House Environmental Resources & Natural Protection Committee

Public Hearing Agenda:

"LNG Export Terminal Proposed for SE PA"
Wednesday, November 5th, 2025
10:00am – 12:00pm
Chester City Hall, Chester PA

10:00am – 10:15am	Call to Order Roll Call Opening Remarks - Mayor Stefan Roots, City of Chester
10:15am – 10:45am	Dr. Robert Howarth Professor of Ecology and Environmental Biology Cornell University Tracy Carluccio Deputy Director Delaware Riverkeeper Network
10:45am – 11:00am	Lauren Minsky Visiting Assistant Professor of Health Studies Haverford College
11:00am – 11:15am	Liz Marx Executive Director PA Utility Law Project
11:15am – 11:45am	James Hiatt Founder For a Better Bayou Zulene Mayfield Chairperson Chester Residents Concerned for Quality Living
11:45am – 12:00pm	Closing Remarks
12:00pm	Adjournment

PA House Environmental & Natural Resource Protection Committee
Public Hearing: LNG Export Terminal
Mayor Stefan Roots Testimony

Wednesday, November 5 | 10am | Chester City Hall Community Room

Introduction

Good morning. I am Mayor Stefan Roots, and on behalf of the people of the city of Chester, I am here to strongly and emphatically say NO to LNG in or near our city.

I've spoken on this issue before and quite frankly, I'm disappointed that we're even having this discussion again.

An LNG Export Terminal would be an extreme health and safety hazard for the city of Chester or any other town along this stretch of the Delaware River.

Safety Hazard

From a safety standpoint, it would be negligent and irresponsible to locate an LNG terminal in this region. Explosions can and do occur with these facilities. The blast zone would displace many residents and put thousands more at serious risk.

Chester is a city of homes and families, children and senior citizens. As we seek to revitalize Chester, my vision is to build new housing and attract new residents to the city. I also want to see Chester become more and more a destination and attraction for visitors. We have a major league soccer stadium that brings tens of thousands of fans to our waterfront every week. We have a brand-new world class sportsplex with a rapidly growing youth sports scene that attracts thousands more visitors to the waterfront every day.
I'm all for new construction in Chester that is safe, healthy, and beneficial to the community. We have new multi-million-dollar development projects underway in the area, including a City of Chester Public Works Garage and a new Power Home Remodeling facility. Both of these projects would be pushed aside by an LNG terminal to accommodate a blast zone.

It would be devastating to our city's progress to put a ticking time bomb LNG terminal on our waterfront in close proximity to thousands of residents, visitors, and workers. This dangerous facility does not belong in a densely populated urban area like the City of Chester.

Health Hazard

An LNG export terminal would also compound our environmental health issues. The City of Chester is officially designated as an environmental justice community due to the fact that there is already so much polluting industry concentrated in and around our city. 8 months ago I sat in a hearing just like this with many of you over at Widener University to testify about the cumulative impacts of pollution on Chester. Chester residents experience FOUR TIMES the national average of infant deaths and childhood asthma. We're still collecting data, but I suspect we would see the same trend with cancer rates in Chester. Pollution is literally killing us in this city.

A polluting LNG export terminal would further burden this community and make those stats even worse. Despite what they may claim, LNG terminals are polluters. Not a single operational LNG terminal in the United States has managed to stay in compliance with the Clean Air Act's air pollution standards.

Chester residents need and deserve fresh air, clean waterways, and safe soil – not more pollution from LNG.

Closing

As is so often the case, outside prospectors try to tempt poor, struggling communities like Chester into what are ultimately deals with the devil. Deals that harm the community for the profit of others. Chester is already suffering from the consequences of such past deals.

We do not need another bad deal that harms the good people who live, work, and play here. As the mayor of Chester, I am calling on this committee to do the right thing, protect some of the most vulnerable people of this Commonwealth, and say NO to an LNG terminal in this region.

Thank you.

Received: 26 March 2024 | Revised: 6 September 2024 | Accepted: 16 September 2024

DOI: 10.1002/ese3.1934

MODELLING AND ANALYSIS

The greenhouse gas footprint of liquefied natural gas (LNG) exported from the United States

Robert W. Howarth

Department of Ecology & Evolutionary Biology, Cornell University, Ithaca, New York, USA

Correspondence
Robert W. Howarth, Department of Ecology & Evolutionary Biology, Cornell University, Ithaca, NY 14853 USA.
Email: howarth@cornell.edu

Funding information
Park Foundation

Abstract

Liquefied natural gas (LNG) exports from the United States have risen dramatically since the LNG-export ban was lifted in 2016, and the United States is now the world's largest exporter. This LNG is produced largely from shale gas. Production of shale gas, as well as liquefaction to make LNG and LNG transport by tanker, is energy-intensive, which contributes significantly to the LNG greenhouse gas footprint. The production and transport of shale gas emits a substantial amount of methane as well, and liquefaction and tanker transport of LNG can further increase methane emissions. Consequently, carbon dioxide (CO_2) from end-use combustion of LNG contributes only 34% of the total LNG greenhouse gas footprint, when CO_2 and methane are compared over 20 years global warming potential (GWP_{20}) following emission. Upstream and midstream methane emissions are the largest contributors to the LNG footprint (38% of total LNG emissions, based on GWP_{20}). Adding CO_2 emissions from the energy used to produce LNG, total upstream and midstream emissions make up on average 47% of the total greenhouse gas footprint of LNG. Other significant emissions are the liquefaction process (8.8% of the total, on average, using GWP_{20}) and tanker transport (5.5% of the total, on average, using GWP_{20}). Emissions from tankers vary from 3.9% to 8.1% depending upon the type of tanker. Surprisingly, the most modern tankers propelled by two- and four-stroke engines have higher total greenhouse gas emissions than steam-powered tankers, despite their greater fuel efficiency and lower CO_2 emissions, due to methane slippage in their exhaust. Overall, the greenhouse gas footprint for LNG as a fuel source is 33% greater than that for coal when analyzed using GWP_{20} (160 g CO_2-equivalent/MJ vs. 120 g CO_2-equivalent/MJ). Even considered on the time frame of 100 years after emission (GWP_{100}), which severely understates the climatic damage of methane, the LNG footprint equals or exceeds that of coal.

KEYWORDS

global warming potential, GWP_{20}, lifecycle analysis, LNG, methane emissions

1 | INTRODUCTION

In this paper, I analyze the greenhouse gas footprint of liquefied natural gas (LNG) produced in and exported from the United States. The United States prohibited the export of LNG before 2016, but since the lifting of the ban at that time, exports have risen rapidly.[1] In 2022, the United States became the largest exporter of LNG globally.[2] Exports of LNG doubled between 2019 and 2023, and if allowed by the United States government to continue, were predicted to double again over the next 4 years.[3] As of 2023, the LNG exported from the United States represented 21% of all global LNG transport.[4] In January of 2024, U.S. President Biden placed a moratorium on increasing exports of LNG pending further study of the consequences of such exports, including the analysis of greenhouse gas emissions.[5] An earlier version of the analysis I present in this paper was used by the White House as evidence for the need for greater study on the greenhouse gas emissions from LNG, particularly methane emissions.[6]

Proponents of increased exports of LNG from the United States to both Europe and Asia have often claimed a climate benefit, arguing that the alternative would be greater use of coal produced domestically in those regions,[3,7] with increased emissions of carbon dioxide. In fact, even though carbon-dioxide emissions are greater from burning coal than from burning natural gas, methane emissions can more than offset this difference.[8–11] As a greenhouse gas, methane is more than 80 times more powerful than carbon dioxide when considered over a 20-year period,[12] and so even small methane emissions can have a large climate impact. Clearly, greenhouse gas emissions from LNG must be larger than from the natural gas from which it is made, because of the energy needed to liquefy the gas, transport the LNG, and regasify it. The liquefaction process alone is highly energy-intensive.[13,14] A lifecycle assessment is required to determine the full magnitude of these LNG greenhouse gas emissions. My analysis builds on earlier lifecycle assessments for LNG.[15–21] Of these, only those since 2015 have analyzed LNG export from the United States, and their focus was on export to China. My focus here is on exports from the United States to Europe as well as to China, using the most recent data on methane emissions from shale gas development in the United States.

Most natural gas production in the United States is shale gas extracted using high volume hydraulic fracturing and high-precision directional drilling, two technologies that only began to be used commercially to develop shale gas in this century.[22,23] It is the rapid increase in shale gas production in the United States that has allowed and driven the increase in export of LNG.[3] As shown in Figure 1, production of natural gas in the United States was relatively flat from 1985 to 2005. Since then, production has risen rapidly, driven almost entirely by the production of shale gas. The United States was a net importer of natural gas from 1985 to 2015, with net exports as LNG only since 2016 driven by production in excess of domestic consumption. Shale gas production is quite energetically intensive, and the related emissions of carbon dioxide need to be considered in any full lifecycle assessment of the greenhouse gas emissions associated with LNG. Further, methane emissions from shale gas can be substantial. Since 2008, methane emissions from shale gas in the United States may have contributed one-third of the total (and large) increase in atmospheric methane globally.[22,23]

The types of ships used to transport LNG have been changing in recent years,[24–26] and more than 85% of the global fleet is composed of tankers less than 20 years old.[4] As of the beginning of 2024, this fleet consisted of 701 tankers, only 21 of them older than 30 years, and 359 new tankers were under construction.[4] Several different modes of propulsion are common in LNG tankers, including steam power and four- and two-stroke engines. The vast majority of these tankers can be powered either burning "boil-off" or other fuels, such as diesel or heavy fuel oil. Boil-off is the evaporative loss of methane due to some heat leakage through insulation and into the tanks that hold LNG. The only common tankers that cannot use boil-off methane for their fuel are slow-speed diesel vessels that instead capture and reliquefy their boil-off. These make up approximately 7% of the global fleet, although no new ones have been delivered since 2015, in part because of difficulty in meeting new emission standards.[4] Steam-powered vessels compose 31.5% of the global fleet. They are relatively inefficient, and so are considered a "superseded technology."[4] Another 28% of the fleet is made up of tankers powered by electric motors with electricity provided from four-stroke generators that can burn two or more fuels.[4] These are more efficient than steam-powered vessels but have high maintenance costs. Among the newest propulsion technologies is the use of two-stroke engines powered by either boil-off or diesel fuel.[4] Dual-fuel two-stroke tankers have greater fuel efficiencies and so are likely to become more common in the future.[25,26]

Emissions of both carbon dioxide and methane vary significantly across these different types of tankers.[27] Tankers powered by four- and two-stroke engines are more efficient than are steam-powered tankers, and so have lower carbon-dioxide emissions.[24,26] However, when these four- and two-stroke vessels burn boil-off, some unburned methane slips through and is emitted in the exhaust gases.[26,28] Steam-powered tankers emit virtually no methane in their exhaust gases which may

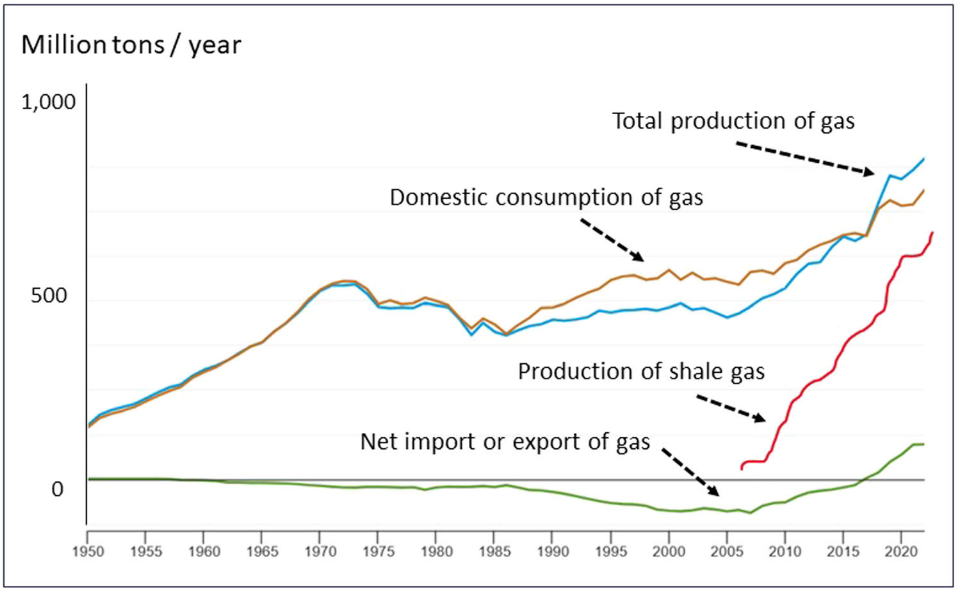


FIGURE 1 Trends in natural gas production in the United States from 1950 to 2022, showing total production of gas (conventional plus shale), production just of shale gas, domestic consumption, and the net import or export of gas. Almost all of the increase in natural gas production since 2005 has been shale gas. The United States was a net importer of natural gas from 1985 to 2015 but has been a net exporter since 2016.

partially offset their higher emissions of carbon dioxide. These differences in emissions from tankers are a major focus of this analysis, which considers four different types of tankers: (1) steam-powered vessels, (2) tankers that are powered by four-cycle engines, (3) more modern tankers powered by two-cycle engines, and (4) tankers that are unable to burn the boil-off of LNG and are powered primarily by diesel oil. My analysis relies heavily on three recent, comprehensive assessments of the use of LNG as a marine fuel.[26–28]

I present a detailed lifecycle assessment for the LNG system that estimates emissions from the production of shale gas feedstock through combustion by the final consumer. My analysis focuses on carbon dioxide and methane and excludes other greenhouse gases, such as nitrous oxide, that are very minor contributors to total emissions for natural gas and LNG systems.[26,29] Included are emissions of carbon dioxide and methane at each step along the supply chain, including those associated with the production, processing, storage, and transport of the shale gas that is the feedstock for LNG (referred to as upstream and midstream emissions), emissions from the energy used to power the liquefaction of shale gas to LNG, emissions from the energy consumed in transporting the LNG by tanker, emissions from the energy used to regasify LNG to gas, and emissions from the delivery of gas to and combustion by the final consumer. For upstream and midstream methane emissions, I rely on a very recent and comprehensive analysis that used almost one million measurements in the United States.[30]

As with some other prior lifecycle assessments for LNG, I explicitly compare the emissions from LNG to those for coal.[17,19–21] Additionally, I compare the greenhouse gas footprint of LNG with the those of oil and natural gas used domestically and with that for electric-driven heat pumps.

2 | METHODS

Calculations use net calorific values (also called lower heating values). Note that the use of net calorific values is standard in most countries, but the United States uses gross calorific values. Emissions expressed using net calorific values are approximately 10% greater than when using gross calorific values.[10,29,31] LNG and heavy fuel oils are assumed to have energy densities of 48.6 and 39 MJ/kg, respectively.[32] I convert methane emissions to carbon-dioxide equivalents using a 20-year global warming potential (GWP_{20}) of 82.5 and a 100-year GWP_{100} of 29.8.[12] Specifying the time frame for comparison is necessary because methane has a far shorter residence time in the atmosphere. The use of GWP_{100} is more common than GWP_{20}, although evidence shows GWP_{100} underestimates the climatic impact of methane, and GWP_{20} is increasingly being favored in many lifecycle assessments.[9,11,20,26,28,33–35] For ease of calculation, this analysis assumes that shale gas and LNG are composed just of methane, ignoring other gases. Table 1 briefly summarizes some of the input parameters for the lifecycle assessment that are detailed below.

TABLE 1 Summary of some of the major input parameters used in liquefied natural gas (LNG) lifecycle assessment.

Stage	Equation	Parameter value	References
Upstream and midstream			
• Methane	Equation (1)	2.8% of production	Sherwin et al.[30]
• CO_2	Equation (2)	612 g CO_2/kg LNG	DEC,[36] Table A.1
Downstream methane	Equation (3)	0.0032 kg/kg LNG	Alvarez et al.[37]
Liquefaction			
• Methane	Equation (4)	3.5 g CH_4/kg LNG	Balcombe et al.[28]
• CO_2	Equation (5)	270 + 57 + 18 g CO_2/kg LNG	Tamura et al.[16] and Okamura et al.[15]
Tankers			
• Methane slip	Equation (6)	0%, 3.8%, or 6.4% of fuel burn	Pavlenko et al.,[26] Balcombe et al.,[34] and Comer et al.[38]
• Fuel consumption	Equations (7) and (8)	108, 130, or 175 tons/day	Raza and Schoyen[39] and Bakkali and Ziomas[24]
• Boil-off	Equation (9)	0.00135 kg CH_4/kg/day	Hassan et al.,[40] Huan et al.,[25] and Rosselot et al.[27]
• Cargo volume	–	68,000 tons LNG	Raza and Schoyen[39]
• Voyage times	–	21.4, 38, or 70 days roundtrip	Oxford Institute for Energy Studies[41]

Note: See text for detailed derivations and discussion.

2.1 | Upstream plus midstream emissions

Upstream plus midstream emissions of both carbon dioxide and methane are based on the total quantity of natural gas and other fuels consumed in the LNG system. In addition to the natural gas burned by the final consumer, natural gas and LNG are burned to provide the energy required for the liquefaction, tanker transport, and regasification processes. The upstream and midstream emissions include emissions in the gas development fields as well as from storage and processing plants and from the high-pressure pipelines that bring natural gas to LNG liquefaction facilities. The following two equations give the upstream plus midstream emissions for methane and carbon dioxide, respectively, in units of methane and g of carbon dioxide/kg of LNG burned by the final consumer:

$$CH_4 = [(0.028)*(1.028)*(1000\,\text{g } CH_4/\text{kg})*\mathbf{LNG.\,tot}] + [\mathbf{Fuel.\,oil}*(3.9\,\text{g}CO_4/\text{kg oil})], \tag{1}$$

$$CO_2 = [(612\,\text{g } CO_2/\text{kg LNG})*\mathbf{LNG.\,tot}] + [\mathbf{Fuel.\,oil}*(616\,\text{g } CO_2/\text{kg oil})], \tag{2}$$

where **LNG.tot** is the total mass of methane gas consumed or emitted, including not only from the final combustion of the regasified LNG fuel but also upstream and midstream, during liquefaction to produce LNG, during transport of LNG in tankers, and emitted from pipelines transporting gas from the LNG destination port to the final consumer. **Fuel.oil** is the quantity of heavy fuel oil or diesel consumed by ships (for those ships that use these as their primary source of energy) divided by the total quantity of LNG delivered per voyage, in units of kg oil/kg LNG. The calculations for **LNG.tot** and for **Fuel.oil** are shown in Equations (3) and (11).

The methane emission factor for natural gas of 0.028 (2.8% of gas production) used in Equation (1) is based on a very recent and comprehensive analysis for upstream and midstream emissions in the United States that combines a very large data set of observations taken by aircraft flyovers with empirically derived simulations.[30] Here, we use their estimates for the Permian Basin, and weigh the upstream emissions by the portion of energy produced as natural gas compared with oil, as recommended by Sherwin et al.[30] Details are provided in Supporting Information Table A. The vast majority of LNG exports from the United States are from Texas and Louisiana.[2] The Permian Basin (west Texas and southeastern New Mexico) and similar oil-associated gas fields are providing most of the gas used for these LNG exports, a trend that is predicted to continue because of the proximity of these fields to the LNG export terminals.[42–44] Methane emissions from producing fuel oil are estimated at 0.10 g CH_4/MJ.[10,45] With an energy density of 39 MJ/kg, this is equivalent to 3.9 g CH_4/kg fuel oil (Equation 1). The emission factors for indirect carbon-dioxide emissions in Equation (2) are 612 g CO_2/kg LNG for natural gas and 616 g CO_2/kg for fuel oil[36] (Supporting Information

Table A.1, converted to net calorific and metric units, and expressed per mass of fuel using the energy densities provided above). These indirect carbon-dioxide emissions are from the energy used to explore and drill gas and oil wells, hydraulically fracture the wells, and process, store, and transport the fuels.

The total mass of methane burned to make carbon dioxide or emitted as methane over the entire lifecycle for LNG is calculated in Equation (3):

$$\mathbf{LNG.tot} = (1\,\mathrm{kg\,/kg\,LNG}) + \mathbf{LNG.liq} + \mathbf{LNG.ship} + \mathbf{Vent.boil.off} + (0.0032\,\mathrm{kg\,/kg\,LNG}), \tag{3}$$

where 1 kg/kg LNG is the quantity of LNG burned by the final consumer. **LNG.liq** is the total mass of LNG consumed or emitted during the liquefaction process, **LNG.ship** is the mass of LNG consumed by a tanker as fuel (for those tankers that burn LNG) divided by the mass of LNG delivered, in units of g CH_4/kg LNG delivered to the destination port. **Vent.boil.off** is the mass of LNG emitted as methane to the atmosphere by tankers that reliquefy boiled-off methane (due to imperfect capture of this methane) divided by the mass of LNG delivered to the destination port, in units of g CH_4/kg LNG. The value of 0.0032 kg/kg LNG is the gas emitted during pipeline transportation from the LNG terminal to the electric plant, where the gas is finally consumed. As is discussed below, my analysis is for the case where LNG is used to produce electricity in the destination country, and the value of 0.0032 kg/kg LNG is for high-pressure delivery pipes from the LNG terminal to an electric plant.[37] Emissions in the destination country would be substantially higher for the case of delivery of gas to homes and commercial buildings for heating.[46]

The calculation for **LNG.ship** is shown in Equation (8). The calculation for **Vent.boil.off** is described in Equation (10). **LNG.liq** is calculated by summing the mass of gas burned to produce the CO_2 emissions for liquefaction shown in Equation (4) (converted from mass of CO_2 to mass of CH_4 by diving by 44 g/mol and multiplying by 16 g/mol) and the mass of methane emitted during liquefaction shown in Equation (5) (converted to units of kg/kg LNG).

2.2 | Emissions at liquefaction plants

A substantial amount of energy is required to liquefy methane into LNG, and this energy is provided by burning natural gas. That is, natural gas is both the feed source and energy source used to produce LNG.[13] Equations (4) and (5) show the emissions of methane and carbon dioxide from the liquefaction process, in units of g CH_4/kg LNG burned by the final consumer and g CO_2/kg LNG burned by the final consumer. Note that emissions of both methane and carbon dioxide from the liquefaction process are larger when expressed per kg of final consumption than per kg of LNG liquefied.

$$CH_4 = (3.5\,\mathrm{g\,CH_4/kg\,LNG}) * (1\,\mathrm{kg\,/kg\,LNG} + \mathbf{LNG.ship} + \mathbf{Vent.boil.off} + 0.0032\,\mathrm{kg\,/kg\,LNG}), \tag{4}$$

$$CO_2 = (270 + 57 + 18\,\mathrm{g\,CO_2/kg\,LNG}) * (1\,\mathrm{kg\,/kg\,LNG} + \mathbf{LNG.ship} + \mathbf{Vent.boil.off} + 0.0032\,\mathrm{kg\,/kg\,LNG}). \tag{5}$$

These two equations are simply multiplying emission factors applicable to the liquefaction process by the total amount of LNG that is transported away from the liquefaction plant in tankers, including LNG burned by the final consumer, LNG burned or emitted by tankers, and methane emissions from pipelines in the destination country that carry gas to the final consumer. As noted in Equation (3), the value of 1 kg/kg LNG represents the LNG burned by the final consumer, and the value of 0.0032 kg/kg LNG is the methane emitted during pipeline transportation from the LNG terminal to the electric plant where the gas is finally consumed.[37]

In Equation (4), 3.5 g CH_4/kg LNG is the total rate of release of unburned methane during liquefaction and for regasification based on the mean from the review by Balcombe et al.[28] Note that a recent paper[47] reported a lower value, which may represent a best case of what is possible, since they required the cooperation from owners of the LNG facilities.[48] The higher value from Balcombe et al.[28] seems likely to be more representative of standard industry performance. For Equation (5), the values 270, 57, and 18 g CO_2/kg LNG are, respectively, the quantities of carbon dioxide emitted from burning gas to power liquefaction, from the CO_2 that was in the natural gas before processing, and from carbon dioxide produced from flaring. Carbon-dioxide emissions from the combustion of the gas powering the plants have been measured at many facilities in Australia, Alaska, Brunei, Malaysia, Indonesia, Oman, and Qatar, with emissions varying from 230 to 410 g CO_2/kg LNG liquefied.[15,16] Here, I use the mean estimate of 270 g CO_2/kg LNG liquefied, which is equivalent to 9.8% of the natural gas being liquefied This is comparable to the value used by Balcombe et al.[28] in their lifecycle assessment and is at the very low end of emission estimates provided by Pace

Global[14] for guidance for new plants built in the United States: 260–370 g CO_2/kg LNG liquefied. My estimate is, therefore, conservative. In addition, carbon dioxide present in unprocessed natural gas, which sometimes contains significant quantities of carbon dioxide, is emitted to the atmosphere as the methane in natural gas is liquefied. These emissions are estimated as 23 to 90 g CO_2/kg LNG liquefied.[15,16] Here, I use a mean estimate of 57 g CO_2/kg. In addition, some natural gas is flared at liquefaction plants to maintain gas pressures for safety, with a range of measured carbon-dioxide emissions from zero up to 50 g CO_2/kg LNG, and a mean estimate of 18 g CO_2/kg.[15,16]

2.3 | Volume of LNG tanker cargo and length of tanker voyages

Emissions of both carbon dioxide and methane from LNG tankers depend on the size of the tanker and the length of cruises. Most LNG tankers have total capacities between 125,000 and 150,000 m^3. In this analysis, I use a value of 135,000 m^3, or 67,500 tons LNG.[39] Generally, not all of the gross LNG cargo is unloaded at the point of destination. Some is retained for the return voyage, both to serve as fuel and to keep the LNG tanks supercooled. Here, I assume that 90% of the cargo is unloaded.[39] Therefore, the average delivered cargo is 60,800 tons LNG.

For the length of the voyage, I use the global average distance for LNG tankers (16,200 km each way) as well as the shortest regular commercial route from the United States (9070 km each way, Sabine Pass, TX to the UK) and the longest regular commercial route from the United States (27,961 km each way, Sabine Pass, TX to Shanghai[41]). Most of the LNG exports from the United States are from the Sabine Pass area, so these distances well characterize US exports.[3] Considering the average speed of 19 knots (35.2 km/h),[41] these cruise distances correspond to times of 19, 10.7, and 35 days each way, respectively, or 38, 21.4, and 70 days roundtrip. Note that the travel distances for LNG tankers have been increasing over time.[49] In 2023, a drought limited the capacity of the Panama Canal, leading to LNG tankers from Texas to Asia taking longer routes through the Suez Canal or south of Good Hope in Africa.[50]

2.4 | Emissions during transport by LNG tankers

The carbon-dioxide emissions during LNG transport are largely from the combustion of the fuel that powers the tankers and related equipment onboard the vessels, such as generators. Methane emissions are largely from the incomplete combustion of fuel by four-cycle and two-cycle tankers, with release of unburned methane in the exhaust gases. As noted in the introduction, my analysis considers four different types of tankers: (1) steam-powered vessels, (2) tankers that are powered by four-cycle engines, (3) modern tankers powered by two-cycle engines, and (4) tankers that are unable to burn the boil-off of LNG and that are powered by diesel oil. Here, I assume that any tanker that can use LNG for its fuel will meet virtually all of its fuel needs from this source. Although most tankers can burn heavy fuel oil and/or diesel oil, consumption of these fuels tends to be very low compared with LNG,[24,34,39] except in those rare times when LNG prices are high relative to fuel oils.[51] And while it might be expected that tankers would burn fuel oil if the rate of unforced boil-off were not sufficient, most tankers instead are likely to force more boil-off for their fuel, if necessary, in part to meet stringent sulfur emission standards for ships that went into effect in 2020.[24]

Emissions of methane and carbon dioxide are calculated using Equations (6) and (7), with units of g CH_4/kg LNG burned by the final consumer and g CO_2/kg LNG burned by the final consumer.

$$CH_4 = [\mathbf{LNG.\ ship} * \mathrm{Slip} * 1000] + \mathbf{Vent.\ boil.\ off}, \tag{6}$$

$$CO_2 = [\mathbf{LNG.\ ship} * (44\,\mathrm{g}\ CO_2/\mathrm{mol}) /(16\,\mathrm{g}\ CH_4/\mathrm{mol}) * 1000\,\mathrm{g}\ CH_4/\mathrm{kg}\ CH_4] + [\mathbf{Fuel.\ oil} * (80\,\mathrm{g}\ CO_2/\mathrm{MJ\ oil}) * (39\,\mathrm{MJ}\ /\mathrm{kg\ oil})], \tag{7}$$

where **Slip** is the fraction of the burned LNG fuel that is emitted unburned as methane in the exhaust stream. Equation (7) converts the mass of LNG methane consumed by ships for fuel to the mass of carbon dioxide emitted using. The value of 80 g CO_2/MJ is the carbon-dioxide emission factor per unit of energy for fuel oil[26] and 39 MJ/kg is the energy density for fuel oil.

For vessels powered by four-stroke engines, I assume **Slip** is 0.064 (6.4%) of the LNG burned by the tanker, the average value measured by Comer et al.[38] in a recent campaign using drones, helicopters, and on-board measurements at sea. This is significantly higher than the values assumed by Balcombe et al.[28] and by Pavlenko et al.[26] For tankers powered by two-stroke engines burning LNG, I assume a 0.038 methane slip rate based on data in Balcombe et al.[34] for a newly commissioned tanker. Note that this is higher than 0.023 reported in Balcombe et al.[28] or values reported in Pavlenko et al.,[26] due to emissions of unburned methane from electric generators, which are necessary for tankers powered by two-stroke engines. Methane emissions in the exhaust of steam-powered tankers are negligible, as are emissions from burning diesel,[26] and are ignored in this analysis.

Equation (8) provides the estimation for LNG consumed by tankers that burn LNG, normalized to the mass of LNG delivered.

$$\textbf{LNG.ship} = \textbf{Days} * (\textbf{LNG.fuel}/60,800,000\ \text{kg LNG}), \tag{8}$$

where **Days** is the number of days for a roundtrip cruise to and from the liquefaction facility, **LNG.fuel** is the rate of LNG consumption per day, and 60,800,000 kg LNG is the average delivered cargo, as discussed above. Fuel consumption rates are assumed to be 175 tons LNG/day for steam-powered tankers, 130 tons LNG/day for ships powered by four-cycle engines, and 108 tons LNG/day for ships powered by modern two-cycle engines.[24,39]

The unforced boil-off of methane during the voyage is calculated in Equation (9).

$$\textbf{Boil.off} = (0.00135\ \text{kg}\ CH_4/\text{kg LNG/day}) * \textbf{Days} * (1000\ \text{g}\ CH_4/\text{kg}\ CH_4), \tag{9}$$

where **Boil.off** is the evaporation from the tankers' LNG tanks during the voyage that occurs from thermal seepage through the insulation of the tanks' insulation. The value of 0.00135 kg CH_4/kg LNG/day is the average rate of boil-off of methane, equivalent to 0.135%/day of the LNG cargo, normalized to the volume of the cargo. This is the mean value for LNG tankers, with rates as low as 0.1%/day at ambient temperatures of 5°C and as high as 0.17%/day at temperatures of 25°C.[25,27,40,52] Note that boil-off occurs not only during the laden voyage transporting the LNG: some LNG is retained as ballast for the return voyage back to the LNG loading terminal. This is necessary to keep the tanks at low temperature, and the mass of methane boiled off per day during the return ballast voyage is essentially the same as during the laden voyage.[40]

$$\textbf{Vent.boil.off} = 0.0035 * \textbf{Boil.off} * \%\textbf{Reliq}, \tag{10}$$

where **%Reliq** is the percentage of **Boil.off** that is not used as fuel by the tanker, but rather is reliquefied. Note that in the past, some tankers simply vented all of the boiled-off methane.[40,52] Even today, most tankers are not equipped to reliquefy boil-off, but these only vent boil-off in excess of their use for fuel. The assumed fraction of methane emitted during reliquefaction, 0.0035, is the same as assumed for shore-based liquefaction plants discussed above.

The quantity of fuel oil or diesel burned by ships, for those ships not burning LNG, is calculated by Equation (11).

$$\textbf{Fuel.oil} = (167,000\ \text{kg oil /day}) * \textbf{Days}/(60,800,000\ \text{kg LNG}), \tag{11}$$

where 167,000 kg oil/day is the rate at which a tanker burns fuel oil and 60,000,800 kg LNG is the quantity of LNG delivered per average cruise. The value of 167,000 kg oil/day is based on data in Bakkali and Ziomas[24] which indicated an equivalent fuel burn rate of 115 tons LNG/day for slow-speed diesel tankers, assuming 80 g CO_2/MJ for fuel oil and 55 g CO_2/MJ for LNG.[26]

2.5 | Final distribution and combustion

In addition to the methane emissions from upstream and midstream sources before the gas is liquefied to become LNG, considered above, emissions occur after regasification and delivery to the final customer. These emissions are less if the gas is used to generate electricity than if it is delivered to homes and buildings. For the analysis presented in this paper, I only consider the case of electricity generation. For this, methane emissions from transmission pipelines and storage in the destination country are estimated as 0.32% of the final gas consumption,[37] or 0.0032 kg methane/kg LNG consumed. As noted above, emissions would be higher for gas used to heat homes and commercial buildings.[46]

When the gas is burned by the final consumer, I use carbon-dioxide emissions of 2750 g CO_2/kg LNG delivered. This is based on the stoichiometry of carbon dioxide (44 g/mole) and methane (16 g/mole). It is equivalent to 55 g CO_2/MJ for natural gas[31] and is also the value assumed by the IMO[53]) for burning LNG in tankers. Methane is never burned with 100% efficiency, and so there is likely some slippage of unburned methane from the combustion. However, I am aware of no data on this for electric-power plants, and assume no slippage in this analysis, to be conservative.

2.6 | Comparison to natural gas, diesel oil, coal, and heat pumps

The emission factors for methane and carbon dioxide for natural gas that are used domestically (i.e., not converted to LNG) are calculated in Equations (12) and (13), in units of g CH_4 or g CO_2/MJ of energy produced.

$$CH_4 = (0.0312)*(1.0312)*(55\,g\ CO_2/MJ) *(mol/44\,g\ CO_2)*(16\,g\ CH_4/mol), \tag{12}$$

$$CO_2 = (55\,g\ CO_2/MJ) + (12.6\,g\ CO_2/MJ), \tag{13}$$

where 0.0312 is the fraction of natural gas that is emitted unburned as methane. This includes 0.028 (2.8%) for upstream and midstream emissions[30] and 0.0032 (0.32%) for downstream emissions (Supporting Information Table A), assuming the gas is used for generation of electric power and not for heating of homes and commercial buildings. These are the same values used for the LNG emission calculations. The value of 55 g CO_2/MJ is for the emissions when the gas is burned[54] (converted to net calorific values), and 12.6 g CO_2/MJ are the indirect emissions from the energy used to develop, process, and transport the gas[36] (Supporting Information Table A-1, converted to net calorific and metric units).

The emission factors of methane and carbon dioxide for coal that is used domestically (not transported long distances by ship) are shown in Equations (14) and (15).

$$CH_4 = 0.21\,g\ CH_4/MJ, \tag{14}$$

$$CO_2 = (99\,g\ CO_2/MJ) + (3.4\,g\ CO_2/MJ), \tag{15}$$

where 0.21 g CH_4/MJ is the emissions factor for methane from the production of coal in the United States based on IPCC data[29] (converted to net calorific values), 99 g CO_2/MJ are the direct emissions when the coal is burned[54] (converted to net calorific values), and 3.4 g CO_2/MJ are the indirect emissions from the energy used to develop and transport the coal[36] (Supporting Information Table A-1, converted to net calorific and metric units). Note that the emission factors used here are significantly larger for methane and somewhat less for indirect carbon-dioxide emissions than used by NETL.[17] Note further that the emission factor for methane is very similar to the mean estimate for deep coal mines in China (0.23 g CH_4/MJ)[55] and for average mining operations in Poland (0.19 g CH_4/MJ).[56]

The emission factors of methane and carbon dioxide for diesel oil that is produced domestically are shown in Equations (16) and (17).

$$CH_4 = 0.40\,g\ CH_4/MJ, \tag{16}$$

$$CO_2 = (75\,g\ CO_2/MJ) + (15.8\,g\ CO_2/MJ), \tag{17}$$

where 0.40 g CH_4/MJ is the emissions factor for methane from the production of diesel oil, 75 g CO_2/MJ are the direct emissions when the oil is burned[54] (converted to net calorific values), and 15.8 g CO_2/MJ are the indirect emissions from the energy used to develop and transport diesel oil[36] (Supporting Information Table A-1, converted to net calorific and metric units). The methane emission factor is from data presented in Supporting Information Materials for Sherwin et al.[30] and is based on oil production from the Permian Basin, apportioning upstream methane emissions to the percent of energy produced that is oil compared with natural gas (58%).

Much natural gas is used to heat homes and commercial buildings, not just for electricity. Heat pumps provide an alternative for this heating. To evaluate the greenhouse gas footprint of a heat pump, we use the average emissions from the electric grid in Europe in 2022, reported as 251 g CO_2-equivalent/kWh, or 70 g CO_2-equivalent/MJ.[57] The average ground-source heat pump has a Coefficient of Performance (COP) of 4.8.[58] The emissions for using a heat pump are estimated by dividing the average grid emissions by the COP.

3 | RESULTS AND DISCUSSION

3.1 | Boil-off and LNG consumption by tankers

The rate of LNG used to power tankers is compared with unforced boil-off in Table 2, for those tankers that can burn LNG. The unforced boil-off predicted from the assumed percentage of gross cargo per day, 0.1% at an ambient temperature of 5°C and 0.17% at a temperature of 25°C,[40] is always less than the fuel required for tankers powered by steam turbines and four-stroke engines. This is also true for tankers powered by modern two-stroke engines at the lower temperature. My analysis therefore assumes that these tankers force additional boil-off to meet their fuel needs,[24] and this additional forced boil-off is included in the overall lifecycle assessment for each type of tanker. For tankers powered by modern two-stroke engines at the higher temperature, the 115 tons LNG/day as unforced boil-off exceed the fuel requirement of 108 tons LNG/day, although not by much (Table 2). These tankers are likely to be equipped with equipment to reliquefy boil-off in excess of their fuel needs. Consequently, I assume that no boil-off from these tankers is vented to the atmosphere and that all is captured.

TABLE 2 Comparison of rate of unforced boil-off and fuel needs to power different types of liquefied natural gas (LNG) tankers.

	Tons LNG/day
Unforced boil-off, ambient temperature of 5°C	67.5[a]
Unforced boil-off, ambient temperature of 25°C	115[a]
Boil-off required for steam-powered tanker burning LNG	175
Boil-off required for tanker powered by four-stroke engines burning LNG	130
Boil-off required for tanker powered by two-stroke engines burning LNG	108

[a]Assumes tanker gross cargo capacity of 67,500 tons. Unforced boil-off is that which occurs due to heat leakage to LNG storage tanks. Tankers can increase boil-off rate to meet fuel demand.

3.2 | Comparison of emissions of CO_2 from final combustion to methane and indirect CO_2 emissions

Table 3 presents emissions of carbon dioxide, methane, and total combined emissions expressed as CO_2-equivalents for each of the four scenarios considered, using different types of tankers and the global average time for voyages. Emissions are separated into the upstream plus midstream emissions, those from liquefaction of gas into LNG, emissions from the tankers, emissions associated with the final transmission to consumers, and direct emissions as the gas is burned by the final consumer to produce electricity. These emissions are also summarized in Figure 2 for the shortest and longest voyage times as well as average voyage time, with emissions broken down into the carbon dioxide emitted as the fuel is burned by the final consumer, other carbon-dioxide emissions, and emissions of unburned methane. For both Figure 2 and the combined emissions presented in Table 3, methane emissions are compared with carbon dioxide using GWP_{20}.[12] Total emissions are comparable across all four scenarios using different types of tankers, ranging from 7370 to 8028 g CO_2-equivalent/kg LNG consumed for the average roundtrip voyage length of 38 days (Table 3). Results using GWP_{100} rather than GWP_{20} are presented in a later section of this paper. As discussed in Section 2, many researchers increasingly favor GWP_{20} for lifecycle assessments, since this better capture the effects of methane on the climate system.[11,20,26,28,33–36]

The direct carbon-dioxide emissions from final combustion are important but not a dominant part of total greenhouse gas emissions across all four scenarios. These final-combustion emissions make up 35%–37% of total greenhouse gas emissions across the four scenarios (Table 3). The largest component of the emissions is from upstream and midstream sources, from producing, processing, storing, and transporting natural gas. The combined emissions for both carbon dioxide and methane from upstream and midstream sources contribute 46%–48% of total emissions for delivered LNG (Table 3). Indirect carbon-dioxide emissions are an important part of these upstream and midstream emissions, reflecting the use of fossil fuels to power the shale gas extraction and processing systems, and make up 9.4%–9.9% of total emissions across the scenarios (Table 3). Methane emissions from upstream and midstream sources are larger (expressed as carbon-dioxide equivalents), contributing 36%–38% of total emissions for delivered LNG (Table 3).

The liquefaction process is an important source of emissions of both carbon dioxide and methane, reflecting the large amount of energy needed to super cool methane to liquid form and the release of some unburned methane at liquefactions facilities (Table 3). Total liquefaction emissions are the third largest source of emissions, after the upstream and midstream emissions and emissions of carbon dioxide from the combustion of gas by the final customer, for all four scenarios, ranging from 8.6% to 9% of total emissions (Table 3).

Tanker emissions are the most variable of the emissions across the scenarios considered, ranging from 3.6% of total emissions in the case where LNG is moved by tankers burning diesel oil to 8.1% when LNG is moved by tankers powered with four-stroke engines when both carbon dioxide and methane are considered (Table 3). The emissions of carbon dioxide by tankers are 2.4% of total emissions for two-stroke-engine tankers, 2.8% for four-stroke-engine tankers, 3.9% for steam-powered tankers, and 4.4% for tankers powered by diesel engines (Table 3), reflecting the different fuel efficiencies of these modes of propulsion. However, the two least efficient types of tankers have zero methane slip emissions, while the more efficient tankers powered by two- and four-stroke engines emit significant methane, 2.8% and 5.3%, respectively, of total emissions for delivered LNG (Table 3). These methane emissions, which result from slippage of methane emitted unburned in the exhaust stream,[26,28,33] more than offset the lower carbon-dioxide emissions. Note that my analysis assumes no methane

TABLE 3 Full lifecycle greenhouse gas emissions for liquefied natural gas (LNG) for four different scenarios for shipping by tanker, using world-average voyage times (38-day roundtrip).

	Carbon dioxide g CO_2/kg	Methane g CH_4/kg	Methane g CO_2-equivalent/kg	Total combined g CO_2-equivalent/kg
Steam-turbine tankers powered by LNG				
Upstream and midstream emissions	768 (9.9%)	36.1	2982 (38%)	3750 (48%)
Liquefaction	383 (4.9%)	3.9	320 (4.1%)	703 (9.0%)
Emissions from tanker	301 (3.9%)	0	0 (0%)	301 (3.9%)
Final transmission and distribution	0 (0%)	3.2	264 (3.4%)	264 (3.4%)
Combustion by final consumer	2750 (35%)	0	0 (0%)	2750 (35%)
Total	**4202** (54%)	**43.2**	**3566** (46%)	**7768**
Four-stroke engine tankers powered by LNG				
Upstream and midstream emissions	753 (9.4%)	35.4	2920 (36%)	3673 (46%)
Liquefaction	375 (4.7%)	3.8	314 (3.9%)	689 (8.6%)
Emissions from tanker	223 (2.8%)	5.2	429 (5.3%)	652 (8.1%)
Final transmission and distribution	0 (0%)	3.2	264 (3.3%)	264 (3.3%)
Combustion by final consumer	2750 (34%)	0	0 (0%)	2750 (34%)
Total	**4101** (51%)	**47.6**	**3927** (49%)	**8028**
Two-stroke engine tankers powered by LNG				
Upstream and midstream emissions	741 (9.6%)	34.9	2876 (37%)	3618 (47%)
Liquefaction	369 (4.8%)	3.7	309 (4.0%)	678 (8.8%)
Emissions from tanker	186 (2.4%)	2.6	212 (2.8%)	397 (5.2%)
Final transmission and distribution	0 (0%)	3.2	264 (3.4%)	264 (3.4%)
Combustion by final consumer	2750 (36%)	0	0 (0%)	2750 (36%)
Total	**4046** (52%)	**44.4**	**3661** (48%)	**7707**
Diesel-powered tankers				
Upstream and midstream emissions	693 (9.4%)	32.6	2689 (36%)	3381 (46%)
Liquefaction	345 (4.7%)	3.5	289 (3.9%)	634 (8.6%)
Emissions from tanker	326 (4.4%)	0.2	15 (0.2%)	340 (4.6%)
Final transmission and distribution	0 (0%)	3.2	264 (3.6%)	264 (3.6%)
Combustion by final consumer	2750 (37%)	0	0 (0%)	2750 (37%)
Total	**4114** (56%)	**39.5**	**3256** (44%)	**7370**

Note: Methane emissions are shown both as mass of methane and mass of CO_2-equivalents based on GWO_{20}. Values are per final mass of LNG consumed. Numbers in parentheses indicate the percent for each component of the total CO_2-equivalents.

emissions from imperfect capture of boil-off used for fuel. I conclude that modern two- and four-stroke powered tankers may emit 30%–215% more total emissions than do steam-powered tankers, despite the lower fuel efficiencies and higher carbon-dioxide emissions for steam. Methane slip makes up 53% of the total tanker emissions for tankers powered by two-stroke engines and 66% for those powered by four-stroke engines. Similarly, Rosselot et al.[27] concluded that methane slip made up 54% of total emissions for a very modern tanker powered with a two-stroke engine

Methane emissions from the final transmission of gas from the regasification terminal to the consumer are relatively small, only 264 g CO_2-equivalent/kg LNG delivered, for all the different tanker scenarios, ranging from 3.3% to 3.4% of total emissions (Table 3). This is because my analysis focuses on the use of LNG to produce electricity, and the transmission pipelines that

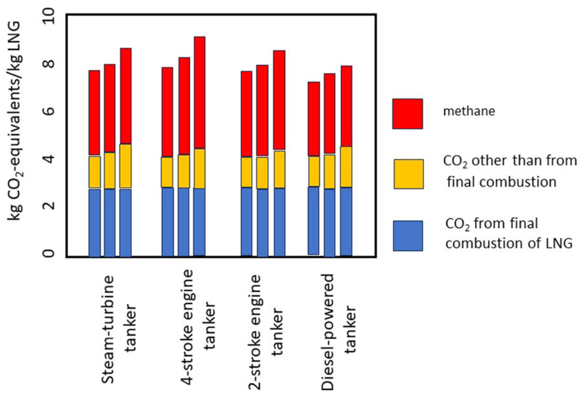


FIGURE 2 Full lifecycle greenhouse gas footprints for LNG expressed per mass of LNG burned by the final consumer, comparing four scenarios where the LNG is transported by different types of tankers. For each type of tanker, scenarios are shown for shortest voyage times (bars to the left), average voyage times (center bars), and longest voyage times (bars to the right). Emissions of methane, the carbon dioxide emitted from the final combustion, and other carbon-dioxide emissions are shown separately. Methane emissions are converted to carbon-dioxide equivalents using GWP_{20}. See text. GWP_{20}, 20-year global warming potential; LNG, liquefied natural gas.

deliver gas to such facilities generally have moderately low emissions.[37] However, LNG is also used to feed gas into urban pipeline distribution systems for use to heat homes and commercial buildings. Methane emissions for these downstream distribution systems can be quite high, with the best studies in the United States finding that 1.7%–3.5% of the gas delivered to customers leaks to the atmosphere unburned (see summary in Howarth[46] and references therein). This corresponds to a range of 1400–2890 g CO_2-equivalent/kg LNG delivered, increasing the total greenhouse gas footprint of LNG by up to 35% above the values shown in Table 3. Emissions from distribution systems are not as well characterized in either Europe or Asia as in the United States,[46] although one study suggests emissions in Paris, France are in the middle range of those observed in the United States.[59]

3.3 | Importance of cruise length

My analysis includes scenarios with the shortest and longest cruise distances from the United States, in addition to the world-average distance shown in Table 3. See Figure 2 and Supporting Information Tables B and C for detailed emission estimates from these shortest and longest voyages. The shortest distance represents a voyage from the Gulf of Mexico loading port to the United Kingdom, while the longest distance is for a voyage from the Gulf of Mexico to Shanghai, China, not going through the Panama Canal. Not surprisingly, total emissions go down for the shorter voyage and increase for the longest voyage for all four scenarios considered. This is particularly true for the scenario where boil-off from LNG is used to power tanker transport (Figure 2 and Supporting Information Tables B and C). For all four scenarios, emissions from fuel consumption increase or decrease as travel distances and time at sea increase or decrease. The upstream and downstream emissions and emissions from liquefaction also increase or decrease as the travel distances change, when expressed per mass of LNG delivered to the final consumer. This reflects an increase or decrease in the total amount of LNG burned or boiled off by tankers during their voyages. Qualitatively, the patterns described above based on world-average tanker travel distances (Table 3) hold across the cases for shorter and longer voyages. In all cases, total greenhouse gas emissions exceed the direct carbon-dioxide emissions when the LNG is burned by the final consumer, by 2.6–2.8-fold for the shortest cruises (Supporting Information Table B) and by 2.8–3.2-fold for the longest cruises (Supporting Information Table C). Upstream and midstream emissions, particularly for methane, are a dominant feature across all time frames and transport by all types of tankers.

3.4 | Comparison to natural gas, diesel oil, coal, and heat pumps

Figure 3 compares the greenhouse gas footprint of LNG for the shortest and longest voyage distances to those of coal used domestically near the site of production, natural gas that is not liquefied but rather used domestically, and diesel oil, based on GWP_{20} for comparing methane to carbon dioxide. Table 4 also shows this comparison with LNG tankers for the average tanker-cruise length, using the average emissions across the three scenarios for transport of LNG by tankers burning LNG boil-off for their fuel. The carbon-dioxide emissions just from combustion are substantially greater for coal, 99 g CO_2/MJ versus 55 g CO_2/MJ for LNG. Total carbon-dioxide emissions from coal, including emissions from developing and transporting the fuel, are also greater than for LNG, but the difference is less, 102.4 g CO_2/MJ for coal versus 83.1 g CO_2/MJ for LNG (Table 4). This is because of greater energy costs and, therefore, higher emissions of carbon dioxide for developing and transporting the LNG compared with coal. Methane emissions for LNG are substantially larger than for coal, 76.5 g CO_2-equivalent/MJ for LNG compared with only 17.3 g CO_2-equivalent/MJ for coal (Table 4). As presented in Section 2, this result for methane emissions for coal is quite

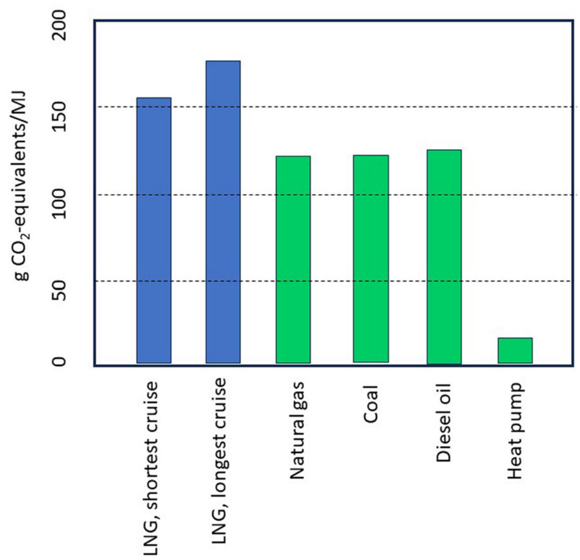


FIGURE 3 Full lifecycle greenhouse gas footprint for LNG for both short and long cruises compared with coal used domestically, diesel oil used domestically, natural gas used domestically, and electric-power ground-source heat pump powered by the average European electric grid. The LNG values are the means for the three types of tankers that burn LNG for fuel. Methane emissions are converted to carbon-dioxide equivalents using GWP_{20}. Note that values are expressed per unit of heat energy for each fuel for delivery to an electric generation plant. This does not include methane emissions from urban distribution systems that deliver to buildings for heat. Emissions for LNG and natural gas used domestically would both increase substantially for this use of gas. See text. GWP_{20}, 20-year global warming potential; LNG, liquefied natural gas.

robust across regions, including China and Poland.[55,56] Consequently, total greenhouse gas emissions are 33% larger for LNG than for coal for the cases of average tanker-cruise lengths, 160 g CO_2-equivalent/MJ for LNG versus 120 g CO_2-equivalent/MJ for coal (Table 4).

Natural gas used domestically in the United States (i.e., not liquefied to LNG) for electricity production has a greenhouse gas footprint that is very similar to that of coal (Figure 3) when methane emissions are included using GWP_{20}, as we have previously demonstrated.[11] Neither natural gas nor coal used domestically in the United States has a large climate advantage over the other.[8] The greenhouse gas footprint for diesel oil from the Permian Basin is also similar to that of coal (Figure 3 and Table 4). However, the footprint for LNG is greater than that of coal, diesel oil, or natural gas even in the case of the shortest cruises. The greenhouse gas footprint for LNG is 28% greater than that of coal for the shortest cruises and 46% greater for the longest cruises (Figure 3).

Also shown in Figure 3 are the greenhouse gas emission estimates for using a ground-source heat pump to heat a home or commercial building, with the pump powered by the average grid electricity for Europe in 2022, as described in the Methods section. Overall emissions are very low, less than 10% of those from burning natural gas, since heat pumps are extremely efficient and gain most of their heat from the environment, not from the electricity. These heat-pump emissions would be zero if the electricity were from 100% renewable sources. Even if the electricity came completely from burning coal, rather than the average European grid energy mix, emissions would be relatively low for the heat pump: 55 g CO_2-equivalent/MJ, assuming the coal power plant had an efficiency of 45%. Clearly heat pumps are far better than heating with LNG from the standpoint of greenhouse gas emissions.

3.5 | Comparison with prior studies

My estimates for the greenhouse gas footprint for LNG exports are at the upper end of those presented in previous studies. Rosselot et al.[20] provide estimates for LNG exported from the United States to China, based on scenarios where the LNG is produced from a gas field in East Texas with relatively low upstream methane emissions and from a gas field in the Permian Basin with higher methane emissions. Using data from their Figure S-5, I calculate total emissions of 95 g CO_2-equivalent/MJ for the East Texas LNG and 175 g CO_2-equivalent/MJ for the LNG produced with gas from the Permian, based on GWP_{20}. These values are 40% lower and 9% higher, respectively, than my estimate of 160 g CO_2-equivalent/MJ (Table 4). Note that Rosselot et al.[20] concluded that LNG produced from gas fields with high methane emissions would be worse than coal from a climate perspective, in agreement with my conclusion. Abrahams et al.[21] show total precombustion emissions (i.e., all emissions other than final combustion) as 86 g CO_2-equivalent/MJ when using GWP_{20} (their Table S7). Adding in the emissions for final combustion of 55 g CO_2/MJ (Table 4), total emissions are 141 CO_2-equivalent/MJ, or 12% lower than my estimate. Gan et al.[18] show the noncombustion emissions of exporting LNG to be in the range of 25–90 g CO_2-equivalent/MJ (their Figure S1, using GWP_{20}). Given combustion emissions of 55 g CO_2/MJ, total emissions would be 80–145 g CO_2-equivalent/MJ, or 9% to 50% less than my estimate. The Gan et al.[18] estimates are based on the GREET model maintained by the US Department of Energy. The NETL[17] report also uses

TABLE 4 Greenhouse gas emissions for liquefied natural gas (LNG) exported from the United States compared with those for diesel oil and coal produced domestically near the final site of consumption.

	Carbon dioxide $g\ CO_2/MJ$	Methane $g\ CH_4/MJ$	Methane $g\ CO_2$-equivalent/MJ	Total combined $g\ CO_2$-equivalent/MJ
Average for LNG				
Upstream and midstream emissions	15.5	0.73	60.1	75.6
Liquefaction	7.7	0.078	6.5	14.2
Emissions from tanker	4.9	0.053	4.4	9.3
Final transmission and distribution	0	0.066	5.4	5.4
Combustion by final consumer	55.0	0	0	55.0
Total	**83.1**	**0.93**	**76.5**	**160**
Diesel oil				
Upstream and transport emissions	15.8	0.40	33.0	48.8
Combustion by final consumer	75.0	0	0	75.0
Total	**90.8**	**0.40**	**33.0**	**123.8**
Coal used domestically				
Upstream and transport emissions	3.4	0.21	17.3	20.7
Combustion by final consumer	99.0	0	0	99.0
Total	**102.4**	**0.21**	**17.3**	**119.7**

Note: LNG estimates are the averages for the three scenarios shown in Table 2 for tankers that are fueled by LNG, using world-average voyage times (38 days). Methane emissions are shown both as mass of methane and mass of carbon-dioxide equivalents based on GWP_{20}. Values expressed per quantity of energy available from the fuel.

the GREET model, and produces similar results: 102 g CO_2-equivalent/MJ for total emissions using GWP_{20} (calculated from information in Table S4 of Rosselot et al.[20]), a value near the middle of those from Gan et al.[18] and 36% lower than my estimate.

A key reason that some of these other studies find that total emissions are lower than what I report here is their use of lower estimates for upstream and midstream emissions of methane. Specifically, the studies by Gan et al.[18] and NETL[17] use the default methane estimates in the GREET model, which are derived from inventory estimates from the US Environmental Protection Agency. The EPA inventory estimates in turn are based on unverified self-reporting from the oil and gas industry, and are clearly too low compared with data derived from independent sources published in the peer-reviewed literature.[46] My study relies on the most robust estimates available for estimates of methane emissions from upstream and midstream sources.[30]

For estimation of total emissions from coal, my estimate of 119.7 g CO_2-equivalent/MJ is well within the range presented in other studies, such as the estimate of 106.6 g CO_2-equivalent/MJ used by NETL[17] and the estimate of 125 g CO_2-equivalent/MJ from Abrahams et al.,[21] using GWP_{20}.

3.6 | GWP time frame—Sensitivity and significance

My analysis is sensitive to the global warming potential that is used, as seen in the online only Supporting Information Figures A and B. Using GWP_{100} of 29.8 instead of GWP_{20} of 82.5,[12] as was used in Figures 2 and 3, decreases the methane emissions expressed as carbon-dioxide equivalents by a factor of 2.77 (i.e., 82.5/29.8). While methane emissions are larger than direct or indirect carbon-dioxide emissions when considered through the GWP_{20} lens for all four scenarios (Figure 2), the direct emissions of carbon dioxide from the final combustion of LNG are larger than methane emissions across all four of the scenarios when using GWP_{100} (Supporting Information Figure A). Similarly, the greenhouse gas footprints of LNG and natural gas that is not liquefied decrease relative to coal when viewed through the lens of GWP_{100} (Supporting Information Figure B and Figure 3) since methane emissions from coal are less than from natural gas and LNG. Total greenhouse gas emissions from LNG estimated using GWP_{100} are equal to those for coal in the scenario with short voyages but are still greater (by 12%) for the longest cruises (Supporting Information Figure B). That is, even using GWP_{100}, the greenhouse gas footprint of LNG is always as large as or larger than that of coal. The greenhouse gas footprint of LNG is always substantially worse than that of natural gas used domestically, whether estimated with GWP_{20} or GWP_{100} (Figure 3 and Supporting Information Figure B). This must be true, since the LNG is made from natural gas but requires substantial energy to liquefy and transport to market.

3.7 | Concluding thoughts

Much of my analysis focuses on comparing the influence of different types of tankers on the LNG greenhouse gas footprint. Surprisingly, tanker type has relatively little influence, since tankers that are more fuel efficient and therefore have lower carbon-dioxide emissions have greater methane slippage in their exhaust. There are relatively few measurements of methane slippage, and I agree with others that it should be a priority to further explore slippage rates.[34,38] The effect of tanker speed on emissions could also be further explored. In this analysis, I use average speeds for the world's LNG tanker fleet in recent years, but slower speeds lead to substantially greater efficiencies, reducing emissions of both carbon dioxide and methane.[27] Nonetheless, emissions from tankers are a small part of the total for LNG.

The largest contributions to the greenhouse gas footprint for LNG exported from the United States are the upstream and midstream emissions from shale gas, particularly for methane. It should come as no surprise, therefore, that studies that assume lower methane emissions conclude that the overall LNG footprint is less than in my analysis. This is certainly the case for those assessments that rely on the GREET model and use the default methane emission factors from that model.[17,18] As noted above, the values used in the GREET model are based on unverified industry reporting to the US Environmental Protection Agency, and these estimates have been repeatedly found to be too low (see review by Howarth[46]). My methane emission factor is derived from the very latest data set from a large body of independent observations (Sherwin et al.[30]) and far better reflects the current state of the science.

Some LNG assessments compare methane and carbon dioxide using GWP_{100} rather than GWP_{20},[17–19] although Rosselot et al.[20] used GWP_{20} as do many studies specifically focused on LNG tanker emissions.[25–28,34] Again, it should not be surprising that those analyses that rely on GWP_{100} report lower total greenhouse gas emissions. While the 100-year time frame of GWP_{100} 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 GWP_{100} dates 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."[60] The latest IPCC AR6 synthesis reports that methane has contributed 0.5°C of the total global warming to date since the late 1800s, compared with 0.75°C for carbon dioxide.[12] 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.[61] Reducing methane emissions rapidly is increasingly viewed as critical to reaching climate targets.[62,63] In this context, many researchers call for using the 20-year time frame of GWP_{20} instead of or in addition to GWP_{100}.[26,28,33–35] GWP_{20} is the preferred approach in my analysis presented in this paper, as was the case for our earlier lifecycle assessment of blue hydrogen.[11] Using GWP_{20}, LNG always has a larger greenhouse gas footprint than coal.

Increasingly, leaders on global climate policy are calling for a rapid move away from all fossil fuels, including natural gas and not just coal.[64,65] With an even greater greenhouse gas footprint than natural gas, ending the use of LNG should be a global priority. I see no need for LNG as an interim energy source, and note that switching from coal to LNG requires massive infrastructure expenditures, for ships and liquefaction plants and the pipelines that supply them. A far better approach is to use financial resources to build a fossil-fuel-free future as rapidly as possible.

ACKNOWLEDGMENTS

I thank Roxanne Marino for valuable discussions leading to this manuscript, Roxanne Marino and Marina Howarth for checking the calculations behind my estimates in the early form of this work, Clark Williams-Derry for important insights, and Kirsten Rosselot, John Lugten, John Godfrey, Jeremy Symons, and six anonymous reviewers for feedback on earlier drafts of the manuscript. This work was supported by a grant from the Park Foundation and by an endowment given by David R. Atkinson to support the professorship at Cornell University held by Robert W. Howarth.

CONFLICT OF INTEREST STATEMENT

The author declares no conflict of interest.

DATA AVAILABILITY STATEMENT

All data used in this paper are from publicly available sources that are identified in the manuscript.

ORCID

Robert W. Howarth http://orcid.org/0000-0001-9531-4288

REFERENCES

1. DiSavino S. After six decades, US set to turn natgas exporter amid LNG boom. *Reuters*. 2017. Accessed October 16, 2023. https://www.reuters.com/article/us-usa-natgas-lng-analysis/after-six-decades-u-s-set-to-turn-natgas-exporter-amid-lng-boom-idUSKBN1700F1
2. EIA. *The United States Became the World's Largest LNG Exporter in the First Half of 2022*. Energy Information Agency, US Department of Energy; 2023. Accessed October 17, 2023. https://www.eia.gov/todayinenergy/detail.php?id=53159
3. Joselow M, Puko T. The next front in the climate fight: U.S. exports of natural gas. *Washington Post*. October 17, 2023. Accessed October 17, 2023. https://www.washingtonpost.com/climate-environment/2023/10/17/natural-gas-exports-climate-activists/?utm_source=newsletter&utm_medium=email&utm_campaign=wp_climate202&wpisrc=nl_climate202
4. IGU. *World LNG Report*. International Gas Union; 2024. Accessed August 20, 2024. https://www.igu.org/resources/2024-world-lng-report/
5. Carbon Brief. What does Biden's LNG "pause" mean for global emissions? *Carbon Brief Oil Gas*. 2024. Accessed March 1, 2024. https://www.carbonbrief.org/qa-what-does-bidens-lng-pause-mean-for-global-emissions/
6. Clarke A. How one methane scientist influenced Biden's pause on LNG approvals. *Bloomberg*. February 29, 2024. Accessed March 1, 2024. https://www.bloomberg.com/news/features/2024-02-29/biden-lng-approval-pause-influenced-by-cornell-methane-scientist
7. Sneath S. LNG export terminals belching more pollution than estimated. *The Lens*. Accessed August 25, 2023. https://thelensnola.org/2023/07/31/lng-export-terminals-belching-more-pollution-than-estimated/?fbclid=IwAR0zBDGWl9AGe446XX1NcWk7CXsr0DTAPHsow8Xdr-n7Ai58nCIchbxpsGVo
8. Gordon D, Reuland F, Jacob DJ, Worden JR, Shindell D, Dyson M. Evaluating net life-cycle greenhouse gas emissions intensities from gas and coal at varying methane leakage rates. *Environ Res Lett*. 2023;18:084008. doi:10.1088/1748-9326/ace3db
9. Howarth RW. A bridge to nowhere: methane emissions and the greenhouse gas footprint of natural gas. *Energy Sci Eng*. 2014;2:47-60. doi:10.1002/ese3.35
10. Howarth RW, Santoro R, Ingraffea A. Methane and the greenhouse gas footprint of natural gas from shale formations. *Clim Change*. 2011;106:679-690. doi:10.1007/s10584-011-0061-5
11. Howarth RW, Jacobson MZ. How green is blue hydrogen? *Energy Sci Eng*. 2021;9:1676-1687. doi:10.1002/ese3.956
12. IPCC. Climate change 2021: the physical science basis. In: Masson-Delmotte V, Zhai P, Pirani A, et al., eds. *Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press; 2021:2391. doi:10.1017/9781009157896
13. Hwang Y, Al-AbulKarem A, Mortazavi A, Radermacher R. Chapter 5—Natural gas liquefaction cycle enhancements and optimization. In: Mokhatab S, Mak J, Valappil J, Wood D, eds. *Handbook of Liquefied Natural Gas*. Elsevier; 2014:229-257. doi:10.1016/B978-0-12-404585-9.00005-2
14. Pace Global. *Life Cycle Assessment of GHG Emissions from LNG and Coal Fired Generation Scenarios: Assumptions and Results*; 2015. Accessed October 16, 2023. https://www.ourenergypolicy.org/wp-content/uploads/2015/10/PACE_Report.pdf
15. Okamura T, Furukawa M, Ishitani H. Future forecast for life-cycle greenhouse gas emissions of LNG and city gas 13A. *Appl Energy*. 2007;84:1136-1149.
16. Tamura I, Tanaka T, Kagajo T, et al. Life cycle CO_2 analysis of LNG and city gas. *Appl Energy*. 2001;68:301-319.
17. NETL. *Life Cycle Greenhouse Gas Perspective on Exporting Liquefied Natural Gas from the United States: 2019 Update*. National Energy Technology Laboratory, US Department of Energy; 2019. Accessed March 21, 2024. https://www.energy.gov/sites/prod/files/2019/09/f66/2019%20NETL%20LCA-GHG%20Report.pdf
18. Gan Y, El-Houjeiri HM, Badahdah A, et al. Carbon footprint of global natural gas supplies to China. *Nat Commun*. 2020;11:824. doi:10.1038/s41467-020-14606-4
19. Nie Y, Zhang S, Liu RE, et al. Greenhouse-gas emissions of Canadian liquefied natural gas for use in China: comparison and synthesis of three independent life cycle assessments. *J Clean Prod*. 2020;258:120701. doi:10.1016/j.jclepro.2020.120701
20. Rosselot KS, Allen DT, Ku AY. Comparing greenhouse gas impacts from domestic coal and imported natural gas electricity generation in China. *ACS Sustainable Chem Eng*. 2021;9:8759-8769. doi:10.1021/acssuschemeng.1c01517?rel=cite-as&ref=PDF&jav=VoR
21. Abrahams LS, Abrahams C, Griffin WM, Matthews HS. Life cycle greenhouse gas emissions from U.S. liquefied natural gas exports: Implications for end uses. Environ. Sci. Technol. 2015;49:3237-3245. doi:10.1021/es505617p
22. Howarth RW. Ideas and perspectives: Is shale gas a major driver of recent increase in global atmospheric methane? *Biogeosciences*. 2019;16:3033-3046. doi:10.5194/bg-16-3033-2019
23. Howarth R. Methane and climate change. In: Stolz JF, Michael Griffin W, Bain DJ, eds. *Environmental Impacts from Development of Unconventional Oil and Gas Reserves*. Cambridge University Press; 2022.
24. Bakkali N, Ziomas L. *Forced Boil Off of Gas: The Future of LNG as a Fuel for LNG Carriers*. McKinsey; 2019. Accessed September 10, 2023. https://www.mckinsey.com/industries/oil-and-gas/our-insights/forced-boil-off-gas-the-future-of-lng-as-a-fuel-for-lng-carriers
25. Huan T, Hongjun F, Wei L, Guoqiang Z. Options and evaluations on propulsion systems of LNG tankers. In: Serpi A, Porru M, eds. *Propulsion Systems*. IntechOpen Books; 2019. doi:10.5772/intechopen.82154
26. Pavlenko N, Comer B, Zhou Y, Clark N. *The Climate Implications of Using LNG as a Marine Fuel*. International Council

on Clean Transportation; 2020. Working paper 2020–02. Accessed October 16, 2023. https://theicct.org/sites/default/files/publications/Climate_implications_LNG_marinefuel_01282020.pdf
27. Rosselot KS, Balcombe P, Ravikumar AP, Allen DT. Simulating the variability of methane and CO_2 emissions from liquefied natural gas shipping: a time-in-mode and carrier technology approach. *ACS Sustainable Chem Eng*. 2023;11:15632-15643. doi:10.1021/acssuschemeng.3c042
28. Balcombe P, Staffell I, Kerdan IG, Speirs JF, Brandon NP, Hawkes AD. How can LNG-fuelled ships meet decarbonisation targets? An environmental and economic analysis. *Energy*. 2021;227:120462. doi:10.1016/j.energy.2021.120462
29. Howarth RW. Methane emissions from fossil fuels: exploring recent changes in greenhouse-gas reporting requirements for the State of New York. *J Integr Environ Sci*. 2020;17:69-81. doi:10.1080/1943815X.2020.1789666
30. Sherwin ED, Rutherford JS, Zhang Z, et al. US oil and gas system emissions from nearly one million aerial site measurements. *Nature*. 2024;627:328-334. doi:10.1038/s41586-024-07117-5
31. Hayhoe K, Kheshgi HS, Jain AK, Wuebbles DJ. Substitution of natural gas for coal: climatic effects of utility sector emissions. *Clim Change*. 2002;54:107-139.
32. Engineering ToolBox. *Fuels—Higher and Lower Calorific Values*. EngineeringToolBox.com; 2003. Accessed October 9, 2023. https://www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html
33. Fesenfeld LP, Schmidt TS, Schrode A. Climate policy for short- and long-lived pollutants. *Nat Clim Change*. 2018;8:933-936. doi:10.1038/s41558-018-0328-1
34. Balcombe P, Heggo DA, Harrison M. Total methane and CO(2) emissions from liquefied natural gas carrier ships: the first primary measurements. *Environ Sci Technol*. 2022;56:9632-9640. doi:10.1021/acs.est.2c01383
35. Ocko IB, Hamburg SP, Jacob DJ, et al. Unmask temporal trade-offs in climate policy debates. *Science*. 2017;356:492-493. doi:10.1126/science.aaj2350
36. DEC. *Statewide Greenhouse Gas Emissions Report*. New York State Department of Environmental Conservation; 2021. Accessed October 16, 2023. https://www.dec.ny.gov/energy/99223.html#Report
37. Alvarez RA, Zavala-Araiza D, Lyon DR, et al. Assessment of methane emissions from the U.S. oil and gas supply chain. *Science*. 2018;361:186-188. doi:10.1126/science.aar7204
38. Comer B, Beecken J, Vermeulen R, et al. *Fugitive and Unburned Methane Emissions from Ships (FUMES): Characterizing Methane Emissions from LNG-Fueled Ships Using Drones, Helicopters, and On-board Measurements*. International Council on Clean Transportation; 2024. Accessed August 21, 2024. https://theicct.org/publication/fumes-characterizing-methane-emissions-from-lng-fueled-ships-using-drones-helicopters-and-on-board-measurements-jan24/
39. Raza Z, Schoyen H. A comparative study of the northern sea route (NSR) in commercial and environmental perspective with focus on LNG shipping. In: *6th International Conference on Maritime Transport, Barcelona, Spain*; 2014. Accessed October 16, 2023. https://www.researchgate.net/publication/272828954_A_COMPARATIVE_STUDY_OF_THE_NORTHERN_SEA_ROUTE_NSR_IN_COMMERCIAL_AND_ENVIRONMENTAL_PERSPECTIVE_WITH_FOCUS_ON_LNG_SHIPPING
40. Hasan MMF, Zheng AM, Karimi IA. Minimizing boil-off losses in liquefied natural gas transportation. *Ind Eng Chem Res*. 2009;48:9571-9580. doi:10.1021/ie801975q
41. Oxford Institute for Energy Studies. *The LNG Shipping Forecast: Costs Rebounding, Outlook Uncertain*. Oxford Institute for Energy Studies; 2018. Accessed October 16, 2023. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2018/02/The-LNG-Shipping-Forecast-costs-rebounding-outlook-uncertain-Insight-27.pdf
42. EIA. *EIA Expects U.S. Natural Gas Production to Rise as Demand for Exports Grows*. Energy Information Agency, US Department of Energy; 2022. Accessed March 28, 2024. https://www.eia.gov/todayinenergy/detail.php?id=51558
43. EIA. *High Natural Gas Production and Storage Injections in September Drove U.S. Prices Down*. Energy Information Agency, US Department of Energy; 2022. Accessed March 28, 2024. https://www.eia.gov/todayinenergy/detail.php?id=54499
44. EIA. *U.S. Natural Gas Production and LNG Exports Will Likely Grow Through 2050 in AEO2023*. Energy Information Agency, US Department of Energy; 2023. Accessed March 28, 2024. https://www.eia.gov/todayinenergy/detail.php?id=56320
45. NETL. *Petroleum-based Fuels Life Cycle Greenhouse Gas Analysis—2005 Baseline Model*. National Energy Technology Laboratory, US Department of Energy; 2008. Accessed September 4, 2019. https://openei.org/wiki/NETL_-_PetroleumBased_Fuels_Life_Cycle_Greenhouse_Gas_Analysis_2005_Baseline_Model
46. Howarth R. Methane emissions from the production and use of natural gas. *EM Mag*. 2022:11-16. Accessed October 16, 2023. https://www.research.howarthlab.org/documents/Howarth2022_EM_Magazine_methane.pdf
47. Innocenti F, Robinson R, Gardiner T, Howes N, Yarrow N. Comparative assessment of methane emissions from onshore LNG facilities measured using differential absorption Lidar. *Environ Sci Technol*. 2023;57:3301-3310. doi:10.1021/acs.est.2c05446
48. Frank J. Study suggests LNG production facilities should monitor methane emissions—just like the rest of the gas supply chain. *EDF Blog*. February 16, 2023. Accessed May 28, 2024. https://blogs.edf.org/energyexchange/2023/02/16/study-suggests-lng-production-facilities-should-monitor-methane-emissions-just-like-the-rest-of-the-gas-supply-chain/
49. Timera Energy. *LNG Shipping Distances Drive Up Costs*; 2019. Accessed October 16, 2023. https://timera-energy.com/lng-shipping-distances-drive-up-costs/
50. Williams C 2023. Cheniere shunning Panama Canal for longer LNG routes to Asia. Reuters. Accessed October 16, 2023. https://www.reuters.com/business/energy/cheniere-shunning-panama-canal-longer-lng-routes-asia-2023-07-11/
51. Jaathan J, Khasawneh R. Update 1-off the boil: LNG tankers burn more oil as gas prices soar. In: *Utilities—Natural Gas*. Reuters; 2021. Accessed October 16, 2023. https://www.reuters.com/article/global-tankers-lng/update-1-off-the-boil-lng-tankers-burn-more-oil-as-gas-prices-soar-idUSL1N2Q50U0

52. BrightHub Engineering. *Dual-Fuel Engines in LNG Tankers*; 2022. Accessed October 12, 2023. https://www.brighthubengineering.com/naval-architecture/111619-propulsion-methods-for-modern-lng-tankers/
53. IMO. *Energy Efficiency of Ships. MEPC 77/6/1*. Marine Environmental Protection Committee, International Maritime Organization; 2021. Accessed September 10, 2023. https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Air%20pollution/MEPC%2077-6-1%20-%202020%20report%20of%20fuel%20oil%20consumption%20data%20submitted%20to%20the%20IMO%20Ship%20Fuel%20Oil%20Consumption%20Database%20in%20GISIS.pdf
54. EIA. *Carbon Dioxide Emissions Coefficients*. Energy Information Agency, US Department of Energy; 2016. Accessed October 11, 2019. https://www.eia.gov/environment/emissions/co2_vol_mass.php
55. Wang K, Zhang J, Cai B, Yu S. Emission factors of fugitive methane from underground coal mines in China: estimation and uncertainty. *Appl Energy*. 2019;250:273-282. doi:10.1016/j.apenergy.2019.05.024
56. Patynska R. Methodology of estimation of methane emissions from coal mines in Poland. *Stud Geotech Mech*. 2014;XXXVI(1):89-101. doi:10.2478/sgem-2014
57. European Environment Agency. *Greenhouse Gas Emission Intensity of Electricity Generation in Europe*. European Union; 2023. Accessed May 28, 2024. https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emission-intensity-of-1?activeAccordion=546a7c35-9188-4d23-94ee-005d97c26f2b
58. Heat Pumps. *The Latest Heat Pump Statistics (Updated May 2024)*. Heat Pumps of London; 2024. Accessed May 28, 2024. https://www.heatpumps.london/blog/everything-you-need-to-know-about-heat-pumps
59. Defratyka SM, Paris JD, Yver-Kwok C, Fernandez JM, Korben P, Bousquet P. Mapping urban methane sources in Paris, France. *Environ Sci Technol*. 2021;55:8583-8591. doi:10.1021/acs.est.1c00859
60. IPCC. Climate change 2013. The physical science basis. In: *Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Change*; 2013. Accessed August 9, 2023. https://www.ipcc.ch/report/ar5/wg1/
61. Ritchie PDL, Alkhayuon H, Cox PM, Wieczorek S. Rate-induced tipping in natural and human systems. *Earth Syst Dyn*. 2023;14:669-683. doi:10.5194/esd-14-669-2023
62. Nzotungicimpaye CM, MacIsaac AJ, Zickfeld K. Delaying methane mitigation increases the risk of breaching the 2°C warming limit. *Commun Earth Environ*. 2023;4:250. doi:10.1038/s43247-023-00898-z
63. Collins WJ, Webber CP, Cox PM, et al. Increased importance of methane reduction for a 1.5 degree target. *Environ Res Lett*. 2018;13:054003. doi:10.1088/1748-9326/aab89c
64. Figueres C. Gas, like coal, has no future as the world wakes up to climate emergency. *South China Morning Post*. August 29, 2021. Accessed August 9, 2023. https://www.scmp.com/comment/opinion/article/3146479/gas-coal-has-no-future-world-wakes-climate-emergency
65. Gaventa J, Pastukhova M. Gas under pressure as IEA launches net-zero pathway. *Energy Monitor*. May 18, 2021. Accessed August 9, 2023. https://energymonitor.ai/policy/net-zero-policy/gas-under-pressure-as-iea-launches-net-zero-pathway

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

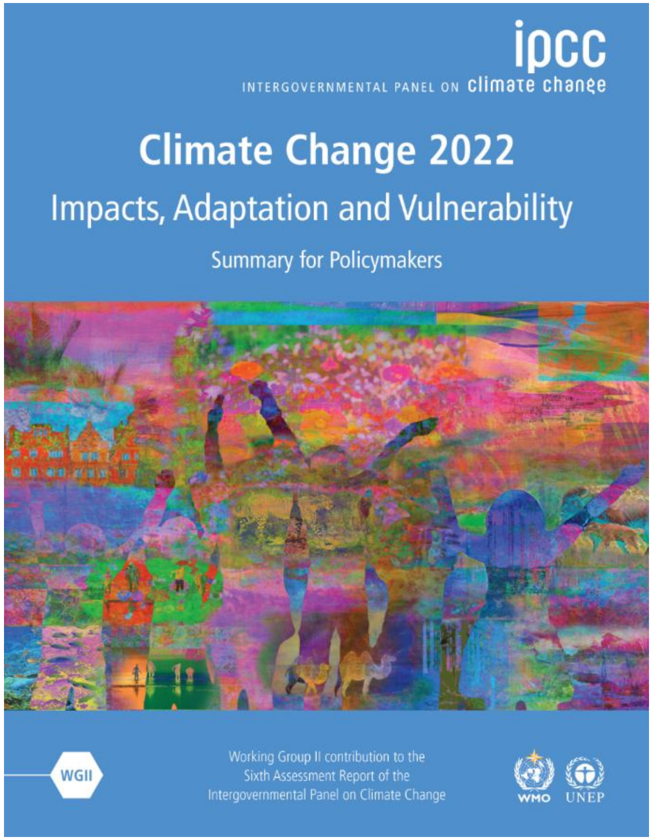
How to cite this article: Howarth RW. The greenhouse gas footprint of liquefied natural gas (LNG) exported from the United States. *Energy Sci Eng*. 2024;12:4843-4859. doi:10.1002/ese3.1934

The greenhouse gas footprint of LNG exports from the United States

Robert Howarth, PhD
The Atkinson Professor of Ecology & Environmental Biology
Cornell University, Ithaca, NY   USA

Hearing on Proposed LNG Export Terminal
Pennsylvania House Environmental Committee

November 5, 2025

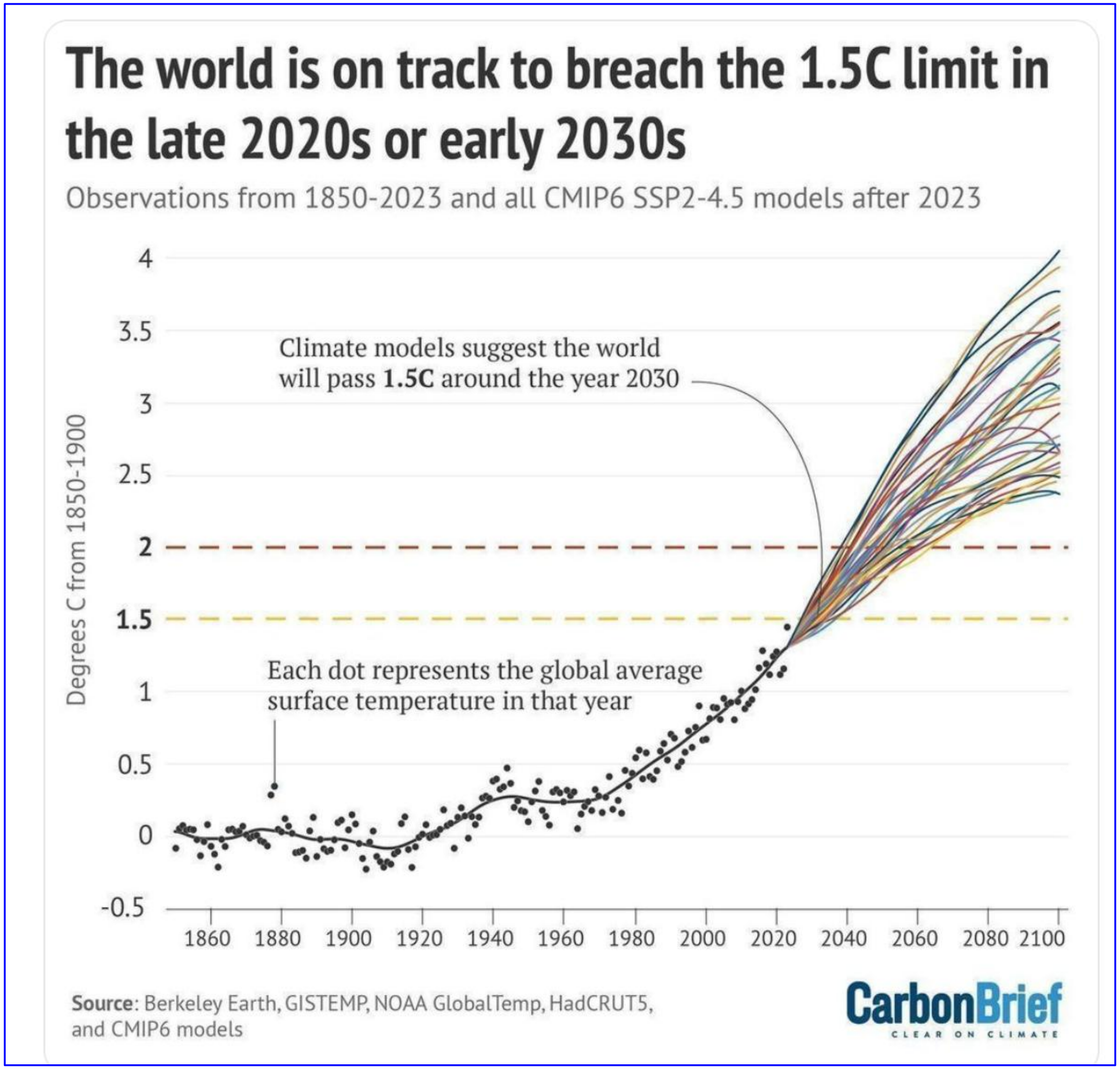


IPCC 2022, final sentence:

"The scientific evidence is unequivocal: climate change is a threat to human well-being and the health of the planet.

Any further delay in concerted global action will miss a brief and rapidly closing window to secure a liveable future."

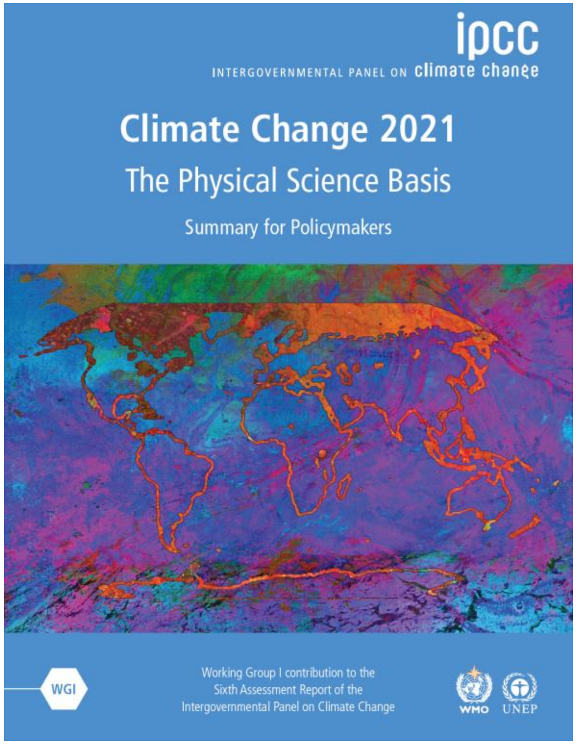
Fossil fuels are responsible for the vast majority of global warming.

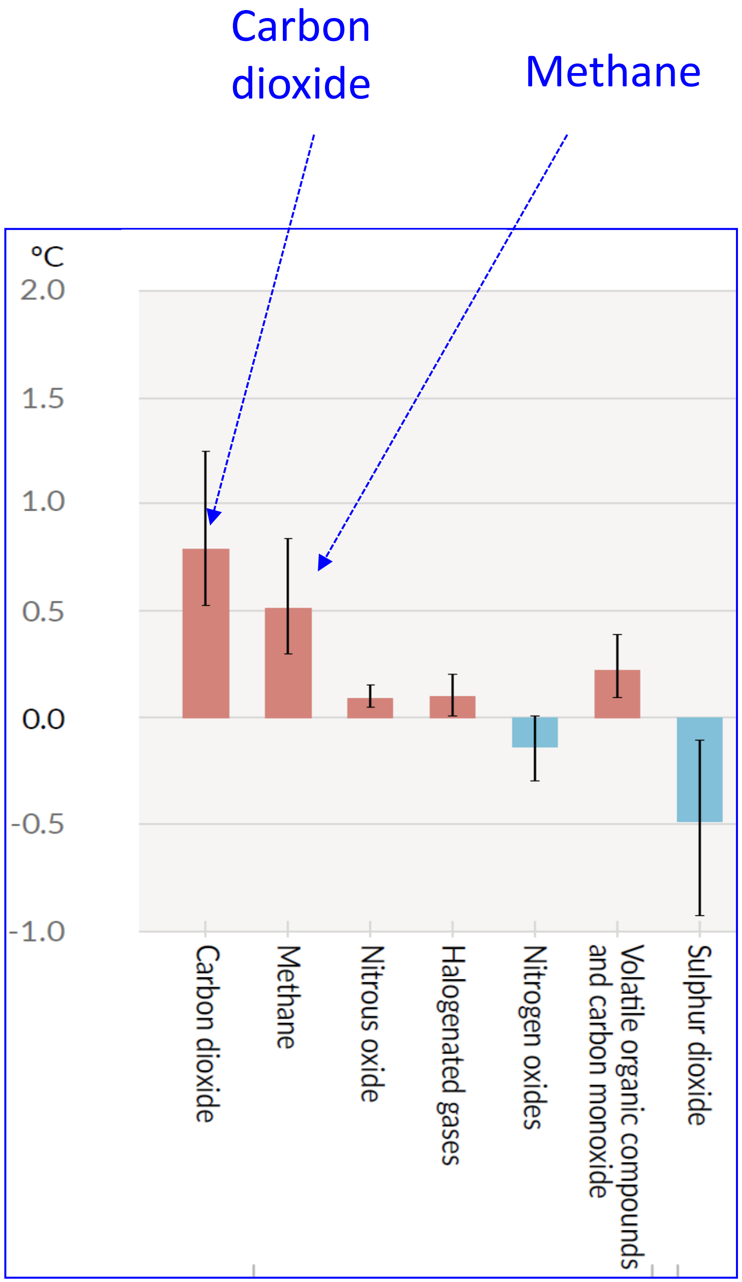


Downloaded from Bluesky, Sept 1, 2025

Methane has contributed 30% of all global warming since start of industrial revolution

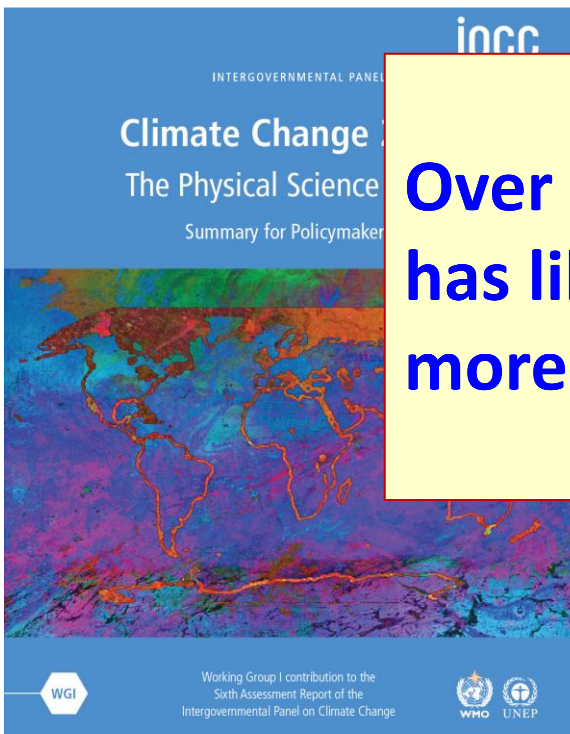
CO_2 has contributed 50%



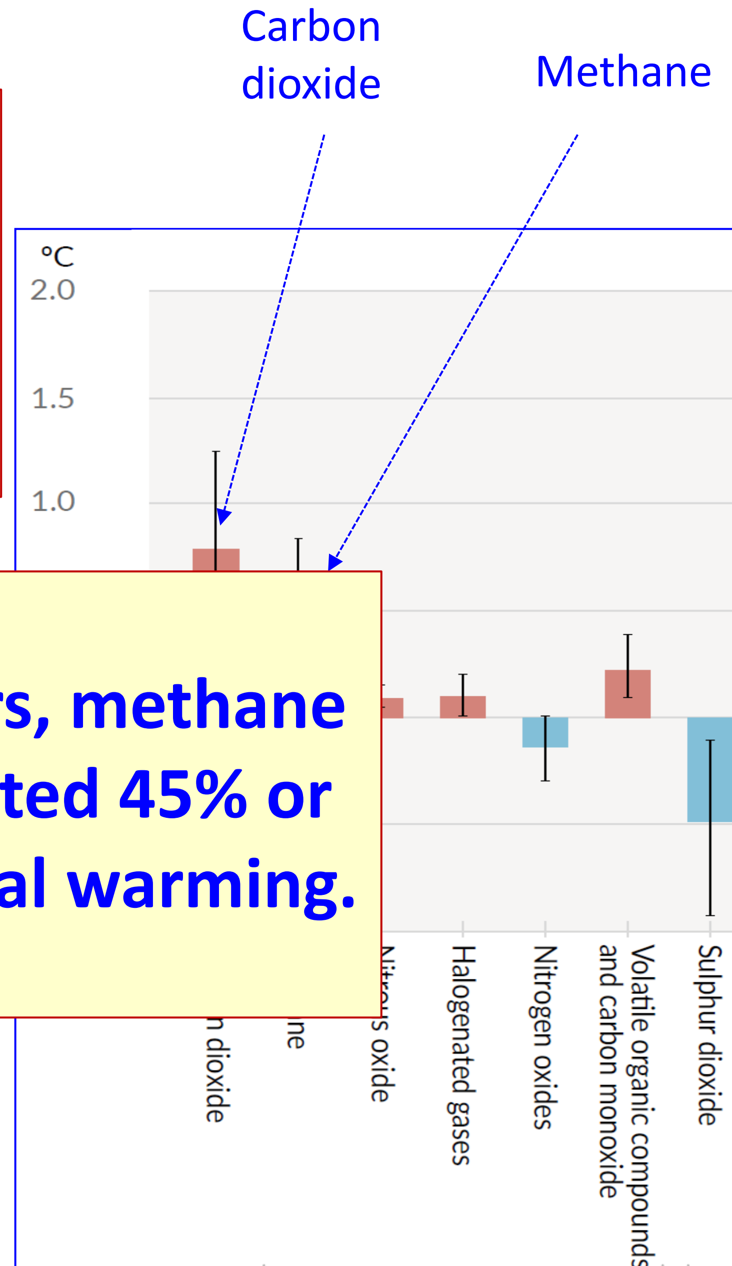


Methane has contributed 30% of all global warming since start of industrial revolution

CO_2 has contributed 50%



Over past 10-20 yrs, methane has likely contributed 45% or more of total global warming.

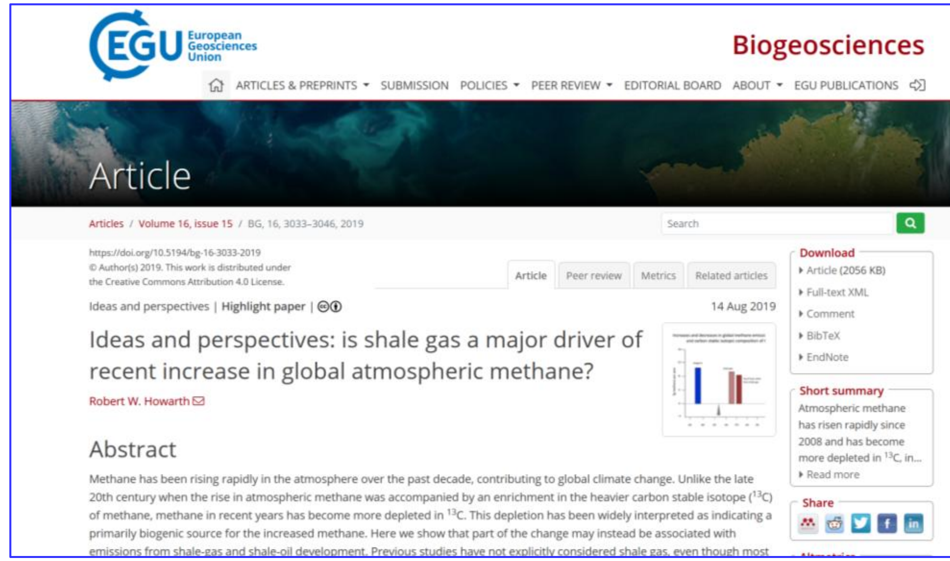


Export of liquefied natural gas (LNG) from the US:

- LNG export from US was banned until 2016.
- US became largest LNG exporter globally in 2022.
- LNG exports continue to grow rapidly.

Wikipedia

- **LNG in US is made almost entirely from fracked shale gas.**
- **Most of the global increase in natural gas production over past 15 years has been shale gas in the US.**
- **This increase in US shale gas production has been responsible for at least 1/3rd of total increase in atmospheric methane globally over this time period (Howarth 2019).**



Howarth 2019

Energy Science & Engineering

Latest issue

Volume 12, Issue 10
October 2024

Finally published in Oct 2024, but I made earlier versions publicly available since submitting a year earlier.

Received: 26 March 2024 | Revised: 6 September 2024 | Accepted: 16 September 2024

DOI: 10.1002/ese3.1934

MODELLING AND ANALYSIS

The greenhouse gas footprint of liquefied natural gas (LNG) exported from the United States

Robert W. Howarth

Department of Ecology & Evolutionary Biology, Cornell University, Ithaca, New York, USA

Correspondence
Robert W. Howarth, Department of Ecology & Evolutionary Biology, Cornell University, Ithaca, NY 14853 USA.
Email: howarth@cornell.edu

Funding information
Park Foundation

Abstract

Liquefied natural gas (LNG) exports from the United States have risen dramatically since the LNG-export ban was lifted in 2016, and the United States is now the world's largest exporter. This LNG is produced largely from shale gas. Production of shale gas, as well as liquefaction to make LNG and LNG transport by tanker, is energy-intensive, which contributes significantly to the LNG greenhouse gas footprint. The production and transport of shale gas emits a substantial amount of methane as well, and liquefaction and tanker transport of LNG can further increase methane emissions. Consequently, carbon dioxide (CO_2) from end-use combustion of LNG contributes only 34% of the total LNG greenhouse gas footprint, when CO_2 and methane are compared over 20 years global warming potential (GWP_{20}) following emission. Upstream and midstream methane emissions are the largest contributors to the LNG footprint (38% of total LNG emissions, based on GWP_{20}). Adding CO_2 emissions from the energy used to produce LNG, total upstream and midstream emissions make up on average 47% of the total greenhouse gas footprint of LNG. Other significant emissions are the liquefaction process (8.8% of the total, on average, using GWP_{20}) and tanker transport (5.5% of the total, on average, using GWP_{20}). Emissions from tankers vary from 3.9% to 8.1% depending upon the type of tanker. Surprisingly, the most modern tankers propelled by two- and four-stroke engines have higher total greenhouse gas emissions than steam-powered tankers, despite their greater fuel efficiency

- **LNG in the United States is made from shale gas, with significant upstream & midstream methane emissions.**
- **Shale gas is also energy intensive, with significant emissions of CO_2 (beyond those released when the fuel is burned) from production, processing, and transport.**

iStock credit sasacvetkovic33

- For LNG, considerable energy also needed to liquefy and regasify, as well as for transport by tanker.
- LNG and shale gas power the energy needed to liquefy and regasify.
- LNG usually powers tankers as well.
- The high use of LNG and gas to power liquefaction and tankers means considerably more shale gas is needed than simply the gas finally delivered as LNG…. And this increases the upstream emissions of methane and indirect CO_2 emissions from the US shale-gas fields.

Also, there can be further methane emissions from tankers. Paradoxically, the most modern tankers (which are far more fuel efficient, so lower CO2 emissions) emit more methane due to slippage" of unburned methane in exhaust from 2-stroke and 4-stroke engines.

Nature

March 13, 2024

Article

US oil and gas system emissions from nearly one million aerial site measurements

https://doi.org/10.1038/s41586-024-07117-5

Received: 22 December 2022

Accepted: 23 January 2024

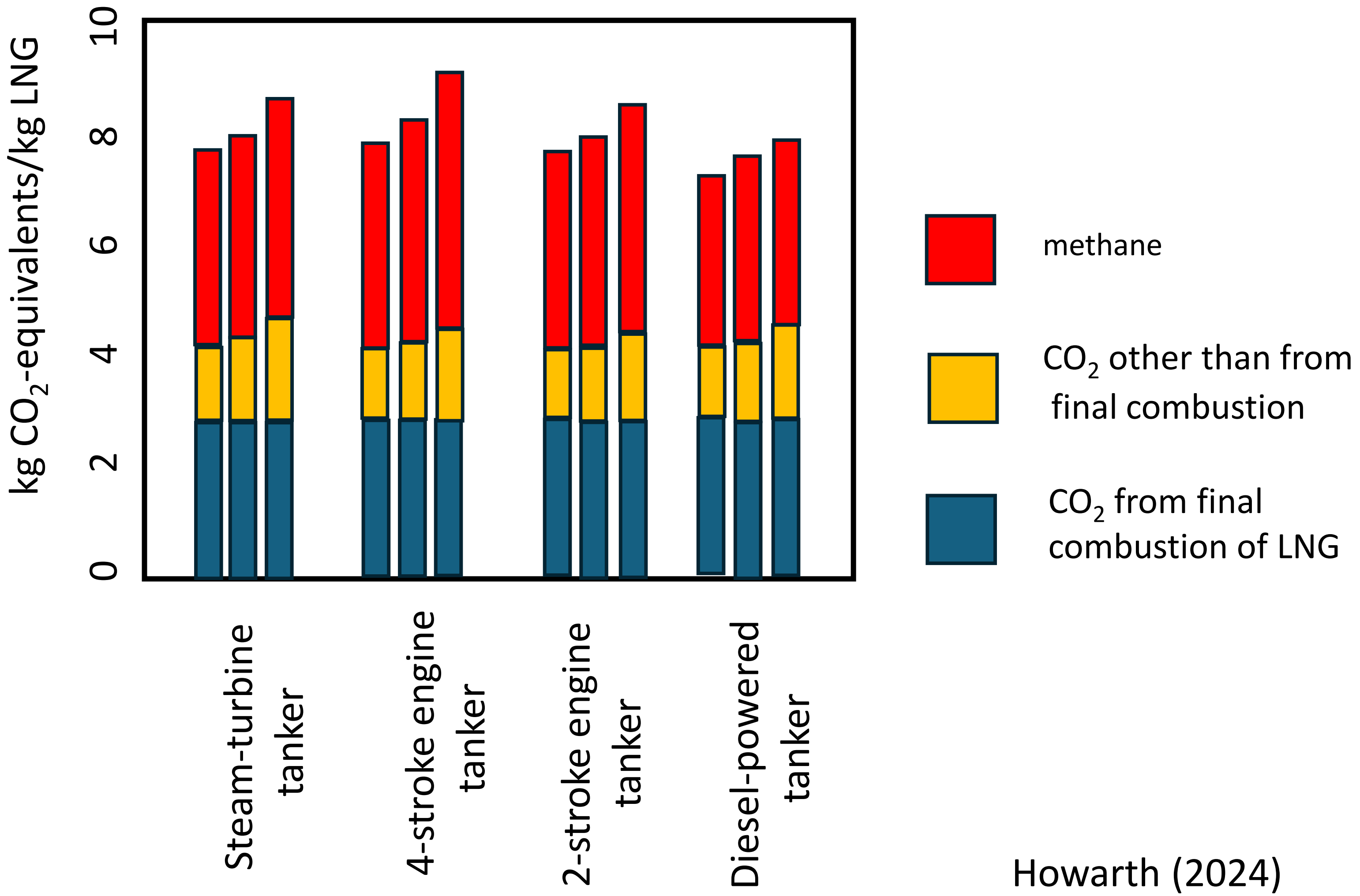
Check for updates

Evan D. Sherwin[1,6✉], Jeffrey S. Rutherford[1,7], Zhan Zhang[1], Yuanlei Chen[1], Erin B. Wetherley[2], Petr V. Yakovlev[2], Elena S. F. Berman[2], Brian B. Jones[2], Daniel H. Cusworth[3], Andrew K. Thorpe[4], Alana K. Ayasse[3], Riley M. Duren[3,4,5] & Adam R. Brandt[1]

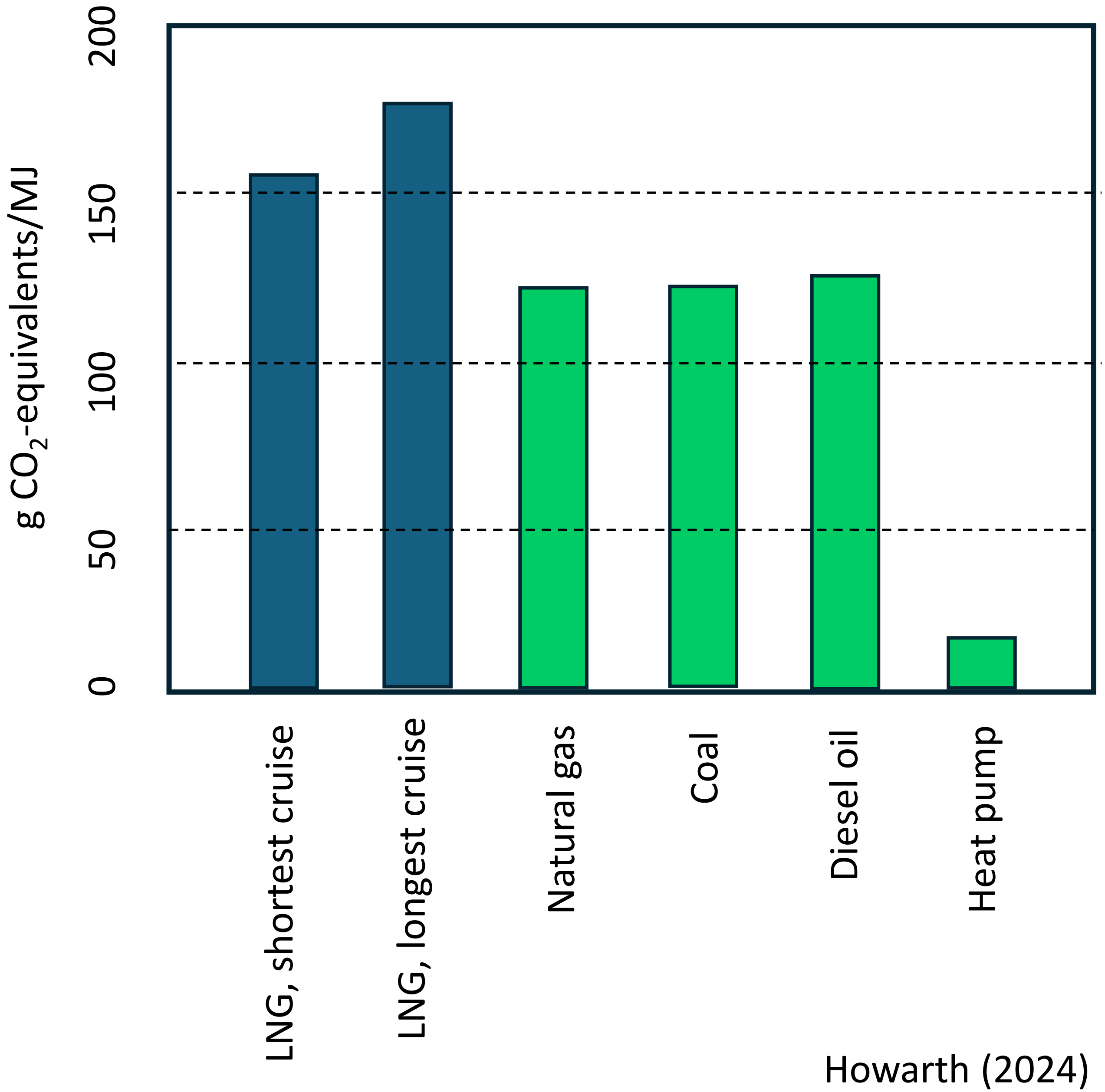
As airborne methane surveys of oil and gas systems continue to discover large emissions that are missing from official estimates[1–4], the true scope of methane emissions from energy production has yet to be quantified. We integrate approximately one million aerial site measurements into regional emissions inventories for six regions in the USA, comprising 52% of onshore oil and 29% of gas production over 15 aerial campaigns. We construct complete emissions distributions for each, employing empirically grounded simulations to estimate small emissions.

Best synthesis of aerial and satellite survey data to estimate upstream and midstream methane emissions for US shale gas fields

Total LNG greenhouse gas emissions are far greater than simply the CO_2 emitted as the fuel is burned.



Howarth (2024)



g CO_2-equivalents/MJ
0
50
100
150
200
LNG, shortest cruise
LNG, longest cruise
Natural gas
Coal
Diesel oil
Heat pump
Howarth (2024)

Many of the sources of "upstream and midstream" methane emissions are inherent in shale-gas development and use (not just "leaks"):

- **Releases during well drilling (in regions with past history of oil, gas, and coal)**
- **Venting from storage & processing facilities**
- **Unlit flares, and incomplete combustion by flares**
- **Incomplete combustion by pipeline compressors**
- **"Blow-downs" for pipeline maintenance**

The Methane Project at Cornell University

LNG has the largest greenhouse gas footprint of any fossil fuel, 33% greater than for coal. The world should move away from LNG as rapidly as possible.

Questions?

The Methane Project is funded by the Park Foundation & an endowment given to Cornell by David R. Atkinson. Further information and papers available at Howarthlab.org

House Environmental Resources & Natural Protection Committee

“LNG Export Terminal Proposed for SE PA”
Chester City Hall, Chester PA
Testimony of Tracy Carluccio, Deputy Director, Delaware Riverkeeper Network
November 5, 2025

Good morning Chair Vitali, minority Chair Jack Rader, and Committee members. Thank you for the opportunity to testify here today. I am addressing the environmental footprint of the proposed Penn America LNG Export Facility, based on the information that is publicly available; some of this we have secured through Right to Know and FOIA requests that are shared on Delaware Riverkeeper Network’s website. The public information available is imprecise and incomplete, however, which we consider unfair and intentional.

What the company has said is they will ship the LNG overseas, they will primarily source the gas from Pennsylvania’s Marcellus and Utica shales, they plan to process up to 1 B cubic feet of gas per day, plan to export 7.2 million metric tonnes of LNG each year and plan to operate for 20 years.[1] This would be the first and only LNG export facility in the Delaware River Watershed and the first in all four watershed states. It would be located in the mostly densely populated region of Pennsylvania.[2] Militating against the plan to construct here, the federal government has advised that LNG facilities should be placed in “remote” locations, away from dense populations, to protect public safety.[3]

From what we do know, it is clear this project is not clean, not carbon neutral, is unsafe, and the company has not interfaced with the people who would be most impacted, as we will hear about from Zulene Mayfield. The project will have enormous negative and long-lived environmental impacts locally, regionally, statewide, and even globally.

To accurately assess the burdens that accompany the proposed Penn America facility, we look at the entire footprint of the life cycle of the gas from the gas wellhead, to the pipelines and related infrastructure, the LNG processing plant, its storage, shipping, and end use.

Let’s look first at the upstream impacts of high-volume hydraulic fracturing or “fracking” – the cradle in this “cradle to grave” journey. In Pennsylvania, 14,380 fracked gas wells have been

[1] KPMG LLC, Penn America Energy, “Economic Impact Analysis (EIA): City of Chester LNG Project, Executive Summary, August, 2016”.
[2] http://www.usa.com/rank/pennsylvania-state--population-density--county-rank.htm
[3] https://www.congress.gov/crs_external_products/RL/PDF/RL32205/RL32205.14.pdf PDF P. 22.

DELAWARE RIVERKEEPER NETWORK
925 Canal Street, Suite 3701
Bristol, PA 19007
Office: (215) 369-1188
fax: (215)369-1181
drn@delawareriverkeeper.org
www.delawareriverkeeper.org

drilled between 2007 and 2023.[4] Pennsylvania is the second greatest producer of natural gas in the nation, second to Texas. These wells have many pathways of pollution.

Of the more than 1,000 chemicals that are confirmed ingredients in fracking fluid that is injected underground to release the gas, hundreds are potentially carcinogenic, toxic or hazardous.[5]

They produce polluted wastewater that contain the frack fluids and proppants and deep geology pollutants brought back up to the surface including heavy metals, and naturally occurring radioactive substances such as Radium-226 and 228.

No matter how the brine, solid cuttings and liquid waste is disposed, stored or reused, the waste is not fully cleaned and poses enormous damage to public health and environment.

But there are more pathways of pollution from fracking. Groundwater and surface water have been contaminated by fracking operations at wells and their operations. For instance, a recent study by Dr. John Stolz of Duquesne University provides incontrovertible evidence of the contamination of drinking water supplies following a well incident called a “frac-out” that occurred in New Freeport, PA in 2022 – the fact is, fracking operations in Pennsylvania can and do pollute our water.

With 1.5 million Pennsylvanians living within a half mile of oil and gas wells, air emissions expose large populations to dangerous pollution. Many more millions live within a half mile of other shale gas infrastructure.[6] More than 200 airborne chemical contaminants have been detected near drilling and fracking operations including the carcinogens benzene and formaldehyde.[7] The effect? Health harms are proliferating.

Hundreds of reports and studies, documented by the Compendium produced by the Concerned Health Professionals of New York and PA Physicians for Social Responsibility and by other professional institutions such as the PA Environmental Health Project (EHP) report higher rates of cancer, heart problems, asthma, and respiratory disease near oil and gas operations. Several studies show birth defects, pre-term birth and low birth weight, and complications during pregnancy.[8] Leukemia levels among children were elevated as much as 6.2 miles from a well, indicating drinking water contamination as the source.[9] Another report found neurological symptoms also reach 6.2 miles.[10]

---

[4] https://www.fractracker.org/2024/08/pennsylvania-oil-and-gas-trends/

[5] Concerned Health Professionals of New York and Physicians for Social Responsibility, *Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking and Associated Gas and Oil Infrastructure (Ninth Edition)*, October 2023, https://concernedhealthny.org/compendium/ (accessed January 2025) at 139.

[6] https://www.environmentalhealthproject.org/white-paper

[7] Concerned Health Professionals of New York and Physicians for Social Responsibility, *Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking and Associated Gas and Oil Infrastructure (Ninth Edition)*, October 2023, https://concernedhealthny.org/compendium/ (accessed January 2025) at 9.

[8] Id. at 10.

[9] Cassandra J. Clark et al., “Unconventional Oil and Gas Development Exposure and Risk of Childhood Acute Lymphoblastic Leukemia: A Case-Control Study in Pennsylvania, 2009-2017,” *Environmental Health Perspectives* 130, no. 8 (August 2022): 087001, https://doi.org/10.1289/EHP11092 .

[10] Holly Elser et al., “Air Pollution, Methane Super-Emitters, and Oil and Gas Wells in Northern California: The Relationship with Migraine Headache Prevalence and Exacerbation,” *Environmental Health* 20, no. 45 (2021), https://doi.org/10.1186/s12940-021-00727-w.

Penn America LNG export plans will require new wells and increased production if the projected volume of LNG needed by Penn America is realized.

Environmental and ecosystem degradation has resulted from fracking well construction, destroying habitats and natural landscapes with industrial development. Pipelines and compressor stations are needed to move the gas and the 93,500+ miles of underground pipelines in Pennsylvania[11] have ruined streams, fragmented forests and more. Natural gas is classified as a hazardous substance[12] and carries never-ending safety threats. There were 108 pipeline safety incidents in Pennsylvania between 2010 and 2018, causing 8 fatalities, 21 injuries, 15 explosions, 1,118 evacuees, and $66,932,124 in property damages[13].

Compressor stations are installed every 50-100 miles along pipelines.[14] They release chemical pollutants into the air such as volatile organic compounds (VOCs), nitrogen oxide compounds (NO_x), and particulate matter,[15] impacting local residents most heavily, many of whom are socially vulnerable and already overburdened.[16]

The next step in the life cycle of LNG is the liquefaction process, turning the methane from a gaseous state into a liquid. This is a highly polluting and energy-intensive process, impacting those closest most intensely. Lauren Minsky will be covering these air pollution details in her testimony so I will not duplicate.

What I will point out here is that the liquid storage phase is fraught with danger and subject to catastrophe should LNG be released into the environment.

First, LNG, is liquefied by freezing it to -260 degrees F. If released to the air, it releases a very cold flammable vapor cloud more than 600 times larger than the storage container.
An unignited ground-hugging vapor cloud can move far distances,[17] and exposure to the vapor can cause extreme freeze burns. If in an enclosed space, it asphyxiates, causing death.[18] If ignited, the fire is inextinguishable; the fire is so hot that second-degree burns can occur within 30 seconds for those exposed within a mile. The cloud can also explode with the force a catastrophically powerful bomb.[19] A Congressional report documents that the Federal Energy Regulatory Commission (FERC) notes that "[hazardous] thermal radiation" can be expected for up

---

[11] https://papipelinesafety.com/

[12] https://primis.phmsa.dot.gov/comm/factsheets/fsproductlist.htm

[13] https://www.fractracker.org/2018/11/rapid-pipeline-development-pa/

[14] Davis, et al, "Community Health Impacts From Natural Gas Pipeline Compressor Stations", Geohealth, 2023 Oct 31;7(11):e2023GH000874. doi: 10.1029/2023GH000874 at https://pmc.ncbi.nlm.nih.gov/articles/PMC10616731/

[15] https://pmc.ncbi.nlm.nih.gov/articles/PMC10616731/

[16] https://pmc.ncbi.nlm.nih.gov/articles/PMC10616731/

[17] "Immediate ignition with liquid still on the ground could cause the spill to develop into a pool fire and present a radiant heat hazard. If there is no ignition source, the LNG will vaporize rapidly forming a cold gas cloud that is initially heavier than air, mixes with ambient air, spreads and is carried downwind." P. 10 "Methane in vapor state can be an asphyxiant when it displaces oxygen in a confined space." P. 11. SP 20534 Special Permit to transport LNG by rail in DOT-113C120W rail tank cars. Final Environmental Assessment. Docket No. PHMSA-2019-0100. December 5, 2019. P. 10.

[18] SP 20534 Special Permit to transport LNG by rail in DOT-113C120W rail tank cars. Final Environmental Assessment. Docket No. PHMSA-2019-0100. December 5, 2019. P, 11.

[19] "LNG tank BLEVE is possible in some transportation scenarios." Sandia National Laboratories, "LNG Use and Safety Concerns (LNG export facility, refueling stations, marine/barge/ferry/rail/truck transport)", Tom Blanchat, Mike Hightower, Anay Luketa. November 2014. https://www.osti.gov/servlets/purl/1367739 P. 23.

to at least ¾ mile.[20] The 2016 U.S. Emergency Response Guidebook advises fire chiefs initially to immediately evacuate the surrounding 1-mile area[21] and during accidents 2 miles have been evacuated.[22] How can we do that in this densely populated area?

After storage, the next phase is shipping. These ships are larger than any ships that travel this far up the Delaware River. For instance, LNG tankers – and not even the largest used on international seas – are about 40% larger than the Dragon tankers used by the Marcus Hook natural gas liquids terminal next to Chester. This would require additional dredging for wharfs and pose safety threats to Delaware River communities. In fact, potential spillage, accidents, and explosions from LNG tankers is one of the reasons the State of Delaware banned LNG terminals in their Coastal Management Zone. And if an LNG tanker were to explode, it would have the force of 69 Hiroshima bombs.[23]

Increased ship traffic means increased harm to many species living in the Delaware. Most notable is the federally endangered Atlantic Sturgeon, a unique ecotype that has been here since ancient times – there are only about 200 adult animals left and ship strikes are their greatest cause of death.

Dr. Robert Howarth has eloquently covered why LNG is a climate disaster, so I will not.

In closing, as you our respected Legislators are well aware, the fundamental purpose of our government is to protect the health, safety, and welfare of Pennsylvanians. Importantly, we are protected by the Environmental Rights Amendment of the Commonwealth's Constitution, Article 1 Section 27, the Green Amendment[24]:

> The people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and esthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people.

And that requires that decisions made by government, including you, our respected Legislators, are based on these inalienable rights. Our communities must all equally be protected, there can be no environmental sacrifice zones. And regarding the environment, our nation has a long tradition of conservation.[25] These are our priorities.

The public will never accept an LNG Export Terminal on the Delaware River. We at Delaware Riverkeeper Network know that this use is simply not compatible with our Delaware River Port Region and would endanger all the values that distinguish us. We are in our third decade of

---

[20] Congressional Research Service, "Liquefied Natural Gas (LNG) Import Terminals: Siting, Safety, and Regulation" Updated 2009. https://www.congress.gov/crs_external_products/RL/PDF/RL32205/RL32205.14.pdf PDF P.17.

[21] US DOT Emergency Response Guidebook. https://www.phmsa.dot.gov/hazmat/erg/emergency-response-guidebook-erg

[22] https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/FIR_and_APPENDICES_PHMSA_WUTC_Williams_Plymouth_2016_04_28_REDACTED.pdf P.2.

[23] Delaware Riverkeeper Network, Protest in Opposition to Petition for Declaratory Order, Delaware River Partners, LLC, FERC Docket No. CP20-522-000. 10.15.2020. PDF P. 17 at https://drive.google.com/file/d/1QtABcHISLqvdvZy1CCXJq8GSbteySWI1/view?pli=1

[24] https://www.legis.state.pa.us/WU01/LI/LI/CT/HTM/00/00.001..HTM

[25] D. Keith Naylor, *Conservation—An American, and Republican, Tradition*, July 2001, https://origins.osu.edu/history-news/conservation-American-and-republican-tradition (accessed January 2025).

defending the the Delaware River, its communities, human and nonhuman, and we remain committed – that means no LNG Export in the Delaware River Watershed. Period.

November 3, 2025

Dear Pennsylvania House Environmental Resources and Natural Protection Committee:

My name is Lauren Minsky and I thank you for inviting me to testify on the environmental health impacts of Penn America's proposed LNG export facility in Eddystone/Chester in southeastern Delaware County (SE Delco). I have a Ph.D. in History (of global environmental health and medicine) from the University of Pennsylvania and I am currently employed as a faculty member in the health studies program at Haverford College here in Delaware County. I am also a resident of Delaware County and a parent raising two children here.

In an effort to better understand the environmental health conditions facing my own and neighboring communities in Delco, I have studied both peer-reviewed publications and publicly available data sources and resources. I testify here today as a concerned resident who has relevant professional expertise and not as a representative of my employer.

While specific details are scant, it is public knowledge that Penn America Energy has proposed the construction of an LNG liquification and export facility somewhere along the Delaware river in southeastern Delaware county.[1] Both Chester city and Eddystone are mentioned as desired target locations in available documents. As seen in this map of dasymetric population density from the 2010 U.S. Census, this stretch of riverfront is densely populated. Taken as a whole, Delaware county has among both the largest and densest population among Pennsylvania's counties. So we need to weigh this proposal very carefully. The well-being of a lot of lives and a lot of families is at stake. [See attached slide 1]

We also need to consider that the southeastern Delaware river front communities of Tinicum, Eddystone, Chester city, Trainer and Marcus Hook *already* constitute an environmental justice region. Approximately a third of the population in this region lives below the poverty line. Legacy pollution is evident in the major superfund sites in this small region, including the first in U.S. history – the Wade Superfund site. Currently, over two dozen active toxic release inventory sites, that report to the EPA because they use and release chemicals known to be hazardous to human health, release their toxic pollutants into this small region's air and water. [See attached slide 2]

These toxic polluters include one of the largest trash incinerators in the U.S. in Chester; several chemical and petrochemical companies; the enormous Energy Transfers' NGL refinery and export plant in Marcus Hook; and Delta Airlines' Monroe Energy's jet-fuel refinery in Trainer. There is also a gas-power plant in Eddystone and a gas power-plant that serves the Kimberly-Clark paper factory in Chester. Southeastern Delaware County riverfront communities are, additionally, surrounded by even more heavily polluting facilities, both to the north with the oil and gas refineries of South Philadelphia and to the east with those across the Delaware river in New Jersey.

I want to be clear, as well, that we are speaking about true fence line communities. Families, many with young children, live in houses, visit shops, and eat in restaurants a mere chain link

---

[1] For an overiew of the project please see: https://delawareriverkeeper.org/issues/environmental-rights-justice-equitable-river/chesterpa-pennamericaenergy-proposedlng-export-project/

fence away from the enormous incinerator in Chester and the existing jet-fuel and NGL refineries in Trainer and Marcus Hook. The impacts of emitted pollution on the air that they breathe is direct and total, unmitigated by distance and any possibility of dissipation. [See attached slide 3]

It is beyond question that the air that these community residents breathe is heavily polluted. The American Lung Association's "State of the Air" report card for 2025 gave Delaware County a grade "F" for particle pollution and a grade "D" for ozone levels. These abysmal scores are for all of the Delaware county, and in the southeastern riverfront communities, the ground ozone level also routinely tests as an "F" because it is out of compliance with standards set by the Clean Air Act.[2]

There is also much more than particulate matter and ozone in SE Delco's air. We know this based on the allowed emissions that are detailed in DEP facility permits and the EPA's TRI data. We also know this based on direct observation and measurement of air composition. A study done by a group of researchers at Johns Hopkins University, recently published in *Environmental Health Perspectives* in March 2025, measured thirty-two volatile organic compounds in the air in these fence-line communities of southeastern PA. The Clean Air Council and Marcus Hook Area Neighbors for Public Health have also been working on a purple air monitoring program to capture direct data on air quality. (Meanwhile the Delaware River Keeper Network, among others, has been doing crucial work monitoring and testing for contaminants in our drinking water sources).[3] [See attached slide 4]

Beyond elevated ozone, particulate matter, and VOC's, the air in southeastern Delaware county contains many other pollutants that are emitted by the existing facilities. These include persistent organic pollutants, heavy metals, greenhouse gases, a range of gaseous pollutants and acid gases, radioactive gas (radon) and radioactive particulate matter; and other particulate matter like PM10 and PM2.5. [See attached slide 5]

There is a vast scientific literature on the statistically-significant links that have been established between exposure to these pollutants and life-altering and life-threatening diseases – from cancers; to pulmonary diseases like asthma and COPD; to cardiovascular, neurological, endocrine, GI, hepatic, metabolic, renal, reproductive and developmental diseases. Covering this is well beyond the scope of my eight-minute testimony here today. What I want to focus on instead is the data that we have about *the lived health experiences of residents of these specific SE Delco communities.*

To start, I will focus on experiences with cancer, drawing upon data on cancer risks and cancer incidence generated by two cancer screening tools. The first is the EPA's AirTox Screen. As explained on the EPA website, this tool "uses the best science and emissions data available to estimate possible health risks from air toxics….the AirToxScreen is a "screening tool" – it helps us

---

[2] For more information, see https://www.lung.org/research/sota]

[3] See Chiger AA, Gigot C, Robinson ES, Tehrani MW, Claflin M, Fortner E, Stark H, Krechmer J, Canagaratna MR, Herndon S, Yacovitch TI, Koehler K, Rule AM, Burke TA, Fox MA, DeCarlo PF, Nachman KE. Improving Methodologies for Cumulative Risk Assessment: A Case Study of Noncarcinogenic Health Risks from Volatile Organic Compounds in Fenceline Communities in Southeastern Pennsylvania. *Environ Health Perspect.* 2025 May;133(5):57004. doi: 10.1289/EHP14696. Epub 2025 May 8. PMID: 40127300; PMCID: PMC12061051.

estimate risks and tells us where to look further. It provides screening-level estimates of the risk of cancer and other serious health effects from breathing air toxics."[4]

The map shown here illustrates what the EPA's air toxic cancer risk index for 2020 shows us when mapped by municipality in Delaware County. It does so against a base layer map that contains some (but not all) of the county's heavily polluting infrastructure, including major air emission plants, superfund sites, storage tanks, pipelines, and inter-states. As you can see, southeastern Delaware county has the highest lifetime air toxics cancer risk, with the largest rates of risk along the Delaware river front, and especially in Trainer and Marcus Hook where the oil and natural gas refineries are located.

We can also see from this map that there is no "bubble" that surrounds SE Delco communities and magically protects more affluent (and often significantly whiter) communities to the west of the Delaware river front. As the wind blows, so does air pollution. In turn, so does the air toxics cancer risk. The EPA's air toxic screen illustrates that *all* Delaware county communities are impacted by air pollution that is produced and released into the air of the Delaware riverfront communities. We are all connected. [See attached slide 6]

The second tool that I draw upon is the People's Cancer Incidence Screening Tool (PCIST). It uses publicly available crude cancer incidence (provided by PA DOH) and U.S. census data (from the ACS) by PA municipality to calculate the comparative crude cancer incidence of twenty-three leading types of cancer (as defined by the CDC). It does so over a 20-year period (2002-2021), because cancer takes a long time to develop and the incidence of rarer types of cancer can vary considerably from year to year. Like the EPA's AirToxScreen, PCIST is a "screening tool", providing screening-level calculations of the incidence of cancers as compared with US national, PA state, and all-county incidence. It enables users to see elevations in the lived cancer incidence rates of a given municipality, and (especially if part of a larger pattern evident in contiguous communities) to pursue further investigation and advocacy.[5]

In the case of Southeastern Delaware county, a combined regional PCIST report for adults in the communities of Tinicum, Eddystone, Chester, Trainer and Marcus Hook reveals several elevated "cancer signals", specifically for laryngeal; liver and bile; Hodgkin's lymphoma; lung and bronchial; pancreatic; esophageal; colon and rectal; stomach cancer; and myeloma. While beyond the scope of this short testimony, even a cursory survey of the scientific literature demonstrates that all of these cancers have statistically significant associations to chemical pollutant exposures, including the rarest of these (laryngeal cancer). Moreover, as the median age of the weighted adult population of southeastern Delaware county is younger than those for the comparative US, Pennsylvania, and Delaware County populations, these "cancer signals" are even more significant and should command our attention given that age is the single greatest risk factor for cancer.[6] [See attached slide 7]

---

[4] Please see: https://www.epa.gov/AirToxScreen/airtoxscreen-frequent-questions#background2

[5] For more details on PCIST, please visit: https://pcist.net; see also: https://www.psrpa.org/post/the-people-s-cancer-incidence-screening-tool-pcist-because-cancer-is-not-our-destiny

[6] As examples and for more details, please see: Nrupen A Bhavsar, Kay Jowers, Lexie Z Yang, Sharmistha Guha, Xuan Lin, Sarah Peskoe, Hannah McManus, Lisa McElroy, Mercedes Bravo, Jerome P Reiter, Eric Whitsel, Christopher Timmins, The association between long-term $PM_{2.5}$ exposure and risk for pancreatic cancer: an application of social informatics, *American Journal of Epidemiology*, Volume 194, Issue 3, March 2025, Pages 730–737; and Zhu AY, McWilliams TL, McKeon TP, Vachani A, Penning TM, Hwang WT.

Cancer is undoubtedly a rare development in children. However, according to the National Cancer Institute, cancer is nevertheless the leading cause of death by disease among children beyond infancy in the US. Among children and adolescents under the age of twenty, the NCI also reports that leukemias, lymphomas, and brain and nervous system cancers are the most common types of cancer. Significantly, all three of these cancers are associated with environmental exposures in the published scientific literature.

Children are far more vulnerable to the carcinogenic impacts of pollution exposures because they receive a significantly larger dose by body weight than adults. Moreover, published research studies conducted around the world establishes that *proximity to oil and natural gas drilling, fracking and refining* is associated with elevated leukemia, lymphoma and brain and nervous system cancers in children. Two recent, formal epidemiological studies conducted here in PA reveal that proximity to shale gas drilling, or fracking wells, with its associated methane and chemical exposures is specifically associated with childhood leukemia and lymphoma.[7] [See attached slide 8]

Given this, it is important for us to consider the cancer signals calculated by PCIST for children aged 0-19 in Southeastern Delaware county where (albeit it at the other end of the pipeline) there is a lot of natural gas, as well as oil and other industrial exposures. PCIST analyses reveal that the strongest and most widely prevalent signals of elevated pediatric cancer in Southeastern Delaware county are also for leukemia; lymphoma; and brain and nervous system cancers. These signals are evident in the calculations for the combined Southeastern Delaware riverfront communities, as well as for the individual municipalities that comprise the SE region and for adjoining ones directly to the west in Delaware county. Indeed, given that the air toxics cancer risk extends westwards across the county, it should not come as a surprise that many Delaware county communities show

---

Association of multi-criteria derived air toxics hazard score with lung cancer incidence in a major metropolitan area. *Front Public Health.* 2023 Jun 26;11:1002597. doi: 10.3389/fpubh.2023.1002597; Wang J, Lin C, Chu Y, Deng H, Shen Z. Association between long-term exposure to air pollution and the risk of incident laryngeal cancer: a longitudinal UK Biobank-based study. *Environ Sci Pollut Res Int.* 2023 Apr;30(20):58295-58303. doi: 10.1007/s11356-023-26519-y. Epub 2023 Mar 28. PMID: 36977870; PMCID; VoPham T, Jones RR. State of the science on outdoor air pollution exposure and liver cancer risk. Environ Adv. 2023 Apr;11:100354. doi: 10.1016/j.envadv.2023.100354. Epub 2023 Feb 12. PMID: 36875691; PMCID: PMC9984166; Yu G, Cui Y, Kang R, Wu J, Ge W, Han J. Air Pollution and the Risk of Liver Cancer Incidence and Mortality: A Systematic Review and Meta-Analysis. *Liver Int.* 2025 Nov;45(11):e70409. doi: 10.1111/liv.70409. PMID: 41144931; and https://www.aacr.org/patients-caregivers/progress-against-cancer/air-pollution-associated-cancer/]

[7] On leukemia, please see: Elliott EG, Trinh P, Ma X, Leaderer BP, Ward MH, Deziel NC. Unconventional oil and gas development and risk of childhood leukemia: Assessing the evidence. *Sci Total Environ.* 2017 Jan 15;576:138-147. doi: 10.1016/j.scitotenv.2016.10.072. Epub 2016 Oct 23. PMID: 27783932; PMCID: PMC6457992 and https://medicine.yale.edu/news-article/deziel/; on lymphoma, please see: Talbott, Evelyn O., Vincent C. Arena, Renwei Wang, Fan Wu, Natalie Price, Jeanine M. Buchanich, Caroline A. Hoffman, Todd Bear, Maureen Lichtveld, and Jian Min Yuan. 2025. "Cumulative Exposure to Unconventional Natural Gas Development and the Risk of Childhood Cancer: A Registry-Based Case–Control Study" *International Journal of Environmental Research and Public Health* 22, no. 1: 68 and https://doi.org/10.3390/ijerph22010068 and https://paenv.pitt.edu/assets/Report_Cancer_outcomes_2023_August.pdf]

elevated signals for pediatric leukemia; lymphoma; and brain and nervous system cancer. [See attached slide 9]

The health conditions that residents of southeastern Delaware county disproportionately suffer from extends well beyond cancer, as well. The following series of maps (which I am today running through very quickly, but which are provided to committee members as part of my submitted written testimony for their closer examination) illustrate that the adult (aged 20+) rates of asthma; chronic obstructive pulmonary disease; disabilities; and mental health symptoms affect Delaware county residents quite widely and are all highest in the southeastern Delaware river front communities in and around Chester. [See attached slides 10-13].

We also need not rely only on quantitative data as presented in charts and maps. We have decades of powerful and detailed testimony given at hearings and public events by Ms. Zulene Mayfield and CRCQL members that clearly details the lived health experiences of Chester residents. A recent community participatory research study published by researchers at Johns Hopkins, the Clean Air Council, and Marcus Hook and Chester residents further details the range of physical and mental symptoms that people suffer from as live in the shadows of heavily polluted refineries, incinerators, and other facilities. Additionally, a report just published in September 2025 by Laura Dagley with Physicians for Social Responsibility details the mental and emotional impact of industrial pollution on fence-line communities. As Dagley writes: "Living under a constant threat – from chemical spills to invisible pollution – creates chronic stress that damages the brain, weakens the immune system, and worsens existing health conditions…At the same time, limited access to medical care and political power leaves many residents with few options for protection or recourse." [8]

Please look closely at this photograph and imagine raising your beautiful children with this as your backyard. [See attached slide 14]

In light of all of the above, is there room for Penn America's proposed LNG liquification and export facility? I firmly say no. For one, as I understand it, the company's intent is to build what will be the largest LNG export plant on the east coast on less than 100 acres. It is intended that the operations of the proposed facility will be substantial, processing up to one billion cubic feet of gas per day and exporting seven million metric tonnes of LNG each year. Yet, most LNG facilities sit on sites that are thousands of acres in size. So, Penn America intends to shoehorn their proposed plant into a densely settled, residential environmental justice zone that, quite literally, has no room. [See attached slide 15]

Moreover, we know based on permits from other LNG export facilities in Maryland, Louisiana, and Texas that, if approved, this proposed facility will add considerable quantities of even more of the toxic pollutants that are already in the air and are already seriously harming residents' health. These pollutants include, but are not limited to, VOCs, heavy metals, greenhouse gases especially

---

[8] See Chiger, Andrea A.; Alford, Echo; Warren, Kearni N; Miari, Eve S; Snyder, Lora; Nixon, Thom; Lightner, Alexis; Kennedy, Ryan; Fox, Mary; DeCarlo, Peter; Nachman, Keeve; Lupolt, Sara. **"**Influences of Chemical and Nonchemical Stressors on Health and Quality of Life in Fenceline Communities: A Community-Based Participatory Research Survey in Southeastern Pennsylvania" in: *Environmental Justice,* 2025; Laura M. Dagley, "The Polluter Next Door: A Report on the Mental and Emotional Impact of Industrial Pollution on Fenceline Communities". September 2025 by Physicians for Social Responsibility].

methane, gaseous pollutants, acid gases, radioactive gas and particulate matter, and PM 10 and PM 2.5 particulate matter.[9] [See attached slide 16]

Additionally, the record of existing LNG plants in the US is not at all promising in terms of compliance with permit limits, including the release of benzene, a potent carcinogen that is especially linked to leukemia in children. According to a report published by the Environmental Integrity Project, a non-profit research organization, every fully operational liquefied LNG terminal in the US has violated federal pollution limits in recent years. Thus, the Penn America LNG plant will surely mean more certain illness, more sacrificed lives cut short. This includes more cases of terminal cancer in children and teenagers who live in communities where their brothers, sisters, cousins, and friends already fall sick and die in elevated numbers – especially along the Delaware riverfront but also throughout Delaware county. No case of cancer in a child is ever an acceptable price to pay simply for Penn America's shareholders (or any others) to make profits.[10]

The LNG environmental health risks also don't end here. A facility like this, where methane is cooled into a highly compressed liquid form, poses a tremendous explosion risk. Methane vapors are highly flammable when mixed with air. An explosion and fire at Freeport LNG in June 2022 was caused by the warming and expansion of LNG within piping due to an improperly isolated pressure relief valve and it shut down the facility for eight months. Moreover, our warming climate and oceans – something tremendously fueled by methane emissions – is producing stronger and more powerful storms. Flooding from a major hurricane event will inundate and seriously damage hazardous facilities like this one along the Delaware riverfront.

Lastly, we *must* also consider the environmental health implications of this proposed facility for our brothers and sisters in western and northern Pennsylvania where shale gas extraction, or fracking, occurs. The fracking process extracts gas from the Marcellus shale using water, respirable silica sand, and chemicals that are carcinogens, endocrine disruptors, and environmental toxins. Fracking also extracts naturally occurring radioactive particulate and gas like radium and radon. The process of fracking frequently contaminates aquifers and drinking water wells through cracks, such that residents are exposed to potent toxins in both their air and water. For more information on this important subject, please read the comprehensive compendium report published by Physicians for Social Responsibility, Concerned Health Professionals of New York, and the Environmental Health Network. Their report reviews all of the scientific literature on the environmental health consequences of fracking and shows that living near fracking is associated with cancer, birth defects, low birth weight, preterm delivery; asthma and respiratory issues; heart and blood pressure problems; skin irritation and dermal symptoms; neurological symptoms including fatigue and migraines; as well as adverse mental health effects.[11]

As mentioned earlier in my testimony, two recent studies conducted in Pennsylvania have specifically shown a statistically significant association between proximity to fracking and the incidence of leukemia and lymphoma in children. The PCIST cancer screening tool, when applied to local communities in the most heavily fracked county in PA (Washington County), similarly finds substantial elevations in rates of leukemia and lymphoma among children. In fact, due to their lived experiences of a very significant rise in pediatric cancer rates, parents in southwestern

---

[9] See: https://www.energy.gov/sites/default/files/2024-12/LNGUpdate_SummaryReport_Dec2024_12pm.pdf
[10] See https://www.theguardian.com/us-news/2025/oct/29/liquefied-natural-gas-terminal-pollution-limits.
[11] See https://psr.org/resources/fracking-compendium-9/

Pennsylvania have created important organizations like MAD-FACTS (Moms and Dads—Family Awareness of Cancer Threat Spike) in Washington County to defend the health of their children.[12]

In conclusion, if we value the health of our families, friends, and neighbors in Delaware County and throughout the Commonwealth of Pennsylvania, we need to build a different future – a livable one in which we can all thrive. We should not be building a future in which growing numbers of parents are burying their children. Building a healthy future means that there is absolutely no room for Penn America's LNG plant – not in Chester, not in Eddystone, not in Marcus Hook, not in South Philly, not in Gibbstown, not anywhere.

Sincerely,

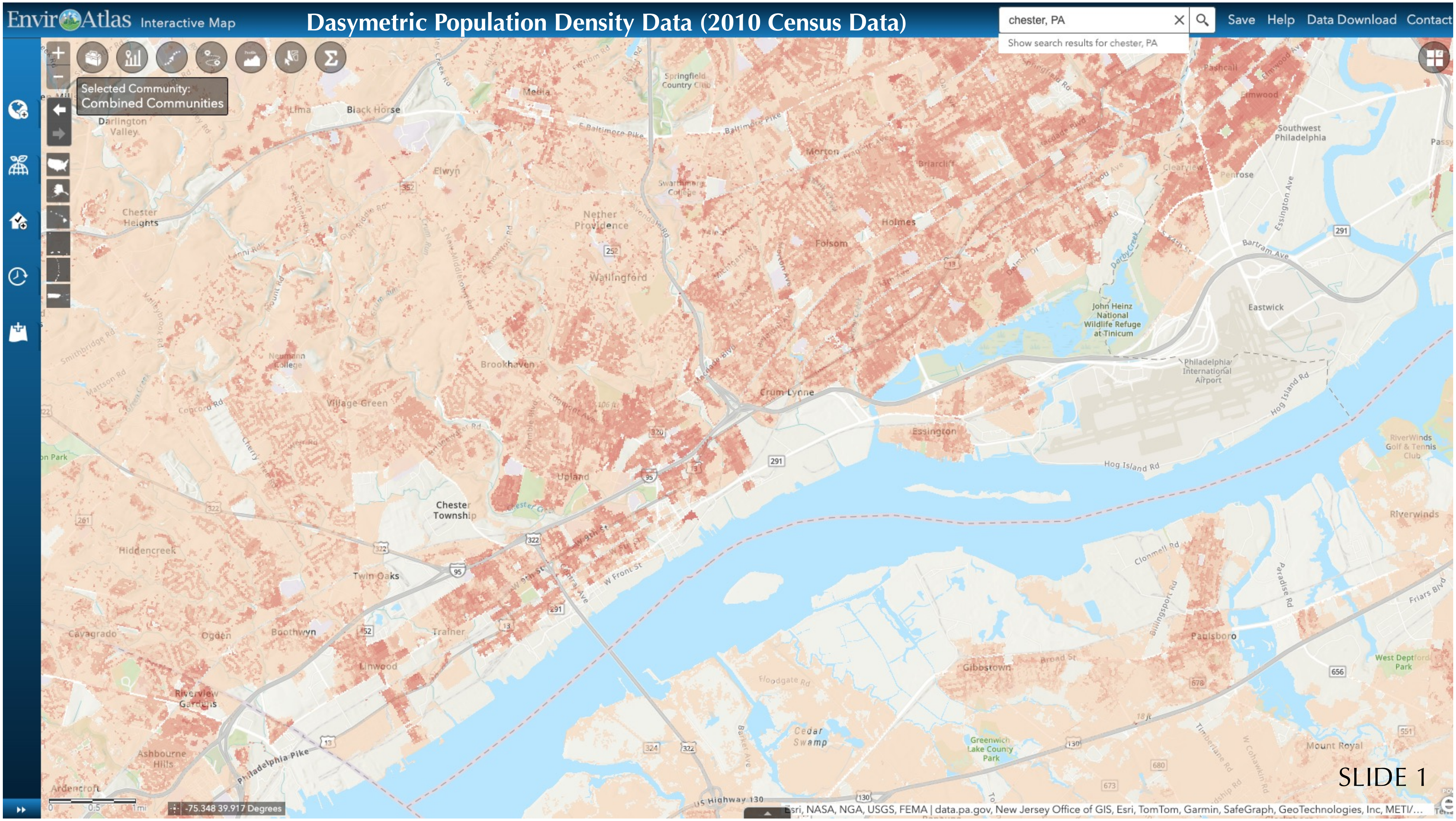
Lauren Minsky, Ph.D.
Health Studies Program at Haverford College
Resident and Mother, Delaware County

---

[12] Please see: https://pcist.net and navigate to Washington County; see also https://mad-facts.org.

No Room for LNG: Dirty Energy, Environmental Health, and Sacrificed Lives in Southeastern Delaware County, PA

Lauren Minsky, Ph.D.
Health Studies Program, Haverford College
Resident and Parent, Delaware County


EnvirOAtlas Interactive Map
Dasymetric Population Density Data (2010 Census Data)
chester, PA
Show search results for chester, PA
Save
Help
Data Download
Contact
Selected Community:
Combined Communities
Media
Lima
Black Horse
Darlington Valley
Springfield Country Club
Elwyn
Morton
Briarcliff
Pashcall
Elmwood
Southwest Philadelphia
Chester Heights
Nether Providence
Swarthmore College
Holmes
Folsom
Penrose
Wallingford
John Heinz National Wildlife Refuge at Tinicum
Eastwick
Brookhaven
Neumann College
Village Green
Crum Lynne
Philadelphia International Airport
Essington
Upland
Chester Township
Hog Island Rd
RiverWinds Golf & Tennis Club
Riverwinds
Hiddencreek
Twin Oaks
W Front St
Cayagrado
Ogden
Boothwyn
Trainer
Paulsboro
Linwood
Gibbstown
West Deptford Park
Riverview Gardens
Cedar Swamp
Greenwich Lake County Park
Ashbourne Hills
Mount Royal
Ardencroft
Philadelphia Pike
US Highway 130
-75.348 39.917 Degrees
Esri, NASA, NGA, USGS, FEMA | data.pa.gov, New Jersey Office of GIS, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/...
SLIDE 1

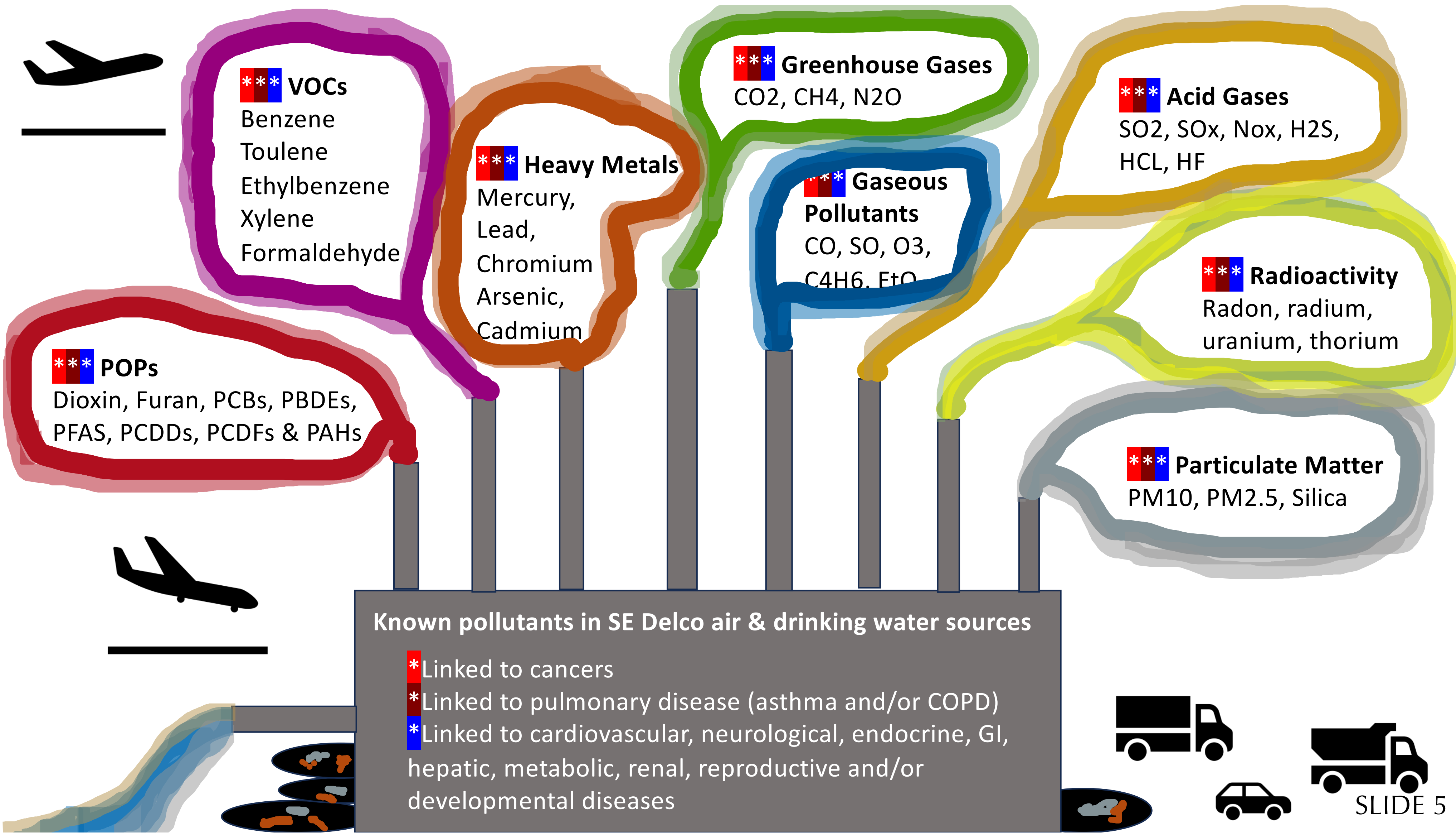
Active Toxic Release Inventory (TRI) Sites reporting to EPA SLIDE 2

Life on the fenceline

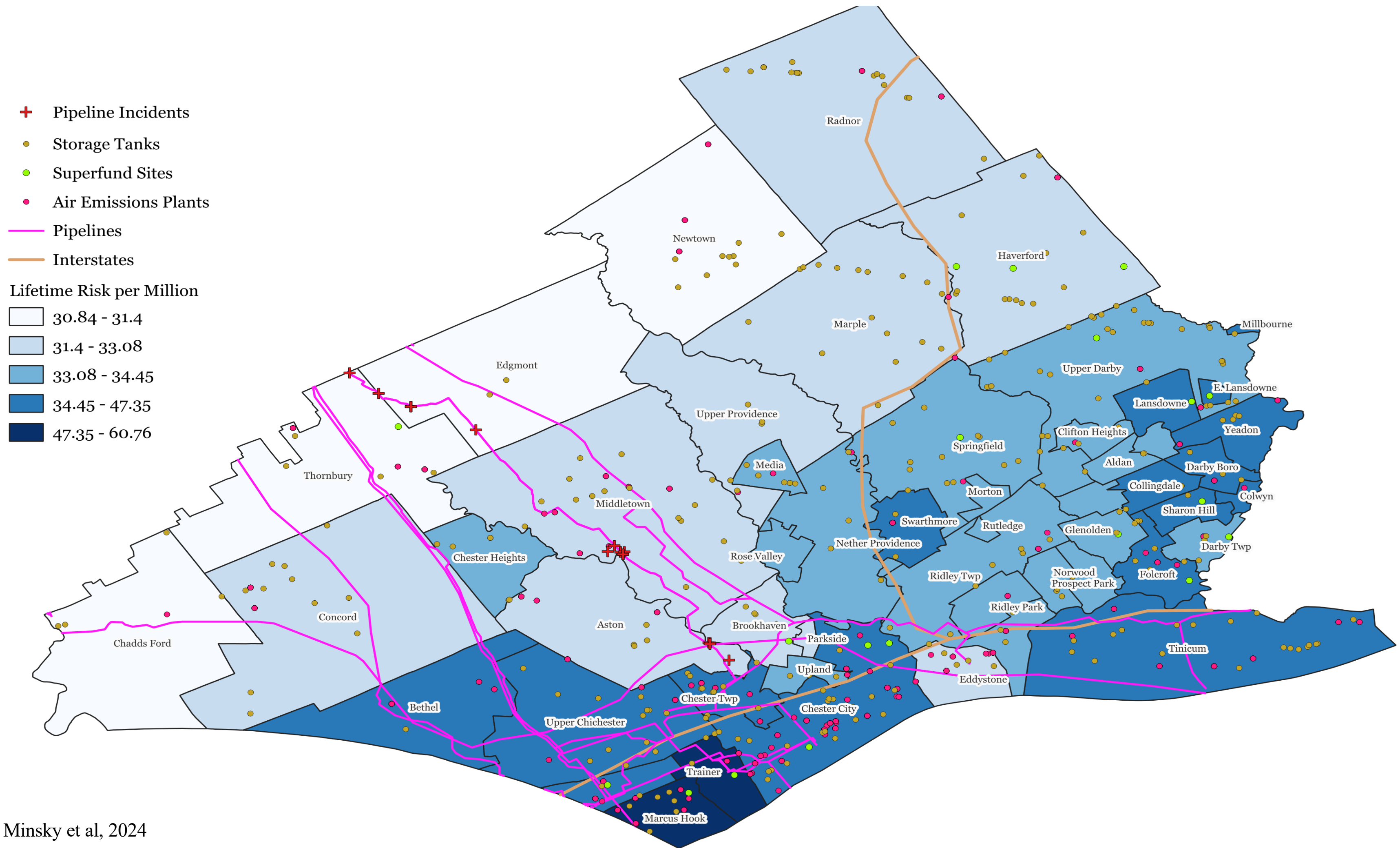
Top: Monroe Energy (Delta Airlines)
Top right: Energy Transfers
Bottom Right: Reworld/Covanta trash incinerator

Much more than particulate matter and ozone is in our air (& water)

Fence-line homes abut Monroe Energy (Delta Airlines) jet-fuel refinery



*** VOCs
Benzene
Toulene
Ethylbenzene
Xylene
Formaldehyde
*** Heavy Metals
Mercury,
Lead,
Chromium
Arsenic,
Cadmium
*** Greenhouse Gases
CO2, CH4, N2O
*** Gaseous Pollutants
CO, SO, O3,
C4H6, EtO
*** Acid Gases
SO2, SOx, Nox, H2S,
HCL, HF
*** Radioactivity
Radon, radium,
uranium, thorium
*** POPs
Dioxin, Furan, PCBs, PBDEs,
PFAS, PCDDs, PCDFs & PAHs
*** Particulate Matter
PM10, PM2.5, Silica
Known pollutants in SE Delco air & drinking water sources
*Linked to cancers
*Linked to pulmonary disease (asthma and/or COPD)
*Linked to cardiovascular, neurological, endocrine, GI, hepatic, metabolic, renal, reproductive and/or developmental diseases



Minsky et al, 2024

Data sources: PolicyMap, EPA, CDC, PDOT, FracTracker Alliance, PA DEP

EPA Air Toxics Cancer Risk Index in Delaware County, PA (2020)

ADULT CANCER IN SE DELCO

During **2002-2021 (20 years),** the average annual crude cancer incidence rate among **all adults aged 20+ years** in **SE Delco** is greater than the corresponding rate for the **US; PA;** & **Delaware County by:**

Adult Cancer in SE Delco 20+ years of age	> US	> PA	> Delco
Laryngeal	103%	71%	72%
Liver and bile	89%	79%	64%
Hodgkin's lymphoma	66%	40%	42%
Lung and bronchial	53%	30%	28%
Pancreatic	36%	13%	19%
Esophageal	31%	4%	13%
Stomach	28%	15%	16%
Colon and rectal	28%	7%	3%
Myeloma	5%	1%	15%

✦ Please visit www.pcist.net or contact PCIST@pm.me for more information about the People's Cancer Incidence Screening Tool

Children play at the WSFS sports complex, a fence line away from the ReWorld incinerator and Monroe Energy's jet fuel refinery

PEDIATRIC CANCER IN WIDER SE DELCO

LEUKEMIA

LYMPHOMA

BRAIN & NERVOUS

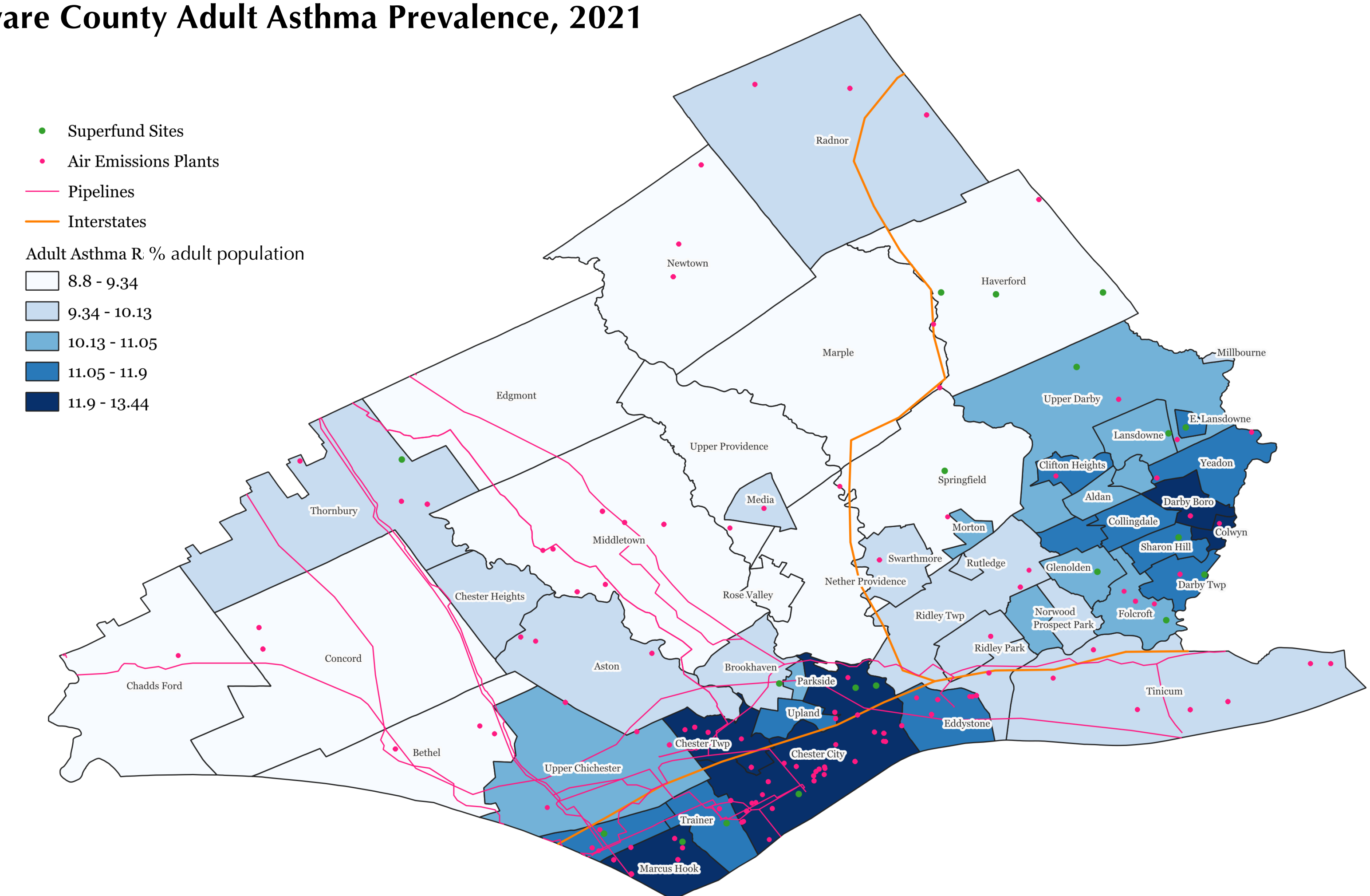
During **2002-2021 (20 years),** the average annual crude cancer incidence rate among **children aged 0-19 years** is higher than the corresponding rate for the **US; PA;** & **Delaware County by:**

Pediatric Leukemia	> US	> PA	> Delco
All SE Delco	18%	24%	33%
Chester City	18%	23%	33%
Eddystone	54%	61%	73%
Trainer	360%	381%	418%
Lower Chichester	20%	25%	35%
Parkside	68%	76%	89%
Upland	114%	124%	141%
Brookhaven	47%	54%	66%
Ridley Park	210%	225%	250%
Ridley Twp	44%	18%	23%

Pediatric Lymphoma	Type	> US	> PA	> Delco
All SE Delco	HL	77%	42%	60%
All SE Delco	NHL	18%	29%	18%
Chester City	HL	47%	18%	33%
Chester City	NHL	11%	21%	11%
Eddystone	HL	1051%	821%	938%
Tinicum	NHL	351%	5%	352%
Upland	HL	221%	262%	301%
Lower Chichester	NHL	349%	390%	350%
Aston	HL	389%	290%	340%
Bethel	HL	49%	19%	35%
Bethel	NHL	49%	63%	50%
Morton	HL	602%	461%	533%

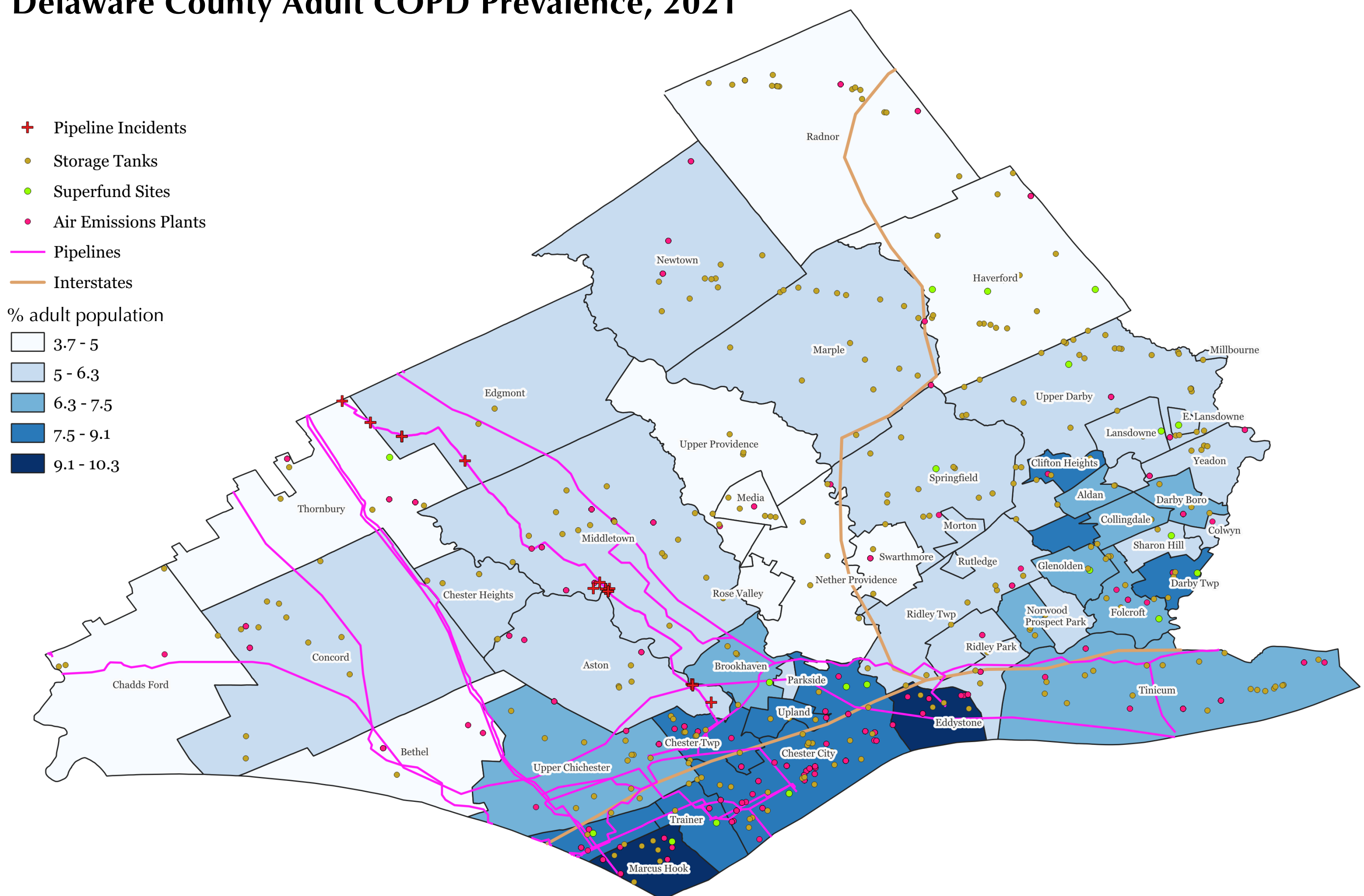
Pediatric Brain+Nervous	> US	> PA	> Delco
All SE Delco	11%	-9%	-5%
Chester Twp	12%	-9%	-4%
Marcus Hook	131%	89%	98%
Tinicum	238%	3%	190%
Trainer	223%	165%	178%
Lower Chichester	69%	38%	45%
Upper Chichester	63%	34%	40%
Upland	50%	23%	29%
Parkside	136%	94%	103%
Ridley Twp	44%	18%	23%
Brookhaven	314%	240%	256%
Nether Providence	68%	38%	44%
Swarthmore	53%	26%	32%
Media	118%	79%	87%
Springfield	81%	49%	56%

Delaware County Adult Asthma Prevalence, 2021



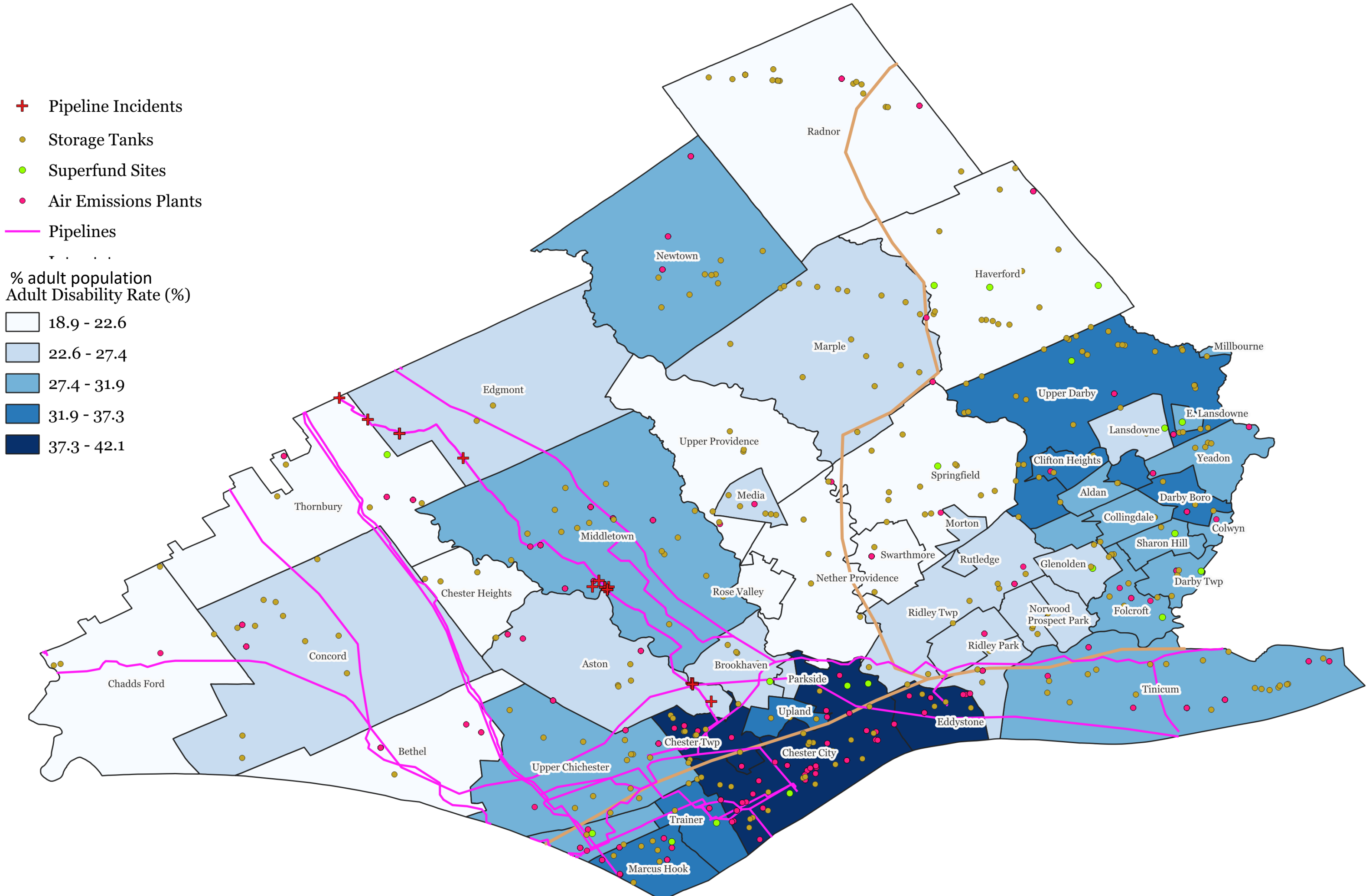
Data source: PolicyMap, CDC, EPA, PDOT, FracTracker Alliance

Delaware County Adult COPD Prevalence, 2021



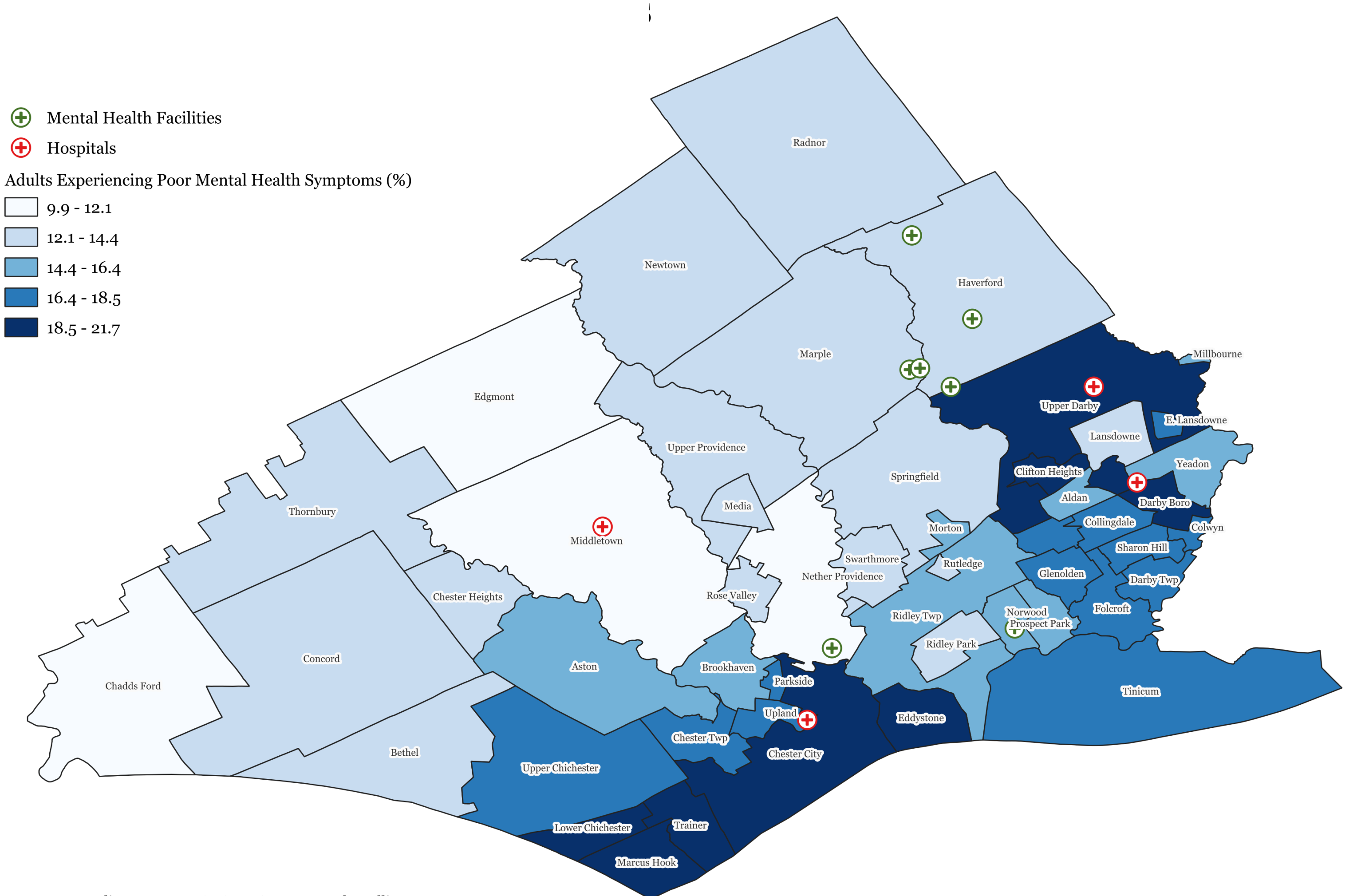
Data sources: PolicyMap, EPA, CDC, PDOT, FracTracker Alliance, PA DEP

Delaware County Adult Disabilities Prevalence, 2021



Data sources: PolicyMap, EPA, CDC, PDOT, FracTracker Alliance, PA DEP

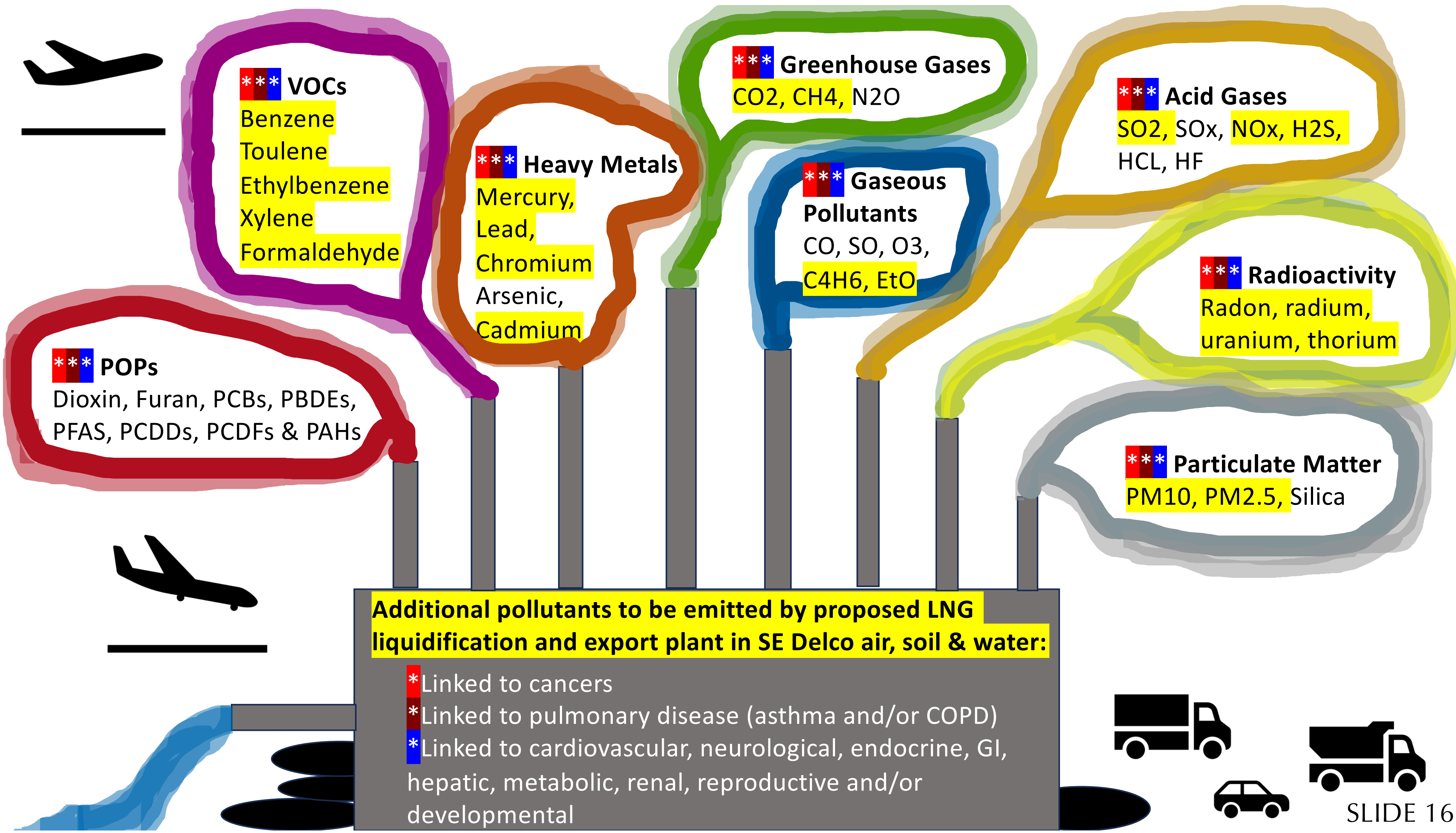
Delaware County Adult Mental Health Symptoms Prevalence, 2021



Data sources: PolicyMap, EPA, CDC, PDOT, FracTracker Alliance, PA DEP

QUALITY OF LIFE?

Room for Penn America's LNG facility?


***VOCs
Benzene
Toulene
Ethylbenzene
Xylene
Formaldehyde
***Heavy Metals
Mercury,
Lead,
Chromium
Arsenic,
Cadmium
***Greenhouse Gases
CO2, CH4, N2O
***Gaseous Pollutants
CO, SO, O3,
C4H6, EtO
***Acid Gases
SO2, SOx, NOx, H2S,
HCL, HF
***Radioactivity
Radon, radium,
uranium, thorium
***POPs
Dioxin, Furan, PCBs, PBDEs,
PFAS, PCDDs, PCDFs & PAHs
***Particulate Matter
PM10, PM2.5, Silica
Additional pollutants to be emitted by proposed LNG liquidification and export plant in SE Delco air, soil & water:
*Linked to cancers
*Linked to pulmonary disease (asthma and/or COPD)
*Linked to cardiovascular, neurological, endocrine, GI, hepatic, metabolic, renal, reproductive and/or developmental


CQL


SYSTEM CHANGE, NOT CLIMATE CHANGE!

BEFORE THE PENNSYLVANIA HOUSE OF REPRESENTATIVES
HOUSE ENVIRONMENTAL AND NATURAL RESOURCE PROTECTION COMMITTEE

TESTIMONY OF ELIZABETH R. MARX

NOVEMBER 5, 2025

Pennsylvania Utility Law Project
Elizabeth R. Marx, Esq.
Executive Director

118 Locust Street
Harrisburg, PA 17101
emarx@pautilitylawproject.org

PULP
PENNSYLVANIA
UTILITY LAW PROJECT

INTRODUCTION

Good afternoon, Chair Vitali, Chair Rader, and Members of the House Environmental and Natural Resource Protection Committee. Thank you for the invitation and opportunity to provide testimony regarding the impact of expanded liquified natural gas (LNG) exports on Pennsylvania ratepayers. It is an honor to come before you today on this important matter.

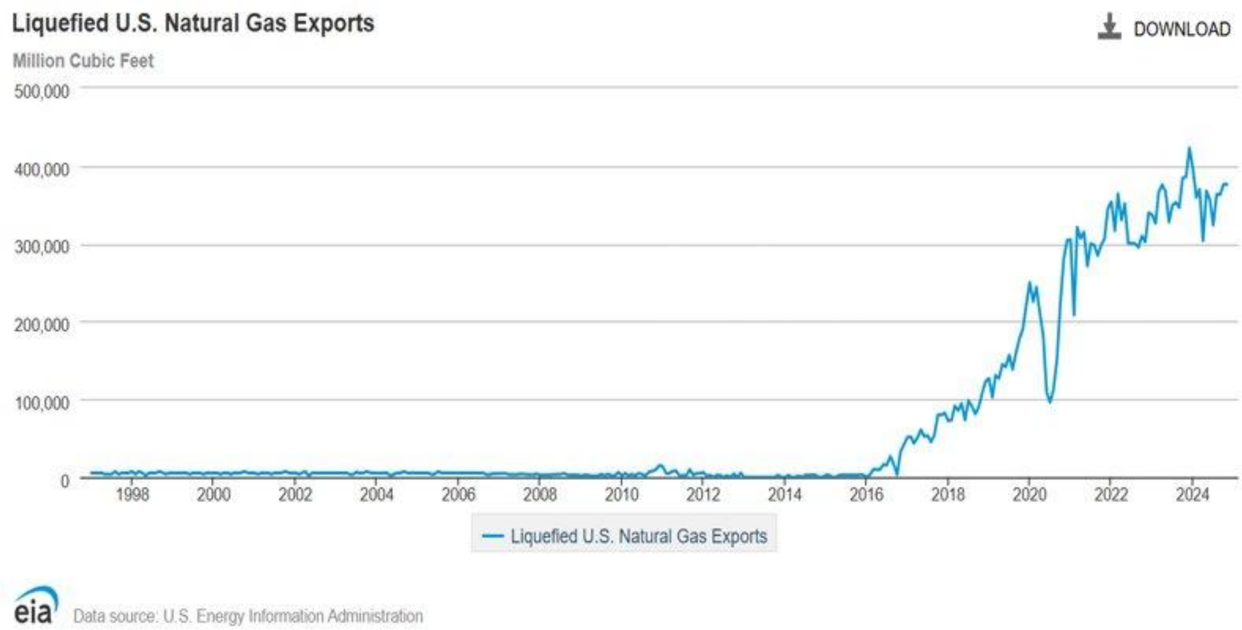
My name is Elizabeth Marx, and I serve as Executive Director of the Pennsylvania Utility Law Project (PULP). PULP is a statewide specialty legal aid office, administratively housed within Regional Housing Legal Services. We are a member of the integrated Pennsylvania Legal Aid Network, and we provide legal representation, policy advocacy, education, and support to low income clients in furtherance of our mission to ensure that Pennsylvanians experiencing poverty can connect to and maintain safe and affordable utility services to their homes.

My testimony today is on behalf of PULP's low income clients from all corners of the Commonwealth. As I will explain, we are deeply concerned about the impact of the rapidly expanding LNG export markets on the affordability of gas and electric service for Pennsylvania families – and the corresponding impact on the ability of economically vulnerable households to maintain energy service to their home.

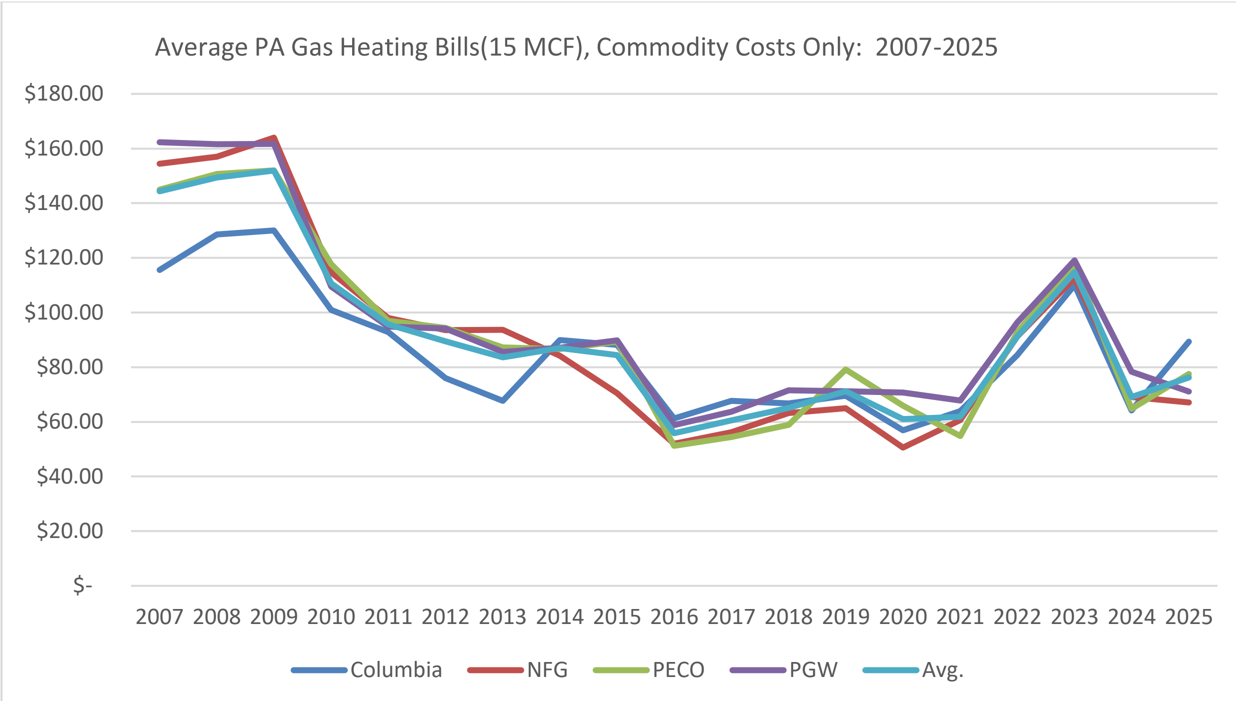
Low income families across Pennsylvania face profound utility insecurity and regularly forego food, medicine, and medical care in order to afford heat, electricity, and running water to their home. Indeed, over 1 million low income families across the state spend greater than 10% of their household income on energy costs alone – leaving very little margin to pay for other necessities.[i]

Last winter, 25,000 families were without safe heat, and as of September 2025, nearly 340,000 households already faced involuntary termination – up 16% over last year.[ii] The number of Pennsylvania families facing acute utility insecurity is likely to grow exponentially in 2025 as disruptions in the availability of federal assistance through SNAP and LIHEAP remains uncertain. For the first time since 1981, Pennsylvania faces a winter without critical home energy relief.

The rapid increase in LNG capacity in the United States is a relatively new factor driving increased energy costs, following an explosion in export capacity in 2016 which moved the United States from a net importer to a net exporter. The chart below from the Energy Information Administration shows the increase in LNG export capacity over the last 30 years.

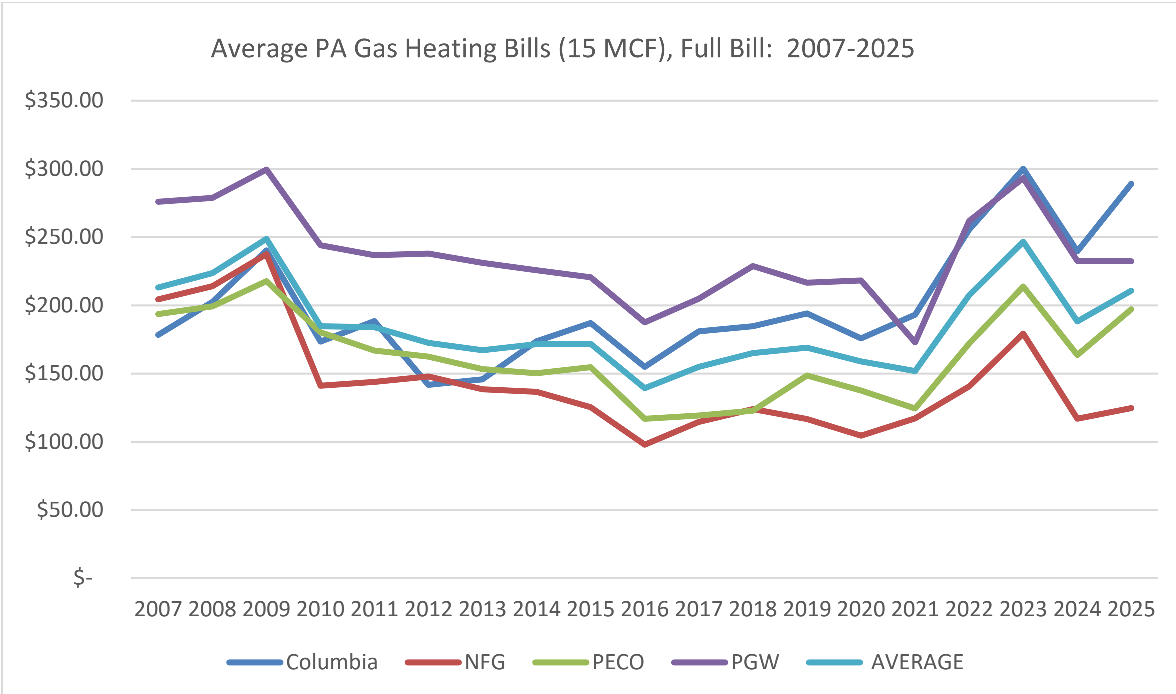


Gas from the Marcellus Shale has kept gas commodity costs relatively low for Pennsylvanians for most of the last decade. As a result, over half of Pennsylvania families now rely on gas as a primary fuel source to heat their homes.[iii] However, the continued expansion of LNG export capacity is forcing Pennsylvanians to compete on the world market for the gas extracted from their backyard. The chart below shows the average commodity costs for average residential gas heating customers (using 15 MCF of gas) from 2007 through 2025: [iv]



As you can see in the data above, after years of declining gas commodity prices driven by expanded fracking in our state, gas prices in Pennsylvania increased dramatically in 2022 and into 2023 – returning Pennsylvania retail gas prices perilously close to pre-Marcellus Shale commodity pricing. This spike in commodity rates occurred after Russia cut off gas supplies to Europe as a strategy in the war on Ukraine – driving record exports to Europe and the surrounding region.

While isolating commodity costs is helpful to show the impact of gas exports abroad on retail gas prices here at home, it does not tell the full story. When gas commodity rates dropped in Pennsylvania during the fracking boom, gas utilities increased infrastructure investments which has a long term effect of increasing utility costs while commodity prices are low which then remain baked into the overall bill when commodity prices increase. .. The chart below shows the average total gas bill for residential gas heating customers (15 MCF of gas) from 2007 through 2025:[v]



As can be seen from the chart above, many gas utilities have surpassed or are close to surpassing their pre-Marcellus gas price on a total bill basis. This has profound effects on households' ability to afford essential service to their homes. Following the spike in gas rates from 2022-2023, involuntary gas terminations increased 40% year over year – resulting in a staggering number of Pennsylvania families without basic gas service.[vi]

The increase in LNG exports not only affects retail gas rates, it also has a significant impact on electricity rates, as 60% of Pennsylvania's electricity is generated by gas fired power plants.[vii] While the immediacy of the impact of gas exports on electricity rates is more gradual, as a result of staggered contracting in the purchase of electricity on the wholesale market, the overall impact will be significant. In short: increases in the wholesale cost of gas has a direct and immediate effect on the price of gas and an indirect but nevertheless profound impact in the cost of Pennsylvanians' electric bills. In the year that followed, as high gas prices found their way into electric generation rates, involuntary termination rates for electricity customers followed suit – increasing 25% year over year from 2023 to 2024. [viii]

.

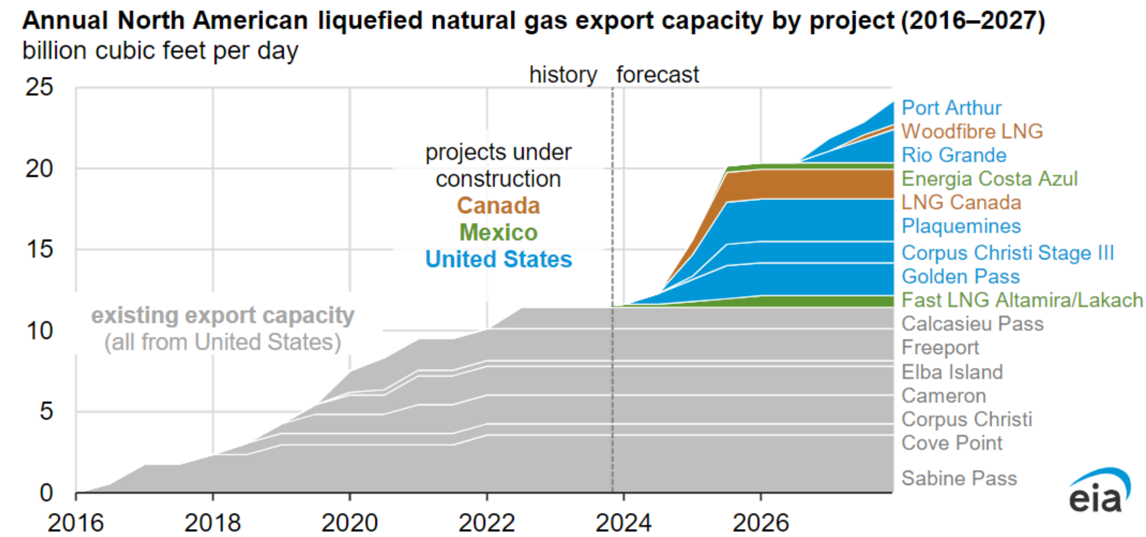
Historically, the federal government has not expressly considered the impact of expanded export facilities on domestic energy prices or, more specifically, on low income families. The Federal Natural Gas Act of 1938 recognizes gas as an essential utility service and prohibits approval of export facilities that are inconsistent with the public interest, but does not further define the term "public interest" – leaving broad discretion to the Department of Energy (DOE) to interpret the term.[ix]

In 2024, DOE paused further approval of new LNG export facilities to review the factors used to determine whether new export facilities are in the public interest.[x] At the time the pause was implemented, DOE's public interest analysis was rooted in the assumption that expanded LNG exports are necessarily good for the economy because it drives higher returns in the market. This high level inquiry ignored evidence of distributional economic harm for vulnerable households, who most often do not have investments that benefit from market gains.

Following a year of study and public comment, DOE released a report in December 2025.[xi] In her remarks releasing the study, then DOE Secretary Granholm concluded that "a business-as-usual approach is neither sustainable or advisable" – and that "unfettered exports" may drive up domestic gas prices by 31% over the next 25 years.[xii]

Between this year and next, LNG export capacity is expected to double, further exposing Pennsylvanians to instabilities in the world market for gas.

LNG export capacity from North America is likely to more than double through 2027



Data source: U.S. Energy Information Administration, *Liquefaction Capacity File*, and trade press
Note: LNG=liquefied natural gas. Export capacity shown is project's baseload capacity. Online dates of LNG export projects under construction are estimates based on trade press.

In light of this projected increase in gas exports overseas, and the increased need for energy here at home to power the unprecedented projected load growth associated with hyperscale AI data centers, domestic gas prices are expected to continue rising dramatically across the state. Pennsylvania families must not be forced to compete with other countries for energy to power their basic needs.

CONCLUSION

Thank you for the opportunity to provide testimony to the Committee regarding the impact of expanded LNG exports on Pennsylvania ratepayers. I look forward to answering any questions you may have this morning, or in the days and weeks to come. Please do not hesitate to reach out directly at emarx@pautilitylawproject.org.

[i] Fisher, Sheehan, & Colton, Pennsylvania Home Energy Affordability Gap (Apr. 2023), available at: http://www.homeenergyaffordabilitygap.com/03a_affordabilityData.html.
[ii] Pennsylvania Public Utility Commission, Terminations and Reconnections: Year-to-Date September 2024 vs. Year-to-Date September 2025, https://www.puc.pa.gov/media/3693/terminations-reconnectionsytd-sept24vs25.pdf.
[iii] EIA, Pennsylvania State Profile and Energy Estimates, available at: https://www.eia.gov/state/?sid=PA.
[iv] Gas commodity prices for average residential customers using 15 MCF/month were compiled from the Public Utility Commission Annual Rate Comparison Reports, available at https://www.puc.pa.gov/filing-resources/reports/rate-comparison-reports/.
[v] The total bill for average residential customers using 15 MCF/month were compiled from the Public Utility Commission Annual Rate Comparison Reports, available at https://www.puc.pa.gov/filing-resources/reports/rate-comparison-reports/.
[vi] Pennsylvania Public Utility Commission, Terminations and Reconnections: Year-to-Date December 2022 vs. Year-to-Date December 2023 As Reported by Utilities Pursuant to Monthly Reporting Requirements at 52. Pa. Code 56.231 (Jan. 2024), available at https://www.puc.pa.gov/media/2735/terminations-reconnectionsytd-dec2022vs23.pdf.
[vii] US DOE, Office of Fossil Energy and Carbon Management, Energy, Economic, and Environmental Assessment of US LNG Exports (Dec. 2025), https://www.energy.gov/sites/default/files/2024-12/LNGUpdate_SummaryReport_Dec2024_12pm.pdf.
[viii] Pennsylvania Public Utility Commission, Terminations and Reconnections:
Year-to-Date December 2023 vs. Year-to-Date December 2024 As Reported by Utilities Pursuant to Monthly Reporting Requirements at 52. Pa. Code 56.231 (Jan. 2025), available at:
https://www.puc.pa.gov/media/3309/terminations-reconnectionsytd-dec2023vs24-v2.pdf.
[ix] 15 USC 717b(a). ("[N[o person shall export any natural gas from the United States to a foreign country or import any natural gas from a foreign country without first having secured an order of the Commission authorizing it to do so. The Commission shall issue such order upon application, unless, after opportunity for hearing, it finds that the proposed exportation or importation will not be consistent with the public interest.").
[x] US DOE, Office of Fossil Energy and Carbon Management, Energy, Economic, and Environmental Assessment of US LNG Exports (Dec. 2025), https://www.energy.gov/sites/default/files/2024-12/LNGUpdate_SummaryReport_Dec2024_12pm.pdf.
[xi] *Id.*
[xii] Timothy Gardner, Biden Administration Releases LNG Export Study, Urging Caution on New Permits, Reuters (Dec. 17, 2024), https://www.reuters.com/business/energy/biden-administration-releases-lng-export-study-urging-caution-new-permits-2024-12-17/.

Written Testimony of James Hiatt

Director, For a Better Bayou
Submitted to the Pennsylvania House Environmental Resources & Energy Committee
Chairman: Representative Greg Vitali
Public Hearing on Liquefied Natural Gas (LNG) Development
November 5, 2025 | Chester, PA

Chairman Vitali and Members of the Committee,
Thank you for the opportunity to testify today. My name is James Hiatt, and I serve as the Director of For a Better Bayou, a community organization based in Lake Charles, Louisiana. I am a third-generation oil and gas worker. My father retired from a refinery, my grandfather from a pipeline company, and I myself worked over a decade in refineries, shipping, and storage terminals. I understand this industry and I'm here today to share what it looks like to live alongside Liquified Natural Gas export terminals.

In Southwest Louisiana there are now three operating LNG export terminals, with two more under construction and several others already permitted. These projects were sold to us as engines of prosperity. Instead, they've brought suffering in the forms of air pollution, damaged fisheries, and destroyed wetlands. We were promised opportunity; what we got was sacrifice.

Fishermen and community members routinely report headaches, and nosebleeds. Parents say their children's asthma has worsened since these terminals began operating, and older residents describe new heart conditions and cancer diagnoses. These aren't abstract risks, they are human realities tied to chronic pollution exposure. Just this past Sunday, a fisherman suffered a near fatal heart attack. Industry would prefer to say that it's from lifestyle choices instead of their massive toxic emissions.

The Environmental Integrity Project's report "Terminal Trouble" was published just last week. It found that all seven currently U.S. LNG export terminals violated the Clean Air Act at least once in the past five years, and five also violated water permits. Together, these export terminals reported 425 pollution incidents releasing more than 14,000 tons of toxic air emissions, yet paid only about $1 million in fines. In 2023 alone, these facilities emitted over 18 million tons of greenhouse gases and 15,700 tons of other pollutants like nitrogen oxides, formaldehyde and sulfur dioxide. This is the cost of doing business in a system of constant, sometimes invisible pollution.

These health impacts are not isolated to Southwest Louisiana. We have met with folks from other Gulf Coast communities with LNG export terminals who also suffer harmful health impacts. Increased allergy sensitivity, cardiovascular disease, cancer, and respiratory distress become part of everyday life. Even when there's no visible flare, optical gas imaging (OGI) cameras show non-stop plumes of gas and other pollutants pouring from these terminals. To the naked eye, the sky looks calm. But through an OGI lens, you can see what the human body already knows: the burning throat, the pounding headache, the metallic taste in the air. The pollution never stops, even when the flame isn't burning.

The 9th Edition of the Physicians for Social Responsibility and Concerned Health Professionals of New York's Compendium backs this up. Drawing from more than 2,500 peer-reviewed studies, it finds strong evidence that oil and gas infrastructure is linked to asthma, cardiovascular disease, headaches, cancers, and premature deaths. The Compendium documents heightened risks of heart attacks, types of hearings, been to court, we've marched and held regulators, agencies and politicians accountable for their actions or lack of.

We are not statistics, we will not live in a sacrifice zone. Josh mattered to us. We matter to us, Our children matter, our community matters. Because of Josh's son and all the children of Delaware County we will fight! The generations to come deserve our fight for us and them. The legislatures have to stop bending to money and defend people. People over pollution.

strokes, respiratory irritation, and nervous-system effects associated with benzene, toluene, and formaldehyde, pollutants routinely emitted and "permitted" at these sites. Our neighbors are living the compendium's footnotes. What the data describes nationally, we are experiencing locally. These are not isolated accidents but part of a consistent pattern of leaks, flares, and equipment malfunctions.

LNG was sold to our region as an engine of economic revival. The Corporations tell communities like ours that this buildout will bring jobs and prosperity. The truth has been limited construction jobs, long-term pollution, and rising living costs. Most of the few good-paying, permanent jobs go to people from outside the community. Analysis from the Institute for Energy Economics and Financial Analysis shows that LNG exports raise domestic gas and electricity prices, leaving families and small businesses paying more. The profits leave the region, while the health costs stay behind.

According to Greenpeace USA and Sierra Club's 2024 report, "Permit to Kill", air pollution from operating LNG terminals already causes an estimated 60 premature deaths and $957 million in annual health costs. If all planned projects proceed, that number rises to 149 deaths and $2.33 billion each year. Cumulatively through 2050, these facilities would cause roughly 4,470 premature deaths and $62 billion in health costs. Low-income and minority communities are hit hardest, facing exposure rates up to 170% higher than white Americans.

In August 2025, a fire erupted at Venture Global's Calcasieu Pass LNG facility and forced an emergency shutdown. The fire burned for 24 minutes, reportedly caused by a 200 gallon oil spill. No one living nearby was notified. The public learned of it only later through a National Response Center report. Earlier this summer, while building its CP2 terminal, Venture Global's dredging overflowed into the Calcasieu River, smothering oyster reefs and fisheries. Residents who depend on those waters are still waiting for accountability. Our regulators are not protecting us, instead they're enabling corporate negligence.

Pennsylvania now faces proposals to develop LNG export infrastructure tied to Marcellus Shale gas. I urge you to look carefully at Louisiana before taking that path. Once an LNG terminal is built, it will define the surrounding community for generations. You inherit the pollution, safety risks, and regulatory costs, while most of the profits leave the state. The communities near your ports could face what we live with every day: constant noise, harmful invisible emissions, and fear of the next explosion. You still have time to decide differently.

What's happening in Southwest Louisiana is not prosperity - it's extraction, in every sense of the word. We are paying with our health, our wetlands, and our way of life. I hope Pennsylvania will heed this warning. The promise of LNG is short-lived; its consequences are generational. Please choose a path that protects your people, your air, and your water. Thank you for the opportunity to share our story.

Respectfully submitted,

James Hiatt
Director, For a Better Bayou
Email: james@betterbayou.net|Website: https://betterbayou.net|Social Media: @betterbayou

Sources:

1. Environmental Integrity Project (2025) – “Terminal Trouble”: https://bit.ly/TerminalTrouble
2. Physicians for Social Responsibility & Concerned Health Professionals of NY (2023) – “Oil & Gas Compendium, 9th Edition”:
https://psr.org/wp-content/uploads/2023/10/fracking-compendium-9.pdf
3. Oilfield Witness YouTube Channel – LNG Impacts on Gulf Coast Communities:
Shrimpers and Pollution Visualization: https://www.youtube.com/watch?v=vyKTVDe1PxU
Fishermen Testimony: https://www.youtube.com/watch?v=8KRr-xn3YFA
4. Institute for Energy Economics and Financial Analysis (IEEFA) – LNG Exports and U.S. Energy Prices:
https://ieefa.org/resources/lng-exports-and-us-power-price
5. Sierra Club & Greenpeace USA (2024) “Permit to Kill”
https://www.greenpeace.org/static/planet4-usa-stateless/2024/12/86998834-permit-to-kill.pdf

Testimony of Zulene Mayfield, Chairperson

Regarding Proposed Liquifield Natural Gasification Facility

House Environmental & Natural Resource Protection Committee

November 5, 2025

Good Morning Representative Greg Vitali, Rep. Radar members of the Committee including Honorable State Rep. Carol Kazeem (159th) District. On behalf of the members of Chester Residents Concerned for Quality Living and the residents of Delaware County welcome you to the oldest city in the Commonwealth. William Penn landed here in 1681. Chester is a community rich in history. Once an economic hub and the center of manufacturing, shipbuilding and heavy industry Chester built the wealth of Southeastern Pennsylvania. Chester suffered like most industrial cities with the decline of industry closing or moving resulting in a loss of residents and economic stability.

I am Zulene Mayfield, Chairperson of Chester Residents Concerned for Quality Living or (CRCQL pronounced circle). CRCQL was formed in 1992 as a direct result of the nation's 4th largest incinerator. The Covanta/Reworld incinerator is now the largest incinerator in the US. Burning over 1.3 million tons of trash per year. Most of which comes from Philadelphia, NY and Delaware County. Chester contributes only 1.8 per cent of the trash they burn. In addition, we have a sewage treatment facility which also incinerates sludge. There are currently 11 major sources of pollution in Chester. In neighboring communities is the refinery complex in Marcus Hook, continuing on the waterfront. You have a power generation facility outdated and was scheduled for closure, prior to the current president ordering it to remain open. Poisoning pollution on top of one of the most densely populated areas in Pennsylvania.

Now to the matter at hand yet another dangerous and polluting proposal. When the community first heard of this LNG we were actually shocked that Chester would even be considered as the site for this facility. We immediately began educating ourselves on what exactly LNG is and how it would and could impact our city. We reached out to all who were familiar with them, advocates, experts, academia and local and international politicians. We continually strive to learn more about this process not to become experts but to have a full understanding. You've heard about the health of our community. We recently had the closure of two hospitals furthering the gap for access to healthcare. In addition, for the population of Chester, some 35,000 there is not one primary care physician here. There is no supermarket, no movie theatre, nada but industries that are literally committing environmental genocide!! And now another! At its very core this is environmental racism. What part of NO is not being understood here. Do we not have the right to determine what we want in our communities or has greed and callousness taken over to create a sacrifice zone? When do the Pennsylvania legislators take seriously the responsibility to protect Pennsylvanians? The Pennsylvania Constitution, Article 1, Section 27 establishes our right to clean air, pure water and to the preservation of the natural scenic historic and esthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations to come. As trustee of these resources , the Commonwealth SHALL conserve and maintain them for the benefit of ALL the people. This right is not distinguished by income level, race, zip code or status. It has to be enforced.

The proponents will say that LNG will generate jobs, some short-term but an insignificant number long term. What is being left out are the qualifications and certifications you must have to work in a LNG, and it seems the five years of experience that the industry requires before you can be employed. They will tout that there will be a tax revenue from LNG, what won't be said is that the LNG industry has found a way to be exempt. Many of the communities that currently have LNG's are poor, the economics promised have never materialized for them. Added insult is that the communities surrounding LNG are not employed by this climate destroying and people poisoning industry. Why are the legislators not protecting Pennsylvanians and welcoming this destructive industry?

Dr. Minksy gave you some information on the cancer rates for us that live in Chester and Delaware County and they are sobering. This coming Saturday CRCQL will hold our "They Matter Event" . This event acknowledges the loss of life to cancer, we celebrate those who have survived and and we encourage those that are battling this disease in Chester, and surrounding communities. We have a block in Chester where every household has lost someone to cancer. This has happened on both sides of the street. Some houses multiple members of a family. We hold this event to remind people that these are not statistics, these are our family members and our friends. In July, CRCQL lost one of our members. His name is Johshua Shockley. Josh was a vibrant man with a smile like sunshine. Josh called me when he was diagnosed with a rare form of cancer. He was full of fear and fight. You see Josh's wife was pregnant and expecting a son. The same day that she delivered their child was his first chemotherapy treatment. Five months after his son was born, Josh died at 38 years of age! The year prior his mother died from cancer.

The promises of jobs and revenue is a trick. I have said this before: if LNG is so great why aren't other communities being denied all of this wealth?

This community has had to withstand these battles for years. Demanding our right to breathe and live just like any other community. We've participated in too many of these

PRIOR PRINTER'S NO. 87 PRINTER'S NO. 1281

THE GENERAL ASSEMBLY OF PENNSYLVANIA

HOUSE BILL

No. 109 Session of 2025

INTRODUCED BY VITALI, RABB, KENYATTA, ISAACSON, FREEMAN, HOHENSTEIN, HILL-EVANS, KHAN, PROBST, SANCHEZ, SAMUELSON, HOWARD, DALEY, SALISBURY, PIELLI, OTTEN, GREEN, WEBSTER, BENHAM, MADDEN, CEPEDA-FREYTIZ, STEELE, SCOTT, TAKAC, KAZEEM, POWELL, KINKEAD, INGLIS, WAXMAN, O'MARA, RIVERA, BOROWSKI, HARKINS, SHUSTERMAN, MAYES, KRAJEWSKI AND A. BROWN, JANUARY 14, 2025

AS REPORTED FROM COMMITTEE ON ENVIRONMENTAL AND NATURAL RESOURCE PROTECTION, HOUSE OF REPRESENTATIVES, AS AMENDED, APRIL 7, 2025

AN ACT

Amending Title 27 (Environmental Resources) of the Pennsylvania Consolidated Statutes, providing for issuance of permits in environmental justice areas.

The General Assembly of the Commonwealth of Pennsylvania hereby enacts as follows:

Section 1. Title 27 of the Pennsylvania Consolidated Statutes is amended by adding a chapter to read:

CHAPTER 43

ISSUANCE OF PERMITS IN ENVIRONMENTAL JUSTICE AREAS

Sec.

§ 4301. Legislative findings and purpose.

The General Assembly finds and declares that:

(1) Low-income, low-wealth communities and communities of color have historically borne and currently bear a disproportionate share of environmental degradation.

(2) The Department of Environmental Protection is the agency charged with administering the laws and regulations in this Commonwealth to prevent and remedy environmental degradation and is one of the agencies charged with conserving, maintaining and restoring this Commonwealth's public natural resources.

(3) Section 27 of Article I of the Constitution of Pennsylvania recognizes that all the people of this Commonwealth have inalienable environmental rights and that the Commonwealth is the trustee of this Commonwealth's public natural resources.

(4) All individuals in this Commonwealth should be able to live in and enjoy a clean and healthy environment that includes outdoor spaces, access to clean energy resources, access to public lands and public natural resources.

(5) The elimination and restoration of disproportionate environmental degradation is recognized as being directly related to the economic vitality of this Commonwealth.

§ 4302. Definitions.

The following words and phrases when used in this chapter shall have the meanings given to them in this section unless the context clearly indicates otherwise:

"Cumulative environmental impacts." The totality of existing and imminent environmental AND PUBLIC HEALTH impacts ~~and~~ OF <-- pollution in a defined geographic area, ~~to~~ INCLUDING POLLUTION <--

OF land, waters ~~of this Commonwealth~~ or ambient air, and regardless of whether the pollution has been authorized under the laws of this Commonwealth.

"Department." The Department of Environmental Protection of the Commonwealth.

"Environmental justice area." A geographic area characterized by increased pollution burden and vulnerable populations based on demographic, economic, health and environmental data.

"Facility." The site of a department-regulated activity that may lead to significant public concern due to potential impacts on human health and the environment. The term includes sites that involve the following:

(1) National Pollutant Discharge Elimination System permits at industrial wastewater facilities that discharge at or above 50,000 gallons per day.

~~(2) Air permits for any new major source of hazardous air pollutants or criteria pollutants.~~

~~(3) Air permits for any major modification of a major source that are subject to Prevention of Significant Deterioration or Nonattainment New Source Review.~~

(2) AIR PERMITS FOR ANY MAJOR STATIONARY SOURCE OF ANY:

(I) VOLATILE ORGANIC COMPOUND;

(II) POLLUTANT REGULATED UNDER 42 U.S.C. § 7411 (RELATING TO STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES) OR 7412 (RELATING TO HAZARDOUS AIR POLLUTANTS); OR

(III) POLLUTANT FOR WHICH A NATIONAL PRIMARY AMBIENT AIR QUALITY STANDARD HAS BEEN PROMULGATED.

~~(4)~~ (3) Waste permits involving a combined monthly volume in excess of 25 tons, or any major modification of waste permits, including changes that result in an increase in capacity or a facility expansion, for landfills, commercial hazardous waste treatment facilities, storage or disposal facilities and other disposal facilities, including a landfill that accepts ash, construction or demolition debris, medical waste or solid waste, transfer stations, recycling centers, commercial incinerators and other waste processing facilities.

~~(5)~~ (4) Mining permits for bituminous and anthracite underground mines, bituminous and anthracite surface mines, large industrial mineral surface and underground mines, coal refuse disposal, coal refuse reprocessing, large coal preparation facility or any revision of permits under this paragraph that involve additional acreage for mineral removal or use of biosolids for reclamation.

~~(6)~~ (5) An individual permit for a land application of biosolids.

~~(7)~~ (6) Concentrated animal feeding operations that are new or expanded operations of greater than 1,000 animal equivalent units, concentrated animal operation of greater than 300 animal equivalent units in a special protection watershed or a concentrated animal operation with direct discharge to surface waters.

~~(8)~~ (7) An electric generating facility with a capacity of more than ~~10~~ NINE megawatts.

~~(9)~~ (8) A sewage treatment plant with a capacity of more than 50,000,000 gallons per day.

~~(10)~~ (9) Underground injection control wells associated with oil and gas development.

~~(11)~~ (10) Other facilities as designated by the Environmental Quality Board through regulations under this chapter. <--

"Permit." A permit, approval of coverage under a general permit, registration or other authorization issued by the department establishing the regulatory and management requirements for a regulated activity as authorized by Federal or State law.

§ 4303. Designation of environmental justice areas.

(a) Method.--The methods to identify an environmental justice area shall be determined and regularly reviewed by the department.

(b) Designation.--No later than 120 days after the effective date of this section, the department shall designate and make publicly available environmental justice areas in this Commonwealth. The department shall update environmental justice area designations every three years.

§ 4304. Permit process.

(a) Department action on permit applications for facilities in environmental justice areas.--Beginning 180 days after the effective date of this section, prior to the department taking an action on an application for a new facility or for the expansion of an existing facility, located in whole or in part in an environmental justice area:

(1) The permit applicant shall prepare and submit with the application for facility permit or other authorization, a cumulative environmental impact report assessing the environmental impact of the proposed new facility or expansion of an existing facility, together with the cumulative impacts on the environmental justice area, and the

adverse environmental effects that cannot be avoided or mitigated should the permit be granted.

(2) Unless a public hearing is otherwise required by the environmental laws and regulations for the permit or authorization, the following shall apply:

(i) The department shall organize and conduct a public hearing in a location as convenient as possible to all interested parties and publish public notices of the hearing in at least two newspapers circulating within the environmental justice area and on the department's publicly accessible Internet website not less than 21 days prior to the hearing.

(ii) At least 14 days prior to the date set for the hearing, a copy of the public notice shall be sent to the clerk of the municipality in which the environmental justice area is located.

(iii) At a public hearing, the permit applicant shall provide clear, accurate and complete information about the proposed new facility or expansion of an existing facility and the potential environmental and health impacts of the new or expanded facility. The hearing shall provide an opportunity for meaningful public participation by residents of the environmental justice area.

(iv) Following the public hearing, the department shall consider the testimony presented and evaluate revisions or conditions to the permit that may be necessary to reduce the adverse impact to the public health or the environment in the environmental justice area.

(b) Decision by department.--The department may not issue a decision on the permit application until at least 60 days after a public hearing.

(c) Additional requirements.--The department may require additional conditions or mitigation measures or may deny a permit application in an environmental justice area based on the cumulative environmental impacts.

(d) Publication.--The applicant shall provide copies of applications for a permit for a facility located in whole or in part in an environmental justice area to the clerk of the municipality in which the environmental justice area is located, who may recommend to the department conditions upon, revisions to or disapproval of the permit only if specific cause is identified. If the department overrides a municipal recommendation, the department shall be required to transmit notice of the department's justification for overriding the municipality's recommendations to the Legislative Reference Bureau for publication in the next available issue of the Pennsylvania Bulletin. If the department does not receive comments within 60 days of receipt of the applications from the permit applicant by the clerk of the municipality, the municipality shall be deemed to have waived the municipality's right to review.

(e) Construction.--The provisions of this section shall be in addition to all requirements under any applicable environmental law.

§ 4305. Regulations and publication.

(a) Promulgation.--The department and Environmental Quality Board shall adopt and promulgate rules and regulations to implement this chapter.

(b) Publication of permits.--In addition to publication requirements under law and regulation, the department shall publish all permits granted under this chapter, along with any guidance documents, on its publicly accessible Internet website.

Section 2. This act shall take effect immediately.

HOUSE OF REPRESENTATIVES
DEMOCRATIC COMMITTEE BILL ANALYSIS

Bill No:	HB0109 PN1281	**Prepared By:**	Andrew McMenamin (717) 783-4043,6941
Committee:	Environmental & Natural Resource Protection	**Executive Director:**	Evan Franzese
Sponsor:	Vitali, Greg		
Date:	4/7/2025		

A. Brief Concept

Gives burdened communities a voice in the permitting process and requires permittees in environmental justice (EJ) areas to prepare a cumulative environmental impact report.

C. Analysis of the Bill

HB 109 amends Title 27 (Environmental Protection) to add Chapter 47 (Issuance of Permits in Burdened Communities), which provides for additional permit review in environmental justice (EJ) areas.

Designation of EJ Areas

Requires DEP to designate environmental justice (EJ) areas in PA no later than 120 days after the passage of this act.

Requires DEP to update EJ area designations every three years.

Permit Process

Requires permit applicants to prepare and submit the following information for a proposed project located in whole or in part in an EJ area:

- a report assessing the environmental impact of the proposed project,
- the cumulative impacts on the EJ area, and
- adverse environmental effects that cannot be avoided or mitigated should the permit be granted.

Requires applicants to provide copies of the permit applications to the clerk of the municipality in which the EJ area is located.

Public Hearing Requirement

Requires the department to organize and conduct a public hearing in a convenient location to interested parties, with a meaningful public participation component and sufficient public notice. Public notice would be required as follows:

- Published in two newspapers circulating within the EJ area.
- Published on the department's website at least 21 days before the hearing.
- Sent to the clerk of the municipality in which the EJ area is located at least 14 days prior to the hearing.

Requires the permit applicant to provide clear, accurate, and complete information about the proposal and potential impacts at the hearing.

Requires the department to consider the testimony presented at the hearing and evaluate revisions or conditions to the permit based on adverse impact to health and the environment in the EJ area.

Permit Decision

Prohibits the department from issuing a permit application decision within 60 days of the public hearing.

Allows the department to require additional conditions or mitigation measures, or deny a permit altogether, in an EJ area based on the cumulative environmental impacts.

Allows the municipality to review the permit application and recommend conditions, revisions, or disapproval of the permit, only if specific cause is identified.

- If the department chooses to override a municipal recommendation, it would be required to publish justification in the PA Bulletin.
- If comments are not received within 60 days of receipt of the permit application, the right to review shall be deemed waived.

Construction

Provides that this section shall be in addition to all requirements under any applicable environmental law.

Regulations

Requires DEP and EQB to promulgate rules and regulations to implement the provisions of this act.

Definitions

Cumulative environmental impacts means the totality of existing and imminent environmental and public health impacts of pollution related to land, water, and air in a defined geographic area.

Environmental justice area means a geographic area characterized by increased pollution burden and vulnerable populations based on demographic, economic, health, and environmental data.

Facility includes, but is not limited to, the following:

- National Pollutant Discharge Elimination System (NPDES) Permits at industrial wastewater facilities that discharge more than 50,000 gallons per day.
- Air permits for any major stationary source of any:
  - volatile organic compound;
  - regulated pollutant
  - pollutant for which a national air quality standard has been promulgated.
- Waste permits involving a combined monthly volume in excess of 25 tons, or any major modification of waste permits.
- Mining permits for bituminous and anthracite mines, large industrial mineral mines, coal refuse facilities, or any permit revisions that involve additional acreage for mineral removal or use of biosolids for reclamation.
- An individual permit for a land application of biosolids.
- Large concentrated animal feeding operations.
- An electric generating facility with a capacity of more than 10 megawatts.
- A sewage treatment plant with a capacity of more than 50,000,000 gallons per day.
- Underground injection control wells associated with oil and gas development.
- Other facilities as designated by the Environmental Quality Board (EQB) by regulation.

Effective Date:

Immediately

G. <u>Relevant Existing Laws</u>

DEP does not currently consider cumulative impacts or evaluate permits based on environmental justice (EJ) concerns.

DEP's Office of Environmental Justice was established via Executive Order 2021-07 on October 28, 2021 and is a point of contact for Pennsylvania residents in low-income communities. Its primary goal is to increase environmental awareness and involvement by communities in the DEP permitting process.

E. Prior Session (Previous Bill Numbers & House/Senate Votes)

HB 109 was previously introduced as HB 652 (Bullock) during the 2023-2024 Legislative Session. HB 652 was reported as amended from the House ERE Committee on a party line vote (14-11), but received no further consideration.