American Gas Association

Energy Analysis

Energy Analysis and Standards
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UNDERSTANDING UPDATES TO THE EPA INVENTORY OF GREENHOUSE GAS EMISSIONS FROM NATURAL GAS SYSTEMS

Introduction

Natural gas is a fuel of choice for consumers because of its low cost, efficient end uses, and environmental attributes. This domestically produced and abundant energy source presents the US with an opportunity to address our energy, economic, and environmental objectives, and natural gas is poised to serve as a foundation fuel for the US economy for years to come. This potential has focused public attention on the environmental footprint of energy production, transportation, distribution, and end-use.

Efficient natural gas technologies serve as low-cost, low-emission options for building energy needs, home comfort, industrial processes, and electricity generation. Furthermore, natural gas is a low-carbon fuel relative to coal and oil; natural gas results in less carbon dioxide for the same amount of beneficial energy. A better understanding of methane emissions released from production and delivery systems will further clarify how the use of natural gas may deliver greater environmental benefits.

The Environmental Protection Agency (EPA) made further updates to its estimates of methane emissions in its *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017*, (*Inventory*) released in April 2019. The *Inventory* incorporates new data available from studies on emissions as well as the EPA's own Greenhouse Gas Reporting Program (GHGRP).

The *Inventory* reveals once again that natural gas distribution systems have a small emissions footprint shaped by a declining trend. Distribution systems owned and operated by local natural gas utilities emit less than 0.1 percent of produced natural gas emissions. These annual emissions declined 73 percent from 1990 to 2017, even as natural gas utility companies added more than 760,000 miles of pipeline to serve 20 million more customers, increases of 50 and 38 percent respectively.

This exceptional record can be traced to gas utilities continuing to make safety their top priority and remaining deeply committed to systematically upgrading infrastructure through risk-based integrity management programs. As companies and the country continue to modernize the natural gas infrastructure base and connect homes and businesses, there will be new opportunities to achieve low-cost carbon emissions reductions by leveraging this existing infrastructure and the nation's abundant natural gas resource.

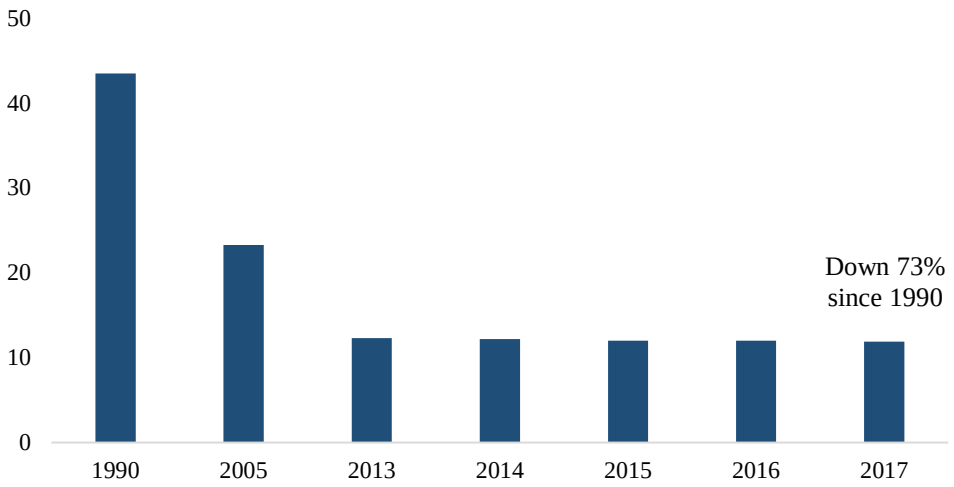


Figure 1: Methane Emissions from Natural Gas Distribution Systems (Million Metric Tons CO_2e)
Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017, Environmental Protection Agency*

Key Findings

- Annual methane emissions from natural gas distribution systems declined 73 percent from 1990 to 2017.

- The natural gas emissions rate of production from distribution systems remains less than 0.1 percent.

- Industry-wide natural gas emissions as a rate of production (the "leakage rate") continue to decline – now at 1.3 percent—a level well below even the most stringent thresholds for immediate climate benefits achieved through coal to natural gas switching.

- Total methane emissions from natural gas systems have declined 15 percent since 1990 to 2017.

- The main sources of methane emissions are enteric fermentation, followed by natural gas systems, landfills, manure management, wastewater treatment and others. Methane emissions from all economic sectors represent 10 percent of all greenhouse gas emissions in the United States. Methane released from natural gas systems accounts for 2.6 percent of all U.S. greenhouse gas emissions.

- EPA continues to frequently revise the inventory for natural gas systems based on information and data from the EPA's Greenhouse Gas Reporting Program (GHGRP), annual Inventory formal public notice records, stakeholder feedback, and new scientific studies.

Recalculations in the 2019 Inventory

- Each year, numerous emissions and sink estimates in the *Inventory* are recalculated and revised, as efforts are made to improve the estimates using better methods and data to improve inventory quality, including transparency, completeness, consistency, and overall usefulness of the report.

- The sum of revisions to calculated estimates for methane released from natural gas systems showed a small increase relative to last year's *Inventory* (2018 edition) of 2 million metric tons of carbon dioxide equivalent (MMTe) to 165 MMTe for year-end 2016, an increase of 1 percent.

- Estimated methane emissions from petroleum systems for 2016 also increased slightly by 2 MMTe, or 6 percent.

- The sum of revisions to combined oil and natural gas systems for 2016 showed a 2 percent increase from 198.9 MMTe to 203.3 MMTe, mainly due to GHGRP data submission revisions.

Table 1: Revisions to Methane Emissions Due to Inventory Updates

Methane Emissions in 2016	Prior Inventory	New Inventory	Change
Exploration	0.7	1.2	71%
Production	106.8	108.4	1%
Processing	11.2	11.7	4%
Transmission & Storage	32.8	32.4	-1%
Distribution	12.0	11.9	-1%
Natural Gas Total	**163.5**	**165.6**	**1%**
Petroleum Field Operations	35.4	37.7	6%
Oil and Gas Total	**198.9**	**203.3**	**2%**

Source: *Inventory of U.S. Greenhouse Gas Emissions, 2018, 2019 editions, Environmental Protection Agency*

- The distribution stage underwent no methodological changes; however, there were recalculations due to updated data on meter and regulator (M&R) station counts from the GHGRP and revisions to GasSTAR data.

- EPA updated its calculation of production and transmission Gas STAR reductions to consider new methods of using net emissions factors associated with pipeline blowdowns. In addition, the line item for gathering pipeline leak Gas STAR reductions was eliminated from the *Inventory*.

Summary and Analysis of EPA *Inventory*

For almost three decades, the Environmental Protection Agency (EPA) has developed and published estimates of greenhouse gas (GHG) emissions in its annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (referenced throughout as the *Inventory*). It is the most comprehensive assessment of U.S. greenhouse gas emissions available.

The *Inventory* covers all major and minor greenhouse gases, including carbon dioxide (CO_2), methane, nitrous oxides, and lesser gases. EPA reports all emissions in units of CO_2-equivalence (CO_2e) by weighting different air emissions by their respective global warming potentials to account for varying levels of radiative forces of each gas relative to CO_2 over a 100-year time horizon. For methane, the EPA uses a global warming potential of 25, consistent with UNFCCC reporting guidelines.[1]

[1] United Nations Framework Convention on Climate Change. The EPA uses a global warming potential of 25 for methane in accordance with the International Panel on Climate Change (IPCC) national inventory reporting guidelines. Higher global warming potentials have been published in the literature, including in fifth Assessment Reports from the IPCC. Using these higher factors would increase the contribution of methane to total greenhouse gases relative to CO_2.

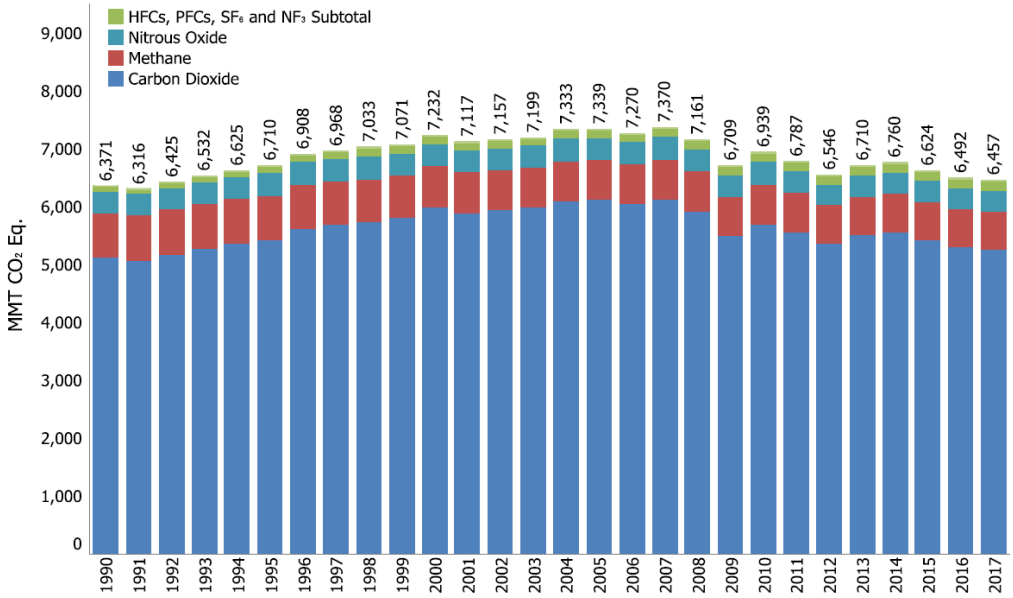


Figure 2: U.S. Greenhouse Gas Emissions (Million Metric Tons CO_2e)

Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017, Environmental Protection Agency*

In 2017, United States greenhouse gas emissions totaled 6,457 million metric tons of carbon dioxide equivalent (MMTe), down 0.5 percent from 2016 and down 12 percent from 2005. Carbon dioxide from fossil fuel combustion accounts for most annual GHG emissions, constituting 82 percent of the total GHG.

Total CO_2 emissions from fossil fuel combustion equaled 4,921 MMTe in 2017, which is 14 percent lower than 2005 levels. Petroleum combustion accounts for the largest amount of energy-related CO_2 emissions with a 44 percent share. Natural gas ranked second among the fossil fuels in this category at 30 percent, followed by coal at 26 percent.

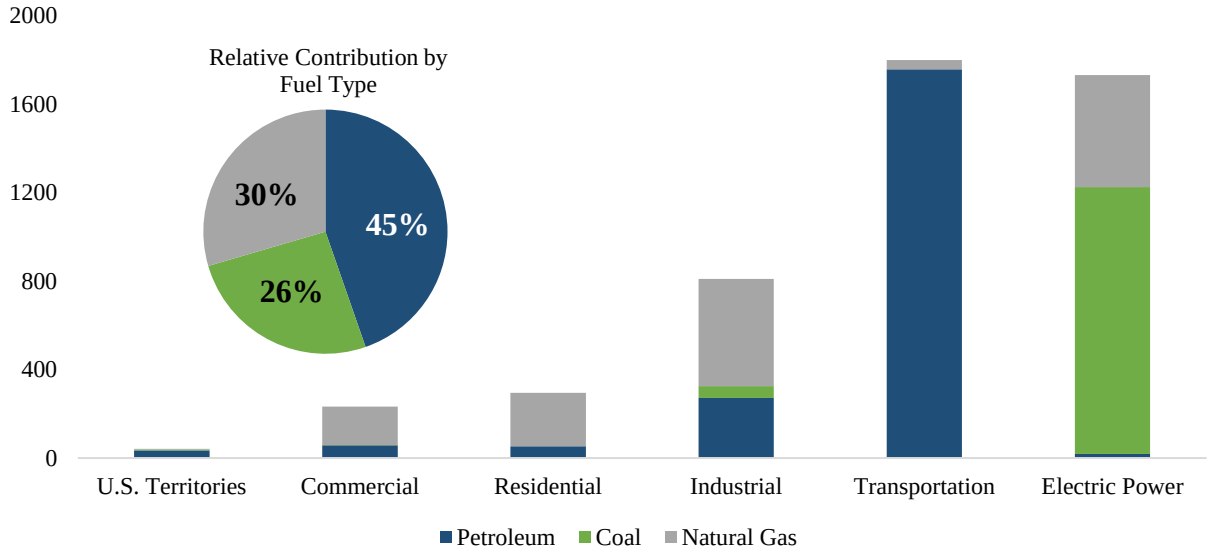


Figure 3: CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type, 2017 (MMTe)

Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017, Environmental Protection Agency*

Because the natural gas share of fossil fuel consumption has increased relative to coal, and given the lower carbon emissions per unit of energy relative to coal, overall CO_2 emissions since 2005 have trended downward.

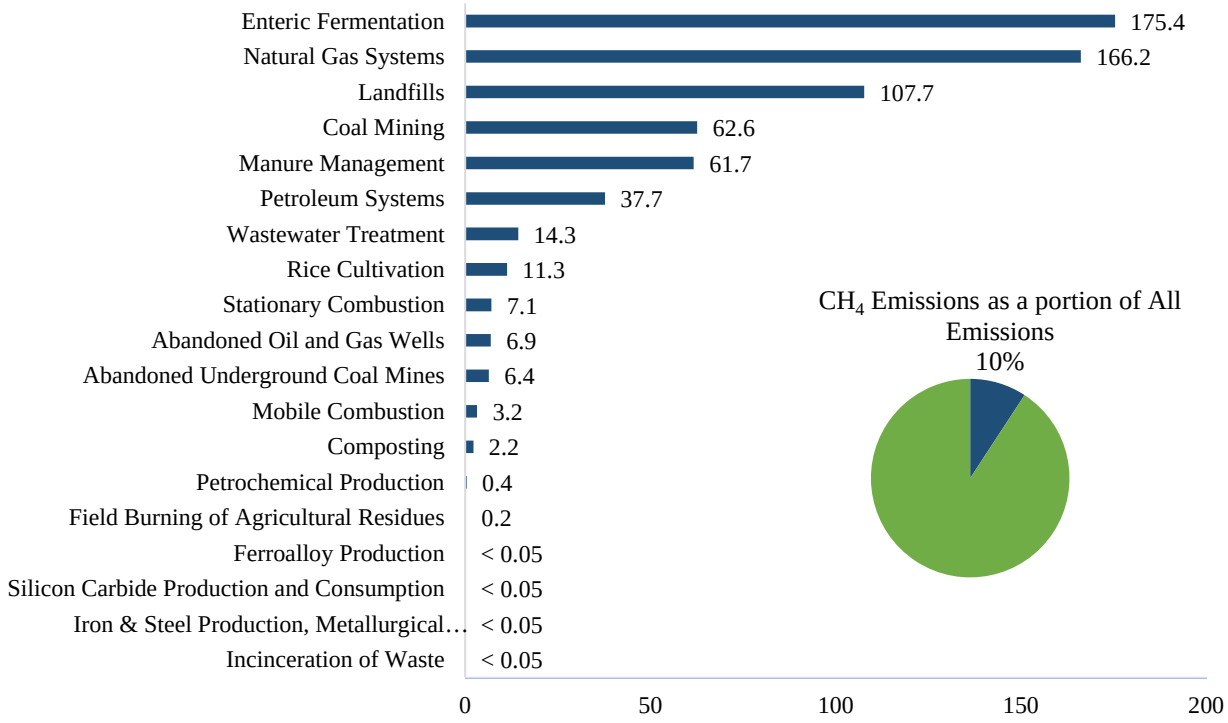


Figure 4: Sources of Methane Emissions 2017 (MMT CO_2 Eq.)

Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017, Environmental Protection Agency*

Methane is the second largest contributor to greenhouse gas emissions after CO_2. Major economic sectors that produce methane emissions are agricultural processes including livestock management and rice cultivation, landfills, petroleum production, and coal mining. In 2017, methane emissions were 656 MMTe and accounted for 10 percent of all U.S. GHG emissions.

Nitrous oxide (N_2O) is the third largest contributor and results primarily from agricultural soil management and mobile and stationary combustion. N_2O emissions accounted for 6 percent of total GHGs in 2017. Other GHGs include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of these gases together account for 3 percent of total U.S. GHG.

Natural Gas System Methane Emissions

The U.S. natural gas system is comprised of thousands of wells and drilling rigs, well completion equipment, numerous processing facilities, trillions of cubic feet of underground storage capacity, millions of meters, and an extensive transmission and distribution network of 2.5 million miles of pipeline. The EPA categorizes this system into four stages: natural gas field production, processing, transmission and storage, and distribution. Methane and, to a lesser extent, CO_2 are the two principal GHGs related to the operation of natural gas systems.

By the categorical conventions used in the *Inventory*, natural gas systems represent the second largest source category for methane in the United States, constituting 25 percent of all methane released, just behind

enteric fermentation (27 percent of methane emissions). In 2017, natural gas system methane emissions equaled 166.2 MMTe, or 2.5 percent of total U.S. greenhouse gases.

The largest share of natural gas system methane emissions stems from field production, which accounts for 65 percent. Processing accounts for 7 percent; transmission and storage stage 20 percent; and distribution at 7 percent. Historical emissions for natural gas systems are listed in Table 2.

Table 2: Methane Emissions from Natural Gas Systems (million metric tons CO_2e)

	1990	2005	2013	2014	2015	2016	2017	1990-2017	Share of Natural Gas System Emissions (2017)
Exploration	4.0	10.9	3.0	1.0	1.0	0.7	1.2	-70%	1%
Production	67.0	89.5	108.5	108.5	108.8	107.1	108.4	62%	65%
Onshore Production	35.0	51.5	53.3	49.3	47.2	46.0	45.1	29%	27%
Offshore Production	3.5	4.3	3.8	3.8	3.8	3.8	3.8	9%	2%
Gathering, Boosting	28.5	33.7	51.4	55.4	57.9	57.4	59.5	109%	36%
Processing	21.3	11.6	10.8	11.1	11.1	11.4	11.7	-45%	7%
Transmission, Storage	57.2	36.1	31.0	32.4	34.2	34.5	32.4	-43%	20%
Distribution	43.5	23.3	12.3	12.2	12.0	12.0	11.9	-73%	7%
Total	**193.1**	**171.4**	**165.6**	**165.1**	**167.2**	**165.7**	**165.6**	**-14%**	**100%**

Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017, Environmental Protection Agency*

Natural gas system performance has generally improved significantly during the past two decades. New control technologies and better industry practices have contributed to significant emission reductions, even as natural gas production and consumption have hit record highs. Since 1990, absolute methane emissions have declined 16 percent as gross natural gas withdrawals climbed 54 percent.

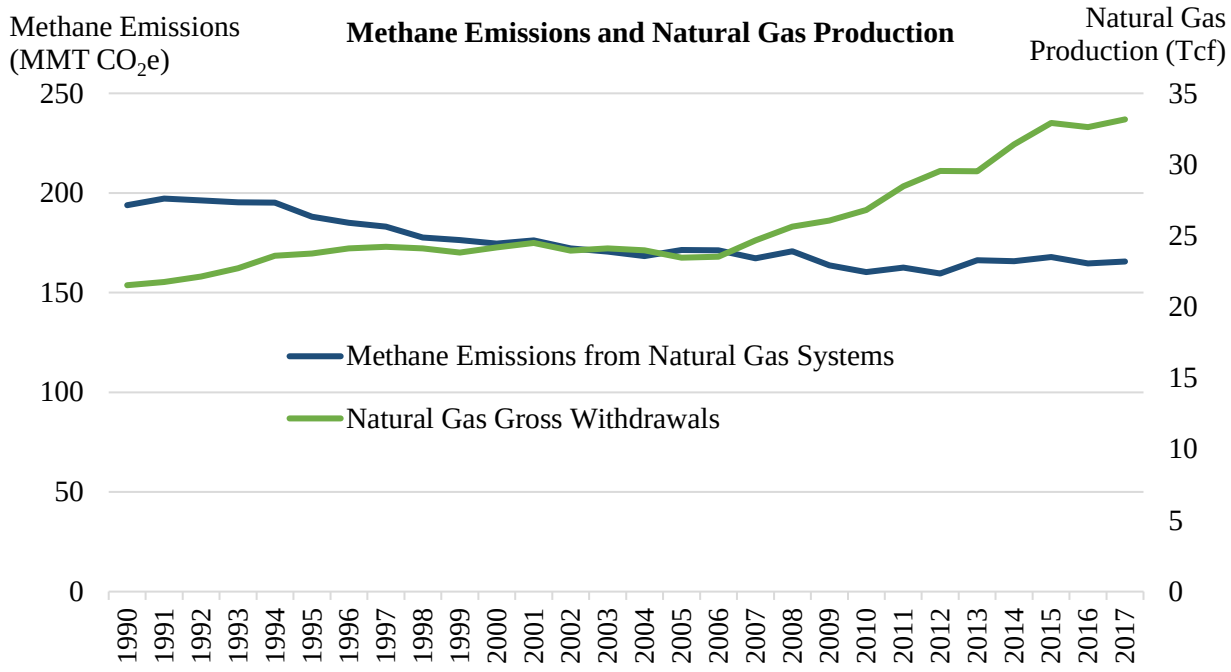


Figure 5: Methane Emissions and Natural Gas Production

Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017, Environmental Protection Agency, Energy Information Administration*

Natural Gas System Carbon Dioxide and Nitrous Oxide Emissions

Natural gas systems emit greenhouse gases other than methane, such as carbon dioxide (CO_2) and nitrous oxide (N_2O). Non-combustion CO_2 emissions from natural gas systems include those resulting from normal operations, routine maintenance, and system upsets. The increased use in plastic pipeline has helped reduce CO_2 emissions in the natural gas distribution system stage. CO_2 emissions from this sector are less than 0.1 MMT CO_2 Eq. across the time series. The 1990 to 2017 decrease in carbon dioxide is due primarily to decreases in acid gas removal emissions in the processing segment, where acid gas removal emissions per plant have decreased over time.

Table 3: Non-Combustion CO_2 Emissions from Natural Gas Systems (MMT)

Stage	1990	2005	2013	2014	2015	2016	2017
Exploration	0.4	1.8	1.3	0.8	0.3	0.2	0.5
Production	1.0	0.8	3.1	3.3	3.4	3.2	2.8
Processing	28.3	18.9	20.5	21.0	21.0	21.7	22.5
Transmission and Storage	0.2	0.2	0.3	0.3	0.3	0.4	0.5
Distribution	0.1	+	+	+	+	+	+
Total	**30.0**	**22.6**	**25.1**	**25.5**	**25.1**	**25.5**	**26.3**

Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017, Environmental Protection Agency*

In this year's *Inventory*, EPA included a calculation of N_2O emission factors for flaring sources throughout all segments, directly from GHGRP data. Prior *Inventories* did not calculate N_2O emissions from natural gas systems. This update was applied for sources in the exploration, production, and transmission and storage segments and did not include distribution systems, as these emissions were designated "Not Occurring." Nitrous Oxide emissions are down over 150 percent in 2017 to 4,735 metric tons from peak levels in 2015. The main decreases in N_2O emissions can be seen in the production and processing segments, where the majority of the emissions occur.

Table 4: N_2O Emissions from Natural Gas Systems (metric tons CO_2-Eq.)

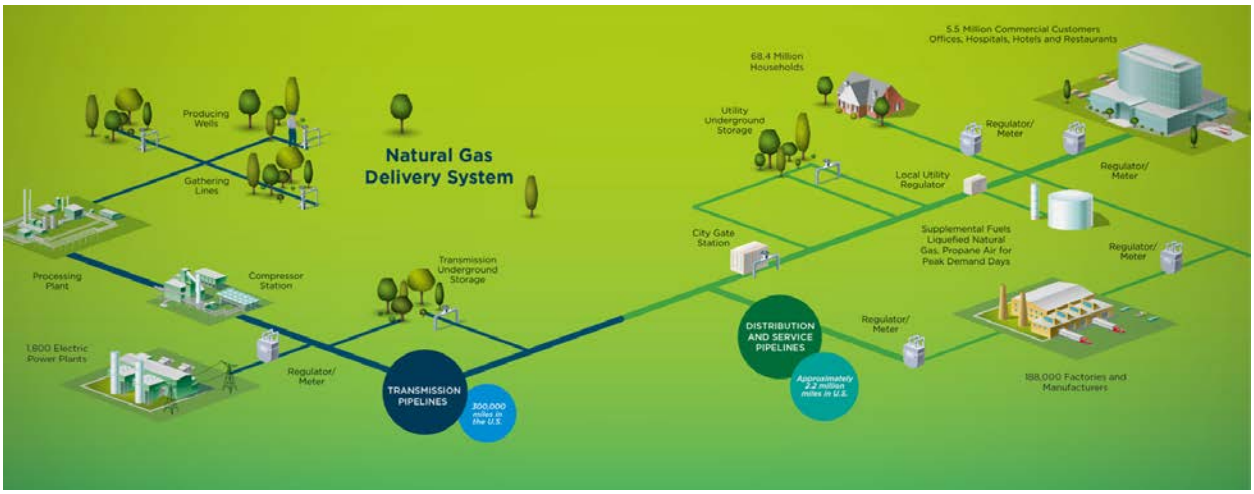
Stage	1990	2005	2013	2014	2015	2016	2017
Exploration	461	1,401	1,179	855	3,215	113	289
Production	162	900	2,330	1,997	2,773	1,019	937
Processing	+	3,351	5,625	5,772	5,772	3,802	3,049
Transmission and Storage	257	309	341	344	347	377	461
Distribution	+	+	+	+	+	+	+
Total	**880**	**5,961**	**9,476**	**8,969**	**12,107**	**5,311**	**4,735**

Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017, Environmental Protection Agency*

Greenhouse gas emissions from both CO_2 and N_2O in the natural gas system are minimal and the trend in recent years has been downward. Non-combustion CO_2 emission levels from natural gas systems have decreased from 30.0 to 26.3 MMT, a 12 percent fall from 1990 to 2017. Nitrous oxides are 61 percent lower than peak 2015 levels and fell 11 percent from 2016 to the most current *Inventory*.

Distribution System Methane Emissions

Natural gas distribution systems, owned and operated by natural gas utilities, deliver natural gas to consumers through an extensive infrastructure comprised of 2.2 million miles of pipeline, compressor stations, meter and regulating facilities, and other related equipment. Gas utilities serve predominantly households and businesses and provide about 30 percent of total natural gas volumes consumed for electricity generation. In 2017, natural gas utilities delivered 58 percent of the natural gas consumed across the country.



Source: *American Gas Association Playbook 2018*

The distribution stage, which includes the regular operation and maintenance of natural gas systems along with emissions releases from accidents, account for 7 percent of estimated methane emissions from the whole natural gas industry. Categories of distribution emission sources include leaks from natural gas pipelines, meters and regulators (M&R) stations, customer meters, upsets (mishaps such as excavation damage), and releases during routine maintenance. Gas utility companies reduce methane emissions each year through voluntary measures and are reported to the EPA through its Natural Gas STAR program.

Overall, emissions from distribution systems have been improving even as the size of the system has grown significantly. Methane emissions from distribution systems were 11.9 MMTe in 2017, a decline of 73 percent from 1990 levels. This drop occurred even as the industry added 350,000 miles of distribution mains and 275,000 miles of service lines (approximately 700,000 miles total) to serve 20 million more customers, a 50 and 38 percent increase in pipeline mileage and customers respectively.

Table 5: Net and Potential Methane Emissions Estimates from the Natural Gas Distribution Stage and Reductions from the Natural Gas STAR Program 2017

Distribution	kt	MMTe	Share
Pipeline Leaks	222.36	5.56	47%
Meter/Regulator (City Gates)	42.60	1.07	9%
Customer Meters	135.92	3.40	29%
Routine Maintenance	5.61	0.14	1%
Upsets	68.08	1.70	14%
Net Emissions	474.6	11.9	100%

Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017, Annex table 3.6-1, Environmental Protection Agency, *These values represent net emissions for these sources*

Table 5 summarizes the breakdown in distribution-stage methane emissions by source category. The majority of distribution emissions are from pipeline leaks and meter/regulator operation. Slightly less than half, 47 percent, of distribution system methane emissions are associated with pipeline leaks, and 9 percent result from the operation of gas meter and regulators at city gates, which connects the transmission system

with the distribution network. Customer meters account for 29 percent. Upsets and routine maintenance together comprise 15 percent.[2]

The historical reductions in this sector are the result of gas utility upgrades to distribution infrastructure, improved leak surveys, and modernized designs. Pipeline networks have been expanded and replaced with modern materials such as protected steel and plastics, which have lower emissions than other pipe materials. Additionally, operators have made significant upgrades and rebuilds to equipment at M&R stations.

Figure 7 reproduces the EPA estimates for pipeline leaks using EPA emission factors for pipeline main and activity (mileage) data from the Department of Transportation. The same figure shows the increasing trend in miles of installed main and the simultaneous decreasing trend in emissions from main pipeline. It illustrates the nation's natural gas utility industry's expanding service territory with a declining environmental footprint.

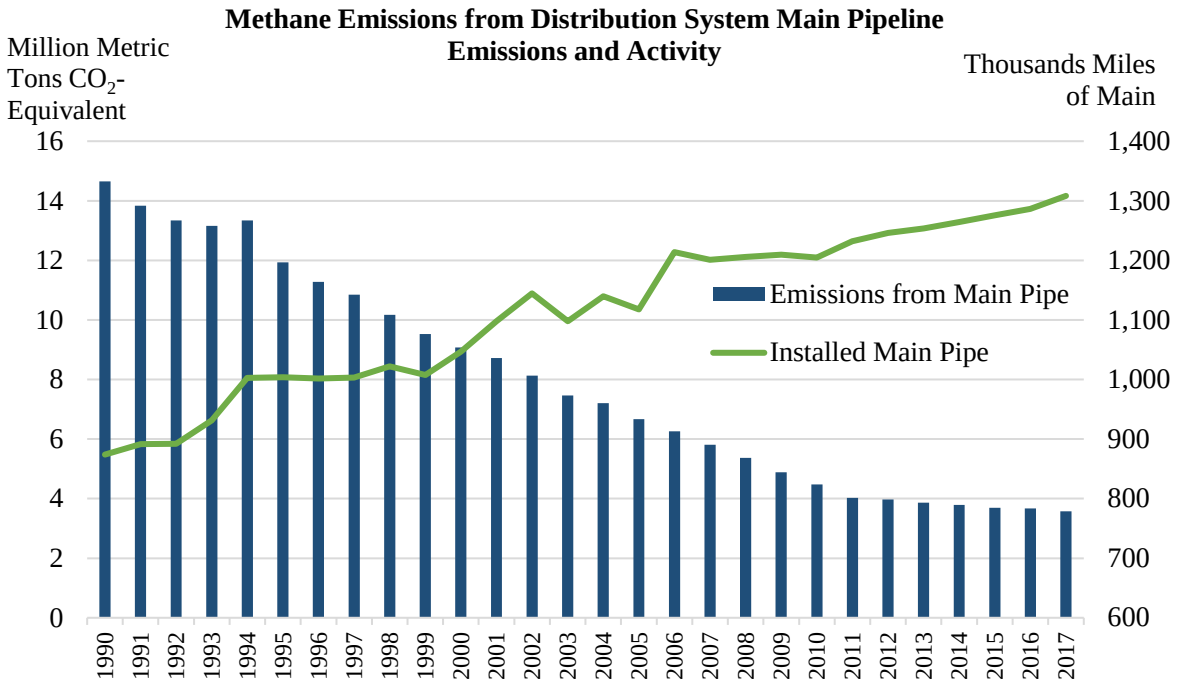


Figure 7: Methane Emissions from Distribution System Main Pipeline – Emissions and Activity
Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017, Environmental Protection Agency*

Summary of Revisions

The EPA routinely makes updates to its estimates of methane emissions using data available from the EPA Greenhouse Gas Reporting Program (GHGRP), data from new studies, and new methodological approaches. Changes to the Inventory data and methods were relatively small compared with recent years. For more analysis see last year's version of this report.

[2] Pipeline leaks are typically classified by the severity of the leak and location to determine whether it represents an actionable condition for immediate repair. Grade 1 leaks require prompt action to protect life and property. Grade 2 leaks should be repaired within a set amount to time, typically on the order of one year. Grade 3 leaks are flagged to be reevaluated during survey schedules or until the leak is regraded or no longer results in a reading.

The combined impact of revisions to 2017 natural gas sector methane emissions, compared to the previous *Inventory*, is an increase from 163.5 to 165.7 MMT CO_2 Eq., a 1 percent increase from year-end 2016 estimates, as shown in detail in Table 4.

Table 6: Summary of Revisions to Natural Gas System Methane Estimates 2016 (MMT CO_2e)[3]

Methane Emissions in 2016	Prior Inventory	New Inventory	Change
Exploration	0.7	1.2	71%
Production	106.8	108.4	1%
Onshore Production	45.4	45.1	-1%
Offshore Production	3.8	3.8	0%
Gathering, Boosting	57.7	59.5	3%
Processing	11.2	11.7	4%
Transmission, Storage	32.8	32.4	-1%
Distribution	12.0	11.9	-1%
Natural Gas Total	**163.5**	**165.7**	**1%**
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Oil and Gas Total	**198.9**	**203.3**	**2%**

Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 2018, 2019 editions, Environmental Protection Agency*

Additionally, EPA calculated N_2O emissions in the current *Inventory*; prior *Inventories* did not calculate and report N_2O emissions from natural gas systems. For each flaring emission source in accordance with GHGRP data, the existing source-specific methodology was used to calculate N_2O emission factors. This update did not apply to distribution systems, as these emissions are designed "Not Occurring" but included sources in the exploration, production, processing, and transmission and storage sectors.

EPA made revisions to its calculation of production and transmission segments of the Gas STAR reductions to consider new methods using net emission factors for certain sources. In previous *Inventories*, the reductions scaling factor for production is the difference of the sum of emissions from sources, divided by the sum of all production emissions. This calculation has been updated as the following, according to the EPA:

> *The calculation was updated this year to remove reductions association with gathering pipeline blowdowns, as net emission factors are now used to calculate emission for that source. In addition, the line item for gathering pipeline leak Gas STAR reductions was removed. Similarly, reductions associated with transmission pipelines blowdowns were removed from the transmission segment.*[4]

Discussion of the Distribution Stage Revisions

Significant revisions to distribution stage methane emissions have been conducted in prior *Inventories*, many of which resulted in significant reductions in emissions factors for many activities within the distribution stage. Discussion on those revisions can be found in a prior version of this annual report.

[3] Additional information on revisions to all oil and gas sector estimates may be found at: https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems

[4] Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017*, main text pp. 3-97

For the 2019 *Inventory*, there were no methodological changes to the estimation of methane or carbon dioxide emissions from the natural gas distribution stage.

Calculation of Methane Emissions Rate of Production

The following analysis calculates an effective emissions rate of production, or, the amount of methane released for each unit of natural gas produced at the wellhead. Many groups use this metric as a benchmark for natural gas system performance. The calculation can be made using EPA estimates for methane emissions from natural gas systems and statistics on annual natural gas production volumes from the U.S. Energy Information Administration (EIA). The section steps through these calculations to derive a value for the emissions rate of production and examine how it has changed over time.

Using the EPA *Inventory*, natural gas systems released 6,624 kilotons of methane in 2017, which is equivalent to 346 Bcf [5]. This value includes emissions from natural gas wells only. It is also necessary to account for methane emissions from petroleum production given that 20 percent of produced natural gas came from oil wells in 2017.

We attribute a portion of methane emissions from petroleum production to the natural gas value based chain on the ratio of natural gas to other produced liquids from oil wells[6]. The natural gas fraction of total energy content (oil plus natural gas) from oil wells was 26 percent in 2017[7]. Applying this factor to total petroleum system methane emissions, we count 20 Bcf of methane from petroleum production as attributable to the natural gas value chain.

To account for the varying share of methane in each stage of the natural gas system, an average percentage of methane content is calculated. We apply the share of methane in each stage to the total emissions of the respective stage using the percentages below. The average of percentages of methane in natural gas per stage concludes a value of 83.3 percent of natural gas is methane when applied to the whole value chain.

Table 7: Methane Content Per Stage of Natural Gas System

Exploration	Onshore Production	Offshore Production	Production	Gathering & Boosting	Processing	Transmission	Distribution
78.8%	78.8%	78.8%	78.8%	78.8%	87.0%	93.4%	93.4%

Using EIA data for U.S. gross natural gas withdrawals of 33,357 Bcf in 2017, and using a calculated methane content of 83 percent for natural gas, we calculate:

$$\frac{346\ Bcf + 20\ Bcf}{33{,}357\ Bcf} * \frac{1}{83\%} = 1.32\%$$

[5] Assuming 0.01917 kg/scf CH_4

[6] This analysis assigns a portion of petroleum system methane emissions from natural gas production out of oil wells to the natural gas system. This contribution is small compared to combustion-related CO_2. Furthermore, these emissions should be considered an upper bound since it is not clear that petroleum system methane emissions would not have occurred otherwise if marketable natural gas was not part of the oil well production. In many cases, oil wells would likely still be produced, and the non-marketed natural gas would have been vented or flared, contributing to the petroleum system footprint and not the natural gas value chain.

[7] Calculated using the gas fraction of total energy from oil wells. Gross natural gas withdrawal from oil wells was 5.9 Tcf in 2012. Crude oil production was 3.2 billion barrels. It is assumed: 1,030 scf/MMBtu for natural gas and 5.8 MMBtu/bbl.

The calculated emissions rate of 1.3 percent is far below earlier estimated emissions rates of 2.2 to 2.4 percent derived using data from prior EPA Inventories, and far below other studies that peg emissions rates even higher.

Table 8: Historical Natural Gas Emissions Rate of Production

1990	2005	2013	2014	2015	2016	2017
2.27%	1.94%	1.50%	1.40%	1.35%	1.35%	1.32%

Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017 Environmental Protection Agency, Energy Information Administration, and AGA Calculations*

Applying this methodology using data from prior years, one can see that the emissions rate of production has steadily decreased during the past two decades, down from 2.2 percent in 1990.

Similarly, one can examine the methane emissions per unit of natural gas produced. Instead of a percentage ratio, as shown previously, we calculate the kilograms of methane emissions released per unit of gross natural gas withdrawals (including attribution of a portion of petroleum system methane emissions). This ratio serves as a measure of the *efficiency* of natural gas production as it relates to methane emissions.

Over the past nearly three decades, annual methane released from natural gas systems has declined as production has risen. As Figure 8 shows, taking the ratio of these values, methane emissions per million cubic feet of natural gas produced (gross withdrawals) have declined 48 percent between 1990 and 2017.

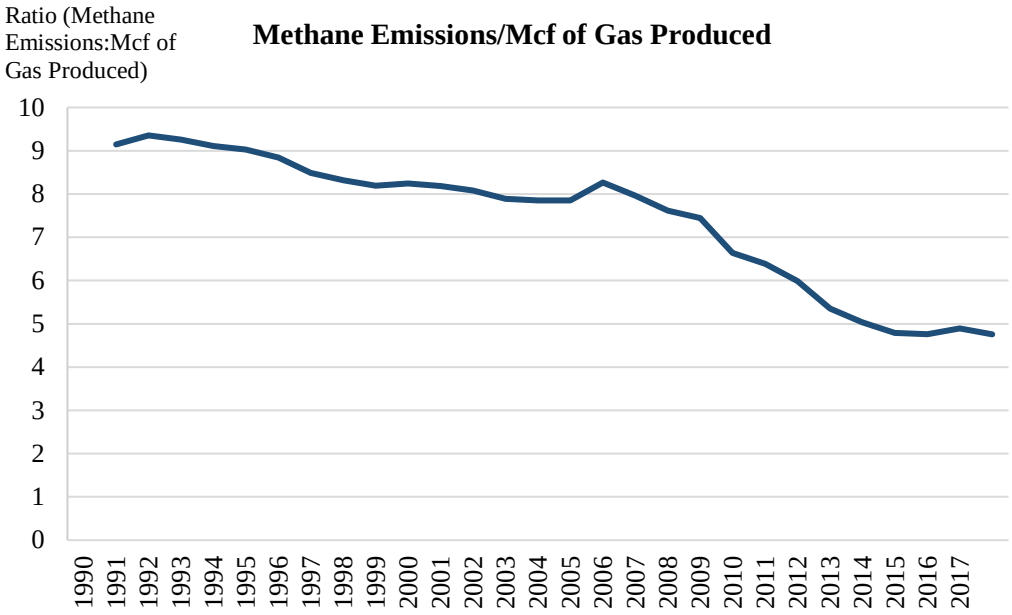

Figure 8: Methane Emissions per Mcf of Gas Produced (kg CO_2e/Mscf Gross Withdrawals)

Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017 Environmental Protection Agency, Energy Information Administration*

Part of this improvement is the application of better industry practices, advances in technology, and investments in lower-emitting equipment and infrastructure. This evolution toward better practices in further evidenced by the shift toward unconventional resource production, which has spurred the use of new extraction and control technologies. Furthermore, industry participation in EPA's voluntary program Natural Gas STAR has been instrumental in advancing cost-effective technologies and practices to control

methane emissions. We anticipate that control technologies for methane emissions will continue to improve over time.

The distribution system share of industry-wide emissions is 7 percent. Therefore, an effective emissions rate of production for distribution system natural gas emissions is less than 0.1%.

The industry and many of its observers routinely reference a natural gas emissions rate of production as the preferred metric by which to account for emissions in relation to industry activity. As such, it is entirely appropriate to use a similar metric for distribution systems to maintain consistency with metrics applied to the entire value chain. However, there are alternative metrics, some of which are laid out below. For example, another approach would be to take the ratio of distribution system emissions and LDC throughput. A series of emissions ratios are laid out below, and details behind the calculations can be found in the Appendix.

Table 9: Distribution System Emission Ratios

Natural Gas System Emissions as % of	
Production	0.09%
Consumption	0.11%
Volumes to Consumers	0.12%
LDC Volumes to Consumers	0.21%

Source: Inventory of U.S. Greenhouse Gas Inventory Emissions and Sinks: 1990-2017, Environmental Protection Agency, Energy Information Administration & AGA calculations

Conclusion

The analysis characterized new estimates for methane emissions and the implications for the GHG profile of natural gas. The EPA *Inventory* affirms a low methane emissions profile for natural gas distribution systems shaped by a declining trend.

The picture of emissions from natural gas systems is continuously evolving and becoming more refined. Improved science and systematic data collection are essential to inform the public debate about the effect of natural gas use on the climate and to support recognition of the benefits of using natural gas to reduce greenhouse gas emissions.

The EPA *Inventory* is a continuous work in progress. Trends in natural gas system emissions are markers that signify directionally how new information better informs understanding of the GHG profile of natural gas production and use. New information will continue to refine the emissions estimates in the *Inventory* and will offer to industry, the public, and policymakers a better understanding where emissions occur and the levels of released methane. Better information helps focus attention on cost-effective opportunities identified in the data.

AGA and its members are committed to supporting studies to collect accurate measurements of emissions from natural gas utility operations. Starting in 2013, a group of 13 natural gas utilities engaged with a research team from the Washington State University on a project to collect new data on distribution system emissions. This work, which identified and quantified equipment-specific leaks, formed the basis of revisions to distribution system emissions found in the current EPA *Inventory*. In addition to this critical research, other studies have examined emissions from other stages of the natural gas value chain, some of which were also incorporated into this year's *Inventory*. Further ongoing data collection and analysis from the government, academia, and industry will help to inform better public understanding of natural gas methane emissions and the role natural gas plays in reducing emissions and addressing climate.

In addition to improvements in estimated emissions from natural gas systems, actual reductions are expected to continue. To share three supporting examples: currently, 42 states plus the District of Columbia, have a program to facilitate accelerated replacement and modernization of natural gas distribution pipelines no longer fit for service. In March 2016, 41 natural gas companies pledged to support as founding partners for EPA's Methane Challenge Program to achieve emissions reductions through a voluntary best management practice commitment framework. And EPA air standards mandating industry adoption of reduced emission completions (RECs) went into effect in 2015 and will improve capture of methane at the wellhead.

Because of improvements in technology, ongoing science, and understanding of existing trends reported by EPA, signs point to continuously improving emissions profile of the natural gas industry and help lay the foundation for natural gas as a critical component of the energy mix for years to come.

Appendix

A.1

Table 10: Calculation of Emissions Rates

Emissions Rates Calculation Based on EPA Inventory (2017)			Relevant Source
[A]	CH_4 Natural Gas Systems (Bcf)	347	EPA
[B]	NG Fraction of Total Energy Content from Oil & Gas Production	26%	EIA
[C]	CH_4 Petroleum Exploration & Production Field Operations (Bcf)	76.68	
[D] = [B] * [C]	NG Fraction of CH_4 from Petroleum Operations (Bcf)	21	EPA, EIA
[E]	U.S. Gross Natural Gas Production	33,170	EIA
[F]	Methane Content of U.S. Pipeline NG	90%	AGA Estimate
([A]+[C])/([D]*[E])	NG Leakage – NG System as % of Total NG Production	1.23%	Calculation
[F]	Methane Emissions – Distribution Systems (Bcf)	25	EPA
[G]	U.S. Natural Gas Consumption (Bcf)	27,089	
[H]	U.S. NG Volumes Delivered to Consumers (Bcf)	25,196	EIA
[I]	LDC NG Volumes Delivered to Consumers (Bcf)	13,934	
[K]	Methane Content of Distribution System Natural Gas	90%	AGA Estimate
Natural Gas Leakage – Distribution Systems as % of:			
[F]/([D]*[K])	Production	0.08%	Calculation
[F]/([G]*[K])	Consumption	0.10%	
[F]/([H]*[K])	Volumes Delivered to Consumers	0.11%	
[F]/([I]*[K])	LDC Volumes Delivered to Consumers	0.20%	

Source: EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016, Energy Information Administration and AGA Calculations

A.2

Table 11: 2017 Data and Methane Emissions (Mg) for the Natural Gas Distribution Stage

Distribution (2017)	Emission Factors		Activity Data	
Normal Fugitives				
Pipeline Leaks				
Mains – Cast Iron	1,157.3	kg/mile	24,493	miles
Mains – Unprotected Steel	861.3	kg/mile	54,818	miles
Mains – Protected Steel	96.7	kg/mile	476,713	miles
Mains – Plastic	28.8	kg/mile	738,067	miles
Services – Unprotected Steel	14.5	kg/service	3,095,829	services
Services – Protected Steel	1.3	kg/service	13,641,543	services
Services – Plastic	0.3	kg/service	49,449,227	services
Services – Copper	4.9	kg/service	789,482	services
Meter/Regulator (City Gates) *				
M&R > 300	2,142.7	kg/station	4,008	stations
M&R 100-300	995.4	kg/station	14,627	stations
M&R < 100	727.2	kg/station	7,818	stations
Reg > 300	868.9	kg/station	4,382	stations
R-Vault > 300	50.6	kg/station	3,602	stations
Reg 100-300	143.4	kg/station	13,256	stations
R-Vault 100-300	50.6	kg/station	11,164	stations
Reg 40-100	163.7	kg/station	39,780	stations
R-Vault 40-100	50.6	kg/station	8,364	stations
Reg < 40	22.4	kg/station	16,868	stations
Customer Meters				
Residential	1.5	kg/meter	54,273,271	outdoor meters
Commercial/Industry	9.7	kg/meter	5,660,960	meters
Routine Maintenance				
Pressure Relief/Valve Relief	1.0	kg/mile	1,294,091	miles main
Pipeline Blowdown	2.0	kg/mile	2,223,094	miles
Upsets				
Mishaps	30.6	kg/mile	2,223,094	miles

Source: Inventory of the U.S. Greenhouse Gas Emissions and Sinks: 1990-2017, Annex Tables 3.6-2,3.6-7, Environmental Protection Agency

A.3

Table 12: Activity Data for Natural Gas Systems, Data Sources/Methodology

Segment/Source	Units	Data Source(s)/Methodology
Distribution		
Pipeline Leaks		
Mains – Cast Iron	Miles	Material-specific mileage of distribution mains in year N (PHMSA 2018b). Refer to EPA 2016d for additional detail.
Mains – Unprotected Steel	Miles	
Mains – Protected Steel	Miles	
Mains – Plastic	Miles	
Total Pipeline Miles	Miles	Total *miles of main* (all pipeline material types)
Services – Unprotected Steel	Services	Material-specific counts of distribution services in year N (PHMSA 2018b). Refer to EPA 2016d for additional details
Services – Protected Steel	Services	
Services – Plastic	Services	
Services – Copper	Services	
Total Services	Services	Total *services* (all pipeline material types)
Meter/Regulator (City Gates)		
M&R > 300	Stations	1990-2006: [Base year 1992 estimate of stations per mile in each category (GRI/EPA 1996)] * [total miles of distribution pipeline in year N] 2007-2010: [Base year 1992 estimate of stations per mile in each category scaled by residential gas consumption in year N (EIA 2018d) compared to base year] * [total miles of distribution in year N] 2011-2017: Year specific GHGRP subpart W reported station count in each category scaled by total miles of mains compared to reported miles of mains. Refer to EPA 2016d for additional detail.
M&R 100-300	Stations	
M&R < 100	Stations	
Reg > 300	Stations	
R-Vault > 300	Stations	
Reg 100-300	Stations	
R-Vault 100-300	Stations	
Reg 40-100	Stations	
R-Vault 40-100	Stations	
Reg < 40	Stations	
Customer Meters		
Residential	Outdoor meters	[Number of residential natural gas consumers in year N (EIA 2018g)] * [Weighted average percentage of meters outdoors (GRI/EPA 1996)]. Refer to EPA 2016d for additional detail
Commercial/Industry	Meters	Total number of commercial + industrial natural gas consumers in year N (EIA 2018g). Refer to EPA 2016d for additional detail.
Routine Maintenance		
Pressure Relief/Valve Releases	Miles main	Total miles of mains (all pipeline material types)
Pipeline Blowdown	Miles	Total miles of distribution pipelines (mains + services) (PHMSA 2018b)
Upsets		
Mishaps (Dig-ins)	Miles	Total miles of distribution pipeline (mains and services) (PHMSA 2018b).

Source: Inventory of U.S. Greenhouse gas Emissions and Sinks: 1990-2017, Annex Table 3.6-8, Environmental Protection Agency

Table 13: Installed Pipeline Main and Emissions from Main Pipe

Year	Installed Main Pipe (Thousand Miles)	Emissions from Main Pipe (MMTe)
1990	873.9	14.65
1991	891.4	13.83
1992	892.0	13.34
1993	931.4	13.16
1994	1,002.7	13.34
1995	1,003.8	11.93
1996	1,001.8	11.28
1997	1,003.1	10.85
1998	1,022.1	10.17
1999	1,007.5	9.52
2000	1,046.8	9.08
2001	1,097.9	8.72
2002	1,144.7	8.13
2003	1,097.9	7.46
2004	1,139.7	7.21
2005	1,117.8	6.67
2006	1,214.0	6.26
2007	1,201.1	5.81
2008	1,205.9	5.37
2009	1,209.5	4.89
2010	1,204.4	4.48
2011	1,232.3	4.02
2012	1,246.3	3.97
2013	1,253.7	3.86
2014	1,264.3	3.78
2015	1,275.7	3.69
2016	1,286.2	3.67
2017	1,308.2	3.57

Source: Department of Transportation Form 7100
Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2017, Annex Table 3.6-1, AGA Calculation

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