Exporting Carbon

Assessing the Greenhouse Gas Impact of U.S. Fossil Fuel Exports

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CONTENTS

FOREWORD

Where does America's responsibility to reduce greenhouse gas emissions begin and end?

It's a basic question, but one that has big implications for the set of tools available to combat climate change.

Americans are accustomed to leading the world in confronting global challenges. President Biden reaffirmed that leadership when he spoke at the Glasgow climate summit in 2021, telling world leaders:

> "We want to do more to help countries around the world, especially developing countries, accelerate their clean-energy transition, address pollution, and ensure the world we all must share a cleaner, safer, healthiest planet. And we have an obligation to help."

Despite this obligation to help other nations, global climate agreements have perpetuated a particularly nationalistic set of blinders when it comes to accounting for and assessing greenhouse gas (GHG) emissions. According to convention, nations are only responsible for tracking and reducing GHG emissions that happen within their national borders.

For decades, the United States has produced abundant emissions data that ignore a key question: how much GHGs are being shipped overseas in the form of exports of coal, oil and gas? These flows have been kept off the books, making them largely invisible to policy makers.

For a long while, the omission of exports was of little consequence to U.S. emissions forecasts. The U.S. was a far bigger importer than exporter, and domestic production was declining. But that picture has changed dramatically, and U.S. GHG assessments have not adapted.

I recall a small meeting with energy mogul T. Boone Pickens in 2008. He told us the world was about to change due to advances in drilling technology. I had previously seen hydraulic fracturing at work, but it was the first time I heard of the coming boom. The rest is, as they say, history. U.S. crude oil production increased by 75% between 2009 and 2015.

As U.S. oil and gas producers clamored for more customers, the government flung the doors wide open for exports. In December 2015 – the same month as the Paris climate agreement – the U.S. lifted its ban on crude oil exports. Two months later, in February 2016, an LNG tanker left Cheniere Energy's Sabine Pass Liquefaction plant in Louisiana. It was the first LNG shipment ever from the lower 48, and the start of an enormous growth boom in capacity to ship methane gas overseas. The U.S. is now the largest exporter of LNG in the world.

Even as U.S. exports climbed, the Paris climate agreement reshaped global ambition from incremental reductions in GHGs to a far more ambitious goal of "net-zero" emissions by mid-century. President Biden would later follow up on the Paris agreement by adding a near-term target of cutting U.S. emissions in half by 2030 (reducing domestic U.S. emissions 50-52% below 2005 levels).

These are transformational emissions goals. Achieving them requires eliminating the vast majority of GHGs from fossil fuel production and consumption – for the U.S. and the world. The confluence of these two trends – increasing U.S. fossil fuel exports on the one hand, and the adoption of transformational goals for ratcheting down fossil fuel emissions on the other – led me to the conclusion that we need a better understanding of the GHG footprint of fossil fuel exports.

Admittedly, this analysis runs counter to strongly held analytical paradigms that have been in place for decades. In addition to the conventional practice of looking only at emissions related to consumption within our borders, analysts have long theorized that supply decisions (such as producing more fossil fuels) don't really matter as much as consumption decisions (such as incentivizing cleaner energy and conservation).

It is standard practice to assume that reduced production would simply be replaced by energy sources that pollute just as much, if not more. I recently documented this in an analysis of Environmental Impact Statements of major fossil fuel projects.[1] I found that federal agencies have undercounted the greenhouse gas emissions of oil and gas permit decisions by an average of 98 percent, using assumptions that go by terms such as leakage, substitution, displacement, and net accounting.

There are three primary reasons why the GHG footprint of fossil fuel exports should be normalized as a standard component of U.S. GHG assessments and forecasts.

First, every tool in the toolbox is needed to combat climate change, and acknowledging America's role in exporting carbon opens the door to additional opportunities for action. It makes little difference to the atmosphere where emissions (and emission reductions) take place around the world..

Second, as demonstrated by the conclusions of this report, the scale of U.S. GHG exports has become far too large to be kept out of sight from policy makers. It should be the goal of emissions inventories and forecasts to shine the most sunlight possible on where we are heading. Having good data on the GHG footprint of exports does not forestall anyone from reaching the verdict that exports are not important, or should be heavily discounted. But that verdict should be a fully informed policy decision rather than obscured by sanitized data.

Third, the shift to global net-zero emissions goals fundamentally challenges prior assumptions that supply policies, including those affecting exports, are not important. As the International Energy Agency and IPCC have both concluded, achieving a net-zero pathway will require actions to guard against locking in new sources of carbon emissions that will compete with cleaner energy and slow the transition to clean energy.[2]

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[1] Symons, J, "Analysis of NEPA Reviews for Fossil Fuel Projects," 2023. See: https://www.symonspa.com/post/analysis-of-nepa-reviews-for-fossil-fuel-projects

[2] See, for example, the International Energy Agency's (IEA's) 2021 "Net-Zero by 2050" report (https://www.iea.org/reports/net-zero-by-2050), which concluded that natural gas production and consumption decline up to 5% annually and that Global LNG exports peak by 2025 under a net-zero by 2050 scenario. IEA concludes: "There is no need for investment in new fossil fuel supply in our net zero pathway." Also, the Intergovernmental Panel on Climate Change (IPCC) concludes in their 2022 Working Group III assessment (https://www.ipcc.ch/2022/04/04/ipcc-ar6-wgiii-pressrelease/) that "cancellation of plans for new fossil fuel infrastructures" is needed to avoid "significant carbon lock-ins, stranded assets, and other additional costs."

These are not theoretical matters. United Nations Secretary General António Guterres has called on the United States and other nations to adopt a "Climate Action Acceleration Agenda," including:[3]

- Shift fossil fuel subsidies to renewables
- End all licensing and funding of new coal, oil and gas
- End expansion of existing oil and gas reserves

The Biden administration faces a number of decisions that will impact future fossil fuel supplies and exports. For example, the administration is responsible for deciding fossil fuel leases for publicly owned lands and waters. They also must approve all new LNG projects, including pending decisions on CP2 LNG, which would be the largest US LNG project ever approved.

Tracking exported GHG is also pertinent to ongoing efforts to reform the federal permit process for energy projects. While there is a common desire to improve the speed of permitting decisions, policy makers diverge when it comes to the ultimate energy goal (especially as it relates to whether federal agencies should approve or deny permits for new fossil fuel projects). This analysis fills in a missing piece of the contextual puzzle.

I want to express my appreciation to the frontline communities and environmental justice leaders, particularly those living in the shadow of export facilities in the Gulf Coast, who have helped me fully see the scale of plans to increase U.S. fossil fuel exports. GHGs are only one facet of policy decisions that directly impact the health and wellbeing of affected communities, many of which already suffer from a legacy of toxic pollution.

After crunching the numbers, I was genuinely surprised by the scale of the impact exports have on the U.S. emissions picture. In hindsight, I shouldn't have been. Fossil fuel production has gone up even as U.S. domestic emissions have gone down. With the U.S. set to make additional cuts in domestic GHGs and further reduce its reliance on fossil fuels, oil and gas companies have a plan: grow production and find new customers overseas.

It's an emissions shell game with far-reaching consequences for the climate.

It is not my intent to add to the drumbeat of bad news on climate change. To the contrary, focusing on fossil fuel supplies opens new opportunities for climate leadership. For example, GHG emissions from U.S. fossil fuel exports would be 47% lower in the U.S. Energy Information Administration's "low oil and gas supply" case, reducing associated climate damages by up to $6 trillion.

If there is one takeaway you take from this report, it should be this: by expanding our field of vision to include fossil fuel supplies and exports, we can find more options to seize the moment and affect positive change.

Jeremy Symons, September 2023

[3] "The United Nations Secretary-General's Climate Action Acceleration Agenda," 2023. See: https://www.un.org/sites/un2.un.org/files/un_sgs_acceleration_agenda.pdf

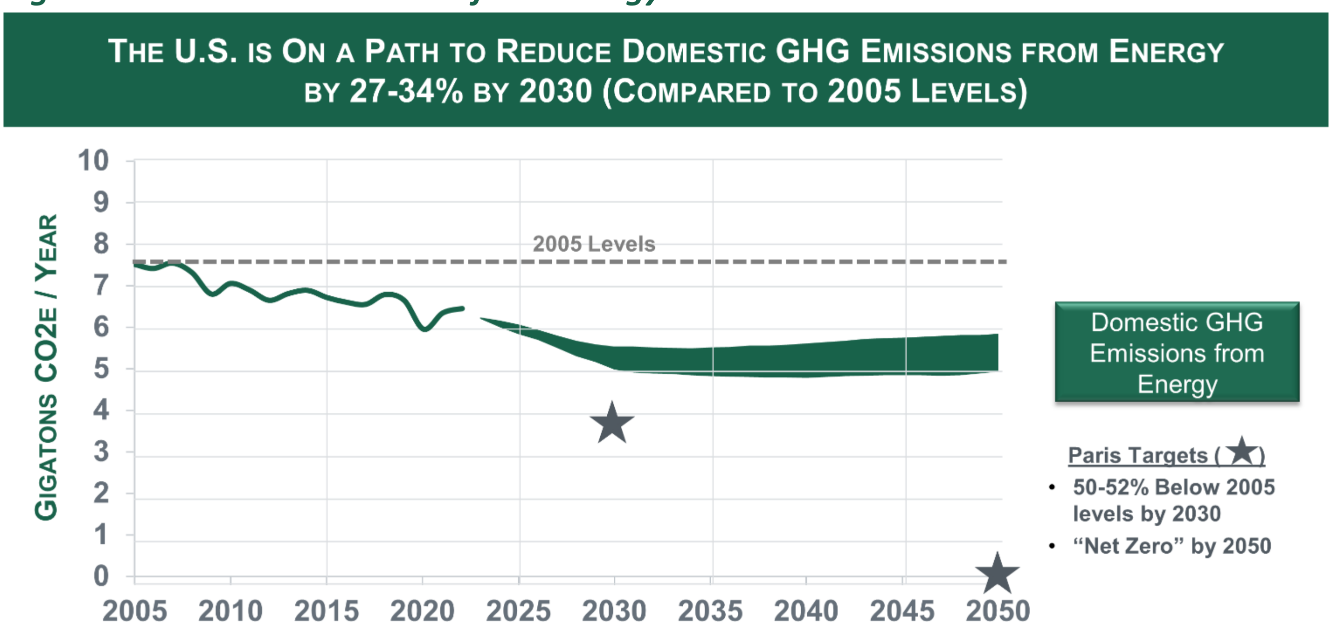
Summary of Findings

- **Finding 1: U.S. Greenhouse Gas (GHG) Emissions Are Expected to Decline Significantly by 2030 but Fall Short of U.S. Paris Commitments**
    - GHG emissions from energy consumed in the United States have decreased by 0.7 gigatons (CO_2e/yr) since 2005 (a 14% reduction)
    - GHG emissions from energy consumed in the United States could reach a 2.0-2.5 gigaton annual reduction by 2030 (27-34% below 2005 levels)
    - Additional reductions are likely from pending regulations and fees
- **Finding 2: US GHG Emissions Are Shifting Overseas as Fossil Fuel Exports Increase**
    - GHG emissions from U.S. fossil fuel exports have increased by 1.8 gigatons (CO_2e) since 2005 (a 463% increase above 2005 levels)
    - GHG emissions from U.S. fossil fuel exports could reach 2.9 gigatons annually by 2030 (a 650% increase above 2005 levels)
    - GHG emissions from U.S. fossil fuel exports would be 47% lower in the Energy Information Administration's (EIA's) "low oil and gas supply" case (compared to the "high oil and gas supply" case)
- **Finding 3: GHG Emissions from U.S. Fossil Fuel Exports Are Increasing in Amounts Greater than the GHG Reductions Being Achieved from U.S. Energy Consumption**
    - When fossil fuel exports are included, U.S. GHGs from energy have increased by 0.7 gigatons CO_2e (9% above 2005 levels)
    - When fossil fuel exports are included, U.S. GHGs from energy are expected to remain above 2005 levels through 2050
- **Finding 4: Climate Damages from U.S. Fossil Fuel Exports Could Reach $18.7 Trillion But Could Be Far Less Under Lower Export Scenarios**
    - Under EIA's "high oil and gas supply" scenario, climate damages from U.S. fossil fuel exports reach $6.1 - $18.7 trillion by 2050
    - Under EIAs "low oil and gas supply" scenario, climate damages from U.S. fossil fuel exports are $2-$6 trillion lower than in EIA's "high oil and gas supply" case

I. Finding 1: U.S. Greenhouse Gas (GHG) Emissions Are Expected to Decline Significantly by 2030 but Fall Short of U.S. Paris Commitments

- ❖ **GHG emissions from energy consumed in the United States have decreased by 0.7 gigatons (CO_2e) since 2005 (a 14% reduction)**
- ❖ **GHG emissions from energy consumed in the United States could reach a 2.0-2.5 gigaton annual reduction by 2030 (27-34% below 2005 levels)**
- ❖ **Additional reductions are likely from pending regulations and fees**

Figure 1 - U.S. Domestic GHGs from Energy



- Forecasts are based on U.S. Energy Information Administration' (EIA'S) *2023 Annual Energy Outlook*
- EIA's forecast includes the Inflation Reduction Act but does not include EPA regulations that have not been finalized
- The emission ranges shown here are bracketed by EIA's "Low Oil & Gas Supply Case" and "High Oil & Gas Supply Case"
- Data includes GHGs (CO2 and methane) from energy

Domestic carbon and methane emissions from U.S. energy consumption declined by 14 percent between 2005 and 2022. Thanks in large part to the clean energy incentives in the 2022 Inflation Reduction Act (IRA), the U.S. is on track to double these emission reductions in the energy sector by 2030. These reductions will put the U.S. closer to its goal of a 50-52% reduction in domestic greenhouse gas emissions in 2030 (across all greenhouse gases) but fall short.

Additional reductions will be achieved after EPA finalizes regulations designed to reduce CO2 and methane from the power sector, motor vehicles, and the oil and gas sector. This analysis, which I based on forecasts in EIA's *Annual Energy Outlook 2023* (see "Data and Methods"), does not include policies that have not been finalized.

Assumptions about oil and gas supplies play a big role in the emissions forecast. If the U.S. follows EIAs "high oil and gas supply" pathway, domestic emissions from the energy sector will fall to 27 percent below 2005 levels by 2030 (see Table 2). If the U.S. follows EIAs "low oil and gas supply" pathway, domestic emissions from the energy sector will fall significantly more – achieving a 34 percent emission reduction by 2030. The difference in supply scenarios amounts to 0.5 gigatons of CO2e annually (see Table 1). This gap widens to 0.9 gigatons by 2050, when emissions are expected to be 22-35% below 2005 levels.

For additional information, see Tables 2 and 3 in Section VII.

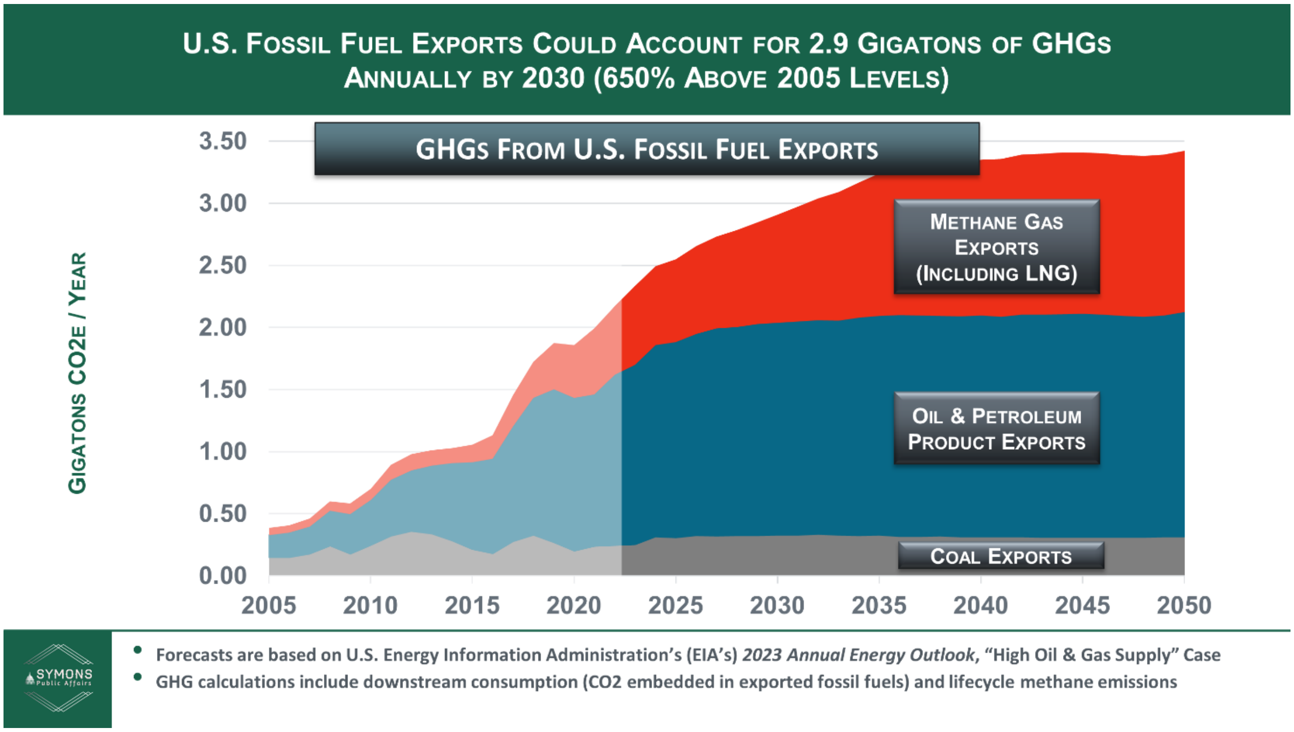
II. Finding 2: US GHG Emissions Are Shifting Overseas as Fossil Fuel Exports Increase

- **GHG emissions from U.S. fossil fuel exports have increased by 1.8 gigatons (CO2e) since 2005 (a 463% increase above 2005 levels)**
- **GHG emissions from U.S. fossil fuel exports could reach 2.9 gigatons annually by 2030 (a 650% increase above 2005 levels)**
- **GHG emissions from U.S. fossil fuel exports would be 47% lower in EIA's "low oil and gas supply" case (compared to the high oil and gas supply case)**

U.S Exports of fossil fuels, especially oil and gas, have been increasing rapidly since the United States' crude oil export ban was lifted in 2015 and the first LNG exports were shipped from the Gulf Coast in February 2016.

This analysis includes calculations of the GHG footprint of U.S. exports based on CO2 emitted when the fuel is combusted overseas, as well as the lifecycle methane emissions from exported products (see "Data and Methods"). Lifecycle methane emissions include leaks of methane that occur during coal mining, oil/gas drilling, gas transmission, processing, shipping, and downstream consumption.

Figure 2 – GHG Emissions from U.S. Fossil Fuel Exports



Increases in oil exports have accounted for the biggest increase in exported GHG emissions through 2022. Looking ahead, LNG exports are expected to drive emissions growth.

Exports today account for about 2.2 gigatons (CO2e) annually,[4] which is equivalent to one-third (33%) of U.S domestic GHGs from energy. By 2050, export emissions will grow to 3.4 gigatons CO2e in the "high oil and gas supply" case or fall slightly to 2.0 gigatons CO2e in the "low" supply case.

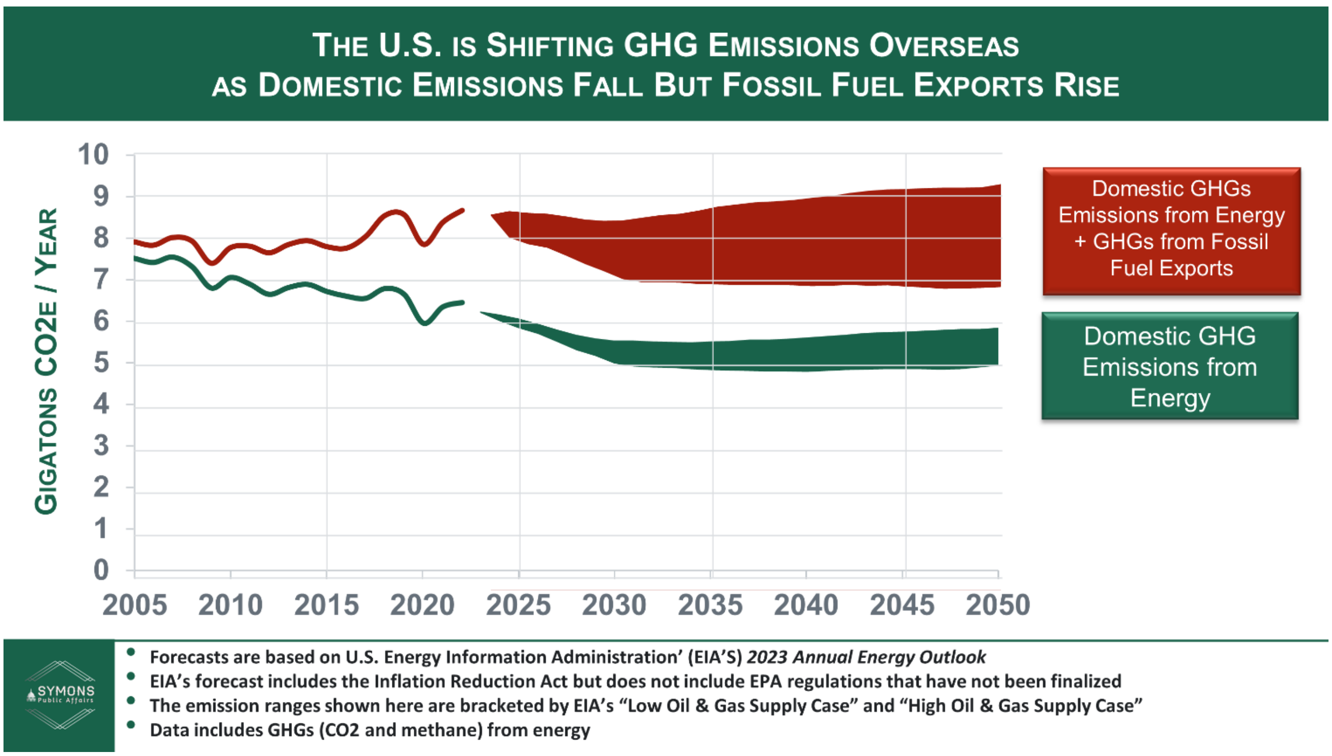
For additional information, see Tables 4-7 in Section VII.

[4] A gigaton equals a billion metric tons. CO2e refers to CO2 equivalents.

III. Finding 3: GHG Emissions from U.S. Fossil Fuel Exports Are Increasing in Amounts Greater than the GHG Reductions Being Achieved from U.S. Energy Consumption

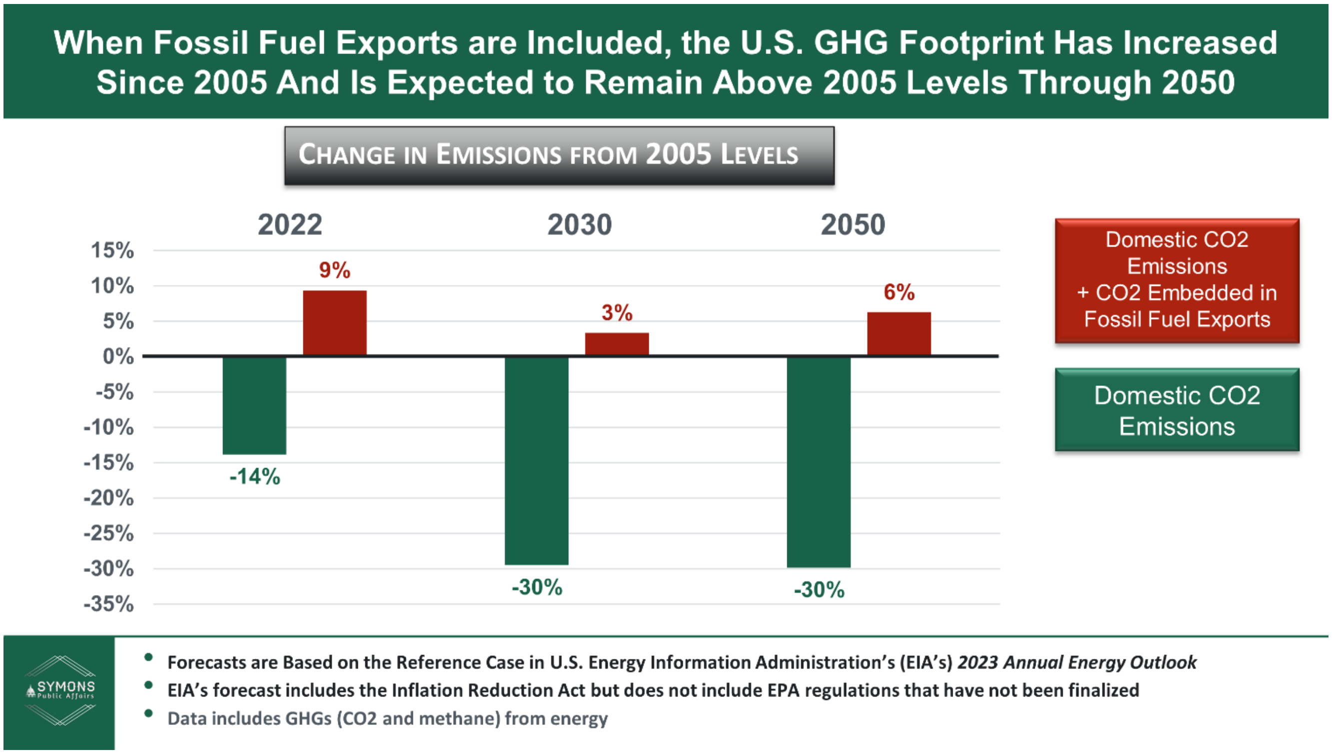
- ❖ **When fossil fuel exports are included, U.S. GHGs from energy have increased by 0.7 gigatons CO2e (9% above 2005 levels)**
- ❖ **When fossil fuel exports are included, U.S. GHGs from energy are expected to remain above 2005 levels through 2050**

Figure 3 – U.S GHG Emissions, With and Without Fossil Fuel Exports



What does America's GHG footprint look like when U.S. domestic emissions forecasts are combined with export projections? GHG emissions from U.S. fossil fuel exports are increasing in amounts greater than the GHG reductions being achieved from U.S. energy consumption. Added together. total U.S. emissions (domestic and exports) could remain above 2005 levels through 2030, and even 2050, based on the "high oil and gas supply" case (shown in Figure 3), as well as the reference case (shown in Figure 4). Only in the "low oil and gas supply case does America's total GHG fall below 2005 levels (a 10% reduction by 2030 and a 12% reduction by 2050). See Tables 8 and 9 in Section VII for additional details.

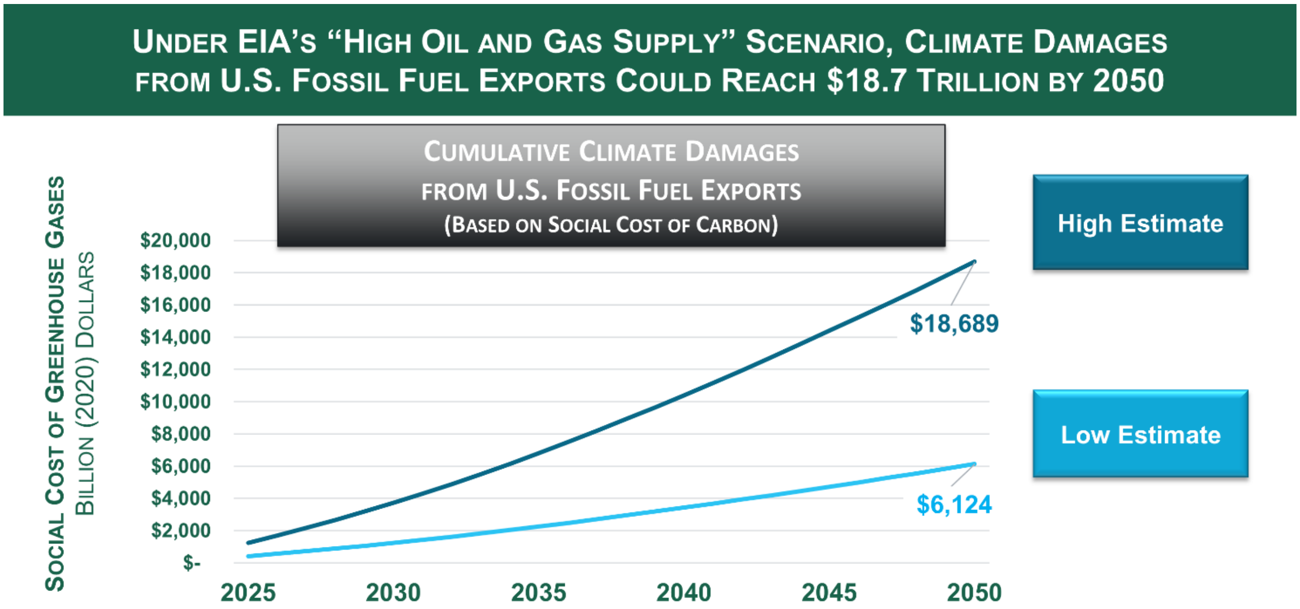
Figure 4 – Change in U.S GHG Emissions, With and Without Fossil Fuel Exports



IV. FINDING 4: CLIMATE DAMAGES FROM U.S. FOSSIL FUEL EXPORTS COULD REACH $18.7 TRILLION BUT COULD BE FAR LESS UNDER LOWER EXPORT SCENARIOS

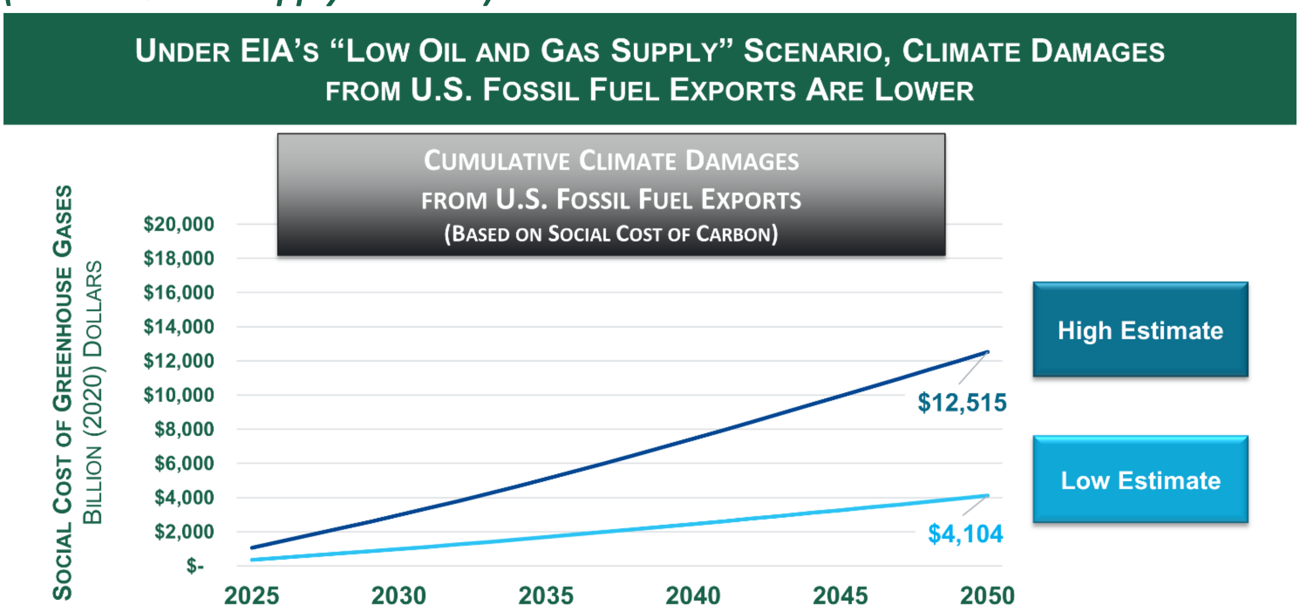
- Under EIA's "high oil and gas supply" scenario, climate damages from U.S. fossil fuel exports reach $6.1 - $18.7 trillion by 2050
- Under EIAs "low oil and gas supply" scenario, climate damages from U.S. fossil fuel exports are $2-$6 trillion lower

Figure 5 – Social Cost of GHGs of U.S. Fossil Fuel Exports (High Oil & Gas Supply Scenario)



- Source of Exports Data: "High Oil and Gas Supply" Case, U.S. Energy Information Administration 2023 Annual Energy Outlook
- Social costs of greenhouse gases (i.e., climate damages) are shown as cumulative (from 2023) and in real (2020) dollars
- The range of low and high estimates are based on the "3% discount rate" (low) and "3% discount rate, 95th percentile" (high) estimates in the 2021 Technical Support Document by the Interagency Working Group on Social Cost of Greenhouse Gases

Figure 6 – Social Cost of GHGs of U.S. Fossil Fuel Exports (Low Oil & Gas Supply Scenario)



- Source of Exports Data: "High Oil and Gas Supply" Case, U.S. Energy Information Administration 2023 Annual Energy Outlook
- Social costs of greenhouse gases (i.e., climate damages) are shown as cumulative (from 2023) and in real (2020) dollars
- The range of low and high estimates are based on the "3% discount rate" (low) and "3% discount rate, 95th percentile" (high) estimates in the 2021 Technical Support Document by the Interagency Working Group on Social Cost of Greenhouse Gases

This analysis applies the IWG's estimates of the SCGHG per ton of GHG emission to the GHG totals arrived at in this analysis for U.S. fossil fuel exports. The cumulative totals (from 2023) are shown for the "high oil and gas supply" scenario in Figure 5 and the "low oil and gas supply" scenario in Figure 6. Annual and cumulative figures are provided in Tables 10 and 11 in Section VII.

Under EIA's "high oil and gas supply" scenario, climate damages from U.S. fossil fuel exports are estimated to be between $6.1 trillion and $18.7 trillion by 2050 (cumulatively from 2023). Under the low supply scenario, damages are estimated to be between $4.1 trillion and $12.5 trillion. The difference between the high and low supply scenarios sheds some light on the enormous potential to avoid climate damages by paying greater attention to fossil fuel supplies and exports.

The range of low and high estimates in each graph is based on different assumptions about the SCGHGs. See Section 5.5 ("Data and Methods: Social Cost of GHGs") for more information.

V. Data and Methods

5.1 *Data Availability*

The data set used in this report is available online at the Symons Public Affairs website: www.SymonsPA.com.

5.2 *GHGs from Energy*

This analysis examines CO2 and methane emissions from energy. These emissions accounted for 82 percent of U.S. domestic GHG emissions in 2021.[5]

Future work could improve on this analysis by including all greenhouse gases. A review of the Climate Deck forecasts from Rhodium Group and Breakthrough Energy, which includes all GHGs, suggests that forecasted reductions in CO2 track closely to the expected reductions in all GHGs (on a percentage decline basis) through 2030.[6] While analysis of all GHGs would create a more robust data set, it seems unlikely that it would significantly alter the findings.

5.3 *Energy Forecasts*

All emissions forecasts in this report are based on calculations by the author using underlying data from the U.S. Energy Information Administration's (EIA's) *Annual Energy Outlook (AEO) 2023*.[7] Each section of this report, as well as the accompanying graphics, clearly indicates which EIA scenarios are being used, as well as any additional data sources and data limitations.

[5] U.S. EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021", Table ES-3. See: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2021

[6] Rhodium Group and Breakthrough Energy, Climate Deck, 2023 Taking Stock Baseline, July 2023. See: https://rhg.com/data_story/climate-deck/

[7] EIA, "ANNUAL ENERGY OUTLOOK 2023." See: https://www.eia.gov/outlooks/aeo/

Historical data is calculated based on EIA's *Monthly Energy Review*.[8]

EIA's AEO was selected for the following reasons:

- The AEO is the official energy forecast of the US Government
- AEO 2023 includes several side cases that are directly relevant to this study, including low and high oil & gas supply cases[9]
- EIA's full data sets are easily accessible online, allowing easy and transparent verification of this result's reports

For purposes of this analysis, the AEO has two notable limitations:

- EIA provides data on CO2 emissions from energy but does not include methane and other GHG emissions
- EIA does not include impacts of proposed but not finalized regulations, such as EPA's power plant and motor vehicle rules

This analysis supplements the EIA data by calculating the CO2 emissions for exports based on EIA's fuels data, and by calculating lifecycle methane emissions for both domestic energy and exports using the emissions factors discussed in the next section.

This analysis does not attempt to assess the impact of pending regulations.

5.4 GHG Emissions

Domestic GHG emissions are sourced directly from EIA Annual Energy Outlook 2023, which provides data on CO2 emissions from energy.

CO2 from exported fossil fuels were calculated by applying the following factors per unit, provided by EIA:[10]

- Natural gas: 52 million metric tons of CO2 per quadrillion Btus (MMmtCO2/quad Btu)
- Coal: 95 MMmtCO2/quad Btu
- Petroleum: 65 MMmtCO2/quad Btu

Methane emissions for domestic and exported energy are calculated on a lifetime basis, according to the following emission factors from Daniel Raimi at Resources for the Future (RFF):[11]

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[8] EIA, "Monthly Energy Review," August 2023. See: https://www.eia.gov/totalenergy/data/monthly/

[9] EIA, "AEO2023 Issues in Focus: Effects of Liquefied Natural Gas Exports on the U.S. Natural Gas Market," available at: https://www.eia.gov/outlooks/aeo/IIF_LNG/pdf/LNG_Issue_in_Focus.pdf

[10] EIA, "Energy Related CO2 Intensities by Fuel." See: https://www.eia.gov/todayinenergy/detail.php?id=27552#:~:text=The%20consumption%20of%20natural%20gas,than%20natural%20gas's%20carbon%20intensity.

11 Raimi, D., Resources for the Future, "The Greenhouse Gas Impacts of Increased US Oil and Gas Production," 2019. See: https://media.rff.org/documents/WP_19-03_Raimi.pdf

- Natural gas: 27.6 MMmtCO2/quad Btu
- Coal: 19.4 MMmtCO2/quad Btu
- Petroleum: 11.4 MMmtCO2/quad Btu

Raimi provides a range of methane factors depending on global warming potentials (GWPs) and assumptions about methane leakage rates. The factors used in this analysis and listed above are based on a 20-year GWP (86), rather than the 100-year GWP used by EPA (25). On this, I find Robert Howarth convincing. Here's how he explains the reasoning for using a 2-year GWP for methane:[12]

> "The latest synthesis report from the Intergovernmental Panel on Climate Change demonstrates that methane plays a far more important role in global warming than was recognized even a few years ago. Specifically, over the time since 1900, methane has contributed 0.5^{o} C of global warming, compared to 0.75^{o} C for carbon dioxide. That is, over more than a century, methane has contributed 33% of the total warming from all greenhouse gases. Using a 100-year GWP dramatically underplays this level of warming, which is far better approximated by the 20-year GWP. The IPCC (2021) specifically concluded that the continued reliance on a 100-year value is arbitrary, not a science-based decision. The decision by the US EPA to use 100-yr GWP was made in 1992, as part of Kyoto Protocol. At that time, the importance of methane as a driver of global warming was very poorly understood. As our scientific knowledge base on methane has improved, the logic for changing to a 20-year GWP grows stronger, and stronger."

In terms of leakage rates, I selected the rate of 2.3% based on the Alvarez et al study (2018), which is 60% higher than the rate assumed by EPA.[13] As described by Raimi:

> "A 2018 meta-analysis (Alvarez et al. 2018) incorporates the findings from studies covering nine major oil- and gas-producing regions to estimate nationwide emissions totals, finding that methane emissions from oil and gas systems were roughly 60 percent higher than EPA estimated."

EPA's emission leak assumptions are widely recognized as too low, and EPA is collecting data to revise and improve its estimates.

Although the 2.3% leak rate is higher than EPA's estimates, it may still be conservative. Several studies since 2018 have found significantly higher emission rates than Alvarez. In a paper

12 Howarth, R. "Comments on Clean Hydrogen Production Standard," November 10, 2022. See: https://www.hydrogen.energy.gov/pdfs/chps/robert-howarth.pdf

13 Alvarez, R. et al, "Assessment of methane emissions from the U.S. oil and gas supply chain," 2018. See: https://www.science.org/doi/10.1126/science.aar7204

published in December 2022, Howarth finds that the average U.S. leak rate in peer reviewed literature is 4.8%.[14]

For this analysis, the 2.3% leak rate is a static assumption that does not change over time. Uncertainty about leak rates are compounded by the uncertainty surrounding how those rates may change over time in response to policies that have not yet been put into effect, such as the Inflation Reduction Act's (IRA's) methane waste fee, set to begin in 2024, and proposed oil and gas methane regulations from EPA and BLM. Directionally, the leak rates should improve. However, efforts to reduce methane emissions have faced a bumpy road, and we follow EIA's lead here in not considering policies that have not yet been finalized. EPA and BLM first proposed regulations in 2015 under President Obama, but they were subsequently rolled back under President Trump. In March, 2023, the House of Representatives passed a bill that would roll back the IRA's methane fee. This sets the stage for the next election, which may decide the fate of both the methane fee and regulations.

All things considered, I felt that the 2.3% leakage rate was a fair, middle-of-the road compromise for this first analysis.

While different assumptions about methane lifecycle impacts could significantly change the methane calculations, the impact would be more modest when it comes to the findings summarized in this report. CO2 accounts for the lion's share of export emissions calculated here (i.e., 79% of the GHGs from exports in 2030).

I appreciated the effort by Raimi to allocate methane production emissions between oil and natural gas, as both are co-produced from wells leaking methane.[15] The methane calculations used in this report are aggregated to include oil and gas, so this assumption should have little impact except when looking at trends for specific fuels (e.g., Figure 2).

It should be noted that this exports analysis underreports on the GHGs associated with exports in one respect: upstream CO2 emissions from fossil fuel production and processing are allocated to the domestic GHG emission numbers. This is to avoid double counting while maintaining the integrity of the EIA CO2 data set. It also allows apples-to-apples comparisons with other domestic GHG numbers.

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[14] Robert Howarth, "Methane Emissions from the Production and Use of Natural Gas," 2022. See: https://www.research.howarthlab.org/documents/Howarth2022_EM_Magazine_methane.pdf

[15] Raimi: "Because most wells produce a combination of dry natural gas (methane), natural gas liquids (ethane, propane, butane, etc.), and crude oil. Much of the associated gas produced from "oil" wells is captured and marketed separately from the oil, raising the question of whether some portion of methane emissions from "oil" wells should be attributed to natural gas systems. Similarly, it may be appropriate to attribute a share of methane emissions from "natural gas" wells to petroleum systems, as many natural gas wells produce substantial volumes of liquid hydrocarbons."

5.5 Social Cost of GHGs

This analysis uses the 2021 estimates of the Social Cost per ton of GHGs from the Interagency Working Group (IWG) on the Social Cost of Greenhouse Gases.[16] These per ton estimates are in 2020 dollars and provided for each year through 2050. These estimates are then applied to this report's GHG estimates for fossil fuel exports.

The range of low and high estimates in this analysis are based on the "3% discount rate" (the "low" estimates for this report) and "3% discount rate, 95th percentile" (the "high" estimates for this report) estimates from the Interagency Working Group. Both use a 3% discount rate that discounts the future benefits of reducing GHG emissions. Three percent is the middle of the three values (2.5%, 3%, 5%) provided by the Interagency Working Group.

The "low" end of this analysis is based on Interagency Working Group estimates that reflect the mid-point of the range of potential economic impact of GHGs across simulations. The "high" end of this analysis is based on an alternative set of figures from the Interagency Working Group that represents the 95th percentile (i.e., the higher-end tail) of estimated economic damages. It is therefore a proxy for the risk that climate change could have more severe economic impacts than suggested by averaging. The Interagency Workgroup characterizes this as "higher-than-expected economic impacts from climate change."

VI. Comparison to Other Studies

A number of studies of U.S. (domestic) GHG emissions have been conducted since enactment of the 2022 Inflation Reduction Act. John Bistline et al published a comparison of nine independent models in *Science* in June 2023.[17] They concluded that, subsequent to the Inflation Reduction Act, the expected emissions gap in 2030 between forecasted emissions and the 2030 emissions target (modelled as 50% below 2030 levels by 2005) will be between 0.5 to 1.1 Gt-CO2e/yr for all greenhouse gases (10 to 17 percentage points). Figure S4 suggests that this gap for CO2 from energy ranges between roughly 0.4 and 1.0 gigatons Co2e/yr in 2030.

Due to significant differences, detailed below, between this study and others, the only apples-to-apples comparison available is domestic CO2 from energy. In this study, the 2030 emissions gap for CO2 from energy is 0.8 to 1.2 Gt-CO2e/yr (14-19 percentage points). This is consistent with the Bistline et al range, but on the high end. This is not surprising. EIA has always been on the conservative side when forecasting transitions away from fossil fuels (a topic I wrote about in the

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[16] Interagency Working Group on the Social Cost of Greenhouse Gases, "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide," 2021. See: www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf

[17] Bistline, J. et al, "Emissions and energy impacts of the Inflation Reduction Act," Science, June 2023. See: https://www.science.org/doi/10.1126/science.adg3781

1990s while working at EPA), and some of the studies included in Bistline et al may include state and federal policy assumptions beyond what EIA included.

Beyond domestic CO2 from energy, however, there are significant differences between this study and Bistline et al, due to significant differences in scope and assumptions, including:

- This study includes GHG emissions embedded in fossil fuel exports. Other studies do not.
- Methane emissions are higher in this study than most other inventories and emissions forecasts, including Bistline et al, because this study uses a 20-year GWP and higher lead rates for methane, as explained in Section 5.4.
- This study includes a range of oil and gas supply scenarios. Other studies often have a similar range, but those differences were not explored in Bistline et al as fully as consumption ranges.
- This study only includes CO2 and methane from energy, omitting other GHGs included in the Bistline et al studies.
- This study does not include sinks.

VII. TABLES

Table 1: Description of AEO 2023 Cases[18]

Reference Case	In the AEO2023 Reference case, we assess how U.S. and world energy markets would operate through 2050 under current laws and regulations as of November 2022 under evolutionary technological growth assumptions. Our key assumptions in the Reference case provide a baseline, or experimental control, for exploring long-term trends.
High Oil and Gas Supply case	Compared with the Reference case, the High Oil and Gas Supply case assumes that the estimated ultimate recovery per well for tight oil, tight gas, or shale gas in the United States is 50% higher. Similarly, this case assumes that undiscovered resources in Alaska and the offshore Lower 48 states are 50% greater than assumed in the Reference case. Technological improvement rates that reduce costs and increase productivity of oil and natural gas production in the United States are also 50% higher than assumed in the Reference case.
Low Oil and Gas Supply case	The Low Oil and Gas Supply case assumes that the estimated ultimate recovery per well for tight oil, tight gas, or shale gas in the United States; the undiscovered resources in Alaska and the offshore Lower 48 states; and rates of technological improvement are all 50% lower than assumed in the Reference case.

[18] EIA, "Appendix: Case Descriptions," 2023. See: https://www.eia.gov/outlooks/aeo/narrative/

Table 2 - GHG Emissions from Energy Consumed in the United States (MMT CO2e, Annual)

	2005	2022	2030	2050
Reference Case	7,531	6,486	5,309	5,281
Low Oil & Gas Supply	7,531	6,486	4,986	4,927
High Oil & Gas Supply	7,531	6,486	5,533	5,844

Table 3 - GHG Emissions from Energy Consumed in the United States (Change from 2005)

	2005	2022	2030	2050
Reference Case	--	-13.9%	-29.5%	-29.9%
Low Oil & Gas Supply	--	-13.9%	-33.8%	-34.6%
High Oil & Gas Supply	--	-13.9%	-26.5%	-22.4%

Table 4 - GHG Emissions from U.S. Fossil Fuel Exports (MMT CO2e, Annual)

	2005	2022	2030	2050
Reference Case	383	2,168	2,867	3,126
Low Oil & Gas Supply	383	2,168	2,103	1,985
High Oil & Gas Supply	383	2,168	2,902	3,416

Table 5 - GHG Emissions from U.S. Fossil Fuel Exports (Change from 2005)

	2005	2022	2030	2050
Reference Case	--	466%	648%	716%
Low Oil & Gas Supply	--	466%	449%	418%
High Oil & Gas Supply	--	466%	657%	791%

Table 6 - GHG Emissions from U.S. Fossil Fuel Exports: High Oil &Gas Supply Case (MMT CO2e, Annual)

	2005	2022	2030	2050
Methane Gas/LNG	59	554	871	1,297
Oil & Petroleum Products	179	1374	1710	1,809
Coal	146	240	321	310
TOTAL	**383**	**2,168**	**2,902**	**3,416**

Table 7 - GHG Emissions from U.S. Fossil Fuel Exports: Low Oil & Gas Supply Case (MMT CO2e, Annual)

	2005	2022	2030	2050
Methane Gas/LNG	59	554	759	706
Oil & Petroleum Products	179	1374	1,025	967
Coal	146	240	319	311
TOTAL	**383**	**2,168**	**2,103**	**1,985**

Table 8 – Total GHG Emissions from Energy (Domestic and Exports) (MMT CO2e, Annual)

	2005	2022	2030	2050
Reference Case	7,914	8,654	8,176	8,407
Low Oil & Gas Supply	7,914	8,654	7,088	6,911
High Oil & Gas Supply	7,914	8,654	8,435	9,260

Table 9 – Total GHG Emissions from Energy (Domestic and Exports) (Change from 2005)

	2005	2022	2030	2050
Reference Case	--	9.4%	3.3%	6.2%
Low Oil & Gas Supply	--	9.4%	-10.4%	-12.7%
High Oil & Gas Supply	--	9.4%	6.6%	17.0%

Table 10 – Annual Social Cost of Carbon – U.S. Fossil Fuel Exports) (Billion 2020 Dollars)

	2030		2050	
	3% Discount Rate	3% Discount Rate, 95th Percentile	3% Discount Rate	3% Discount Rate, 95th Percentile
Low Oil & Gas Supply	$130	$393	$169	$516
High Oil & Gas Supply	$180	$543	$290	$888

Table 11 – Cumulative Social Cost of Carbon – U.S. Fossil Fuel Exports) (Billion 2020 Dollars)

	2030		2050	
	3% Discount Rate	3% Discount Rate, 95th Percentile	3% Discount Rate	3% Discount Rate, 95th Percentile
Low Oil & Gas Supply	$987	$2,969	$4,094	$12,515
High Oil & Gas Supply	$1,237	$3,721	$6,113	$18,657