Updated Natural Gas Pathways in GREET 2022

by
A. Burnham
Systems Assessment Center
Energy Systems Division, Argonne National Laboratory

October 2022

CONTENTS

TABLES

Updated Natural Gas Pathways in GREET 2022

Andrew Burnham

Argonne National Laboratory

October 2022

1 BACKGROUND

Argonne National Laboratory researchers have been analyzing the environmental impacts of natural gas (NG) production and use for more than 20 years. With the rapid development of shale gas production in the past few years, significant efforts have been made to examine various stages of natural gas pathways to estimate their life-cycle impacts. In 2011, Argonne researchers examined the uncertainty associated with key parameters for shale gas and conventional NG pathways to identify data gaps that required further attention (Clark et al. 2011). Clark et al. (2011) based much of their analysis of methane (CH_4) emissions on the United States Environmental Protection Agency's (EPA's) 2011 greenhouse gas inventory (GHGI), as this was the first EPA GHGI to incorporate shale gas and included significant revisions to its liquid unloading leakage estimates (EPA 2011). In addition, the report examined the water, materials, and fuel needed to drill and construct NG wells. From 2013 to 2016, Argonne researchers updated the GREET model based on EPA's latest GHG inventories, which included several methodological changes for estimating natural gas CH_4 emissions (Burnham et al. 2013; Burnham et al. 2014; Burnham et al. 2015; Burnham 2016). In 2015 and 2017, Argonne analyzed the environmental impacts, including CH_4 leakage and air pollutant emissions, of heavy-duty natural gas vehicles (Cai et al. 2015; Cai et al. 2017). In 2017, GREET was updated based on the work documented in Cai et al. (2017), which examined natural gas vehicle upstream freshwater consumption, greenhouse gas (GHG) emissions, and nitrogen oxides (NO_x) and particulate matter (PM) emissions as well as supplementary analysis of the 2017 EPA GHGI (Burnham 2017).

One of the key challenges in estimating fugitive greenhouse gas emissions for natural gas pathways is the discrepancies between the results from bottom-up analyses and top-down analyses (Burnham et al. 2014; Burnham et al. 2015). Brandt et al. (2014) reviewed the technical literature published on natural gas CH_4 emissions in previous 20 years that measured leakage from individual devices or facilities (bottom-up analysis) as well as atmospheric measurements (top-down analysis) in order to better understand the discrepancies between the estimates from the two approaches. Brandt et al. (2014) found that national scale atmospheric measurements suggest EPA's total CH_4 inventory undercounts emissions by 50% (+/- 25%), though they discuss the difficulties in trying to attribute the emissions to specific sectors (e.g. natural gas, petroleum, coal, agricultural, landfills). Those atmospheric measurements point to the NG sector for unaccounted emissions and that a small fraction of "superemitters" (e.g. sources with extremely high emissions, much larger than normal operation) was likely an important reason why the estimates from airborne measurements were typically higher than inventories.

From 2013 to 2018, a collaboration of the Environmental Defense Fund (EDF), universities, research institutions, and companies have completed 16 projects to collect data on methane emissions from the natural gas supply chain (EDF 2018). The EPA has incorporated data from these efforts, (e.g. updated emission factors for production, processing, transmission, and distribution equipment) to improve its GHGI (Burnham et al. 2015). In 2018, EDF and many of its collaborators published an analysis synthesizing data collected across the 16 projects (Alvarez et al. 2018). The researchers, similar to Brandt et al. (2014) but with updated data, used a bottom-up analysis supplemented by a top-down analysis (covering 30% of U.S. gas production) to estimate national CH_4 emissions from natural gas and oil supply chains. Their facility-based estimate of 2015 NG and oil supply chain emissions was ~60% higher than the U.S. EPA GHGI estimate. Alvarez et al. (2018) facility-based methodology uses downwind measurements which, unlike solely relying on component-based calculations as done in the GHGI, can capture emissions released during abnormal operating conditions.

Following up on the Brandt et al. (2014) and Alvarez et al. (2018) studies, Rutherford et al. (2021) developed a new bottom-up inventory-based CH_4 emissions model for natural gas and oil production activities. This work also found that the EPA GHGI was undercounting emissions and that the main source of divergence between their and EPA estimates were unintentional emissions from liquid storage tanks and other equipment leaks. Rutherford et al. (2021) estimate of 2015 NG and oil production CH_4 emissions was ~83% higher than the U.S. EPA GHGI estimate, while Alvarez et al. (2018) estimate was ~117% higher.

These synthesis studies have consistently demonstrated that the EPA GHGI is undercounting emissions. In GREET 2021, we changed the default CH_4 emissions to be based on a hybrid bottom-up and top-down approach using the analyses of Alvarez et al. (2018) and Rutherford et al. (2021) to scale emissions from the latest GHGI (Burnham 2021). We still provide the EPA GHGI data as an option for users to select. In GREET 2022, both the default hybrid option and the EPA option are updated based on the latest GHGI’s detailed process-level emissions.

2 DATA

2.1 EPA Upstream Greenhouse Gas

Table 1 and Table 2 list the key parameters and data sources for upstream greenhouse gas emissions from EPA natural gas pathways used to update GREET1_2022. The data from EPA (2022) and EIA (2021 and 2022) natural gas throughput is for calendar year 2020. The EPA (2022) GHGI data update resulted in slightly higher (about 5%) methane emissions, with the increase largely due to new estimates of post-meter emissions. The natural gas throughput decreased about 1% percent from 2019 to 2020 (EIA 2022).

2.2 Emissions Hybrid Bottom-Up and Top-Down Upstream Greenhouse Gas Emissions

Table 3 lists the key parameters and data sources for methane leakage for the hybrid bottom-up and top-down option based on Alvarez et al. (2018) and Rutherford et al. (2021). The hybrid estimate for NG production emissions is based on Rutherford et al. (2021) methane emissions for natural gas production stages, which we matched to the EPA GHGI categories we use (i.e. completion, workover, liquid unloading, and well equipment). However, Rutherford et al. (2021) does not examine gathering and boosting (G&B) emissions; therefore, we use the G&B data from Alvarez et al. (2018).

For the NG production, processing, transmission, and distribution emissions we scaled our EPA 2022 results (Table 1), by the ratio of the hybrid's source-based results as compared to EPA's GHGI results. As seen in Table 4, hybrid GREET1_2022 production estimates are about 50% higher than EPA 2022 estimates, while processing and transmission are 60% and 40% higher, respectively. Neither Rutherford et al. (2021) nor Alvarez et al. (2018) examine emissions from the NG distribution sector, so EPA GHGI values are used. In total, the hybrid GREET1_2022 emission results are about 40% higher than EPA 2022 results.

Table 1 Key Parameters for EPA Natural Gas Simulations in GREET1_2022

	Units	Conventional	Shale	Source/Notes
Well Lifetime	Years	30	30	ANL assumption
Well Methane Content	mass %	76	84	EPA 2022
NG Production over Well Lifetime	NG billion cubic feet	N/A	1.6	INTEK 2011
NG Production over Well Lifetime	NG million Btu	N/A	1,600,000	INTEK 2011 and ANL: NG LHV
NGL Production over Well Lifetime	NGL million Btu	N/A	460,100	EPA 2022 and EIA 2016
Well Completion and Workovers (Vent)	metric ton NG per completion	0.71	3.5	Conv: EPA 2010 Shale: EPA 2022
Well Completion and Workovers (w/ REC)	metric ton NG per completion	N/A	3.1	EPA 2022
Well Completions that Vent	%	N/A	1	EPA 2022
Well Workovers that Vent	%	N/A	5	EPA 2022
Average Number of Workovers per Well Lifetime	Workovers occurrences per lifetime	0.2	0.2	EPA 2012
Liquid Unloading (Vent)	g CH_4 per million Btu NG	3	3	EPA 2022
Gathering and Boosting (Leak/Vent)	g CH_4 per million Btu NG	28	28	EPA 2022
Well Equipment (Leak/Vent)	g CH_4 per million Btu NG	45	45	EPA 2022
Well Equipment Flaring	Btu NG per million Btu NG	2,044	2,030	EPA 2022
Well Equipment (CO_2 from Venting)	g CO_2 per million Btu NG	80	80	EPA 2022
Processing (Leak/Vent)	g CH_4 per million Btu NG	4	4	EPA 2022
Processing Flaring	Btu NG per million Btu NG	3,405	3,405	EPA 2022
Processing (CO_2 from Venting)	g CO_2 per million Btu NG	449	449	EPA 2022
Transmission and Storage (Leak/Vent)	g CH_4 per million Btu NG	49	49	EPA 2022
Distribution (Leak/Vent)	g CH_4 per million Btu NG	27	27	EPA 2022
Distribution - Station (Leak/Vent)	g CH_4 per million Btu NG	20	20	EPA 2022 and EIA 2013

Table 2 Natural Gas and Crude Throughput by Stage for GREET1_2022

	Units	Values	Sources
Dry NG Production	Quadrillion Btu	32.9	EIA 2022
NGL Production	Quadrillion Btu	6.3	EIA 2021
NG Production Stage (Dry NG and NGL)	Quadrillion Btu	39.2	EIA 2022 and EIA 2021
NG Processing Stage (Dry NG and NGL)	Quadrillion Btu	39.2	EIA 2022 and EIA 2021
NG Transmission	Quadrillion Btu	32.9	EIA 2022
Percent of Local Distribution NG Deliveries	%	63.0	EIA 2013
NG Distribution	Quadrillion Btu	20.6	EIA 2022 and EIA 2013

Table 3 Hybrid CH_4 Emissions by Stage for GREET1_2022

	Units	EPA GHGI	Hybrid	Sources
NG Production: Completion	gigagram	32	34	Rutherford et al. 2021 and EPA 2021
NG Production: Workover	gigagram	11	2	Rutherford et al. 2021 and EPA 2021
NG Production: Liquid Unloading	gigagram	168	244	Rutherford et al. 2021 and EPA 2021
NG Production: Well Equipment	gigagram	1,793	3,052	Rutherford et al. 2021 and EPA 2021
NG Production: Gathering and Boosting	gigagram	2,300	2,600	Alvarez et al. 2018
NG Processing	gigagram	450	720	Alvarez et al. 2018
NG Transmission	gigagram	1,300	1,800	Alvarez et al. 2018
NG Distribution	gigagram	440	440	Alvarez et al. 2018

Table 4 Summary of Differences in CH_4 Emissions per Throughput of Each Stage between EPA and Hybrid data in GREET1_2022

Sector	Process	Unit	EPA Conven-tional GREET1_2022	EPA Shale GREET1_2022	Hybrid Conven-tional GREET1_2022	Hybrid Shale GREET1_2022	Hybrid Conven-tional % Change	Hybrid Shale % Change
Production	Completion	g CH_4 /million Btu NG	0.5	1.3	0.6	1.4	5%	5%
	Workover		0.0	0.3	0.0	0.1	-79%	-79%
	Liquid Unloading		3.3	3.3	4.8	4.8	46%	46%
	Well Equipment		45.1	45.1	76.7	76.7	70%	70%
	Gathering and Boosting		27.6	27.6	31.2	31.2	13%	13%
	Total		**76.5**	**77.5**	**113.3**	**114.2**	**48%**	**47%**
Processing	Processing		3.8	3.8	6.0	6.0	60%	60%
Transmission	Transmission and Storage		48.8	48.8	67.6	67.6	38%	38%
Distribution	Distribution		27.1	27.1	27.1	27.1	0%	0%
Distribution	Distribution (station pathway)		19.6	19.6	19.6	19.6	0%	0%
Total			**156.2**	**157.2**	**214.0**	**214.9**	**37%**	**37%**
Total (station pathway)			**148.7**	**149.7**	**206.6**	**207.4**	**39%**	**39%**

3 REFERENCES

Alvarez, R., et al., 2018, Assessment of methane emissions from the U.S. oil and gas supply chain, Science, DOI: 10.1126/science.aar7204.

Burnham et al. 2013. "Updated Fugitive Greenhouse Gas Emissions for Natural Gas Pathways in the GREET^{TM} Model," Argonne National Laboratory.

Burnham et al. 2014. "Updated Fugitive Greenhouse Gas Emissions for Natural Gas Pathways in the GREET1_2014 Model," Argonne National Laboratory.

Burnham et al. 2015. "Updated Fugitive Greenhouse Gas Emissions for Natural Gas Pathways in the GREET1_2015 Model," Argonne National Laboratory.

Burnham. 2016. "Updated Fugitive Greenhouse Gas Emissions for Natural Gas Pathways in the GREET1_2016 Model," Argonne National Laboratory.

Burnham. 2017. "Updated Natural Gas Pathways in the GREET1_2017 Model," Argonne National Laboratory.

Burnham. 2021. "Updated Natural Gas Pathways in the GREET 1_2021 Model," Argonne National Laboratory.

Clark et al. 2011. "Life-Cycle Analysis of Shale Gas and Natural Gas, Coal, and Petroleum," ANL/ESD/11-11, Argonne National Laboratory.

EDF. 2018. Methane research series: 16 studies, http://www.eia.gov/cfapps/ngqs/ngqs.cfm. (accessed September 25, 2018).

EIA. 2013. Natural Gas Annual Respondent Query System (EIA-176 Data through 2011), http://www.eia.gov/cfapps/ngqs/ngqs.cfm. (accessed September 15, 2015).

EIA. 2021. "Natural Gas Annual 2020," U.S. EIA: Washington, DC. September 30. https://www.eia.gov/naturalgas/annual/pdf/nga20.pdf. (accessed September 14, 2022).

EIA. 2022. U.S. Natural Gas Summary: Natural Gas Gross Withdrawals and Production, http://www.eia.gov/dnav/ng/ng_prod_sum_dcu_NUS_a.htm. (accessed September 14, 2022).

EPA. 2010. "Greenhouse Gas Emissions Reporting from the Petroleum and Natural Gas Industry, Background Technical Support Document," U.S EPA: Washington, DC.

EPA. 2011. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009," EPA 430-R-13-005; U.S. EPA: Washington, DC.

EPA. 2012. "Oil and Natural Gas Sector: Standards of Performance for Crude Oil and Natural Gas Production, Transmission, and Distribution, Background Supplemental Technical Support Document for the Final New Source Performance Standards," U.S. EPA: Washington, DC.

EPA. 2021. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019," EPA 430-R-21-005; U.S. EPA: Washington, DC.

EPA. 2022. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020," EPA 430-R-22-003; U.S. EPA: Washington, DC.

INTEK, Inc. and U.S. EIA. 2011. "Review of Emerging Resources: U.S. Shale Gas and Shale Oil Plays," U.S. EIA: Washington, DC.

Rutherford, J. S., et al. 2021. Closing the methane gap in US oil and natural gas production emissions inventories. Nature Communications, 12(1), 1–12.