Updated Fugitive Greenhouse Gas Emissions for Natural Gas Pathways in the GREET1_2016 Model

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1 BACKGROUND

Argonne National Laboratory researchers have been analyzing the environmental impacts of natural gas (NG) production and use for more than 15 years. With the rapid development of shale gas production in the past few years, significant efforts have been made to examine the methane (CH_4) emissions from various stages of natural gas pathways to estimate their life-cycle greenhouse gas (GHG) emissions. 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 (Burnham et al. 2011). Burnham et al. (2011) based much of their analysis 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). From 2013 to 2015, 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). Methane emissions continue to receive significant scrutiny as many studies have analyzed whether the EPA's inventory fully captures the actual emissions from the natural gas industry. In addition to properly estimating emissions, regulatory and voluntary efforts have been proposed to reduce current emissions. The Obama Administration has set a goal to reduce oil and gas CH_4 emissions by 40-45% from 2012 levels by 2025, so further scrutiny of the sources of these emissions is needed (White House, 2015).

While many analyses have found shortcomings in the EPA's GHGI, the EPA has worked each year to update its data and methodology. Therefore, as we need detailed process-level emissions, we used the 2016 EPA GHGI to update GREET. We will continue to monitor and evaluate emerging research in this area and update GREET accordingly.

2 DATA

2.1 Key GREET Parameters

Table 1 and Table 2 list the key parameters and data sources for natural gas pathways used to update GREET1_2016. The data from EPA (2016) and EIA (2015 and 2016) natural gas throughput is for calendar year 2014. In the following sections, we briefly summarize where changes have occurred since the previous release of GREET (Burnham et al. 2015).

2.2 Shale Gas Well Completion and Workover CH_4 Emissions

In the latest inventory, the EPA (2016) incorporated the latest Greenhouse Gas Emissions Reporting Program (GHGRP) data into their estimate of net (i.e. controlled) emission factors for completions and workovers. The EPA continues to separate completions and workovers into four categories: (1) hydraulic fracturing completions and workovers that vent, (2) flared hydraulic fracturing completions and workovers, (3) hydraulic fracturing completions and workovers with reduced emission completions (RECs), and (4) hydraulic fracturing completions and workovers with RECs that flare. The GHGI shows that 2014 CH_4 emission rates for each category, which is the average of 2011-2014 GHGRP data, has stayed the same with the addition of 2014 data (EPA 2016).

EPA also uses the GHGRP dataset to estimate completion and workover activity data, which were also updated to take into account changes in REC counts and flaring. We use these activity data to estimate the percentage of wells that vent versus the ones that use RECs. From 2013 to 2014, the percentage of wells that vent increased from 35% to 63%. Flaring emissions from completions and workovers are included in the shale gas "well equipment flaring" category in Table 1.

Table 1 Key Parameters for Natural Gas Simulations in GREET1_2016

	Units	Conventional	Shale	Source/Notes
Well Lifetime	Years	30	30	Argonne assumption
Well Methane Content	mass %	76	83	EPA 2016
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 Argonne assumption of NG LHV
NGL Production over Well Lifetime	NGL million Btu	N/A	242,000	EPA 2016 and EIA 2015
Well Completion and Workovers (Venting)	metric ton NG per completion or workover	0.71	37	Conv: EPA 2010 and Shale: EPA 2016
Well Completion and Workovers (w/ REC)	metric ton NG per completion or workover	N/A	3	EPA 2016
Well Completions/ Workovers that Vent	%	N/A	63	EPA 2016
Controlled CH_4 Reductions for Completion/Workovers	%	0	0	EPA 2016
Average Number of Workovers per Well Lifetime	Workovers occurrences per lifetime	0.2	0.2	EPA 2012
Liquid Unloading (Venting)	g CH_4 per million Btu NG	9	9	EPA 2016
Controlled CH_4 Reductions for Liquid Unloading	%	0	0	EPA 2016
Potential Well Equipment (Leakage and Venting)	g CH_4 per million Btu NG	150	150	EPA 2016
Controlled CH_4 Reductions for Well Equipment	%	10	10	EPA 2016

Table 1 (Cont.)

	Units	Conventional	Shale	Source/Notes
Well Equipment Flaring	Btu NG per million Btu NG	10,486	10,327	EPA 2016
Well Equipment (CO_2 from Venting)	g CO_2 per million Btu NG	17	17	EPA 2016
Processing (Leakage and Venting)	g CH_4 per million Btu NG	26	26	EPA 2016
Processing (CO_2 from Venting)	g CO_2 per million Btu NG	819	819	EPA 2016
Transmission and Storage (Leakage and Venting)	g CH_4 per million Btu NG	75	75	EPA 2016
Distribution (Leakage and Venting)	g CH_4 per million Btu NG	28	28	EPA 2016
Distribution - Station (Leakage and Venting)	g CH_4 per million Btu NG	18	18	EPA 2016 and EIA 2013

Table 2 Natural Gas Throughput by Stage for GREET1_2016

	Units	Values	Sources
Dry NG Production	Quadrillion Btu	25.3	EIA 2016
NGL Production	Quadrillion Btu	3.7	EIA 2015
NG Production Stage (Dry NG and NGL)	Quadrillion Btu	29.0	EIA 2016 and EIA 2015
NG Processing Stage (Dry NG and NGL)	Quadrillion Btu	29.0	EIA 2016 and EIA 2015
NG Transmission	Quadrillion Btu	25.3	EIA 2016
Percent of Local Distribution NG Deliveries	%	63.0	EIA 2013
NG Distribution	Quadrillion Btu	15.8	EIA 2016 and EIA 2013

2.3 Summary

Table 3 summarizes the CH_4 fugitive emission for both shale and conventional NG in GREET1_2016 and compares them to previous estimates in GREET1_2015. Shale gas CH_4 emissions are increased significantly as a greater percentage of wells vented, while flaring has also increased (as seen in Table 1). Liquid unloading emissions was reduced slightly, while the well equipment category increased dramatically as gathering and boosting emissions were significantly revised. In addition, transmission and distribution were much lower than previous estimates. The data behind these changes were developed in part through a collaboration of the Environmental Defense Fund, universities, research institutions, and companies (Marchese et al. 2015, Zimmerle et al. 2015, Lamb et al. 2015). While individual sector emissions have large changes, the overall numbers are up by about 4% to 6%.

Table 4 compares the leakage rate based on NG throughput by stage from several EPA reports with those used in the GREET1_2016 model, while Table 5 lists reported and calculated leakage rates based on gross NG production of various studies, though leakage rates are not always comparable if they use different denominators.

The EPA's estimates of NG system CH_4 emissions have decreased significantly since its 2011 inventory with inclusion of the latest bottom-up studies, while top-down analyses suggest these CH_4 emissions should be higher. We will continue to update GREET as more research is pursued to reduce the discrepancies between bottom-up and top-down analyses of CH_4 emissions in the NG system.

Table 3 Summary of Differences in CH_4 Emissions per Throughput of Each Stage between GREET1_2015 and GREET1_2016

Sector	Process	Unit	Conventional GREET1_2015	Shale GREET1_2015	Conventional GREET1_2016	Shale GREET1_2016	Conventional % Change	Shale % Change
Production	Completion	g CH_4/million Btu NG	0.5	7.2	0.5	11.8	0%	64%
	Workover		0.0	1.4	0.0	2.4	0%	64%
	Liquid Unloading		9.6	9.6	9.0	9.0	-6%	-6%
	Well Equipment		52.2	52.2	134.9	134.9	159%	159%
Processing	Processing	g CH_4/million Btu NG	26.7	26.7	26.2	26.2	-2%	-2%
Transmission	Transmission and Storage	g CH_4/million Btu NG	84.5	84.5	74.6	74.6	-12%	-12%
Distribution	Distribution	g CH_4/million Btu NG	88.9	88.9	28.0	28.0	-68%	-68%
Distribution	Distribution (station pathway)	g CH4/million Btu NG	69.1	69.1	17.7	17.7	-74%	-74%
Total		**g CH_4/million Btu NG**	**262.4**	**270.5**	**273.2**	**286.9**	**4%**	**6%**
Total (station pathway)		**g CH_4/million Btu NG**	**242.5**	**250.6**	**262.9**	**276.6**	**8%**	**10%**

Table 4 GREET and EPA Leakage Rates Based on NG Throughput by Stage

	CH_4 Emissions: Percent of Volumetric NG Stage Throughput						
Sector	EPA GHGI - 5yr avg (2011)	EPA GHGI - 2011 Data (2013)	EPA GHGI - 2012 Data (2014)	EPA GHGI - 2013 Data (2015)	EPA GHGI - 2014 Data (2016)	GREET - Conv. Gas (2016)	GREET - Shale Gas (2016)
Gas Field	1.32	0.45	0.34	0.34	0.71	0.70	0.77
Completion/ Workover						0.00	0.07
Unloading						0.04	0.04
Other Sources						0.65	0.65
Processing	0.17	0.12	0.13	0.16	0.13	0.13	0.13
Transmission and Storage	0.49	0.44	0.39	0.44	0.36	0.36	0.36
Distribution	0.57	0.36	0.40	0.43	0.14	0.14	0.14
Total	2.53	1.37	1.25	1.36	1.33	1.32	1.38

Table 5 Selected Leakage Rates Based on Gross NG Production

	CH$_4$ Emissions: Percent of Volumetric NG Stage Throughput									
Sector	EPA GHGI - 2011 data (2013)[a]	Univ. Texas - Production (2013)[b]	EPA GHGI - 2012 data (2014)[c]	Stanford - US (2014)[d]	IUP - Bakken (2014)[e]	IUP - Eagle Ford (2014)[e]	EPA GHGI - 2013 data (2015)[f]	CSU / WSU - US Combined (2015)	Harvard - Boston (2015)[j]	EPA GHGI - 2014 data (2016)[k]
Gas Field	0.44	0.38	0.33		2.8-17.4	2.9-15.3	0.31	0.58[g]		0.68
Completion/ Workover	0.14	0.03	0.04				0.01			0.01
Unloading	0.04	0.04	0.05				0.04			0.04
Other Sources	0.26	0.31	0.25				0.25			0.63
Processing	0.16		0.15				0.15	0.09[g]		0.15
Transmission and Storage	0.34		0.35				0.36	0.25[h]		0.20
Distribution	0.23		0.21				0.22	0.07[i]	2.1-3.3	0.07
Total	1.17		1.03	3.6-7.1			1.03	0.99		1.11

[a] EPA - US GHGI 2011 data (2013) divided by EIA 2011 gross withdrawals

[b] Univ. Texas - Production (Allen et al 2013) - equipment measurements divided by EIA gross withdrawals, used EPA 2011 data (2013) for some other sources

[c] EPA - US GHGI 2012 data (2014) divided by EIA 2012 gross withdrawals

[d] Stanford - US (Brandt et al. 2014) estimate is based on allocating all excess leakage from NG, oil, and geologic seep sources to the NG industry; values are an upper level bound and not a best estimate

[e] IUP - Bakken and Eagle Ford (Schneising et al. 2014) - leakage rate is based on both NG and oil production in those areas converted to energy basis

[f] EPA - US GHGI 2013 data (2015) divided by EIA 2013 gross withdrawals

[g] CSU / WSU - US Combined – Production and Processing (2015) estimate from Marchese et al. (2015) - NG gathering and processing facility-level emissions used to model US and replaced respective estimates in EPA 2012 GHGI (2014); total production and processing divided by EIA 2012 gross withdrawals

[h] EPA - CSU / WSU - US Combined – Transmission and Storage (2015) estimate from Zimmerle et al. (2015) equipment and site-level measurements and activity data used to model US transmission and storage emissions divided by EIA 2012 gross withdrawals

[i] EPA - CSU / WSU - US Combined – Distribution (2015) estimate from Lamb et al. (2015) direct measurements used to model US distribution emissions divided by EIA 2011 gross withdrawals

[j] Harvard – Boston (McKain 2015) - tower measurements including NG transmission, distribution, and end-use emissions in Boston divided by consumption

[k] EPA - US GHGI 2014 data (2016) divided by EIA 2014 gross withdrawals

3 REFERENCES

Allen et al. 2013. "Measurements of Methane Emissions at Natural Gas Production Sites in the United States," Proceedings of the National Academy of Sciences, September, 16.

Brandt et al. 2014. "Methane Leaks from North American Natural Gas Systems," Science, 343, 733–735.

Burnham et al. 2011. "Life-Cycle Greenhouse Gas Emissions of Shale Gas, Natural Gas, Coal, and Petroleum," Environmental Science & Technology, 46 (2), 619-627.

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.

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. 2015. "Natural Gas Annual 2014," U.S. EIA: Washington, DC. October 31.

EIA. 2016. 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 July 11, 2016).

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. 2013. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011," EPA 430-R-13-001; U.S. EPA: Washington, DC.

EPA. 2014. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012," EPA 430-R-14-003; U.S. EPA: Washington, DC.

EPA. 2015. “Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013,” EPA 430-R-15-004; U.S. EPA: Washington, DC.

EPA. 2016. “Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014,” EPA 430-R-16-002; 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.

Lamb et al. 2015, “Direct Measurements Show Decreasing Methane Emissions from Natural Gas Local Distribution Systems in the United States,” Environmental Science & Technology 49 (8), DOI: 10.1021/es505116p

Marchese et al. 2015, “Methane Emissions from United States Natural Gas Gathering and Processing,” Environmental Science & Technology 49 (17), DOI: 10.1021/acs.est.5b02275

McKain et al. 2015. “Methane emissions from natural gas infrastructure and use in the urban region of Boston, Massachusetts,” Proceedings of the National Academy of Sciences, Vol. 112, No. 7. DOI:10.1073/pnas.1416261112

Schneising et al. 2014. “Remote sensing of fugitive methane emissions from oil and gas production in North American tight geologic formations,” Earth's Future, 2 (10), 548 – 558.

White House. 2015. “FACT SHEET: Administration Takes Steps Forward on Climate Action Plan by Announcing Actions to Cut Methane Emissions,” The White House, Office of the Press Secretary: Washington, DC. January 14.

Zimmerle et al. 2015. “Methane Emissions from the Natural Gas Transmission and Storage System in the United States,” Environmental Science & Technology 49 (15), DOI: 10.1021/acs.est.5b01669