Is LNG a Bridge Fuel in the Mitigation of Global Warming: A Critical Review of Studies at the EDF, NRDC, and Bloomberg

BY MARC VATTER

Abstract

I review research saying that exports of LNG from the U.S. are, on the whole, as dirty as coal, in terms of methane leaks and emissions of CO_2 during liquefaction. I show these concerns to be based on misinterpretation of data, unrealistic assumptions, and omissions of key metrics, and, therefore, invalid.

Introduction

Several studies (see references) have examined the effect of liquefied natural gas (LNG) production, storage, transport, and combustion on emissions of methane (CH_4) and other greenhouse gases (CO_2 and NO_x). Substitution of natural gas for coal and oil in electric generation and transportation has done much to lower emissions[1], but some observers question whether LNG represents the same kind of "low hanging fruit" or "bridge fuel" in the mitigation of global warming that pipeline gas does.

Here, I review and critique mainly studies done through the Environmental Defense Fund (EDF), the Natural Resources Defense Council (NRDC), and Bloomberg News that criticize LNG because of emissions of CH_4 and CO_2.

Upstream emissions of methane

A crucial input to the different LNG studies, though it affects emissions from both pipeline gas and LNG, is the rate of emissions of methane associated with its production, storage, transport, and combustion.

> Looking at the full lifecycle of coal, gas and LNG, a study in 2019 by the U.S. National Environmental Technology Lab (NETL) found that U.S.-produced LNG shipped from the U.S. Gulf [Coast] to Rotterdam in the Netherlands, would produce between 20% and 53% less GHG [greenhouse gas] emissions over 100 years than burning lignite coal sourced in Europe and burned in a European power plant. For exports of LNG to China, U.S. LNG would generate between 21% and 54% less emissions than regionally sourced coal.
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> A study by the American Petroleum Institute (API), using updated emissions modeling available in 2020, indicates that U.S. LNG exports to China, Germany and India would generate, on average, 50.5% fewer lifecycle greenhouse gas emissions than coal-fired power.
>
> U.S. environmental groups dispute the findings favorable to LNG exports. Environmental Defense Fund (EDF) questions a key assumption of NETL's analysis, namely the relatively low methane leakage rate for the production and transmission front-end segments of the lifecycle. NETL's study uses a methane leakage rate of 1.2%, based on production of unconventional (fracked) natural gas in the Marcellus and Utica basins in Pennsylvania and Ohio. But EDF points out that much of the U.S. gas that is liquefied comes from the Permian Basin in Texas and New Mexico, where it has been tracking methane emissions by satellite and mobile ground-level monitors *since 2018*. EDF has found emissions of methane are, on average, more than 3.5%.[2] [emphasis added]

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This quote comes from an article published in January 2021. In 2018 and 2019, flaring of gas in the Permian spiked because of rapidly increasing production that interacted with congestion of takeaway capacity in pipelines.

> Record-high oil and gas production from West Texas' Permian Basin also has led to record-high waste and pollution in the form of gas flaring.
>
> As companies drill for oil, they're also pumping out large volumes of associated natural gas that frequently has nowhere to go because of temporary pipeline shortages in the region. So they're opting to simply waste the gas by burning it off in a practice known as flaring until new outlets can carry their energy products to market.
>
> Norwegian research firm Rystad Energy estimates that Permian flaring averaged a record of 407 million cubic feet per day in the third quarter of this year and will keep rising next year up to at least 600 million cubic feet a day. The current flared gas amounts are worth more than $1 million per day.[3]
>
> In 2018-19, midstream players in the Permian Basin rushed to satisfy the demand for pipeline capacity driven by booming oil and gas production. The associated natural gas production had reached ~17 billion cubic feet per day (bcfd) and robust drilling activity and moderate gas prices had pressurized the midstream operators to expand the existing pipeline infrastructure network, particularly in the Delaware basin [a part of the Permian]. By early 2020, Gulf Coast Express and Carlsbad Gateway Pipeline came online and the natural gas transport capacity outstripped supply, albeit by a much smaller margin due to comparatively robust gas prices, as well as increased gas-to-oil ratios from aging wells in the Permian.
>
> Permian associated gas production increased from 15.7 bcfd in 2020 to 18.2 bcfd in 2021. It surpassed

the pre-Covid natural gas production levels of ~17.4 bcfd in March 2020. Most of the increase in associated gas production is attributed to the increase in takeaway capacity recently. In 2021, two major gas pipeline projects, the Permian Highway and Whistler projects, came online to increase takeaway capacity from the Permian Basin by roughly a quarter...[4]

Flaring fell sharply in March and April of 2020 before flattening out. In August of 2021 it fell again to 380 MMcfd. At a current price of $4/Mcf, this would amount to $1.5 million/day lost revenue. It's still a lot of money wasted every day.

The results are clearly basin-dependent... The Marcellus Shale, the queen of U.S. shale basins, is gas-only and allows less leaks in their gas production. The Permian and Bakken are mainly oil, and operators tend to flare the associated gas...[5]

EDF's critique of the 2019 NETL study is based mainly on anomalously high and, in the long run, unprofitable emissions of CH_4 during the three-year period 2018-20. The methodological challenge of separating "signal" from "noise" in a sample consisting mostly of what would be outliers in a longer sample would be Herculean. One can surmise that leak rates in the long run are below EDF's estimated 3.5%.

According to Swanson et al. (2020), the NRDC study[6],

> Because methane is such a potent GHG, calculated lifecycle emissions for exported LNG are *strongly influenced* by the analytical assumptions made for the amounts of methane that leak or are otherwise released (e.g., via flaring) from the wells, pipelines, valves, compressors, and processing facilities through which the gas passes during its life-cycle. [p. 25; emphasis added]

I focus mainly on methane leaks here because of the strong influence noted by the NRDC. Some studies estimate a "breakeven" point, in terms of the methane leak rate, at which U.S. LNG exports emitted just as much in the way of standardized GHGs as coal; a leak rate below the breakeven point indicates that substitution of LNG for coal in electric generation would reduce global warming. According to the NRDC, "the Carnegie Mellon study estimated that the 'breakeven' point at which U.S. LNG exports emitted as much greenhouse gases as coal in the near-term time frame was a methane leakage rate of 3.0 percent. The 2014 NETL study reported a lower breakeven point of 1.4 to 1.9 percent methane leakage."

The latter are the low end (20 year) breakeven points for U.S. exports to Asia and Europe, respectively, reported in Table 61 on page 14 of NETL's 2014 study. NRDC does not mention the corresponding 100 year breakeven points of 4.6% and 5.8%, reported in the same table. Moreover, though they use many data from the 2019 NETL update, wherein the 20 year breakeven rates were raised to 3.1% and 3.6%, and the 100 year breakeven rates were raised to 8.2% and 9.1%, respectively, the NRDC researchers chose to conclude that LNG was as dirty as coal, from a climate perspective, using only the outdated, 20 year, 2014 NETL breakeven rates:

> The Carnegie Mellon study estimated that the "breakeven" point at which U.S. LNG exports emitted as much greenhouse gases as coal in the near-term time frame was a methane leakage rate of 3 percent. The 2014 NETL study reported an even lower breakeven point of 1.4 to 1.9 percent methane leakage. These rates are solidly within the range measured for methane emissions from the North American gas production and processing industries. Therefore, unless methane leakage rates are kept at very low levels, replacing coal-fired power plants with gas plants fueled by imported U.S. LNG may actually provide little or no climate benefit to either the importing countries or the world. [p. 14]

Here is a relevant excerpt from the 2019 NETL study:

> Exhibit 6-8 shows the upstream and cradle-through-delivery methane emission rates for all scenarios. It also shows the breakeven upstream emission rates for each scenario; breakeven rates were calculated by comparing the expected results for natural gas to the expected results for coal. The breakeven rates for the 20-yr [global warming potential] are lower than those for the 100-yr GWP because methane has a higher GWP over 20 years than it does over 100 years.

If I divide methane leaks from natural gas systems, abandoned oil and gas wells, and stationary and mobile combustion reported by the Environmental Protection Agency (EPA) for 2020 by natural gas production reported by the Energy Information Administration (EIA),

Exhibit 6-8. Coal and Natural Gas Breakeven for U.S. LNG and Russian Natural Gas Scenarios

Scenario	Upstream Emission Rate	Cradle-through-delivery Emission Rate	Breakeven Upstream Emission Rate		Breakeven Upstream Emission Rate/ Upstream Emission Rate	
			100-yr GWP	20-yr GWP	100-yr GWP	20-yr GWP
U.S. LNG to Rotterdam	0.7%	1.1%	9.1%	3.6%	12.8	5.1
U.S. LNG to Shanghai	0.7%	1.2%	8.2%	3.1%	11.5	4.4
Russia NG to Rotterdam	4.1%	4.1%	11.2%	4.7%	2.7	1.1
Russia NG to Shanghai	5.1%	5.1%	11.1%	4.6%	2.2	0.9
Algeria LNG to Rotterdam*	1.5%	2.1%	8.9%	3.3%	5.9	2.2
Australia LNG to Shanghai*	1.5%	2.0%	9.3%	3.6%	6.2	2.0

**Scenarios not included in Exhibit 6-9 and 6-10*

I get a leak rate of 0.94%.[7] Alvarez et al. (2018) refer to the same sources, but include emissions from natural gas systems, petroleum systems, stationary combustion, abandoned oil and gas wells, mobile combustion, and petrochemical production because they are interested in the entire oil and gas supply chain.[8] The 2015 values for the sum of these, divided by production of natural gas, gives a CH_4 emission rate of 1.44%. Multiplying 1.44% by 1.6 equates to their independent estimate of 2.3%.

> Methane emissions from the U.S. oil and natural gas supply chain were estimated by using ground-based, facility-scale measurements and validated with aircraft observations in areas accounting for ~30% of U.S. gas production. When scaled up nationally, our facility-based estimate of 2015 supply chain emissions is 13 ± 2 teragrams per year, equivalent to 2.3% of gross U.S. gas production. This value is ~60% higher than the U.S. Environmental Protection Agency inventory estimate, likely because existing inventory methods miss emissions released during abnormal operating conditions. [abstract]

Treating the categories listed above as representing emissions of methane associated with *all domestic production and combustion of oil and gas* replicates Alvarez et al.'s 60% adjustment.

The EPA and EIA data referred to by Alvarez et al. for 2015, updated data for 2020, and the 60% adjustment are shown in Table 1, where I also calculate the emissions rates from production, storage, and transport of natural gas production and combustion, excluding those associated with petroleum systems and petrochemical production, since little of the latter contribute to the LNG supply chain. When I apply the 60% adjustment to those, I get emissions rates of 1.9% in 2015 and 1.5% in 2020.

The NRDC study [p. 11] mischaracterizes the Alvarez et al. (2018) emissions rate of 2.3% as being associated with natural gas alone, when, in fact, it is associated with all *oil* and gas: "A recent study of methane emissions for the U.S. gas supply chain estimated that 2.3 percent of gross U.S. gas production is lost as leaks or intentional releases." This error of interpretation overstates the rate associated with production, storage, transport, and combustion of natural gas by 2.3 – 1.9 = 0.4% in 2015, and, implicitly, by 1.9 – 1.5 = 0.4% in 2020. EPA has separated emissions associated with oil from those associated with natural gas, and, if they have done a good job of this, the fact that the two are complements in production should not give reason to lump oil back in with gas for the purpose of estimating emissions associated with the use of LNG. (I lump them together in the case of abandoned oil and gas wells because EPA has not separated them.) Thus, even the low, outdated 2014 NETL breakeven rates (1.4 to 1.9) that the NRDC selects are not "solidly within the range measured for methane emissions from the North American gas production and processing industries".

Oil and gas are also substitutes in consumption, and prices of substitutes move together, so any policy based on estimated emissions from LNG that mistakenly include emissions from oil that, thereby, reduces the supply of LNG will raise the demand for oil, among other things inefficiently offsetting reductions in emissions from lower supply of LNG, while raising the price of the necessity that is energy, as well.

The NRDC study includes a caveat regarding declining emissions rates from U.S. production, storage, and transport of natural gas:

> Our analysis is based on currently reported quantitative data, assessments, and models. It is possible that future life-cycle GHG emissions from LNG exports could be reduced using a number of strategies, including decreasing methane leakage during all life-cycle stages; decarbonizing LNG shipping and the electricity grid in exporting countries; and using carbon capture, utilization, and storage (CCUS) in electricity generation facilities powered by imported LNG. It is likely (and to be hoped) that implementation of some or all of these strategies will progress during the coming decades. However, for this analysis we chose to use recent, published, empirical emissions data rather than to make speculative quantitative assumptions for various emissions reduction strategies in the future. [p. 23]

NRDC acknowledges the possibility of declining leak rates in the future, but does not mention the historical downward trend shown in Figure 1, where I report the metric shown for 2015 and 2020 in line J of Table 1, which is based on the unadjusted government data, for the historical period beginning in 1990 and a simple extrapolation of the historical trend to 2050. The 2020 rate of 0.89% falls about midway between NETL's

Table 1: Emissions of methane in the U.S. associated with oil and gas

	kt of CH4 emitted	2015	2020
A	natural gas systems	6,686	6,596
B	petroleum systems	1,579	1,609
C	stationary combustion	340	317
D	abandoned oil and gas wells	285	276
E	mobile combustion	85	88
F	petrochemical production	7	13
G	MT of natural gas produced	692,934,323	855,019,747
H	Emissions of O&G supply chain/NG production	1.4%	1.2%
I	with Alvarez et al. (2018) adjustment	2.3%	1.9%
J	Emissions from NG production, transport, and combustion/NG production	1.2%	0.9%
K	with Alvarez et al. (2018) adjustment	1.9%	1.5%

A-F U.S. EPA, Trends in U.S. Greenhouse Gas Emissions and Sinks, 2019 and 2022
G U.S. EIA, U.S. natural gas gross withdrawals, Source Key N9010US2, given in MCF, with MMBtu = 1000*1.037*MCF and MT = MMBtu/49.2579
H [1000*(A+B+C+D+E+F)/0.90718474]/G
I H*1.6
J [1000*(A+C+D+E)/0.90718474]/G
K J*1.6

upstream and "cradle through delivery"[9] emission rates for U.S. LNG delivered to Rotterdam or Shanghai, and well below any of the breakeven rates shown in their Exhibit 68, and also well below the three percent breakeven rate estimated at Carnegie Mellon. If I apply the Alvarez et al. (2018) 60% upward adjustment, as in line K of Table 1, the resulting emission rate of 1.42% in 2020 would still fall well below all of the breakeven

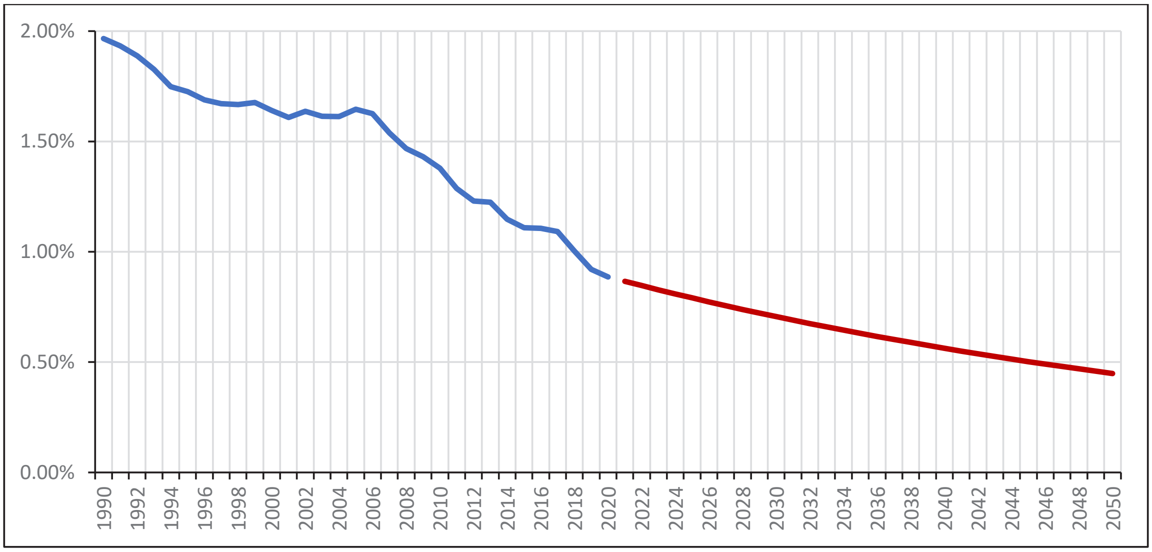

Figure 1: CH_4 production and combustion emissions / production

points from NETL in 2019 and Carnegie Mellon.

With or without the Alvarez et al. adjustment, the extrapolated trend is more reasonable than assuming that emission rates would remain constant. The equation for the trend is $R_t = 0.978R_{t-1}$, where R_t is the emissions rate in Year t, a constant term, if added, would not be statistically significant at the 90% level, and the 95% confidence interval for the stochastic trend is $0.978 \pm 2.262*0.0075 < 1$, so one can reject NRDC's assumption using standard statistical criteria.[10] A simple reason for this is that venting and flaring are typically unprofitable in the long run.

> The [International Energy Agency] identified the five most cost-effective methods for reducing the industry's scope 1 and 2 emissions. The leading method is cutting methane emissions from oil and gas operations.
>
> The second most important measure is an overall elimination of non-emergency flaring, a practice that sent about 500 mt of CO_2e into the atmosphere in 2022. The IEA suggests bringing the excess gas to consumers via new or existing pipeline networks, converting it into compressed or *liquified natural gas*, or reinjecting it into reservoirs to increase pressure. [emphasis added]
>
> …while eliminating flaring would cost the industry $70 billion today, it could also generate $91 billion in revenue by 2030.
>
> The IEA estimates that 15% of energy-related emissions, or 5.1 billion mt of CO_2e, stem from upstream and midstream oil and gas activities – from extracting the fuels out the ground to delivering them to end users. But that 15% is also the lowest hanging fruit for reductions.
>
> "These emissions can and should drop by more than half by 2030, and it's one of the cheapest ways of cleaning up the energy system," IEA Energy Analyst Peter Zeniewski said in a tweet…[11]

"Speculative" is not a fair characterization of the expected decline in emissions rates; there are good theoretical and empirical reasons to expect continued improvement. Given the trend, emissions rates in the production of natural gas would continue to fall farther below NETL's breakeven points, and below half a percent before 2050.

It does not appear to me that LNG is as dirty as coal, at least in terms of the strong influence of upstream leaks of methane.

Emissions of CO_2 during liquefaction

A second climate-related criticism of LNG as a bridge fuel in the process of mitigation of global warming centers on CO_2 emitted in the process of liquefaction. Table 2 uses estimates from Traywick et al. (2020) that "Not all [U.S.] export terminals are completed and in use, but if they were, simply operating them could spew 78 million tons of CO_2 into the air every year, according to data compiled by Bloomberg from environmental filings. That's comparable to the emissions of 24 coal plants, or 18 gigawatts of coal-fired power".

In Table 2, I monetize emissions at \$100/tCO_2, based on Vatter (2022), but also a not uncommon value. I monetize energy from both LNG and coal using futures prices in Europe for December 2026, a long term expectation that is not excessively influenced by recent volatility. I measure energy from LNG as equal to that from exports in 2021, likely overstating the rate of emissions if combined with Traywick et al.'s 78 million tons, since full operation of the liquefaction plants had not obtained in 2021. I use a heat rate for gas-fired generation of 8,000 Btu/kwh. I use a plant factor of 0.53 for coal-fired generation from EIA (2022b), and an emissions rate of 1.0235 tCO_2/MWh, which is the U.S. national average for 2021, from EIA (2022c). This gives emissions from coal of 86 million tons, nine percent

Table 2: Comparison of CO_2 emissions during liquefaction with those of combustion of coal in the generation of electricity

Row	Variable	Value	Source	Comment
A	$/tCO$_2$	100	Vatter; https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3821603, accessed December 26, 2022	
B	tCO$_2$/year for USGC liquefaction	78,000,000	Bloomberg; https://www.bloomberg.com/news/articles/2020-01-23/gas-exports-have-dirty-secret-a-carbon-footprint-rivaling-coal-s, accessed December 26, 2022	
C	$/year CO$_2$ damages USGC liquefaction (A*B)	7,800,000,000		
D	$/MMBtu for LNG at TTF for December 2026	12.06	NYMEX; https://www.cmegroup.com/markets/energy/natural-gas/dutch-ttf-natural-gas-usd-mmbtu-icis-heren-front-month.html, accessed December 26, 2022	
E	US LNG exports in 2021 (bcf)	3560.82	EIA; https://www.eia.gov/energyexplained/natural-gas/liquefied-natural-gas.php, accessed December 26, 2022	
F	MMBtu/Mcf	1.037		
G	US LNG exports in 2021 (MMBtu; 1,000,000*E*F)	3,692,570,340		
H	Heat rate for natural gas (Btu/kwh)	8,000	Power Magazine; https://www.powermag.com/utilities-and-industry-continue-learnings-around-benefits-of-heat-rate-improvement/#:~:text=For%20existing%20gas%2Dfired%20combined,3%2C412%20%2F%200.46%20%3D%207%2C400)., accessed January 6, 2023.	
I	GWh from US LNG exports in 2021	461,571		
J	$ value of US LNG exports in 2021 at TTF (D*G)	44,536,090,871		
K	$ value of CO$_2$ damages/$ value of LNG exports (C/J)	0.1751		A kind of upper bound, since exports corresponding to the 78,000,000 in emissions would be expected to be higher than exports in 2021.
L	Coal fired capacity with equivalent emissions (GW)	18	Ibid, Bloomberg	
M	Plant factor for coal	0.53	EIA; https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_07_a, accessed December 26, 2022	
N	Annual GWh for equivalent coal (L*M*8,766)	83,628		
O	CO$_2$ emissions rate for coal 2021 (tCO$_2$/MWh)	1.023516375	EIA; https://www.eia.gov/tools/faqs/faq.php?id=74&t=11, accessed December 26, 2022	
P	tCO$_2$/year for equivalent coal (1,000*N*O)	85,594,259		
Q	$/year CO$_2$ damages for equivalent coal (A*P)	8,559,425,891		
R	$/mt of coal in Europe for December 2026	154.15	NYMEX; https://www.cmegroup.com/markets/energy/coal/coal-api-2-cif-ara-argus-mccloskey.settlements.html, accessed December 26, 2022	
S	kwh/mt coal	2,712	How Stuff Works; https://science.howstuffworks.com/environmental/energy/question481.htm#:~:text=Although%20coal%20fired%20power%20generators,kWh%20or%202%2C460%20kWh%2Fton., accessed December 26, 2022	
T	$/year value of equivalent coal (1,000,000*N*R/S)	4,753,948,971		
U	$ value of CO$_2$ damages/$ value of equivalent coal (Q/T)	1.8005		
V	Relative economic CO$_2$ damage intensity of LNG (K/U)	0.0973		
W	Relative energy content of LNG for equivalent emissions of CO$_2$ (I/N)	5.52		

higher than Traywick et al.'s 78 million tons. According to Hong and Slatick (1994), lignite, assumed to be used in Europe but rarely used in the U.S., is five percent cleaner, in terms of CO_2, partially offsetting the discrepancy.

Row K shows the dollar social cost of CO_2 emissions from liquefaction as a fraction of the dollar value of the energy from the LNG: 0.1751. Row U shows the dollar social cost of CO_2 emissions from coal-fired generation as a fraction of the dollar value of the energy from coal: 1.8005; about ten times the ratio for LNG, as shown in Row V. This factor of ten does not depend on the monetary cost of emissions. For the roughly equivalent emissions, the electric energy generated using U.S. exports of LNG is five and a half times the electric energy from the coal, as shown in Row W. Even under an assumption (2021 exports) that makes LNG seem dirtier than it really is, in terms of emissions of CO_2, there is ample economic reason to substitute LNG for coal based on internal social value, and to substitute LNG for coal based on emissions of CO_2 per Watt hour of electricity generated.

Conclusion

Exports of U.S. LNG to Europe are much cleaner than European coal, when either is used to generate electricity there, inasmuch as cleanliness depends on the rate at which methane leaks from production, storage, transport, and combustion of natural gas. EDF erroneously applies anomalously high leak rates in the Permian basin to a long run issue, leak rates that are very likely profitable to lower in the long run. That NRDC researchers concluded that U.S. exports of LNG are as dirty as coal results from their ignoring NETL's breakeven leakage rates for periods longer than 20 years and, moreover, from ignoring NETL's higher 2019 updated estimated breakeven leakage rates, in favor of its outdated 2014 estimates, from attributing emissions of methane that are actually associated with petroleum with production, storage, transport and combustion of natural gas, and from the implausible assumption that the long term downward trend in the rate at which methane leaks from production, storage, transport, and combustion of natural gas would immediately level off, despite the prevalence of leaks in the Permian Basin that are very likely profitable to repair in the long run.

Taking Traywick et al.'s conclusion that the CO_2 emissions of liquefaction are similar to those of European coal, when used to generate electricity there, as given, there is still a tremendous positive difference between the internal social value of energy from LNG and that from coal, as measured by the market value of the fuel relative to the damage costs of emissions. Since energy is a necessity, a significant share of the value of the LNG would accrue to poorer people. The big difference in market values obtains in large part because the electricity generated from the LNG in question is much greater than the energy that would be generated from the coal: For equivalent emissions, U.S. exports of LNG can be used to generate at least five and a half times the electric energy from the coal. EDF's, NRDC's, and Bloomberg's overestimating emissions related to LNG could cause policymakers to miss the low hanging fruit of mitigation that substitution of LNG for coal represents and, thereby, accelerate global warming.

Inasmuch as the cleanliness of U.S. exports of LNG to Europe depends on leaks of methane in production, storage, transport, and combustion of natural gas and emissions of CO_2 during liquefaction taken together, U.S. exports of LNG to Europe are both much cleaner than European coal used to generate electricity there and of much greater net social benefit per unit of GHGs emitted.

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Footnotes

[1] McLaughlin and Disavino (2022).

[2] Adler (2021).

[3] Pipe Exchange (2018).

[4] Gupta (2021).

[5] Palmer (2022).

[6] Swanson et al. (2020).

[7] Environmental Protection Agency (2019), Environmental Protection Agency (2022), and Energy Information Administration (2022a).

[8] Stationary and mobile combustion do not include flaring; emissions from flaring are counted as emissions from natural gas systems; see the last sentence on page 2-16 of EPA (2022). On page 2-31, the 2022 EPA report says "Stationary combustion emissions of CH4 and N2O are also based on the EIA residential fuel-consuming sector." On page 232, in Table 211, "stationary sources" of CH4 emissions related to electric power "Includes only stationary combustion emissions related to the generation of electricity".

[9] Perhaps not a well-chosen metaphor, as the sequencing for a baby goes the other way.

10 The critical value and standard error correspond to a sample size of ten because EPA does not report data for all years.

[11] Muldor (2023).