Maryland Department of the Environment

Appendix E

NG Life-Cycle GHG Emissions Inventory Attributable to Fracked Gas in 2017

2030 GGRA Plan

Maryland
Department of
the Environment

Larry Hogan
Governor

Boyd Rutherford
Lieutenant Governor

Ben Grumbles
Secretary

State of Maryland

Natural Gas Life-Cycle Greenhouse Gas Emissions Inventory Attributable to Fracked Gas in 2017

March 12, 2020

Prepared by:
Maryland Department of the Environment
Climate Change Division

Maryland Department of the Environment
2017 GHG Life-Cycle Emissions Inventory from Fracked Natural Gas

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ACRONYMS AND ABBREVIATIONS

µg/m3	microgram(s) per cubic meter
AERMAP	AERMOD terrain preprocessor
AERMET	AERMOD meteorological preprocessor
AERMOD	American Meteorological Society/EPA Regulatory Model
AQS	Air Quality System
BPIPPRM	Building Profile Input Program for the Plume Rise Model Enhancements algorithm
CAA	Clean Air Act
CEV	Critical emission value
CFR	Code of Federal Regulations
COA	Consent Order and Agreement
CSAPR	Cross State Air Pollution Rule (CSAPR)
EGU	Electric Generating Unit
EMF	Emission Modeling Framework
EPA	U.S. Environmental Protection Agency
FGD	Flue gas desulfurization
FIP	Federal Implementation Plan
FR	Federal Register
g/s	gram(s) per second
LAER	Lowest Achievable Emission Rate
lb/hr	pound(s) per hour
MACT	Maximum Achievable Control Technology
MARAMA	Mid-Atlantic Regional Air Management Association
MATS	Mercury and Air Toxic Standards
MDE	Maryland Department of the Environment
NAAQS	National Ambient Air Quality Standard
NEI	National Emission Inventory
NESHAP	National Emission Standards for Hazardous Air Pollutants
NID	Novel integrated desulfurization
NOV	Notice of Violation
NOx	Nitrogen oxides
NSPS	New Source Performance Standards
NSR	New Source Review
ppb	parts per billion
ppm	parts per million
RACM	Reasonably Available Control Measure
RACT	Reasonably Available Control Technology
RFP	Reasonable Further Progress
SCC	Source Classification Code
SIP	State Implementation Plan
SO_2	Sulfur dioxide
SOx	Sulfur oxides
TSD	Technical Support Document
TSP	Total Suspended Particles
TVOP	Title V Operating Permit

TABLE OF CONTENTS

INDEX OF TABLES

INDEX OF EQUATIONS

EXECUTIVE SUMMARY

This report provides an analysis of methane emissions that occur outside of Maryland from the production and transport of fracked natural gas consumed in Maryland. The analysis includes fugitive leakage emissions and well construction emissions. The report uses the total natural gas consumption in Maryland for year 2017 as a baseline and analyzes four scenarios that represent the amount of natural gas consumed due to fracking activities. The first scenario uses the US Energy Information Administration (EIA) statistic that 67% of the natural gas consumed is derived from fracking. The other three cases are based on the fact that before 2006, there was no fracking in Maryland and the surrounding areas. All four scenarios estimate the impact of methane emissions on climate change using both the 100-year methane Global Warming Potential (GWP) for methane and the 20-year GWP from the latest Intergovernmental Panel on Climate Change (IPCC) assessment report (AR5).

The analysis found that Maryland's natural gas consumption in 2017 that was associated with out-of-state fracking resulted in methane emissions ranging from as low as 0.1691 MMTCO2e to as high as 5.545 MMTCO2e, depending on the scenario and choice of 100-year or 20-year GWP (Table ES-1). MDE believes that Scenario 1 is the least accurate case, as it is based on national data. The other three cases are based off Maryland-specific data and thus should be considered more reliable.

Table ES-1: Out-of-state methane emissions associated with natural gas consumption in Maryland in 2017.

Scenario	2017 Emissions (million metric tons CO2 equivalent)	
	100-year GWP	20-year GWP
Scenario 1: National Average Fracking Share	1.93	5.55
Scenario 2: 2017 NG consumption above 2006 consumption	0.55	1.53
Scenario 3: 2017 NG consumption above 1997-2005 average	0.35	0.97
Scenario 4: 2017 NG consumption above 1997-2005 maximum	0.17	0.43

This analysis has been updated with 2017 consumption data, to better compare to Maryland's 2017 Greenhouse Gas Emissions Inventory.

1.0 BACKGROUND

The Maryland Department of the Environment (MDE) was tasked with additional greenhouse gas emission inventory requirements by the Maryland Commission on Climate Change in the 2017 Annual Report. The Maryland Commission on Climate Change recommended[1] the following to MDE:

> The Commission recommends that MDE continue to work with the STWG, the University of Maryland, and the Departments of Natural Resources and Agriculture to ensure that MDE's Greenhouse Gas Emission Inventory is locally relevant and complete. Specifically MDE should continue to examine improvements to: life cycle emissions of fossil fuels extracted out of state but burned in state, and emissions sink methodologies for in-state forests, wetlands, and agriculture. As required by law, this work will be completed by the end of 2018 as part of the final publication of the 2017 emissions inventory

The Maryland Commission on Climate Change through the Mitigation Working Group worded the recommendation to MDE as follows:

> Regarding the State's GHG Emissions Inventory, due in 2018, the MWG recommends that MDE continue to work with the STWG, the University of Maryland, and the Departments of Natural Resources and Agriculture to ensure that the Inventory is both locally relevant and complete. This includes consideration of life-cycle emissions generated by out-of-state extraction, processing, and transportation of fossil fuel energy consumed in-state; and applying advanced methods to generate a more accurate accounting of emissions sinks such as agricultural soil and forestry management.

This report documents MDE's work on the life cycle greenhouse gas emissions of natural gas extracted out of state through fracking but burned in state. MDE published an earlier version of this report in 2018. This update includes more analysis specific to 2017, and estimates using both the 100-year and 20-year GWP for methane.

[1] http://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Documents/MCCC_2017_final.pdf

2.0 PURPOSE AND OBJECTIVE

2.1 Purpose

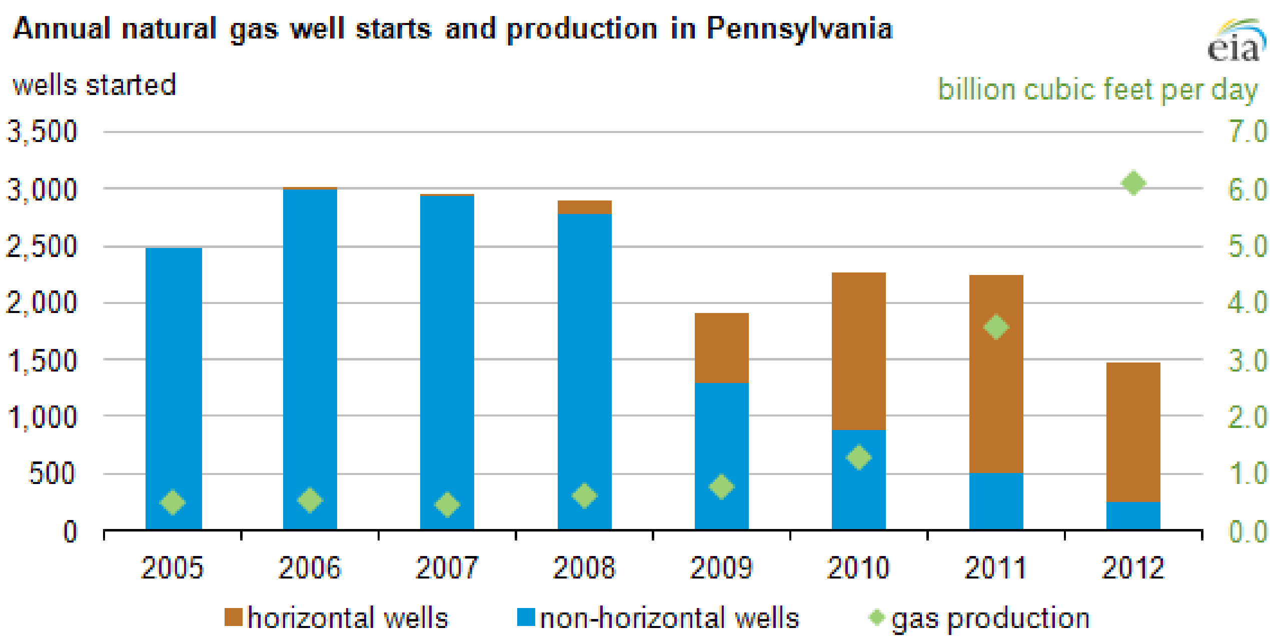
The purpose of this document is to provide a report, complete with methods, data, calculations and references that satisfy the recommendations of the Maryland Commission on Climate Change regarding the life-cycle emissions of fracked natural gas consumed in Maryland.

2.2 Objective

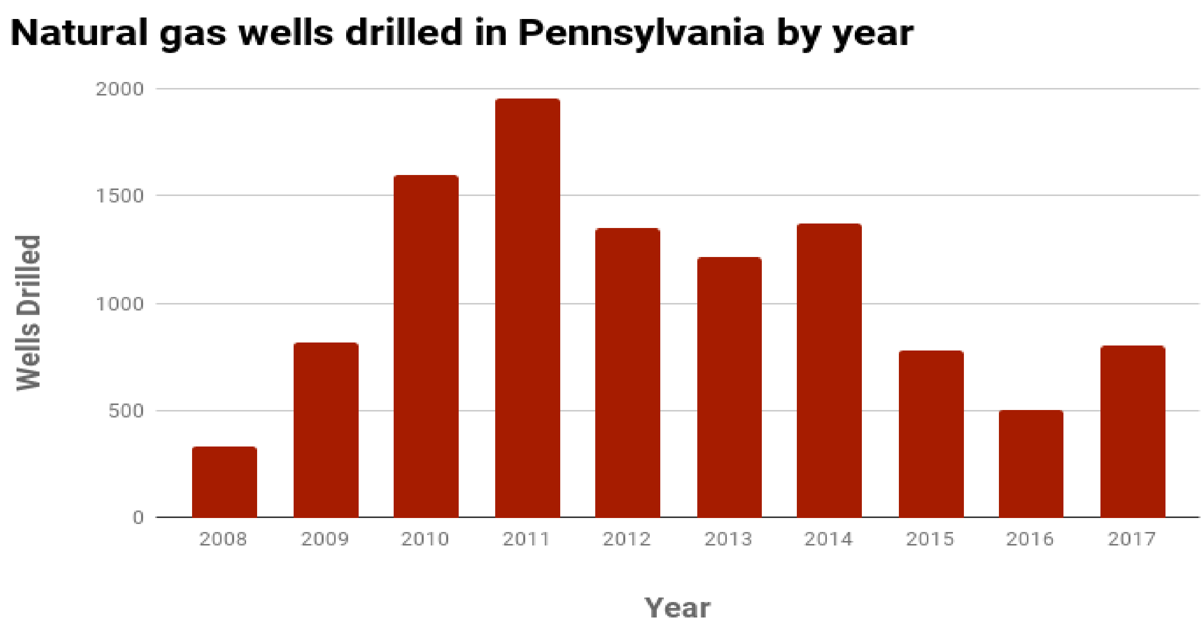
Prepare a 2017 GHG emissions inventory that accounts for the life-cycle greenhouse gas emissions from the consumption of the additional natural gas attributable to the fracking industry in nearby states.

3.0 HISTORY OF UNCONVENTIONAL WELLS/FRACKING IN THE MARCELLUS SHALE REGION

As can be seen from the following graphs and information, the construction of unconventional natural gas fracking wells in the Marcellus Shale region did not start until after 2006. The majority of wells were started after 2010. This point is important within a Maryland greenhouse gas emissions inventory context because the consumption of fracked natural gas in Maryland during the calendar year 2006 for the MD GHG Base Year Emissions Inventory can be considered negligible.



Source: Pennsylvania Department of Environmental Protection.
Note: New wells, or well starts, reflect the number of spudded wells, or wells that began drilling during the year. The figure above does not reflect the number of wells drilled, completed, or permitted.



Source: Pennsylvania Department of Environmental Protection. Wells drilled indicates number of unconventional (horizontally drilled) wells. 2017 data reflects the number of wells drilled through mid-December.

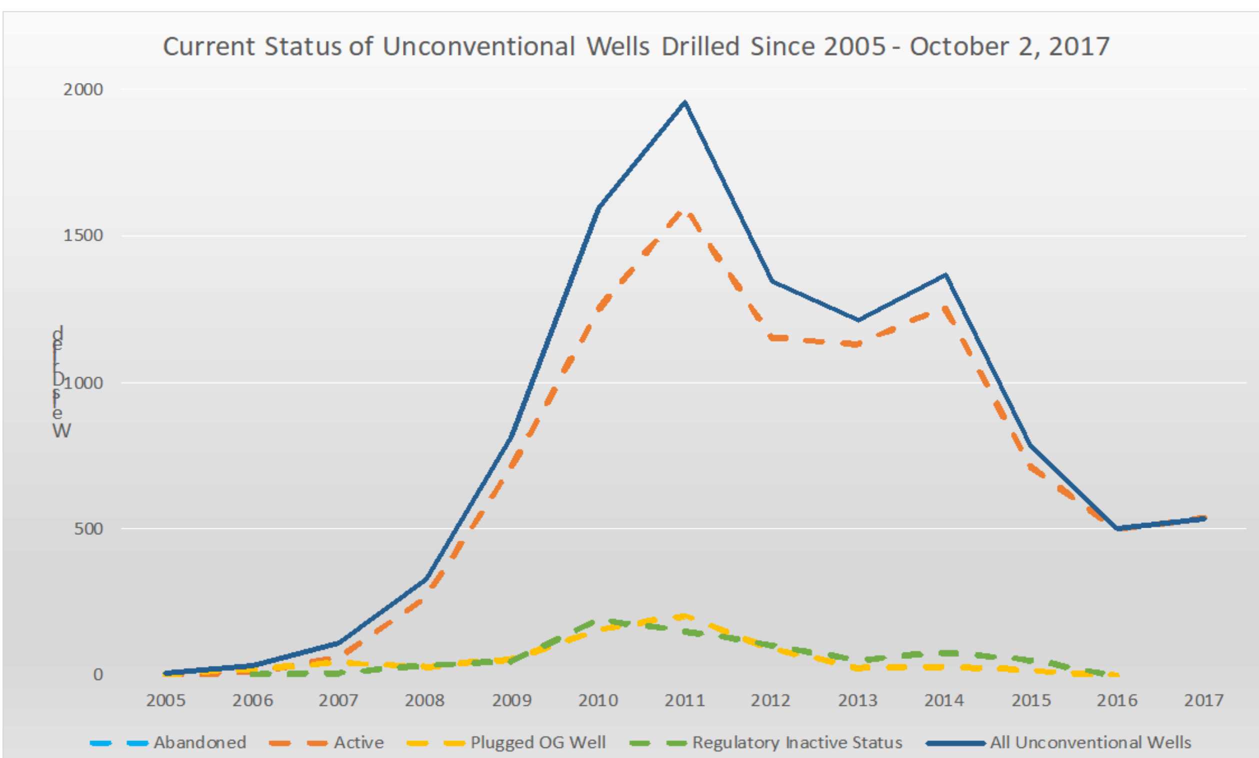


Chart 1: This chart shows the current status of unconventional wells in Pennsylvania, arranged by the year the well was drilled. Note that there are two abandoned wells in 2009 and one more in 2014, although those totals are not visible at this scale.
https://www.fractracker.org/2017/10/life-expectancy-marcellus-shale/

4.0 METHODS AND PROCEDURES

Three distinct processes contribute to GHG emissions in the production, distribution and consumption of natural gas from fracking wells. These processes are:

1. Construction/Development of the unconventional fracking well
2. Distribution of the natural gas
3. Combustion of the natural gas

Construction/Development of the Well

Greenhouse gas emissions are produced during the construction and development of the well. This is a one-time event in the life time of a well. Sources of greenhouse gas emissions during the construction and development of a well include:

- Drilling Rigs
- Hydraulic Fracturing Pumps
- Mud Degassing
- Well Completion Venting

Distribution of Natural Gas from the Well

Sources of greenhouse gas emissions during the distribution of natural gas from out-of-state unconventional fracking wells include:

- Leakage from pipelines, fittings and pumping stations

In-state distribution of the gas is already included in the 2017 greenhouse gas emissions inventory.

Combustion of the Supplied Natural Gas

The combustion of natural gas supplied from out-of-state unconventional fracking wells is already included in the 2017 greenhouse gas emissions inventory.

4.1 Methodology for Estimating Emissions

The main equation used to estimate the greenhouse gas emissions from the consumption of natural gas from out-of-state unconventional fracking wells is provided below:

Equation 1: Main GHG Emission Estimate Equation

Total Annual GHG Emissions from NG Consumption from Out-of-State Fracking Wells ($CO2_E$)	=	Annual Fugitive Leakage Emissions from Natural Gas Consumed in Maryland from Out-of-State Fracking Wells	+	Annualized Well Construction Emissions from Natural Gas Consumed by Maryland from Out-of-State Fracking Wells

4.1.1 Leakage Emissions

The equation used to estimate the greenhouse gas emissions from the fugitive leakage of the natural gas consumed by Maryland from out-of-state unconventional fracking wells is provided below:

Equation 2: GHG Leakage Emission Estimate Equation

Fugitive Leakage Emissions from NG Consumption from Out-of-State Fracking Wells ($CO2_E$)	=	Amount of NG Consumed by MD from Out-of-State Fracking Wells	X	Leakage Rate (%)	X	% of Methane in NG Stream	X	GWP Methane	X	Percentage of Pipeline Outside MD

AMOUNT OF NATURAL GAS CONSUMED FROM OUT-OF-STATE FRACKING WELLS

MDE collected total annual natural gas consumption data from the U.S. Energy Information Administration (EIA)[2]. The data was used as a baseline to establish the quantity of natural gas consumed by the State of Maryland prior to the installation and development of unconventional fracking wells in neighboring states. Prior to 2006, the consumption of natural gas produced from unconventional fracking wells in Maryland can be considered negligible (See Section 3). Table 1 below reports the total amount of natural gas consumed by all sources in Maryland per year.

[2] U.S. Energy Information Administration - https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SMD_a.htm

Table 2: Consumption of Natural Gas in MD – Total All Sources[3]

Date	Maryland Natural Gas Total Consumption (MMcf)	
1997	212,017	
1998	188,552	
1999	196,350	
2000	212,133	
2001	178,376	
2002	196,276	
2003	197,024	
2004	194,725	
2005	202,509	
2006	182,294	
2007	201,053	→ Start date for the installation and development of unconventional natural gas fracking wells in neighboring states
2008	196,067	
2009	196,510	
2010	212,020	
2011	193,986	
2012	208,946	
2013	197,356	
2014	207,103	
2015	215,005	
2016	219,024	
2017	222,877	
1997 – 2005 Average	197,551	
Min	178,376	
Max	212,133	

The EIA data shows that prior to 2007, the start date for the installation and development of natural gas fracking wells in neighboring states, the maximum amount of natural gas consumed was 212,133 MMcf in 2000, the minimum was 182,294 in 2006 and the average between 1997 and 2005 was 197,551. The production of and infrastructure for natural gas consumption in Maryland, prior to the installation and development of natural gas fracking wells in neighboring states, was capable of delivering 212,133 MMcf of natural gas per year. Natural gas supplied above these levels could be attributed to unconventional natural gas fracking activities.

Another method to determine the amount of natural gas consumed in Maryland due to fracking wells in neighboring states would be to establish the percent of the total natural gas nationally that is produced from fracking and apply the percentage to that consumed in Maryland. Nationally, fracking produces two-thirds (67 percent)[4] of the natural gas in the United States, according to the US Energy Information Administration, and approximately 50 percent of the nation's oil.

[3] U.S. Energy Information Administration (EIA) – Natural Gas Consumption by End Use – Maryland https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SMD_a.htm
[4] https://www.eia.gov/todayinenergy/detail.php?id=26112

LEAKAGE RATE

The process of delivering natural gas from a wellhead to a consumer is not a closed system; leakage does occur in the infrastructure along the way. The leakage rate has been studied by scientists, scholars and engineers. The leakage rate varies from study to study. A short synopsis of some of the leakage rate studies is summarized below.

Journal of Cleaner Production - Volume 148, 1 April 2017, Pages 118-126[5]
A synthesis of new methane (CH_4) emission data from a recent series of ground-based field measurements shows that 1.7% of the methane in natural gas is emitted between extraction and delivery (with a 95% confidence interval from 1.3% to 2.2%). This synthesis was made possible by a recent series of methane emission measurement campaigns that focused on the natural gas supply chain, production through distribution. The new data were translated to a standard basis, augmented with other data sources as needed, and simulated using a Monte Carlo-enabled, life cycle model.

Environmental Defense Fund
The findings reported feature measurements at over 400 well pads in six basins and scores of midstream facilities, data from component measurements, and aerial surveys covering large swaths of U.S. oil and gas infrastructure.

Steve Hamburg, EDF's chief scientist, says that still leaves out the "fat-tail" super-emissions. He reckons about 2-2.5% of the gas flowing through the American supply chain leaks out, in total. "The new study estimates the current leak rate from the U.S. oil and gas system is 2.3 percent, versus the current EPA inventory estimate of 1.4 percent."[6]

EPA Study
The EPA 2012 study found the leakage rate to be 2.4%, with a 95% confidence interval of 1.9-3.1%.[7].

CO_2 Scorecard
Another study[8] by CO_2 Scorecard uses three scenarios based on EPA data; one with the leakage rate set to 1.22%, one with a leakage rate set to 1.50% that was deemed more realistic, and one at 2.00% that "many organizations estimate that a leakage rate of 2-3% cancels out all of natural gas's CO_2 emissions advantage over coal.

MDE decided to use the highest leakage rate of 2.5% to be even more conservative than the Environmental Defense Fund.

[5] https://www.sciencedirect.com/science/article/pii/S0959652617301166
[6] https://www.edf.org/media/new-study-finds-us-oil-and-gas-methane-emissions-are-60-percent-higher-epa-reports-0
[7] U.S. Environmental Protection Agency (2011) Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2009 (EPA Publication 430-R-11-005).
[8] https://co2scorecard.org/home/researchitem/28

PERCENT OF METHANE IN NATURAL GAS STREAM

An EPA study[9] and other literature searches[10,11] show that the percent of methane in pipeline natural gas is approximately 98%.

GLOBAL WARMING POTENTIAL - METHANE

The following table includes the 100-year and 20-year time horizon global warming potential (GWP) of methane (CH_4) relative to CO_2.

Table 3: Global warming potential (GWP) values[12] relative to CO_2

Industrial designation or common name	Chemical formula	Fifth Assessment Report (AR5)	
		GWP values for 100-year time horizon	GWP values for a 20-year time horizon
Carbon dioxide	CO_2	1	1
Methane	CH_4	28	84

MDE is using the IPCC Fifth Assessment Report (AR5) GWP of 28 for methane for a 100-year time horizon, and 84 for the 20-year time horizon.

PERCENTAGE OF PIPELINE OUTSIDE OF MARYLAND

The percentage represents the amount of pipeline that transmits the fracked natural gas from Pennsylvania to Maryland that is outside of Maryland. MDE followed the main transmission pipelines from Washington County, Pennsylvania to Baltimore, Maryland. This map is presented in Appendix C.
In a best case scenario the fracked natural gas would travel from the wells in Washington County, PA due south into Maryland. In a worst case scenario, the fracked natural gas would travel from the wells in Washington County, PA toward Philadelphia and turn south into Maryland. MDE chose the worst case scenario in order to offset the maximum amount of fugitive gas released in transmission. This percentage was estimated to be 85.7%.

4.1.2 Annualized Well Construction Emissions

Greenhouse gas emissions from unconventional natural gas fracking activities occur not only from the lost fugitive gas in the transmission and distribution stream, but also in the construction of the

[9] https://www.epa.gov/natural-gas-star-program/overview-oil-and-natural-gas-industry
[10] http://scifun.chem.wisc.edu/chemweek/methane/methane.html
[11] https://www.uniongas.com/about-us/about-natural-gas/chemical-composition-of-natural-gas
[12] https://ar5-syr.ipcc.ch/ipcc/ipcc/resources/pdf/IPCC_SynthesisReport.pdf

wells themselves. In order to quantify GHG emissions from the well construction activities, MDE collected well production emissions data from the Commonwealth of Pennsylvania.

PA Department of Environmental Protection (DEP) collects methane and carbon dioxide emissions data from each well site location. The data is specific to the geographic coordinates of every well permit and includes a wide variety of construction equipment including blow-down vents, dehydrators, drill rigs, engines, heaters, pumps and tanks. PA DEP created a spreadsheet[13] that MDE used to estimate the GHG emissions from well construction for the number of wells necessary to supply Maryland with the amount of natural gas consumed by out-of-state fracking wells. In order to use the spreadsheet, MDE needed to determine how many wells were necessary to produce the excess natural gas on a case-by-case basis. MDE took the average production of the 50 biggest wells in Washington County, PA and determined how many wells on average it would take to supply Maryland with the difference in fuel from 2006.

[13] https://www3.epa.gov/carbon-footprint-calculator/tool/userarchiveversion/documents/SubW_Screening_Tool_Onshore_Production.xls

5.0 RESULTS AND CONCLUSIONS

The greenhouse gas emissions attributable to unconventional natural gas fracking wells in neighboring states is directly proportional to the amount of natural gas assumed to come from the wells. MDE completed four separate analyses. Each of the analyses varied the amount of natural gas consumed in Maryland attributable to unconventional fracking wells. The secondary analyses duplicated each original scenario with a differing GWP; it used the 20-year methane GWP of 84 instead of 28 (the 100-year GWP). The other variables were kept constant; these variables include the following:

Leakage Rate Percent	**2.5%**	
NG Conversion	**48,700**	**ft^3/metric ton**
NG CH_4 %	**0.98**	**% CH_4 in NG Stream**

The main equation used to estimate the greenhouse gas emissions from the consumption of natural gas from out-of-state unconventional fracking wells is provided below:

Equation 1: Main GHG Emission Estimate Equation

Total Annual GHG Emissions from NG Consumption from Out-of-State Fracking Wells ($CO2_E$)	=	Annual Fugitive Leakage Emissions from Natural Gas Consumed in Maryland from Out-of-State Fracking Wells	+	Annualized Well Construction Emissions from Natural Gas Consumed by Maryland from Out-of-State Fracking Wells

Where the equation used to estimate the greenhouse gas emissions from the fugitive leakage of the natural gas consumed by Maryland from out-of-state unconventional fracking wells is provided below:

Equation 2: GHG Leakage Emission Estimate Equation

Fugitive Leakage Emissions from NG Consumption from Out-of-State Fracking Wells ($CO2_E$)	=	Amount of NG Consumed by MD from Out-of-State Fracking Wells	X	Leakage Rate (%)	X	% of Methane in NG Stream	X	GWP Methane	X	Percentage of Pipeline Outside MD

The four separate analyses and the results are described below. Each equation in the analysis shows the 28 GWP value, but the will also include the results for both 28 and 84 GWP, respectively. The calculation for well construction emissions is based off resources from the PA DEP.

5.1 Scenario 1 – National Percent of Natural Gas Attributable to Fracking Applied to Maryland Consumption

Assumption
According to the U.S. Energy Information Administration[14], 67% of the natural gas in consumed in the U.S is derived from fracking.

Basis
The U.S. EIA tracks the amount of natural gas produced in the U.S. and the type of well used in the production. The 67 percent number is the most recent data available.

Equations 1, 2 and 3 are used to estimate the greenhouse gas emissions.

AMOUNT OF NATURAL GAS CONSUMED FROM OUT-OF-STATE FRACKING WELLS
In this scenario the amount of natural gas consumed from unconventional out-of-state fracking wells is considered to be 67 (⅔) percent of the total amount of natural gas consumed in the state. In 2017 this amounted to 149,328 mmcf of natural gas.

Equation 2 then yields the following greenhouse gas emissions for fugitive leakage emissions.

$$\text{MMT CO2E} = \frac{(222{,}877 \times 0.67 \times 1{,}000{,}000 \times 0.025 \times 0.98 \times 28 \times .857)}{(48{,}700 \times 1{,}000{,}000)}$$

$$\text{MMT CO2E} = 1.803$$

The PA DEP's spreadsheet was used to determine the well construction emissions. In this scenario, 20 wells were necessary to supply Maryland with the 149,328 mmcf of natural gas.

2017 Total Emissions (100-yr GWP) = (0.1225 + 1.803)
2017 Total Emissions (100-yr GWP) = 1.926 mmtCO2e

2017 Total Emissions (20-yr GWP) = 5.545 mmtCO2e

The State recognizes that this is the least accurate case, as it relies on national data. The following three cases are based off Maryland-specific data and thus should be considered more reliable.

[14] https://www.eia.gov/todayinenergy/detail.php?id=26112

5.2 Scenario 2 – All Consumption above 2006 Level Attributable to Fracking

Assumption
The difference in natural gas consumption from the current year and 2006 consumption is due to fracking.

Basis
Before 2006 there was no fracking in Maryland and the surrounding region. Assuming all natural gas consumption since then is due to fracking will lead us to the least conservative estimate possible.

Equations 1 and 2 are used to estimate the greenhouse gas emissions.

AMOUNT OF NATURAL GAS CONSUMED FROM OUT-OF-STATE FRACKING WELLS
In this scenario the amount of natural gas consumed from unconventional out-of-state fracking wells is considered to be the difference natural gas consumed in the state from the specific year minus 2006's consumption. In 2017 this amounted to 40,583 mmcf of natural gas. Equation 2 then yields the following greenhouse gas emissions for fugitive leakage emissions.

$$\text{MMT CO2E} = \frac{((222{,}877 - 182{,}294) \times 1{,}000{,}000 \times 0.025 \times 0.98 \times 28 \times .857)}{(48{,}700 \times 1{,}000{,}000)}$$

$$\text{MMT CO2E} = 0.4900$$

The PA DEP's spreadsheet was used to determine the well construction emissions. In this scenario, 6 wells were necessary to supply Maryland with the 40,583 mmcf of natural gas.

2017 Total Emissions (100-yr GWP) = (0.05789) + 0.4900
2017 Total Emissions (100-yr GWP) = 0.5479 mmtCO2e

2017 Total Emissions (20-yr GWP) = 1.532 mmtCO2e

5.3 Scenario 3 – Consumption above the Average Consumption between 1997 - 2005 Attributable to Fracking

Assumption
The difference in natural gas consumption from the current year and the average consumption of 1997-2005 is due to fracking.

Basis
Before 2006 there was no fracking in Maryland and the surrounding region. Assuming all natural gas consumption since then is due to fracking will lead us to the least conservative estimate possible. Using the average of 1997-2005 is an alternative that takes more data into account, aiming for a more accurate estimate.

Equations 1 and 2 are used to estimate the greenhouse gas emissions.

AMOUNT OF NATURAL GAS CONSUMED FROM OUT-OF-STATE FRACKING WELLS
In this scenario the amount of natural gas consumed from unconventional out-of-state fracking wells is considered to be the difference natural gas consumed in the state from the specific year minus the average consumption of 1997-2005. In 2017 this amounted to 25,326 mmcf of natural gas. Equation 2 then yields the following greenhouse gas emissions for fugitive leakage emissions.

$$\text{MMT CO2E} = \frac{((222{,}877 - 197{,}551) \times 1{,}000{,}000 \times 0.025 \times 0.98 \times 28 \times .857)}{(48{,}700 \times 1{,}000{,}000)}$$

$$\text{MMT CO2E} = 0.3058$$

The PA DEP's spreadsheet was used to determine the well construction emissions. In this scenario, 4 wells were necessary to supply Maryland with the 25,326 mmcf of natural gas.

2017 Total Emissions (100-yr GWP) = 0.0487 + 0.3058
2017 Total Emissions (100-yr GWP) = 0.3544 mmtCO2e

2017 Total Emissions (20-yr GWP) = 0.9686 mmtCO2e

5.4 Scenario 4 – Consumption above Maximum Consumption in MD between 1997 - 2005 Attributable to Fracking

Assumption

The difference in natural gas consumption from the current year and max consumption year between 1997 and 2005 is due to fracking.

Basis

Before 2006 there was no fracking in Maryland and the surrounding region. Using the year with the maximum natural gas consumption of 1997-2005 is an alternative that sets a lower bound for our cases, and will be the most conservative estimate.

Equations 1 and 2 are used to estimate the greenhouse gas emissions.

Amount of Natural Gas Consumed from Out-of-State Fracking Wells

In this scenario the amount of natural gas consumed from unconventional out-of-state fracking wells is considered to be the difference natural gas consumed in the state from the specific year minus 2000's consumption. In 2017 this amounted to 10,744 mmcf of natural gas. Equation 2 then yields the following greenhouse gas emissions for fugitive leakage emissions.

$$\text{MMT CO2E} = \frac{((222{,}877 - 212{,}133) \times 1{,}000{,}000 \times 0.025 \times 0.98 \times 28 \times .857)}{(48{,}700 \times 1{,}000{,}000)}$$

$$\text{MMT CO2E} = 0.1297$$

The PA DEP's spreadsheet was used to determine the well construction emissions. In this scenario, 2 wells were necessary to supply Maryland with the 10,744 mmcf of natural gas.

2017 Total Emissions (100-yr GWP) = 0.03942 + 0.1297
2017 Total Emissions (100-yr GWP) = 0.1691

2017 Total Emissions (20-yr GWP) = 0.4299

5.5 Conclusions

The analysis found that Maryland's natural gas consumption in 2017 that was associated with out-of-state fracking resulted in methane emissions ranging from as low as 0.1691 MMTCO2e to as high as 5.545 MMTCO2e, depending on the scenario and choice of 100-year or 20-year GWP.

APPENDICES

Appendix A – EIA Total Natural Gas Consumption in Maryland

Appendix B – Unconventional Natural Gas Production

Appendix C – Percentage of Natural Gas Pipeline Outside of Maryland

APPENDIX A: EIA Total Natural Gas Consumption in Maryland

Date	Maryland Natural Gas Total Consumption (MMcf)
1997	212,017
1998	188,552
1999	196,350
2000	212,133
2001	178,376
2002	196,276
2003	197,024
2004	194,725
2005	202,509
2006	182,294
2007	201,053
2008	196,067
2009	196,510
2010	212,020
2011	193,986
2012	208,946
2013	197,356
2014	207,103
2015	215,005
2016	218,683
2017	222,877
1997 – 2005 Average	197,551

Data Source:
U.S. Energy Information Administration (EIA) – Natural Gas Consumption by End Use – Maryland
https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SMD_a.htm

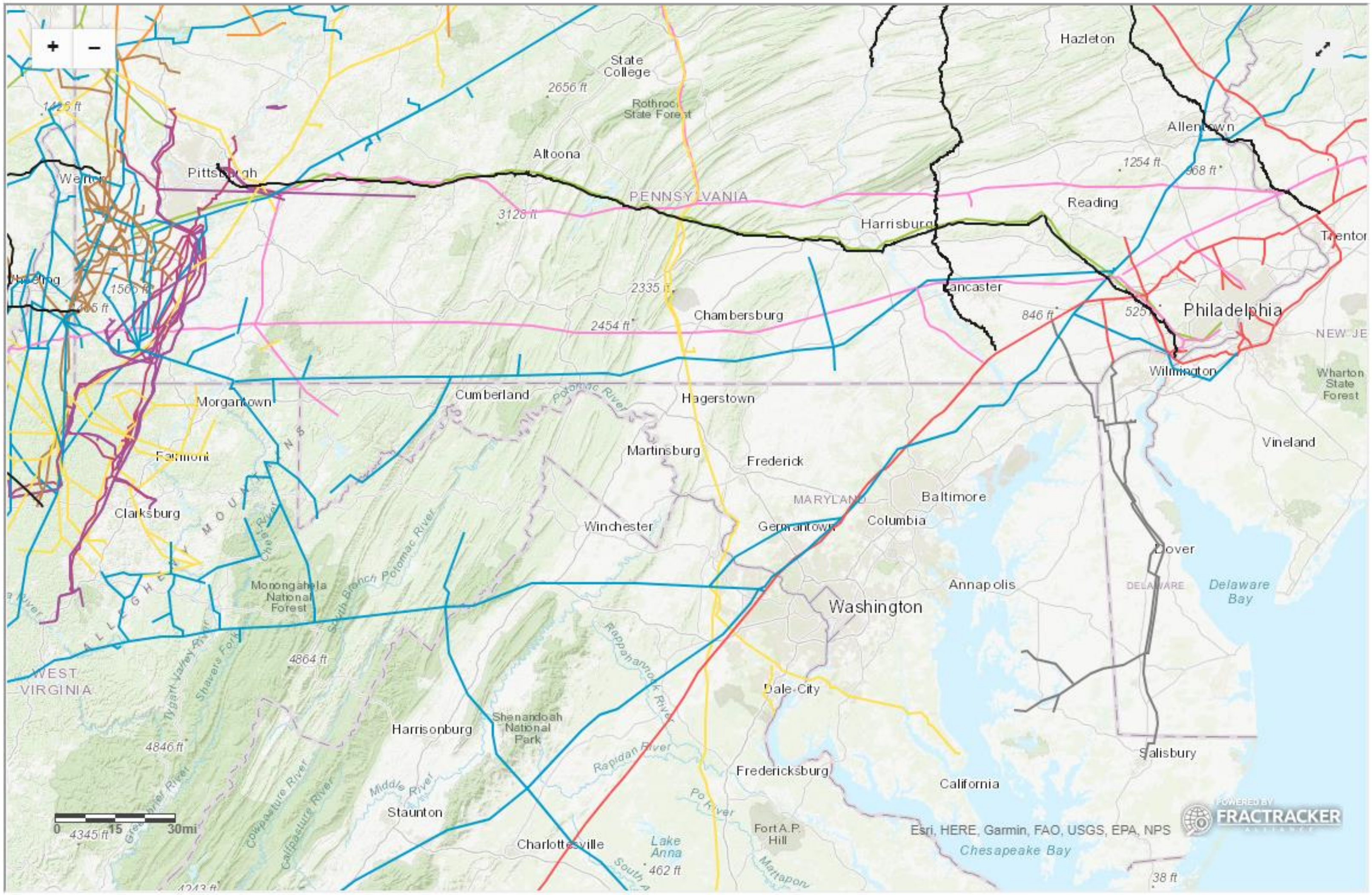
APPENDIX B: Unconventional Natural Gas Well Production

PENNSYLVANIA NATURAL GAS FRACKING WELLS - WASHINGTON COUNTY - PRODUCTION - 2016

Well Name	Well Location	Well Owner	Production (mcf)
X-MAN 5H	Washington County | Amwell Township	Gas company: RICE	11,147,649
HULK 8H	Washington County | Amwell Township	Gas company: RICE	10,188,867
HULK 4H	Washington County | Amwell Township	Gas company: RICE	9,981,502
MONO 4H	Washington County | North Bethlehem Township	Gas company: RICE	9,566,283
BROVA 11H	Washington County | North Bethlehem Township	Gas company: RICE	9,051,675
HULK 6H	Washington County | Amwell Township	Gas company: RICE	8,894,418
US NATURAL RESOURCES UNIT 10H	Washington County | Somerset Township	Gas company: RANGE	8,892,389
US NATURAL RESOURCES UNIT 8H	Washington County | Somerset Township	Gas company: RANGE	8,775,712
HAROLD HAYWOOD WAS 3H	Washington County | Carroll Township	Gas company: EQT	8,336,063
R SMITH 592302	Washington County | Carroll Township	Gas company: EQT	8,226,795
R. SMITH 592300	Washington County | Carroll Township	Gas company: EQT	8,182,121
US NATURAL RESOURCES UNIT 7H	Washington County | Somerset Township	Gas company: RANGE	8,098,811
SWAGLER 6H	Washington County | Somerset Township	Gas company: RICE	7,753,259
IRON MAN 2H	Washington County | North Bethlehem Township	Gas company: RICE	7,709,554
DMC PROPERTIES UNIT 10H	Washington County | Donegal Township	Gas company: RANGE	7,653,677
WATERBOY 2H	Washington County | South Strabane Township	Gas company: RICE	7,633,418
BRUCE WAYNE A 5H	Washington County | Somerset Township	Gas company: RICE	7,590,559
WOLVERINE 10H	Washington County | Fallowfield Township	Gas company: RICE	7,550,917
US NATURAL RESOURCES UNIT 1H	Washington County | Somerset Township	Gas company: RANGE	7,509,289
LUSK 3H	Washington County | West Pike Run Township	Gas company: RICE	7,505,226
MAD DOG 2020 9H	Washington County | West Pike Run Township	Gas company: RICE	7,491,997
CRUM NV55CHS	Washington County | Morris Township	Gas company: CNX	7,341,067
CONSOL NV57GHS	Washington County | Morris Township	Gas company: CNX	7,320,787
WATERBOY 4H	Washington County | South Strabane Township	Gas company: RICE	7,237,383
MAD DOG 2020 5H	Washington County | West Pike Run Township	Gas company: RICE	7,217,543
ZORRO 2H	Washington County | North Bethlehem Township	Gas company: RICE	7,211,088
ZORRO 4H	Washington County | North Bethlehem Township	Gas company: RICE	7,114,035
ZORRO 12H	Washington County | North Bethlehem Township	Gas company: RICE	7,112,693
CRUM NV55EHS	Washington County | Morris Township	Gas company: CNX	7,092,172
MONO 3H	Washington County | North Bethlehem Township	Gas company: RICE	7,077,962
COFFIELD/GOTTSCHALK NV34JHS	Washington County | Morris Township	Gas company: CNX	7,064,743

Well Name	Well Location	Well Owner	Production (mcf)
CONSOL NV57CHS	Washington County | Morris Township	Gas company: CNX	7,057,533
CRUM NV55DHS	Washington County | Morris Township	Gas company: CNX	7,036,440
MARCHEZAK JOHN 11528 6H	Washington County | Somerset Township	Gas company: RANGE	7,005,841
BROVA 9H	Washington County | North Bethlehem Township	Gas company: RICE	6,985,394
MONO 1H	Washington County | North Bethlehem Township	Gas company: RICE	6,980,881
GOLDEN GOOSE 8H	Washington County | North Bethlehem Township	Gas company: RICE	6,972,823
R SMITH 592299	Washington County | Carroll Township	Gas company: EQT	6,939,464
TRAX FARMS 592309	Washington County | Union Township	Gas company: EQT	6,931,540
BIER ALBERT 11409 2H	Washington County | North Strabane Township	Gas company: RANGE	6,910,832
X-MAN 7H	Washington County | Amwell Township	Gas company: RICE	6,891,663
CONSOL NV57JHS	Washington County | Morris Township	Gas company: CNX	6,880,198
BROVA 3H	Washington County | North Bethlehem Township	Gas company: RICE	6,804,626
BROVA 7H	Washington County | North Bethlehem Township	Gas company: RICE	6,802,426
BIG DADDY SHAW 6H	Washington County | Somerset Township	Gas company: RICE	6,760,695
MONO 7H	Washington County | North Bethlehem Township	Gas company: RICE	6,758,712
MAD DOG 2020 0H	Washington County | West Pike Run Township	Gas company: RICE	6,758,703
BROVA 4H	Washington County | North Bethlehem Township	Gas company: RICE	6,757,596
WATERBOY 8H	Washington County | South Strabane Township	Gas company: RICE	6,750,199
COFFIELD/GOTTSCHALK NV34GHS	Washington County | Morris Township	Gas company: CNX	6,725,720

APPENDIX C: Percentage of Natural Gas Pipeline Outside of Maryland



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[15] https://www.alleghenyfront.org/mapping-the-pipeline-boom/