American Gas Association

Energy Markets, 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.

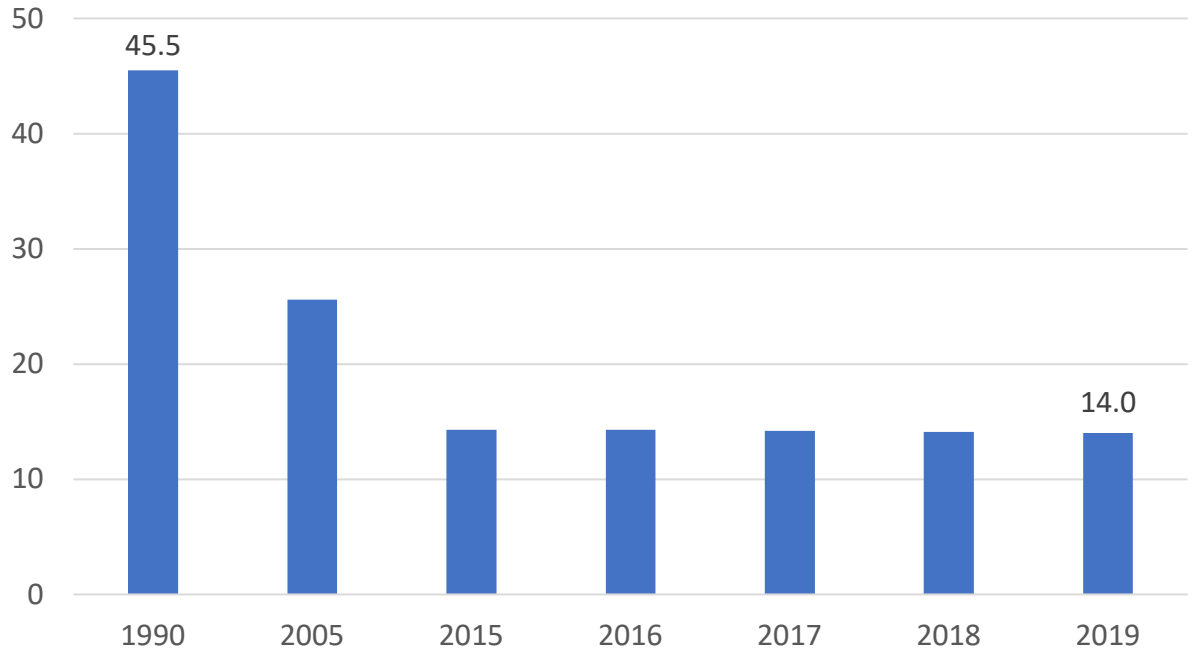
Efficient natural gas technologies serve as low-cost, low-emission options for building energy needs, home comfort, industrial processes, and electricity generation. Furthermore, natural gas is a low-carbon fuel relative to coal and oil; natural gas results in less carbon dioxide for the same amount of useful 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: 1990-2019 (Inventory)*, released in April 2021. The *Inventory* incorporates new data available from studies on emissions as well as the EPA's 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 69 percent from 1990 to 2019, even as natural gas utility companies added more than 788,000 miles of pipelines to serve 21 million more customers, increases of 44 and 39 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_2-equivalent (MMTe)



Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Environmental Protection Agency

Key Findings:

- Annual methane emissions from natural gas distribution systems declined 69 percent from 1990 to 2019.
- The natural gas emissions rate of production from distribution systems remains unchanged at 0.08 percent.
- Industry-wide natural gas emissions as a rate of production (the "leakage rate") are now 1.0 percent – a level well below the most stringent thresholds for immediate climate benefits achieved through coal to natural gas switching.
- Total methane emissions from natural gas systems have declined 16 percent from 1990 to 2019.
- 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 2.7 percent of all US greenhouse gas emissions.
- Methane emissions from natural gas distribution were revised up 20 percent for year-end 2018 estimates compared with the prior EPA inventory. Recalculations based on updated methodologies resulted in a 165 percent increase in estimated methane emissions from commercial and industrial customer meters.

Recalculations in the 2021 Inventory

Each year, several estimates of emissions and sinks in the *Inventory* are recalculated and revised. EPA periodically updates data and calculation methods for specific source estimates to improve inventory quality, including transparency, completeness, consistency, and overall usefulness of the report.

Recalculations to natural gas systems in this year's *Inventory* include:

- Update to produced water methodology:
  - EPA developed a revised estimate for produced water from natural gas wells. Revised estimate covers all gas formations (only two coalbed methane formations were estimated previously). The updated methodology includes updates to the produced water quantities and the emission factor.
- Update to customer meters methodology:
  - EPA updated the commercial and industrial meters methodologies to use leak data from a GTI 2009 and a GTI 2019 study. EPA applied weighted average population emission factors (EF) from the two studies across the time series for the methodology implemented in the *Inventory*.
  - The previous *Inventory* used a lower EF (based on commercial meter measurements only) and applied that EF to both commercial and industrial meter counts. The updated methodology used commercial meter data from both the 2009 and 2019 GTI studies to develop an EF that is applied to commercial meter counts, and uses industrial meter data from both the 2009 (leak emissions only) and GTI 2019 studies to develop an EF that is applied to industrial meter counts.

Table 1: Commercial and Industrial Meter National Emissions (Metric Tons CH_4)

Source	1990	2005	2015	2016	2017	2018	2019
Commercial Meters	99,129	121,634	127,615	128,108	128,698	129,130	129,796
Industrial Meters	22,926	21,653	19,775	19,828	19,419	19,426	19,239
Total	**122,055**	**143,287**	**147,390**	**147,936**	**148,118**	**148,555**	**149,036**
Previous Estimate	*43,362*	*52,605*	*54,919*	*55,129*	*55,324*	*56,140*	*NA*

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Environmental Protection Agency

Table 2: Commercial and Industrial Meter National Emissions (Metric Tons CO_2)

Source	1990	2005	2015	2016	2017	2018	2019
Commercial Meters	2,919	3,581	3,757	3,772	3,789	3,802	3,822
Industrial Meters	675	638	582	584	572	572	566
Total	**3,594**	**4,219**	**4,340**	**4,356**	**4,361**	**4,374**	**4,388**
Previous Estimate	*1,277*	*1,549*	*1,617*	*1,623*	*1,629*	*1,653*	*NA*

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, 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 most significant in the distribution sector for this year.

The combined impact of revisions to 2018 natural gas sector emissions, compared to the previous *Inventory*, is an increase from 140.0 to 152.5 MMT CO_2 Eq., an 8.9 percent increase from year-end 2018 estimates, as shown in detail in Table 3.

Table 3: Summary of Revisions to Natural Gas System Methane Emissions 2018 (MMTe)

Methane Emissions in 2018	Prior Inventory	New Inventory	Change
Exploration	1.1	0.8	-27.3%
Production	80.9	90.8	12.2%
Onshore Production	45.3	51.7	14.1%
Offshore Production	0.8	0.8	0.0%
Gathering, Boosting	34.8	38.3	10.1%
Processing	12.2	12.1	-0.8%
Transmission, Storage	33.9	34.8	2.7%
Distribution	11.8	14.1	19.5%
Natural Gas Total	**140.0**	**152.5**	**8.9%**
Petroleum Field Operations	36.2	37.3	3.0%
Oil and Gas Total	**176.2**	**189.8**	**7.7%**

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 2020, 2021 editions, Environmental Protection Agency

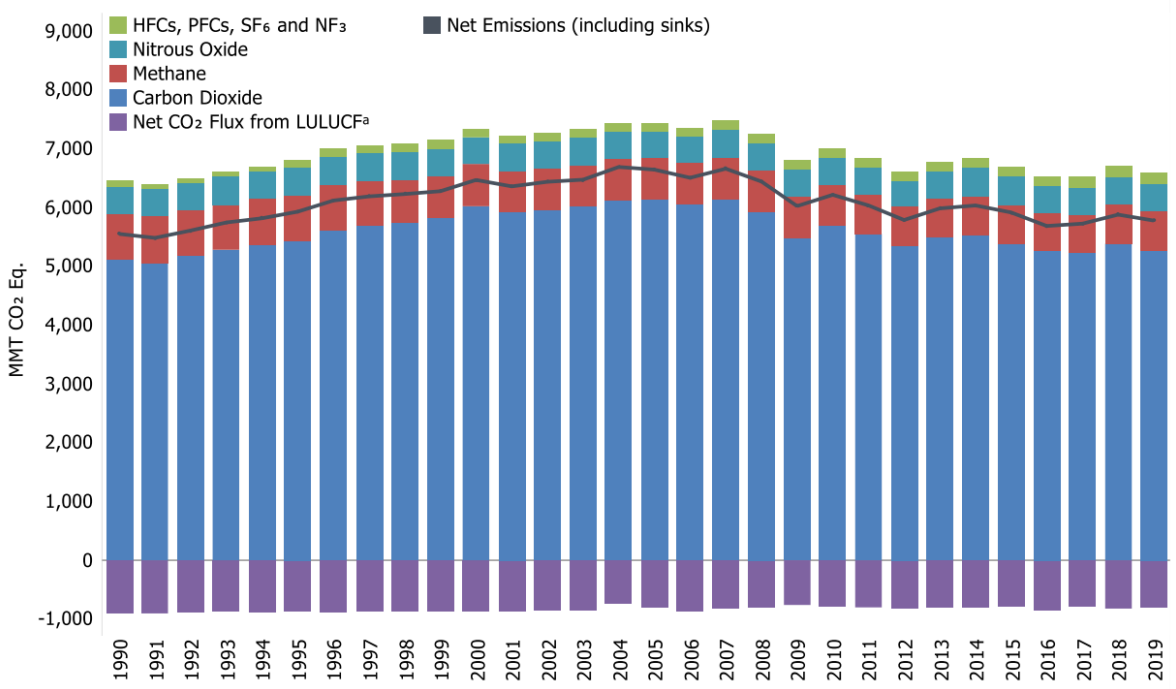
Summary and Analysis of EPA Inventory

For 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 US greenhouse gas emissions available.

The *Inventory* covers all major and minor greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), nitrous oxides (N_2O), 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 of 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 (MMTe)

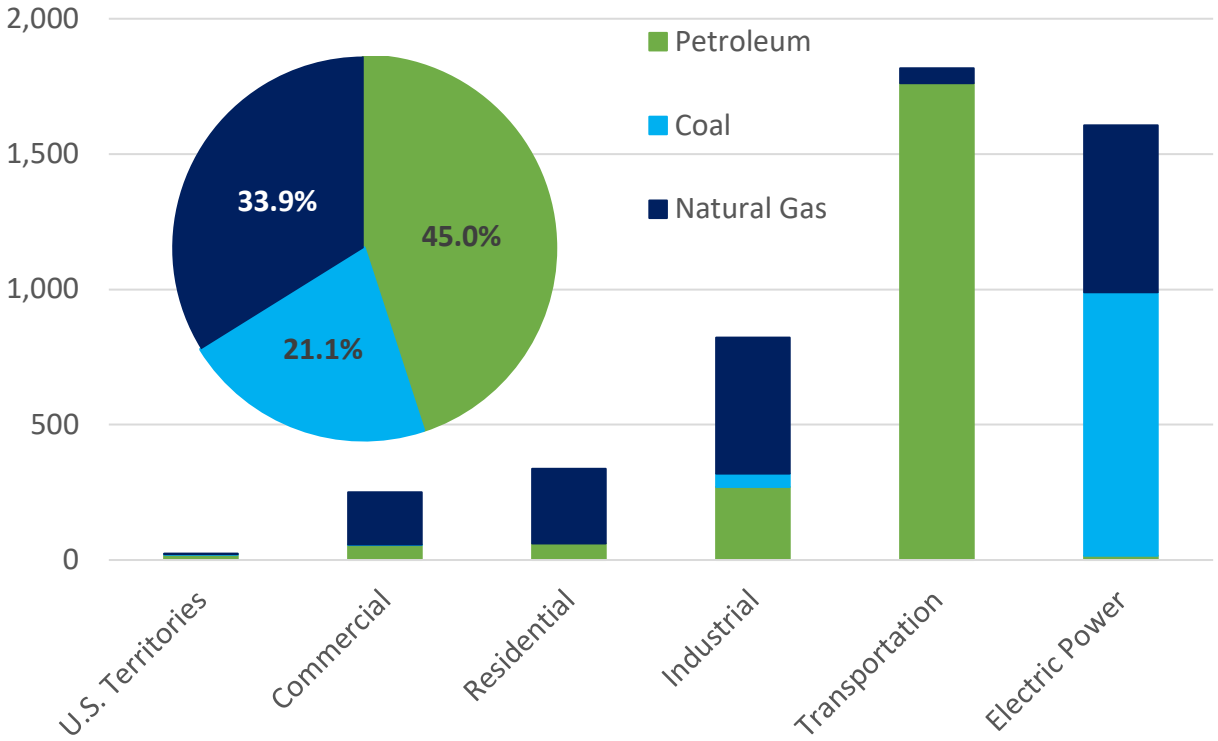


Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Environmental Protection Agency

In 2019, United States greenhouse gas emissions totaled 6,558.3 million metric tons of carbon dioxide equivalent (MMTe), down 1.7 percent from 2018 and down 13.0 percent from 2005. CO_2 from fossil fuel combustion accounts for most annual GHG emissions, constituting 74 percent of the total GHG emissions.

Total CO_2 emissions from fossil fuel combustion equaled 4,856.7 MMTe in 2019, which is 16 percent lower than 2005 levels. Petroleum combustion accounts for 45 percent of energy-related CO_2 emissions, the largest share of all fuels. Natural gas ranked second among the fossil fuels in this category at 34 percent followed by coal at 21 percent.

Figure 3: CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type, 2019 (MMTe)

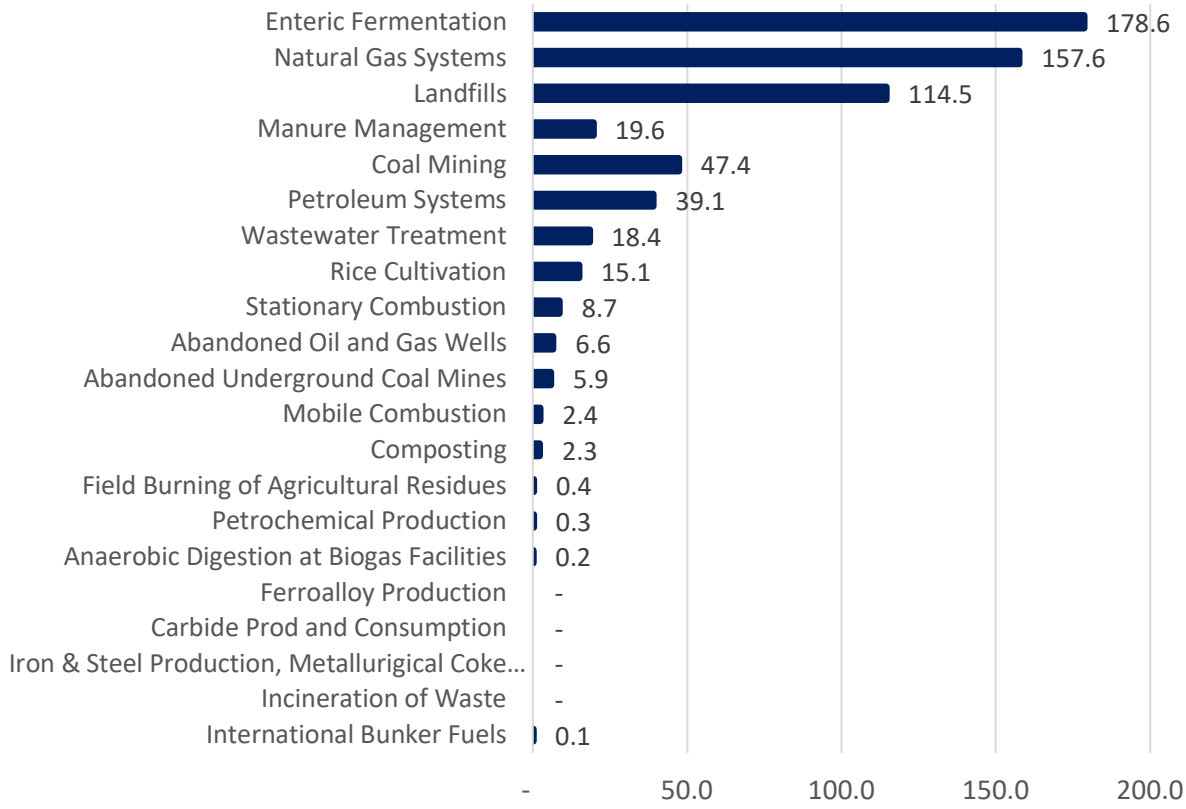


Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Environmental Protection Agency

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.

Methane is the second-largest source of 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 2019, methane emissions were 659.7 MMTe and accounted for 10 percent of all US GHG emissions.

Figure 4: Sources of Methane Emissions 2019 (MMTe)



Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Environmental Protection Agency

Nitrous oxide (N_2O) is the third-largest source of US greenhouse gas emissions, accounting for 7 percent of total GHGs in 2019. Primary sources of N_2O are agricultural soil management and mobile and stationary combustion.

Other GHGs include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). Emissions of these gases together accounted for 3 percent of total US GHG emissions in 2019.

Natural Gas System Methane Emissions

The US natural gas system is comprised of hundreds of thousands of producing wells, hundreds of operating drilling rigs, well completion equipment, numerous processing facilities, trillions of cubic feet of underground storage capacity, millions of customer meters, and an extensive transmission and distribution network of 2.6 million miles of pipeline.

The EPA categorizes the natural gas system into four stages: natural gas field production, processing, transmission and storage, and distribution. Methane, CO_2 and, to a lesser extent, N_2O, are the three 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, accounting for 24 percent of all methane emissions, just behind enteric fermentation (27 percent of methane emissions). In 2019, natural gas system methane emissions equaled 157.6 MMTe or 2.4 percent of total US greenhouse gases.

The largest share of natural gas system methane emissions stems from field production, which accounts for 60 percent. The processing stage accounts for 8 percent, transmission and storage 24 percent, and distribution at 9 percent. Historical emissions for natural gas systems are listed in Table 4.

Table 4: Methane Emissions from Natural Gas Systems (MMTe)

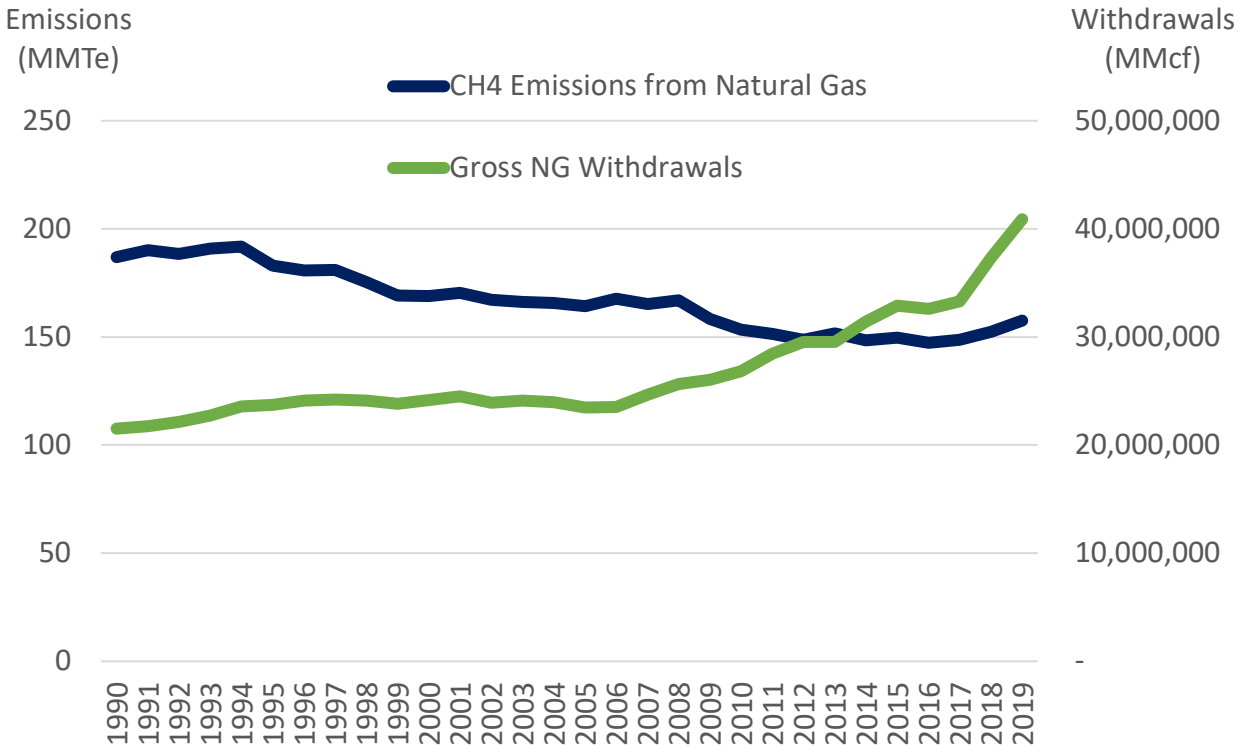
	1990	2005	2015	2016	2017	2018	2019	1990-2019	Share of Natural Gas System Emissions, 2019
Exploration	4.2	10.3	1.0	0.7	1.2	0.8	0.5	-88%	0.3%
Production	58.8	80.4	89.3	86.6	89.4	90.8	93.7	59%	59.5%
Onshore	36.0	54.9	52.1	49.5	50.7	51.7	52.0	44%	33.0%
Offshore	4.3	1.8	0.6	0.8	0.7	0.8	0.8	-81%	26.0%
Gathering, Boosting	18.5	23.9	36.6	36.3	38.0	38.3	40.9	121%	0.5%
Processing	21.3	11.6	11.0	11.2	11.5	12.1	12.4	-42%	7.9%
Transmission, Storage	57.2	36.1	34.1	34.5	32.4	34.8	37.0	-35%	23.5%
Distribution	45.5	25.6	14.3	14.3	14.2	14.1	14.0	69%	8.9%
Total	**186.9**	**164.2**	**149.8**	**147.3**	**148.7**	**152.5**	**157.6**	**-16%**	**100.0%**

Note: Totals may not sum due to independent rounding

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Environmental Protection Agency

Natural gas system methane emissions have declined 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 90 percent.

Figure 5: Methane Emissions and Natural Gas Production



Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Environmental Protection Agency

Natural Gas System CO_2 and N_2O Emissions

Natural gas systems emit greenhouse gases other than methane, such as carbon dioxide (CO_2) and nitrous oxide (N_2O). Sources of non-combustion CO_2 emissions from natural gas systems include those resulting from normal operations, routine maintenance, and system upsets. Emissions of N_2O from flaring activities are included in the *Inventory*, with most of the emissions occurring in the processing and production segments.

Greenhouse gas emissions from both CO_2 and N_2O in the natural gas system are minimal. Non-combustion CO_2 emission levels from natural gas systems have increased from 32.0 to 37.2 MMT, a 16 percent rise from 1990 to 2019. N_2O emissions are 41 percent lower than peak 2015 levels but rose 1 percent from 2018 to the most current *Inventory*.

The increased use in plastic materials for gas distribution pipeline has helped reduce CO_2 emissions in the natural gas distribution systems stage. CO_2 emissions from this sector are less than 0.1 MMT CO_2-eq. across the time series. The combined impact of revisions to 2018 natural gas sector CO_2 emissions due to recalculations resulted in a decrease of 3 percent in non-combustion CO_2 emissions from natural gas systems from 1990 to 2018 compared to the previous *Inventory*.

Table 5: Non-Combustion CO_2 Emissions from Natural Gas Systems (MMT)

Stage	1990	2005	2015	2016	2017	2018	2019
Exploration	0.4	1.7	0.3	0.2	0.4	0.4	0.2
Production	3.0	4.5	7.6	7.5	7.3	9.8	11.0
Processing	28.3	18.8	21.0	22.0	23.0	23.1	24.8
Transmission and Storage	0.2	0.2	0.2	0.3	0.5	0.5	1.2
Distribution	0.1	+	+	+	+	+	+
Total	**32.0**	**25.2**	**29.1**	**30.1**	**31.2**	**33.9**	**37.2**

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Environmental Protection Agency

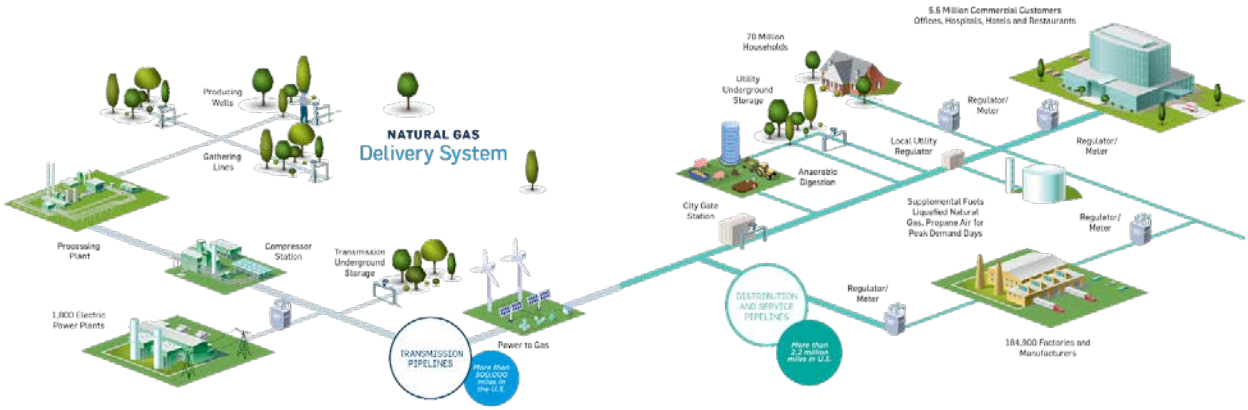
Table 6: N_2O Emissions from Natural Gas Systems (Metric Tons CO_2-Eq)

Stage	1990	2005	2015	2016	2017	2018	2019
Exploration	458	1,348	3,248	115	244	2,267	123
Production	4,359	5,804	9,835	8,892	4,453	5,094	5,591
Processing	NO	3,348	5,766	3,819	3,066	3,587	4,987
Transmission and Storage	257	309	346	382	462	234	630
Distribution	NO	NO	NO	NO	NO	NO	NO
Total	**5,073**	**10,808**	**19,196**	**13,209**	**8,226**	**11,182**	**11,331**

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Environmental Protection Agency

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 2.6 million miles of pipeline, compressor stations, meter and regulating facilities, and other related equipment. Gas utilities serve predominantly households and businesses and provide about one-quarter of natural gas volumes consumed for electricity generation. In 2019, natural gas utilities delivered 54 percent of the natural gas consumed across the country.



Source: AGA Playbook 2020

The distribution stage, which includes the regular operation and maintenance of natural gas systems along with emissions releases from accidents, account for nine 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, including those reported to the EPA through its Natural Gas STAR and Methane Challenge programs.

Overall, emissions from distribution systems have been improving, even as the size of the system has grown significantly. Methane emissions from distribution systems were 14.0 MMTe in 2019, a decline of 69 percent from 1990 levels. This drop occurred even as the industry added 788,000 miles of pipelines to serve 21 million more customers.

Table 7: Methane Emissions from the Natural Gas Distribution Stage, 2019

Distribution	kt	MMTe	Share
Pipeline Leaks	209.0	5.2	37%
Meter/Regulator (City Gates)	43.7	1.1	8%
Customer Meters	232.2	5.8	41%
Routine Maintenance	5.7	0.1	1%
Upsets	69.3	1.7	12%
Net Emissions	**559.9**	**14.0**	**100%**

*Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Annex Table 3.6-1, Environmental Protection Agency, *These values represent net emissions for these sources*

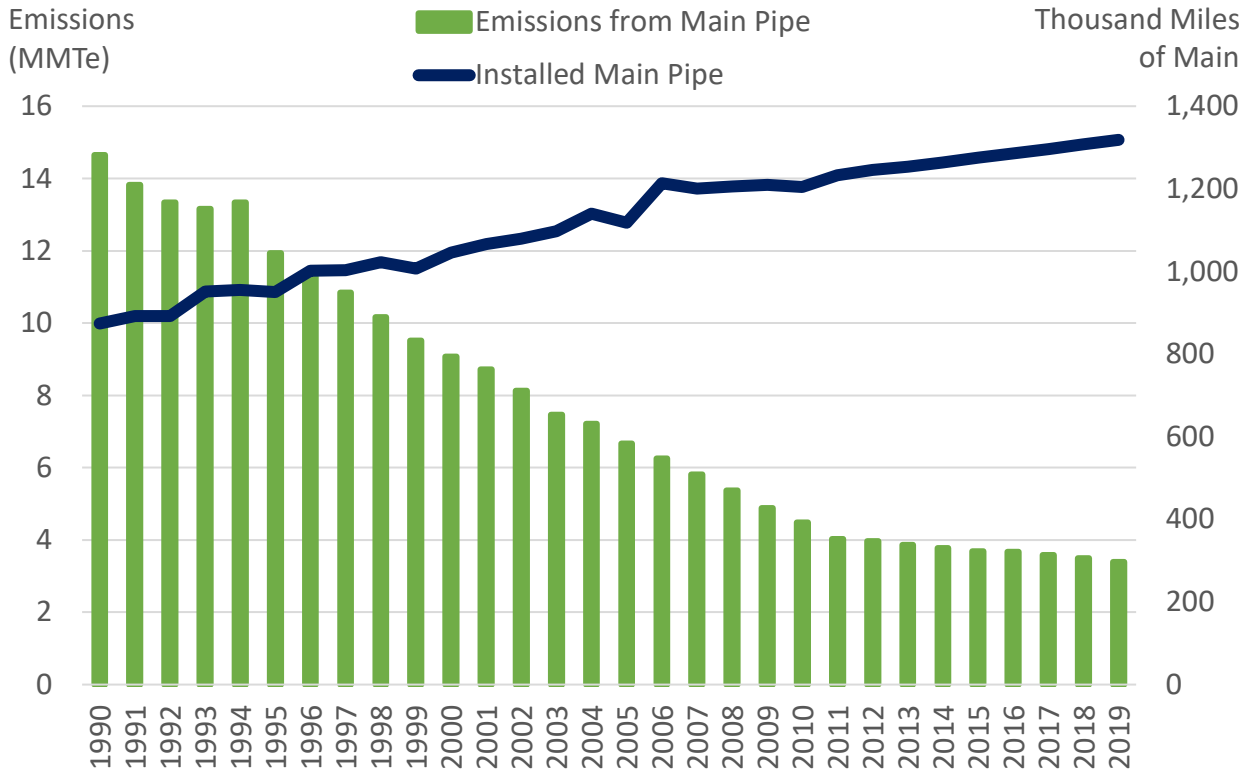
Table 7 summarizes the breakdown in distribution-stage methane emissions by source category. The majority of distribution emissions are from pipeline leaks and meter/regulator operation. Less than half, 37 percent, of distribution system methane emissions are associated with pipeline leaks, and 8 percent of methane emissions 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 41 percent. Upsets and routine maintenance together comprise 13 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 plastic, 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's environmental footprint.

Figure 7: Methane Emissions from Distribution System Main Pipeline – Emissions and Activity



Source: Department of Transportation Form 7100, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Annex Table 3.6-1, AGA Calculation

[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 of 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.

Methane and N_2O Emissions from Stationary Gas Combustion

The direct combustion of fuels by stationary sources, or stationary combustion, is another source of methane and nitrous oxide (N_2O). Methane and N_2O emissions from stationary combustion sources depend on fuel characteristics, size and vintage of the combustion technology, pollution control equipment, and operation and maintenance of the combustion equipment. Methane emissions from stationary combustion are primarily a function of the methane content of the fuel and combustion efficiency of the appliance.

The EPA develops estimates of methane and N_2O emissions from stationary combustion using methods from the Intergovernmental Panel of Climate Change (IPCC). Estimates were obtained by multiplying emission factors – by sector and fuel type – by fossil fuel and wood consumption data. This "top-down" methodology is characterized by two basic steps, 1) determining energy consumption by sector and fuel type and 2) determining the amount of methane and N_2O emitted.

In the *Inventory*, energy consumption from combustion activities is grouped by sector: industrial, commercial, residential, electric power, and US territories. For methane and N_2O emissions from industrial, commercial, residential, and U.S. Territories, estimates were based upon consumption of coal, gas, oil, and wood. Activity data for the fuel type for each of these sectors, such as gallons of fuel oil, tons of wood, etc., is then multiplied by default emission factors to obtain emission estimates described below.

Emission factors for the residential, commercial, and industrial sectors are defined by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006). Table 8 provides factors used for each sector and fuel type.

For the electric power sector, emissions were estimated by multiplying fossil fuel and wood consumption by technology- and fuel-specific IPCC emission factors shown in Table 9. These emission factors were taken from an EPA publication on emission rates for combustion sources, EPA's Compilation of Air Pollutant Emission Factors, AP-42, for combined cycle natural gas units. The EPA AP-42 emission factors have been developed and compiled from source test data, material balance studies, and engineering estimates. The EPA AP-42 emission factors were in large part used in developing the 2006 IPCC Guidelines as the factors suggested by the IPCC as a set of default emission factors in order to improve the completeness of the *Inventory* work. Table 10 shows activity factors which are used for the emissions estimates.

Table 8: Methane and N_2O Emission Factors for Natural Gas by Sector (g/GJ)

Natural Gas End-Use Sector	CH_4	N_2O
Residential	5	0.1
Commercial	5	0.1
Industrial	1	0.1
U.S. Territories	1	0.1

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Annex 3.1, Environmental Protection Agency

Table 9: Methane and N_2O Emissions Factors by Technology Type for the Electric Power Sector (g/GJ)

Natural Gas End-Use Sector	CH_4	N_2O
Boilers	1.0	0.3
Gas-Fired Gas Turbines > 3 MW	3.7	1.3
Large Dual-Fuel Engines	258	NA
Combined Cycle	3.7	1.3

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Annex 3.1, Environmental Protection Agency

Table 10: Fuel Consumption by Stationary Combustion for Calculating Methane Emissions (tBtu)

End-Use Sector	1990	2005	2015	2016	2017	2018	2019
Residential	4,487	4,946	4,777	4,506	4,563	5,174	5,205
Commercial	2,680	3,073	3,316	3,224	3,273	3,638	3,645
Industrial	7,713	7,331	8,679	8,769	8,872	9,335	9,515
Electric Power	2,376	5,562	9,707	10,003	9,381	10,747	11,552
U.S. Territories	0	24	57	64	48	48	48
Natural Gas Total	**17,255**	**20,937**	**26,536**	**26,565**	**26,137**	**28,943**	**29,965**

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Annex 3.1, Environmental Protection Agency

In 2019, methane emissions from natural gas stationary combustion accounted for 13.3 and 33.3 percent of the direct fossil fuel (including natural gas, coal, fuel oil, and wood) methane emissions from the residential and commercial sectors, respectively. Methane emissions from natural gas combustion in the residential and commercial sectors in 2019 increased 20 and 33 percent respectively from 1990 and registered no change from 2018. More detailed emissions from natural gas combustion can be found in Table 11 below. In 2019, estimated methane emissions from natural gas stationary combustion represented 1.5 percent of total natural gas system methane emissions.

Table 11: Methane Emissions from Stationary Combustion (MMTe)

Sector/Fuel Type	1990	2005	2015	2016	2017	2018	2019
Electric Power	**0.4**	**0.9**	**1.2**	**1.2**	**1.1**	**1.2**	**1.3**
Coal	0.3	0.4	0.3	0.2	0.2	0.2	0.2
Fuel Oil	+	+	+	+	+	+	+
Natural Gas	0.1	0.5	0.9	0.9	0.9	1.0	1.1
Wood	+	+	+	+	+	+	+
Industrial	**1.8**	**1.7**	**1.6**	**1.6**	**1.5**	**1.5**	**1.5**
Coal	0.4	0.3	0.2	0.2	0.2	0.1	0.1
Fuel Oil	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Natural Gas	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Wood	1.0	1.0	1.1	1.0	1.0	1.0	1.0
Commercial	**1.1**	**1.1**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**
Coal	+	+	+	+	+	+	+
Fuel Oil	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Natural Gas	0.3	0.4	0.4	0.4	0.4	0.4	0.4
Wood	0.5	0.5	0.6	0.6	0.6	0.6	0.6
Residential	**5.2**	**4.1**	**4.5**	**3.9**	**3.8**	**4.5**	**4.6**
Coal	0.2	0.1	0.0	0.0	0.0	0.0	0.0
Fuel Oil	0.3	0.3	0.2	0.2	0.2	0.2	0.2
Natural Gas	0.5	0.6	0.6	0.5	0.5	0.6	0.6
Wood	4.1	3.1	3.7	3.1	3.0	3.7	3.8
U.S. Territories	**+**	**0.1**	**+**	**+**	**+**	**+**	**+**
Coal	+	+	+	+	+	+	+
Fuel Oil	+	0.1	+	+	+	+	+
Natural Gas	NO	+	+	+	+	+	+
Wood	NO	NO	NO	NO	NO	NO	NO
Total	**8.6**	**7.8**	**8.5**	**7.9**	**7.6**	**8.5**	**8.7**

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Environmental Protection Agency
Note: Totals may not sum due to independent rounding

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 within the different sectors across the natural gas supply chain, from production, gathering processing, transmission and storage and distribution. 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 US 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 6,305 kilotons of methane in 2019, which is equivalent to 328.9 Bcf[3]. This value includes emissions from natural gas wells only. It is also necessary to

[3] Assuming 0.01917 kg/scf CH_4

account for methane emissions from petroleum production given that 11 percent of produced natural gas came from oil wells in 2019.

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.[4] The natural gas fraction of total energy content (oil plus natural gas) from oil wells was 15.9 percent in 2019.[5] Applying this factor to total petroleum system methane emissions, we count 12.9 Bcf of methane from petroleum production as attributable to the natural gas value chain.

An average percentage of methane content is calculated to account for the varying share of methane in each stage of the natural gas system. 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 84.3 percent of natural gas is methane when applied to the whole value chain.

Table 12: Methane Content per Stage on Natural Gas System

Exploration	Onshore Production	Offshore Production	Production (Total)	Gathering, Boosting	Processing	Transmission	Distribution
78.8%	78.8%	78.8%	78.8%	78.8%	87.0%	93.4%	93.4%

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Environmental Protection Agency

Using EIA data for US gross natural gas withdrawals of 40,892 Bcf in 2019, and using a calculated methane content of 84 percent for natural gas, we calculate:

$$\frac{328.9\ Bcf + 12.9\ Bcf}{40{,}892} \times \frac{1}{84.3} = 1.00\%$$

The calculated emissions rate of 1.00 percent is far below earlier estimated emissions rates of 2.2 percent derived using data from prior EPA Inventories, and far below other studies that peg emissions rates even higher.

Table 13: Historical Natural Gas Emissions Rate of Production

1990	2005	2015	2016	2017	2018	2019
2.21%	1.87%	1.21%	1.20%	1.18%	1.05%	1.00%

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, 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.

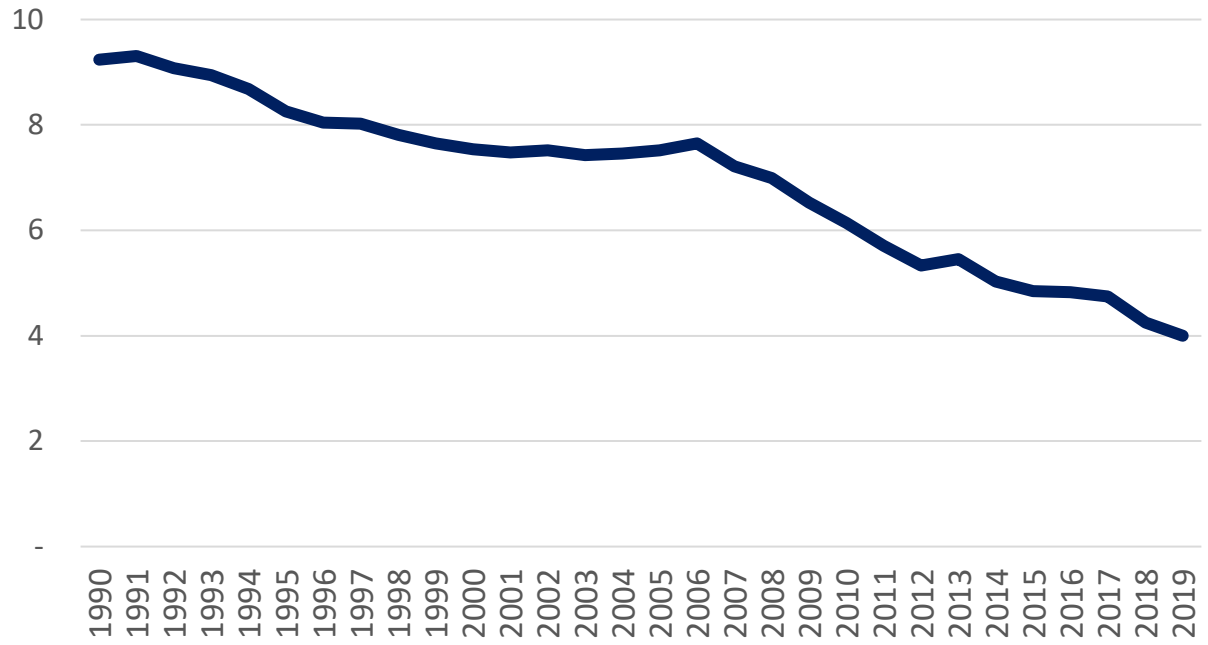
[4] This analysis assigns a portion of petroleum system methane emissions from natural gas production out of oil wells to the natural gas system. This contribution is small compared to combustion-related CO_2. Furthermore, these emissions should be considered an upper bound since it is not clear that 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.

[5] Calculated using the gas fraction of total energy from oil wells. It is assumed: 1,030 scf/MMBtu for natural gas and 5.8 MMBtu/bbl.

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 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 69 percent between 1990 and 2019.

Figure 8: Methane Emissions per Mcf of Gas Produced (MMTe / Mcf Gross Withdrawals)



Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, 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 is 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 9 percent. Therefore, an effective emissions rate of production for distribution system natural gas emissions is 0.08%.

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 14: Distribution System Emission Ratios

Natural Gas System Emissions as % of	
Production	0.08%
Consumption	0.11%
Volumes to Consumers	0.12%
LDC Volumes to Consumers	0.22%

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Environmental Protection Agency, Energy Information Administration, and 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 including the District of Columbia, have a program to facilitate accelerated replacement and modernization of natural gas distribution pipeline no longer fit for service. In March 2016, 41 natural gas companies pledged to participate 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 15: Calculation of Emissions Rates

Emissions Rates Calculation Based on EPA Inventory (2019)			Relevant Source
[A]	CH_4 Natural Gas Systems (Bcf)	328.9	EPA
[B]	NG Fraction of Total Energy Content from Oil & Gas Production	15.9%	EIA
[C]	CH_4 Petroleum Exploration and Production Field Operations (Bcf)	81.5	
[D] = [B] * [C]	NG Fraction of CH_4 from Petroleum Operations (Bcf)	12.9	EPA, EIA
[E]	US Gross Natural Gas Production	40,892	EIA
[F]	Methane Content of U.S. Pipeline NG	84.3%	AGA Estimate
([A]+[C])/([D]*[E])	NG Leakage – NG System as % of Total NG Production	1.0%	Calculation
[F]	Methane Emissions – Distribution Systems (Bcf)	29.2	EPA
[G]	U.S. Natural Gas Consumption (Bcf)	31,099	
[H]	U.S. NG Volumes Delivered to Consumers (Bcf)	28,619	EIA
[I]	LDC NG Volumes Delivered to Consumers (Bcf)	15,505	
[K]	Methane Content of Distribution System Natural Gas	84.3%	AGA Estimate
Natural Gas Leakage – Distribution Systems as % of:			
[F]/([D]*[K])	Production	0.08%	Calculation
[F]/([G]*[K])	Consumption	0.11%	
[F]/([H]*[K])	Volumes Delivered to Consumers	0.12%	
[F]/([I]*[K])	LDC Volumes Delivered to Consumers	0.22%	

Source: EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Energy Information Administration and AGA Calculations

A.2

Table 16: 2019 Data and Methane Emissions for the Natural Gas Distribution Stage

Distribution (2019)	Emission Factors		Activity Data	
Normal Fugitives				
Pipeline Leaks				
Mains – Cast Iron	1,157.3	kg/mile	21,273	Miles
Mains – Unprotected Steel	861.3	kg/mile	50,272	Miles
Mains – Protected Steel	96.7	kg/mile	473,381	Miles
Mains – Plastic	28.8	kg/mile	771,763	Miles
Services – Unprotected Steel	14.5	kg/service	2,730,142	Services
Services – Protected Steel	1.3	kg/service	12,853,773	Services
Services – Plastic	0.3	kg/service	51,240,857	Services
Services – Copper	4.9	kg/service	679,701	Services
Meter/Regulator (City Gates)				
M&R > 300	2,142.7	kg/station	4,099	Stations
M&R 100-300	995.4	kg/station	14,960	Stations
M&R < 100	727.2	kg/station	7,996	Stations
Reg > 300	868.9	kg/station	4,482	Stations
R-Vault > 300	50.6	kg/station	4,113	Stations
Reg 100-300	143.4	kg/station	13,559	Stations
R-Vault 100-300	50.6	kg/station	12,936	Stations
Reg 40-100	163.7	kg/station	40,688	Stations
R-Vault 40-100	50.6	kg/station	9,299	Stations
Reg < 40	22.4	kg/station	17,253	Stations
Customer Meters				
Residential	1.5	kg/meter	55,840,963	Outdoor meters
Commercial	23.4	kg/meter	5,546,847	Meters
Industrial	105.0	kg/meter	183,233	Meters
Routine Maintenance				
Pressure Relief/Valve Relief	1.0	kg/mile	1,316,689	Miles main
Pipeline Blowdown	2.0	kg/mile	2,262,562	Miles
Upsets				
Mishaps	30.6	kg/mile	2,262,562	Miles

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Annex Tables 3.6-2, 3.6-7, Environmental Protection Agency

A.3

Table 17: 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 2020b). Refer to EPA 2016 d for additional details.
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 2020b). 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 type)
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 2020d) compared to base year] * [total miles of distribution pipeline in year N]. 2011-2019: 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 2020g)] * [Weighted average percentage of meters outdoors (GRI/EPA 1996)]. Refer to EPA 2016d for additional detail.
Commercial	Meters	Total number of commercial natural gas consumers in year N (EIA 2020g). Refer to EPA 2021a for additional detail.
Industrial	Meters	
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 2020b)
Upsets		
Mishaps (Dig-ins)	Miles	Total miles of distribution pipeline (mains and services) (PHMSA 2020b)

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Annex Table 3.6-8, Environmental Protection Agency

Table 18: Installed Pipeline Main and Emissions from Main Pipe

Year	Installed Main Pipe (Thousand Miles)	Emissions from Main Pipe (MMTe)
1990	874.0	14.65
1991	891.4	13.83
1992	892.0	13.34
1993	951.8	13.16
1994	955.6	13.34
1995	949.8	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	1,045.6	9.08
2001	1,066.3	8.72
2002	1,079.6	8.13
2003	1,097.9	7.46
2004	1,139.8	7.21
2005	1,117.8	6.67
2006	1,214.0	6.26
2007	1,201.1	5.81
2008	1,206.0	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	1,295.9	3.58
2018	1,307.6	3.49
2019	1,318.5	3.40

Source: Department of Transportation Form 7100, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019, Annex Table 3.6-1, AGA Calculation

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