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Submitted via regulations.gov

Christopher A. Wright
U.S. Department of Energy
Office of Regulation, Analysis, and Engagement
Office of Fossil Energy and Carbon Management
Forrestal Building, Room 3E-056
1000 Independence Avenue SW
Washington, DC 20585

Re: The Positive Domestic and Global Benefits of U.S. LNG

Dear Secretary Wright,

On behalf of the American Exploration & Production Council (AXPC), we appreciate the opportunity to provide our perspective on the critical role of U.S. liquefied natural gas (LNG) in strengthening both domestic and global energy security, economic growth, and environmental progress. As an organization representing leading independent oil and natural gas producers across the United States, AXPC members are committed to responsible energy development, innovation, and emissions management while ensuring continued investment in the U.S. economy.

The Department of Energy's (DOE) recent 2024 LNG Export Study provides a valuable assessment of the impacts of U.S. LNG exports, reinforcing what producers and consumers alike have long recognized: increased U.S. LNG exports deliver significant benefits, including:

- **Economic Growth & Job Creation:** U.S. LNG exports contribute substantially to the economy, with historical data showing an estimated $408 billion added to U.S. GDP from 2016 to 2024. Increased LNG production strengthens industrial growth and supports high-quality jobs in communities across the country.
- **Energy Security & Global Stability:** American LNG is a reliable and geopolitically strategic energy source, particularly for U.S. allies such as those in Europe, who have increasingly turned to U.S. LNG to reduce dependence on Russian gas. The study confirms that U.S. LNG enhances global energy security without compromising domestic supply.
- **Environmental Benefits:** The DOE analysis highlights that U.S. LNG displaces higher-emission fuels globally, helping to reduce greenhouse gas emissions while maintaining energy affordability. Advanced emissions reduction efforts by U.S. producers—including investments in methane mitigation and carbon capture—further strengthen LNG's role as a lower-carbon energy source.

While the study provides an important foundation for assessing the future of U.S. LNG, we encourage DOE to continue refining its methodology to ensure that future analyses accurately capture the ongoing innovations in emissions management, infrastructure investment, and the long-term economic contributions of LNG exports. Additionally, we believe that some of the study's assumptions—particularly regarding market dynamics, emissions profiles, and regional price impacts—warrant further scrutiny. Our recommendations identify areas where adjustments could lead to a more accurate representation of the economic and environmental impacts of

U.S. LNG, ensuring that future assessments better reflect the realities of global energy markets. We also encourage the Department to recognize the importance of U.S. LNG as a strategic asset in shaping global geopolitics and energy policy.

AXPC appreciates DOE's engagement on this critical issue, and we look forward to working with the department to advance its goals. Our industry remains committed to responsible energy development that benefits both the United States and the broader global community.

Sincerely,

Rebecca Denney
Director, Regulatory Policy
American Exploration & Production Council

1.0 Introduction

The American Exploration & Production Council (AXPC) is a national trade association representing leading independent upstream oil and natural gas companies engaged in the exploration and production of oil and natural gas across the United States. Our members are committed to responsible energy development, innovation, and sustainability while playing a vital role in strengthening U.S. energy security and economic growth. As the U.S. continues to lead in global liquefied natural gas (LNG) exports, AXPC has a strong interest in ensuring that energy policies, including the Department of Energy's (DOE) analysis of LNG exports, accurately reflect market dynamics, industry advancements in emissions management, and the broader benefits of U.S. LNG. Increased LNG exports not only bolster domestic production and job creation but also enhance global energy security, reduce reliance on higher-emission fuel sources, and support economic stability for U.S. allies and trading partners. Accordingly, we appreciate the opportunity to provide comments on the DOE's "2024 LNG Export Study: Energy, Economic, and Environmental Assessment of U.S. LNG Exports" (the Report) and offer insights to ensure that future assessments fully capture the critical role of U.S. LNG in global energy markets.

The Report's analysis conducted by four research teams employing four models is a first-of-its-kind understanding of domestic and international impacts of U.S. LNG exports. We highlight some of the key findings in the Report which demonstrate the economic and environmental benefits of U.S. LNG exports, specifically that increased U.S. LNG exports will increase U.S. gross domestic product (GDP), increase industrial growth, and displace more emission-intense sources of fuel globally, all with minimal impact on domestic natural gas consumption and residential energy prices.

However, there are some assumptions in the analysis that could be improved to more accurately reflect market dynamics, emission management practices, and available historic data. We provide recommendations to be included in any future iterations of this report to more accurately represent the natural gas industry's emissions profile and macroeconomic behaviors.

Lastly, while the Report and multiple Appendices discuss a number of important topics, there are some additional aspects to be considered when evaluating the U.S. LNG industry. Specifically, energy security impacts and global socioeconomic improvement should be considered when evaluating U.S. LNG export approvals.

A Note on Uncertainty:

While the Report provides a robust analysis of the benefits of U.S. LNG exports, its findings are presented as point estimates without assessment of uncertainty. We caution against interpreting these estimates with absolute precision as implied by the Report. Instead, we have focused on the broad trends observed across the model results rather than any individual point estimate.

2.0 The Report's Findings and Analysis Confirm the Benefits of U.S. LNG Exports

Key Findings of the Report

Economic Benefits of U.S. LNG Exports

- Increased U.S. LNG exports drive higher GDP, industrial growth, and job creation.
- LNG exports contribute to a stronger U.S. trade balance and capital investment in infrastructure.
- Historical data show substantial economic gains from LNG exports, with an estimated $408 billion added to U.S. GDP (2016–2024).
- Retirement funds and investors benefit from the financial growth of natural gas producers and LNG infrastructure companies.
- Gas price impacts on American consumers can be considered inconclusive when accounting for the uncertainties in the analysis.

Energy Security and Global Market Influence

- Domestic energy security is not compromised by increased LNG exports - supply is sufficient for both domestic and export markets.
- U.S. LNG exports enhance global energy security, particularly for Europe, which now relies more on U.S. LNG after reducing Russian imports.
- The U.S. remains a key energy supplier to global markets, with an increasing role in shaping energy geopolitics.

Environmental and Emissions Considerations

- DOE's analysis confirms that U.S. LNG displaces more emissions-intensive fuels globally, reducing greenhouse gas (GHG) emissions.

The Report demonstrates the clear economic benefits of LNG exports to the U.S.

The economic assessment findings in Appendices A and B of the 2024 Report demonstrate a number of economic benefits to the U.S. that increased LNG exports (DP:MR vs DP:ExFID) would bring. In our view, readers should focus on the high-level or overall trends of the analysis rather than the exact figures which are likely to exhibit false precision as the analysis involves high levels of uncertainty.

The report projects that in 2050, **Henry Hub (HH) prices would be 30% higher** in DP:MR vs DP:ExFID, but **residential NG prices would only increase by 4%**[1]**.** The high-level trend therefore shows an increase in wholesale gas prices, but only a modest impact on American consumers.

It also shows that increased LNG exports would increase industrial output by 1.3% (or $203 billion in 2050[2]) with 72% of this growth driven by increased oil and gas activity. Regional[3] analysis shows that in most cases, industrial output grows, except certain regions in the 'low

[1] 2024 Report, Summary Report, pp. S-4

[2] 2024 Report, Summary Report, pp. S-5

[3] 2024 Report, Appendix B, pp. B-36

U.S. supply case'. **The overall trend therefore shows that increased exports are positive for U.S. industrial growth.** While the Report describes these impacts as 'modest' and explains that only in one region (West South Central) does the increase exceed 3%, the small percentage increase is likely a reflection of the large size of the overall U.S. industrial sector rather than LNG having a small impact. Instead, the data demonstrate that LNG is a significant contributor to the U.S. economy.

Additionally, the report shows that GDP would increase by 0.2% in 2050 with increased U.S. LNG exports (DP:MR vs. DP:ExFID)[Error! Bookmark not defined.]. GDP growth is also observed in both the Low and High U.S. Supply scenarios[4]. **The Report is clear that the high-level trend shows that increased U.S. LNG exports result in an increase in GDP.** Rather than focusing on specific percentage increases, we should recognize the consistent trend of U.S. LNG exports driving economic growth.

The historical contribution of U.S. LNG exports to U.S. GDP is notable. S&P Global, which also provided the model of the U.S. economy used to generate GDP estimates in the report, estimates that LNG exports have contributed $408 billion to U.S GDP from 2016 – 2024[5]. LNG has contributed substantially to the U.S. economy in the past and will continue to do so.

The Report demonstrates the greenhouse gas emission reduction benefits of liquefied natural gas (LNG) global exports.

The updated Report's Appendix C presents a consequential life cycle assessment (CLCA) of U.S. LNG exports, analyzing how global emissions change under different U.S. export levels, policies, and technology implementations. This analysis provides a first-of-its-kind evaluation of the potential broader climate impacts of U.S. LNG exports by considering not only direct emissions from LNG production and transport but also how global energy markets respond to increased LNG availability.

The study models 14 key scenarios and finds that, on average, U.S. LNG exports displace a more GHG-intensive energy mix (see Table 35). The analysis relies on the GCAM model, which estimates global GHG emissions under different LNG export scenarios compared to a reference case (existing & FID export levels). The model evaluates many variables, but we focus on the three key drivers of net emissions:

1. Direct emissions from the U.S. LNG supply chain, including production, processing, pipeline transmission, liquefaction, and consumption.
2. Market substitution effects, where increased U.S. LNG exports lead to shifts in global energy consumption patterns, replacing other fuels with different emissions profiles.
3. Changes in total global energy consumption (global services provided)

Table 35 in the Report shows that in most scenarios, U.S. LNG's direct supply chain emissions are more than offset by market substitution effects, meaning it on average replaces higher-emission fuels such as coal, oil, or alternative sources of natural gas. However, as shown in Table 25 in the Report, the study still finds a net positive emissions intensity across all scenarios (meaning an increase in global emissions relative to the reference case), despite U.S. LNG generally displacing more emissions-intensive fuels.

This is primarily due to the third factor – over the time period studied, increased LNG exports coincide with economic growth and greater energy use in some regions, which results in higher levels of global energy consumption and thus higher overall emissions relative to the reference

[4] 2024 Report, Appendix B, pp. B-31

[5] Major New US Industry at a Crossroads: A US LNG Impact Study – Phase 1, S&P Global, December 2024

case, regardless of the energy source. This is demonstrated in Figure 1, where we show as an example the results from the DP: MR case. We adapt data from Table 35, which reports net total emissions change relative to the reference case for each of three key drivers described above, and then normalize emissions to the change in U.S. LNG exports to recreate the calculated net consequential emissions intensity. Results from the DP: MR scenario are used to illustrate the drivers, but we note that this trend is observed across most scenarios.

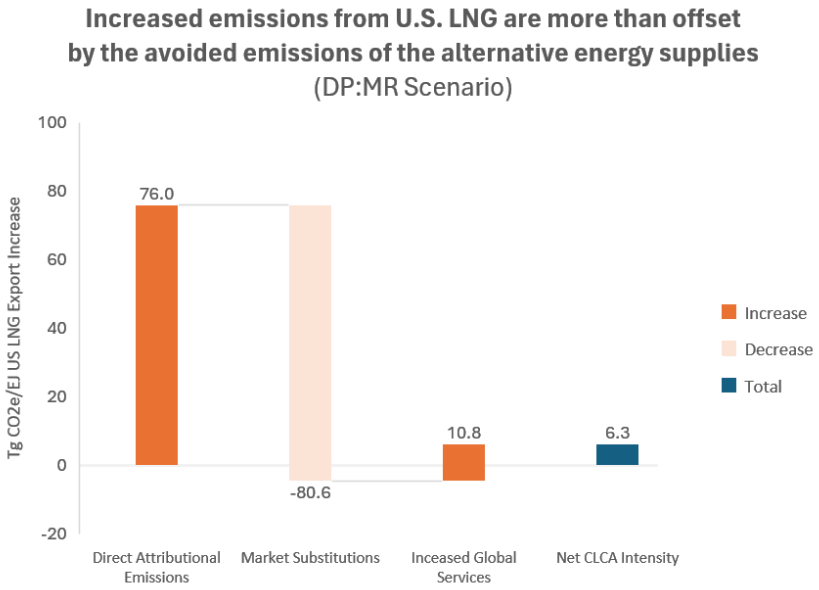

Figure 1. Adapted from data reported in Table 35 of the Report. The three drivers of net consequential emissions intensity are direct attributional emissions, market substitution effects, and increases in global services. The DP: MR scenario illustrates that increased emissions from U.S. LNG (Direct Attributional Emissions) are more than offset by the avoided emissions of the alternative energy supplies that would have been consumed in the absence of U.S. LNG (Market Substitutions). However, because of the increased global energy demand enabled by U.S. LNG (increased global services), there is a net positive emissions intensity.

The sensitivity analysis in Table 34 further illustrates this dynamic. When global energy consumption is held constant (matching the reference case), the net emissions impact of U.S. LNG exports becomes negative in nearly all scenarios (meaning a global decrease in emissions relative to the reference case). This reinforces the conclusion that U.S. LNG primarily displaces more carbon-intensive fuels, leading to overall emissions reductions when underlying energy demand is unchanged.

The 2018 Report included high-level qualitative messages describing the wider economic benefits of LNG Exports to the U.S. economy. These messages are absent from the 2024 Report, but they are still important, relevant and true.

Section IV of the 2018 Report entitled ‘Macroeconomic Outcomes’ notes a number of key, qualitative economic messages — all of which are absent from the 2024 Report but remain accurate and should have been incorporated.

The 2018 Report states that if LNG Exports increase, U.S. NG producers will generate additional profits by selling more U.S. LNG on the international market. As an example, if we take the difference between the cumulative LNG volumes (from 2025 to 2050) between the DP:MR and DP:ExFID in the Report - 314 bcf - and assume the average December 2024 HH price of $3/mmbtu, this equates to approximately $320 billion of potential additional producer revenue. Each $1/mmbtu increase in the HH price adds an additional $107 billion of potential

producer revenue over the period. The increase in revenue provides material economic benefits to the U.S.

The 2018 Report also notes that increased exports drive higher demand for labor, capital investment in NG production, and related goods used in NG production[7]. The 2018 Report then notes that increased exports of LNG will improve the U.S. trade balance, resulting in wealth transfer to the U.S., which increases the value of the dollar and reduces prices of imported goods[7]. As a result, households and businesses benefit from greater purchasing power due to lower prices on imported goods and services.

The effect of this is overall economic welfare - the sum of domestically produced and imported goods consumed by households increases. The 2018 Report says:

"*This is the fundamental reason for the overall increase in economic welfare and aggregate consumption as LNG exports increase"*[6].

Another benefit highlighted in the 2018 Report is that "if U.S. households, or their retirement funds, hold stock in natural gas producers, they will benefit from the increase in the value of their investment"[7] (this will also be true for gas infrastructure owners, such as LNG facility and pipeline operators). Many retirement funds hold oil and gas stocks, attracted by traditionally high dividends and growth potential, and therefore an expected economic effect would be for retirement funds to benefit.

The 2018 report also notes that new liquefaction facilities will require capital investment. If this capital originates from sources outside the U.S., it will represent another form of capital investment and economic benefit for the U.S[7]. If domestic capital is used, then the U.S. economy benefits further through returns to the investor or financier.

The 2018 Report finds that GDP benefits because NG production and export provide higher returns and as good or better wages than for many other industries[8]. And further reports that "all negatively affected sectors continue to grow robustly at higher levels of LNG exports, albeit at slightly lower rates of increase than they would at lower levels of LNG exports". These two points suggest that although some other industries may see slower growth in the event of higher LNG exports, these other industries would still grow robustly, plus the LNG export industry generates such high returns and higher wages that overall, this increases GDP.

An additional benefit not mentioned in the 2018 Report is the increased tax revenue, due to increase U.S. Exports, that would be collected by the U.S. Government. This tax revenue can then be spent on improved public services for the benefit of the U.S. population or reducing the deficit.

Although these additional benefits are difficult to quantify precisely, we believe that these continue to apply and are important. We therefore believe these key points should be considered in interpreting the results from 2024.

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[6] 2018 Report, pp.70

[7] 2018 Report, pp.64

[8] 2018 Report, pp.69

3.0 Opportunities to Improve the Report's Underlying Analysis

The 2024 Report provides a robust analysis demonstrating that U.S. LNG exports are in the public interest, delivering economic benefits, enhancing energy security, and reducing global greenhouse gas emissions by displacing more carbon-intensive fuels. However, while the report's findings support the positive role of U.S. LNG in global energy markets, certain aspects of the analysis could be refined in future iterations. Improved assumptions, enhanced data integration, and a more nuanced approach to market and emissions modeling would strengthen the report's conclusions and provide a more accurate representation of the long-term impacts of LNG exports. The following sections outline key areas for improvement.

The Report's suggestion that a 0.05% to 0.5% change in household energy expenditures is within the margin of error and likely is not statistically significant given the modeling's uncertainties.

Our understanding is that household expenditure and energy burden were calculated using the HEIDM model, which takes the gas and electricity price inputs from NEMS. NEMS has an Electricity Market Module (EMM) which models the electricity system of the U.S. Although NEMS is not open source, documentation on the EIA website gives some insight[9].

The EMM models the U.S. electricity system in each of 25 regions and by year, by dispatching different sources of power based on their cost using a levelized cost of electricity (LCOE) methodology where a cost is calculated for each electricity generation technology[10]. Each technology competes on cost for the electricity demand, with the lowest cost technology being used first, and the model solves iteratively for each region until demand for each time period is met. The modeling includes seasonal demand changes, emissions requirements, and electricity trade between regions. The EMM calculates the price of electricity based on the competitive prices for states that are deregulated, and the revenue requirement (i.e. electricity prices are capped based a regulated return on investment for the power producer) for states with regulated electricity markets. These output electricity prices are then used as inputs to HEIDM to calculate the cost of electricity to households. The LCOE method has limitations as it oversimplifies by having a single cost for each technology when in reality cost varies for each power station, and in each region. The electricity price modeling is in our view well documented and explained, and despite its limitations follows a reasonable approach considering the high level of the study.

There is little information on the HEIDM model other than that included in the 2024 Report[11]. However, HEIDM methodology appears to be less complicated than NEMS. It uses data on 7.5 million U.S. households collected by the American Community Survey (ACS) which includes household income and household energy expenditure by income group. HEIDM takes gas and electricity prices from NEMS and models the change on each income group. This in our view is a reasonable approach and gives a high-level overview of the impacts on each group. The sample size of 7.5 million is substantial and gives good credibility to this analysis. However, the source data from the ACS[12] shows the margins of error in the population data to be in the range of 0.2% - 0.5%. This is a very low margin of error, however the energy burden analysis in the

[9] https://www.eia.gov/outlooks/aeo/nems/overview/pdf/0581(2023).pdf and https://www.eia.gov/analysis/pdfpages/m068index.php

[10] For example, combined cycle gas turbine would be considered one technology, wind turbines would be another

[11] 2024 Report, Appendix B, pp B-8

[12] U.S. Census Bureau data tables - https://data.census.gov/

2024 Report indicates an increase in energy burden (with increasing exports) of between 0.05% and 0.5% depending on U.S. region[13] which is within the 0.5% margin of error in some of the data. There will also be further error margins in the input data to HEIDM because it receives data from NEMS, and there are uncertainties in input data to NEMS from GCAM. Therefore, there is a risk that energy burden results may not be statistically significant.

Any increase in electricity and NG prices would increase household energy burden. But the 2024 Report should consider the statistical significance of model outputs, contextualize the findings, and appropriately caveat these when discussing the results.

The 2024 Report shows that the regional NG price differentials increase in all regions with increased U.S. LNG exports. However, the projected increases in regional price differential are likely overstated because any increase would incentivize infrastructure development, increase NG trade flow between regions, and thus limit the divergence of regional prices.

According to the Report, in the DP:MR scenario, the wholesale NG price differential between the East, and the Gulf Coast regions in 2050 is projected to be:

- $1.4 / mmbtu (High U.S. Supply Case)
- $2.1 / mmbtu (MR Case)
- $4.2 / mmbtu (Low U.S. Supply Case)[14]

This is displayed graphically in Figure 2.

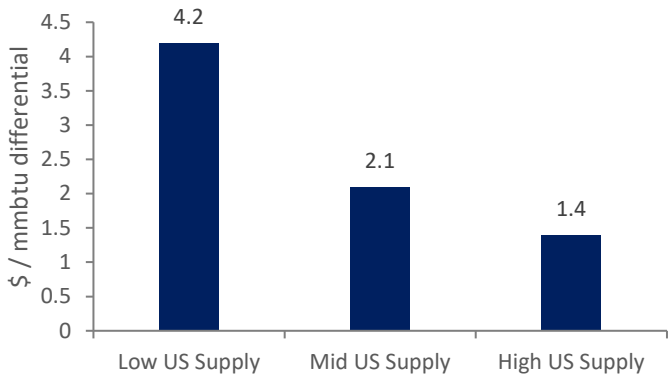

Figure 2. Gulf Coast gas price premium to East Coast in 2050, by U.S. Supply Case (DP:MR Scenario)

These figures, illustrated in Figure 2, suggest a substantial shift in regional pricing due to increased LNG exports. However, past data shows that, for example, both Illinois and Pennsylvania Citygate NG prices traded on average at a slight premium (of $0.45 / mmbtu and $0.2 / mmbtu respectively) to the Alabama Citygate price over the period 2022-2024.

It is highly unlikely that a long-term differential of $4.2 / mmbtu or $2.1 / mmbtu could exist between regions in such an interconnected market. When U.S. regional price differences widen significantly, pipeline infrastructure development becomes economically viable. In other words, this creates an opportunity for a gas transporter to build infrastructure to take advantage of this arbitrage so long as the cost of the pipeline is less than the difference in prices between the

[13] 2024 Report, Appendix B, pp B-49

[14] Data from 2024 Report, Appendix B, Table 17, pp.B-61 to 62

regions. The result of this is that the prices between the regions do not diverge further (other than during short term supply or demand shocks, such as rapid seasonal weather changes).

Industry data supports this perspective. For example, a 2021 research paper written in conjunction with the DOE and the National Renewable Energy Laboratory[15] estimates a cost of natural gas transmission in the U.S. of $3.7 per MWh per 1000 km, which equates to approximately $1.10/mmbtu per 1000km. Given that Pennsylvania is roughly 1,560 km from Alabama, and some areas of Tennessee are about 1,000 km from Alabama, we estimate that if Gulf Coast-East region price differentials exceed $1.1–1.7/mmbtu, new infrastructure would likely be developed, preventing further price divergence.

To improve the accuracy of price projections, we recommend that future DOE modeling includes a cap on regional price divergence, based on the cost of transporting NG between regions to simulate the effect of new infrastructure expansion in response to sustained price differentials.

Uncertainty in upstream supply chain emissions is not considered in the breakeven analysis, potentially understating the global emission benefits of U.S. LNG exports.

The uncertainty range in life cycle emissions intensity is just as important as the central estimate and should be considered when the results are employed. The 2024 Report Appendix C uses only the central estimate from the NETL Report. This ignores uncertainty in the project direct GHG emissions, which has implications for the overall consequential emissions.

Emissions Estimates and Uncertainty Ranges

- NETL estimates the U.S. average life cycle emissions to be 8.63 g CO_2e/MJ LHV 100-yr GWP AR6, with a 95% mean confidence interval (CI) of 5.4 – 12.8 g CO_2e/MJ[16] (production through transmission network).
- Scaling to a production through liquefaction basis, this equates to a central estimate of 9.2 g CO_2e/MJ of gas exported[17].
- DOE updated the liquefaction GHG emissions intensity from past studies, utilizing available data from operating liquefaction facilities. The production-weighted average based on 2020 data vintage was calculated to be 5.27 (or 5.3) g CO_2e/MJ lower heating value (LHV), 100-yr global warming potential (GWP), AR6[18] .
- The total project direct emissions intensity (production through liquefaction) used in the DOE modeling is the central estimate of 14.5 g CO_2e/MJ (LHV, 100-yr GWP).

Both NETL and DOE acknowledge the importance of uncertainty in emissions estimates:

- From the NETL 2024 Report[19]:

  "...the uncertainty estimates provided are just as important as the average values and should be considered when third parties use these estimates. Any users of these

[15] Daniel DeSantis, Brian D. James, Cassidy Houchins, Genevieve Saur, Maxim Lyubovsky, Cost of long-distance energy transmission by different carriers, iScience, Volume 24, Issue 12, 2021

[16] The NETL Report is on an HHV basis, but all DOE Consequential LCA results are on an LHV basis, so to avoid confusion, LHV is used here.

[17] NETL estimates that 1.07 kg of natural gas is delivered to the liquefaction facility per 1 kg of LNG produced. This scaling is reported in the DOE Consequential study Appendix C.

[18] IPCC Sixth Assessment Report, 100-yr GWP of methane = 29.8

[19] https://www.netl.doe.gov/energy-analysis/details?id=546d4009-c43b-43f5-bcc9-64d5e63fc8d5

estimates should ensure that the characterization of uncertainty fits their goals and that the uncertainty is incorporated into their analyses."

- From the 2024 Report (DOE):

  "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. […] A full uncertainty analysis encompassing all underlying factors is beyond the scope of this study." Note that no one technology-policy scenario is more likely or correct than another, as DOE states *"the study does not attach probabilities to any of the scenarios examined."*

Implications: Emissions Benefits of U.S. LNG

Incorporating the published uncertainty range from NETL into the overall project direct emissions calculated results in a range of 11 to 19 g CO_2e/MJ on a 100-yr GWP basis. **This means the "true" average U.S. LNG emissions intensity could fall anywhere within this range.** Further, when considering uncertainty in the U.S. production through transmission supply chain emissions, several "breakeven emission intensities" overlap with the 95% CI. **This indicates in some scenarios that consequential emissions intensity could be net negative, meaning a global decrease in emissions relative to the reference case**. The uncertainty range is just as important as the central estimate in interpreting results.

Figure 3 illustrates this relationship:

- The breakeven emissions intensity for each scenario (calculated based on the percentages in Table 27 of the Report) is shown as a vertical bar.
- The horizontal lines are the U.S. LNG project direct emissions intensities, shown as
  - the lower bound of the 95% CI,
  - the central estimate (used in the Report), and
  - the upper bound of the 95% CI.

When the breakeven bars intersect with one of the horizontal lines, the consequential GHG intensity is potentially negative. In other words, if uncertainty had been considered in the analysis, some of the results presented in the conclusions may have changed. The overlap of

the 95% CI and the breakeven rate indicates there is potential for the net consequential emissions intensity to be negative even with the global increases of energy services provided.

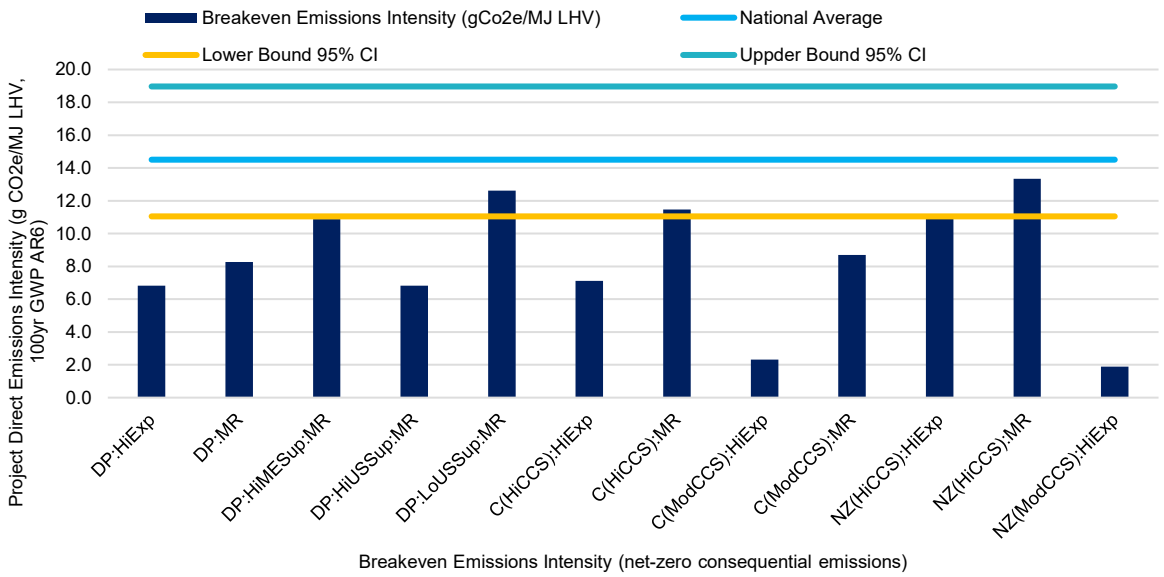

Figure 3. Breakeven Emissions Intensity versus 95% CI for Upstream Emissions Intensity. NETL 95% CI in upstream U.S. Average emissions intensity has been incorporated into the total project-direct emissions.

Upstream U.S. supply chain emissions intensity is just one potential source of uncertainty in Appendix C. Throughout, uncertainty in the emission estimates is not discussed in reference to the results and it is unclear if it is accounted for in any way in the modeling. The various technology and policy scenarios serve as a bounding exercise to handle uncertainty in the energy mix, but this does not account for the equally important uncertainty in the emissions intensity of the many energy supply chains represented in the model.

Considerations to Enhance U.S. LNG Emissions Modeling

The assumption that U.S. LNG life cycle emissions intensity will remain constant through 2050 is a key area for improvement in future analyses. The 2024 DOE report holds U.S. LNG export emissions intensity flat at 14.5 g CO2e/MJ (LHV, production through liquefaction), based on 2020 data from NETL and the EPA Greenhouse Gas Reporting Program (GHGRP). While 2020 data may provide a reasonable short-term emissions estimate, it is unlikely to accurately reflect emissions trends through 2050, given ongoing regulatory measures and voluntary industry initiatives aimed at reducing emissions.

Impact of Baseline Year Selection on Emissions Estimates

The choice of baseline data year and life cycle assessment (LCA) model significantly influences results. A recent peer-reviewed[20] study using Cheniere's proprietary LCA model offers an important benchmark. This study, which relied on GHGRP data and similar U.S. supply chain assumptions (e.g., 600 miles of pipeline, 10 compressor stations), estimated the 2022 U.S. average life cycle emissions intensity for the production-through-transmission network at:

- 0.38 tonne CO2e/tonne LNG (100-year GWP, AR6)

[20] https://pubs.acs.org/doi/10.1021/acssuschemeng.4c07162

- 7.76 g CO2e/MJ (converted using 49 MJ/kg LHV)

This 7.76 g CO2e/MJ estimate is 10% lower than NETL's 2020 estimate of 8.63 g CO2e/MJ, indicating that emissions intensity may already be declining. While this estimate falls within NETL's 95% confidence interval, the DOE report does not fully account for such uncertainty, making the specific choice of average emissions intensity a critical factor in interpreting results.

Projected Emissions Reductions

A more comprehensive approach to emissions modeling should:

- Use the latest available emissions data to reflect ongoing industry advancements.
- Incorporate dynamic emissions projections, rather than assuming emissions remain constant through 2050.

While forecasting emissions intensity over the next three decades involves uncertainty, multiple factors suggest that U.S. LNG emissions intensity will continue to decline:

Voluntary Initiatives

- In recent years, industry participation in voluntary methane reduction initiatives has expanded, improving measurement, reporting, and mitigation strategies.
- Half of AXPC members are OGMP 2.0 (the Oil and Gas Methane Partnership 2.0) members demonstrating their strong commitment to transparent emissions tracking, reporting, and verification, as well as to methane emission reductions.
- 90% of AXPC members have quantitative emission reduction goals tied to corporate compensation.
- 100% of AXPC members have a commitment to end routine flaring by 2030 or have already eliminated the practice from their operations.
- The Clean Air Task Force estimated in a 2024 report that the U.S. upstream industry had reduced its NGSI Methane Intensity by 57% since 2015.[21]

Regulatory Drivers

- The Final New Source Performance Standards (NSPS) and Emissions Guidelines (EG) under 40 CFR part 60 subparts OOOOb and OOOOc are projected to reduce 58 million short tons of methane emissions from 2024 to 2038.[22]

Top-Down Trends

- Satellite-based methane observations from oil and gas production regions in North America indicate a steady decline in methane emissions intensity from 2010 to 2019.
- U.S. average methane emissions intensity fell 0.13% per year, decreasing from 3.7% in 2010 to 2.5% in 2019.
- Of the eight largest oil and gas producing regions, six exhibited a downward trend in methane intensity.

[21] https://www.catf.us/resource/benchmarking-methane-other-greenhouse-gas-emissions/

[22] https://www.epa.gov/system/files/documents/2023-12/eo12866_oil-and-gas-nsps-eg-climate-review-2060-av16-ria-20231130.pdf

- Figure 3, from the PNAS paper (April 2023, Figure 4), illustrates these trends in annual average methane emissions intensity from U.S. oil and gas operations.

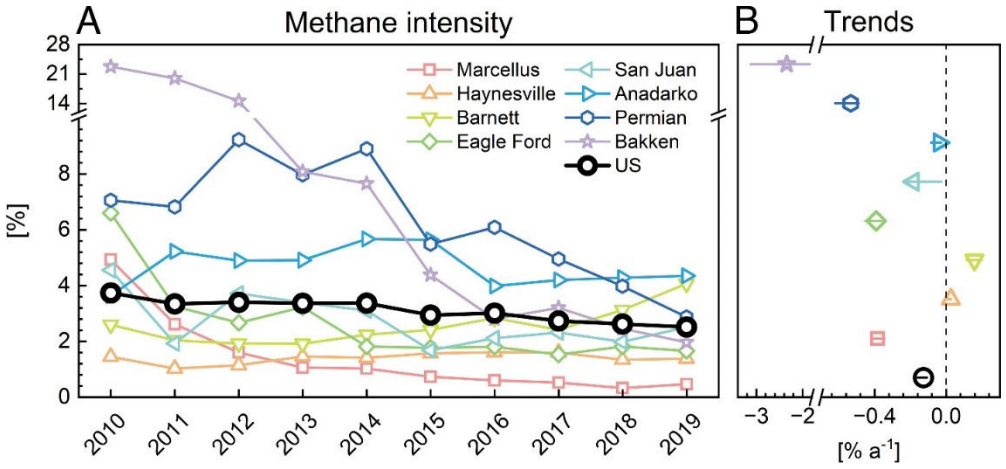

Figure 4. Methane intensity in major U.S. oil and gas producing regions based on satellite measurements, as published by Lu et al. in PNAS, April 2023[23]

Future Research Considerations

The continued focus on GHG emissions reductions, particularly methane, suggests that emissions intensity will decline further, though not necessarily at the same rate as seen from 2010 to 2019, when many of the most cost-effective mitigation measures were first implemented. Future consequential life cycle assessments (CLCA) must integrate these observed downward trends in emissions intensity when evaluating the net climate impact of U.S. LNG exports.

While regional and operator-specific variations will persist, the overall trend across available data and expected federal regulations indicates that U.S. LNG emissions intensity is unlikely to remain static and should be modeled accordingly in future analyses.

The assumption of a constant U.S. LNG life cycle emission intensity through 2050 is an area for improvement in future analysis. The choice of baseline data year (2020) has implications on the results, and the paired drivers of regulatory and voluntary initiatives suggests emissions intensity will trend downward in the future.

Future study updates should consider life cycle supply chain emissions uncertainty, and enhance the representation of emissions intensity projected through 2050, incorporating measurement-informed data domestically and globally, particularly for methane emissions.

As shown above, the net consequential emissions intensity is sensitive to the choice of data year. Future analysis would be improved with updated data vintage and more thorough consideration of model uncertainty in the results reporting and interpretation. Further consideration should be given to representing future emissions, as U.S. supply chain GHG intensity is unlikely to remain constant from 2020 through 2050. Additionally, future CLCA research must incorporate more empirical data, specifically for methane, to improve data quality of the inputs and thereby improve the quality of the outputs.

[23] Observation-derived 2010-2019 trends in methane emissions and intensities from US oil and gas fields tied to activity metrics | PNAS

While NETL has incorporated some measurement-informed data sources into their recent work, there is more work to be done to ensure fair comparison of the emissions intensity of global gas sources. The NPC[24] report outlines some of the key challenges that must be overcome to robustly incorporate direct measurement data into LCAs. Future work should focus on overcoming these challenges and incorporating empirical data into LCA models, **and this must be considered for operations not only in the U.S. but globally. It is just as important to accurately represent the emissions of global energy supply chains as it is U.S. LNG supply chains when determining the consequential emissions intensity of increased U.S. LNG exports**, particularly given U.S. LNG is found to largely substitute other global sources of natural gas in the 2024 Report. These methane data concerns must be addressed across global natural gas supply chains.

Given established uncertainties, modeling projections further out in time only raise the uncertainty and undercuts the credibility of those projections.

The 2024 Report projects results out to 2050. Considering that the report deals with high levels of uncertainty, it is therefore likely that uncertainty will grow to be higher in results for 2050 than for results closer to present.

The report states that "there should be recognition of the inherent uncertainty in conclusions, especially given their size relative to the overall global economy and energy system"[25]. However, key conclusions are given with precise levels of accuracy. For example, the report shows an increase in the HH price from $3.53 / mmbtu to $4.62 / mmbtu, which is to the nearest cent. In the results for energy burden, an increase of 0.05% is reported for one of the regions[26].

Given these high levels of established uncertainties, the focus of the Report's analysis should be on the high-level trends shown in the data rather than the precise figures. Any future updated reports should also consider applying error margins where possible and rounding figures to an appropriate level of accuracy to avoid giving the impression of high levels of accuracy.

4.0 The Executive Summary Does Not Capture the Report's Key Findings, Supporting Analysis, and Global Considerations

The Executive Summary Omits Critical Findings Highlighting the Benefits of U.S. LNG.

The 2024 Report contains key findings on the important contribution of U.S. LNG Exports to worldwide energy security. The Executive Summary accompanying the Report's release[27] explains that the U.S. provides cost-competitive LNG to the global market and has an important role in diversifying energy supply for the world. However, it also highlights that European policies are moving to reduce the use of fossil fuels, and that China has become the largest importer of LNG and is expected to have the highest LNG imports in 2050. Beyond that, the Executive Summary skirts past some of the more positive findings included in the Report.

The 2024 Report explains that increasing LNG exports by 32.6 Bcf/d leads to a 28% (30.2 Bcf/d) increase in gas production and no change in domestic consumption. This indicates that the incremental NG demand for U.S. LNG exports can be met with additional U.S. natural gas

[24] https://chartingthecourse.npc.org/

[25] 2024 Report, Summary Report, pp. S-v

[26] 2024 Report, Appendix B, pp B-49

[27] 2024 Report, Summary Report, pp. S-5 and S-6

production[28], that there is enough NG to supply both export and domestic consumers and therefore U.S. domestic consumers have security of supply.

The report also explains that with increasing LNG exports, the U.S. becomes more influential in the global energy market. For example, in 2024, the U.S. supplied 55% of Europe's LNG, whereas a decade earlier the U.S. exported no LNG at all. We would add that since the start of the Ukraine war, the U.S. has had a key role in helping to replace the reduced flows of Russian gas which is important for European industries and consumers. The U.S. now has a leading role in Europe's energy security, due to this shift in gas supply coming from the west rather than the east, and has strengthened U.S. – Europe relations whilst also bringing economic benefits to the U.S.

In saying that EU legislation has been passed to phase out fossil fuels, whilst also saying that China is the world's largest LNG importer, the 2024 Report could be seen to be implying that the U.S. will be supplying China with gas. However, this narrative does not consider that although China is now the world's largest LNG importer, its 2023 share of worldwide LNG imports was 18%[29]. Worldwide demand is spread across multiple countries (for example, in 2023, Europe accounted for 31% of demand, Japan 16.5%, and Korea 11%). In 2023, 34% of China's LNG came from Australia, 23% from Qatar and only 4% from the U.S.[30]. Therefore, although China is the world's largest importer of LNG, it does not import even close to a majority of the world's LNG, and only 4% of China's LNG comes from the U.S.

Section B of the Executive Summary of the Report should highlight that the modeling shows that U.S. domestic energy security is secure, even with increased exports. It should also more strongly highlight the positives of U.S. LNG on worldwide energy security and how this increases the influence of the U.S and mitigates the effect of the Ukraine war on Europe.

The 2024 Report does say that 'the destination of U.S. LNG in the future is less certain'[27], and it would be highly speculative to predict where U.S. LNG will be exported to in 2050. The comments regarding China in the report could be further contextualized with recent figures on China's share of worldwide imports.

Increased LNG Exports increases global energy access and fosters vast socioeconomic improvements across the world

In modern times, no country has managed to substantially reduce poverty without greatly increasing the use of energy. Moreover, in areas with the highest poverty, people pay a high price for the energy they use (in cash or labor) because their incomes are low and the fuels they use are so much less efficient. There are estimated to be 600 million people in Sub-Saharan Africa without access to electricity[31]. Modern energy boosts productivity and income, improves healthcare and education and reduces environmental and health damage from traditional fuels such as firewood[32]. A reliable source of gas can be used for a gas to power project and directly by industry to power factories. Energy access is usually a cause of economic development, rather than an effect (causation rather than correlation).

As a case study, Ghana has seen electricity access increase from 45% to 84% of the population, and clean cooking fuel access increase from 6% to 25%, from 2000 to 2018. Over

[28] 2024 Report, Summary Report, pp. S-31

[29] Energy Institute Statistical Review of World Energy 2024, Source Data workbook, 'Gas – LNG Imports Bcm' sheet

[30] Energy Institute Statistical Review of World Energy 2024, Source Data workbook, 'Gas Trade – LNG' sheet

[31] IEA Africa Energy Outlook 2019 (https://www.iea.org/reports/africa-energy-outlook-2019)

[32] Jamal Saghir, World Bank, Energy and Poverty: Myths, Links, and Policy Issues, No.4, May 2005

the same period, GDP increased by 300% from $63 billion to $191 billion (2018 U.S. Dollars)[33]. Many Sub-Saharan African countries have much lower electricity access, with Tanzania having 37% and Ethiopia 45% in 2018[31], indicating that there is an unmet need for electricity across the continent. In many countries gas is a key component of the power generation mix.

Increased access to gas and power increases global services. Access to cheaper and more reliable energy reduces business costs and increases productivity in areas that previously did not have access to energy. This increases the goods and services available for domestic consumers and for export. Increased job opportunities and wages as a result of the economic growth also increase the number of people who can afford to pay for these goods and services, thus driving further growth in global services.

By increasing gas supply to the world, the U.S. can contribute to increasing access to gas and electricity, increasing global services, and therefore driving economic development to help lift people out of poverty.

[33] IEA Ghana Energy Outlook (https://www.iea.org/articles/ghana-energy-outlook)