Analysis of the Gibbstown LNG Export Terminal Emissions from Cradle to Grave and Dashboard to Calculate Emissions of Similar Natural Gas Projects

This workbook analyzes the lifecycle emissions related to the Gibbstown LNG export terminal, including annual CO2e emissions related to daily facility operations and the upfront construction of the Wyalusing and Gibbstown facilities.

Authors: Jackie Litynski, Ellen Carlson, Jon Tabernero, and Pat Knight; Synapse Energy Economics

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Acronym List

Index	Acronym	Definition
1.	SCF	Standard Cubic Feet
2.	LNG	Liquified Natural Gas
3.	BOG	Boil-Off-Gas
4.	MTPA	million tons per annum
5.	BCF	Billion cubic feet
6.	GWP	Global Warming Potential
7.	CO2e	Carbon Dioxide Equivalent
8.	IPCC	Intergovernmental Panel on Climate Change
9.	AR4	IPCC Fourth Assessment Report
10.	AR6	IPCC Sixth Assessment Report
11.	GHG	Greenhouse Gas
12.	PA	Pennsylvania
13.	DEP	Department of Environmental Protection
14.	CH4	Methane
15.	N2O	Nitrous oxide
16.	kg	kilogram
17.	km	kilometer
18.	MMbbl	Million barrels of oil
19.	MMscf	Million standard cubic feet
20.	bbl	Barrels of oil
21.	NETL	National Energy Technology Laboratory
22.	psig	pounds per square inch gauge (measurement of pressure)
23.	lb	pounds
24.	AP-42	US EPA's Compilation of Air Pollutant Emissions Factors
25.	TPY	tons per year
26.	gal	gallon
27.	TEU-mi	Twenty-foot equivalent unit (TEU) per mile (a TEU is a commonly defined container unit for shipping cargo with volume of 20' length x 8'6" height x 8' width)
28.	PHMSA	Pipeline and Hazardous Materials Safety Administration
29.	NGP	Natural Gas Processing
30.	VMT	vehicle miles travelled
31.	PR	Puerto Rico
32.	NG	Natural Gas
33.	g	grams

Inputs and Results by Lifecycle Step

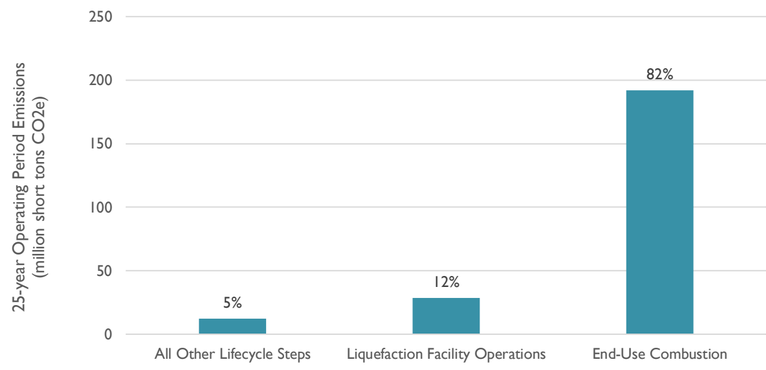
Below are the results and the inputs that users can update, organized by step in the natural gas lifecycle process. Users can update cells in blue to their own inputs. Cells not in blue should not be changed.

Analysis Results by Lifecycle Step

This table compiles the total emissions for each step in the natural gas lifecycle for the Gibbstown LNG Export Terminal.

Lifecycle Category	Lifecycle Step	Upfront Emissions *short tons CO2e (20 year GWP)*	Ongoing Emissions *short tons CO2e (20 year GWP)*	Total Emissions *short tons CO2e (20 year GWP)*	*Emissions as a Percent of Total* %
Upfront Emissions	Facility Construction*	97,439	0	97,439	*0.04%*
Upstream Operating Emissions	Gas Production	142,473	50,835	193,308	*0.08%*
	Pipeline and Compressor Station	0	103,842	103,842	*0.04%*
Midstream Operating Emissions	Liquefaction Facility*	*0*	28,459,993	28,459,993	*12.22%*
	Domestic Transport	0	1,027,898	1,027,898	*0.44%*
	Export Facility*	*0*	384,850	384,850	*0.17%*
Downstream Operating Emissions	Sea Transport	0	7,430,441	7,430,441	*3.19%*
	Regasification	0	2,891,046	2,891,046	*1.24%*
	Foreign Pipeline Transport	0	180,211	180,211	*0.08%*
	End-use Combustion	0	192,138,030	192,138,030	*82.50%*
Total	**Total**	**239,912**	**232,667,146**	**232,907,057**	***100.00%***

**Liquefaction facility and export facility construction emissions were estimated together, due to a lack of data for constructing just one of the components.*



Inputs by Lifecycle Step

Below are the inputs that users can update, organized by step in the natural gas lifecycle process. Users can update cells in blue to their own inputs. Cells not in blue should not be changed.

Lifecycle Step	Input	Default or User Input	Default Value (Gibbstown)	User Input	Units	Notes
General	LNG Exported	Default	128	64	*bcf/year*	This input describes how much LNG is exported from the corresponding export facility. It is used as the throughout of LNG for each stage in the lifecycle analysis. The default value is the proposed LNG export capabilities of the Gibbstown export terminal.
	LNG Exported	Default	2.6	1.31	*mtpa*	This input describes how much LNG is exported from the corresponding export facility. It is used as the throughout of LNG for each stage in the lifecycle analysis. The default value is the proposed LNG export capabilities of the Gibbstown export terminal.
	Years for Ongoing Emissions	Default	25	1	*years*	This input is the years of ongoing emissions calculated for the lifecycle analysis. You may consider using the project's lifetime, so as to calculate the emissions over the projects entire life.
Gas Production	*The Gas Production data scales with BCF, so there are no additional inputs here for users to update.*					
Pipeline and Compressor Stations (Domestic)	Miles of Transmission	Default	30	50	*miles*	This input is the miles of natural gas transmission lines from the wellhead and processing plants to the liquefaction facility. The default value is based on the approximate distance from wellheads in the Marcellus Shale area of Pennsylvania to the Wyalusing Liquefaction facility.
Construction Emissions for Liquefaction and Export Facilities	Liquefaction construction duration	Default	29	35	*months*	Total project construction length. The default value is based on the Wyalusing liquefaction facility expected construction length.
	Export construction duration	Default	15	10	*months*	Total project construction length. The default value is based on the Gibbstown export terminal expected construction length.
	Total volume of dredged material	Default	665,000	600,000	*cubic yards*	Total volume of dredged sediment during construction of new dock at Gibbstown export terminal. The default is based on the Gibbstown facility land development application.
Liquefaction Facility Annual Operating Emissions *If the annual Wyalusing facility operating emissions update or a user is modeling a different liquefaction facility, they may put in a non-default value here. If users do not know their exact facility operating emissions, but know an updated BCF value, they can select "Yes" in cell D40 to automatically scale the emissions from the BCF input, above. If users have their own emissions value, they can select "No" in cell D40. Users can then input their liquefaction facility operating emissions (cells F41 and F42) and the corresponding GWP source or value (D43).*	Facility annual emissions (operating and fugitive)	Default	1,107,782	1,138,400	*short tons CO2e/year*	Annual facility emissions, including operating and fugitive emissions. Default values is Wyalusing liquefaction facility annual total facility GHG emissions per year in AR4 GWP-100. User Input value is based on the additional questions in the section, below.
	Should the annual facility emissions scale with BCF?	Yes	-	-	-	Asks users whether the non-default value should scale based on LNG export volume (which is set in the first section, above) or be a specific user input (defined based on the subsequent questions, below).
	What are the annual facility operating emissions (short tons CO2e)?	-	-	1,107,679	*short tons CO2e/year*	User inputs annual facility operating emissions into the blue highlighted cell as CO2e. The GWPs of the above below and this cell must be the same.
	What are the annual facility fugitive emissions (short tons CO2e)?	-	-	2,572	*short tons CO2e/year*	User inputs annual facility fugitive emissions in the blue highlighted cell as CO2e. The GWPs of the above cell and this cell must be the same.
	What is the data source for your GWP values for your annual facility emissions?	AR6 GWP-20	-	-	-	User selects the CH4 GWP data source used for the annual facility operating and fugitive emissions inputs. These two inputs must have the same GWP value. If the GWP source is not listed, select "other" and input it into the blue cell in the row below.
	CH4 GWP Value of Input Data	CH4	83	100	*GWP*	User inputs the CH4 GWP value into the blue highlighted cell, if using. The final GWP value used is displayed in black text. CO2 GWPs are always 1, so no input is needed.

Domestic Transport by Train and Truck	Train distance travelled	Default	255	200	*miles*	Distance LNG is transported by train. Default value is based on expected train route between Wyalusing liquefaction facility and Gibbstown export terminal, along existing train lines.
	Number of train cars	Default	150	50	*train cars/day*	Number of train cars per day transporting LNG. Default is based on approved PHMSA rail permit.
	Truck distance travelled	Default	174	200	*miles*	Distance LNG is transported by truck. Default is based on expected truck routes between Wyalusing liquefaction facility and Gibbstown export terminal.
	Number of trucks	Default	400	300	*cars/day*	Number of truck cars per day transporting LNG. Default is based on PA DEP application for Wyalusing facility.
	Rail percent of transports	Default	50%	50%	%	Percent share of LNG transported by rail. Default assumes that half of the LNG is transported by truck and half by train, since no Gibbsotown applications have proposed a specific transportation split. The percent transported by train and truck must sum to 100%.
	Truck percent of transports	Default	50%	50%	%	Percent share of LNG transported by truck. Default assumes that half of the LNG is transported by truck and half by train, since no Gibbsotown applications have proposed a specific transportation split. The percent transported by train and truck must sum to 100%.
	Number of valves	Default	1,059	1059.0	*valves*	User inputs automatically scaled based on the total number of train and truck cars transporting LNG daily. Users can also input their own values for each input.
	Number of pump seals	Default	0	0.0	*pump seals*	User inputs automatically scaled based on the total number of train and truck cars transporting LNG daily. Users can also input their own values for each input.
	Number of connectors	Default	962	962.0	*connectors*	User inputs automatically scaled based on the total number of train and truck cars transporting LNG daily. Users can also input their own values for each input.
	Number of other leak sources	Default	0	0.0	*sources*	User inputs automatically scaled based on the total number of train and truck cars transporting LNG daily. Users can also input their own values for each input.
	Number of vapor recovery compressors	Default	0	0.0	*compressors*	User inputs automatically scaled based on the total number of train and truck cars transporting LNG daily. Users can also input their own values for each input.
Export Facility	Emissions source scale factor: 5 flare sources	Default	8%	25%	%	Scaling factor for flare emissions, compared to a Canadian LNG facility.. Assumes approximately 2 flares at Gibbstown site. User Input based on whether LNG throughput volume is set to "User Input" above.
	Emissions source scale factor: fugitive sources	Default	8%	50%	%	Scaling factor for fugitive sources, compared to a Canadian LNG facility. User Input based on whether LNG throughput volume is set to "User Input" above.
	Emissions source scale factor: domestic marine shipping activities	Default	8%	20%	%	Scaling factor for marine shipping emissions, compared to a Canadian LNG facility. User Input based on whether LNG throughput volume is set to "User Input" above.
Sea Transport	Sea Travel Distance #1	Default	16,000	13,000	*km*	Total roundtrip distance from export facility to Destination #1 import terminal. Default Destination #1 is from Gibbstown export facility to Ireland. Default distance was estimated using ArcGIS.
	Sea Travel Distance #2	Default	11,400	10,000	*km*	Total roundtrip distance from export facility to Destination #2 import terminal. Default Destination #2 is from Gibbstown export facility to Puerto Rico. Default distance was estimated using ArcGIS.
	Percent of LNG to Destination #1	Default	50%	60%	%	Proportion of exported LNG transported to Destination #1. Default assumes that 50% of the gas is exported to Ireland and the other 50% is exported to Puerto Rico.
	Percent of LNG to Destination #2	Default	50%	40%	%	Proportion of exported LNG transported to Destination #2. Default assumes that 50% of the gas is exported to Ireland and the other 50% is exported to Puerto Rico.
Regasification Facility	-	-	-	-	-	*There are no specific inputs for the Regasification Facility stage, as these scale with the volume of LNG exported.*
Foreign Pipeline and Compressor Stations	Miles of transmission in Destination #1	Default	40	60	*miles*	Pipeline distance from import terminal to regasification. Default assumption is based on transit of gas via pipeline from the import terminal to a nearby power plant.
	Miles of transmission in Destination #2	Default	20	30	*miles*	Pipeline distance from import terminal to regasification. Default assumption is based on transit of gas via pipeline from the import terminal to a nearby power plant.
Combustion	*The Combustion data scales with BCF, so there are no additional inputs here for users to update.*					

Inputs and Results by Lifecycle Step

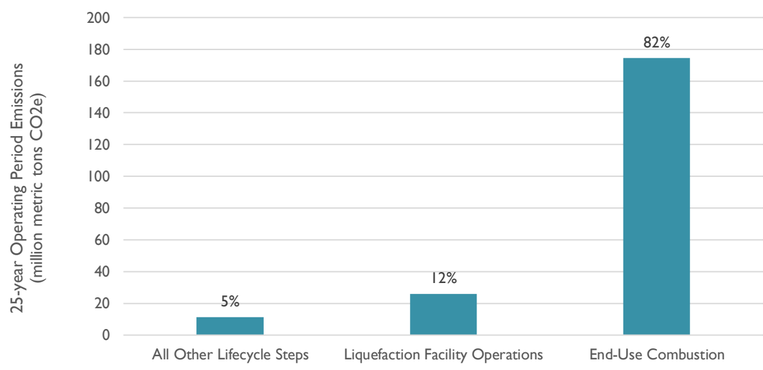
Below are the results in metric tons, organized by step in the natural gas lifecycle process. To update inputs, see the "Dashboard_ShortTons" worksheet.

Analysis Results by Lifecycle Step

This table compiles the total emissions for each step in the natural gas lifecycle for the Gibbstown LNG Export Terminal.

Lifecycle Category	Lifecycle Step	Upfront Emissions *metric tons CO2e (20 year GWP)*	Ongoing Emissions *metric tons CO2e (20 year GWP)*	Total Emissions *metric tons CO2e (20 year GWP)*	*Emissions as a Percent of Total* %
Upfront Emissions	Facility Construction*	88,420	0	88,420	*0.04%*
Upstream Operating Emissions	Gas Production	129,285	46,130	175,415	*0.08%*
	Pipeline and Compressor Station	0	94,231	94,231	*0.04%*
Midstream Operating Emissions	Liquefaction Facility*	*0*	25,825,765	25,825,765	*12.22%*
	Domestic Transport	0	932,757	932,757	*0.44%*
	Export Facility*	*0*	349,229	349,229	*0.17%*
Downstream Operating Emissions	Sea Transport	0	6,742,687	6,742,687	*3.19%*
	Regasification	0	2,623,454	2,623,454	*1.24%*
	Foreign Pipeline Transport	0	163,531	163,531	*0.08%*
	End-use Combustion	0	174,353,929	174,353,929	*82.50%*
Total	**Total**	**217,706**	**211,131,711**	**211,349,417**	***100.00%***

**Liquefaction facility and export facility construction emissions were estimated together, due to a lack of data for constructing just one of the components.*



Library

This sheet contains general data sources and information relevant to multiple production steps

Table 1. IPCC AR6 Global Warming Potential, Used for Final GWP-20 Calculations

Notes: These values are used to calculate the final CO2e emissions for the Gibbstown results and Dashboard results.
Based on IPCC AR6, these GWPs are used to calculate CO2e emissions in this workbook.
The CH4 value used is the "CH4-fossil" value, not the "CH4-non fossil" value.

Source(s): *Forster, P., T. Storelvmo, K. Armour, W. Collins, J.-L. Dufresne, D. Frame, D.J. Lunt, T. Mauritsen, M.D. Palmer, M. Watanabe, M. Wild, and H. Zhang, 2021: The Earth's Energy Budget,*

Table 7.15 | Emissions metrics for selected species: global warming potential (GWP), global temperature-change potential (GTP).

Gas	GWP-20	GWP-100
CO2	1	1
CH4	82.5	29.8
N2O	273	273

Table 2. EPA Global Warming Potential, Used for Converting Data Back to Tons of CH4

Notes: These GWPs are used to back calculate the total GHGs of CH4 from the liquefaction facility emissions. We do not use these to calculate the final Gibbstown or Dashboard results.
Assuming this GWP used in PA DEP, based on Jordan Cove EIS. This GWP is used to back calculate short tons of CH4 and N2O from CO2e in various steps in the natural gas process. The GWPs from IPCC AR6, above, are the GWP values used throughout this workbook.

Source(s): *US Environmental Protection Agency. Inventory of US Greenhouse Gas Emissions and Sinks. 2021. Available at: https://www.epa.gov/sites/production/files/2021-04/documents/us-ghg-inventory-2021-main-text.pdf*

Table ES-1: Global Warming Potentials (100-Year Time Horizon) Used in this Report

Gas	GWP-100
CO2	1
CH4	25
N2O	298

Table 3. IPCC AR4 Global Warming Potentials, Used for Converting Data Back to Tons of CH4

Notes: This table is used to back calculate the total GHGs of CH4 from the regasification facility emissions.

Source: *Intergovernmental Panel on Climate Change. 2007. "IPCC Fourth Assessment Report: 2.10.2 Direct Global Warming Potentials." Available at: https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html*

	20-year	100-year
Carbon Dioxide	1	1
Methane	72	25
Nitrous oxide	289	298

Table 4. Natural Gas Conversions

Notes: Converting natural gas between metric tons/tonnes and cubic feet

Source(s):

Hofstrand, D. *Natural Gas and Coal Measurements and Conversions.* Iowa State University. Available at: https://www.extension.iastate.edu/agdm/wholefarm/html/c6-89.html

Energy Transfer. *Properties and Characteristics of LNG.* Available at: *https://lclngmessenger.energytransfer.com/InfoPost/resources/documents/PropertiesofLNG.pdf.*

Shively, B. *Understanding Liquefied Natural Gas (LNG) Units.* Energy Dynamics. Available at: https://www.enerdynamics.com/Energy-Currents_Blog/Understanding-Liquefied-Natural-Gas-LNG-Units.aspx

1	metric ton liquefied natural gas (LNG)
48,700	cubic feet of natural gas
1	gallon liquefied natural gas (LNG)
81.5	cubic feet of natural gas
1	million metric tons per year (MTPA LNG)
49	BCF per year (gas)
1	BCF natural gas
1.06.E+09	MJ natural gas

Table 5. Unit Conversions

Notes:

Source(s): *Butcher, Kenneth S, Linda D Crown, and Elizabeth J Gentry. 2006. "The International System of Units (SI) - Conversion Factors for General Use." National Institute of Standards and Technology. https://doi.org/10.6028/NIST.SP.1038.*

Conversion between kg, metric tons, and short tons	
1000	kg
1	metric ton
1.102	short tons

Conversion between cubic yards and cubic meters	
1	cubic yard
0.76455	cubic meters

Conversion between km and miles	
1	km
0.621371	miles

Pounds to Short Tons	
2000	pounds
1	short ton

Table 6. Days per Year
Notes:
Source(s):
365.25 days/year

Upfront Construction

This sheet calculates the GHG emissions related to construction of the Wyalusing Liquefaction facility and Gibbstown Logistics Center.

Section A. Results Table

	Upfront Emissions *short tons CO2e/year*	Ongoing Emissions *short tons CO2e/year*	Total Emissions *short tons CO2e/year*
Gas Liquefaction Facility, 20-year GWP	97,439	0	97,439
Gas Liquefaction Facility, 100-year GWP	97,070	0	97,070

Section B. Data and Calculations

Section B1. Upfront Emissions Data and Calculations

Construction:

Input	Value	Units	Notes	Source
Total project construction duration	44	months	Combined Gibbstown and Wyalusing construction periods	
LNG Exported	2.60	mpta		
Capacity-weighted average monthly construction	712	(short tons CO2e/month)/mpta		
Average construction emissions per month	1,852	short tons CO2e/month		
Total estimated construction emissions	81,475	short tons CO2e	*AR4 100 year GWP*	
Construction emissions, CO2	80,867	short tons CO2		
Construction emissions, CH4	6.57	short tons CH4		
Construction emissions, N2O	1.49	short tons N2O		
Total construction emissions, all GHG	81,816	short tons CO2e	*20 year GWP AR6*	
Total construction emissions, all GHG	81,470	short tons CO2e	*100 year GWP AR6*	

Section B2. Upfront Emissions Data and Calculations: Dredging Emissions

Dredging:

Input	Value	Units	Notes	Source
Total dredged material	665,000	cubic yards		
Total dredged material	508,426	cubic meters		
Carbon content of dredged soil	0.013	short tons CO2/cubic meter		
Carbon emissions from dredging	6,833	short tons CO2	This is applicable to both 20-year and 100-year GWPs, since it only includes CO2 emissions	

Section B3. Upfront Emissions Data and Calculations: Concrete Emissions

Concrete:

Input	Value	Units	Notes	Source
Concrete per mtpa	16,120	cubic yards concrete/mtpa		
Gibbstown mtpa	2.60	mtpa		
Estimated concrete produced	41,911	cubic yards of concrete		
Average CO2 emissions factor for concrete	418	lbs CO2/cubic yard		
Average CO2 emissions factor for concrete	0.21	short tons CO2/cubic yard		
Concrete emissions, CO2	8,754	short tons CO2		
Average CH4 emissions factor for concrete	0.02	lbs CH4/cubic yard		
Average CH4 emissions factor for concrete	0.00001	short tons CH4/cubic yard		
Concrete emissions, CH4	0.44	short tons CH4		
Total construction emissions, all GHG	8,791	short tons CO2e	*20 year GWP AR6*	
Total construction emissions, all GHG	8,767	short tons CO2e	*100 year GWP AR6*	

Section C. Sources

Section C1. Gibbstown Logistics Center Description (from site plan)

Sources: Delaware River Partners, LLC. November 2019. "Application for Land Development." Avail
Delaware River Partners, LLC – Gibbstown Logistics Center Dock 2. 2020. Delaware Rive

Note:

Gibbstown Logistics Center Description (From Site Plan)

Component	Value	Unit
New dock construction time	15	months
LNG Exported from Gibbstown	128	bcf
LNG Exported from Gibbstown	2.6	mpta
Total volume of dredged sediment for new dock	665,000	cubic yards

Section C2. Wyalusing Liquefaction Project Description

Source: Engineering, Procurement, and Construction Agreement (January 2019) Available at: https:

Note:

Component	Value	Unit
Total disturbed acreage	119.4	acres
Site area	219	acres
Project construction duration	29	months

Section C3. Operating and Construction Data for US LNG Facilities

Sources: *Federal Energy Regulatory Commission. 2019. "Jacksonville Project Final Environmental Impact Statement." Available at: https://www.ferc.gov/sites/default/files/2020-05/04-12-19-FEIS.pdf; Federal Energy R*

Note:

Facility	Export Capacity (mtpa)	Operating GHG Emissions (short tons CO2e/yr)	LNG Terminal Construction GHG Emissions (short tons CO2e)	Construction Length (months)	Average Monthly Construction Emissions (short tons CO2e/month)	Average Monthly Construction Emissions per Capacity (short tons CO2e/month/mtpa)	Source
Eagle Jacksonville	1	112,265	18,135	42	432	432	Federal Energy Regulatory Com
Texas LNG Terminal	4.5	613,901	143,197	44	3,254	723	Federal Energy Regulatory Com
Cove Point	4.85	2,030,998	168,258	48	3,505	723	Federal Energy Regulatory Com
Gulf LNG	5.4	2,885,787	205,607	60	3,427	635	Federal Energy Regulatory Com
Corpus Christi LNG	8.24	3,340,000	622,135	72	8,641	1,049	Federal Energy Regulatory Com

Section C4. Lake Charles LNG Liquefaction Facility Construction Emissions

Source: Federal Energy Regulatory Commission. 2015. "Final Environmental Impact Statement - Lake Charles Liquefacti

Note:

Table 4.11.1-7: Liquefaction Facility Construction Emissions

Construction Activity	CO2 (short tons)	CH4 (short tons)	N2O (short tons)	CO2e (short tons)
Worker commuting	5,290	1.9	0.2	5,401.9
Construction dirt work	51,388	3	1	51,735.92
Construction plant work	225,184.0	18	4	226,970

Section C5. Construction Emission Composition Ratio Calculations

Source: Section C4, above.

Note:

	Total (short tons)	Total (short tons CO2e)	Percent of total CO2e
CO2	281,862	281,862	99.3%
CH4	23	573	0.2%
N2O	5	1,550	0.5%
Total CO2e		283,984	100%

Section C6. Construction, Water usage, and Concrete Data for US LNG Facilities

Sources: *MTPA and Concrete volume from: Federal Energy Regulatory Commission. 2019. "Jacksonville Project Final Environmenta*

Note:

Facility	Export Capacity (mtpa)	Concrete (cubic yards)	Concrete per mtpa	Source
Eagle Jacksonville	1	10,000	10,000	MTPA and Concrete
Cove Point	4.85	85,000	17,526	MTPA Volume from
Cameron LNG facility	12	250,000	20,833	MTPA Value from: C
Average			16,120	

Section C7. Carbon content of Delaware river sediment

Source: Delaware Estuary Benthic Inventory. 2016. "Bay Bottom Inventory - Total Organic Carbon
"Dredge Material Placement and Behavior." Available at: http://www.mgs.md.gov/coastal_g

Note:

Component	Value	Unit
Average total organic carbon (TOC) concentration in sediment samples	12342	mg TOC/kg
Carbon concentration percentage	1.23%	percent concentration of TOC
Average total organic carbon (TOC) concentration in sediment samples	0.0136	short tons/kg
Density of dredged sediment	1.2	g/cubic centimeter
Density of dredged sediment	1200	kg/cubic meter
Carbon concentration by volume in sediment	14810400	mg/cubic meter
Carbon concentration by volume in sediment	0.013	short tons/cubic meter

Section C8. Emissions from Concrete Production

Source: Prusinski, Jan R, Medgar L Marceau, and Martha G VanGeem. n.d. "LIFE CYCLE INVENTORY OF SLAG CEMENT CONCRETE." https://www.ecocem.co.uk/wp-content/uploads/2016/08/ECL009_Life_Cycle_Inventory_of_GGBS_Cement_Concrete.pdf.

Note: Since we don't know which type of concrete will be used, we are assuming an average of the values listed below.

US Cust. Units (lb/cubic yard)

28 day comp. strength	3,000 psi				5,000 psi			7,500 psi			10,000 psi				Unspecified			Average
Mixture	**R-3-0**	**R-3-35**	**R-3-50**	**R-3-20F**	**R-5-0**	**R-5-35**	**R-5-50**	**P-7-0**	**P-7-35**	**P-7-50**	**P-10-0**		**P-10-35**	**P-10-50**	**B-0**	**B-35**	**B-50**	
CO2	385	269	220	318	555	382	307	812	550	438	723		492	393	367	260	213	417.75
SO2	0.918	0.688	0.591	0.77	1.289	0.947	0.799	1.85	1.33	1.11	1.66		1.2	1	0.89	0.678	0.585	1.02
NOX	1.201	0.865	0.723	1.008	1.693	1.19	0.975	2.42	1.66	1.34	2.17		1.51	1.22	1.13	0.823	0.688	1.29
VOC	0.053	0.048	0.046	0.05	0.062	0.055	0.051	0.073	0.061	0.056	0.071		0.06	0.056	0.051	0.046	0.044	0.06
CO	0.543	0.436	0.391	0.477	0.714	0.555	0.487	0.957	0.716	0.614	0.88		0.668	0.577	0.515	0.415	0.373	0.58
CH4	0.019	0.015	0.013	0.017	0.026	0.02	0.017	0.037	0.027	0.022	0.033		0.024	0.021	0.018	0.014	0.013	0.02
Particulate matter	1.83	1.52	1.39	1.64	1.64	1.82	1.62	2.89	2.19	1.89	2.69		2.07	1.81	1.71	1.42	1.3	1.84
Port. Cement kiln dust	19.6	12.7	7.8	15.7	15.7	19.1	14.7	44.2	28.7	22.1	39		25.4	19.5	18.2	11.9	9.1	20.21
Slag reject	0	0.224	0.173	0	0	0.338	0.259	0	0.508	0.391	0		0.449	0.345	0	0.21	0.161	0.19

Gas Production

This sheet calculates the GHG emissions related to gas production for the Gibbstown LNG Export Terminal.

Section A. Results Table

	Upfront Emissions	Ongoing Emissions	Total Emissions
	short tons CO2e	*short tons CO2e*	*short tons CO2e*
Gas Production, 20-year GWP	142,473	2,033	144,506
Gas Production, 100-year GWP	51,463	734	52,197

Section B. Data and Calculations

Section B1. Natural Gas Throughput

Description	Value	Units	Notes	Source
Natural gas input into pipeline	128	bcf/year		

Section B2. Production Emissions Data and Calculations

Description	Value	Units	Notes	Source
Well drilling	52	*kg CH4/well*	upfront emissions	Littlefield et al., 2019.
Compressor blowdowns	77	*kg CH4/compressor*	ongoing emissions	Littlefield et al., 2019.
Compressor blowdowns	0.078	*compressors/well*	ongoing emissions	Littlefield et al., 2019.
Pressure relief valve (PRV) upsets	0.70	*kg CH4/PRV*	ongoing emissions	Littlefield et al., 2019.
Pressure relief valve (PRV) upsets	2.4	*PRV/well*	ongoing emissions	Littlefield et al., 2019.
Vessel blowdowns	1.6	*kg CH4/vessel*	ongoing emissions	Littlefield et al., 2019.
Vessel blowdowns	0.93	*vessel/well*	ongoing emissions	Littlefield et al., 2019.
Wells	1,205	*wells/year*	upfront emissions	
Drilling Emissions	62,684	*kg CH4/year*	upfront emissions	
Compressor blowdowns	7,240	*kg CH4*	ongoing emissions	
Pressure relief valve (PRV) upsets	2,025	*kg CH4*	ongoing emissions	
Vessel blowdowns	1,794	*kg CH4*	ongoing emissions	
Total Upfront Production	62,684	*kg CH4/year*	upfront emissions	
Total Upfront Production	69	*short tons CH4/year*	upfront emissions	
Total Upfront Production	142,473	*short tons CO2e (20 year)*	upfront emissions	
Total Upfront Production	51,463	*short tons CO2e (100 year)*	upfront emissions	
Total Ongoing Production	11,059	*kg CH4*	ongoing emissions	
Total Ongoing Production	12	*short tons CH4*	ongoing emissions	
Total Ongoing Production	1,005	*short tons CO2e (20 year)*	ongoing emissions	
Total Ongoing Production	363	*short tons CO2e (100 year)*	ongoing emissions	

Section B3. Gathering Emissions Data and Calculations

Description	Value	Units	Notes	Source
Mishaps	14	kg CH4/mile	ongoing emissions	Littlefield et al., 2019.
Mishaps	81	wells/facility	ongoing emissions	Littlefield et al., 2019.
Mishaps	0.67	miles/well	ongoing emissions	Littlefield et al., 2019.
Production per well (national average)	290,715	cf/well/day	ongoing emissions	US EIA, 2022
Production days per year	365.25	days/year	ongoing emissions	
Production per well per year	106,183,654	cf/well/year	ongoing emissions	US EIA, 2022
Production per well per year	0.11	bcf/well/year	ongoing emissions	
Natural gas produced	128	bcf/year	ongoing emissions	
Wells used	1,205	wells used/year	ongoing emissions	
Mishaps, miles	807.66	miles/year	ongoing emissions	
Mishaps, emissions	11,307.20	kg CH4	ongoing emissions	
Mishaps, emissions	12	short tons CH4	ongoing emissions	
Mishaps, emissions	1,028	short tons CO2e (20 year)	ongoing emissions	
Mishaps, emissions	371	short tons CO2e (100 year)	ongoing emissions	

Section C. Sources

Section C1. Source for Table B45. Pennsylvania oil and gas well summary statistics, 2020

Source: US Energy Information Administration. January 2022. "US Oil and Natural Gas Wells by Production Rate: Appendix B." Available at: https://www.eia.gov/petroleum/wells/

Notes:

Table B45. Pennsylvania oil and gas well summary statistics, 2020

	Oil wells						Gas wells							Total wells			
Prod. rate bracket (BOE/d)	number of oil wells	percent of oil wells	Annual oil prod. (MMbbl)	percent of oil prod.	Oil rate per Well (b/d)	Annual gas prod. (Bcf)	Gas rate per well (Mcf/d)	number of gas wells	percent of gas wells	Annual gas prod. (Bcf)	rcent of gas Prod.	Gas rate per well (Mcf/d)	Annual oil prod. (MMbbl)	Oil rate per well (b/d)	number of total wells	Annual oil prod. (MMbbl)	Annual gas prod. (Bcf)	Horizontal well count
0–1	8,614	95.9	0.4	41.9	0.1	0.9	0.3	48,462	69.5	36.8	0.5	2.2	0.3	0.0	57,076	0.7	37.7	86
1–2	128	1.4	0.0	5.4	1.0	0.1	1.6	8,387	12.0	25.0	0.4	8.2	0.0	0.0	8,515	0.1	25.1	36
2–4	131	1.5	0.1	11.3	2.2	0.2	4.1	2,284	3.3	12.8	0.2	15.6	0.0	0.0	2,415	0.1	13.0	33
4–6	15	0.2	0.0	1.7	3.7	0.0	9.1	350	0.5	3.6	0.1	28.6	0.0	0.0	365	0.0	3.6	32
6–8	15	0.2	0.0	0.9	5.1	0.0	10.5	166	0.2	2.2	0.0	40.8	0.0	0.1	181	0.0	2.2	30
8–10	52	0.6	0.2	17.6	8.3	0.1	2.7	94	0.1	1.8	0.0	53.4	0.0	0.0	146	0.2	1.8	27
Subtotal <=10	**8,955**	**99.7**	**0.7**	**78.8**	**0.3**	**1.2**	**0.5**	**59,743**	**85.6**	**82.1**	**1.2**	**3.9**	**0.3**	**0.0**	**68,698**	**1.0**	**83.4**	**244**
10–12	22	0.2	0.1	10.3	11.4	0.0	2.5	57	0.1	1.3	0.0	65.0	0.0	0.0	79	0.1	1.3	24
12–15	1	0.0	0.0	0.0	10.6	0.0	0.0	57	0.1	1.6	0.0	79.9	0.0	0.2	58	0.0	1.6	28
Subtotal <=15	**8,978**	**99.9**	**0.8**	**89.1**	**0.3**	**1.3**	**0.5**	**59,857**	**85.8**	**85.0**	**1.2**	**4.0**	**0.3**	**0.0**	**68,835**	**1.1**	**86.3**	**296**
15–20	1	0.0	0.0	0.6	14.9	0.0	5.5	101	0.1	3.7	0.1	103.2	0.0	0.1	102	0.0	3.7	67
20–25	0	0.0	0.0	0.0	0.0	0.0	0.0	96	0.1	4.6	0.1	134.8	0.0	0.2	96	0.0	4.6	79
25–30	0	0.0	0.0	0.0	0.0	0.0	0.0	123	0.2	7.3	0.1	164.3	0.0	0.3	123	0.0	7.3	114
30–40	7	0.1	0.1	10.3	36.0	0.0	8.8	318	0.5	23.9	0.3	209.6	0.0	0.3	325	0.1	23.9	304
40–50	0	0.0	0.0	0.0	0.0	0.0	0.0	403	0.6	38.9	0.5	268.5	0.1	0.5	403	0.1	38.9	393
50–100	0	0.0	0.0	0.0	0.0	0.0	0.0	2,030	2.9	321.9	4.5	437.2	0.5	0.7	2,030	0.5	321.9	2,007
Subtotal <=100	**8,986**	**100.0**	**0.9**	**100.0**	**0.3**	**1.3**	**0.5**	**62,928**	**90.2**	**485.3**	**6.8**	**21.7**	**1.0**	**0.0**	**71,914**	**1.9**	**486.5**	**3,260**
100–200	0	0.0	0.0	0.0	0.0	0.0	0.0	2,352	3.4	738.1	10.3	869.3	0.7	0.8	2,352	0.7	738.1	2,349
200–400	0	0.0	0.0	0.0	0.0	0.0	0.0	2,020	2.9	1,223.4	17.1	1,683.3	1.1	1.5	2,020	1.1	1,223.4	2,019
400–800	0	0.0	0.0	0.0	0.0	0.0	0.0	1,352	1.9	1,588.6	22.2	3,314.2	0.7	1.4	1,352	0.7	1,588.6	1,351
800–1,600	0	0.0	0.0	0.0	0.0	0.0	0.0	650	0.9	1,396.0	19.5	6,600.9	0.7	3.5	650	0.7	1,396.0	649
1,600–3,200	0	0.0	0.0	0.0	0.0	0.0	0.0	375	0.5	1,280.8	17.9	12,742.6	0.6	5.7	375	0.6	1,280.8	375
3,200–6,400	0	0.0	0.0	0.0	0.0	0.0	0.0	106	0.2	459.5	6.4	24,607.7	0.0	0.0	106	0.0	459.5	106
6,400–12,800	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0
> 12,800	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0
Total	**8,986**	**100.0**	**0.9**	**100.0**	**0.3**	**1.3**	**0.5**	**69,783**	**100.0**	**7,171.7**	**100.0**	**290.2**	**4.8**	**0.2**	**78,769**	**5.7**	**7,173.0**	**10,109**

Notes:

Source: State and federal administrative oil & gas data thru Enverus

1. The total volumes shown in the distribution tables may not exactly agree with other related data, including other EIA sources. Major reasons for differences include the timing of updates from state and commercial sources, the summed production of available well-level production data versus state-level aggregations of production, and how a well is defined and which entities are counted and summed.

2. Wells counted for this report include sidetracks, completions, recompletions, and leases. This definition includes all oil and natural gas producing entities available in the Enverus database.

3. For late reporting states, the last year of available data is repeated for missing years For example, Kentucky 2019 data are used for 2020. Maryland 2016 data are used for 2017 through 2020. Missouri 2019 data are used for 2020. Tennessee 2016 data are used for 2017 through 2020. All years are missing for Illinois and Indiana. Tennessee 2016 data are used for 2017 through 2020. All years are missing for Illinois and Indiana.

4. To be consistent between states a GOR of 6,000 (cf/bbl) for each years production was used to define oil versus gas wells. If the GOR was less (greater) than 6,000 (cf/bbl) the well was classed an oil (gas) well.

5. To determine production rate brackets for the first and last year of a well's life, we divided the annual production by the number of days in the productive months. For the middle years, we divided the annual production by 365 or 366 days.

6. Natural gas volumes have been converted from the various state pressure bases to the federal base (14.73 pounds per square inch absolute).

Data available as of November 2021.

Section C2. Source for Exhibit 3-16. GHGI Emission and Activity Factors and Corresponding Natural Gas Throughput

Source: Littlefield, J., S. Roman-White, D. Augustine, A. Pegallapati, G. G. Zaimes, S. Rai, G. Cooney, and T. J. Skone. April 2019. "Life Cycle Analysis of Natural Gas Extraction and Power Generation." National Energy Technology Lab

Notes:

Exhibit 3-16. GHGI Emission and Activity Factors and Corresponding Natural Gas Throughput

Stage (or substage)	Emission Source	Vent	Fugitive	Emissions				Natural Gas Throughput	
				GHGI Emission Factor	Units (annualized)	Activity Factor	Units	Throughput	Units
Production	Well drilling	•		52	kg CH_4/completed well	*	completed wells	EUR*	Bcf/well-life
	Compressor blowdowns	•		77	kg CH_4/compressor	0.078 *	compressors/well wells	Annual production*	Mcf/basin-yr
	PRV (pressure relief valve) upsets	•		0.70	kg CH_4/PRV	2.4 *	PRV/well wells	Annual production*	Mcf/basin-yr
	Vessel blowdowns	•		1.6	kg CH_4/vessel	0.93 *	vessels/well wells	Annual production*	Mcf/basin-yr
Gathering	Mishaps	•		14	kg CH_4/mile	81 0.67	wells/facility miles/well	Annual production*	Mcf/basin-yr
Processing	Pneumatics	•		3,173	kg CH_4/facility	1	facilities	33.6	Bcf/facility-yr
Transmission	Dehydrator vents	•		1.8	kg CH_4/MMscf NG dehydrated	1.19E+06	MMscf NG	28.2	Tcf transmission
Transmission Pipeline	Pipeline fugitives		•	1,120	kg CH_4/mile	301,257	miles	28.2	Tcf transmission
Storage	Dehydrator vents	•		2.3	kg CH_4/MMscf dehydrated	1.85E+06	MMscf dehydrated	9.24	Tcf capacity
	Station venting	•		84,000	kg CH_4/station	*	Bcf station capacity	9.24	Tcf capacity
Distribution	Customer meters (residential)		•	1.5	kg CH_4/meters	5.43E+07	meters	13.9	Tcf distributed
	Customer meters (commercial/industrial)		•	9.7	kg CH_4/meter	5.66E+06	meters	13.9	Tcf distributed
	PRV (pressure relief valve) upsets	•		1.00	kg CH_4/mile	1.28E+06	miles	13.9	Tcf distributed
	Pipeline blowdowns	•		2.00	kg CH_4/mile	2.19E+06	miles	13.9	Tcf distributed
	Mishaps (dig ins)	•		31	kg CH_4/mile	2.19E+06	miles	13.9	Tcf distributed

* In some instances, throughput is variable across basins and extraction technologies. This variability is based on NETL's stratification of the data by basins and extraction technologies. Variability in activity factors are based on stratification of GHGRP data as shown in **Exhibit 3-8** through **Exhibit 3-15**, and variability in natural gas throughputs are based on stratification of DI Desktop data.

Section C3. Natural Gas Loss Rate From Extraction, Processing, and Transmission

Source: Page 72. Available at: https://www.energy.gov/sites/prod/files/2019/09/f66/Life%2

Notes:

Value	Description
1.20%	Loss rate from extraction through transmission of natural gas

Pipeline and Compressor Station(s)

This sheet calculates the GHG emissions related to gas transportation via pipelines from natural gas wells in Pennsylvania to the Wyalusing liquefaction facility for the Gibbstown LNG Export Terminal.

Section A. Results Table

	Upfront Emissions *metric tons CO2e/yr*	Ongoing Emissions *metric tons CO2e/yr*	Total Emissions *metric tons CO2e/yr*
Pipeline and Compressor Station(s), 20-year GWP	0	4,154	4,154
Pipeline and Compressor Station(s), 100-year GWP	0	1,500	1,500

No upfront emissions were c The above uses a 20-year GWP to calculate CO2e

Section B. Data and Calculations

Section B1. Natural Gas Throughput

Description	Value	Units	Notes	Source
Amount of natural gas transported	128	bcf		

Section B2. Pipeline Emissions Data and Calculations

Description	Value	Units	Notes	Source
Transmission emissions per mile	1,120	kg CH4/mile		Littlefield et al., 2019.
Miles of transmission:	30	miles	This is a general assumption based on the relative proximity between the natural gas wells in the Marcellus Shale and the Wyalusing liquefa	
Transmission emissions	33,600	kg CH4		
Transmission emissions	37	short tons CH4		
Transmission emissions	3,055	short tons CO2e (20 year)		
Transmission emissions	1,103	short tons CO2e (100 year)		

Section B3. Processing Emissions Data and Calculations

Description	Value	Units	Notes	Source
Processing/Pneumatics Emissions	3,173	kg CH4 / facility		Littlefield et al., 2019.
Processing/Pneumatics Emissions	33.6	Bcf/facility-yr		Littlefield et al., 2019.
Processing/Pneumatics Emissions	128	Bcf throughput per year		
Processing/Pneumatics Emissions	3.81	facilities used/year		
Processing/Pneumatics Emissions	12,088	kg CH4 / year		
Processing/Pneumatics Emissions	13	short tons CH4		
Processing/Pneumatics Emissions	1,099	short tons CO2e (20 year)		
Processing/Pneumatics Emissions	397	short tons CO2e (100 year)		

Section C. Sources

Section C1. Source for Exhibit 3-16. GHGI Emission and Activity Factors and Corresponding Natural Gas Throughput

Source: Littlefield, J., S. Roman-White, D. Augustine, A. Pegallapati, G. G. Zaimes, S. Rai, G. Cooney, and T. J. Skone. April 2019. "Life Cycle Analysis of Natural Gas Extraction and Power Generation." Natio

Notes:

Exhibit 3-16. GHGI Emission and Activity Factors and Corresponding Natural Gas Throughput

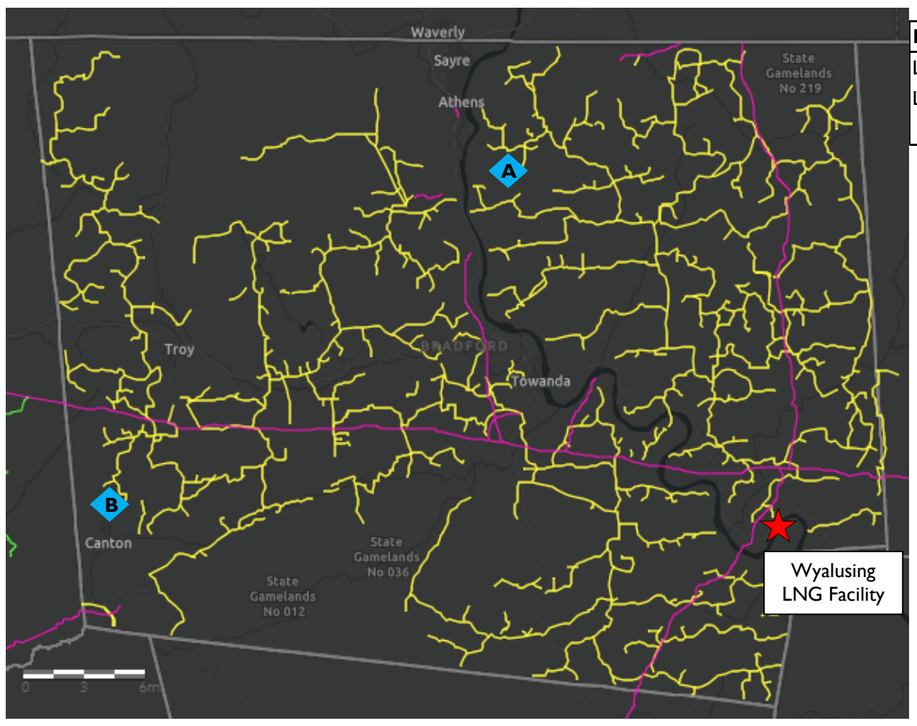
Stage (or substage)	Emission Source	Vent	Fugitive	GHGI Emission Factor	Emissions nits (annualize	Activity Factor	Units	Natural Gas Throughput Throughput	Units
Production	Well drilling	•		52	:H4/completed	*	:ompleted well:	EUR*	Bcf/well-life
	Compressor blowdowns	•		77	; CH4/compress	0.078 *	ompressors/we wells	ınual productio	Mcf/basin-yr
	PRV (pressure relief valve) upsets	•		0.70	kg CH4/PRV	2.4 *	PRV/well wells	ınual productio	Mcf/basin-yr
	Vessel blowdowns	•		1.6	kg CH4/vessel	0.93 *	vessels/well wells	ınual productio	Mcf/basin-yr
Gathering	Mishaps	•		14	kg CH4/mile	81 0.67	wells/facility miles/well	ınual productio	Mcf/basin-yr
Processing	Pneumatics	•		3,173	kg CH4/facility	1	facilities	33.6	Bcf/facility-yr
Transmission	Dehydrator vents	•		1.8	kg CH4/MMscf NG dehydrated	1.19E+06	MMscf NG	28.2	Tcf transmission
Transmission Pipeline	Pipeline fugitives		•	1,120	kg CH4/mile	301,257	miles	28.2	Tcf transmission
Storage	Dehydrator vents	•		2.3	kg CH4/MMscf dehydrated	1.85E+06	Mscf dehydrat	9.24	Tcf capacity
	Station venting	•		84,000	kg CH4/station	*	:f station capac	9.24	Tcf capacity
Distribution	Customer meters (residential)		•	1.5	kg CH4/meters	5.43E+07	meters	13.9	Tcf distributed
	Customer meters (commercial/industrial)		•	9.7	kg CH4/meter	5.66E+06	meters	13.9	Tcf distributed
	PRV (pressure relief valve) upsets	•		1.00	kg CH4/mile	1.28E+06	miles	13.9	Tcf distributed
	Pipeline blowdowns	•		2.00	kg CH4/mile	2.19E+06	miles	13.9	Tcf distributed
	Mishaps (dig ins)	•		31	kg CH4/mile	2.19E+06	miles	13.9	Tcf distributed

* In some instances, throughput is variable across basins and extraction technologies. This variability is based on NETL's stratification of the data by basins and extraction technologies. Variability in activity factors are based on stratification of GHGRP data as shown in **Exhibit 3-8** through **Exhibit 3-15**, and variability in natural gas throughputs are based on stratification of DI Desktop data.

Section C2. Estimated Transmission Distance

Source: Kelso, Matt. 2018. "Pennsylvania Pipelines and Pollution Events." FracTracker Alliance. July 27, 2018. Available at: https://www.fractracker.org/2018/07/

Notes:



Location	Distance (approximat	Unit
Location A (near Athens)	27	miles
Location B (near Canton)	33	miles
Average distance	30	miles

Gas Liquefaction Facility

This sheet calculates the GHG emissions related to natural gas liquefaction at the Wyalusing Liquefaction facility.

Section A. Results Table

	Upfront Emissions *units*	Ongoing Emissions *short tons CO2e/year*	Total Emissions *short tons CO2e/year*
Gas Liquefaction Facility, 20-year GWP	*See "Construction" tab*	1,138,400	1,138,400
Gas Liquefaction Facility, 100-year GWP	*See "Construction" tab*	1,112,521	1,112,521

Section B. Data and Calculations

Section B1. Natural Gas Throughput

Description	Value	Units	Notes	Source
Amount of natural gas liquefied	128	bcf/year		

Section B2. Ongoing Operating Emissions Data and Calculations per BCF

This section is used to calculate the Default Wyalusing facility emissions or the User Input emissions scaled to BCF of throughput, based on the Dashboard inputs. If users input their own facility emissions in the Dashboard, Section B3 is used instead.

Input	Value	Units	Notes	Source
Natural Gas Throughput (Gibbstown documentation)	128		Natural gas throughput in Gibbstown documentation as of December 2022, used to scale User Input levels of natural gas throughput.	
Operating Facility Annual Emissions, All GHGs	8,654	short tons CO2e/bcf/year	*100 year GWP (AR4 values)*	
Operating Facility Annual Emissions, CH4	3.03	short tons CH4/bcf/year		
Operating Facility Annual Emissions, CO2	8,577	short tons CO2/bcf/year		
Operating Facility Annual Emissions, All GHGs	8,827	short tons CO2e/bcf/year	*20 year GWP (AR6)*	
Operating Facility Annual Emissions, All GHGs	8,668	short tons CO2e/bcf/year	*100 year GWP (AR6)*	
Fugitive Facility Annual Emissions, CH4	0.80	short tons CH4/ybcf/year		
Fugitive Facility Annual Emissions, CO2	0.00016	short tons CO2/bcf/year		
Fugitive Facility Annual Emissions, All GHGs	66.3	short tons CO2e/bcf/year	*20 year GWP*	
Fugitive Facility Annual Emissions, All GHGs	24.0	short tons CO2e/bcf/year	*100 year GWP*	
Annual Emissions, All GHGs	8,894	short tons CO2e/bcf/year	*20 year GWP (AR6)*	
Annual Emissions, All GHGs	8,692	short tons CO2e/bcf/year	*100 year GWP (AR6)*	
Annual Emissions, All GHGs	1,138,400	short tons CO2e/year	*20 year GWP (AR6)*	
Annual Emissions, All GHGs	1,112,521	short tons CO2e/year	*100 year GWP (AR6)*	

Section B3. Ongoing Operating Emissions Data and Calculations

This section is used if a user inputs their own facility emissions in the Dashboard. If users choose to use the Default emissions or scale emissions with BCF in the Dashboard, Section B2 is used instead.

Input	Value	Units	Notes	Source
Operating Facility Annual Emissions, All GHGs	1,107,679	short tons CO2e/year	*100 year GWP (AR4 values)*	
Operating Facility Annual Emissions, CH4	118	short tons CH4/year		
Operating Facility Annual Emissions, CO2	1,097,888	short tons CO2/year		
Operating Facility Annual Emissions, All GHGs	1,107,592	short tons CO2e/year	*20 year GWP (AR6)*	
Operating Facility Annual Emissions, All GHGs	1,101,393	short tons CO2e/year	*100 year GWP (AR6)*	
Fugitive Facility Annual Emissions, All GHGs	103	short tons CO2e/year		
Fugitive Facility Annual Emissions, CH4	102.88	short tons CH4/year		
Fugitive Facility Annual Emissions, CO2	0.02	short tons CO2/year		
Fugitive Facility Annual Emissions, CH4 (CO2e)	8,487.60	short tons CO2e/year	User Input GWP: AR6 GWP-20	
Fugitive Facility Annual Emissions, CO2 (CO2e)	0.02	short tons CO2e/year	User Input GWP: AR6 GWP-20	
CH4 percent of Fugitive Emissions (CO2e)	100%	CH4 percent of CO2e		
Fugitive Facility Annual Emissions, CH4	1.25	short tons CH4/year		
Fugitive Facility Annual Emissions, CO2	0.00	short tons CO2/year		
Fugitive Facility Annual Emissions, All GHGs	102.88	short tons CO2e/year	*20 year GWP (AR6)*	
Fugitive Facility Annual Emissions, All GHGs	37.16	short tons CO2e/year	*100 year GWP (AR6)*	
Annual Emissions, All GHGs	1,107,695	short tons CO2e/year	*20 year GWP (AR6)*	
Annual Emissions, All GHGs	1,101,430	short tons CO2e/year	*100 year GWP (AR6)*	

Section C. Sources

Section C1. Estimate of CO2 portion of facility emissions

Source: AP 42 Fifth Edition Compilation of Air Pollutant Emissions Factors, Volume 1: Stationary Point and Area Sources. Available at: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors#5thed

Note: *Estimated % proportion CO2 calculated using AP-42 emissions factors and PA DEP Air Quality Application emission calculation tables*

Percent composition	Process Turbines (LM6000PF+) [1]	Gas Turbine Generators (SGT-400) [1]	Steam Boilers [1]	Regeneration Gas Heater	Generators	Fire Pumps	Thermal Oxidizer	Flares	***Total***
Share of total facility emissions	47.4%	19.9%	5.4%	1.7%	0.2%	0.0%	24.1%	1.3%	*100.0%*
Estimated % share CO2	99.90%	99.90%	99%	99%	99%	99%	97%	99%	
Aggregated % share	47.31%	19.84%	5.37%	1.69%	0.23%	0.02%	23.33%	1.32%	*99.1%*
% share not CO2									***0.88%***

Section C2. Table A-1 Summary of Potential Emissions

Source: PA DEP Air Quality Plan Approval 7/24/2019, available at: https://files.dep.state.pa.us/RegionalResources/NCRO/NCROPortalFiles/NewFortressEnergy/Air_Quality_Plan_Approval_7-24-19.pdf

Note: *Table updated from Air Quality Application with correct approved numbers in Plan Approval*

		Controlled Potential Annual Emiss	Controlled Potential Annual Emissions (TPY)								
Pollutant	Facility Annual Emissions (TPY)	Unit	Process Turbines (LM6000PF+) [1]	Gas Turbine Generators (SGT-400) [1]	Steam Boilers [1]	Regeneration Gas Heater	Generators	Fire Pumps	Thermal Oxidizer	Flares	Fugitives
NO_x	97.86	tons/year	32.98	13.46	3.75	6.41	12.82	0.42	27.37	6.55	
CO	90.87	tons/year	17.83	7.29	10.5	6.57	13.14	0.3	16.5	26.99	
VOC	36.3	tons/year	12.03	8.97	1.92	3.05	6.1	0.038	0.021	2.49	17.46
PM/PM-10/PM-2.5	99.95	tons/year	57.15	26.64	8.41	2.08	4.16	0.024	2.44	2.51	0.09
SO_x	83.25	tons/year	16.93	7.1	1.94	0.61	1.22	0.02	55.86	0.75	
GHG (CO2e)	1,107,679	tons/year	524,532	219,981	60,105	18,899	2570	236	266,454	14,815	
NH_3	49.02	tons/year	29.76	12.48	6.78						
Total HAPs [2]	8.77	tons/year									
H2SO4	25.9	tons/year	18.38	6.17	1.33						

1. Potential emission estimates are extremely conservative in that emission based on 100% operation. Units are design with redundancy - i.e. not needed to operate full load all year.

2. Largest single HAPs emitted are formaldehyde at 4.55 TPY and Hexane at 1.1 TPY. Therefore facility not major for HAPs

Section C3. Table A-10.a Fugitive Emissions: Natural Gas Equipment Leaks

Source: PA DEP. Minor Source Plan Approval Application for Natural Gas Processing Plant. December 2018. Available at: https://files.dep.state.pa.us/RegionalResources/NCRO/NCROPortalFiles/NewFortressEnergy/New%20Fortress%20Energy%20LNG%20Plant%20Plan%20Approval%20Application%20(December%202018).pdf

Notes: Submitted to PA DEP by Bradford County Real Estate Partners LLC

Components	Phase	TOC/VOC Emission Factor (lb/hour/component)	Actual Component Count	Hourly CH4 Emissions (a),(b) (lb/hr)	Annual CH4 Emissions [d] (tons/year)	Hourly CO2 Emissions (a)*[b] (lb/hr)	Annual CO2 Emissions [d] (tons/yr)	Hourly VOC Emissions (a*[c] (lb/hr)	Annual VOC Emissions [d], (tons/year)	
Valves	Gas/Vapor	9.9E-03 (1)	1,414	13.72	60.09	0.00E+00	1.00E-02	3.20E-01	5.70E-01	
Pressure Relief Valves	Gas/Vapor	1.9E-02 (1)	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	*No PSVs vented to atmosphere*
Pump Seals		2.9E-03 (1)	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Flanges	Gas/Vapor	8.6E-04 (1)	1,275	1.07	4.7	2.20E-04	9.60E-04	2.50E-02	4.40E-02	
Compressor Seals		1.9E-02 (1)	10	0.19	0.83	3.90E-05	1.70E-04	4.50E-03	7.80E-03	
Sampling Connections		3.3E-02 (2)	2	2.8	12.28	5.80E-04	0.00E+00	7.00E-02	1.20E-01	
Total					**77.89**		**0.02**		**0.73**	

Calculations:

(a) Hourly Emissions (lb/hr) = [Emission Factor (lb TOC/hr/component)] x [Count (component)] x [CH_4/CO_2//VOC Content (Mass %)] / [TOC Content (Mass %)]

(b) Hourly Emissions (lb/hr) = [Emission Factor (lb VOC/hr/component)] x [Count (component)] x [CH_4/CO_2 Content (Mass %)] / [VOC Content (Mass%)]

(c) Hourly Emissions (lb/hr) = [Emission Factor (lb VOC/hr/component)] x [Count (component)]

CH_4 Content (mass %) = 97.5

CO_2 Content (mass %) = 0.02

VOC Content (mass %) = 2.30

TOC Content (mass %) = 99.70

(d) Annual Emissions (tons/yr) = [Hourly Emissions (lb/hr)] x [Hours of Operation (hr/yr)] / [2,000 lb/ton]

Hours of Operation (hr/yr) = 8,760

LDAR Program Reduction = 60% Based on 60% reduction for quarterly LDAR per PADEP GP5 support Document

(e) HAPS estimated at percent as for Thermal Oxidizer 10.80% 0.08 TPY

Notes:

(1) EPA-453/R-95-017 Protocol for Equipment Leak Emission Estimates, EPA, November 1995. Table 2-4. Oil and Gas Production Operations Average Emission Factors (page 2-15), total organic compounds emission factors (TOC).

(2) EPA-453/R-95-017 Protocol for Equipment Leak Emission Estimates, EPA, November 1995. Table 2-2. Refinery Average Emission Factors (page 2-13), non-methane organic compounds emission factor (VOC).

Section C4. Table A-10.b Fugitive Emissions: LNG Equipment Leaks

Source: PA DEP. Minor Source Plan Approval Application for Natural Gas Processing Plant. December 2018. Available at: https://files.dep.state.pa.us/RegionalResources/NCRO/NCROPortalFiles/NewFortressEnergy/New%20Fortress%20Energy%20LNG%20Plant%20Plan%20Approval%20Application%20(December%202018).pdf

Notes: Submitted to PA DEP by Bradford County Real Estate Partners LLC

Components	Phase	TOC/VOC Emission Factor (lb/hr/component)	Actual Component Count	Hourly CH4 Emissions (a),(b) (lb/hr)	Annual CH Emissions [d] (tons/yr)	Hourly CO_2 Emissions (a)*[b]) (lb/hr)	Annual CO2 Emissions [d] (tons/yr)	Hourly VOC Emissions (a),(c) (lb/hr)	Annual VOC Emissions [d] (tons/yr)	
Valves	Liquid	0.0055	634	3.42	14.97	0	0	0.08	0.14	
Pressure Relief Valves	Liquid	0.017	0	0	0	0	0	0	0	*No PSVs vented to atmosphere*
Pump Seals		0.0029	0	0	0	0	0	0	0	
Flanges	Liquid	2.40E-04	321	0.08	0.33	1.60E-05	6.80E-05	1.80E-03	3.10E-03	
Compressor Seals		1.90E-02	0	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Sampling Connections	All	0.033	1	1.4	6.14	0.00029	0	0.03	0.06	
Total					**21.44**		**0**		**0.2**	

Calculations:

(a) Hourly Emissions (lb/hr) = [Emission Factor (lb TOC/hr/component)] x [Count (component)] x [CH_4/CO_2//VOC Content (Mass %)] / [TOC Content (Mass %)]

(b) Hourly Emissions (lb/hr) = [Emission Factor (lb VOC/hr/component)] x [Count (component)] x [CH_4/CO_2 Content (Mass %)] / [VOC Content (Mass%)]

(c) Hourly Emissions (lb/hr) = [Emission Factor (lb VOC/hr/component)] x [Count (component)]

CH_4 Content (mass %) = 97.5

CO_2 Content (mass %) = 0.02

VOC Content (mass %) = 2.30

TOC Content (mass %) = 99.70

(d) Annual Emissions (tons/yr) = [Hourly Emissions (lb/hr)] x [Hours of Operation (hr/yr)] / [2,000 lb/ton]

Hours of Operation (hr/yr) = 8,760

LDAR Program Reduction = 60% Based on 60% reduction for quarterly LDAR per PADEP GP5 support Document

(e) HAPS not expected to be present

Notes:

(1) EPA-453/R-95-017 Protocol for Equipment Leak Emission Estimates, EPA, November 1995. Table 2-4. Oil and Gas Production Operations Average Emission Factors (page 2-15), total organic compounds emission factors (TOC).

(2) EPA-453/R-95-017 Protocol for Equipment Leak Emission Estimates, EPA, November 1995. Table 2-2. Refinery Average Emission Factors (page 2-13), non-methane organic compounds emission factor (VOC)

Section C5. Table A-10.c Fugitive Emissions: Refrigerated Vapor Equipment Leaks

Source: PA DEP. Minor Source Plan Approval Application for Natural Gas Processing Plant. December 2018. Available at: https://files.dep.state.pa.us/RegionalResources/NCRO/NCROPortalFiles/NewFortressEnergy/New%20Fortress%20Energy%20LNG%20Plant%20Plan%20Approval%20Application%20(December%202018).pdf

Notes: Submitted to PA DEP by Bradford County Real Estate Partners LLC

Components	Phase	TOC/VOC Emission Factor (lb/hr/component)	Actual Component Count	Hourly CH4 Emissions ("'(b) (lb/hr)	Annual CH4 Emissions [d] (tons/yr)	Hourly CO2 Emissions (a)[b]+ (lb/hr)	Annual CO2 Emissions [d] (tons/yr)	Hourly VOC Emissions (a'[c]+ (lb/hr)	Annual VOC Emissions [d], (tons/yr)	
Valves	Gas/Vapor	9.9E-03 (1)	423	0.66	2.9	0	0	3.53	6.19	
Pressure Relief Valves	Gas/Vapor	1.9E-02 (1)	0	0	0	0	0	0	0	*No PSVs vented to atmosphere*
Pump Seals		2.9E-03 (1)	0	0	0	0	0	0	0	
Flanges	Gas/Vapor	8.6E-04 (1)	901	0.12	0.54	0	0	0.65	1.14	
Compressor Seals		1.9E-02 (1)	4	0.01	0.05	0	0	0.065	0.11	
Sampling Connections		3.3E-02 (2)	2	0.01	0.05	0	0	0.07	0.12	
Total					**3.55**		**0**		**7.56**	

Calculations:

(a) Hourly Emissions (lb/hr) = [Emission Factor (lb TOC/hr/component)] x [Count (component)] x [CH_4/CO_2/VOC Content (Mass %)] / [TOC Content (Mass %)]

(b) Hourly Emissions (lb/hr) = [Emission Factor (lb VOC/hr/component)] x [Count (component)] x [CH_4/CO_2 Content (Mass %)] / [VOC Content (Mass%)]

(c) Hourly Emissions (lb/hr) = [Emission Factor (lb VOC/hr/component)] x [Count (component)]

CH_4 Content (mass %) = 15.0

CO_2 Content (mass %) = 0.00

VOC Content (mass %) = 80.00

TOC Content (mass %) = 95.00

(d) Annual Emissions (tons/yr) = [Hourly Emissions (lb/hr)] x [Hours of Operation (hr/yr)] / [2,000 lb/ton]

Hours of Operation (hr/yr) = 8,760

LDAR Program Reduction = 60% Based on 60% reduction for quarterly LDAR per PADEP GP5 support Document

(e) Refrigerant not a HAP

Notes:

(1) EPA-453/R-95-017 Protocol for Equipment Leak Emission Estimates, EPA, November 1995. Table 2-4. Oil and Gas Production Operations Average Emission Factors (page 2-15), total organic compounds emission factors (TOC).

(2) EPA-453/R-95-017 Protocol for Equipment Leak Emission Estimates, EPA, November 1995. Table 2-2. Refinery Average Emission Factors (page 2-13), non-methane organic compounds emission factor (VOC)

Section C6. Natural Gas Consumed During Liquefaction Process

Source: Pospisil, J., P. Charvat, O. Arsenyeva, L. Klimes, M. Spilacek, J.J. Klemes. 2018. "Energy demand of liquefaction and regasificatino of natural gas and the potential of LNG for operative thermal energy storage." *Renewable and Sustainable Energy Reviews* . Page 5.

Notes:

Gas consumed during the liquefaction process	Source
9-10%	Kandiyoti R. (Rafael). Pipelines: flowing oil and crude politics. London, UK: I.B. Tauris; 2008.
5-6%	Ulvestad M, Overland I. Natural gas and CO2 price variation: impact on the relative cost-efficiency o
5-15%	Selfors A, Thorsen K, Hofstad K, Fagerlund K, Wiggen T. Natural gas: a general introduction. Norwe
9%	Jung Y, Yokobori K, Doi N, Peng H, Wang Z, Sinygin O. Natural gas pipeline development in Northe
8.5%	Average amount of gas consumed during liquefaction

Domestic Transport

This sheet calculates the GHG emissions related to transporting LNG by train and truck from the Wyalusing Liquefaction Facility to the Gibbstown LNG Export Terminal.

Section A. Results Table

	Upfront Emissions *units*	Ongoing Emissions *short tons CO2e/yr*	Total Emissions *short tons CO2e/yr*
Domestic Transport, 20-year GWP	0	41,116	41,116
Domestic Transport, 100-year GWP	0	24,523	24,523

No upfront emissions were calculated, under the assumption that the infrastructure is already built.

Section B. Data and Calculations

Section B1. Natural Gas Throughput

Description	Value	Units	Notes	Source
Amount of natural gas transported from liquefaction facility	128	bcf		

Section B2. Train Transportation Emissions

Calculated as if trains transport 100% of the LNG throughput

Input	Value	Unit	Notes	Source
Distance travelled	255	Miles	*Estimation from Google Maps route between Wyalusing, PA, and Gibbstown, NJ*	
Number of trains	150	train cars/day	*Estimation from Application*	Pipeline and Hazardous Materials Safety Administration (PHMSA). July 2019. "ETS LLC SP 20534 Application (REDACTED)." Available at: https://www.regulations.gov/document/PHMSA-2019-0100-0941
Emission Factor	144.97	gCO2/TEU-mi		PHMSA, 2019
Emission Factor	0.000160	short ton CO2/TEU-mi		
Operating days per year	365.25	days/year		
Emissions per day	6	short tonCO2/day		
Annual Emissions	2,232	short tonCO2/year	*Calculated as if trains transport 100% of the LNG throughput*	

Section B3. Truck Transportation Emissions

Calculated as if trucks transport 100% of the LNG throughput

Input	Value	Unit	Notes	Source
Distance travelled	174.04	Miles	*Estimation from Google Maps route*	
Number of trucks	400	cars/day		
Emission Factor	1001	gCO2/TEU-mi		
Emission Factor	0.001	short ton CO2/TEU-mi		
Operating days per year	365.25	days/year		
Emissions per day	77	short tonCO2/day		
Annual Emissions	28,049	short tonCO2/year	*Calculated as if trucks transport 100% of the LNG throughput*	

Section B4. Transport Emission Calculations

Percent transported by rail	Rail	Truck	Total	Unit		Notes	Source
Percent share of transports	50.00%	50.00%	100%	%		*Input. Total must sum to 100%*	
Transport emissions proportion	1,116	14,024	15,140	short ton CO2e/year			

Section B5. Venting, Flaring, and Fugitive Emissions during Transit

Input	Value	Unit	Notes	Source
Number of Cars (default)	550	Number of cars transporting L	Includes both train and truck cars	
Valves	1.93	Number of valves/LNG car	*Assumes comparable number of units to refrigerated liquid equipment leaks*	
Pump seals	-	Number of pump seals/LNG c	*Assumes comparable number of units to refrigerated liquid equipment leaks*	
Connectors	1.75	Number of connectors/LNG C	*Assumes comparable number of units to refrigerated liquid equipment leaks*	
Other leak sources	-	Number of other leak sources	*Assumes comparable number of units to refrigerated liquid equipment leaks*	
Vapor recovery compressors	-	Number of vapor recovery cor	*Assumes comparable number of units to refrigerated liquid equipment leaks*	
Number of Cars (user input or default)	550			
Valves	1,059	Number of valves	*Assumes comparable number of units to refr*	PA DEP, 2018
Pump seals	-	Number of pump seals	*Assumes comparable number of units to refr*	PA DEP, 2018
Connectors	962	Number of connectors	*Assumes comparable number of units to refr*	PA DEP, 2018
Other leak sources	-	Number of other leak sources	*Assumes comparable number of units to refr*	PA DEP, 2018
Vapor recovery compressors	-	Number of vapor recovery cor	*Assumes comparable number of units to refr*	PA DEP, 2018
Valve leakage	1,260	scf/hour		
Pump seal leakage	-	scf/hour		
Connector leakage	327	scf/hour		
Other leak sources leakage	-	scf/hour		
Vapor recovery compressor leakage	-	scf/hour		
Days per year	365.25	days/year		
Valve leakage	11,047,001	scf/year		
Pump seal leakage	-	scf/year		
Connector leakage	2,867,183	scf/year		
Other leak sources leakage	-	scf/year		
Vapor recovery compressor leakage	-	scf/year		
Valve emissions	250	short tons of CH4/year		
Pump seal emissions	-	short tons of CH4/year		
Connector emissions	65	short tons of CH4/year		
Other leak sources emissions	-	short tons of CH4/year		
Vapor recovery compressor emissions	-	short tons of CH4/year		
Total Leakage Emissions	315	short tons of CH4/year		
Total Leakage Emissions (20-year GWP)	25,976	short tons CO2e/year		
Total Leakage Emissions (100-year GWP)	9,383	short tons CO2e/year		

Section C. Sources

Section C1. Engine Emissions

Source: PHMSA *SP 20534 Special Permit to transport LNG by rail in DOT-113C120W rail tank cars* , availab

Note: Table 3 is standard comparison of emissions, not specific to this project

Note: "A standardized unit, g/TEU-mi, converted the grams of pollutant produced per twenty-foot equ

Table 3. GHG Emission Factors for Transportation Modalities (g/TEU-mi)

Mode	CO2
Truck	1001
Rail	144.97
Ship	292.83

A standardized comparison of the emissions of substances produced from rail and truck transportation methods was calculated by the United States Department of Tr

Section C2. Train Transportation

Source: PHMSA, *Application for a Special Permit to Transport Methane, Refridgerated Liquid in DOT 113 Tan*

Notes: Submitted to PHMSA by Energy Transport Solutions, LLC on August 21, 2017

Description	Value	Units	Notes
Train cars per unit train	50-100	cars	*Application, page 6*
Total proposed operating unit trains	2	unit trains/day	*Application, page 7*
Average cars per unit train	75	cars	
Estimated cars operated per day	150	cars/day	

Section C3. Wyalusing Project Description

Source: PA DEP. Minor Source Plan Approval Application for Natural Gas Processing Plant. December 2018. Available at: https://files.dep.state.pa.us/RegionalResources/NCRO

Notes: Submitted to PA DEP by Bradford County Real Estate Partners LLC

Step/part	Process	Value	Unit
Truck loading	Loading bays	18	trucks/load
Truck loading	Tanker truck nominal capacity	10,000	gal/truck
Truck loading	Tanker truck fill rate	300	gal/minute
Truck loading	Daily onsite vehicular traffic	400	vehicles
Truck loading	Distance traveled	68,620	VMT
Production	Estimated nominal daily average of LNG production	4,000,000	gallons/day

Section C4. Truck Transport Volume Calculations

Source: Section C2, above.

Notes:

Estimated annual volume transported by truck	Based on estimate of average gallons produced per day	119.07	bcf/year by Truck
Truck loading rate	Total for all truck bays	324,000	gal/hour
Truck loading hours		12	hours/day
Estimated annual gallons of LNG transported by truck		1,420,092,000	gal/year
Estimated maximum volume of LNG transported by truck	Based on truck capacity and loading assumptions	115.74	bcf/year
Total LNG transported	Total LNG exported from Gibbstown	128.00	Total bcf/year exported
Maximum percent of total LNG exports transported by truck		90.4%	LNG exported by truck

Section C5. Truck and Rail Transportation Route Distances

Source: Delaware Riverkeeper Network. "LNG Gibbstown Interactive Map" Available at: https://www.delawareriverkeeper.org/taxonomy/term/

Notes:

Truck Route A

Name	Miles
29	9.46
309	18.07
115	2.82
476	13.13
6	25.34
476	94.28
95	2.97
44	2.37
322	3.69
130	1.28
Repauna Ave	0.63
Total miles	174.04

Rail Route A

Total miles
255

Section C6. Storage, Loading, and Unloading Loss Rates for LNG

Source: The LEVON Group, LLC. May 2015. "Liquefied Natural Gas (LNG) Operations: Consistent Methodology for Estimating Greenhouse Gas Emissions." *Energy API.* Avail

Notes: Most or all venting from LNG storage tanks is captured and redirected to storage tanks or flared. As a result, the CH4 emissions from venting of stored LNG are typically negligible.

Table 12. Storage, Load, and Unloading: Typical Loss Rates

Source	Typical Venting or L	Units
BOG from storage tanks (a)	0.05%	Of total tank volume per day
BOG from vessels during shipping (b)	0.15%	Of total ship storage volume per day
Transfer pipe loss - foam insulation (c)	0.0012%	per km LNG transfer pipe (d)
Transfer pipe loss - powder insulation (c)	0.0006%	per km LNG transfer pipe (d)
Transfer pipe loss - vacuum insulation	0.000120%	per km LNG transfer pipe (d)

BOG = boil-off-gas

(a) D. Féger, "An innovative way of reducing BOG on existing or 'new built' LNG storage tanks", ,Proceedings LNG16 Congress, Algeria, April 2010

(b) Sempra LNG, "GHG life-cycle emissions study: U.S. Natural Gas Supplies and International LNG", November 2008

(c) B. Kitzel, "Choosing the right insulation", LNG Industry, Spring 2008

(d) Based on LNG transfer rate of 228m3/min and heat transfer coefficient of pipe wall insulation, U(w/m2k)= 0.26 (foam), 0.13 (powder), and 0.026 (vacuum),

(e) EPA, Natural Gas Star, "Liquefied Natural Gas Emissions Reduction Opportunities: Lessons Learned" Natural Gas STAR Technology Transfer Workshop, Alaska, May 2006

Section C7. Default Methane Emission Factors per Component Population for LNG Storage and Import/Export Terminals

Source: The LEVON Group, LLC. May 2015. "Liquefied Natural Gas (LNG) Operations: Consistent Methodology for Estimating Greenhouse Gas Emissions." *Energy API.* Avail

Notes:

Table 13. Default Methane Emission Factors per Component Population for LNG Storage and Import/Export Terminals

Component/Device	Emissions Factor (a) (scf/hour/component)
Valve	1.19
Pump Seal	4.00
Connectors (flanges and threaded fittings)	0.34
Other (b)	1.77
Vapor Recovery Compressors ©	4.17 (per compressor)

(a) See Reference 20; based on an assumed methane content of 93.4%

(b) Emission factor is in terms of scf/hour/compressor

(c) Emission factor is in terms of scf/hour/compressor

Section C8. Table A-10.d Fugitive Emissions: Refrigerated Liquid Equipment Leaks

Source: PA DEP. Minor Source Plan Approval Application for Natural Gas Processing Plant. December 2018. Available at: https://files.dep.state.pa.us/RegionalResources/NCRO/NCROPortalFiles/NewFortressEnergy/New%20Fortress%20Energy%20LNG%20Plant%20Plan%20Approval%20Application%20(December%20

Notes: Submitted to PA DEP by Bradford County Real Estate Partners LLC

Bradford County Real Estate Partners LLC

Natural Gas Processing Plant

Table A-10.d Fugitive Emissions: Refrigerated Liquid Equipment Leaks

Components	Phase	TOC/VOC Emission Factor (lb/hr/component)		Actual Component Count	Hourly CH4 Emissions (a),(b) (lb/hr)	Annual CH4 Emissions (d) (tons/yr)	Hourly CO2 Emissions (a),(b) (lb/hr)	Annual CO2 Emissions (d) (tons/yr)	Hourly VOC Emissions (a),(c) (lb/hr)	Annual VOC Emissions (d) (tons/yr)
Valves	Liquid	0.0055	(1)	1059	0.92	4.04	0	0	4.92	8.61
Pressure Relief Valves	Liquid	0.017	(1)	0	0	0	0	0	0	0
Pump Seals		0.0029	(1)	0	0	0	0	0	0	0
Flanges	Liquid	0.00024	(1)	962	0.04	0.16	0	0	0.2	0.34
Compressor Seals		0.019	(1)	0	0	0	0	0	0	0
Sampling Connections	All	0.033	(2)	0	0	0	0	0	0	0
Total						**4.2**		**0**		**8.96**

No PSVs vented to atmosphere

Calculations:

(a) Hourly Emissions (lb/hr) = [Emission Factor (lb TOC/hr/component)] x [Count (component)] x [CH4/CO2//VOC Content (Mass %)] / [TOC Content (Mass %)]

(b) Hourly Emissions (lb/hr) = [Emission Factor (lb VOC/hr/component)] x [Count (component)] x [CH4/CO2 Content (Mass %)] / [VOC Content (Mass%)]

(c) Hourly Emissions (lb/hr) = [Emission Factor (lb VOC/hr/component)] x [Count (component)]

CH4 Content (mass %) = 15.0

CO2 Content (mass %) = 0.00

VOC Content (mass %) = 80.00

TOC Content (mass %) = 95.00

(d) Annual Emissions (tons/yr) = [Hourly Emissions (lb/hr)] x [Hours of Operation (hr/yr)] / [2,000 lb/ton]

Hours of Operation (hr/yr) = 8,760

LDAR Program Reduction = 60% Based on 60% reduction for quarterly LDAR per PADEP GP5 support Document

(e) Refrigerant not a HAP

Notes:

(1) EPA-453/R-95-017 Protocol for Equipment Leak Emission Estimates, EPA, November 1995. Table 2-4. Oil and Gas Production Operations Average Emission Factors (page 2-15), total organic compounds emission factors (TOC).

(2) EPA-453/R-95-017 Protocol for Equipment Leak Emission Estimates, EPA, November 1995. Table 2-2. Refinery Average Emission Factors (page 2-13), non-methane organic compounds emission factor (VOC).

Export Facility

This sheet calculates the GHG emissions related to exporting LNG from the Gibbstown LNG Export Terminal.

Section A. Results Table

	Upfront Emissions	Ongoing Emissions	Total Emissions
	units	*short tons CO2e/yr*	*short tons CO2e/yr*
Export Facility, 20-year GWP	*see "Construction" tab*	15,394	15,394
Export Facility, 100-year GWP	*see "Construction" tab*	10,510	10,510

Section B. Data and Calculations

Section B1. Natural Gas Throughput

Description	Value	Units	Notes	Source
Amount of natural gas exported		128 bcf/year		

Section B2. Ongoing Emissions from Gibbstown Export Facility

Emissions associated with arrival of tanks/trucks, loading ships, storage. Scaling based on Canada LNG facility example.

Emissions Source	Scale Factor	GHG Emission rate (tonnes/year)			GHG Emission (short tons/year) (AR6 20-year	GHG Emission (short tons/year) (AR6 100-year GWP)	Notes
		CO2	CH4	N2O			
8 Gas turbines	0%	0	0	0	0	0	*Liquefaction not included at the Gibbstown export facility*
4 incinerators	0%	0	0	0	0	0	*Liquefaction not included at the Gibbstown export facility*
2 flare derricks (5 flare sources)	8%	6,576	0.43	0.13	7,324	7,298	*Gibbstown is a smaller facility*
Fugitive sources	8%	0.07	84	0	7,601	2,746	*Gibbstown is a smaller facility*
Shipping activities - domestic marine	8%	418	0	0	469	466	*Gibbstown is a smaller facility*
Shipping activities - International marir	0%	0	0	0	0	0	*Calculated in a separate step*
Total GHG emissions from Project operation, excluding international		6,994	84	0.14	15,394	10,510	

Section C. Sources

Section C1. LNG Canada Example

Source: LNG Canada Export Terminal Environmental Assessment Application. Available at: https://www.jbic.go.jp/ja/business-areas/environment/projects/pdf/62412_24.pdf

Note:

Component	Value	Unit
Number of liquefaction trains	4	trains
Carrier visits per year	350	ships/year
Inlet gas	4.2	bcf/day
Inlet gas	1534.05	bcf/year
Emissions Scale Ratio	8.3%	
Annual LNG production	26	million metric tons per annum (mtpa)
Phase 1 construction length	60	months
Number of berths	2	docks

Table 5.3-8: Estimated GHG Emissions during Construction

Source:	GHG Emissions (tonnes)			Total
	CO2	CH4	N2O	Tonnes CO2e
Land clearing				166137
Site preparation	20190	1.12	8.2	22661
Instrumental, mechanical, electrical installation (Phase 1)	7695	0.43	3.13	8637
Instrumental, mechanical, electrical installation (subsequent phase)	7695	0.43	3.13	8637
Marine terminal construction (Phase 1)	5054	0.5	0.94	5437
Marine terminal construction (subsequent phases)	5054	0.5	0.94	5437
Shipping activities - domestic marine	22779	0.42	1.12	23123
On road transportation	15810	0.18	0.13	15854
Total GHG emissions from construction	84276	3.57	17.58	255742

Note: using AR4 GWP values for CO2e calculation

Table 5.3-9: Estimated GHG Emissions during Operation

Source:	GHG Emission rate (tonnes/year)			
	CO2	CH4	N2O	CO2e
8 Gas turbines	3054358	63	56	3072
4 incinerators	704917	345	208	775636
2 flare derricks (5 flare sources)	78810	5.2	1.5	79398
Fugitive sources	0.89	1002		25056
Shipping activities - domestic marine	5008	0.65	0.15	5067
Shipping activities - International marine	83396	0.59	4.8	84827
Total GHG emissions from Project operation, excluding international marine emissions	3843094	1415	266	3957728

Note: using AR4 GWP values for CO2e calculation

Sea Transportation

This sheet calculates the GHG emissions related to transporting LNG via carrier ship from the Gibbstown LNG Export Terminal to foreign import terminals in Ireland and Puerto Rico.

Section A. Results Table

	Upfront Emissions	Ongoing Emissions	Total Emissions
	units	*units*	*units*
Sea Transportation, 20-year GWP	0	297,218	297,218
Sea Transportation, 100-year GWP	0	192,828	192,828

No upfront emissions related to construction were calculated, under the assumption that the vessels used were already constructed.

Section B. Data and Calculations

Section B1. Natural Gas Throughput

Description	Value	Units	Notes	Source
Amount of natural gas transported via carrier ship	128	bcf/year		

Section B2. Sea Transport Data Inputs

Description	Value	Units	Notes	Source
Days at dock/loading:	1	day		Balcombe et al., 2022.
Days sailing from Texas to Belgium:	16	days		Balcombe et al., 2022.
Unloading days:	1	day		Balcombe et al., 2022.
Return voyage	14	days	includes 13 days of travel and 1 day refueling	Balcombe et al., 2022.
Tonnes of LNG delivered:	67,500	tonnes of LNG delivered to Belgium		Balcombe et al., 2022.
BCF of LNG delivered	3.29	bcf of LNG delivered to Belgium		
Distance from Texas to Belgium and back	20,211	km		Balcombe et al., 2022.
Distance from PA to Ireland and back	16,000	km	Approximate measure using ArcGIS	
Distance from PA to Puerto Rico and back	11,400	km	Approximate measure using ArcGIS	
LNG Exported from Gibbstown	128	bcf natural gas/year		
Equivalent trips needed per year	39	Belgium equivalent trips per year		
Percent of LNG to Ireland	50%	%		
Percent of LNG to Puerto Rico	50%	%		
Trips to Ireland per year	19	trips/year		
Trips to Puerto Rico per year	19	trips/year		
Ireland % of Belgium Emissions per trip	79%	%		
Puerto Rico % of Belgium Emissions per trip	56%	%		

Section B3. Sea Transport Emission Calculations

Description	Value	Units	Notes	Source
CO2 emissions	4,600	tonnes CO2		Balcombe et al., 2022.
CH4 emissions	68	tonnes CH4	This is equivalent to 0.1% of the delivered LN	Balcombe et al., 2022.
CO2 emissions	5,069	short tons CO2 per trip		
CH4 emissions	75	short tons CH4 per trip		
CO2 emissions, to Ireland	78,131	short tons of CO2 per year		
CO2 emissions, to PR	55,669	short tons of CO2 per year		
CH4 emissions, to Ireland	1,157	short tons of CH4 per year		
CH4 emissions, to PR	824	short tons of CH4 per year		
Total CO2 emissions	133,800	short tons of CO2 per year		
Total CH4 emissions	1,981	short tons of CH4 per year		
Total CH4 emissions (20-year GWP)	163,418	short tons of CO2e per year (20 year GWP)		
Total CH4 emissions (100-year GWP)	59,028	short tons of CO2e per year (100 year GWP)		
Total GHG Emissions (20-year GWP)	297,218	short tons of CO2e per year (20 year GWP)		
Total GHG Emissions (100-year GWP)	192,828	short tons of CO2e per year (100 year GWP)		

Section C. Sources

Section C1. Project Overview and Emissions for LNG Carrier Ship Example

Source: Balcombe, P., D. Heggo, and M. Harrison. June 2022. "Total Methane and CO2 Emissions from Liquefied Natural Gas Carrier Ships: The First Primary Measurements." Environmental Science & Technology. Available at: https://pul

Notes:

Description	Value	Units	Notes
Days at dock/loading:	1	day	Balcombe et al, 2022, Section 2.2. Voyage (Page 9633).
Days sailing from Maine to Belgium:	16	days	Balcombe et al, 2022, Section 2.2. Voyage (Page 9633).
Unloading days:	1	day	Balcombe et al, 2022, Section 2.2. Voyage (Page 9633).
Return voyage	14	days	Includes 13 days of travel and 1 day refueling. Balcombe et al, 2022, Section 2.2. Voyage (Page 9633).
Tonnes of LNG delivered:	67,500	tonnes of LNG delivered to Belgium	Balcombe et al, 2022, Section 2.4. Emissions Modeling (Page 9634).
CO2 emissions	4600	tonnes CO2	Balcombe et al, 2022, Section 2.4. Emissions Modeling (Page 9634).
CH4 emissions	68.1	tonnes CH4	This is equivalent to 0.1% of the delivered LNG. Balcombe et al, 2022, Section 2.4. Emissions Modeling (Page 9634).

Section C2. Supplemental Information for LNG Carrier Ship Example

Source: Balcombe, P., D. Heggo, and M. Harrison. June 2022. "Total Methane and CO2 Emissions from Liquefied Natural Gas Carrier Ships: The First Primary Measurements: Supplemental Information." Environmental Science & Technol

Notes:

Description	Value	Units	Notes
Distance Traveled	20210.7	km	Round trip distance, less distance traveled before loading.

Regasification Facility

This sheet calculates the GHG emissions related to foreign regasification of LNG that passed through the Gibbstown LNG Export Terminal.

Section A. Results Table

	Upfront Emissions *units*	Ongoing Emissions *Short tons of CO2e/year*	Total Emissions *Short tons of CO2e/year*
Regasification Facility, 20-year GWP	0	115,642	115,642
Regasification Facility, 100-year GWP	0	112,976	112,976

No upfront emissions were calculated, under the assumption that the infrastructure is already built.

Section B. Data and Calculations

Section B1. Natural Gas Throughput

Description	Value	Units	Notes	Source
Amount of natural gas regasified		128 bcf/year		

Section B2. Everett LNG Terminal Average Emission Rates

	CO2	CH4	N2O
Derived Emissions Rate (Metric Tons of GHG / mmcf)	0.79	3.59E-04	1.46E-06
Derived Emissions Rate (short tons GHG / mmcf)	0.87	3.95E-04	1.61E-06

Section B3. Scaled Regasification Emissions

	CO2	CH4	N2O	Total CO2e
Total Emissions (short tons GHG)	111,412	50.59	0.21	N/A
Total Emissions (short tons CO2e, 20-year GWP)	111,412	4,174	56	115,642
Total Emissions (short tons CO2e, 100-year GWP)	111,412	1,508	56	112,976

Section C. Sources

Section C1. LNG Shipment Data for Everett LNG Terminal

Source: US Environmental Protection Agency. "Distrigas of Massachusetts LLC." GHG Data. Available at: https://ghgdata.epa.gov/ghgp/service/facilityDetail/2020?id=10037

Notes: The Everett LNG Terminal in Everett, MA is used to scale the Regasification emissions, because the facility is relatively similar in size capacity of the Gibbstown L

Reported GHG Emissions from EPA Facility Level Data Tool, Department of Energy.

Year	Annual LNG Imports (MMCF)	CO2 (metric tons)	CH4 (metric tons)	N2O (metric tons)	CO2 (metric tons/mmcf)	CH4 (metric tons/mmcf)	N2O (metric tons/mmcf)
2011	135,278	112,929	25	0.211	0.83	1.86E-04	1.56E-06
2012	86,609	71,522	19	0.133	0.83	2.22E-04	1.54E-06
2013	63,987	49,242	21	0.091	0.77	3.31E-04	1.42E-06
2014	28,825	17,728	13	0.032	0.62	4.54E-04	1.11E-06
2015	49,683	34,859	13	0.063	0.70	2.68E-04	1.27E-06
2016	69,928	58,241	24	0.109	0.83	3.45E-04	1.56E-06
2017	63,936	53,771	16	0.101	0.84	2.48E-04	1.58E-06
2018	50,636	41,210	18	0.079	0.81	3.62E-04	1.56E-06
2019	35,406	29,912	14	0.055	0.84	4.08E-04	1.55E-06
2020	29,396	23,787	12	0.044	0.81	4.17E-04	1.50E-06
2021	21,423	17,132	15	0.031	0.80	7.03E-04	1.45E-06

Foreign Transport to Combustion Facility

This sheet calculates the GHG emissions related to transporting natural gas via pipeline from a foreign regasification facility to an end use combustion site, for gas that passed through the Gibbstown LNG Export Terminal.

Section A. Results Table

	Upfront Emissions	Ongoing Emissions	Total Emissions
	units	*short tons CO2e (20 year GWP)*	*short tons CO2e (20 year GWP)*
Foreign Transport to Combustion Facility, 20-	0	7,208	7,208
Foreign Transport to Combustion Facility, 100	0	2,604	2,604

No upfront emissions were calculated, under the assumption that the infrastructure is already built.

Section B. Data and Calculations

Section B1. Natural Gas Throughput

Description	Value	Units	Notes	Source
Amount of natural gas transported	128	bcf/year		

Section B2. Processing and Transmission Emissions Factors

Description	Value	Units	Notes	Source
Processing emissions per facility	3,173	kg CH4/facility		Littlefield et al., 2019.
Processing throughput per facility	33.6	Bcf/facility-year		Littlefield et al., 2019.
Transmission emissions per throughput	1.8	kg CH4/MMscf NG dehydrated		Littlefield et al., 2019.
Transmission emissions per mile	1,120	kg CH4/mile		Littlefield et al., 2019.

Section B3. Pipeline Emissions

Description	Value	Units	Notes	Source
Miles of transmission in Ireland	40	miles	This assumes transmission of the natural gas from a coastal import terminal to the a nearby power plant in Ireland.	
Miles of transmission in Puerto Rico	20	miles	This assumes transmission of the natural gas from a coastal import terminal to a nearby power plant in Puerto Rico.	
Miles of transmission:	60	miles		
Transmission emissions	67,200	kg CH4		
Transmission emissions	74	short tons CH4		
Transmission emissions	6,109	short tons CO2e (20 year)		
Transmission emissions	2,207	short tons CO2e (100 year)		

Section B4. Processing Emissions

Description	Value	Units	Notes	Source
Processing/Pneumatics Emissions	3.81	facilities used/year		
Processing/Pneumatics Emissions	12,088	kg CH4 / year		
Processing/Pneumatics Emissions	13	short tons CH4		
Processing/Pneumatics Emissions	1,099	short tons CO2e (20 year)		
Processing/Pneumatics Emissions	397	short tons CO2e (100 year)		

Section C. Sources

Section C1. Source for Exhibit 3-16. GHGI Emission and Activity Factors and Corresponding Natural Gas Throughput

Source: Littlefield, J., S. Roman-White, D. Augustine, A. Pegallapati, G. G. Zaimes, S. Rai, G. Cooney, and T. J. Skone. April 2019. "Life Cycle Analysis of Natural Gas Extraction and Power Generation." Nationa

Notes:

Exhibit 3-16. GHGI Emission and Activity Factors and Corresponding Natural Gas Throughput

Stage (or substage)	Emission Source	Vent	Fugitive	GHGI Emission Factor	Emissions nits (annualize	Activity Factor	Natural Gas Throughput Units	Throughput	Units
Production	Well drilling	•		52	:H4/completed	*	:ompleted well	EUR*	Bcf/well-life
	Compressor blowdowns	•		77	; CH4/compress	0.078 *	ompressors/we wells	nual productio	Mcf/basin-yr
	PRV (pressure relief valve) upsets	•		0.70	kg CH4/PRV	2.4 *	PRV/well wells	nual productio	Mcf/basin-yr
	Vessel blowdowns	•		1.6	kg CH4/vessel	0.93 *	vessels/well wells	nual productio	Mcf/basin-yr
Gathering	Mishaps	•		14	kg CH4/mile	81 0.67	wells/facility miles/well	nual productio	Mcf/basin-yr
Processing	Pneumatics	•		3,173	kg CH4/facility	1	facilities	33.6	Bcf/facility-yr
Transmission	Dehydrator vents	•		1.8	kg CH4/MMscf NG dehydrated	1.19E+06	MMscf NG	28.2	Tcf transmission
Transmission Pipeline	Pipeline fugitives		•	1,120	kg CH4/mile	301,257	miles	28.2	Tcf transmission
Storage	Dehydrator vents	•		2.3	kg CH4/MMscf dehydrated	1.85E+06	Mscf dehydrat	9.24	Tcf capacity
	Station venting	•		84,000	kg CH4/station	*	:f station capac	9.24	Tcf capacity
Distribution	Customer meters (residential)		•	1.5	kg CH4/meters	5.43E+07	meters	13.9	Tcf distributed
	Customer meters (commercial/industrial)		•	9.7	kg CH4/meter	5.66E+06	meters	13.9	Tcf distributed
	PRV (pressure relief valve) upsets	•		1.00	kg CH4/mile	1.28E+06	miles	13.9	Tcf distributed
	Pipeline blowdowns	•		2.00	kg CH4/mile	2.19E+06	miles	13.9	Tcf distributed
	Mishaps (dig ins)	•		31	kg CH4/mile	2.19E+06	miles	13.9	Tcf distributed

* In some instances, throughput is variable across basins and extraction technologies. This variability is based on NETL's stratification of the data by basins and extraction technologies. Variability in activity factors are based on stratification of GHGRP data as shown in **Exhibit 3-8** through **Exhibit 3-15**, and variability in natural gas throughputs are based on stratification of DI Desktop data.

Combustion Facility

This sheet calculates the GHG emissions related to end use natural gas combustion for gas that passed through the Gibbstown LNG Export Terminal.

Section A. Results Table

	Upfront Emissions *units*	Ongoing Emissions *Short Tons of CO2e*	Total Emissions *Short Tons of CO2e*
Combustion Facility, 20-year GWP	0	7,685,521	7,685,521
Combustion Facility, 100-year GWP	0	7,677,865	7,677,865

No upfront emissions were calculated, under the assumption that the infrastructure is already built.

Section B. Data and Calculations

Section B1. Natural Gas Throughput

Description	Value	Units	Notes	Source
Amount of natural gas combusted		128 bcf/year		

Section B2. Emissions Calculations for End Use Combustion

Pollutant	Emissions Rate (kg of GHG/scf)	Total Emissions (kg of GHG)	Total Emissions (kg of CO2e, 20-	Total Emissions (kg of CO2e, 100-year GWP)	Total Emissions (short tons of	Total Emissions (short tons of
CO2	0.0544	6,963,200,000	6,963,200,000	6,963,200,000	7,673,446	7,673,446
CH4	0.000001030	131,840	10,876,800	3,928,832	11,986	4,330
N2O	0.0000	294	80,371	80,371	89	89
Total CO2e					7,685,521	7,677,865

Section C. Sources

Section C1. Emissions Factors for GHGs from Natural Gas Combustion

Source:	US Environmental Protection Agency. January 2016
Notes:	Table A-1: Emission Factors for Equation 1 (EF1) - I

Pollutant	Units	Emissions Rate
CO2	kg CO2/scf	0.05
CH4	g CH4/scf	0.00103
N2O	g N2O/scf	0.0000023