Status of U.S. LNG Export Permits and Associated Greenhouse Gas Emissions

November 2023

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Contents

Cover Photo Credit: John Allaire

I. Foreword by Bill McKibben

I confess that I hadn't taken as seriously as I should have the problem of US exports of gas.

Like most of us, I tend to focus on the things we measure most regularly—how much greenhouse gas the US is emitting, and how much new renewable energy we're installing.

But when I started reporting on this topic this summer, I realized anew that, in the US, we have to focus more on exports, because that's where our fossil fuel growth is coming. Under the arcane rules of international carbon accounting, these emissions will be credited against the countries—mostly in Asia—where the gas is burned. But the atmosphere doesn't care.

The effort of the hydrocarbon industry to keep its business model alive through export is akin to what the cigarette industry did after its legal settlements in the US: it expanded abroad. But in this case, the secondhand smoke spreads around the world almost instantly, heating the planet everywhere. The numbers make it clear that LNG is even worse for the climate than coal—though, of course, the real comparison should be with sun and wind, now the cheapest forms of energy on earth.

And the numbers are staggering.

If the LNG buildout goes ahead as the industry plans, it will wipe out every bit of progress America has made on reducing emissions since 2005.

If the LNG buildout goes ahead as the industry plans, the emissions from those exports in 2030 will be roughly akin to the emissions from every home, factory, and car in the EU.

If the LNG buildout goes ahead as the industry plans, the US will be the greatest climate hypocrite of all time.

Luckily, the Biden administration can halt that expansion in its tracks, by taking a good long look at the criteria the Department of Energy uses to grant export licenses. It's our only chance to defuse this most massive of climate bombs.

Bill McKibben, November 2023

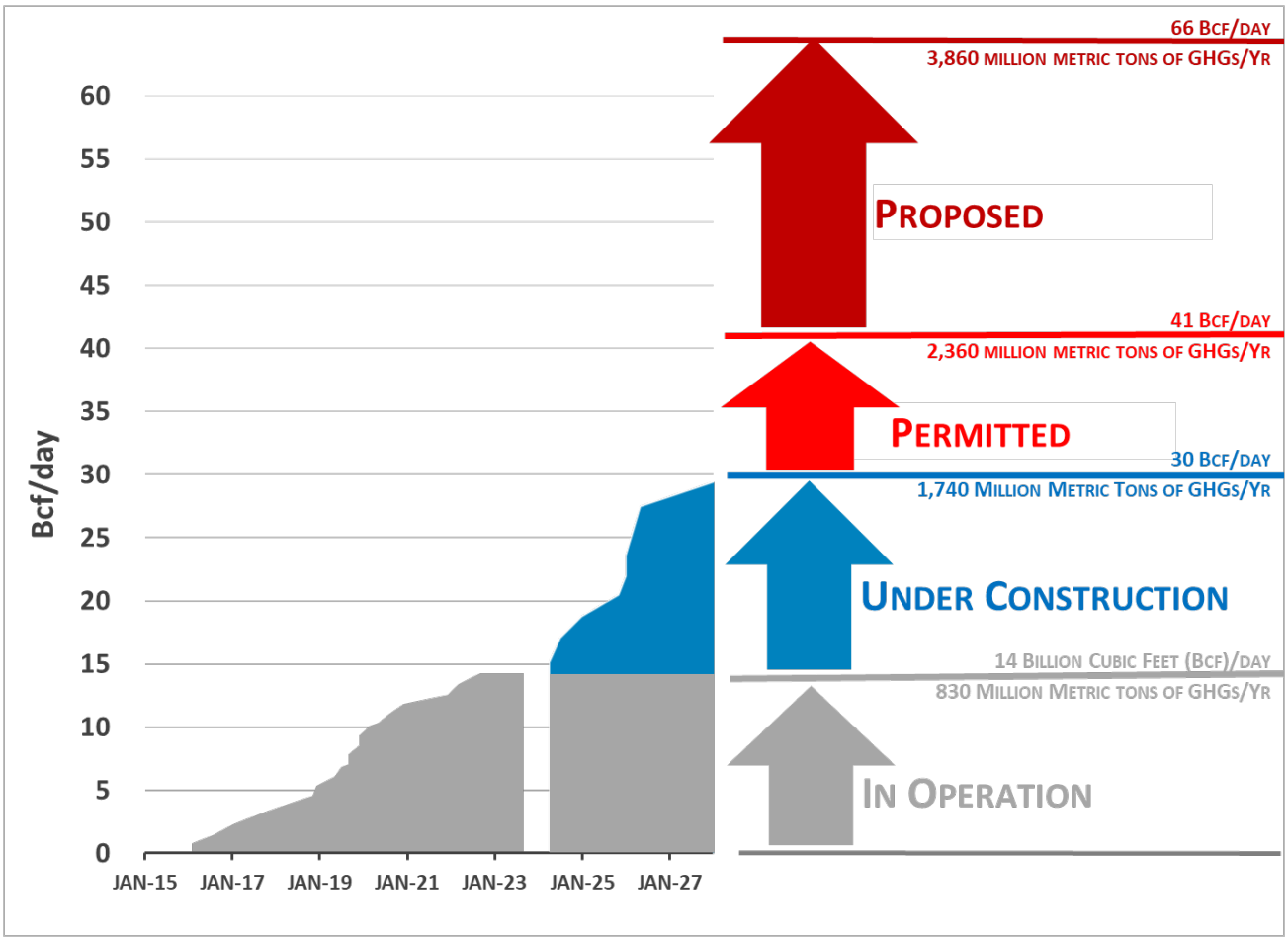
I. Summary of Findings

- **Finding 1:** US LNG exports have doubled since 2019
- **Finding 2:** Projects under construction will **double** US LNG export capacity over 2023 levels by 2027
- **Finding 3:** The US is surpassing its LNG commitments to Europe and current US LNG exports are sufficient to meet Europe's LNG needs
- **Finding 4:** Companies are seeking approval for new LNG projects that would **quadruple** US LNG export capacity compared to current (2023) levels
- **Finding 5: US LNG expansion will compete with renewable energy** – not coal and gas – around the world
- **Finding 6:** If all projects are approved, GHG emissions from DOE-authorized LNG exports would be **3.9 gigatons** annually; US-sourced LNG emissions would be larger than the GHG emissions from the European Union, whether using a gross or net accounting approach
- **Finding 7**: If all projects currently in the permitting pipeline are approved, GHG emissions from US-approved LNG exports would be **greater than one thousand coal-fired power plants**
- **Finding 8:** If all projects currently in the permitting pipeline are approved, GHG emissions from U.S.-approved LNG exports would be **equivalent to 850 million gasoline-powered vehicles**

Figure 1 – Summary of Gross and Net GHGs from US-Sourced LNG

	LNG Capacity (Bcf/day)	Total (Gross) GHG Emissions (MMT CO2-e/yr)	Equivalent Emissions		Net GHG Emissions (MMT CO2-e/yr)
			Coal-Fired Power Plants	Million Gas-Powered Vehicles	
In Operation	14.3	836	224	186	760
Under Construction	15.5	908	243	202	825
Permitted	10.6	620	166	138	564
Proposed	25.6	1,496	400	332	1,360
Total	**66.1**	**3,860**	**1033**	**857**	**3,509**

Figure 2 – Summary of LNG Volumes and GHGs, by Permit Status



Author Acknowledgments and Request for Feedback

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II. INTRODUCTION

The Natural Gas Act requires that the U.S. Department of Energy (DOE) determines whether applications to export liquified natural gas (LNG) are in the "public interest" before issuing a permit.[1]

In September 2023, House Republicans sought to strip DOE of this responsibility, preparing legislation (H.R. 1130) for a floor vote.[2] President Biden strongly opposed this attempt to repeal DOE's public interest determination responsibility. According to the White House policy statement, the bill would undermine the ability of the United States to ensure that LNG exports are "consistent with our economic, energy security, foreign policy, and environmental interests."

It stands to reason that DOE would be fully utilizing the responsibility that President Biden defended. Given President Biden's whole-of-government approach to climate change, which he has recognized as an "existential threat," it also stands to reason that DOE's due diligence of LNG exports would include assessing the full impact that planned expansion of US LNG exports will have on President Biden's climate commitments.

And yet, DOE has never denied any LNG project as not in the public interest. When DOE authorizes an application for LNG exports, they specifically authorize those exports to continue until the year 2050, when the world is supposed to have achieved net-zero greenhouse gas (GHG) emissions. In other words, each time DOE issues a permit approving new LNG exports, the administration is locking in a potential stream of exports – and associated GHG emissions – for decades. Despite this potential for carbon and methane lock-in, DOE has never assessed the impacts of LNG authorizations against net-zero climate goals.

In fact, DOE authorized an increase in LNG exports in March 2023 without providing any quantified assessment of the project's greenhouse gas (GHG) emissions at all (DOE 2023). This is consistent with DOE's long practice of evading the issue. DOE claims that evaluating whether LNG exports will increase or decrease GHG emissions on a global scale is too difficult an endeavor because of "challenges associated with modeling net changes" in GHGs. DOE justified its recent authorizations as being in the public interest by alleging that "DOE is unable to conclude that an increase in exports of U.S. LNG…will increase global GHG emissions in a material or predictable way, …." (DOE 2023, p. 69).

This is a peculiar position for a federal agency whose bread and butter is energy forecasts. In the same 2023 decision, DOE had no trouble modeling the economic benefits of LNG projects across global markets. The International Energy Agency (IEA, of which the US Secretary of Energy serves

[1] More specifically, the Natural Gas Act requires DOE to make public interest determinations on applications to export LNG to countries where the U.S. does not have existing free trade agreements (non-free trade agreement nations, or non-FTANs). Exports to non-FTANs accounted for 89 percent of US LNG exports in 2022. DOE must automatically authorize LNG exports to free trade nations. (EIA-a) The US has free trade agreements with 20 nations. 88% of gas exports to free trade agreement nations is by pipeline to Mexico and Canada, while only 12 percent is in the form of LNG (EIA-a).

[2] There was no final vote. The House voted down a measure setting the rules to bring HR 1130 and a defense authorization bill to the floor. The rule was defeated in the face of GOP defections on defense spending.

on the governing board) readily assessed LNG flows in their *2023 World Energy Outlook.* IEA concluded that the world is "amply supplied" for LNG (IEA 2023, p. 139). They found that global LNG projects already under construction will overshoot the amount of LNG consumption needed for the world to meet a net-zero GHG trajectory, leading to an LNG "glut." The natural gas buildout "creates the clear risk of locking in fossil fuel use and putting the 1.5°C goal out of reach" LNG (IEA 2023, p. 19).

2.1 Flaws in DOE's Current Approach to Assessing GHG Emissions from LNG

In evaluating LNG projects, DOE relies on a 2019 GHG study by the National Energy Technology Laboratory. This study found that: "Compared to domestically produced and combusted gas, there is a significant increase in the life cycle GHG emissions that are attributed to the LNG supply chain, specifically from liquefaction, tanker transport, and regasification processes" (NETL/DOE 2019, p. 22).

This finding is never mentioned in DOE's LNG export authorizations. Instead, DOE focuses on the report's more ambiguous findings comparing LNG's lifecycle GHGs to coal and Russian gas. In the March 2023 LNG approval, DOE writes:

> *"The 2019 Update concluded that the use of U.S. LNG exports for power production in European and Asian markets will not increase global GHG emissions from a life cycle perspective, when compared to regional coal extraction and consumption for power production. On this basis, DOE found that the 2019 Update supports the proposition that exports of LNG from the lower-48 states will not be inconsistent with the public interest."* (DOE 2023, p. 21)

This rationale ignores the rapid uptake of renewable energy technologies, particularly solar and wind power, around the world. **Looking forward, US LNG expansion will compete with renewable energy, not coal and gas**. Renewables increase significantly while electricity generation from fossil fuels declines across all energy scenarios, according to IEA (see Section 3.6).

President Biden has committed the US to achieving a zero-emission US electric grid by 2035 and net-zero economy-wide emissions by 2050. The US long-term strategy to achieve these goals is anchored in decarbonizing the electric power sector by shifting from fossil fuels to renewable energy (such as solar and wind), as well as electrifying other sectors of the economy to further reduce dependence on fossil fuels, including gas (State Department 2021).

A similar pathway is needed globally. Global net-zero goals require robust investment in renewable energy technologies and energy efficiency, all of which will be slowed by locking in more fossil fuel infrastructure.

DOE's approach is also at odds with new guidance from the Council on Environmental Quality (CEQ) instructing federal agencies to assess "whether and to what extent the proposal's reasonably foreseeable GHG emissions are consistent with GHG reduction goals, such as those reflected in the U.S. nationally determined contribution under the Paris Agreement."

It is particularly troublesome that DOE's default position in the face of incomplete energy modeling is to assume LNG exports do no climate harm. The default should be to assume the obvious: that LNG GHGs matter and should be counted.

The question for DOE is not whether LNG has higher or lower emissions than coal. Rather, DOE should be able to demonstrate that it is more probable than not that increased LNG emissions are consistent with net-zero climate goals.

No such evidence has been produced by DOE or any governmental or independent scientific study. Why? Because it's not plausible. As this report demonstrates, the volume of GHGs associated with all planned US LNG projects, including those that will require DOE approvals, is simply too large to be compatible with the climate pathways to achieve science-based climate goals.

2.2 Opportunities to Update and Improve DOE's Approach

An update is in order from DOE's prior attempt to account for GHGs from LNG. The world has changed since 2019, when the Trump administration had disavowed the Paris Climate Agreement. Climate goals and pathways have become clearer.

In addition, the scientific basis for quantifying the impact of methane emissions leaked from natural gas systems has improved significantly, with alarming conclusions. Since 2019, a number of peer-reviewed studies have demonstrated that U.S. natural gas contributes as much or more to climate change as coal due to the potent impact of methane leaks (Howarth and Jacobson 2021; Gordon et al 2023, Zhang et al 2020). Despite government and corporate aspirations over the past decade to rein in US methane leaks, the evidence shows that natural gas emissions in the US remain far above the break-even line with coal.

LNG emissions are even higher than natural gas consumed in the US because of CO_2 and methane emissions associated with liquefaction, shipping, and regasification. A forthcoming study by Robert Howarth of Cornell University evaluates the lifecycle GHGs of LNG exports based on recent studies, including methane leaks during shipping across different ship fuel types (Howarth 2023 Pre-Print). According to the pre-print copy of his paper, which was submitted to a journal in October 2023 and is currently undergoing peer review:

> "While some proponents of LNG have argued it has a climate benefit by replacing coal, the analysis presented here disproves this. Across all scenarios considered, total greenhouse gas emissions from LNG are larger than those from coal… The footprint for LNG is greater than that of either coal or natural gas even in the case of short cruises using tankers that are powered by LNG, where the LNG emissions are 24% larger than for coal."

In this report, I apply Howarth's preliminary findings to the LNG volumes that have been authorized by the US or that are in the permitting pipeline pending decisions by the Biden administration.

DOE can take four actions to remedy the Department's outdated approach:

1) First, DOE should set aside outdated assumptions that LNG exports should be compared to fossil fuels. DOE should instead evaluate the GHG emissions of LNG exports against the decarbonization pathway needed to meet net-zero by 2050 goals, in which case LNG is increasingly competing with renewable energy for power generation. This report models such an approach, using the Net Zero Emissions by 2050 scenario from IEA's World Energy Outlook 2023. DOE authorizes projects to operate through 2050, meaning the GHG emissions are authorized for decades, making today's decisions even more crucial for our long-term ability to meet our climate goals.

2) Second, DOE should transparently assess the full (i.e., gross) lifecycle emissions of LNG projects for each new authorization of LNG exports. Gross emissions reflect all of the carbon and methane added to the atmosphere from the LNG, without netting out emissions from any that may be displaced. Although DOE has avoided including this accounting when it comes to authorizations for LNG exports, the practice of providing estimates of gross emissions alongside net emissions is increasingly common among federal agencies when conducting environmental assessments (Symons 2023). A transparent inventory of the scale of the actual emissions going into the atmosphere provides an important baseline to understand the potential scale of the impact and its impact on global carbon budgets. Although the 2019 NTEL/DOE GHG report is outdated, it nevertheless provides sufficient data for DOE to make these calculations quite easily, as I have done in section IV of this report.

3) Third, DOE should update lifecycle GHG assessments of LNG to account for recent peer-reviewed science, especially regarding methane leak rates. In updating its analysis, DOE should continue its practice of analyzing a 20-year global warming potential (GWP) for methane (in addition to a 100-year GWP) given that the fate of 1.5 degrees goals will be decided within that timeframe. Methane has a particularly high warming impact in the first 20 years after its release to the atmosphere. As President Biden said to world leaders in Glasgow in 2021, this is the "decisive decade" on climate change. Only evaluating emissions over a 100-year timeline suggests a luxury of time that we do not actually have.

4) Finally, DOE should assess the cumulative GHG impacts from the steady stream of LNG projects that DOE has approved. DOE's one-at-a-time approach assumes each project operates in a vacuum. In reality, as shown in this report, DOE has already approved enough LNG to more than double current export capacity. In addition to improving its current course of project-by-project evaluations, a comprehensive assessment of LNG would better position DOE to answer the central question: what level of authorized LNG exports is too much?

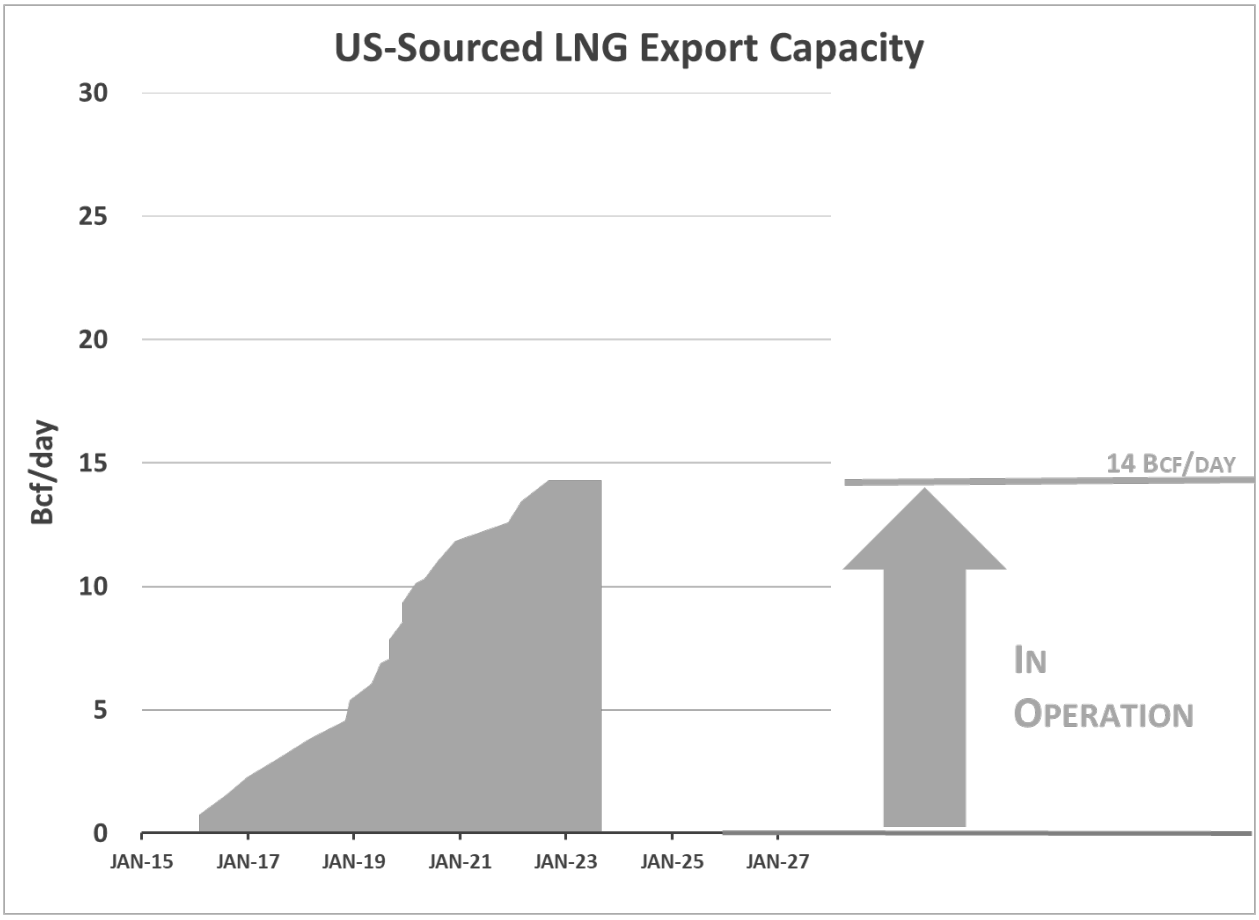
III. Findings

3.1 Finding 1: US LNG exports have doubled since 2019

The first U.S. exports of LNG began in 2016. In 2022, the US became the world's largest exporter of LNG. As of October 2023, seven U.S. LNG facilities are in operation with a total DOE-approved export capacity of 14.3 billion cubic feet (Bcf) per day.

US LNG exports increased from 1,820 Bcf in 2019 to 3,866 Bcf in 2022. US LNG exports climbed to the second highest level on record in October 2023, eclipsed only in April of this year.

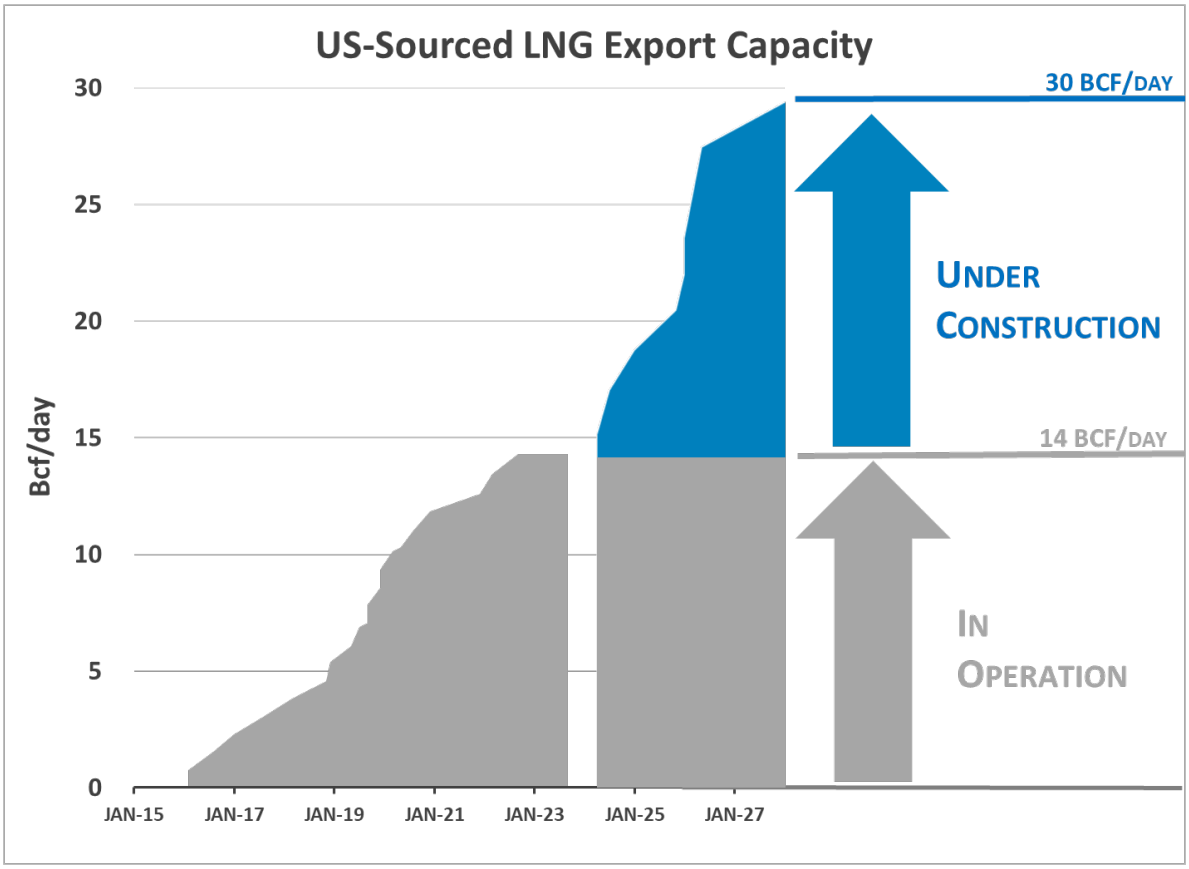
Figure 3 – Currently Operational US-Sourced LNG Capacity



3.2 Finding 2: Projects under construction will double US LNG export capacity over 2023 levels by 2027

DOE has issued export permits for six US-sourced LNG export facilities that are currently under construction, totaling 15.5 Bcf/day of US-sourced LNG export capacity that will become operational within the next few years. This capacity will more than double the current operating capacity approved by DOE (14.3 Bcf/day).

Figure 4 – US-Sourced LNG In Operation and Under Construction



"US-sourced LNG" refers to all LNG exports from the U.S. and Mexico that are sourced from US natural gas. DOE must review and approve applications for all exports of US-sourced LNG to non-free trade nations, even if the natural gas is liquefied at Mexican facilities for further export. One of the projects currently under construction, Energía Costa Azul (1.7 Bcf/day), will liquefy US-sourced LNG in Mexico. Because this project and other similar projects rely on US gas and require approval from DOE, they are included in this report.

3.3 Finding 3: The US is surpassing its LNG commitments to Europe and current US LNG exports are sufficient to meet Europe's LNG needs

After Russia invaded Ukraine in February 2022, European demand for LNG imports soared as EU countries sought alternatives to Russian gas. President Biden met specific commitments to provide an additional 15 billion cubic meters (bcm) of US LNG to Europe. In 2022, the United States delivered 56 bcm to Europe, an increase of 34 bcm from 2021. In joint statements in 2023 (here and here), the United States and EU acknowledged that the US more than doubled its 2022 target and is meeting EU's current LNG needs.

Current levels of US LNG exports – let alone the doubling of US export capacity that is under construction – are more than sufficient to meet Europe's national security needs. In 2023, European LNG imports have flattened, according to the Institute for Energy Economics and Financial Analysis (IEEFA 2023). European LNG imports increased just 4% from January through September, compared to the same period in 2022. Europe's LNG needs are expected to decline from 2023 through 2030 as Europe reduces gas demand.

For 2023 through 2030, the United States has committed to provide Europe with approximately 50 bcm annually. The United States has already exceeded its 2023 goal, delivering 56 bcm from January to September (IEEFA 2023-a). Gas storage facilities in Europe are nearly full heading into winter.

3.4 Finding 4: Companies are seeking approval for new LNG projects that would quadruple US LNG export capacity compared to current (2023) levels

If all projects currently in the permitting pipeline are approved, the total LNG export capacity for US-sourced gas would more than quadruple the amount of US-sourced LNG export capacity that is currently in operation, increasing capacity from 14.3 Bcf/day to 66.1 Bcf/day.

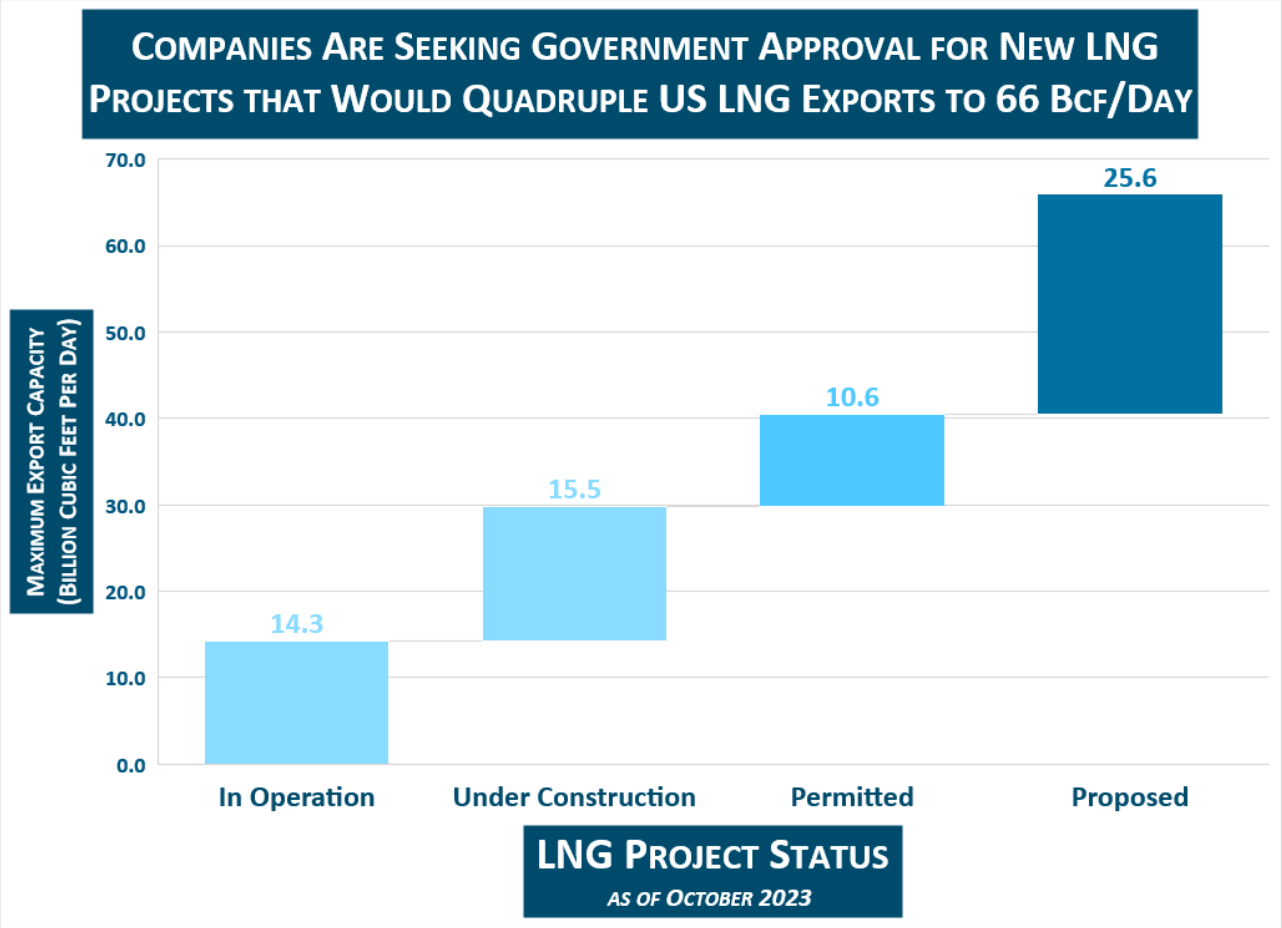
LNG export status is defined as follows:

- **In Operation –** The total permitted amount of authorized LNG exports from facilities currently shipping US-sourced LNG. Actual LNG shipments may be lower than the amounts authorized by DOE, which are based on each company's application and usually reflect maximum capacity.
- **Under Construction –** The total permitted amount of authorized LNG exports from facilities that have been authorized by DOE and have broken ground on construction.
- **Permitted –** The total permitted amount of authorized LNG exports from facilities that have been authorized by DOE but have not broken ground on construction, usually because they are seeking financing and have not reached a Final Investment Decision (FID). This figure excludes projects that received LNG export permits from DOE but will need to

reapply to DOE, pursuant to DOE's 2023 policy statement on extensions.[3] Those projects are captured instead in the following category – "proposed."

- **Proposed –** The maximum capacity of projects that are pending at DOE and/or FERC, are in pre-filing with FERC, or have port permits pending with the Maritime Administration. This includes projects that previously received LNG export permits from DOE but will need to reapply to DOE, pursuant to DOE's 2023 order on extensions, because those permits expire in 2026 or sooner.

Figure 5 – US-Sourced LNG Export Capacity by Volume and Status



[3] DOE approvals for LNG exports are only valid if the applicant begins shipping LNG within 7 years. For purposes of this report, any facility that has received a permit but not begun construction, and whose permit expires in 2026 or sooner, is deemed to require a renewal (construction typically takes a minimum of 3 years).

3.5 Finding 5: US LNG expansion will compete with renewable energy – not coal and gas – around the world

As DOE considers whether further US LNG expansion is in the public interest, an important question is what impact expanded US LNG exports will have on global energy markets and emissions. Because new construction of liquefaction capacity takes a minimum of three years to construct after approval and a Final Investment Decision, DOE decisions should look ahead toward markets in 2027 and beyond.

Thanks to enormous gains in renewable energy, particularly wind and solar-powered electricity, the global energy landscape has changed significantly since NETL's 2019 analysis. If new projects are authorized by DOE today, **US LNG expansion currently will compete with renewable energy, not fossil fuels.**

Across all scenarios in IEA's *World Energy Outlook (IEA 2023)*, renewables-sourced electricity increases significantly while electricity generation from fossil fuels declines. In IEA's most bullish fossil fuel forecast (the Stated Policies Scenario, which assumes that nations do not meet their climate commitments), global electricity generation will almost triple by 2035 and quadruple by 2050 (an increase of 14 TWh/yr in 2035 and 29 TWh/yr by 2050, compared to 2022 levels). In contrast, electricity generation from fossil fuels is projected to decline by 23% (minus 4 TWh/yr) by 2035 and 25% by 2050 (minus 6 TWh/yr).

Figure 6 – Global Electricity Generation

Based on IEA's World Energy Outlook (IEA 2023)

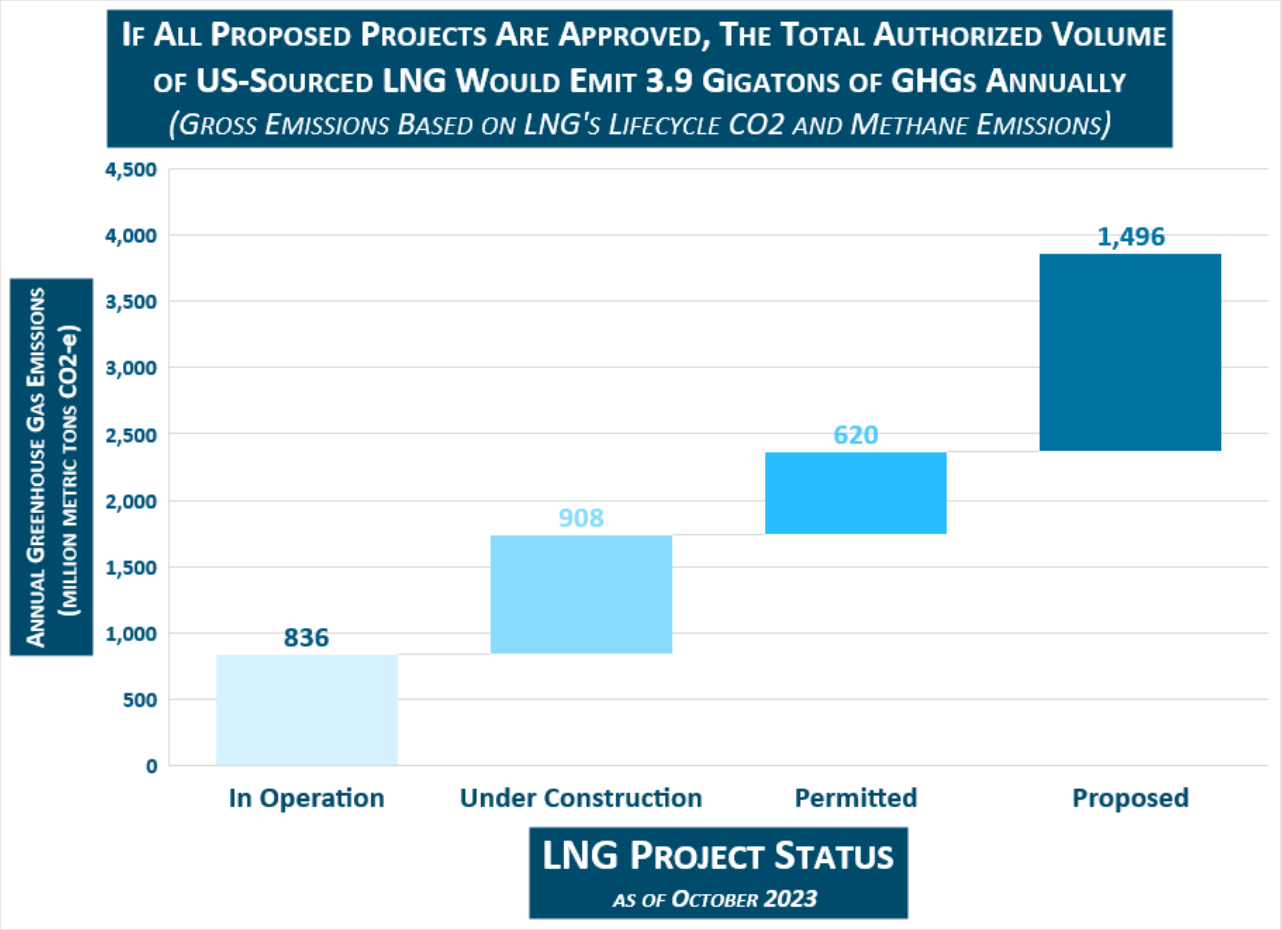
	2022	2035		2050	
	Electricity Generation (TWh)	Global Electricity Generation (TWh)	Change from 2022	Global Electricity Generation (TWh)	Change from 2022
Stated Policies Scenario					
- Renewables	8,599	23,051	168%	37,973	342%
- Fossil Fuels	17,637	13,623	-23%	11,463	-35%
Net Zero Emissions by 2050 Scenario					
- Renewables	8,599	36,739	327%	68,430	696%
- Fossil Fuels	17,637	4,467	-75%	1,154	-93%

3.6 Finding 6: If all projects are approved, GHG emissions from DOE-authorized LNG exports would be 3.9 gigatons annually; US-sourced LNG emissions would be larger than the GHG emissions from the European Union, whether using a gross or net accounting approach

GHG emissions in this report are calculated based on the lifecycle GHGs from LNG, including CO_2 and methane emissions at all stages: upstream emissions (natural gas production, processing, transmission), liquefaction, shipping, regassification, downstream transmission, and final combustion. The top line findings expressed in this report are based on Howarth 2023. I provide additional calculations for comparison using DOE/NETL's 2019 study.

If all projects currently in the permitting pipeline are approved, the full (gross) lifecycle GHG emissions from all approved US-sourced LNG exports would be 3.9 gigatons of CO_2-equivalent annually. That is equivalent to 63% of current (2021) U.S. GHG emissions. It is also larger than the total GHG emissions from the European Union.

Figure 7 – Total (Gross) GHGs from Approved and Proposed US-Sourced LNG



I calculated net GHG emissions against the net-zero by the 2050 pathway identified by IEA 2023. Specifically, the net emissions calculation subtracts (from the gross calculation) the lifecycle emissions from an equivalent amount of electricity generation fueled by the average grid fuel mix identified in the IEA net-zero pathway. IEA's carbon intensity factors were supplemented by upstream emissions from coal and gas based on emissions factors identified in DOE/NETL 2019.

If all projects currently in the permitting pipeline are approved, the net lifecycle GHG emissions from all approved US-sourced LNG exports would be 3.6 gigatons of CO2-equivalent annually. That is equivalent to 57% of current (2021) U.S. GHG emissions. Both the gross and net emissions from cumulative, planned LNG are larger than the total GHG emissions from the European Union.

Figure 8 – Gross and Net GHGs from Approved and Proposed US-Sourced LNG

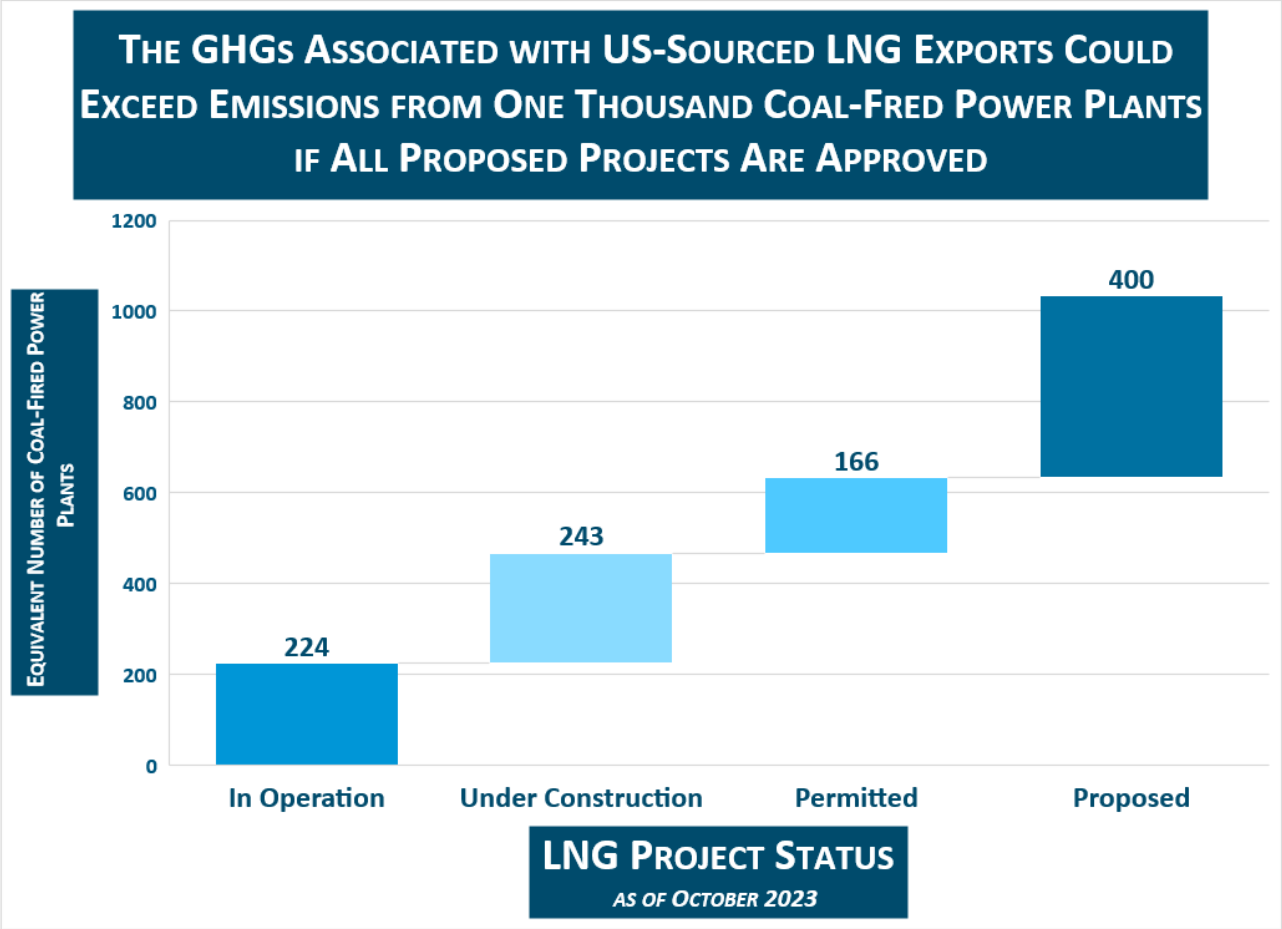
Based on Gross Lifecycle GHG Emission Factors from Howarth (2023)

	LNG Capacity (Bcf/day)	Gross GHG Emissions (MMT CO2 -e/yr)	Net GHG Emissions (MMT CO2 -e/yr)
In Operation	14.3	836	760
Under Construction	15.5	908	825
Permitted	10.6	620	564
Proposed	25.6	1,496	1,360
Total	**66.1**	**3,860**	**3,509**

3.7 Finding 7: If all projects currently in the permitting pipeline are approved, GHG emissions from US-approved LNG exports would be greater than one thousand coal-fired power plants

If all projects currently in the permitting pipeline are approved, the lifecycle GHG emissions from approved levels of US-sourced LNG exports would be 3.9 gigatons of CO2-equivalent annually, which is equivalent to 1,033 coal-fired power plants.

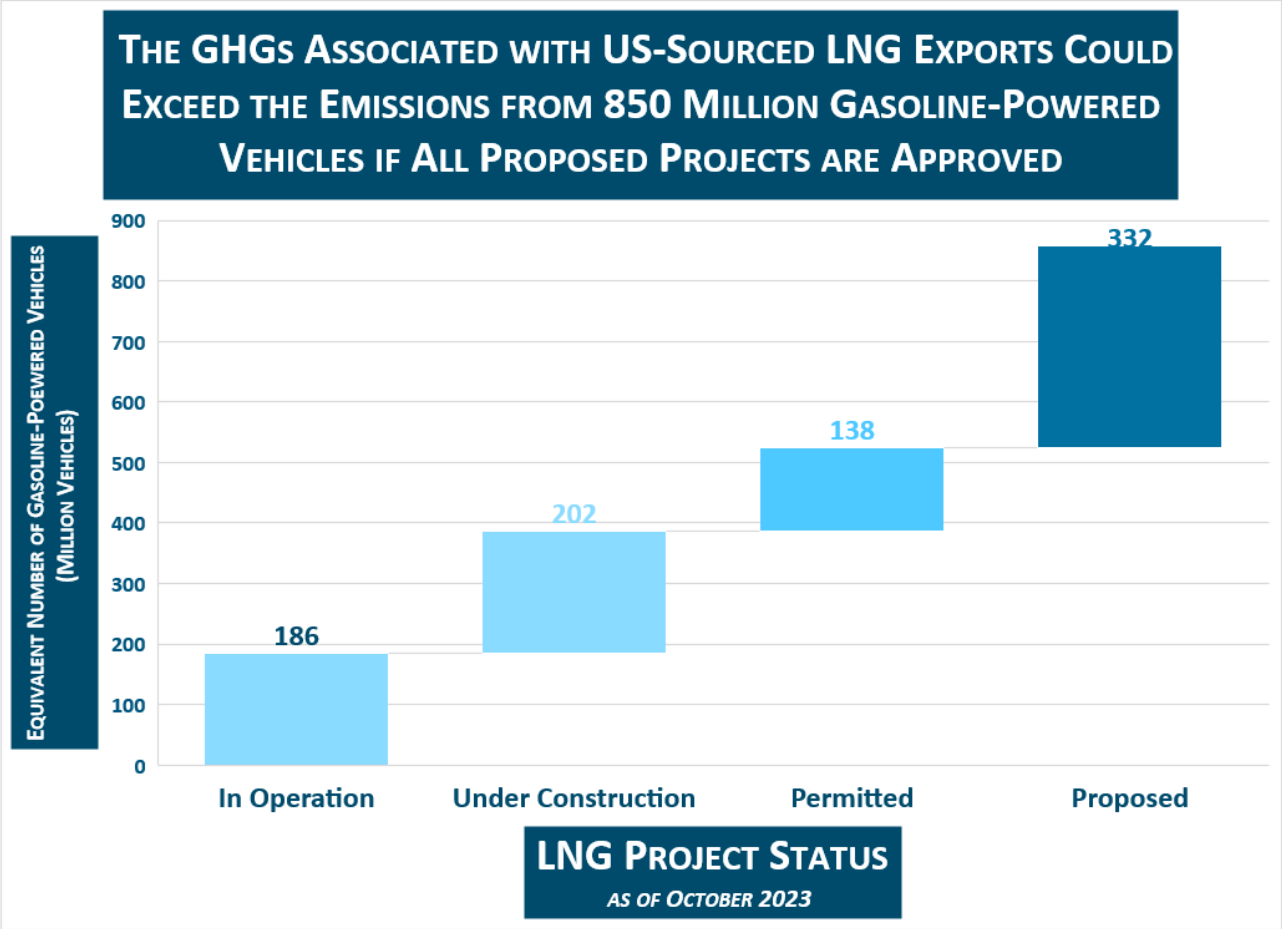
Figure 9 – GHGs from Approved and Planned LNG Exports, Expressed as Equivalent Emissions from Coal-Fired Power plants



3.8 Finding 8: If all projects currently in the permitting pipeline are approved, GHG emissions from U.S.-approved LNG exports would be equivalent to 850 million gasoline-powered vehicles

If all projects currently in the permitting pipeline are approved, the lifecycle GHG emissions from approved levels of US-sourced LNG exports would be 3.9 gigatons of CO2-equivalent annually, which is equivalent to 850 million gasoline-powered vehicles.

Figure 10 – GHGs from Approved and Planned LNG Exports, Expressed as Equivalent Emissions from Vehicles (in Millions)



IV. Comparison to DOE/NETL Estimates

DOE relies on a 2019 National Energy Technology Laboratory (NETL) study on the lifecycle GHG emissions of LNG. Howarth 2023 finds significantly higher (+50%) lifecycle emissions than NETL 2019. Howarth includes emission sources not included in the NETL study. Also, NETL assumes lifecycle LNG methane leak rates of 1.6% across the entire LNG system, from natural gas production through liquefaction and delivery. These rates are significantly below the conclusions of multiple, more recent, studies on US shale gas leakage rates, even though those studies don't include the LNG-specific leaks from liquefaction, shipping, and regasification.

This section provides comparative information on what the calculations would be using the NETL 2019 emission factors. This study uses a simple average of the EU and Asian numbers, splitting the difference between the two. All numbers are based on a GWP of 20 for methane, consistent with Howarth 2023 (see discussion under methodology).

Figure 11 – Gross and Net GHGs from Approved and Proposed US-Sourced LNG

Based on Gross Lifecycle GHG Emission Factors from DOE/NETL (2019)

	LNG Capacity (Bcf/day)	Gross GHG Emissions (MMT CO2 -e/yr)	Net GHG Emissions (MMT CO2 -e/yr)
In Operation	14.3	528	452
Under Construction	15.5	574	491
Permitted	10.6	392	336
Proposed	25.6	946	810
Total	**66.1**	**2,441**	**2,089**

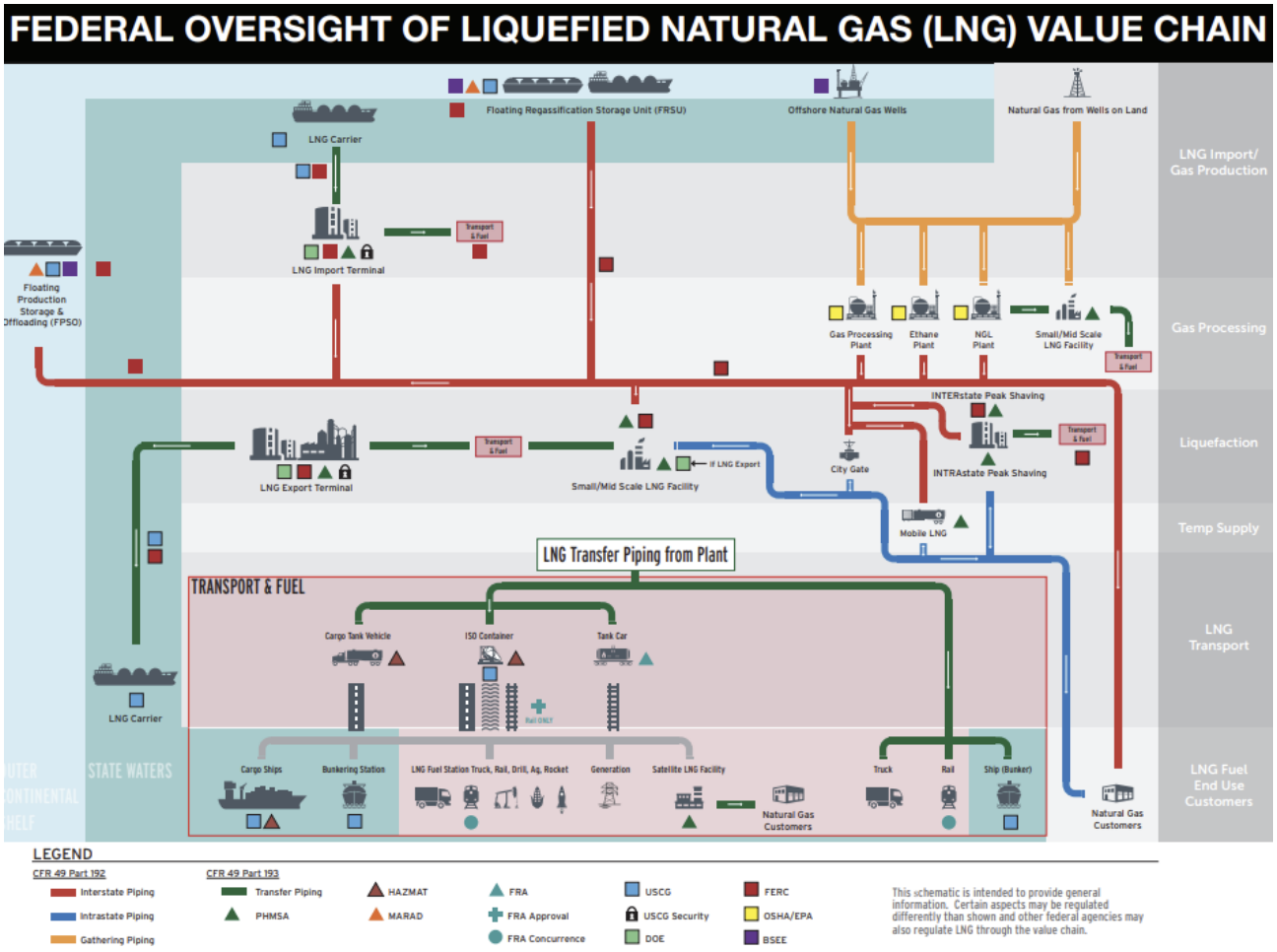
V. Overview of Federal Agency LNG Responsibilities

US LNG facilities are subject to regulation from multiple federal agencies, including: FERC (construction/siting), DOE (public interest determination), Marine Administration (ports), DOT (PHMSA, Maritime Administration), EPA (air and water permits), and Army Corps of Engineers (Clean Water Act, dredging). DOE has given FERC the lead on preparing environmental impact statements. DOE makes its public interest determination after FERC approves a project.

Each of these agencies has a critical role. This report focuses on DOE because DOE has been uniquely charged under the Natural Gas Act with determining if authorizing LNG exports is in the "public interest."

Figure 12 – Federal Oversight of LNG

Source: DOT/PHMSA



VI. Data and Methods

6.1 Inventory of LNG Projects

The inventory of LNG projects (see Section VII) was built based on the following sources:

- US Energy Information Administration, "US Liquefaction Capacity"
- USDOE, "Summary of LNG Export Applications of the Lower 48 States"
- US DOE, "Policy Statement on Export Commencement Deadlines in Natural Gas Export Authorizations"
- US FERC, "North American LNG Export Terminals – Existing, Approved not Yet Built, and Proposed"
- US DOT, Maritime Administration, "Pending Applications"
- Sierra Club, "US LNG Export Tracker"

6.2 Emission Factors

The following emission factors are used in this report. DOE/NETL 2019 expressed emissions in terms of g CO2-e per kWh (gross caloric). Howarth 2023 expresses emissions in grams CO2-e per kg (net caloric). I calculated the figures in italics for this report.

Figure 13 – Emission Factors and Conversions

	Scenario	Grams CO2-e per kg LNG	grams CO2-e/ kWh	grams CO2-e per cubic foot	MMT CO2-e per Bcf	Annual MMT CO2-e per Bcf/day
DOE/NETL (2019)	LNG (US Gulf Coast to Europe/Asia, averaged)		***751***	*101*	*0.1012*	*36.9*
Howarth (2023)	LNG (Steam tankers powered by LNG; (US Gulf Coast to Europe/Asia, averaged)	**7,506**		*160*	*0.1601*	*58.4*
IEA (2023)	Avg. global electricity intensity (2025-2050), Net Zero by 2050 Scenario		*108*	*15*	*0.0146*	*5.3*

There are a number of subtle variations across sources on energy data as it relates to LNG, including energy content of LNG and natural gas, as well as electricity heat rates. I found the results of this study to be robust across different data sources, with only marginal variations.

To convert Howarth's data, I used a value of 48.6 MJ per kg of LNG (Lower Heating Value, or LHV), consistent with the value used in Howarth 2023, based on his source: Engineering Toolbox (Engineering Toolbox 2003). I also used a factor of 1.036 MJ per cubic foot (LHV), also based on Engineering Toolkit. This figure is for natural gas. The energy content of LNG might be slightly higher, but Engineering Toolkit did not provide. Howarth's numbers are expressed in LHVs.

To convert DOE/NETL and IEA data, I used a factor of 7.42 cubic feet of natural gas per kWh, which is based on U.S. EIA data for 2022 (EIA-b). EIA uses High Heating Values.

6.3 Global Warming Potentials

The factors used in this analysis and listed above are based on a 20-year GWP for methane. The reason is simple: we are in a race to avoid exceeding climate thresholds (including 1.5 degrees) but are on course to fly past them within the next two decades. As President Biden said to global leaders at Glasgow, this is the decisive decade. Using a 100-year GWP masks the higher impact of methane over the next 20 years.

A more rigorous explanation is provided by Howarth (2023):

> *While the 100-year time frame of GWP100 is widely used in lifecycle assessments and greenhouse gas inventories, it understates the extent of global warming that is caused by methane, particularly on the time frame of the next several decades. The use of GWP100 dates back to the Kyoto Protocol in the 1990s, and was an arbitrary choice made at a time when few were paying much attention to the role of methane as an agent of global warming. As the Intergovernmental Panel on Climate Change stated in their AR5 synthesis report, "there is no scientific argument for selecting 100 years compared with other choices" (IPCC 2013). The latest IPCC AR6 synthesis reports that methane has contributed 0.5o C of the total global warming to date since the late 1800s, compared to 0.75o C for carbon dioxide (IPCC 2021). And the rate of global warming over the next few decades is critical, with the rate of warming important in the context of potential tipping points in the climate system (Ritchie et al. 2023). Reducing methane emissions rapidly is increasingly viewed as critical to reaching climate targets (Collins et al. 2018; Nzotungicimpaye et al. 2023). In this context, many researchers call for using the 20-year time frame of GWP20 instead of or in addition to GWP100 (Howarth 2014, 2020; Ocko et al. 2017; Fesenfeld et al. 2018; Pavlenko et al. 2020; Howarth and Jacobson 2021; Balcombe et al. 2021,2022).*

VII. Data Tables: Inventory of LNG Permit Applications and Associated GHGs

		Project	Location	Company	DOE Permit Status (expiration date; Docket Number)	FERC Permit Status	Maritime Admin. Permit Status	Bcf/day (DOE Export Application)
In Operation	1	Sabine Pass	Texas	Cheniere	Approved	Approved		4.56
	2	Cove Point	Maryland	Berkshire Hathaway	Approved	Approved		0.77
	3	Corpus Christi	Texas	Cheniere	Approved	Approved		2.40
	4	Cameron (Hackberry)	Louisiana	Sempra	Approved	Approved		2.12
	5	Elba Island	Georgia	Kinder Morgan	Approved	Approved		0.50
	6	Freeport	Texas	Freeport LNG	Approved	Approved		2.38
	7	Calcasieu Pass	Louisiana	Venture Global	Approved	Approved		1.58
		Subtotal						**14.31**
Under Construction	8	Golden Pass LNG	Texas	ExxonMobil - Golden Pass	Approved (exp. 9/30/2025)	Approved		2.57
	9	Plaquemines LNG	Louisiana	Venture Global	Approved (exp. 10/16/2026)	Approved		3.85
	10	Driftwood LNG	Louisiana	Tellurian	Approved (exp, 5/2/2026)	Approved		3.88
	11	Corpus Christi Stage III	Texas	Cheniere	Approved (exp. 2/10/2027)	Approved		1.59
	12	Port Arthur (Trains 1&2)	Texas	Sempra	Approved (exp. 6/18/2028)	Approved		1.91
	13	Energía Costa Azul	Mexico	Energía Costa Azul	Approved (exp. 3/29/2026)	Approved		1.74
		Subtotal						**15.54**
Permitted (Not Yet Under Construction)	14	Texas LNG	Texas	Glenfarne	Approved (exp. 2/10/2027)	Approved		0.55
	15	Rio Grande LNG	Texas	NextDecade	Approved (exp. 2/10/2027)	Approved		3.61
	16	Alaska LNG	Alaska	Alaska Gasline	Approved (exp. 8/20/2032)	Approved		2.55
	17	Cameron LNG (Train 4)	Louisiana	Sempra	Approved (exp. 5/5/2026)	Approved		1.41
	18	Freeport LNG (Train 4)	Texas	Freeport LNG	Approved (exp. 5/28/2026)	Approved		0.72
	19	Eagle LNG	Florida	Eagle LNG Partners	Approved (exp. 10/3/2026)	Approved		0.14
	20	Vista Pacifico LNG	Mexico	Sempra	Approved (exp. 12/20/2029)	Approved		0.55
	21	Amigo LNG	Mexico	Epcilon LNG LLC	Approved (exp. 12/82027)	Approved		1.08
		Subtotal						**10.61**
Planned (Requires New or Renewed Permits)	22	Magnolia LNG	Louisiana	Glenfarne	Approved (exp. 11/30/2023)	Approved		1.23
	23	Lake Charles LNG	Louisiana	Energy Transfer	Approved (exp.12/16/2025)	Approved		2.30
	24	Freeport LNG (Train 4)	Texas	Freeport LNG	Approved (exp.5/28/2026)	Approved		0.72
	25	Gulf LNG	Mississippi	Kinder Morgan	Approved (exp. 7/31/2026)	Approved		1.53
	26	Mexico Pacific Limited LNG	Mexico	Mexico Pacific Limited	Approved (exp. 12/14/2025)	Approved		1.70
	27	Delfin LNG	Gulf of Mexico	Delfin Midstream	Approved (exp. 6/1/2024)	Approved		1.80
	28	Commonwealth LNG	Louisiana	Commonwealth LNG	Pending (19-134-LNG)	Approved		1.21
	29	Port Arthur LNG Trains 3 & 4	Texas	Sempra	Pending (20-23-LNG)	Approved		1.86
	30	CP2 LNG	Louisiana	Venture Global	Pending (21-131-LNG)	Pending		3.96
	31	Calcasieu Pass LNG (uprate)	Louisiana	Venture Global	Pending (amendment to 15-25-LNG)	Approved		0.06
	32	Plaquemines LNG (uprate)	Louisiana	Venture Global	Pending (16-28-LNG)	Pending		0.45
	33	Corpus Christi LNG (Trains 8-9)	Texas	Cheniere	Pending (23-46-LNG)	Pending		0.47
	34	Elba Island LNG (uprate)	Georgia	Kinder Morgan	Pending (23-109-LNG)	Pending		0.08
	35	Fourchon LNG	Louisiana	Energy World USA	Pending (17-105-LNG)	Pre-Filing		0.71
	36	Delta LNG	Louisiana	Venture Global		Pre-Filing		2.76
	37	Mexico Pacific Limited (Phase 1 expansion)	Mexico	Mexico Pacific Limited	Pending (22-167-LNG)			0.80
	38	NFE Altamira FLNG	Mexico	New Fortress Energy	Pending (22-110-LNG)			0.40
	39	Gulfstream LNG	Louisiana	Gulfstream LNG Development	Pending (23-34-LNG)			0.65
	40	Grand Isle LNG	Louisiana	Grand Isle LNG			Pending	0.56
	41	New Fortress Energy Louisiana FLNG	Louisiana	New Fortress Energy	Pending (22-39-LNG)		Pending	0.56
	42	West Delta LNG	Louisiana	West Delta LNG			Pending	0.90
	43	Sabine Pass – Stage 5	Louisiana	Cheniere		Pre-Filing		0.90
		Subtotal						**25.61**
Total								**66.07**

		Project	Bcf/day (DOE Export Application)	Gross GHGs (Million Metric Tons CO2-e/Yr)	Coal-Fired Power Plant Equivalencies	Vehicle Equivalencies (Millions)	Net GHGs (Million Metric Tons CO2-e/Yr)
In Operation	1	Sabine Pass	4.56	271	73	60	248
	2	Cove Point	0.77	46	12	10	42
	3	Corpus Christi	2.40	143	38	32	130
	4	Cameron (Hackberry)	2.12	126	34	28	115
	5	Elba Island	0.50	30	8	7	27
	6	Freeport	2.38	142	38	31	129
	7	Calcasieu Pass	1.58	94	25	21	86
		Subtotal	**14.31**	**851**	**228**	**189**	**777**
Under Construction	8	Golden Pass LNG	2.57	153	41	34	139
	9	Plaquemines LNG	3.85	229	61	51	209
	10	Driftwood LNG	3.88	231	62	51	211
	11	Corpus Christi Stage III	1.59	95	25	21	86
	12	Port Arthur (Trains 1&2)	1.91	114	30	25	104
	13	Energía Costa Azul	1.74	103	28	23	95
		Subtotal	**15.54**	**924**	**247**	**205**	**844**
Permitted (Not Yet Under Construction)	14	Texas LNG	0.55	33	9	7	30
	15	Rio Grande LNG	3.61	215	57	48	196
	16	Alaska LNG	2.55	152	41	34	139
	17	Cameron LNG (Train 4)	1.41	84	22	19	77
	18	Freeport LNG (Train 4)	0.72	43	11	10	39
	19	Eagle LNG	0.14	8	2	2	8
	20	Vista Pacifico LNG	0.55	33	9	7	30
	21	Amigo LNG	1.08	64	17	14	59
		Subtotal	**10.61**	**631**	**169**	**140**	**577**
Planned (Requires New or Renewed Permits)	22	Magnolia LNG	1.23	73	20	16	67
	23	Lake Charles LNG	2.30	137	37	30	125
	24	Freeport LNG (Train 4)	0.72	43	11	10	39
	25	Gulf LNG	1.53	91	24	20	83
	26	Mexico Pacific Limited LNG	1.70	101	27	22	92
	27	Delfin LNG	1.80	107	29	24	98
	28	Commonwealth LNG	1.21	72	19	16	66
	29	Port Arthur LNG Trains 3 & 4	1.86	111	30	25	101
	30	CP2 LNG	3.96	236	63	52	215
	31	Calcasieu Pass LNG (uprate)	0.06	4	1	1	3
	32	Plaquemines LNG (uprate)	0.45	27	7	6	24
	33	Corpus Christi LNG (Trains 8-9)	0.47	28	7	6	26
	34	Elba Island LNG (uprate)	0.08	5	1	1	4
	35	Fourchon LNG	0.71	42	11	9	39
	36	Delta LNG	2.76	164	44	36	150
	37	Mexico Pacific Limited (Phase 1 expansion)	0.80	48	13	11	43
	38	NFE Altamira FLNG	0.40	24	6	5	22
	39	Gulfstream LNG	0.65	39	10	9	35
	40	Grand Isle LNG	0.56	33	9	7	30
	41	New Fortress Energy Louisiana FLNG	0.56	33	9	7	30
	42	West Delta LNG	0.90	54	14	12	49
	43	Sabine Pass – Stage 5	0.90	54	14	12	49
		Subtotal	**25.61**	**1,523**	**408**	**338**	**1,391**
Total			**66.07**	**3,929**	**1,052**	**872**	**3,589**

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