From Shale to Ship: The Potential for Lower Carbon U.S. LNG Production

Thomas N. Russo

Many liquified natural gas (LNG), oil, and natural gas companies in the United States are committed to reducing emissions, achieving the nation's climate commitments, and continuing America's role of providing reliable, ever-cleaner energy to US allies worldwide.[1] The central question is how quickly these companies can achieve these goals and provide significant supplies of lower-carbon LNG to global customers.

This author believes that US LNG producers and customers can catalyze and accelerate the production of lower-carbon LNG. Other factors that will accelerate this transition include: (1) extreme climate events that will drive customer preferences; (2) the effectiveness of new environmental regulations; (3) technological improvements; (4) permitting of interstate natural gas pipelines; and (5) global LNG price levels.

[1] CLNG, API & NGSA. (2023, June 26). Joint comments to U.S. Department of Energy Notice of Request for Information on Opportunities to Reduce Greenhouse Gas Emissions and Other Air Pollutants Associated with U.S. Liquefied Natural Gas Exports (No. DE–FOA–0003052). Retrieved from https://bit.ly/44QFxTj.

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DEFINITION AND OVERVIEW

Before discussing the above factors, it is important to define what lower-carbon LNG is. This author believes lower-carbon LNG is not restricted only to measures taken by the LNG export facility. Instead, lower-carbon LNG production and cargo must reflect a set of practices and mitigation measures implemented from shale-to-ship at a minimum.

Lower-carbon US LNG production would create a competitive edge for US LNG export companies competing in the global market and improve the energy security of the US and its allies.

US LNG, oil, and natural gas companies will soon face new regulations requiring them to reduce and assess greenhouse gases (GHG), which include carbon dioxide (CO_2), methane, and nitrogen oxide (NOx). Most of these federal regulations stem from provisions of the Inflation Reduction Act (IRA), Clean Air Act (CAA), Protecting Our Infrastructure of Pipelines Enhancing Safety (PIPES) Act of 2020, and the National Environmental Policy Act (NEPA). In the short term, these requirements will be burdensome for the industry. However, in the long run, they can result in lower-carbon US LNG production and cargo that benefit LNG companies and buyers who use LNG for heating, power production, and cooling large buildings. Other lower-carbon US LNG production beneficiaries include fertilizer and hydrogen producers since natural gas is a primary feedstock for these industries. Lower-carbon US LNG production would create a competitive edge

Figure 1. Major LNG export trade flows in 2022

for US LNG export companies competing in the global market and improve the energy security of the US and its allies. This author believes the faster the industry can achieve lower-carbon LNG production, the greater the likelihood of extending natural gas as a global bridge fuel to renewable energy generation.

Two issues warrant increased efforts to produce lower-carbon US LNG. The first is the increasing role of the US as the leading global LNG supplier, especially to Europe and the United Kingdom **(Figure 1),** and the growth of LNG Import (regasification) terminals globally.

Growth in LNG regasification capacity in Europe is due to the curtailment of Russian pipeline natural gas following the ongoing conflict between Russia and Ukraine. Asian and Middle East countries have also added regasification facilities due to heightened concerns regarding global warming as record heat waves, droughts, and significant flooding impact more countries **(Figure 2)**.[2] In 2022, the LNG industry added 31.2 Million Tons per Annum (MTPA) of regasification capacity. These projects included nine new import terminals and the completion of three expansion projects at existing terminals in the Netherlands, Croatia, and China. The most significant regasification capacity addition in 2022 was from Nong Fab LNG in Thailand, with 7.5 MTPA.[3]

US LNG companies must use their combined purchasing power to persuade natural gas producers, gatherers, processing plants, and pipelines to aggressively decarbonize their facilities and O&M practices.

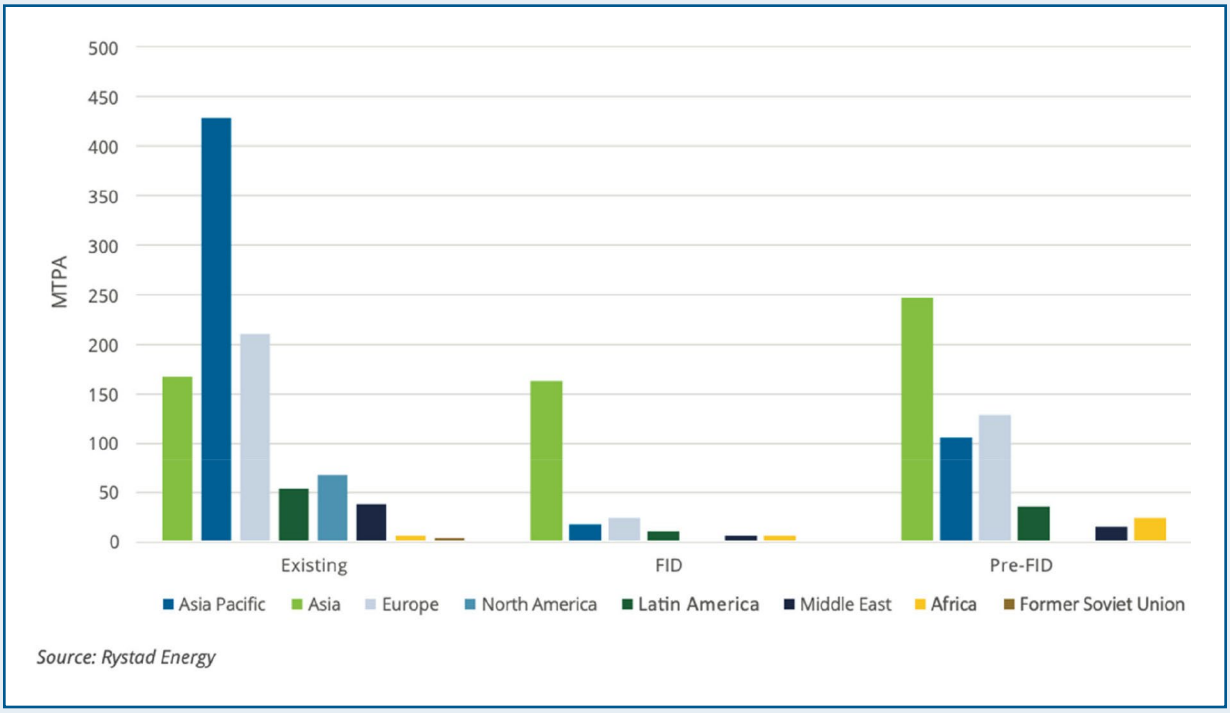
Whether the US LNG companies will capitalize on these regulations and prioritize GHG emissions reduction is still an open question. Indeed, the industry will have to comply with the regulations. However, this author believes the US LNG industry must go beyond mere compliance and change its current operation and maintenance (O&M) practices.

US LNG companies must use their combined purchasing power to persuade natural gas producers, gatherers, processing plants, and pipelines to aggressively decarbonize their facilities and O&M practices. The industry must also partner with equipment manufacturers to inform them of the need for

[2] Patterson, S., Hiller, J., & Lukpat, A. (2023, July 15). Weeks of extreme heat strain small businesses and economy. *The Wall Street Journal*. Retrieved from https://on.wsj.com/3DJ0bZM

[3] International Gas Union. (2023, July 12). *2023 World LNG report (14th ed.).* Retrieved from https://bit.ly/3CU1V1b

Figure 2. Major LNG export trade flows in 2022



technologies to help meet the new regulatory requirements. This author discusses the "carrots and sticks" that the US LNG industry and other companies in the supply chain must contend with and some tools available to produce lower-carbon LNG.

GLOBAL AND US LNG INDUSTRY POSITIONS ON REDUCING GHG EMISSIONS

Decarbonization is becoming more prominent in the US LNG industry's project pipeline and news releases. Cheniere, Sempra Energy, NextDecade, and Egyptian LNG are considering using carbon capture, utilization, and storage (CCUS) in their liquefaction plants to reduce carbon emissions. In Canada, the Cedar LNG and Woodfibre LNG projects are not relying on CCUS. Instead, they plan to use renewable hydroelectricity to power their liquefaction operations.[4] Other LNG companies are considering feedstocks such as renewable natural gas or biomethane to produce lower-carbon LNG. While encouraging, this author believes that CCUS or biomethane are not "silver bullets" for the industry due to technology risks. Implementing a CCUS project at an LNG export terminal is also limited by existing CO_2 pipeline infrastructure and geological caverns to sequester the gas. Also, building new CO_2 pipelines may be challenging due to public opposition.

On June 26, 2023, the US LNG, oil and natural gas industry represented by the Center for LNG (CLNG), American Petroleum Institute (API), and Natural Gas Supply Association (NGSA) filed Joint Comments to the US Department of Energy's (DOE) Request for Information on Opportunities to reduce GHGs from LNG exports.[5] The Joint Comments are extraordinary because they recognize that producing lower-carbon LNG requires actions upstream, at the LNG facility, and on the water. The Joint Comments also identify current technologies used and ways to measure results **(Table 1)**.

ROLE OF UPSTREAM AND MIDSTREAM OIL AND GAS COMPANIES

The level of success that upstream and midstream oil and natural gas companies have in

[4] Ibid.

[5] See Note 1.

Table 1. Technologies and strategies used to mitigate GHG emissions and other environmental impacts of LNG and upstream gas facilities

LNG Facilities	
• **High-efficiency gas turbines:** using high-efficiency gas turbines requires less natural gas, reducing emissions from the liquefaction process. • **Electrification:** electrification of components of the liquefaction process can reduce facility emissions. Operators are also committing to sourcing renewable energy to power their electrified processes. • **Waste heat recovery:** liquefaction facilities capture heat emitted from liquefaction processes before entering the atmosphere. This heat can then be used in other processes or to generate electricity. • **Seal gas recovery:** compressors used at liquefaction facilities can result in small amounts of natural gas into the atmosphere. Seal gas recovery captures this gas before it can be emitted.	• **Leak detection and repair (LDAR):** LDAR programs allow operators to quickly identify and repair leaks, minimizing the emissions associated with the leaked gas entering the atmosphere. • **Pressure safety valve monitoring:** leaky valves may result in unintentional emissions. Increased monitoring of these valves improves leak detection, minimizing subsequent gas leaks. • **Compressed air valve control:** LNG facilities may use compressed air to control valves (instead of using natural gas), which reduces vented emissions. • **Pipe flange management**: using specific types of pipe flanges and ensuring regular inspection and maintenance can reduce vented emissions. • **Pneumatic devices:** see Upstream Facilities • **Flaring reductions:** see Upstream Facilities • **Carbon capture and storage:** see Upstream Facilities
At Upstream Activities	
• **Electrification:** natural gas production sites by using lower-emission power (wind, solar, hydro, and natural gas). • **Flaring reductions:** upstream producers are employing programs to eliminate and reduce routine flaring. • **Methane detection and monitoring:** use of forward looking infrared (FLIR) handheld gas detection scanners, drone/aerial technologies, and in-plant gas monitoring systems in leak detection and repair programs. Detection of fugitive emissions enables operators to quickly identify and repair leaks. • **Pneumatic devices**: transitioning from high-bleed pneumatic devices to low- or no-bleed devices or electrical pumps or controllers can reduce vented emissions. • **Commercializing and scaling carbon capture and storage (CCS):** investing in CCS and assessing the potential to implement CCS at natural gas processing facilities will greatly reduce emissions. • **Offsetting emissions:** employing high-quality carbon credits to offset emissions that cannot be reduced through operational changes.	

Source: See Note 1.

reducing GHGs will determine US LNG companies' ability to produce lower-carbon LNG. If producers and pipeline companies don't reduce their GHG emissions, opposition to drilling wells on federal land and new interstate natural gas pipelines will grow.

The US ranks sixth for flaring volumes and intensity amongst the top 10 countries **(Figure 3)**.[6] The CAA and EPA enforcement regulations are responsible for lower-carbon emissions in the US. These data support claims that US LNG facilities already produce lower-carbon cargo than other LNG exporting companies. However, as discussed below, new GHG emission reduction regulations will enable the US LNG industry to widen the gap with other global LNG producers, notably Russia, and appeal to countries that wish to purchase lower-carbon cargos.

As shown in **Figure 4**, US LNG facilities alone contribute relatively small amounts of GHG emissions. The most significant GHG emitters are companies involved in oil and gas production, gas gathering and boosting, gas processing, and natural gas transmission (pipelines). It is clear that lower-carbon US LNG production will not be attainable without significant GHG emission reductions upstream.

[6] The World Bank. (2022). Global gas flaring data. Global Gas Flaring Reduction Partnership (GGFR). Retrieved from https://bit.ly/3YqKlNd

Figure 3. Flaring volumes and intensity of major oil and gas-producing countries

Source: See Note 6.

US LNG companies can use their growing purchasing power of feed gas to influence natural gas producers, processors, and pipelines to reduce their GHG emissions. The US LNG fleet currently exports between 10 to 14 billion cubic feet per day (Bcf/d) of LNG.[7] Natural gas producers are all anxious to reach global markets. However, they won't be able to without new interstate natural gas pipelines. As discussed below under "Higher Social Cost of Greenhouse Gases and Environmental Reviews," the overall natural gas industry's growth, especially US LNG, is tied to whether new interstate natural gas pipelines can be timely permitted and constructed.

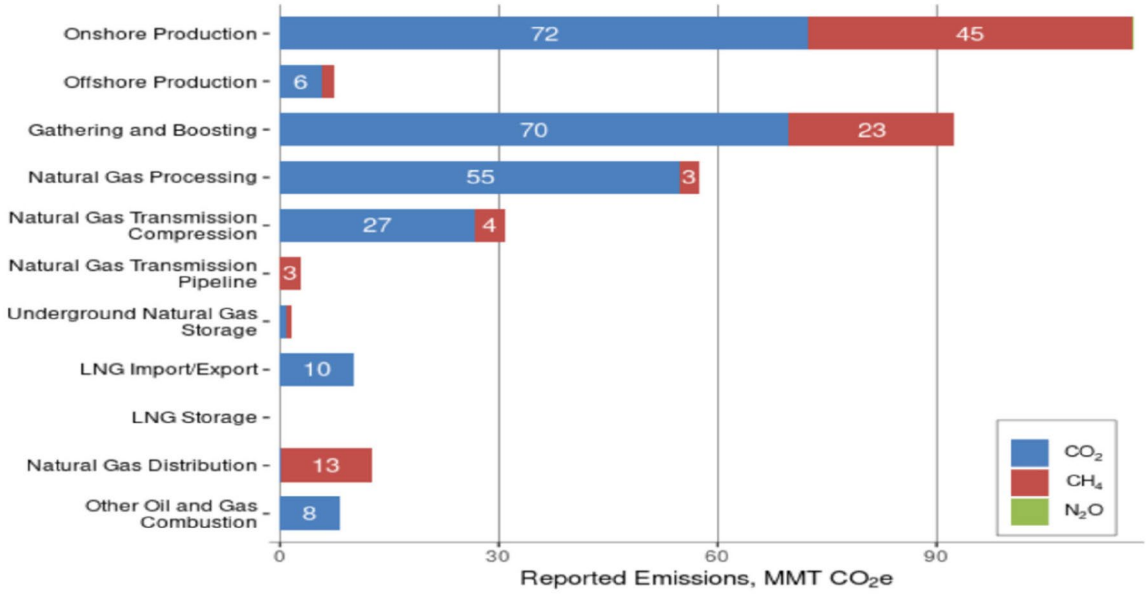
Some operating US LNG facilities and those under construction are comparable to large natural gas utilities. As shown in **Table 2**, the Federal Energy Regulatory Commission's (FERC) Form 552 Annual Natural Gas Report shows that Sabine Pass Liquefaction's gas purchases of 669 Bcf in 2022 were 1.7 times greater than 395.5 Bcf of natural gas purchased by Southern California Gas Company (SoCalGas), a large natural gas utility.

Based on FERC data dated July 11, 2023, five new US LNG export projects totaling 11.83 Bcf/day of capacity are under construction.[8] Also, another 12 projects totaling 17 Bcf/day have regulatory approval but have not begun construction. Even

[7] Operating US LNG Export facilities include Cove Point, Cameron, Sabine Pass, Corpus Christi, Freeport, Calcasieu Pass and Elba Island.

[8] Federal Energy Regulatory Commission. (2023, July 27). *North American LNG export terminals—existing, approved not yet built, and proposed.* Retrieved from https://bit.ly/44KaS9S

Figure 4. Sources of GHG emissions in the oil and gas industry



Source: US 2019 EPA Greenhouse Gas Reporting Program

if LNG companies only build half of the approved LNG projects, it will add a significant demand for feed gas and pipelines to transport it. LNG companies would be better positioned to influence upstream and midstream companies to decarbonize or not purchase their gas.

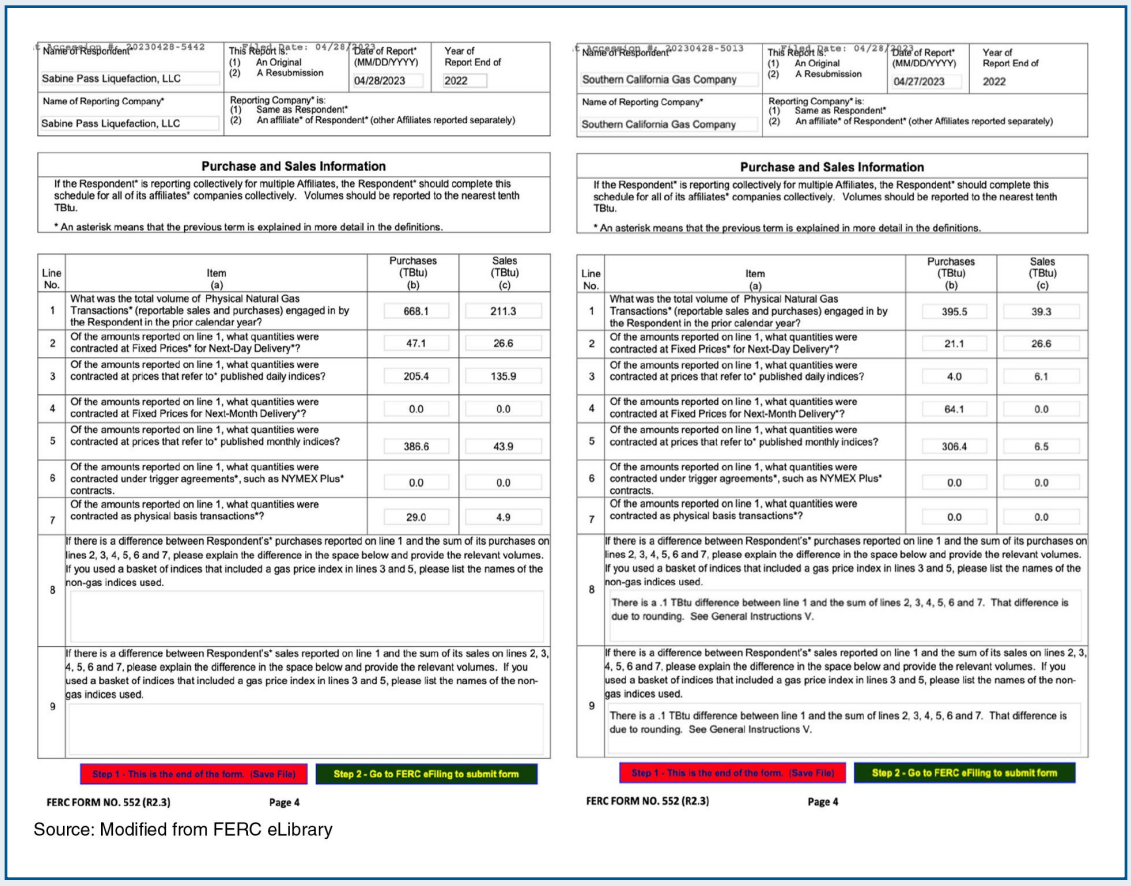
DRIVERS BEHIND DECARBONIZATION OF US LNG

Many recent laws and proposed regulations will drive the decarbonization of US LNG and upstream and midstream oil and natural gas companies. EPA's proposed methane reduction regulations and charge provisions will affect most oil and natural gas infrastructure, except for natural gas utility distribution lines (**Figure 5**). However, the Pipeline & Hazardous Material Administration's (PHMSA) proposed methane reduction regulations will require natural gas pipeline, distribution, and LNG facilities to measure, report and reduce emissions quickly. As discussed above, DOE contacted the industry for comments on reducing GHG emissions from LNG exports.

Table 3 indicates that EPA will target the 846 facilities that comprise onshore oil and gas production, gas gathering, and boosting. These facilities emit 66.1 million metric tons of carbon dioxide equivalents ($MMTCO_2e$), or 84 percent of the emissions reported each year. EPA will also pay closer attention to the 624 natural gas pipeline compressor stations and the 457 natural gas processing plants since they affect landowners and environmental justice (EJ) communities.

EPA will assess penalties for non-compliance based on the Methane Charge provisions in the IRA **(Table 4).** This author believes that the penalty provision is designed to make it very expensive for oil and gas companies to continue their operations as "business as usual." Methane charges begin at $900 per metric ton of methane in fiscal year (FY) 2026 and rise to $1,500 per ton in FY 2028. The Congressional Budget Office estimates that revenues will decline significantly between $850 million and $1.4 trillion in FY 2028 as companies take steps to reduce methane emissions.

Table 2. Comparison of annual natural gas purchases in 2022 by Sabine Pass Liquefaction LLC and SoCalGas



Sabine Pass Liquefaction, LLC

Name of Respondent	This Report is:	Date of Report* (MM/DD/YYYY)	Year of Report End of
Sabine Pass Liquefaction, LLC	(1) An Original (2) A Resubmission	04/28/2023	2022

Name of Reporting Company*	Reporting Company* is:
Sabine Pass Liquefaction, LLC	(1) Same as Respondent* (2) An affiliate* of Respondent* (other Affiliates reported separately)

Purchase and Sales Information

If the Respondent* is reporting collectively for multiple Affiliates, the Respondent* should complete this schedule for all of its affiliates* companies collectively. Volumes should be reported to the nearest tenth TBtu.

* An asterisk means that the previous term is explained in more detail in the definitions.

Line No.	Item (a)	Purchases (TBtu) (b)	Sales (TBtu) (c)
1	What was the total volume of Physical Natural Gas Transactions* (reportable sales and purchases) engaged in by the Respondent in the prior calendar year?	668.1	211.3
2	Of the amounts reported on line 1, what quantities were contracted at Fixed Prices* for Next-Day Delivery*?	47.1	26.6
3	Of the amounts reported on line 1, what quantities were contracted at prices that refer to* published daily indices?	205.4	135.9
4	Of the amounts reported on line 1, what quantities were contracted at Fixed Prices for Next-Month Delivery*?	0.0	0.0
5	Of the amounts reported on line 1, what quantities were contracted at prices that refer to* published monthly indices?	386.6	43.9
6	Of the amounts reported on line 1, what quantities were contracted under trigger agreements*, such as NYMEX Plus* contracts.	0.0	0.0
7	Of the amounts reported on line 1, what quantities were contracted as physical basis transactions*?	29.0	4.9
8	If there is a difference between Respondent's* purchases reported on line 1 and the sum of its purchases on lines 2, 3, 4, 5, 6 and 7, please explain the difference in the space below and provide the relevant volumes. If you used a basket of indices that included a gas price index in lines 3 and 5, please list the names of the non-gas indices used.		
9	If there is a difference between Respondent's* sales reported on line 1 and the sum of its sales on lines 2, 3, 4, 5, 6 and 7, please explain the difference in the space below and provide the relevant volumes. If you used a basket of indices that included a gas price index in lines 3 and 5, please list the names of the non-gas indices used.		

Step 1 - This is the end of the form. (Save File) Step 2 - Go to FERC eFiling to submit form

FERC FORM NO. 552 (R2.3) Page 4

Southern California Gas Company

Name of Respondent	This Report is:	Date of Report* (MM/DD/YYYY)	Year of Report End of
Southern California Gas Company	(1) An Original (2) A Resubmission	04/27/2023	2022

Name of Reporting Company*	Reporting Company* is:
Southern California Gas Company	(1) Same as Respondent* (2) An affiliate* of Respondent* (other Affiliates reported separately)

Purchase and Sales Information

If the Respondent* is reporting collectively for multiple Affiliates, the Respondent* should complete this schedule for all of its affiliates* companies collectively. Volumes should be reported to the nearest tenth TBtu.

* An asterisk means that the previous term is explained in more detail in the definitions.

Line No.	Item (a)	Purchases (TBtu) (b)	Sales (TBtu) (c)
1	What was the total volume of Physical Natural Gas Transactions* (reportable sales and purchases) engaged in by the Respondent in the prior calendar year?	395.5	39.3
2	Of the amounts reported on line 1, what quantities were contracted at Fixed Prices* for Next-Day Delivery*?	21.1	26.6
3	Of the amounts reported on line 1, what quantities were contracted at prices that refer to* published daily indices?	4.0	6.1
4	Of the amounts reported on line 1, what quantities were contracted at Fixed Prices for Next-Month Delivery*?	64.1	0.0
5	Of the amounts reported on line 1, what quantities were contracted at prices that refer to* published monthly indices?	306.4	6.5
6	Of the amounts reported on line 1, what quantities were contracted under trigger agreements*, such as NYMEX Plus* contracts.	0.0	0.0
7	Of the amounts reported on line 1, what quantities were contracted as physical basis transactions*?	0.0	0.0
8	If there is a difference between Respondent's* purchases reported on line 1 and the sum of its purchases on lines 2, 3, 4, 5, 6 and 7, please explain the difference in the space below and provide the relevant volumes. If you used a basket of indices that included a gas price index in lines 3 and 5, please list the names of the non-gas indices used.	There is a .1 TBtu difference between line 1 and the sum of lines 2, 3, 4, 5, 6 and 7. That difference is due to rounding. See General Instructions V.	
9	If there is a difference between Respondent's* sales reported on line 1 and the sum of its sales on lines 2, 3, 4, 5, 6 and 7, please explain the difference in the space below and provide the relevant volumes. If you used a basket of indices that included a gas price index in lines 3 and 5, please list the names of the non-gas indices used.	There is a .1 TBtu difference between line 1 and the sum of lines 2, 3, 4, 5, 6 and 7. That difference is due to rounding. See General Instructions V.	

Step 1 - This is the end of the form. (Save File) Step 2 - Go to FERC eFiling to submit form

FERC FORM NO. 552 (R2.3) Page 4

Source: Modified from FERC eLibrary

On May 4, 2023, PHMSA released proposed regulations entitled "Pipeline Safety: Gas Leak Detection and Repair."[9] The rule is a part of the PIPES Act of 2020 that would reduce methane emissions from:

- More than 2.7 million miles of new and existing natural gas transmission, distribution, and gathering pipelines,
- 400+ underground natural gas storage facilities, and
- 165 LNG facilities

The facilities affected by the proposed regulations require:

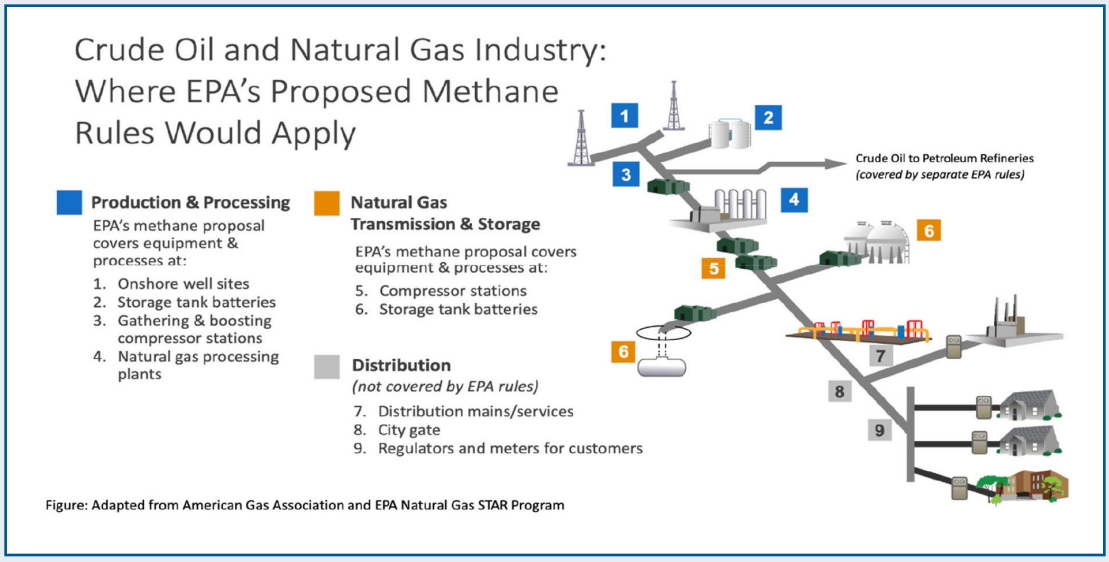
1. Increased frequency for leakage surveys, and Advanced Leak Detection Programs standard for pipeline operators,
2. Companies to identify, locate, classify, and repair all leaks promptly,
3. Natural gas pipeline operators to classify and repair leaks following a schedule determined by the severity of public safety and environmental risks, and
4. Companies should propose mitigation of intentional emissions like "blowdowns" on natural gas transmission pipelines, tank boil-offs at LNG facilities, and other facilities.

HIGHER SOCIAL COST OF GREENHOUSE GASES AND ENVIRONMENTAL REVIEWS

The DOE, FERC, and MARAD are required by NEPA to conduct environmental reviews on LNG export projects and interstate natural gas pipelines. As a part of NEPA compliance, the President's Council on Environmental Quality (CEQ) has emphasized analyzing project impacts on climate

[9] Federal Register. (2023, May 18). *Pipeline safety: Gas pipeline leak detection and repair*. Retrieved from https://bit.ly/47bGpn8

Figure 5. EPA's Proposed Methane Regulations Coverage of the Oil and Gas Industry



change and EJ communities since January 2021. CEQ issued new guidelines for assessing GHG and climate change on January 9, 2023.[10] In a separate report, EPA recommended using the social cost of carbon (SCC) methodology to assess climate change. The SCC methodology provides additional context and expresses climate impacts as dollars.

The Trump Administration set the SCC at $7 per ton, which had little impact on eroding the economic benefits of proposed LNG and pipeline projects. The Biden Administration raised the SCC to $51 per metric ton. On November 11, 2022, EPA proposed raising the SCC to much higher levels.[11] EPA issued a report that discussed raising the SCC to $120, $190, or $340 per metric ton of CO_2, using discount rates of 2.5 percent, 2.0 percent, and 1.5 percent, respectively. These discount rates reflect the weight given to future impacts of climate change.[12]

EPA's SCC proposal also has implications for methane and NO_x. As shown in **Table 5**, the social cost of each ton of methane is $1,600 compared to $190 per ton for carbon. Such high values can make it difficult for FERC, MARAD, and the DOE to justify and approve projects.

If EPA succeeds in raising the SC-C to $135 per ton, LNG and pipeline companies will have to upgrade and rethink their GHG emission mitigation and the procurement of equipment and components. To reduce the high SC-C values, LNG and natural gas pipeline companies must also identify GHG mitigation measures and convince federal regulators that their projects are in the public interest. They can achieve this by incorporating specific mitigation and changes in their O&M procedures. Equipment manufacturers and service providers should not be mere spectators. They must also develop cost-effective environmental solutions that support LNG and interstate natural gas pipeline project applications. Companies should incorporate GHG emission mitigation measures during the proposed projects' front-end engineering and design (FEED) studies.

The recent decline in the growth of new interstate natural gas pipelines is alarming **(Figure 6)**.[13]

[10] Federal Register Notices. (2023, January 9). Retrieved from https://bit.ly/3qBqDRY

[11] U.S. Environmental Protection Agency. (2022, November 11). *Biden-Harris administration strengthens proposal to cut methane pollution to protect communities, combat climate change, and bolster American innovation.* Retrieved from https://bit.ly/44wdJn7

[12] Farah, N.H., & Clark, L. (2022, November 21). EPA floats sharply increased social cost of carbon. *Energywire*. Retrieved from https://bit.ly/44QxHJ3

[13] U.S. Energy Information Administration. (2023, March 2). *The least U.S. interstate natural gas pipeline capacity on record was added in 2022.* Retrieved from https://bit.ly/43tCeQI

Table 3. Number of reporting facilities and methane emissions subject to the Inflation Reduction Act methane charge

Number of Reporting Facilities and Methane Emissions Subject to IRA Methane Charge

Facility Type	Number of Reporting Facilities	Reported Methane Emissions ($MMTCO_2e$)
Onshore petroleum and natural gas production	485	44.2
Onshore petroleum and natural gas gathering and boosting	361	21.9
Onshore natural gas transmission compression	624	4.2
Onshore natural gas transmission pipeline	39	2.9
Natural gas processing	457	2.9
Offshore petroleum and natural gas production	141	1.5
Underground natural gas storage	50	0.6
Liquefied natural gas import and export equipment	10	0.1
Liquefied natural gas storage	5	0.001
Total	**2,172**	**78.3**

Table 4. EPA's estimate of methane emissions subject to the charge

Estimate of Methane Emissions Subject to Charge

	FY2026	FY2027	FY2028	FY2029	FY2030	FY2031
CBO Revenue Estimate (Net)	$850 million	$1,350 million	$1,400 million	$1,200 million	$1,050 million	$500 million
Estimate of Gross Revenue from Methane Charge	$1,133 million	$1,800 million	$1,867 million	$1,600 million	$1,400 million	$667 million
Methane Charge (dollars per metric ton of methane)	$900	$1,200	$1,500	$1,500	$1,500	$1,500
Estimated Methane Emissions Subject to the Charge (million metric tons methane)	1.3	1.5	1.2	1.1	0.9	0.4
Estimated Methane Emissions Subject to the Charge (million metric tons CO_2e)	31	38	31	27	23	11

Source: Congressional Research Service. (2022, August 29). Inflation Reduction Act's methane emissions charge: In brief. Retrieved from https://bit.ly/3O1usYq.

Natural gas pipelines in 2022 set a historic low at 897 million cubic feet per day. This finding does not bode well for the growth of the US LNG industry, which will require greater quantities of feed gas to sustain future growth. While the drop in pipeline capacity additions can't be attributed to higher SC-C values, it shows how the concerns and controversy over climate change and impacts on landowners and EJ communities have damaged the natural gas industry.

It is also becoming harder to permit and construct LNG projects because of the impacts

Table 5. Estimates of SC-GHG in 2020 dollars

EXTERNAL REVIEW DRAFT

Table ES.1: Estimates of the Social Cost of Greenhouse Gases (SC-GHG), 2020-2080 (2020 dollars)

	SC-GHG and Near-term Ramsey Discount Rate								
	$SC\text{-}CO_2$ (2020 dollars per metric ton of CO_2)			$SC\text{-}CH_4$ (2020 dollars per metric ton of CH_4)			$SC\text{-}N_2O$ (2020 dollars per metric ton of N_2O)		
Emission Year	2.5%	2.0%	1.5%	2.5%	2.0%	1.5%	2.5%	2.0%	1.5%
2020	120	190	340	1,300	1,600	2,300	35,000	54,000	87,000
2030	140	230	380	1,900	2,400	3,200	45,000	66,000	100,000
2040	170	270	430	2,700	3,300	4,200	55,000	79,000	120,000
2050	200	310	480	3,500	4,200	5,300	66,000	93,000	140,000
2060	230	350	530	4,300	5,100	6,300	76,000	110,000	150,000
2070	260	380	570	5,000	5,900	7,200	85,000	120,000	170,000
2080	280	410	600	5,800	6,800	8,200	95,000	130,000	180,000

Values of $SC\text{-}CO_2$, $SC\text{-}CH_4$, and $SC\text{-}N_2O$ are rounded to two significant figures. The annual unrounded estimates are available in Appendix A.4 and at: www.epa.gov/environmental-economics/scghg.

Source: U.S. Environmental Protection Agency. (2022, September). Report on the social cost of greenhouse gases: Estimates incorporating recent scientific advances. https://bit.ly/3zc1Ch1.

on EJ communities. In April 2021, environmental and citizen groups successfully challenged Next-Decade's Rio Grande LNG in the courts because FERC's NEPA reviews on climate change and EJ communities were deficient.[14] As a result, Next-Decade experienced a 20-month delay by FERC to redo its analysis and issue an approval on April 20, 2023.[15]

On July 28, 2023, CEQ proposed new NEPA Implementing Regulations Revisions Phase 2.[16] These new regulations would codify the requirements to analyze GHG emissions, climate change, and EJ community impacts in its NEPA regulations.[17] If the proposed regulations are retained in CEQ's final rule, then DOE, FERC, and MARAD would have these impacts in their NEPA reviews. If these federal agencies refuse to do so, the courts will overturn their decisions.

Using higher values for the SC-C, new methane reduction regulations and charges, and codification of climate change and EJ analysis in NEPA reviews will pose an existential threat to the growth of new LNG export and interstate natural gas pipeline projects.

HOW LNG AND PIPELINES ARE UNDERESTIMATING REGULATORY AND LITIGATION RISK

Using higher values for the SC-C, new methane reduction regulations and charges, and codification of climate change and EJ analysis in NEPA reviews will pose an existential threat to the growth of new LNG export and interstate natural gas pipeline projects. The danger is grave if LNG and natural

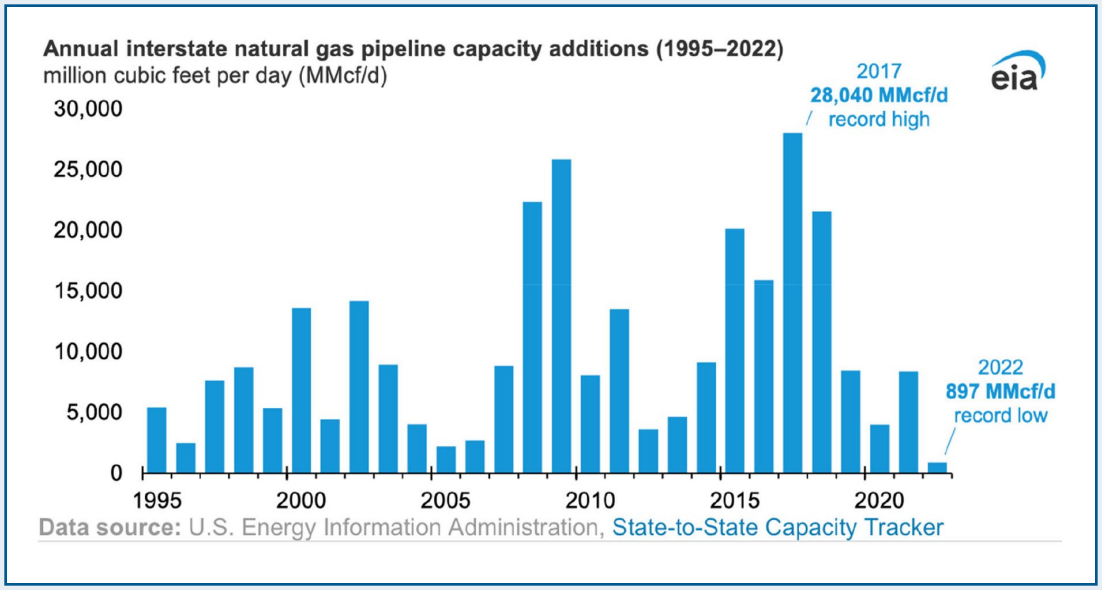
[14] Vecinos Para el Bienestar de la Comunidad Costera v. FERC. (2021, August 3). Retrieved from https://bit.ly/3qaYotq

[15] Paul, C. (2023, April 21). Divided US FERC grants new approval for NextDecade's Rio Grande LNG project. *S&P Global*. Retrieved from https://bit.ly/3O3sSXK

[16] Council on Environmental Quality. (2023). *National Environmental Policy Act Implementing Regulations Revisions Phase 2*. Retrieved from https://bit.ly/3OdcAKo

[17] Bravender, R. (2023, July 28). NEPA 'Phase 2' revamp aims to reverse Trump, boost renewables. *Greenwire*. Retrieved from https://bit.ly/3Kh6He0

Figure 6. Historic US interstate natural gas pipeline capacity additions



gas pipeline companies don't alter their industry practices.

US LNG and pipeline applicants have underestimated the regulatory and litigation risks when developing their proposals in FEED studies. Historically, they have focused on costs and efficiency and downplayed environmental risks like GHG and climate change. The companies typically propose standard mitigation in their DOE, FERC, and MARAD applications and then rely on the regulators' NEPA environmental review to be issued. This "check-the-box" approach yields poor results and invites delays.

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What the LNG and natural gas industry fail to recognize is that FERC and other regulators' litigation risks are much greater regarding compliance with NEPA and associated climate change and EJ requirements. The regulators are also under intense pressure from Congress and the Executive branches of government to achieve clean energy goals. Even if projects survive the federal review process, they can run into headwinds at the state level, which can deny construction permits pursuant to Section 401 of the Clean Water Act and consistency determinations required by the Coastal Zone Management Act.

The reluctance of LNG and pipeline applicants to provide FERC and other regulators with GHG data and an analysis of their projects' climate change impacts will lead to interminable delays in project approvals and construction. LNG and pipeline companies should provide the data and mitigation GHG and EJ impacts just as they do for fish, wildlife, water quality, endangered species, and cultural resources. It's critical that this information is in the regulator's administrative record and that companies showcase their GHG and EJ mitigation. Mitigation could include:

1. Eliminating blowdowns during O&M and using technologies such as ZEVAC (Zero Emissions Vacuum & Compression) & ULC's Drawdown Compressor,[18]

[18] See Southern Company Gas—reducing emissions using innovative recapture technology. (2022). Retrieved from https://bit.ly/3EqTBqy; and Drawdown Compressor—ULC Technologies. (2022). Retrieved from https://bit.ly/3L4filn

2. Installing real-time monitoring at LNG and pipeline compressor stations,

3. Implementing measures outlined in Table 1 and quantifying GHG emission reductions, and

4. Sourcing LNG feed gas and transporting it from producers that certify their gas, also called Responsibly Sourced Gas, or from companies of One Future, an organization whose goal is to reduce methane emissions.

Many in the industry may question the practicality of doing extra work to analyze and mitigate their LNG and pipeline projects' climate change and EJ impacts. They reason that opponents of fossil fuels will always sue FERC and other regulators, so what's the point? FERC's NEPA review of the highly controversial Alaska LNG project is an excellent example of a successful outcome when a regulator does its job and has a reasonable NEPA analysis.[19] In FERC's case, the courts upheld the NEPA analysis, and the plaintiffs' motions were dismissed.

CONCLUSION

The production of lower-carbon US LNG will occur with or without the cooperation of the LNG, oil, and natural gas industry. However, this transition will be less costly and happen faster if US companies change decades-old O&M practices and the way they approach siting of LNG and interstate natural gas pipelines. Rather than fighting efforts to address climate change and EJ impacts and inviting litigation and project delay, companies must proactively mitigate these effects and assist federal regulators with NEPA compliance.

LNG companies should use their growing purchasing power to influence upstream and midstream companies to reduce GHG emissions and their projects' impacts on EJ communities. The US LNG industry must also enlist the support of manufacturers and technology companies in designing components that reduce GHG emissions at their plants. Finally, the US LNG, oil, and natural gas companies should implement programs and technologies to minimize flaring and blowdowns and embrace real-time monitoring of GHG emissions.

Lower-carbon US LNG production would enhance the energy security of the US and its allies. It would also make US LNG more competitive in the global market and make it easier for policymakers to justify US LNG purchases, rather than LNG imports from Russia and other exporting countries. Lower-carbon US LNG production would also extend the life of LNG as a bridge-fuel to Asian countries switching from coal to natural gas-fired power plants. Also, lower-carbon natural gas in the US would decarbonize the production of gray and blue hydrogen.

Rather than fighting efforts to address climate change and EJ impacts and inviting litigation and project delay, companies must proactively mitigate these effects and assist federal regulators with NEPA compliance.

If the US LNG, oil, and natural gas industry do not update their approach to dealing with the new NEPA and methane reduction regulations and likely use of the SC-C, the consequences are bleak for future US LNG growth. Environmental and community groups will be successful in overturning federal agency decisions on LNG and pipeline projects with greater frequency. Prolonged and costly delays will be the hallmark of US LNG, which may affect the willingness of LNG off-takers to subscribe to new LNG capacity. This author also believes that capacity additions of interstate natural gas pipelines will not be sufficient to support the future growth of US LNG facilities. Many LNG facilities may delay or not make final investment decisions if they perceive bottlenecks that reduce their access to sufficient volumes of feed gas. As a result, the US will lose a strategic energy security tool to counter growing LNG production from Russia. Finally, countries that import US LNG will find it harder to justify the current level of US LNG imports, especially if the Russia–Ukraine War ends or hostilities come to a stalemate.

[19] Panahi, S.J. & Rigney, M. (2023, May 30). D.C. Circuit upholds FERC's NEPA review of Alaskan LNG Project *Washington Energy Report*. Retrieved from https://bit.ly/3Ojuqvh