.3 | 8.1 | -6.4 | 19.8 | 49,458 | 11.3 | 118.6 | 10.5 | -4.0 |
| **2043** | 8.5 | 49,315 | 16.3 | 49,374 | 7.7 | 58.5 | 7.6 | -6.9 | 20.9 | 49,433 | 12.4 | 118.1 | 9.5 | -5.0 |
| **2044** | 8.5 | 49,291 | 17.0 | 49,352 | 8.5 | 60.6 | 7.1 | -7.4 | 22.1 | 49,409 | 13.5 | 117.6 | 8.7 | -5.8 |
| **2045** | 8.5 | 49,267 | 17.8 | 49,329 | 9.3 | 62.8 | 6.8 | -7.7 | 23.2 | 49,384 | 14.7 | 117.1 | 8.0 | -6.5 |
| **2046** | 8.5 | 49,141 | 18.3 | 49,200 | 9.8 | 58.4 | 6.0 | -8.5 | 24.1 | 49,250 | 15.5 | 109.3 | 7.0 | -7.5 |
| **2047** | 8.5 | 49,016 | 18.8 | 49,070 | 10.2 | 54.0 | 5.3 | -9.3 | 24.9 | 49,117 | 16.4 | 101.5 | 6.2 | -8.3 |
| **2048** | 8.5 | 48,890 | 19.3 | 48,940 | 10.7 | 49.6 | 4.6 | -9.9 | 25.8 | 48,984 | 17.2 | 93.8 | 5.4 | -9.1 |
| **2049** | 8.5 | 48,765 | 19.8 | 48,810 | 11.2 | 45.2 | 4.0 | -10.5 | 26.6 | 48,851 | 18.1 | 86.0 | 4.8 | -9.8 |
| **2050** | 8.5 | 48,639 | 20.3 | 48,680 | 11.7 | 40.8 | 3.5 | -11.0 | 27.5 | 48,717 | 18.9 | 78.2 | 4.1 | -10.4 |
| **Cum.** | **227** | **1,552,340** | **341** | **1,553,051** | **113** | **711** | **6.3** | **-8.2** | **416** | **1,553,792** | **189** | **1,452** | **7.7** | **-6.8** |

*Table C-4.44. Annual and Cumulative Emissions, U.S. LNG Exports, and Consequential Analysis of DP High Middle East Supply Scenarios (AR6-100 Basis)*

| Year | *DP Hi ME Sup: ExFID* | | | *DP Hi ME Sup: MR* | | *DP Hi ME Sup: MR vs ExFID* | | | |
|---|---|---|---|---|---|---|---|---|---|
| | US LNG EJ | GHG Tg $CO_2e$ | | US LNG EJ | GHG Tg $CO_2e$ | D LNG EJ | D GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ |
| **2020** | 2.4 | 53,780 | | 2.4 | 53,780 | 0.0 | 0.0 | | |
| **2021** | 3.2 | 53,230 | | 3.2 | 53,230 | 0.0 | 0.0 | | |
| **2022** | 4.0 | 52,681 | | 4.0 | 52,681 | 0.0 | 0.0 | | |
| **2023** | 4.8 | 52,131 | | 4.8 | 52,131 | 0.0 | 0.0 | | |
| **2024** | 5.6 | 51,582 | | 5.6 | 51,582 | 0.0 | 0.0 | | |
| **2025** | 6.3 | 51,032 | | 6.3 | 51,032 | 0.0 | 0.0 | | |
| **2026** | 6.5 | 50,662 | | 6.5 | 50,662 | 0.0 | 0.0 | | |
| **2027** | 6.6 | 50,291 | | 6.6 | 50,291 | 0.0 | 0.0 | | |
| **2028** | 6.8 | 49,921 | | 6.8 | 49,921 | 0.0 | 0.0 | | |
| **2029** | 6.9 | 49,551 | | 6.9 | 49,551 | 0.0 | 0.0 | | |
| **2030** | 7.1 | 49,180 | | 7.1 | 49,180 | 0.0 | 0.0 | | |
| **2031** | 7.4 | 49,401 | | 7.6 | 49,402 | 0.2 | 0.5 | 2.2 | -12.3 |
| **2032** | 7.7 | 49,623 | | 8.1 | 49,624 | 0.4 | 1.0 | 2.2 | -12.3 |
| **2033** | 8.0 | 49,844 | | 8.6 | 49,845 | 0.7 | 1.5 | 2.2 | -12.3 |
| **2034** | 8.2 | 50,065 | | 9.1 | 50,067 | 0.9 | 2.0 | 2.2 | -12.3 |
| **2035** | 8.5 | 50,286 | | 9.7 | 50,288 | 1.1 | 2.5 | 2.2 | -12.3 |
| **2036** | 8.5 | 50,158 | | 10.4 | 50,166 | 1.9 | 8.0 | 4.2 | -10.3 |
| **2037** | 8.5 | 50,030 | | 11.2 | 50,044 | 2.6 | 13.4 | 5.1 | -9.4 |
| **2038** | 8.5 | 49,903 | | 11.9 | 49,922 | 3.4 | 18.9 | 5.6 | -9.0 |
| **2039** | 8.5 | 49,775 | | 12.7 | 49,799 | 4.1 | 24.3 | 5.9 | -8.7 |
| **2040** | 8.5 | 49,647 | | 13.4 | 49,677 | 4.9 | 29.8 | 6.1 | -8.4 |
| **2041** | 8.5 | 49,635 | | 14.1 | 49,666 | 5.5 | 30.8 | 5.6 | -9.0 |
| **2042** | 8.5 | 49,623 | | 14.7 | 49,654 | 6.1 | 31.7 | 5.2 | -9.4 |
| **2043** | 8.5 | 49,610 | | 15.3 | 49,643 | 6.8 | 32.7 | 4.8 | -9.7 |
| **2044** | 8.5 | 49,598 | | 15.9 | 49,632 | 7.4 | 33.7 | 4.6 | -10.0 |
| **2045** | 8.5 | 49,586 | | 16.5 | 49,620 | 8.0 | 34.7 | 4.3 | -10.2 |
| **2046** | 8.5 | 49,468 | | 17.0 | 49,497 | 8.4 | 29.6 | 3.5 | -11.0 |
| **2047** | 8.5 | 49,350 | | 17.4 | 49,375 | 8.8 | 24.5 | 2.8 | -11.7 |
| **2048** | 8.5 | 49,232 | | 17.8 | 49,252 | 9.3 | 19.5 | 2.1 | -12.4 |
| **2049** | 8.5 | 49,114 | | 18.2 | 49,129 | 9.7 | 14.4 | 1.5 | -13.0 |
| **2050** | 8.5 | 48,996 | | 18.6 | 49,006 | 10.1 | 9.3 | 0.9 | -13.6 |
| **Cum.** | **228** | **1,556,984** | | **329** | **1,557,347** | **100** | **363** | **3.6** | **-10.9** |

Table C-4.45. Annual and Cumulative Emissions, U.S. LNG Exports, and Consequential Analysis of DP High U.S. Supply Scenarios (AR6-100 Basis)

| Year | *DP Hi US Sup: ExFID* | | | *DP Hi US Sup: MR* | | *DP Hi US Sup: MR vs ExFID* | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **US LNG** | **GHG** | | **US LNG** | **GHG** | **D LNG** | **D GHG** | **Cons GHG** | **PNDE** |
| | **EJ** | **Tg $CO_2$e** | | **EJ** | **Tg $CO_2$e** | **EJ** | **Tg $CO_2$e** | **g $CO_2$e/MJ** | **g $CO_2$e/MJ** |
| **2020** | 2.4 | 53,766 | | 2.4 | 53,766 | 0.0 | 0.0 | | |
| **2021** | 3.2 | 53,216 | | 3.2 | 53,216 | 0.0 | 0.0 | | |
| **2022** | 4.0 | 52,667 | | 4.0 | 52,667 | 0.0 | 0.0 | | |
| **2023** | 4.8 | 52,117 | | 4.8 | 52,117 | 0.0 | 0.0 | | |
| **2024** | 5.6 | 51,568 | | 5.6 | 51,568 | 0.0 | 0.0 | | |
| **2025** | 6.3 | 51,019 | | 6.3 | 51,019 | 0.0 | 0.0 | | |
| **2026** | 6.5 | 50,647 | | 6.5 | 50,647 | 0.0 | 0.0 | | |
| **2027** | 6.6 | 50,276 | | 6.6 | 50,276 | 0.0 | 0.0 | | |
| **2028** | 6.8 | 49,905 | | 6.8 | 49,905 | 0.0 | 0.0 | | |
| **2029** | 6.9 | 49,534 | | 6.9 | 49,534 | 0.0 | 0.0 | | |
| **2030** | 7.0 | 49,162 | | 7.0 | 49,162 | 0.0 | 0.0 | | |
| **2031** | 7.3 | 49,371 | | 7.6 | 49,372 | 0.3 | 0.8 | 2.8 | -11.7 |
| **2032** | 7.6 | 49,580 | | 8.2 | 49,581 | 0.6 | 1.6 | 2.8 | -11.7 |
| **2033** | 7.9 | 49,788 | | 8.8 | 49,791 | 0.9 | 2.4 | 2.8 | -11.7 |
| **2034** | 8.2 | 49,997 | | 9.4 | 50,000 | 1.2 | 3.3 | 2.8 | -11.7 |
| **2035** | 8.5 | 50,205 | | 10.0 | 50,209 | 1.5 | 4.1 | 2.8 | -11.7 |
| **2036** | 8.5 | 50,044 | | 11.1 | 50,064 | 2.6 | 19.6 | 7.6 | -6.9 |
| **2037** | 8.5 | 49,883 | | 12.2 | 49,918 | 3.7 | 35.2 | 9.5 | -5.0 |
| **2038** | 8.5 | 49,722 | | 13.3 | 49,772 | 4.8 | 50.7 | 10.5 | -4.0 |
| **2039** | 8.5 | 49,560 | | 14.5 | 49,627 | 5.9 | 66.2 | 11.2 | -3.3 |
| **2040** | 8.5 | 49,399 | | 15.6 | 49,481 | 7.0 | 81.8 | 11.6 | -2.9 |
| **2041** | 8.5 | 49,377 | | 16.7 | 49,463 | 8.2 | 85.1 | 10.4 | -4.1 |
| **2042** | 8.5 | 49,356 | | 17.8 | 49,444 | 9.3 | 88.4 | 9.5 | -5.0 |
| **2043** | 8.5 | 49,334 | | 18.9 | 49,425 | 10.4 | 91.7 | 8.8 | -5.7 |
| **2044** | 8.5 | 49,312 | | 20.0 | 49,407 | 11.5 | 95.1 | 8.3 | -6.3 |
| **2045** | 8.5 | 49,290 | | 21.1 | 49,388 | 12.6 | 98.4 | 7.8 | -6.7 |
| **2046** | 8.5 | 49,168 | | 22.0 | 49,265 | 13.4 | 96.4 | 7.2 | -7.3 |
| **2047** | 8.5 | 49,047 | | 22.8 | 49,141 | 14.2 | 94.4 | 6.6 | -7.9 |
| **2048** | 8.5 | 48,925 | | 23.6 | 49,017 | 15.1 | 92.3 | 6.1 | -8.4 |
| **2049** | 8.5 | 48,803 | | 24.4 | 48,894 | 15.9 | 90.3 | 5.7 | -8.8 |
| **2050** | 8.5 | 48,681 | | 25.2 | 48,770 | 16.7 | 88.3 | 5.3 | -9.2 |
| **Cum.** | **228** | **1,552,720** | | **383** | **1,553,906** | **156** | **1,186** | **7.6** | **-6.9** |

*Table C-4.46. Annual and Cumulative Emissions, U.S. LNG Exports, and Consequential Analysis of DP Low U.S. Supply Scenarios (AR6-100 Basis)*

| Year | *DP Lo US Sup: ExFID* | | | *DP Lo US Sup: MR* | | | *DP Lo US Sup: MR vs ExFID* | | |
|---|---|---|---|---|---|---|---|---|---|
| | US LNG EJ | GHG Tg $CO_2e$ | | US LNG EJ | GHG Tg $CO_2e$ | D LNG EJ | D GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ |
| **2020** | 2.4 | 53,794 | | 2.4 | 53,794 | 0.0 | 0.0 | | |
| **2021** | 3.2 | 53,236 | | 3.2 | 53,236 | 0.0 | 0.0 | | |
| **2022** | 4.0 | 52,678 | | 4.0 | 52,678 | 0.0 | 0.0 | | |
| **2023** | 4.8 | 52,119 | | 4.8 | 52,119 | 0.0 | 0.0 | | |
| **2024** | 5.5 | 51,561 | | 5.5 | 51,561 | 0.0 | 0.0 | | |
| **2025** | 6.3 | 51,003 | | 6.3 | 51,003 | 0.0 | 0.0 | | |
| **2026** | 6.4 | 50,624 | | 6.4 | 50,624 | 0.0 | 0.0 | | |
| **2027** | 6.4 | 50,245 | | 6.4 | 50,245 | 0.0 | 0.0 | | |
| **2028** | 6.5 | 49,866 | | 6.5 | 49,866 | 0.0 | 0.0 | | |
| **2029** | 6.5 | 49,487 | | 6.5 | 49,487 | 0.0 | 0.0 | | |
| **2030** | 6.6 | 49,108 | | 6.6 | 49,108 | 0.0 | 0.0 | | |
| **2031** | 6.8 | 49,308 | | 6.8 | 49,308 | 0.0 | 0.0 | | |
| **2032** | 7.0 | 49,508 | | 7.0 | 49,508 | 0.0 | 0.0 | | |
| **2033** | 7.2 | 49,708 | | 7.2 | 49,708 | 0.0 | 0.0 | | |
| **2034** | 7.4 | 49,907 | | 7.4 | 49,907 | 0.0 | 0.0 | | |
| **2035** | 7.6 | 50,107 | | 7.6 | 50,107 | 0.0 | 0.0 | | |
| **2036** | 7.8 | 49,940 | | 7.8 | 49,940 | 0.1 | 0.2 | 3.2 | -11.3 |
| **2037** | 8.0 | 49,773 | | 8.1 | 49,774 | 0.1 | 0.5 | 3.2 | -11.3 |
| **2038** | 8.1 | 49,606 | | 8.4 | 49,607 | 0.2 | 0.7 | 3.2 | -11.3 |
| **2039** | 8.3 | 49,439 | | 8.6 | 49,440 | 0.3 | 1.0 | 3.2 | -11.3 |
| **2040** | 8.5 | 49,273 | | 8.9 | 49,274 | 0.4 | 1.2 | 3.2 | -11.3 |
| **2041** | 8.5 | 49,243 | | 9.1 | 49,244 | 0.6 | 1.2 | 2.0 | -12.5 |
| **2042** | 8.5 | 49,213 | | 9.3 | 49,214 | 0.8 | 1.2 | 1.5 | -13.1 |
| **2043** | 8.5 | 49,183 | | 9.6 | 49,184 | 1.0 | 1.2 | 1.1 | -13.4 |
| **2044** | 8.5 | 49,153 | | 9.8 | 49,154 | 1.2 | 1.2 | 0.9 | -13.6 |
| **2045** | 8.5 | 49,123 | | 10.0 | 49,124 | 1.5 | 1.2 | 0.8 | -13.7 |
| **2046** | 8.5 | 48,982 | | 10.3 | 48,984 | 1.7 | 2.3 | 1.3 | -13.2 |
| **2047** | 8.5 | 48,841 | | 10.5 | 48,845 | 2.0 | 3.4 | 1.7 | -12.8 |
| **2048** | 8.5 | 48,701 | | 10.8 | 48,705 | 2.3 | 4.6 | 2.0 | -12.5 |
| **2049** | 8.5 | 48,560 | | 11.1 | 48,566 | 2.5 | 5.7 | 2.3 | -12.3 |
| **2050** | 8.5 | 48,419 | | 11.3 | 48,426 | 2.8 | 6.9 | 2.5 | -12.1 |
| **Cum.** | **221** | **1,549,708** | | **238** | **1,549,740** | **18** | **32** | **1.8** | **-12.7** |

*Table C-4.47. Annual and Cumulative Emissions, U.S. LNG Exports, and Consequential Analysis of Commitments (High CCS) Scenarios (AR6-100 Basis)*

| Year | C (High CCS): ExFID | | C (High CCS): MR | | C (High CCS): MR vs ExFID | | | | C (High CCS): Hi Exp | | C (High CCS): Hi Exp vs ExFID | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | US LNG EJ | GHG Tg $CO_2e$ | US LNG EJ | GHG Tg $CO_2e$ | D LNG EJ | D GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ | US LNG EJ | GHG Tg $CO_2e$ | D LNG EJ | D GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ |
| **2020** | 2.4 | 53,903 | 2.4 | 53,903 | 0.0 | 0.0 | | | 2.4 | 53,903 | 0.0 | 0.0 | | |
| **2021** | 3.2 | 53,160 | 3.2 | 53,160 | 0.0 | 0.0 | | | 3.2 | 53,160 | 0.0 | 0.0 | | |
| **2022** | 4.0 | 52,417 | 4.0 | 52,417 | 0.0 | 0.0 | | | 4.0 | 52,417 | 0.0 | 0.0 | | |
| **2023** | 4.8 | 51,674 | 4.8 | 51,674 | 0.0 | 0.0 | | | 4.8 | 51,674 | 0.0 | 0.0 | | |
| **2024** | 5.6 | 50,931 | 5.6 | 50,931 | 0.0 | 0.0 | | | 5.6 | 50,931 | 0.0 | 0.0 | | |
| **2025** | 6.3 | 50,188 | 6.3 | 50,188 | 0.0 | 0.0 | | | 6.3 | 50,188 | 0.0 | 0.0 | | |
| **2026** | 6.4 | 50,016 | 6.4 | 50,016 | 0.0 | 0.0 | | | 6.4 | 50,016 | 0.0 | 0.0 | | |
| **2027** | 6.5 | 49,845 | 6.5 | 49,845 | 0.0 | 0.0 | | | 6.5 | 49,845 | 0.0 | 0.0 | | |
| **2028** | 6.5 | 49,674 | 6.5 | 49,674 | 0.0 | 0.0 | | | 6.5 | 49,674 | 0.0 | 0.0 | | |
| **2029** | 6.6 | 49,502 | 6.6 | 49,502 | 0.0 | 0.0 | | | 6.6 | 49,502 | 0.0 | 0.0 | | |
| **2030** | 6.7 | 49,331 | 6.7 | 49,331 | 0.0 | 0.0 | | | 6.7 | 49,331 | 0.0 | 0.0 | | |
| **2031** | 6.9 | 47,989 | 6.9 | 47,989 | 0.0 | 0.0 | | | 7.3 | 47,991 | 0.4 | 1.6 | 4.4 | -10.2 |
| **2032** | 7.1 | 46,648 | 7.1 | 46,648 | 0.0 | 0.0 | | | 7.8 | 46,651 | 0.7 | 3.1 | 4.4 | -10.2 |
| **2033** | 7.3 | 45,306 | 7.3 | 45,306 | 0.0 | 0.0 | | | 8.4 | 45,311 | 1.1 | 4.7 | 4.4 | -10.2 |
| **2034** | 7.5 | 43,965 | 7.5 | 43,965 | 0.0 | 0.0 | | | 9.0 | 43,971 | 1.4 | 6.3 | 4.4 | -10.2 |
| **2035** | 7.8 | 42,623 | 7.8 | 42,623 | 0.0 | 0.0 | | | 9.6 | 42,631 | 1.8 | 7.8 | 4.4 | -10.2 |
| **2036** | 7.9 | 41,510 | 8.2 | 41,507 | 0.3 | -2.8 | -10.5 | -25.0 | 10.3 | 41,524 | 2.4 | 14.1 | 5.8 | -8.7 |
| **2037** | 8.1 | 40,396 | 8.6 | 40,390 | 0.5 | -5.7 | -10.5 | -25.0 | 11.1 | 40,416 | 3.1 | 20.3 | 6.6 | -7.9 |
| **2038** | 8.2 | 39,282 | 9.0 | 39,273 | 0.8 | -8.5 | -10.5 | -25.0 | 11.9 | 39,308 | 3.7 | 26.5 | 7.2 | -7.4 |
| **2039** | 8.4 | 38,168 | 9.5 | 38,157 | 1.1 | -11.4 | -10.5 | -25.0 | 12.7 | 38,201 | 4.3 | 32.7 | 7.6 | -7.0 |
| **2040** | 8.5 | 37,054 | 9.9 | 37,040 | 1.4 | -14.2 | -10.5 | -25.0 | 13.5 | 37,093 | 5.0 | 38.9 | 7.8 | -6.7 |
| **2041** | 8.5 | 35,492 | 10.2 | 35,487 | 1.7 | -5.1 | -3.1 | -17.6 | 14.2 | 35,543 | 5.6 | 51.0 | 9.1 | -5.4 |
| **2042** | 8.5 | 33,930 | 10.5 | 33,934 | 2.0 | 4.0 | 2.0 | -12.5 | 14.8 | 33,993 | 6.3 | 63.2 | 10.0 | -4.5 |
| **2043** | 8.5 | 32,368 | 10.8 | 32,381 | 2.3 | 13.0 | 5.7 | -8.8 | 15.5 | 32,443 | 7.0 | 75.3 | 10.8 | -3.7 |
| **2044** | 8.5 | 30,805 | 11.1 | 30,828 | 2.6 | 22.1 | 8.5 | -6.0 | 16.2 | 30,893 | 7.6 | 87.4 | 11.5 | -3.1 |
| **2045** | 8.5 | 29,243 | 11.4 | 29,274 | 2.9 | 31.2 | 10.8 | -3.7 | 16.8 | 29,343 | 8.3 | 99.5 | 12.0 | -2.5 |
| **2046** | 8.5 | 27,683 | 11.5 | 27,708 | 3.0 | 25.7 | 8.6 | -5.9 | 17.3 | 27,766 | 8.8 | 83.3 | 9.5 | -5.0 |
| **2047** | 8.5 | 26,122 | 11.6 | 26,142 | 3.1 | 20.3 | 6.5 | -8.0 | 17.8 | 26,189 | 9.2 | 67.1 | 7.3 | -7.2 |
| **2048** | 8.5 | 24,561 | 11.7 | 24,576 | 3.2 | 14.8 | 4.6 | -9.9 | 18.2 | 24,612 | 9.7 | 50.9 | 5.3 | -9.3 |
| **2049** | 8.5 | 23,001 | 11.8 | 23,010 | 3.3 | 9.3 | 2.8 | -11.7 | 18.7 | 23,036 | 10.1 | 34.6 | 3.4 | -11.1 |
| **2050** | 8.5 | 21,440 | 11.9 | 21,444 | 3.4 | 3.8 | 1.1 | -13.4 | 19.1 | 21,459 | 10.6 | 18.4 | 1.7 | -12.8 |
| **Cum.** | **222** | **1,268,227** | **254** | **1,268,324** | **31** | **97** | **3.1** | **-11.4** | **329** | **1,269,014** | **107** | **787** | **7.3** | **-7.2** |

*Table C-4.48. Annual and Cumulative Emissions, U.S. LNG Exports, and Consequential Analysis of Commitments (Moderate CCS) Scenarios (AR6-100 Basis)*

| Year | C (Mod CCS): ExFID | | C (Mod CCS): MR | | C (Mod CCS): MR vs ExFID | | | | C (Mod CCS): Hi Exp | | C (Mod CCS): Hi Exp vs ExFID | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | US LNG EJ | GHG Tg $CO_2e$ | US LNG EJ | GHG Tg $CO_2e$ | Δ LNG EJ | Δ GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ | US LNG EJ | GHG Tg $CO_2e$ | Δ LNG EJ | Δ GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ |
| **2020** | 2.4 | 53,903 | 2.4 | 53,903 | 0.0 | 0.0 | | | 2.4 | 53,903 | 0.0 | 0.0 | | |
| **2021** | 3.2 | 53,061 | 3.2 | 53,061 | 0.0 | 0.0 | | | 3.2 | 53,061 | 0.0 | 0.0 | | |
| **2022** | 4.0 | 52,220 | 4.0 | 52,220 | 0.0 | 0.0 | | | 4.0 | 52,220 | 0.0 | 0.0 | | |
| **2023** | 4.8 | 51,378 | 4.8 | 51,378 | 0.0 | 0.0 | | | 4.8 | 51,378 | 0.0 | 0.0 | | |
| **2024** | 5.6 | 50,536 | 5.6 | 50,536 | 0.0 | 0.0 | | | 5.6 | 50,536 | 0.0 | 0.0 | | |
| **2025** | 6.3 | 49,694 | 6.3 | 49,694 | 0.0 | 0.0 | | | 6.3 | 49,694 | 0.0 | 0.0 | | |
| **2026** | 6.4 | 49,527 | 6.4 | 49,527 | 0.0 | 0.0 | | | 6.4 | 49,527 | 0.0 | 0.0 | | |
| **2027** | 6.4 | 49,359 | 6.4 | 49,359 | 0.0 | 0.0 | | | 6.4 | 49,359 | 0.0 | 0.0 | | |
| **2028** | 6.5 | 49,191 | 6.5 | 49,191 | 0.0 | 0.0 | | | 6.5 | 49,191 | 0.0 | 0.0 | | |
| **2029** | 6.6 | 49,024 | 6.6 | 49,024 | 0.0 | 0.0 | | | 6.6 | 49,024 | 0.0 | 0.0 | | |
| **2030** | 6.6 | 48,856 | 6.6 | 48,856 | 0.0 | 0.0 | | | 6.6 | 48,856 | 0.0 | 0.0 | | |
| **2031** | 6.8 | 47,265 | 6.8 | 47,265 | 0.0 | 0.0 | | | 7.1 | 47,278 | 0.4 | 12.9 | 35.8 | 21.3 |
| **2032** | 6.9 | 45,674 | 6.9 | 45,674 | 0.0 | 0.0 | | | 7.6 | 45,700 | 0.7 | 25.8 | 35.8 | 21.2 |
| **2033** | 7.1 | 44,084 | 7.1 | 44,084 | 0.0 | 0.0 | | | 8.2 | 44,122 | 1.1 | 38.7 | 35.8 | 21.2 |
| **2034** | 7.2 | 42,493 | 7.2 | 42,493 | 0.0 | 0.0 | | | 8.7 | 42,545 | 1.4 | 51.5 | 35.8 | 21.2 |
| **2035** | 7.4 | 40,902 | 7.4 | 40,902 | 0.0 | 0.0 | | | 9.2 | 40,967 | 1.8 | 64.4 | 35.8 | 21.2 |
| **2036** | 7.6 | 39,170 | 7.7 | 39,171 | 0.1 | 1.6 | 16.1 | 1.6 | 9.9 | 39,230 | 2.3 | 60.3 | 26.7 | 12.2 |
| **2037** | 7.8 | 37,437 | 8.0 | 37,440 | 0.2 | 3.1 | 16.1 | 1.6 | 10.5 | 37,493 | 2.7 | 56.2 | 20.7 | 6.2 |
| **2038** | 8.1 | 35,704 | 8.4 | 35,709 | 0.3 | 4.7 | 16.1 | 1.6 | 11.2 | 35,756 | 3.2 | 52.0 | 16.4 | 1.9 |
| **2039** | 8.3 | 33,971 | 8.7 | 33,978 | 0.4 | 6.3 | 16.1 | 1.6 | 11.9 | 34,019 | 3.6 | 47.9 | 13.2 | -1.3 |
| **2040** | 8.5 | 32,239 | 9.0 | 32,246 | 0.5 | 7.8 | 16.2 | 1.6 | 12.6 | 32,282 | 4.1 | 43.7 | 10.7 | -3.8 |
| **2041** | 8.5 | 30,953 | 9.1 | 30,960 | 0.6 | 7.4 | 12.1 | -2.4 | 13.1 | 30,999 | 4.6 | 46.0 | 10.1 | -4.5 |
| **2042** | 8.5 | 29,668 | 9.3 | 29,675 | 0.7 | 7.0 | 9.5 | -5.0 | 13.6 | 29,716 | 5.1 | 48.2 | 9.5 | -5.0 |
| **2043** | 8.5 | 28,382 | 9.4 | 28,389 | 0.9 | 6.5 | 7.6 | -6.9 | 14.1 | 28,433 | 5.5 | 50.5 | 9.1 | -5.4 |
| **2044** | 8.5 | 27,097 | 9.5 | 27,103 | 1.0 | 6.1 | 6.2 | -8.3 | 14.6 | 27,149 | 6.0 | 52.7 | 8.7 | -5.8 |
| **2045** | 8.5 | 25,811 | 9.6 | 25,817 | 1.1 | 5.6 | 5.1 | -9.4 | 15.0 | 25,866 | 6.5 | 54.9 | 8.4 | -6.1 |
| **2046** | 8.5 | 24,429 | 9.6 | 24,433 | 1.1 | 4.5 | 4.0 | -10.5 | 15.4 | 24,489 | 6.9 | 59.9 | 8.7 | -5.8 |
| **2047** | 8.5 | 23,047 | 9.7 | 23,050 | 1.1 | 3.3 | 2.9 | -11.6 | 15.8 | 23,111 | 7.2 | 64.9 | 9.0 | -5.6 |
| **2048** | 8.5 | 21,664 | 9.7 | 21,666 | 1.1 | 2.1 | 1.9 | -12.6 | 16.1 | 21,734 | 7.6 | 69.8 | 9.2 | -5.3 |
| **2049** | 8.5 | 20,282 | 9.7 | 20,283 | 1.1 | 0.9 | 0.8 | -13.7 | 16.5 | 20,357 | 8.0 | 74.8 | 9.4 | -5.1 |
| **2050** | 8.5 | 18,900 | 9.7 | 18,899 | 1.1 | -0.2 | -0.2 | -14.7 | 16.9 | 18,979 | 8.3 | 79.7 | 9.6 | -5.0 |
| **Cum.** | **220** | **1,205,919** | **231** | **1,205,985** | **11** | **67** | **5.9** | **-8.6** | **307** | **1,206,973** | **87** | **1,055** | **12.1** | **-2.4** |

*Table C-4.49. Annual and Cumulative Emissions, U.S. LNG Exports, and Consequential Analysis of Net Zero 2050 (High CCS) Scenarios (AR6-100 Basis)*

| Year | NZ (Hi CCS): ExFID | | NZ (High CCS): MR | | NZ (High CCS): MR vs ExFID | | | | NZ (High CCS): Hi Exp | | NZ (High CCS): Hi Exp vs ExFID | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | US LNG EJ | GHG Tg $CO_2e$ | US LNG EJ | GHG Tg $CO_2e$ | Δ LNG EJ | Δ GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ | US LNG EJ | GHG Tg $CO_2e$ | Δ LNG EJ | Δ GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ |
| **2020** | 2.4 | 53,903 | 2.4 | 53,903 | 0.0 | 0.0 | | | 2.4 | 53,903 | 0.0 | 0.0 | | |
| **2021** | 3.2 | 53,160 | 3.2 | 53,160 | 0.0 | 0.0 | | | 3.2 | 53,160 | 0.0 | 0.0 | | |
| **2022** | 4.0 | 52,417 | 4.0 | 52,417 | 0.0 | 0.0 | | | 4.0 | 52,417 | 0.0 | 0.0 | | |
| **2023** | 4.8 | 51,674 | 4.8 | 51,674 | 0.0 | 0.0 | | | 4.8 | 51,674 | 0.0 | 0.0 | | |
| **2024** | 5.6 | 50,931 | 5.6 | 50,931 | 0.0 | 0.0 | | | 5.6 | 50,931 | 0.0 | 0.0 | | |
| **2025** | 6.3 | 50,188 | 6.3 | 50,188 | 0.0 | 0.0 | | | 6.3 | 50,188 | 0.0 | 0.0 | | |
| **2026** | 6.4 | 48,171 | 6.4 | 48,171 | 0.0 | 0.0 | | | 6.4 | 48,171 | 0.0 | 0.0 | | |
| **2027** | 6.4 | 46,155 | 6.4 | 46,155 | 0.0 | 0.0 | | | 6.4 | 46,155 | 0.0 | 0.0 | | |
| **2028** | 6.4 | 44,138 | 6.4 | 44,138 | 0.0 | 0.0 | | | 6.4 | 44,138 | 0.0 | 0.0 | | |
| **2029** | 6.5 | 42,121 | 6.5 | 42,121 | 0.0 | 0.0 | | | 6.5 | 42,121 | 0.0 | 0.0 | | |
| **2030** | 6.5 | 40,105 | 6.5 | 40,105 | 0.0 | 0.0 | | | 6.5 | 40,105 | 0.0 | 0.0 | | |
| **2031** | 6.7 | 39,193 | 6.7 | 39,193 | 0.0 | -0.1 | | | 7.0 | 39,187 | 0.4 | -5.9 | -16.4 | -30.9 |
| **2032** | 6.8 | 38,281 | 6.8 | 38,281 | 0.0 | -0.2 | | | 7.6 | 38,270 | 0.7 | -11.8 | -16.4 | -30.9 |
| **2033** | 7.0 | 37,370 | 7.0 | 37,369 | 0.0 | -0.3 | | | 8.1 | 37,352 | 1.1 | -17.7 | -16.4 | -30.9 |
| **2034** | 7.2 | 36,458 | 7.2 | 36,457 | 0.0 | -0.4 | | | 8.6 | 36,434 | 1.4 | -23.6 | -16.4 | -30.9 |
| **2035** | 7.4 | 35,546 | 7.4 | 35,546 | 0.0 | -0.5 | | | 9.2 | 35,517 | 1.8 | -29.5 | -16.4 | -30.9 |
| **2036** | 7.6 | 33,933 | 7.7 | 33,931 | 0.2 | -2.8 | -18.6 | -33.1 | 9.9 | 33,916 | 2.3 | -17.7 | -7.7 | -22.2 |
| **2037** | 7.8 | 32,321 | 8.1 | 32,316 | 0.3 | -5.2 | -17.1 | -31.6 | 10.7 | 32,315 | 2.8 | -5.9 | -2.1 | -16.6 |
| **2038** | 8.1 | 30,708 | 8.5 | 30,701 | 0.5 | -7.6 | -16.6 | -31.1 | 11.4 | 30,714 | 3.3 | 5.8 | 1.8 | -12.8 |
| **2039** | 8.3 | 29,095 | 8.9 | 29,086 | 0.6 | -9.9 | -16.3 | -30.8 | 12.2 | 29,113 | 3.8 | 17.6 | 4.6 | -9.9 |
| **2040** | 8.5 | 27,483 | 9.3 | 27,471 | 0.8 | -12.3 | -16.2 | -30.7 | 12.9 | 27,512 | 4.4 | 29.4 | 6.7 | -7.8 |
| **2041** | 8.5 | 26,115 | 9.5 | 26,108 | 0.9 | -6.2 | -6.7 | -21.2 | 13.4 | 26,154 | 4.9 | 39.6 | 8.1 | -6.4 |
| **2042** | 8.5 | 24,746 | 9.6 | 24,746 | 1.1 | -0.1 | -0.1 | -14.6 | 14.0 | 24,796 | 5.4 | 49.9 | 9.2 | -5.3 |
| **2043** | 8.5 | 23,378 | 9.8 | 23,384 | 1.3 | 5.9 | 4.6 | -9.9 | 14.5 | 23,438 | 6.0 | 60.2 | 10.1 | -4.4 |
| **2044** | 8.5 | 22,010 | 10.0 | 22,022 | 1.5 | 12.0 | 8.3 | -6.2 | 15.0 | 22,080 | 6.5 | 70.4 | 10.8 | -3.7 |
| **2045** | 8.5 | 20,642 | 10.2 | 20,660 | 1.6 | 18.1 | 11.1 | -3.4 | 15.6 | 20,722 | 7.0 | 80.7 | 11.5 | -3.0 |
| **2046** | 8.5 | 19,147 | 10.2 | 19,161 | 1.6 | 14.1 | 8.5 | -6.0 | 16.0 | 19,207 | 7.4 | 59.3 | 8.0 | -6.5 |
| **2047** | 8.5 | 17,653 | 10.2 | 17,663 | 1.7 | 10.1 | 6.0 | -8.5 | 16.3 | 17,691 | 7.8 | 37.8 | 4.9 | -9.7 |
| **2048** | 8.5 | 16,158 | 10.2 | 16,164 | 1.7 | 6.0 | 3.6 | -11.0 | 16.7 | 16,175 | 8.2 | 16.4 | 2.0 | -12.5 |
| **2049** | 8.5 | 14,664 | 10.3 | 14,666 | 1.7 | 2.0 | 1.2 | -13.3 | 17.1 | 14,659 | 8.6 | -5.0 | -0.6 | -15.1 |
| **2050** | 8.5 | 13,169 | 10.3 | 13,167 | 1.7 | -2.0 | -1.1 | -15.7 | 17.5 | 13,143 | 8.9 | -26.4 | -3.0 | -17.5 |
| **Cum.** | **219** | **1,071,033** | **236** | **1,071,054** | **17** | **21** | **1.2** | **-13.3** | **312** | **1,071,356** | **93** | **324** | **3.5** | **-11.0** |

*Table C-4.50. Annual and Cumulative Emissions, U.S. LNG Exports, and Consequential Analysis of Net Zero 2050 (Moderate CCS) Scenarios (AR6-100 Basis)*

| Year | NZ (Mod CCS):ExFID | | NZ (Mod CCS): MR | | NZ (Mod CCS): MR vs ExFID | | | | NZ (Mod CCS): Hi Exp | | NZ (Mod CCS): Hi Exp vs ExFID | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | US LNG EJ | GHG Tg $CO_2e$ | US LNG EJ | GHG Tg $CO_2e$ | Δ LNG EJ | Δ GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ | US LNG EJ | GHG Tg $CO_2e$ | Δ LNG EJ | Δ GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ |
| **2020** | 2.4 | 53,903 | 2.4 | 53,903 | 0.0 | 0.0 | | | 2.4 | 53,903 | 0.0 | 0.0 | | |
| **2021** | 3.2 | 53,061 | 3.2 | 53,061 | 0.0 | 0.0 | | | 3.2 | 53,061 | 0.0 | 0.0 | | |
| **2022** | 4.0 | 52,220 | 4.0 | 52,220 | 0.0 | 0.0 | | | 4.0 | 52,220 | 0.0 | 0.0 | | |
| **2023** | 4.8 | 51,378 | 4.8 | 51,378 | 0.0 | 0.0 | | | 4.8 | 51,378 | 0.0 | 0.0 | | |
| **2024** | 5.6 | 50,536 | 5.6 | 50,536 | 0.0 | 0.0 | | | 5.6 | 50,536 | 0.0 | 0.0 | | |
| **2025** | 6.3 | 49,694 | 6.3 | 49,694 | 0.0 | 0.0 | | | 6.3 | 49,694 | 0.0 | 0.0 | | |
| **2026** | 6.3 | 47,497 | 6.3 | 47,497 | 0.0 | 0.0 | | | 6.3 | 47,497 | 0.0 | 0.0 | | |
| **2027** | 6.4 | 45,300 | 6.4 | 45,300 | 0.0 | 0.0 | | | 6.4 | 45,300 | 0.0 | 0.0 | | |
| **2028** | 6.4 | 43,103 | 6.4 | 43,103 | 0.0 | 0.0 | | | 6.4 | 43,103 | 0.0 | 0.0 | | |
| **2029** | 6.4 | 40,906 | 6.4 | 40,906 | 0.0 | 0.0 | | | 6.4 | 40,906 | 0.0 | 0.0 | | |
| **2030** | 6.4 | 38,710 | 6.4 | 38,710 | 0.0 | 0.0 | | | 6.4 | 38,710 | 0.0 | 0.0 | | |
| **2031** | 6.5 | 36,973 | 6.5 | 36,973 | 0.0 | 0.0 | | | 6.9 | 36,978 | 0.4 | 4.7 | 12.9 | -1.6 |
| **2032** | 6.6 | 35,236 | 6.6 | 35,236 | 0.0 | 0.0 | | | 7.3 | 35,245 | 0.7 | 9.3 | 12.9 | -1.6 |
| **2033** | 6.7 | 33,499 | 6.7 | 33,499 | 0.0 | 0.0 | | | 7.7 | 33,513 | 1.1 | 14.0 | 12.9 | -1.6 |
| **2034** | 6.7 | 31,763 | 6.7 | 31,763 | 0.0 | 0.0 | | | 8.2 | 31,781 | 1.4 | 18.6 | 12.9 | -1.6 |
| **2035** | 6.8 | 30,026 | 6.8 | 30,026 | 0.0 | 0.0 | | | 8.6 | 30,049 | 1.8 | 23.3 | 12.9 | -1.6 |
| **2036** | 6.9 | 28,853 | 6.9 | 28,853 | 0.0 | 0.0 | | | 9.1 | 28,887 | 2.2 | 34.1 | 15.8 | 1.3 |
| **2037** | 7.0 | 27,679 | 7.0 | 27,679 | 0.0 | 0.0 | | | 9.6 | 27,724 | 2.5 | 44.9 | 17.8 | 3.3 |
| **2038** | 7.2 | 26,505 | 7.2 | 26,505 | 0.0 | 0.0 | | | 10.0 | 26,561 | 2.9 | 55.7 | 19.3 | 4.8 |
| **2039** | 7.3 | 25,332 | 7.3 | 25,332 | 0.0 | 0.0 | | | 10.5 | 25,399 | 3.2 | 66.5 | 20.5 | 6.0 |
| **2040** | 7.4 | 24,158 | 7.4 | 24,158 | 0.0 | 0.0 | | | 11.0 | 24,236 | 3.6 | 77.4 | 21.5 | 7.0 |
| **2041** | 7.3 | 22,563 | 7.3 | 22,563 | 0.0 | 0.0 | | | 11.3 | 22,639 | 4.0 | 76.1 | 19.2 | 4.7 |
| **2042** | 7.2 | 20,968 | 7.2 | 20,968 | 0.0 | 0.0 | | | 11.5 | 21,043 | 4.3 | 74.9 | 17.3 | 2.8 |
| **2043** | 7.1 | 19,372 | 7.1 | 19,372 | 0.0 | 0.0 | | | 11.8 | 19,446 | 4.7 | 73.7 | 15.7 | 1.2 |
| **2044** | 7.1 | 17,777 | 7.1 | 17,777 | 0.0 | 0.0 | | | 12.1 | 17,849 | 5.0 | 72.5 | 14.4 | -0.1 |
| **2045** | 7.0 | 16,181 | 7.0 | 16,181 | 0.0 | 0.0 | | | 12.4 | 16,253 | 5.4 | 71.3 | 13.2 | -1.3 |
| **2046** | 6.8 | 15,196 | 6.8 | 15,196 | 0.0 | 0.0 | | | 12.6 | 15,260 | 5.8 | 63.4 | 11.0 | -3.5 |
| **2047** | 6.7 | 14,212 | 6.7 | 14,212 | 0.0 | 0.0 | | | 12.8 | 14,267 | 6.1 | 55.5 | 9.1 | -5.5 |
| **2048** | 6.5 | 13,227 | 6.5 | 13,227 | 0.0 | 0.0 | | | 13.0 | 13,274 | 6.5 | 47.5 | 7.3 | -7.2 |
| **2049** | 6.3 | 12,242 | 6.3 | 12,242 | 0.0 | 0.0 | | | 13.2 | 12,282 | 6.8 | 39.6 | 5.8 | -8.7 |
| **2050** | 6.2 | 11,257 | 6.2 | 11,257 | 0.0 | 0.0 | | | 13.4 | 11,289 | 7.2 | 31.7 | 4.4 | -10.1 |
| **Cum.** | **195** | **989,329** | **195** | **989,329** | **0** | **0** | **N/A** | **N/A** | **271** | **990,283** | **76** | **955** | **12.6** | **-1.9** |

*Table C-4.51. Annual and Cumulative Emissions, U.S. LNG Exports, and Consequential Analysis of Defined Policies Scenarios (AR6-20 Basis)*

| Year | DP: ExFID | | DP: MR | | DP: MR vs ExFID | | | | DP: Hi Exp | | DP: Hi Exp vs ExFID | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | US LNG EJ | GHG Tg $CO_2$e | US LNG EJ | GHG Tg $CO_2$e | Δ LNG EJ | Δ GHG Tg $CO_2$e | Cons GHG g $CO_2$e/MJ | PNDE g $CO_2$e/MJ | US LNG EJ | GHG Tg $CO_2$e | Δ LNG EJ | Δ GHG Tg $CO_2$e | Cons GHG g $CO_2$e/MJ | PNDE g $CO_2$e/MJ |
| **2020** | 2.4 | 73,863 | 2.4 | 73,863 | 0.0 | 0.0 | | | 2.4 | 73,863 | 0.0 | 0.0 | | |
| **2021** | 3.2 | 72,973 | 3.2 | 72,973 | 0.0 | 0.0 | | | 3.2 | 72,973 | 0.0 | 0.0 | | |
| **2022** | 4.0 | 72,083 | 4.0 | 72,083 | 0.0 | 0.0 | | | 4.0 | 72,083 | 0.0 | 0.0 | | |
| **2023** | 4.8 | 71,193 | 4.8 | 71,193 | 0.0 | 0.0 | | | 4.8 | 71,193 | 0.0 | 0.0 | | |
| **2024** | 5.6 | 70,303 | 5.6 | 70,303 | 0.0 | 0.0 | | | 5.6 | 70,303 | 0.0 | 0.0 | | |
| **2025** | 6.3 | 69,413 | 6.3 | 69,413 | 0.0 | 0.0 | | | 6.3 | 69,413 | 0.0 | 0.0 | | |
| **2026** | 6.5 | 69,271 | 6.5 | 69,271 | 0.0 | 0.0 | | | 6.5 | 69,271 | 0.0 | 0.0 | | |
| **2027** | 6.6 | 69,129 | 6.6 | 69,129 | 0.0 | 0.0 | | | 6.6 | 69,129 | 0.0 | 0.0 | | |
| **2028** | 6.7 | 68,987 | 6.7 | 68,987 | 0.0 | 0.0 | | | 6.7 | 68,987 | 0.0 | 0.0 | | |
| **2029** | 6.8 | 68,845 | 6.8 | 68,845 | 0.0 | 0.0 | | | 6.8 | 68,845 | 0.0 | 0.0 | | |
| **2030** | 7.0 | 68,703 | 7.0 | 68,703 | 0.0 | 0.0 | | | 7.0 | 68,703 | 0.0 | 0.0 | | |
| **2031** | 7.3 | 69,025 | 7.5 | 69,027 | 0.2 | 1.6 | 8.6 | -12.7 | 7.8 | 69,029 | 0.6 | 3.9 | 7.2 | -14.1 |
| **2032** | 7.6 | 69,348 | 8.0 | 69,351 | 0.4 | 3.3 | 8.6 | -12.7 | 8.7 | 69,356 | 1.1 | 7.9 | 7.2 | -14.1 |
| **2033** | 7.9 | 69,670 | 8.5 | 69,675 | 0.6 | 4.9 | 8.6 | -12.7 | 9.6 | 69,682 | 1.7 | 11.8 | 7.2 | -14.1 |
| **2034** | 8.2 | 69,992 | 9.0 | 69,999 | 0.8 | 6.5 | 8.6 | -12.7 | 10.4 | 70,008 | 2.2 | 15.8 | 7.2 | -14.1 |
| **2035** | 8.5 | 70,314 | 9.5 | 70,323 | 1.0 | 8.2 | 8.6 | -12.7 | 11.3 | 70,334 | 2.8 | 19.7 | 7.2 | -14.1 |
| **2036** | 8.5 | 70,185 | 10.4 | 70,204 | 1.8 | 18.9 | 10.3 | -11.0 | 12.5 | 70,228 | 4.0 | 43.2 | 10.8 | -10.5 |
| **2037** | 8.5 | 70,056 | 11.3 | 70,086 | 2.7 | 29.7 | 10.9 | -10.4 | 13.8 | 70,123 | 5.3 | 66.6 | 12.7 | -8.6 |
| **2038** | 8.5 | 69,927 | 12.2 | 69,967 | 3.6 | 40.4 | 11.2 | -10.1 | 15.0 | 70,017 | 6.5 | 90.1 | 13.9 | -7.4 |
| **2039** | 8.5 | 69,798 | 13.0 | 69,849 | 4.5 | 51.2 | 11.4 | -9.9 | 16.3 | 69,911 | 7.7 | 113.5 | 14.7 | -6.6 |
| **2040** | 8.5 | 69,669 | 13.9 | 69,731 | 5.4 | 61.9 | 11.5 | -9.8 | 17.5 | 69,806 | 9.0 | 137.0 | 15.2 | -6.0 |
| **2041** | 8.5 | 69,744 | 14.7 | 69,806 | 6.2 | 61.3 | 9.9 | -11.3 | 18.7 | 69,877 | 10.1 | 132.6 | 13.1 | -8.2 |
| **2042** | 8.5 | 69,820 | 15.5 | 69,881 | 6.9 | 60.7 | 8.8 | -12.5 | 19.8 | 69,948 | 11.3 | 128.2 | 11.4 | -9.9 |
| **2043** | 8.5 | 69,896 | 16.3 | 69,956 | 7.7 | 60.1 | 7.8 | -13.5 | 20.9 | 70,020 | 12.4 | 123.8 | 10.0 | -11.3 |
| **2044** | 8.5 | 69,971 | 17.0 | 70,031 | 8.5 | 59.5 | 7.0 | -14.3 | 22.1 | 70,091 | 13.5 | 119.4 | 8.8 | -12.4 |
| **2045** | 8.5 | 70,047 | 17.8 | 70,106 | 9.3 | 58.9 | 6.4 | -14.9 | 23.2 | 70,162 | 14.7 | 114.9 | 7.8 | -13.4 |
| **2046** | 8.5 | 70,016 | 18.3 | 70,068 | 9.8 | 52.0 | 5.3 | -15.9 | 24.1 | 70,120 | 15.5 | 103.6 | 6.7 | -14.6 |
| **2047** | 8.5 | 69,985 | 18.8 | 70,030 | 10.2 | 45.0 | 4.4 | -16.9 | 24.9 | 70,077 | 16.4 | 92.3 | 5.6 | -15.6 |
| **2048** | 8.5 | 69,954 | 19.3 | 69,992 | 10.7 | 38.1 | 3.5 | -17.7 | 25.8 | 70,035 | 17.2 | 81.0 | 4.7 | -16.6 |
| **2049** | 8.5 | 69,923 | 19.8 | 69,954 | 11.2 | 31.1 | 2.8 | -18.5 | 26.6 | 69,993 | 18.1 | 69.6 | 3.9 | -17.4 |
| **2050** | 8.5 | 69,892 | 20.3 | 69,916 | 11.7 | 24.2 | 2.1 | -19.2 | 27.5 | 69,950 | 18.9 | 58.3 | 3.1 | -18.2 |
| **Cum.** | **227** | **2,171,997** | **341** | **2,172,715** | **113** | **718** | **6.3** | **-14.9** | **416** | **2,173,530** | **189** | **1,533** | **8.1** | **-13.1** |

Table C-4.52. Annual and Cumulative Emissions, U.S. LNG Exports, and Consequential Analysis of DP High Middle East Supply Scenarios (AR6-20 Basis)

| Year | *DP Hi ME Sup: ExFID* | | | *DP Hi ME Sup: MR* | | *DP Hi ME Sup: MR vs ExFID* | | | |
|---|---|---|---|---|---|---|---|---|---|
| | US LNG EJ | GHG Tg $CO_2e$ | | US LNG EJ | GHG Tg $CO_2e$ | D LNG EJ | D GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ |
| **2020** | 2.4 | 73,874 | | 2.4 | 73,874 | 0.0 | 0.0 | | |
| **2021** | 3.2 | 72,985 | | 3.2 | 72,985 | 0.0 | 0.0 | | |
| **2022** | 4.0 | 72,097 | | 4.0 | 72,097 | 0.0 | 0.0 | | |
| **2023** | 4.8 | 71,208 | | 4.8 | 71,208 | 0.0 | 0.0 | | |
| **2024** | 5.6 | 70,319 | | 5.6 | 70,319 | 0.0 | 0.0 | | |
| **2025** | 6.3 | 69,431 | | 6.3 | 69,431 | 0.0 | 0.0 | | |
| **2026** | 6.5 | 69,292 | | 6.5 | 69,292 | 0.0 | 0.0 | | |
| **2027** | 6.6 | 69,154 | | 6.6 | 69,154 | 0.0 | 0.0 | | |
| **2028** | 6.8 | 69,016 | | 6.8 | 69,016 | 0.0 | 0.0 | | |
| **2029** | 6.9 | 68,877 | | 6.9 | 68,877 | 0.0 | 0.0 | | |
| **2030** | 7.1 | 68,739 | | 7.1 | 68,739 | 0.0 | 0.0 | | |
| **2031** | 7.4 | 69,080 | | 7.6 | 69,081 | 0.2 | 1.0 | 4.6 | -16.7 |
| **2032** | 7.7 | 69,421 | | 8.1 | 69,423 | 0.4 | 2.1 | 4.6 | -16.7 |
| **2033** | 8.0 | 69,762 | | 8.6 | 69,766 | 0.7 | 3.1 | 4.6 | -16.7 |
| **2034** | 8.2 | 70,104 | | 9.1 | 70,108 | 0.9 | 4.2 | 4.6 | -16.7 |
| **2035** | 8.5 | 70,445 | | 9.7 | 70,450 | 1.1 | 5.2 | 4.6 | -16.7 |
| **2036** | 8.5 | 70,357 | | 10.4 | 70,367 | 1.9 | 9.8 | 5.2 | -16.1 |
| **2037** | 8.5 | 70,269 | | 11.2 | 70,283 | 2.6 | 14.4 | 5.5 | -15.8 |
| **2038** | 8.5 | 70,181 | | 11.9 | 70,200 | 3.4 | 19.0 | 5.6 | -15.7 |
| **2039** | 8.5 | 70,093 | | 12.7 | 70,116 | 4.1 | 23.6 | 5.7 | -15.6 |
| **2040** | 8.5 | 70,005 | | 13.4 | 70,033 | 4.9 | 28.2 | 5.7 | -15.5 |
| **2041** | 8.5 | 70,096 | | 14.1 | 70,123 | 5.5 | 27.2 | 4.9 | -16.3 |
| **2042** | 8.5 | 70,188 | | 14.7 | 70,214 | 6.1 | 26.2 | 4.3 | -17.0 |
| **2043** | 8.5 | 70,279 | | 15.3 | 70,304 | 6.8 | 25.2 | 3.7 | -17.5 |
| **2044** | 8.5 | 70,370 | | 15.9 | 70,395 | 7.4 | 24.2 | 3.3 | -18.0 |
| **2045** | 8.5 | 70,462 | | 16.5 | 70,485 | 8.0 | 23.2 | 2.9 | -18.4 |
| **2046** | 8.5 | 70,442 | | 17.0 | 70,458 | 8.4 | 16.5 | 2.0 | -19.3 |
| **2047** | 8.5 | 70,422 | | 17.4 | 70,432 | 8.8 | 9.8 | 1.1 | -20.2 |
| **2048** | 8.5 | 70,402 | | 17.8 | 70,405 | 9.3 | 3.1 | 0.3 | -20.9 |
| **2049** | 8.5 | 70,382 | | 18.2 | 70,379 | 9.7 | -3.6 | -0.4 | -21.6 |
| **2050** | 8.5 | 70,362 | | 18.6 | 70,352 | 10.1 | -10.3 | -1.0 | -22.3 |
| **Cum.** | **228** | **2,178,114** | | **329** | **2,178,366** | **100** | **252** | **2.5** | **-18.8** |

*Table C-4.53. Annual and Cumulative Emissions, U.S. LNG Exports, and Consequential Analysis of DP High U.S. Supply Scenarios (AR6-20 Basis)*

| Year | *DP Hi US Sup: ExFID* | | | *DP Hi US Sup: MR* | | *DP Hi US Sup: MR vs ExFID* | | | |
|---|---|---|---|---|---|---|---|---|---|
| | US LNG EJ | GHG Tg $CO_2e$ | | US LNG EJ | GHG Tg $CO_2e$ | D LNG EJ | D GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ |
| **2020** | 2.4 | 73,858 | | 2.4 | 73,858 | 0.0 | 0.0 | | |
| **2021** | 3.2 | 72,970 | | 3.2 | 72,970 | 0.0 | 0.0 | | |
| **2022** | 4.0 | 72,081 | | 4.0 | 72,081 | 0.0 | 0.0 | | |
| **2023** | 4.8 | 71,192 | | 4.8 | 71,192 | 0.0 | 0.0 | | |
| **2024** | 5.6 | 70,304 | | 5.6 | 70,304 | 0.0 | 0.0 | | |
| **2025** | 6.3 | 69,415 | | 6.3 | 69,415 | 0.0 | 0.0 | | |
| **2026** | 6.5 | 69,274 | | 6.5 | 69,274 | 0.0 | 0.0 | | |
| **2027** | 6.6 | 69,133 | | 6.6 | 69,133 | 0.0 | 0.0 | | |
| **2028** | 6.8 | 68,992 | | 6.8 | 68,992 | 0.0 | 0.0 | | |
| **2029** | 6.9 | 68,851 | | 6.9 | 68,851 | 0.0 | 0.0 | | |
| **2030** | 7.0 | 68,710 | | 7.0 | 68,710 | 0.0 | 0.0 | | |
| **2031** | 7.3 | 69,033 | | 7.6 | 69,036 | 0.3 | 2.4 | 8.1 | -13.1 |
| **2032** | 7.6 | 69,356 | | 8.2 | 69,361 | 0.6 | 4.7 | 8.1 | -13.1 |
| **2033** | 7.9 | 69,680 | | 8.8 | 69,687 | 0.9 | 7.1 | 8.1 | -13.1 |
| **2034** | 8.2 | 70,003 | | 9.4 | 70,012 | 1.2 | 9.5 | 8.1 | -13.1 |
| **2035** | 8.5 | 70,326 | | 10.0 | 70,338 | 1.5 | 11.9 | 8.1 | -13.1 |
| **2036** | 8.5 | 70,197 | | 11.1 | 70,226 | 2.6 | 28.8 | 11.2 | -10.1 |
| **2037** | 8.5 | 70,068 | | 12.2 | 70,113 | 3.7 | 45.7 | 12.4 | -8.9 |
| **2038** | 8.5 | 69,939 | | 13.3 | 70,001 | 4.8 | 62.7 | 13.0 | -8.2 |
| **2039** | 8.5 | 69,810 | | 14.5 | 69,889 | 5.9 | 79.6 | 13.4 | -7.8 |
| **2040** | 8.5 | 69,681 | | 15.6 | 69,777 | 7.0 | 96.5 | 13.7 | -7.6 |
| **2041** | 8.5 | 69,759 | | 16.7 | 69,856 | 8.2 | 97.0 | 11.9 | -9.4 |
| **2042** | 8.5 | 69,837 | | 17.8 | 69,935 | 9.3 | 97.5 | 10.5 | -10.7 |
| **2043** | 8.5 | 69,916 | | 18.9 | 70,014 | 10.4 | 98.1 | 9.4 | -11.8 |
| **2044** | 8.5 | 69,994 | | 20.0 | 70,093 | 11.5 | 98.6 | 8.6 | -12.7 |
| **2045** | 8.5 | 70,073 | | 21.1 | 70,172 | 12.6 | 99.1 | 7.9 | -13.4 |
| **2046** | 8.5 | 70,046 | | 22.0 | 70,140 | 13.4 | 94.3 | 7.0 | -14.2 |
| **2047** | 8.5 | 70,019 | | 22.8 | 70,108 | 14.2 | 89.4 | 6.3 | -15.0 |
| **2048** | 8.5 | 69,992 | | 23.6 | 70,077 | 15.1 | 84.6 | 5.6 | -15.6 |
| **2049** | 8.5 | 69,965 | | 24.4 | 70,045 | 15.9 | 79.8 | 5.0 | -16.2 |
| **2050** | 8.5 | 69,938 | | 25.2 | 70,013 | 16.7 | 75.0 | 4.5 | -16.8 |
| **Cum.** | **228** | **2,172,411** | | **383** | **2,173,673** | **156** | **1,262** | **8.1** | **-13.2** |

*Table C-4.54. Annual and Cumulative Emissions, U.S. LNG Exports, and Consequential Analysis of DP Low U.S. Supply Scenarios (AR6-20 Basis)*

| Year | *DP Lo US Sup: ExFID* | | | *DP Lo US Sup: MR* | | *DP Lo US Sup: MR vs ExFID* | | | |
|---|---|---|---|---|---|---|---|---|---|
| | US LNG EJ | GHG Tg $CO_2e$ | | US LNG EJ | GHG Tg $CO_2e$ | D LNG EJ | D GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ |
| **2020** | 2.4 | 73,889 | | 2.4 | 73,889 | 0.0 | 0.0 | | |
| **2021** | 3.2 | 72,990 | | 3.2 | 72,990 | 0.0 | 0.0 | | |
| **2022** | 4.0 | 72,092 | | 4.0 | 72,092 | 0.0 | 0.0 | | |
| **2023** | 4.8 | 71,193 | | 4.8 | 71,193 | 0.0 | 0.0 | | |
| **2024** | 5.5 | 70,295 | | 5.5 | 70,295 | 0.0 | 0.0 | | |
| **2025** | 6.3 | 69,396 | | 6.3 | 69,396 | 0.0 | 0.0 | | |
| **2026** | 6.4 | 69,246 | | 6.4 | 69,246 | 0.0 | 0.0 | | |
| **2027** | 6.4 | 69,097 | | 6.4 | 69,097 | 0.0 | 0.0 | | |
| **2028** | 6.5 | 68,947 | | 6.5 | 68,947 | 0.0 | 0.0 | | |
| **2029** | 6.5 | 68,797 | | 6.5 | 68,797 | 0.0 | 0.0 | | |
| **2030** | 6.6 | 68,648 | | 6.6 | 68,648 | 0.0 | 0.0 | | |
| **2031** | 6.8 | 68,962 | | 6.8 | 68,962 | 0.0 | 0.0 | | |
| **2032** | 7.0 | 69,276 | | 7.0 | 69,276 | 0.0 | 0.0 | | |
| **2033** | 7.2 | 69,590 | | 7.2 | 69,590 | 0.0 | 0.0 | | |
| **2034** | 7.4 | 69,904 | | 7.4 | 69,904 | 0.0 | 0.0 | | |
| **2035** | 7.6 | 70,218 | | 7.6 | 70,218 | 0.0 | 0.0 | | |
| **2036** | 7.8 | 70,083 | | 7.8 | 70,084 | 0.1 | 0.3 | 4.2 | -17.0 |
| **2037** | 8.0 | 69,949 | | 8.1 | 69,949 | 0.1 | 0.6 | 4.2 | -17.0 |
| **2038** | 8.1 | 69,814 | | 8.4 | 69,815 | 0.2 | 0.9 | 4.3 | -17.0 |
| **2039** | 8.3 | 69,680 | | 8.6 | 69,681 | 0.3 | 1.3 | 4.3 | -17.0 |
| **2040** | 8.5 | 69,546 | | 8.9 | 69,547 | 0.4 | 1.6 | 4.3 | -17.0 |
| **2041** | 8.5 | 69,615 | | 9.1 | 69,616 | 0.6 | 1.2 | 2.0 | -19.3 |
| **2042** | 8.5 | 69,683 | | 9.3 | 69,684 | 0.8 | 0.8 | 1.0 | -20.3 |
| **2043** | 8.5 | 69,752 | | 9.6 | 69,753 | 1.0 | 0.4 | 0.4 | -20.9 |
| **2044** | 8.5 | 69,821 | | 9.8 | 69,821 | 1.2 | 0.0 | 0.0 | -21.3 |
| **2045** | 8.5 | 69,890 | | 10.0 | 69,890 | 1.5 | -0.4 | -0.3 | -21.5 |
| **2046** | 8.5 | 69,844 | | 10.3 | 69,844 | 1.7 | 0.5 | 0.3 | -21.0 |
| **2047** | 8.5 | 69,798 | | 10.5 | 69,799 | 2.0 | 1.4 | 0.7 | -20.6 |
| **2048** | 8.5 | 69,751 | | 10.8 | 69,754 | 2.3 | 2.3 | 1.0 | -20.2 |
| **2049** | 8.5 | 69,705 | | 11.1 | 69,708 | 2.5 | 3.2 | 1.3 | -20.0 |
| **2050** | 8.5 | 69,659 | | 11.3 | 69,663 | 2.8 | 4.1 | 1.5 | -19.8 |
| **Cum.** | **221** | **2,169,129** | | **238** | **2,169,147** | **18** | **18** | **1.0** | **-20.2** |

*Table C-4.55. Annual and Cumulative Emissions, U.S. LNG Exports, and Consequential Analysis of Commitments (High CCS) Scenarios (AR6-20 Basis)*

| Year | C (High CCS): ExFID | | C (High CCS): MR | | C (High CCS): MR vs ExFID | | | | C (High CCS): Hi Exp | | C (High CCS): Hi Exp vs ExFID | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | US LNG EJ | GHG Tg $CO_2e$ | US LNG EJ | GHG Tg $CO_2e$ | D LNG EJ | D GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ | US LNG EJ | GHG Tg $CO_2e$ | D LNG EJ | D GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ |
| **2020** | 2.4 | 73,991 | 2.4 | 73,991 | 0.0 | 0.0 | | | 2.4 | 73,991 | 0.0 | 0.0 | | |
| **2021** | 3.2 | 72,853 | 3.2 | 72,853 | 0.0 | 0.0 | | | 3.2 | 72,853 | 0.0 | 0.0 | | |
| **2022** | 4.0 | 71,716 | 4.0 | 71,716 | 0.0 | 0.0 | | | 4.0 | 71,716 | 0.0 | 0.0 | | |
| **2023** | 4.8 | 70,579 | 4.8 | 70,579 | 0.0 | 0.0 | | | 4.8 | 70,579 | 0.0 | 0.0 | | |
| **2024** | 5.6 | 69,441 | 5.6 | 69,441 | 0.0 | 0.0 | | | 5.6 | 69,441 | 0.0 | 0.0 | | |
| **2025** | 6.3 | 68,304 | 6.3 | 68,304 | 0.0 | 0.0 | | | 6.3 | 68,304 | 0.0 | 0.0 | | |
| **2026** | 6.4 | 68,351 | 6.4 | 68,351 | 0.0 | 0.0 | | | 6.4 | 68,351 | 0.0 | 0.0 | | |
| **2027** | 6.5 | 68,399 | 6.5 | 68,399 | 0.0 | 0.0 | | | 6.5 | 68,399 | 0.0 | 0.0 | | |
| **2028** | 6.5 | 68,446 | 6.5 | 68,446 | 0.0 | 0.0 | | | 6.5 | 68,446 | 0.0 | 0.0 | | |
| **2029** | 6.6 | 68,493 | 6.6 | 68,493 | 0.0 | 0.0 | | | 6.6 | 68,493 | 0.0 | 0.0 | | |
| **2030** | 6.7 | 68,541 | 6.7 | 68,541 | 0.0 | 0.0 | | | 6.7 | 68,541 | 0.0 | 0.0 | | |
| **2031** | 6.9 | 67,133 | 6.9 | 67,133 | 0.0 | 0.0 | | | 7.3 | 67,136 | 0.4 | 3.4 | 9.5 | -11.7 |
| **2032** | 7.1 | 65,725 | 7.1 | 65,725 | 0.0 | 0.0 | | | 7.8 | 65,732 | 0.7 | 6.9 | 9.5 | -11.7 |
| **2033** | 7.3 | 64,317 | 7.3 | 64,317 | 0.0 | 0.0 | | | 8.4 | 64,327 | 1.1 | 10.3 | 9.5 | -11.7 |
| **2034** | 7.5 | 62,909 | 7.5 | 62,909 | 0.0 | 0.0 | | | 9.0 | 62,923 | 1.4 | 13.7 | 9.5 | -11.7 |
| **2035** | 7.8 | 61,501 | 7.8 | 61,501 | 0.0 | 0.0 | | | 9.6 | 61,518 | 1.8 | 17.1 | 9.5 | -11.7 |
| **2036** | 7.9 | 60,365 | 8.2 | 60,362 | 0.3 | -2.9 | -10.6 | -31.8 | 10.3 | 60,386 | 2.4 | 21.4 | 8.8 | -12.5 |
| **2037** | 8.1 | 59,228 | 8.6 | 59,222 | 0.5 | -5.7 | -10.6 | -31.8 | 11.1 | 59,253 | 3.1 | 25.6 | 8.3 | -12.9 |
| **2038** | 8.2 | 58,091 | 9.0 | 58,082 | 0.8 | -8.6 | -10.6 | -31.8 | 11.9 | 58,121 | 3.7 | 29.8 | 8.1 | -13.2 |
| **2039** | 8.4 | 56,954 | 9.5 | 56,943 | 1.1 | -11.5 | -10.6 | -31.8 | 12.7 | 56,988 | 4.3 | 34.0 | 7.9 | -13.4 |
| **2040** | 8.5 | 55,817 | 9.9 | 55,803 | 1.4 | -14.3 | -10.6 | -31.8 | 13.5 | 55,856 | 5.0 | 38.2 | 7.7 | -13.6 |
| **2041** | 8.5 | 54,079 | 10.2 | 54,072 | 1.7 | -6.8 | -4.1 | -25.4 | 14.2 | 54,125 | 5.6 | 46.6 | 8.3 | -13.0 |
| **2042** | 8.5 | 52,340 | 10.5 | 52,341 | 2.0 | 0.7 | 0.4 | -20.9 | 14.8 | 52,395 | 6.3 | 54.9 | 8.7 | -12.5 |
| **2043** | 8.5 | 50,601 | 10.8 | 50,610 | 2.3 | 8.3 | 3.6 | -17.6 | 15.5 | 50,665 | 7.0 | 63.3 | 9.1 | -12.2 |
| **2044** | 8.5 | 48,863 | 11.1 | 48,879 | 2.6 | 15.8 | 6.1 | -15.1 | 16.2 | 48,934 | 7.6 | 71.6 | 9.4 | -11.9 |
| **2045** | 8.5 | 47,124 | 11.4 | 47,147 | 2.9 | 23.4 | 8.1 | -13.2 | 16.8 | 47,204 | 8.3 | 80.0 | 9.6 | -11.6 |
| **2046** | 8.5 | 45,463 | 11.5 | 45,480 | 3.0 | 16.8 | 5.6 | -15.6 | 17.3 | 45,523 | 8.8 | 60.6 | 6.9 | -14.4 |
| **2047** | 8.5 | 43,802 | 11.6 | 43,812 | 3.1 | 10.3 | 3.3 | -17.9 | 17.8 | 43,843 | 9.2 | 41.2 | 4.5 | -16.8 |
| **2048** | 8.5 | 42,141 | 11.7 | 42,144 | 3.2 | 3.8 | 1.2 | -20.1 | 18.2 | 42,162 | 9.7 | 21.8 | 2.3 | -19.0 |
| **2049** | 8.5 | 40,479 | 11.8 | 40,477 | 3.3 | -2.8 | -0.8 | -22.1 | 18.7 | 40,482 | 10.1 | 2.4 | 0.2 | -21.0 |
| **2050** | 8.5 | 38,818 | 11.9 | 38,809 | 3.4 | -9.3 | -2.7 | -24.0 | 19.1 | 38,801 | 10.6 | -17.0 | -1.6 | -22.9 |
| **Cum.** | **222** | **1,844,865** | **254** | **1,844,882** | **31** | **17** | **0.6** | **-20.7** | **329** | **1,845,490** | **107** | **626** | **5.8** | **-15.4** |

*Table C-4.56. Annual and Cumulative Emissions, U.S. LNG Exports, and Consequential Analysis of Commitments (Moderate CCS) Scenarios (AR6-20 Basis)*

| Year | C (Mod CCS): ExFID | | C (Mod CCS): MR | | C (Mod CCS): MR vs ExFID | | | | C (Mod CCS): Hi Exp | | C (Mod CCS): Hi Exp vs ExFID | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | US LNG EJ | GHG Tg $CO_2e$ | US LNG EJ | GHG Tg $CO_2e$ | D LNG EJ | D GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ | US LNG EJ | GHG Tg $CO_2e$ | D LNG EJ | D GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ |
| **2020** | 2.4 | 73,991 | 2.4 | 73,991 | 0.0 | 0.0 | | | 2.4 | 73,991 | 0.0 | 0.0 | | |
| **2021** | 3.2 | 72,682 | 3.2 | 72,682 | 0.0 | 0.0 | | | 3.2 | 72,682 | 0.0 | 0.0 | | |
| **2022** | 4.0 | 71,374 | 4.0 | 71,374 | 0.0 | 0.0 | | | 4.0 | 71,374 | 0.0 | 0.0 | | |
| **2023** | 4.8 | 70,065 | 4.8 | 70,065 | 0.0 | 0.0 | | | 4.8 | 70,065 | 0.0 | 0.0 | | |
| **2024** | 5.6 | 68,756 | 5.6 | 68,756 | 0.0 | 0.0 | | | 5.6 | 68,756 | 0.0 | 0.0 | | |
| **2025** | 6.3 | 67,448 | 6.3 | 67,448 | 0.0 | 0.0 | | | 6.3 | 67,448 | 0.0 | 0.0 | | |
| **2026** | 6.4 | 67,501 | 6.4 | 67,501 | 0.0 | 0.0 | | | 6.4 | 67,501 | 0.0 | 0.0 | | |
| **2027** | 6.4 | 67,554 | 6.4 | 67,554 | 0.0 | 0.0 | | | 6.4 | 67,554 | 0.0 | 0.0 | | |
| **2028** | 6.5 | 67,608 | 6.5 | 67,608 | 0.0 | 0.0 | | | 6.5 | 67,608 | 0.0 | 0.0 | | |
| **2029** | 6.6 | 67,661 | 6.6 | 67,661 | 0.0 | 0.0 | | | 6.6 | 67,661 | 0.0 | 0.0 | | |
| **2030** | 6.6 | 67,714 | 6.6 | 67,714 | 0.0 | 0.0 | | | 6.6 | 67,714 | 0.0 | 0.0 | | |
| **2031** | 6.8 | 65,928 | 6.8 | 65,928 | 0.0 | 0.0 | | | 7.1 | 65,943 | 0.4 | 14.5 | 40.2 | 18.9 |
| **2032** | 6.9 | 64,143 | 6.9 | 64,143 | 0.0 | 0.0 | | | 7.6 | 64,171 | 0.7 | 28.9 | 40.1 | 18.9 |
| **2033** | 7.1 | 62,357 | 7.1 | 62,357 | 0.0 | 0.0 | | | 8.2 | 62,400 | 1.1 | 43.4 | 40.1 | 18.9 |
| **2034** | 7.2 | 60,571 | 7.2 | 60,571 | 0.0 | 0.0 | | | 8.7 | 60,629 | 1.4 | 57.8 | 40.1 | 18.9 |
| **2035** | 7.4 | 58,785 | 7.4 | 58,785 | 0.0 | 0.0 | | | 9.2 | 58,857 | 1.8 | 72.3 | 40.1 | 18.9 |
| **2036** | 7.6 | 56,926 | 7.7 | 56,928 | 0.1 | 1.6 | 16.2 | -5.0 | 9.9 | 56,992 | 2.3 | 65.8 | 29.1 | 7.8 |
| **2037** | 7.8 | 55,068 | 8.0 | 55,071 | 0.2 | 3.2 | 16.3 | -5.0 | 10.5 | 55,127 | 2.7 | 59.2 | 21.8 | 0.5 |
| **2038** | 8.1 | 53,209 | 8.4 | 53,214 | 0.3 | 4.7 | 16.3 | -5.0 | 11.2 | 53,262 | 3.2 | 52.6 | 16.6 | -4.7 |
| **2039** | 8.3 | 51,350 | 8.7 | 51,357 | 0.4 | 6.3 | 16.3 | -5.0 | 11.9 | 51,396 | 3.6 | 46.1 | 12.7 | -8.6 |
| **2040** | 8.5 | 49,492 | 9.0 | 49,500 | 0.5 | 7.9 | 16.3 | -5.0 | 12.6 | 49,531 | 4.1 | 39.5 | 9.7 | -11.6 |
| **2041** | 8.5 | 48,084 | 9.1 | 48,091 | 0.6 | 6.8 | 11.2 | -10.1 | 13.1 | 48,124 | 4.6 | 39.6 | 8.7 | -12.6 |
| **2042** | 8.5 | 46,676 | 9.3 | 46,682 | 0.7 | 5.7 | 7.8 | -13.5 | 13.6 | 46,716 | 5.1 | 39.7 | 7.9 | -13.4 |
| **2043** | 8.5 | 45,269 | 9.4 | 45,273 | 0.9 | 4.6 | 5.4 | -15.9 | 14.1 | 45,308 | 5.5 | 39.8 | 7.2 | -14.1 |
| **2044** | 8.5 | 43,861 | 9.5 | 43,864 | 1.0 | 3.5 | 3.6 | -17.7 | 14.6 | 43,901 | 6.0 | 39.9 | 6.6 | -14.7 |
| **2045** | 8.5 | 42,453 | 9.6 | 42,456 | 1.1 | 2.4 | 2.2 | -19.1 | 15.0 | 42,493 | 6.5 | 40.0 | 6.1 | -15.1 |
| **2046** | 8.5 | 41,017 | 9.6 | 41,018 | 1.1 | 1.0 | 0.9 | -20.3 | 15.4 | 41,061 | 6.9 | 44.2 | 6.4 | -14.8 |
| **2047** | 8.5 | 39,581 | 9.7 | 39,581 | 1.1 | -0.3 | -0.3 | -21.6 | 15.8 | 39,630 | 7.2 | 48.4 | 6.7 | -14.6 |
| **2048** | 8.5 | 38,145 | 9.7 | 38,143 | 1.1 | -1.7 | -1.5 | -22.8 | 16.1 | 38,198 | 7.6 | 52.7 | 6.9 | -14.3 |
| **2049** | 8.5 | 36,709 | 9.7 | 36,706 | 1.1 | -3.0 | -2.7 | -24.0 | 16.5 | 36,766 | 8.0 | 56.9 | 7.1 | -14.1 |
| **2050** | 8.5 | 35,273 | 9.7 | 35,268 | 1.1 | -4.4 | -3.9 | -25.2 | 16.9 | 35,334 | 8.3 | 61.2 | 7.3 | -13.9 |
| **Cum.** | **220** | **1,757,251** | **231** | **1,757,289** | **11** | **38** | **3.4** | **-17.9** | **307** | **1,758,194** | **87** | **943** | **10.8** | **-10.4** |

*Table C-4.57.Annual and Cumulative Emissions, U.S. LNG Exports, and Consequential Analysis of Net Zero 2050 (High CCS) Scenarios (AR6-20 Basis)*

| Year | NZ (Hi CCS): ExFID | | NZ (High CCS): MR | | NZ (High CCS): MR vs ExFID | | | | NZ (High CCS): Hi Exp | | NZ (High CCS): Hi Exp vs ExFID | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | US LNG EJ | GHG Tg $CO_2e$ | US LNG EJ | GHG Tg $CO_2e$ | D LNG EJ | D GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ | US LNG EJ | GHG Tg $CO_2e$ | D LNG EJ | D GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ |
| **2020** | 2.4 | 73,991 | 2.4 | 73,991 | 0.0 | 0.0 | | | 2.4 | 73,991 | 0.0 | 0.0 | | |
| **2021** | 3.2 | 72,853 | 3.2 | 72,853 | 0.0 | 0.0 | | | 3.2 | 72,853 | 0.0 | 0.0 | | |
| **2022** | 4.0 | 71,716 | 4.0 | 71,716 | 0.0 | 0.0 | | | 4.0 | 71,716 | 0.0 | 0.0 | | |
| **2023** | 4.8 | 70,579 | 4.8 | 70,579 | 0.0 | 0.0 | | | 4.8 | 70,579 | 0.0 | 0.0 | | |
| **2024** | 5.6 | 69,441 | 5.6 | 69,441 | 0.0 | 0.0 | | | 5.6 | 69,441 | 0.0 | 0.0 | | |
| **2025** | 6.3 | 68,304 | 6.3 | 68,304 | 0.0 | 0.0 | | | 6.3 | 68,304 | 0.0 | 0.0 | | |
| **2026** | 6.4 | 66,223 | 6.4 | 66,223 | 0.0 | 0.0 | | | 6.4 | 66,223 | 0.0 | 0.0 | | |
| **2027** | 6.4 | 64,143 | 6.4 | 64,143 | 0.0 | 0.0 | | | 6.4 | 64,143 | 0.0 | 0.0 | | |
| **2028** | 6.4 | 62,063 | 6.4 | 62,063 | 0.0 | 0.0 | | | 6.4 | 62,063 | 0.0 | 0.0 | | |
| **2029** | 6.5 | 59,982 | 6.5 | 59,982 | 0.0 | 0.0 | | | 6.5 | 59,982 | 0.0 | 0.0 | | |
| **2030** | 6.5 | 57,902 | 6.5 | 57,902 | 0.0 | 0.0 | | | 6.5 | 57,902 | 0.0 | 0.0 | | |
| **2031** | 6.7 | 57,002 | 6.7 | 57,002 | 0.0 | -0.1 | | | 7.0 | 56,998 | 0.4 | -4.7 | -13.0 | -34.3 |
| **2032** | 6.8 | 56,103 | 6.8 | 56,103 | 0.0 | -0.2 | | | 7.6 | 56,094 | 0.7 | -9.4 | -13.0 | -34.3 |
| **2033** | 7.0 | 55,204 | 7.0 | 55,204 | 0.0 | -0.3 | | | 8.1 | 55,190 | 1.1 | -14.1 | -13.0 | -34.3 |
| **2034** | 7.2 | 54,305 | 7.2 | 54,304 | 0.0 | -0.4 | | | 8.6 | 54,286 | 1.4 | -18.8 | -13.0 | -34.3 |
| **2035** | 7.4 | 53,405 | 7.4 | 53,405 | 0.0 | -0.5 | | | 9.2 | 53,382 | 1.8 | -23.5 | -13.0 | -34.3 |
| **2036** | 7.6 | 51,650 | 7.7 | 51,647 | 0.2 | -3.0 | -19.7 | -41.0 | 9.9 | 51,636 | 2.3 | -13.6 | -5.9 | -27.1 |
| **2037** | 7.8 | 49,895 | 8.1 | 49,889 | 0.3 | -5.5 | -18.2 | -39.4 | 10.7 | 49,891 | 2.8 | -3.7 | -1.3 | -22.6 |
| **2038** | 8.1 | 48,139 | 8.5 | 48,131 | 0.5 | -8.0 | -17.7 | -38.9 | 11.4 | 48,145 | 3.3 | 6.1 | 1.8 | -19.4 |
| **2039** | 8.3 | 46,384 | 8.9 | 46,373 | 0.6 | -10.6 | -17.4 | -38.7 | 12.2 | 46,400 | 3.8 | 16.0 | 4.1 | -17.1 |
| **2040** | 8.5 | 44,629 | 9.3 | 44,615 | 0.8 | -13.1 | -17.3 | -38.5 | 12.9 | 44,654 | 4.4 | 25.8 | 5.9 | -15.3 |
| **2041** | 8.5 | 43,200 | 9.5 | 43,193 | 0.9 | -7.8 | -8.3 | -29.6 | 13.4 | 43,234 | 4.9 | 33.3 | 6.8 | -14.5 |
| **2042** | 8.5 | 41,772 | 9.6 | 41,770 | 1.1 | -2.4 | -2.2 | -23.5 | 14.0 | 41,813 | 5.4 | 40.8 | 7.5 | -13.8 |
| **2043** | 8.5 | 40,344 | 9.8 | 40,347 | 1.3 | 2.9 | 2.3 | -19.0 | 14.5 | 40,392 | 6.0 | 48.3 | 8.1 | -13.2 |
| **2044** | 8.5 | 38,916 | 10.0 | 38,924 | 1.5 | 8.2 | 5.6 | -15.6 | 15.0 | 38,971 | 6.5 | 55.7 | 8.6 | -12.7 |
| **2045** | 8.5 | 37,488 | 10.2 | 37,501 | 1.6 | 13.5 | 8.3 | -12.9 | 15.6 | 37,551 | 7.0 | 63.2 | 9.0 | -12.3 |
| **2046** | 8.5 | 35,912 | 10.2 | 35,921 | 1.6 | 9.2 | 5.6 | -15.7 | 16.0 | 35,952 | 7.4 | 40.4 | 5.5 | -15.8 |
| **2047** | 8.5 | 34,336 | 10.2 | 34,341 | 1.7 | 4.9 | 2.9 | -18.3 | 16.3 | 34,354 | 7.8 | 17.7 | 2.3 | -19.0 |
| **2048** | 8.5 | 32,760 | 10.2 | 32,761 | 1.7 | 0.6 | 0.4 | -20.9 | 16.7 | 32,755 | 8.2 | -5.1 | -0.6 | -21.9 |
| **2049** | 8.5 | 31,184 | 10.3 | 31,181 | 1.7 | -3.7 | -2.1 | -23.4 | 17.1 | 31,157 | 8.6 | -27.9 | -3.3 | -24.5 |
| **2050** | 8.5 | 29,609 | 10.3 | 29,601 | 1.7 | -8.0 | -4.6 | -25.8 | 17.5 | 29,558 | 8.9 | -50.6 | -5.7 | -26.9 |
| **Cum.** | **219** | **1,619,433** | **236** | **1,619,408** | **17** | **-24** | **-1.4** | **-22.7** | **312** | **1,619,609** | **93** | **176** | **1.9** | **-19.4** |

*Table C-4.58. Annual and Cumulative Emissions, U.S. LNG Exports, and Consequential Analysis of Net Zero 2050 (Moderate CCS) Scenarios (AR6-20 Basis)*

| Year | NZ (Mod CCS):ExFID | | NZ (Mod CCS): MR | | NZ (Mod CCS): MR vs ExFID | | | | NZ (Mod CCS): Hi Exp | | NZ (Mod CCS): Hi Exp vs ExFID | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | US LNG EJ | GHG Tg $CO_2e$ | US LNG EJ | GHG Tg $CO_2e$ | D LNG EJ | D GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ | US LNG EJ | GHG Tg $CO_2e$ | D LNG EJ | D GHG Tg $CO_2e$ | Cons GHG g $CO_2e$/MJ | PNDE g $CO_2e$/MJ |
| **2020** | 2.4 | 73,991 | 2.4 | 73,991 | 0.0 | 0.0 | | | 2.4 | 73,991 | 0.0 | 0.0 | | |
| **2021** | 3.2 | 72,682 | 3.2 | 72,682 | 0.0 | 0.0 | | | 3.2 | 72,682 | 0.0 | 0.0 | | |
| **2022** | 4.0 | 71,374 | 4.0 | 71,374 | 0.0 | 0.0 | | | 4.0 | 71,374 | 0.0 | 0.0 | | |
| **2023** | 4.8 | 70,065 | 4.8 | 70,065 | 0.0 | 0.0 | | | 4.8 | 70,065 | 0.0 | 0.0 | | |
| **2024** | 5.6 | 68,756 | 5.6 | 68,756 | 0.0 | 0.0 | | | 5.6 | 68,756 | 0.0 | 0.0 | | |
| **2025** | 6.3 | 67,448 | 6.3 | 67,448 | 0.0 | 0.0 | | | 6.3 | 67,448 | 0.0 | 0.0 | | |
| **2026** | 6.3 | 65,077 | 6.3 | 65,077 | 0.0 | 0.0 | | | 6.3 | 65,077 | 0.0 | 0.0 | | |
| **2027** | 6.4 | 62,706 | 6.4 | 62,706 | 0.0 | 0.0 | | | 6.4 | 62,706 | 0.0 | 0.0 | | |
| **2028** | 6.4 | 60,335 | 6.4 | 60,335 | 0.0 | 0.0 | | | 6.4 | 60,335 | 0.0 | 0.0 | | |
| **2029** | 6.4 | 57,963 | 6.4 | 57,963 | 0.0 | 0.0 | | | 6.4 | 57,963 | 0.0 | 0.0 | | |
| **2030** | 6.4 | 55,592 | 6.4 | 55,592 | 0.0 | 0.0 | | | 6.4 | 55,592 | 0.0 | 0.0 | | |
| **2031** | 6.5 | 53,721 | 6.5 | 53,721 | 0.0 | 0.0 | | | 6.9 | 53,727 | 0.4 | 5.7 | 15.9 | -5.4 |
| **2032** | 6.6 | 51,850 | 6.6 | 51,850 | 0.0 | 0.0 | | | 7.3 | 51,862 | 0.7 | 11.4 | 15.9 | -5.4 |
| **2033** | 6.7 | 49,979 | 6.7 | 49,979 | 0.0 | 0.0 | | | 7.7 | 49,996 | 1.1 | 17.1 | 15.9 | -5.4 |
| **2034** | 6.7 | 48,108 | 6.7 | 48,108 | 0.0 | 0.0 | | | 8.2 | 48,131 | 1.4 | 22.9 | 15.9 | -5.4 |
| **2035** | 6.8 | 46,237 | 6.8 | 46,237 | 0.0 | 0.0 | | | 8.6 | 46,266 | 1.8 | 28.6 | 15.9 | -5.4 |
| **2036** | 6.9 | 45,024 | 6.9 | 45,024 | 0.0 | 0.0 | | | 9.1 | 45,062 | 2.2 | 38.4 | 17.8 | -3.5 |
| **2037** | 7.0 | 43,811 | 7.0 | 43,811 | 0.0 | 0.0 | | | 9.6 | 43,859 | 2.5 | 48.2 | 19.1 | -2.1 |
| **2038** | 7.2 | 42,597 | 7.2 | 42,597 | 0.0 | 0.0 | | | 10.0 | 42,656 | 2.9 | 58.1 | 20.2 | -1.1 |
| **2039** | 7.3 | 41,384 | 7.3 | 41,384 | 0.0 | 0.0 | | | 10.5 | 41,452 | 3.2 | 67.9 | 21.0 | -0.3 |
| **2040** | 7.4 | 40,171 | 7.4 | 40,171 | 0.0 | 0.0 | | | 11.0 | 40,249 | 3.6 | 77.8 | 21.6 | 0.3 |
| **2041** | 7.3 | 38,466 | 7.3 | 38,466 | 0.0 | 0.0 | | | 11.3 | 38,539 | 4.0 | 73.8 | 18.6 | -2.7 |
| **2042** | 7.2 | 36,760 | 7.2 | 36,760 | 0.0 | 0.0 | | | 11.5 | 36,830 | 4.3 | 69.8 | 16.1 | -5.1 |
| **2043** | 7.1 | 35,055 | 7.1 | 35,055 | 0.0 | 0.0 | | | 11.8 | 35,121 | 4.7 | 65.8 | 14.0 | -7.2 |
| **2044** | 7.1 | 33,350 | 7.1 | 33,350 | 0.0 | 0.0 | | | 12.1 | 33,412 | 5.0 | 61.8 | 12.3 | -9.0 |
| **2045** | 7.0 | 31,645 | 7.0 | 31,645 | 0.0 | 0.0 | | | 12.4 | 31,702 | 5.4 | 57.8 | 10.7 | -10.6 |
| **2046** | 6.8 | 30,621 | 6.8 | 30,621 | 0.0 | 0.0 | | | 12.6 | 30,669 | 5.8 | 47.9 | 8.3 | -13.0 |
| **2047** | 6.7 | 29,597 | 6.7 | 29,597 | 0.0 | 0.0 | | | 12.8 | 29,635 | 6.1 | 38.0 | 6.2 | -15.1 |
| **2048** | 6.5 | 28,573 | 6.5 | 28,573 | 0.0 | 0.0 | | | 13.0 | 28,601 | 6.5 | 28.0 | 4.3 | -16.9 |
| **2049** | 6.3 | 27,549 | 6.3 | 27,549 | 0.0 | 0.0 | | | 13.2 | 27,567 | 6.8 | 18.1 | 2.6 | -18.6 |
| **2050** | 6.2 | 26,525 | 6.2 | 26,525 | 0.0 | 0.0 | | | 13.4 | 26,534 | 7.2 | 8.2 | 1.1 | -20.1 |
| **Cum.** | **195** | **1,507,012** | **195** | **1,507,012** | **0** | **0** | **N/A** | **N/A** | **271** | **1,507,858** | **76** | **845** | **11.2** | **-10.1** |