August 15, 2024

UNDERSTANDING GREENHOUSE GAS EMISSIONS FROM NATURAL GAS — EPA 2024 INVENTORY (1990–2022)

KEY FINDINGS

Economy-Wide Emissions

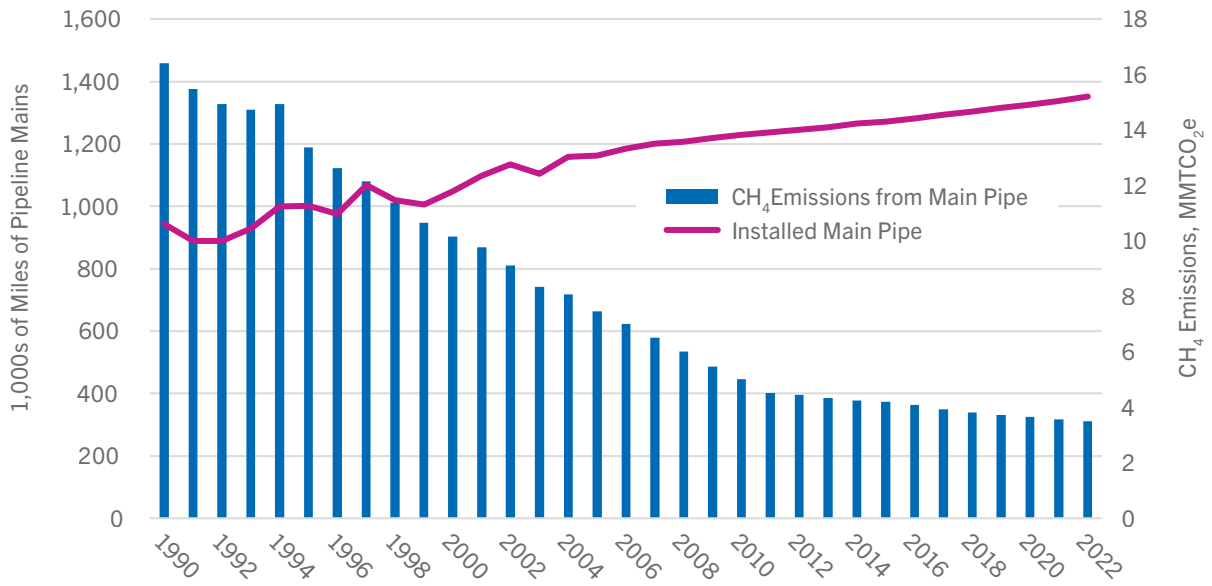
- In 2022, net U.S. greenhouse gas (GHG) emissions were 5,489 million metric tons of carbon dioxide (CO_2) equivalent ($MMTCO_2e$). Gross U.S. greenhouse gas emissions from sources only were 6,343 $MMTCO_2e$ in 2022.
- Overall, net economy-wide emissions have increased by 1 percent since 2021, likely due to the continued rebound of economic activity after the height of the COVID-19 pandemic.
- Net greenhouse gas emissions were 16.5 percent below 2005 levels. The decline is primarily due to a shift to less CO_2-intensive natural gas and an increase in the use of renewable energy generation in the electric power sector.
- Transportation activities accounted for the largest portion (over 28 percent) of total gross U.S. GHG emissions in 2022.
- Emissions from electric power generation accounted for the second-largest portion (nearly 25 percent), while emissions from industry accounted for the third-largest portion (nearly 23 percent).
- Carbon sequestration from the Land Use, Land-Use Change and Forestry (LULUCF) sector offset nearly 15 percent of total emissions in 2022.

Natural Gas Systems

- Total GHG emissions (methane, carbon dioxide and nitrous oxide) from natural gas systems in 2022 were 209.7 $MMTCO_2e$, a decrease of 17 percent from 1990 and a decrease of 0.3 percent from 2021, both primarily due to decreases in methane (CH_4) emissions. This represents 3.3 percent of total U.S. gross greenhouse gas emissions.
- Total methane (CH_4) emissions from natural gas systems were 173.1 $MMTCO_2e$ in 2022, a nearly 21 percent decrease compared to 1990 emissions and a 1 percent decrease from 2021 emissions. Since 2011, GHG emissions from natural gas systems have decreased by 5 percent, primarily due to decreases in CH_4 emissions.
- Natural gas distribution system greenhouse gas emissions, i.e. those associated with natural gas utility operations, were 15.3 $MMTCO_2e$, representing 0.24% of total U.S. gross greenhouse gas emissions.
- Total natural gas system methane emissions as a share of U.S. natural gas gross withdrawals are 0.81%.
- The ratio of methane emissions from natural gas distribution systems to total U.S. natural gas deliveries is 0.12%.

- Natural gas distribution accounted for 9 percent of CH_4 emissions from natural gas systems and less than 0.1 percent of CO_2 emissions from natural gas systems.
- There were 1,352,384 miles of distribution mains in 2022, an increase of 55 percent (480,227 miles) since 1990 (PHMSA 2022).
- Figure 1 illustrates distribution system CH_4 emissions and corresponding installed main pipe activity trends for the 1990 to 2022 time series.

Figure 1: Distribution System Main Pipe – Activity and CH_4 Emissions



Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022. Annex Table 3.6.1 Environmental Protection Agency

- National total dry gas production in the United States increased by 104 percent from 1990 to 2022 — this includes a 5 percent increase from 2021 to 2022 and a 59-percent increase from 2011 to 2022.
- Of the overall GHG emissions from natural gas systems (209.7 $MMTCO_2e$), 83 percent are CH_4 emissions (173.1 $MMTCO_2e$), 17 percent are CO_2 emissions (36.5 $MMTCO_2e$) and less than 0.1 percent are nitrous oxide (N_2O) emissions (0.15 $MMTCO_2e$).
- The change in natural gas system greenhouse gas emissions trend varies across segments and gases. Overall, the 1990 to 2022 decrease in CH_4 emissions is due primarily to the reduction of emissions from the following segments: distribution (70 percent decrease), transmission and storage (38 percent decrease), processing (37 percent decrease) and exploration (97 percent decrease).
- Over the same period, the natural gas production segment saw increased CH_4 emissions of 38 percent (with onshore production emissions increasing 16 percent, offshore production emissions decreasing 86 percent, gathering and boosting [G&B] emissions increasing 108 percent) and post-meter emissions increasing by 65 percent.
- CH_4 emissions from the transmission and storage segment accounted for approximately 23 percent of CH_4 emissions from natural gas systems. In comparison, CO_2 emissions from transmission and storage accounted for 3 percent of the CO_2 emissions from natural gas systems.

- CH_4 emissions from transmission and storage decreased by 38 percent from 1990 to 2022 due to reduced pneumatic device and compressor station emissions (including emissions from compressors and leaks). Transmission and storage CH_4 emissions declined by 1 percent from 2021 to 2022 due to reduced emissions from pipeline venting transmission compressors.
- CO_2 emissions from transmission and storage were 6.6 times higher in 2022 than in 1990 due to increased emissions from liquefied natural gas (LNG) export terminals. Transmission and storage CO_2 emissions increased by 36 percent from 2021 to 2022, also due to LNG export terminals and flaring (both transmission and storage).
- The quantity of LNG exported from the United States increased by a factor of 74 from 1990 to 2022 and by 9 percent from 2021 to 2022.
- In 2022, LNG emissions were about 1 percent of CH_4 and 86 percent of CO_2 emissions from transmission and storage.
- N_2O emissions from transmission and storage increased by 405 percent from 1990 to 2022 and increased by 177 percent from 2021 to 2022.

INTRODUCTION

Natural gas, gas utilities and the delivery infrastructure are essential to meeting our nation's GHG emissions-reduction goals, including pathways to achieve net-zero emissions.

Natural gas is a fuel of choice for consumers because of its low cost, efficient end uses and environmental attributes. Natural gas is a domestically produced and abundant energy source that presents the United States with an opportunity to address energy, economic and environmental objectives while serving as a foundational fuel for the U.S. economy for years to come. This potential has focused public attention on the environmental footprint of energy production, transportation, distribution and end-use.

Natural gas is a low-carbon fuel relative to coal and oil, resulting in less carbon dioxide (CO_2) emitted for the same amount of valuable energy produced. Efficient natural gas technologies are low-cost, low-emission options for home comfort, industrial processes, electricity generation and many building energy needs. A better understanding of the methane (CH_4) emissions released from production and delivery systems will further clarify how using natural gas may deliver greater environmental benefits.

Since the early 1990s, the United States Environmental Protection Agency (EPA) has developed and published estimates of national GHG emissions in its annual Inventory of U.S. Greenhouse Gas Emissions and Sinks (referenced throughout as the GHGI or "Inventory"). The GHGI is the most comprehensive assessment of U.S. GHG emissions available. The Inventory covers the most important GHGs emitted by human activity, including CO_2, CH_4, nitrous oxide (N_2O) and several fluorine-containing halogenated substances. EPA reports all GHG emissions in units of carbon dioxide equivalents (CO_2e) by weighting different air emissions by their respective global warming potentials (GWPs) to account for varying levels of radiative forces of each gas relative to CO_2 over a 100-year time horizon.

EPA published its annual Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022 in

April 2024 (2024 GHGI). The 2024 GHGI updates the U.S. Greenhouse Gas Emissions and Sinks: 1990-2021 published in April 2023 (2023 GHGI) and incorporates new data from GHG emissions studies and EPA's Greenhouse Gas Reporting Program (GHGRP).[1]

This report details data and commentary from the 2024 Inventory's section on the natural gas system. The American Gas Association (AGA) contracted SLR Consulting to present the data and analysis outlined in the Inventory. AGA then provided additional analysis, adding context and perspective to the report and describing retrospective changes throughout the Inventory.

OVERVIEW

In the Inventory, six emission subcategories — (i.e., segments) compose natural gas systems: exploration, production (including gathering and boosting), processing, transmission and storage, distribution and post-meter. The post-meter segment was added to the Inventory in 2022, with additional retroactive calculations conducted by the EPA to account for previous years' post-meter emissions.

Within the natural gas distribution segment, there were 1,352,384 miles of distribution mains in 2022, an increase of 55 percent or 480,227 miles since 1990.[2] Distribution system CH_4 and CO_2 emissions — primarily from fugitive emissions from pipelines and metering and regulating (M&R) stations — accounted for 9 percent of CH_4 emissions and less than 0.1 percent of CO_2 emissions from natural gas systems. The increased use of plastic piping, which has lower emissions than other pipe materials, and upgrades at M&R stations have reduced CH_4 and CO_2 emissions from distribution systems. Distribution system CH_4 emissions in 2022 were 70 percent lower than 1990 levels and 1 percent lower than 2021 emissions. Annual CO_2 emissions from this segment are less than 0.1 million metric tons of CO_2 across the time series 1990 to 2022.

This exceptional record can be traced to gas utilities continuing to make safety their top priority while remaining deeply committed to systematically upgrading infrastructure through risk-based integrity management programs. AGA and the natural gas utility industry have collectively committed to reducing greenhouse gas emissions while improving the safety and environmental profile of the natural gas system. The industry can point to many metrics demonstrating investment and progress in reducing greenhouse gas emissions, particularly CH_4.[3]

CH_4 emissions from the post-meter segment[4] accounted for approximately 8 percent of emissions from natural gas systems in 2022. Post-meter CH_4 emissions increased by 65 percent from 1990 to 2022 and increased by 3 percent from 2021 to 2022 due to increases in the number of residential houses using natural gas and increased natural gas consumption at industrial facilities and power plants. Post-meter CO_2 emissions account for less than 0.01 percent of total CO_2 emissions from natural gas systems.

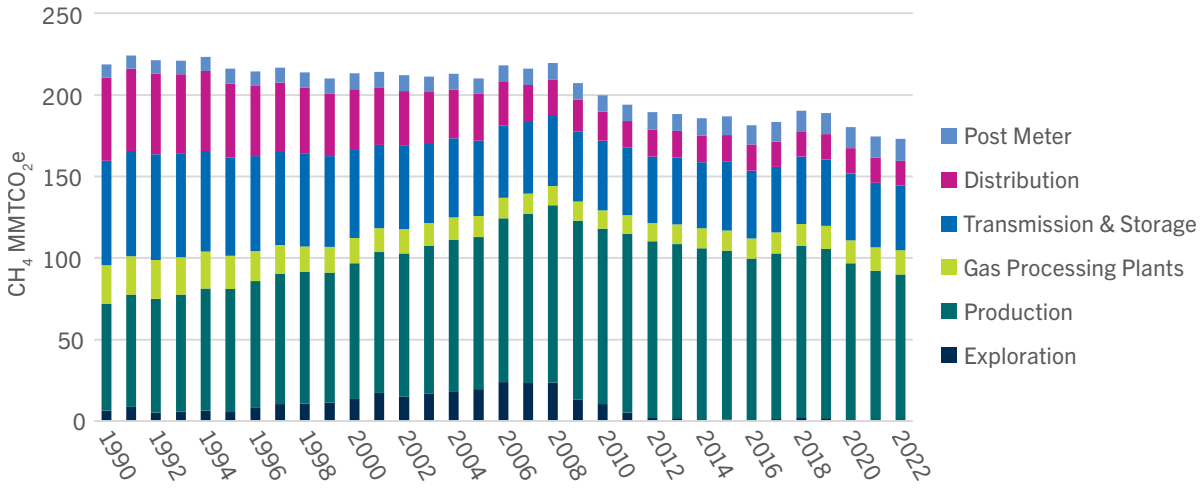
As gas companies continue to modernize the natural gas infrastructure base while connecting new

1 The Greenhouse Gas Reporting Program (GHGRP) collects detailed annual emissions data from the largest GHG emitting facilities in the United States. See https://www.epa.gov/ghgreporting.
2 Gas Distribution Annual Data. Pipeline and Hazardous Materials Safety Administration, U.S. Department of Transportation, Washington, DC. Available online at: https://www.phmsa.dot.gov/data-and-statistics/pipeline/annual-report-mileage-gas-distribution-systems.
3 https://playbook.aga.org/
4 Post-meter includes leak emissions from residential and commercial appliances, industrial facilities and power plants and natural gas-fueled vehicles.

customers, there will be new opportunities to achieve low-cost carbon emissions reductions by leveraging existing infrastructure, the nation's abundant natural gas resources and renewable fuels such as hydrogen and renewable natural gas.

Figure 2 illustrates the trend in CH_4 emissions over the 1990 to 2022 time series in terms of million metric tons CO_2e ($MMTCO_2e$).

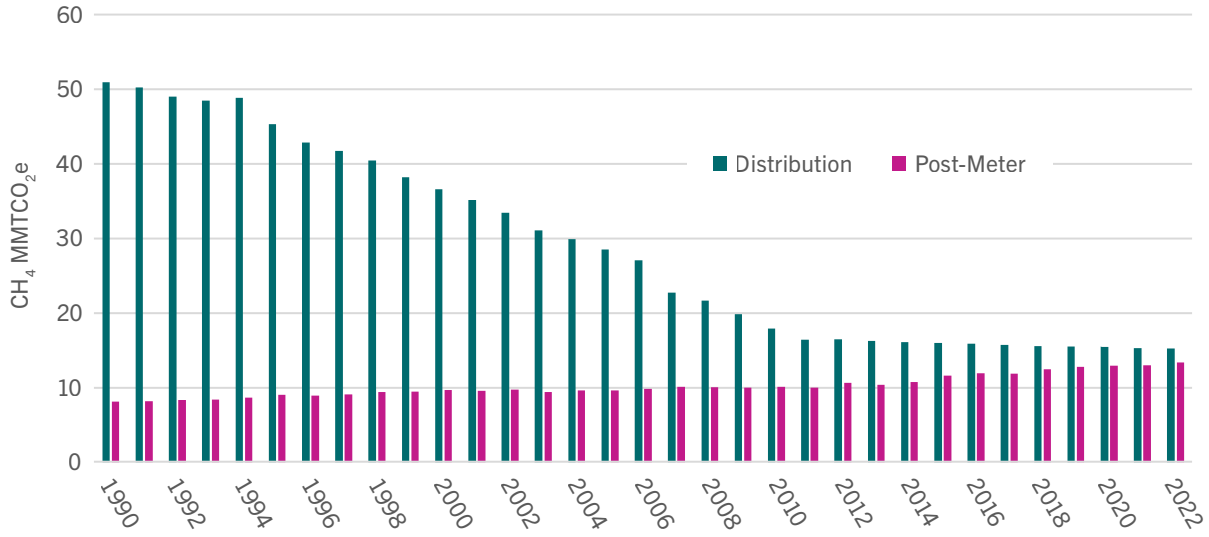
Figure 2: CH_4 Emissions from Natural Gas Systems over the 1990 to 2022 time Series ($MMTCO_2e$)



Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022. Annex Table 3.6.1 Environmental Protection Agency

Trends in CH_4 emissions ($MMTCO_2e$) from the distribution and post-meter segments are illustrated in Figure 3. Note that AGA has identified several data gaps and uncertainties within EPA's analysis of post-meter emissions. In particular, the EPA estimates for post-meter emissions likely contain significant uncertainties. See the section on post-meter emissions for further discussion.

Figure 3: CH_4 Emissions from Natural Gas Distribution and Post-Meter Segments ($MMTCO_2e$)



Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022. Annex Table 3.6.1 Environmental Protection Agency

SUMMARY OF UPDATES

In accordance with internationally accepted methods provided by the Intergovernmental Panel on Climate Change (IPCC), EPA seeks to improve GHG emission estimates each year "through the use of better methods and/or data with the goal of improving Inventory quality and reducing uncertainties, including the transparency, completeness, consistency and overall usefulness of the [Inventory]." EPA follows the 2006 IPCC Guidelines for National Greenhouse Gas Inventories in implementing methodological changes and refinements over time. Improvements in Inventory calculation methodologies impact the current and future annual Inventories and, in some cases, result in recalculating emissions from the previous Inventory's time series (e.g., 1990–2021).

- EPA updated the methodology to estimate national-level activity data for transmission compressor stations (i.e., station and compressor counts).
- EPA updated the Inventory with CO_2 and CH_4 estimates resulting from underground natural gas storage well events that occurred in several years across the Inventory time series.
- Transmission pipeline venting CH_4 emission estimates in the 2024 GHGI are on average 0.1 percent lower across the 1990 to 2021 time series than in the previous Inventory. The CH_4 emissions estimate for 2021 is 4 percent lower than in the previous Inventory. These changes were due to GHGRP submission revisions.
- There were no significant methodological updates to the distribution segment. Recalculation using updated data resulted in an average decrease in CH_4 emissions across the 1990 to 2021 time series of less than 0.1 percent and an average decrease in calculated CO_2 emissions across the 1990 to 2021 time series of less than 0.1 percent, as compared to the previous Inventory.
- There were no methodological updates to estimate post-meter emissions and recalculations using updated data resulted in an average decrease in CH_4 emissions across the 1990 to 2021 time series of less than 0.1 percent and an average decrease in calculated CO_2 emissions across the 1990 to 2021 time series of less than 0.1 percent, compared to the previous Inventory.

RECALCULATIONS IN THE 2024 INVENTORY

Recalculations of natural gas systems emissions in this year's Inventory include:

- Methodological updates to transmission compressor station activity data, completions and workovers and underground natural gas storage well events.
- Recalculations due to Greenhouse Gas Reporting Program (GHGRP) submission revisions.
- Recalculations due to updated well counts and production data from the Enverus energy metrics tracking platform.
- Table 1 includes natural gas system segments with recalculations resulting in a change of greater than 0.05 $MMTCO_2e$ comparing the previous estimate for 2021 to the current (recalculated) estimate for 2022.

Table 1: Recalculations of CH_4 in Natural Gas Systems ($MMTCO_2e$)

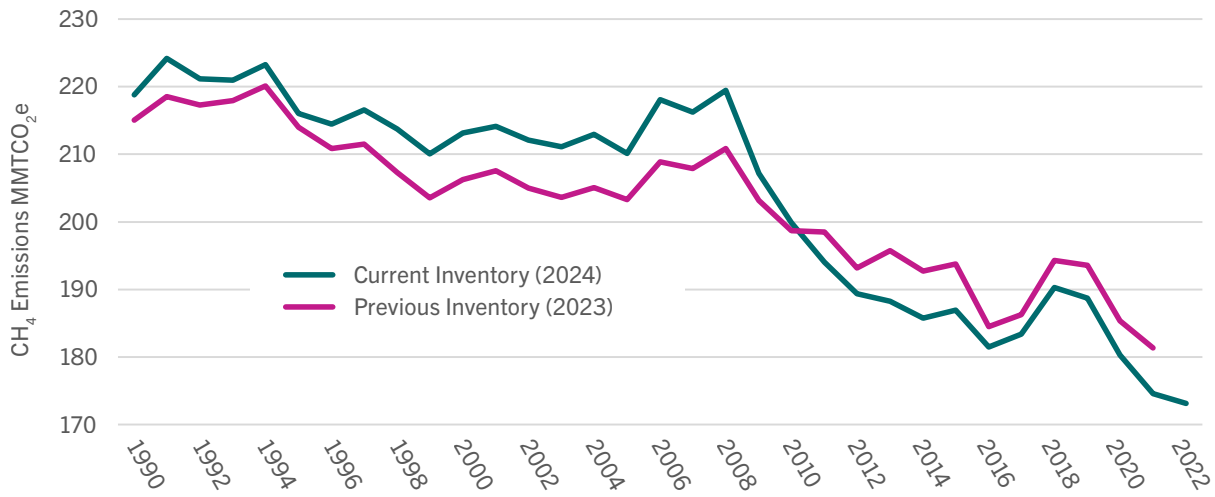
	Previous Estimate Year 2021, 2023 Inventory	Current Estimate Year 2021, 2024 Inventory	Current Estimate Year 2022, 2024 Inventory	Change (%)
Exploration	0.2	0.1	0.2	-50%
Production	95.1	92.2	89.7	-2%
Processing	14.3	14.2	15.1	-1%
Transmission & Storage	44.5	39.8	39.6	-11%
Distribution	15.3	15.3	15.2	0%
Post-Meter	13	13	13.4	0%
Total	**181.4**	**174.6**	**173.1**	**-4%**

Note: Totals may not sum due to independent rounding.

Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022. Table 3-81 Environmental Protection Agency

Figure 4 illustrates the quantitative impacts of EPA's recalculation of the CH_4 Inventory for the time series 1990 through 2022 for Natural Gas Systems.

Figure 4: Impacts of Recalculation of Net CH_4 Emissions from Natural Gas Systems



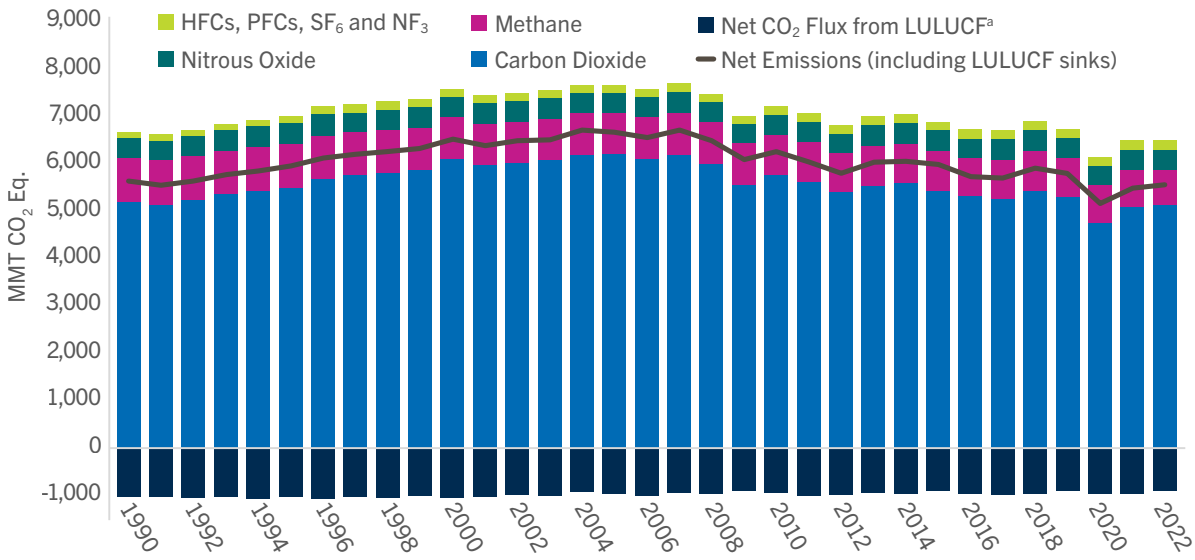
Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022. Annex Table 3.6.1 Environmental Protection Agency

SUMMARY AND ANALYSIS OF EPA INVENTORY

The trends in U.S. GHG emissions by gas for the 1990 through 2022 time series are illustrated in Figure 5 in terms of $MMTCO_2e$. Overall, from 1990 to 2022, total emissions of CO_2 decreased by 1.5 percent, total emissions of CH_4 decreased by 19.4 percent and total emissions of N_2O decreased by 4.5 percent. During the same period, emissions of fluorinated gases rose by 58 percent.[5] U.S. GHG emissions were partly offset by carbon sequestration in managed forests, urban area trees, agricultural soils, landfilled yard trimmings and coastal wetlands. These carbon sinks were estimated to offset 14.5 percent of total gross emissions in 2022.

5 Fluorinated gases including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6) and nitrogen trifluoride (NF_3)

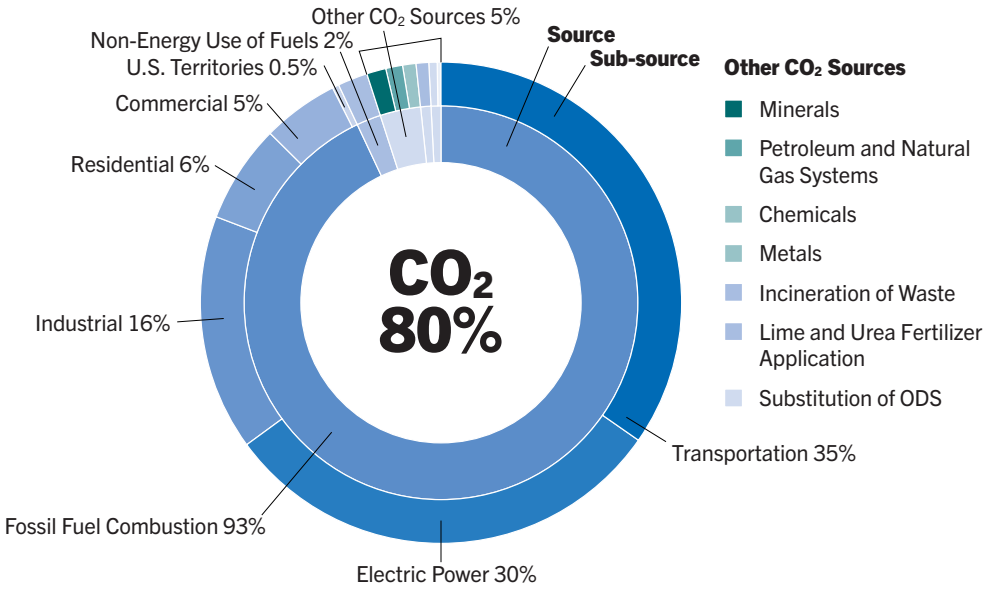
Figure 5: U.S. GHG Emissions and Sinks by Gas ($MMTCO_2e$)



Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, Figure 2-1
Environmental Protection Agency

As shown in Figure 6, CO_2 accounted for 80 percent of total U.S. emissions in 2022. CO_2 emissions have decreased 18 percent since 2005 and two percent since 1990. Fossil fuel combustion was the largest source, accounting for 93 percent of CO_2 emissions. Changes in emissions from fossil fuel combustion have been the main factor influencing U.S. emission trends. Net carbon fluxes from the Land Use, Land-Use Change and Forestry (LULUCF) sector provided a steady sink equivalent to 15 percent of total U.S. GHG emissions in 2022, as shown in Figure 5, above.

Figure 6: 2022 U.S. Sources of CO_2 Emissions

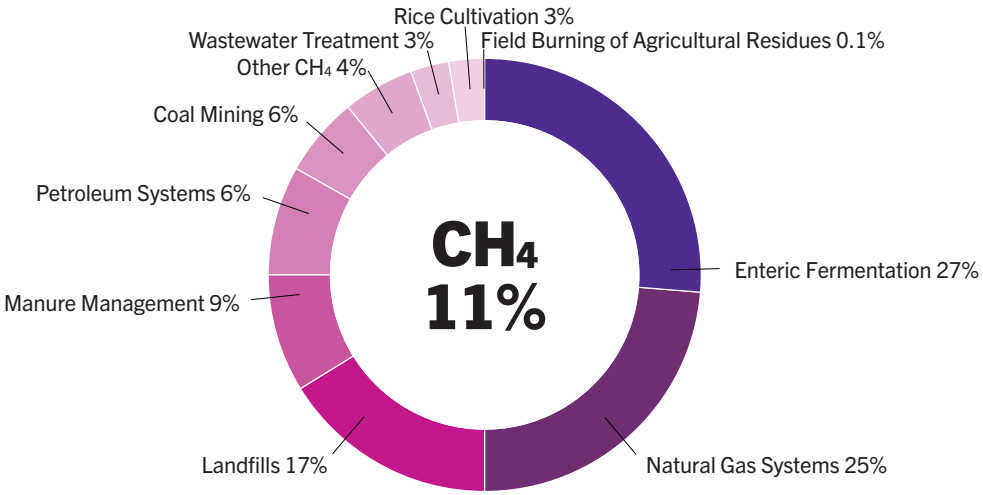


Source: Data Highlights, Figure 2 — Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022,
Environmental Protection Agency

CH_4 accounted for 11 percent of emissions in 2022. CH_4 emissions have decreased by 12 percent since 2005, 19 percent since 1990 and three percent from 2021 to 2022. Key trends include reduced

emissions from natural gas systems due to decreases in emissions from distribution, transmission and storage; decreases in emissions from landfills due to increased landfill gas collection and fewer decomposable materials discarded in landfills; and increased emissions from livestock in line with increasing cattle populations. Figure 7 provides a breakdown of U.S. sources of CH_4 emissions in 2022.

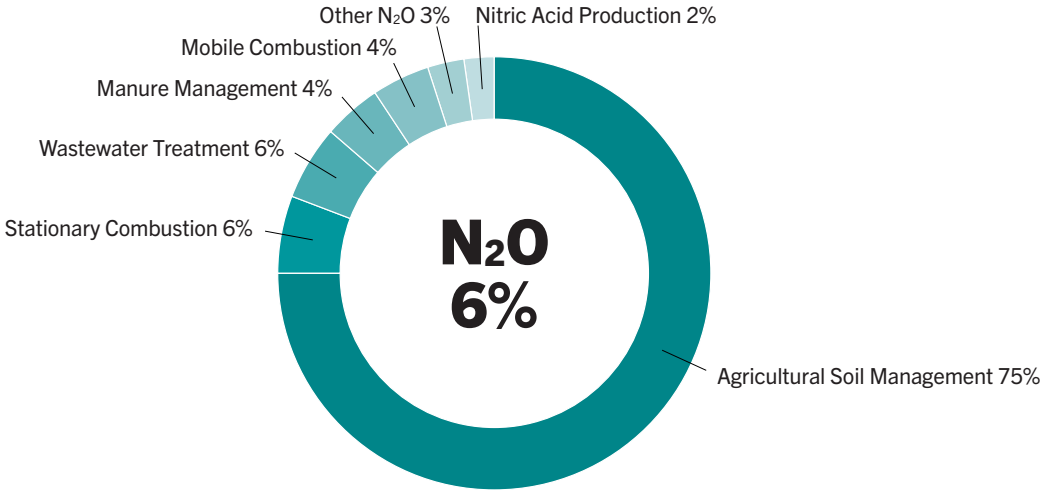
Figure 7: 2022 U.S. Sources of CH_4 Emissions



Source: Data Highlights, Figure 3 — Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, Environmental Protection Agency

Nitrous Oxide (N_2O) accounted for six percent of total U.S. GHG emissions in 2022. N_2O emissions have decreased by seven percent since 2005, five percent since 1990 and two percent in 2022. In 2022, emissions were influenced by changes in emissions from agricultural soils due to interannual weather patterns, fertilizer use and crop production; growing population and protein consumption impacting wastewater treatment industrial wastewater; changes in livestock populations and manure management systems; and impacts of national emission control standards on mobile combustion in on-road vehicles. Figure 8 provides a breakdown of U.S. N_2O emission sources in 2022.

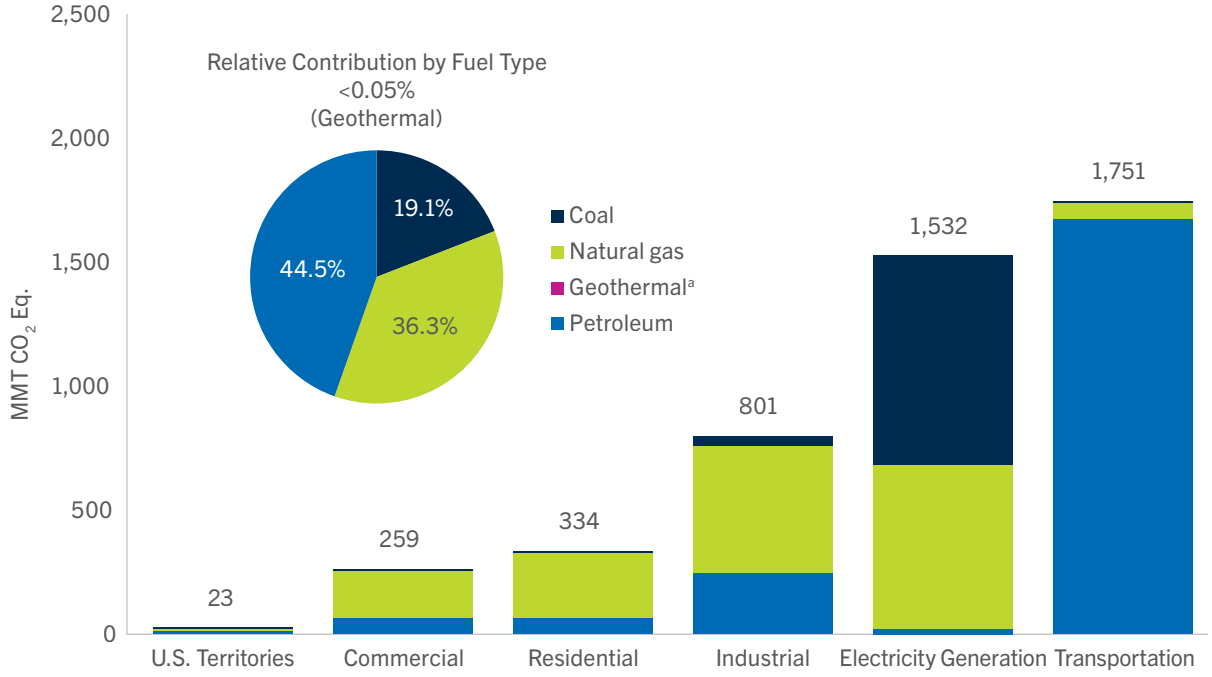
Figure 8: 2022 U.S. Sources of N_2O Emissions



Source: Data Highlights, Figure 4 — Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, Environmental Protection Agency

Figure 9 illustrates the distribution of CO_2 emissions from fossil fuel combustion between sectors by fuel type in 2022.

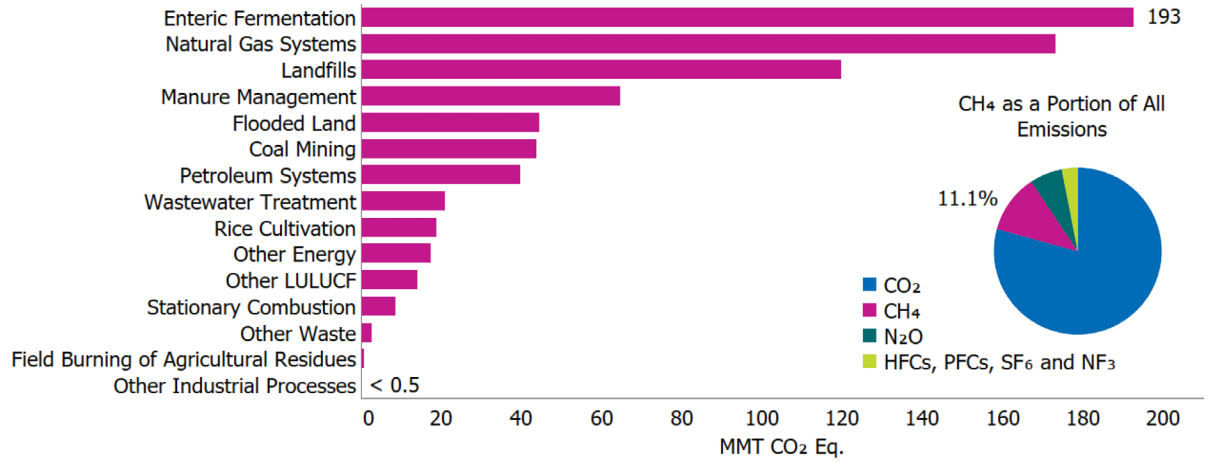
Figure 9: 2022 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type ($MMTCO_2e$)



Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, Figure 3-6
Environmental Protection Agency

As shown in Figure 10, the main anthropogenic sources of CH_4 in the United States include enteric fermentation from domestic livestock, natural gas systems, landfills, domestic livestock manure management, coal mining and petroleum systems.

Figure 10: 2022 Sources of CH_4 Emissions



Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, Figure ES-8
Environmental Protection Agency

Natural gas systems were the second largest anthropogenic source category of CH_4 emissions in the United States in 2022, accounting for 173.1 $MMTCO_2e$ of CH_4 (24.6 percent of total CH_4 emissions and 2.7 percent of total gross emissions). Emissions have decreased by 45.7 $MMTCO_2e$ (20.9 percent) since 1990, largely due to decreases in emissions from distribution, transmission and storage. The decrease in distribution emissions is due mainly to reduced emissions from pipeline and distribution station leaks, and the decrease in transmission and storage emissions is due mainly to reduced compressor station emissions (including emissions from compressors and leaks).

NATURAL GAS SYSTEMS CH_4 EMISSIONS

The U.S. 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. EPA categorizes the natural gas system into six segments: exploration, production (includes gathering and boosting), processing, transmission and storage, distribution and post-meter.

According to the categorical conventions used in the Inventory, natural gas systems represent the second largest source category for CH_4 in the United States, accounting for nearly 25 percent of all CH_4 emissions in 2022. In 2022, natural gas system CH_4 emissions equaled 173.1 $MMTCO_2e$ or 2.7 percent of total gross U.S. GHGs.

Both 2022 and historical CH_4 emissions from natural gas systems by segment are summarized in Table 2. In 2022, the production segment accounted for the largest share of natural gas system CH_4 emissions (51.8 percent), followed by transmission and storage (22.9 percent), distribution (8.8 percent), gas processing (8.7 percent) and the post-meter segment (7.7 percent). The increased use of plastic materials for gas distribution pipelines, as well as upgrades at M&R stations, has helped reduce both CH_4 and CO_2 emissions in the natural gas distribution segment (CO_2 emissions are discussed below).

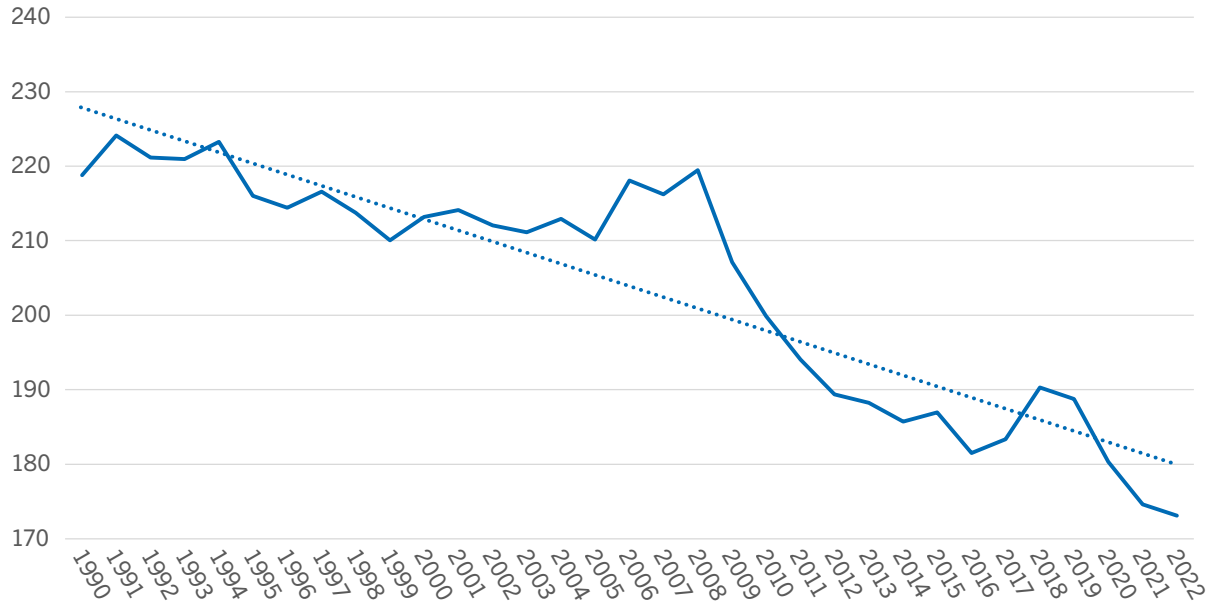
Table 2: CH_4 Emissions from Natural Gas Systems ($MMTCO_2e$)

Segment	1990	2000	2010	2020	2022	1990-2022	Share of Natural Gas System Emissions, 2022
Exploration	6.7	13.7	10.5	0.2	0.2	-97%	0.1%
Production	65.2	83	107.5	96.7	89.7	38%	51.8%
Processing	23.9	15.5	11.3	13.8	15.1	-37%	8.7%
Transmission & Storage	64	54.6	42.6	41.1	39.6	-38%	22.9%
Distribution	50.9	36.6	17.9	15.5	15.2	-70%	8.8%
Post-Meter	8.1	9.7	10.1	13	13.4	65%	7.7%
Total	**218.8**	**213.2**	**199.9**	**180.3**	**173.1**	**-21%**	**100%**

Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, Table 3-73 Environmental Protection Agency

Figure 11 illustrates the trend, including a linear trendline, in total CH_4 emissions from natural gas systems during the time series 1990 through 2022 expressed in terms of $MMTCO_2e$.

Figure 11: Trends in Total CH_4 Emissions from Natural Gas Systems, 1990 to 2021 ($MMTCO_2e$)



Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022.
Annex Table 3.6.1 Environmental Protection Agency

NATURAL GAS SYSTEMS CO_2 AND N_2O EMISSIONS

Certain subsegments of natural gas systems emit CO_2 and N_2O. Sources of non-combustion CO_2 emissions from natural gas systems include those resulting from normal operations, routine maintenance and system upsets. For natural gas system segments, the Inventory excludes all combustion CO_2 emissions except flaring CO_2 emissions. All combustion CO_2 emissions (except flaring) are accounted for in Section 3.1 of the Inventory – CO_2 from Fossil Fuel Combustion. CO_2 and N_2O from flaring activities within natural gas systems are included in the Inventory, with most of the emissions occurring in the processing and production segments.

Emissions of both CO_2 and N_2O from natural gas systems are minimal. Non-combustion CO_2 emission levels from natural gas systems have increased from 32.4 to 36.5 MMT, a 13 percent rise from 1990 to 2022. N_2O emissions were estimated to be 0.15 $MMTCO_2e$ in 2022, a 3,205 percent increase compared to 1990 emissions and a 1,104 percent increase compared to 2021 levels. The EPA attributes the increase in N_2O emissions from 1990 to 2022 and from 2021 to 2022 to increases in emissions from condensate tank flaring. Table 3 and Table 4 summarize CO_2 and N_2O emissions, respectively, across the time series from 1990 to 2022.

CO_2 emissions from the natural gas distribution segment are less than 0.1 MMT across the time series.

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

Segment	1990	2000	2010	2020	2022	1990-2022	Share of Natural Gas System Emissions, 2022
Exploration	0.6	1.3	2.0	0.1	+	+	+
Production	3.2	4.1	5.7	9.1	8.6	169%	23.6%
Processing	28.3	20.4	18.6	25.5	26.7	-6%	73.2%
Transmission & Storage	0.2	0.2	0.2	2.0	1.2	500%	3.3%
Distribution	0.1	+	+	+	+	+	+
Post-Meter	+	+	+	+	+	+	+
Total	**32.4**	**26.0**	**26.5**	**36.7**	**36.5**	**13%**	**100.0%**

+ Does not exceed 0.05 MMTe

Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, Table 3-75 Environmental Protection Agency

Table 4: N_2O Emissions from Natural Gas Systems (Metric Tons CO_2 eq.)

Segment	1990	2000	2010	2020	2022	1990-2022	Share of Natural Gas System Emissions, 2022
Exploration	518	912	1,434	46	27	-95%	0.02%
Production	3,853	5,046	7,045	3,687	142,002	3585%	93.4%
Processing	NO	1,894	4,261	4,353	8,808	*	5.8%
Transmission & Storage	228	258	303	943	1,149	404%	0.8%
Distribution	NO	NO	NO	NO	NO	NO	NO
Post-Meter	NO	NO	NO	NO	NO	NO	NO
Total	**4,599**	**8,109**	**13,042**	**9,029**	**151,986**	**3205%**	**100.0%**

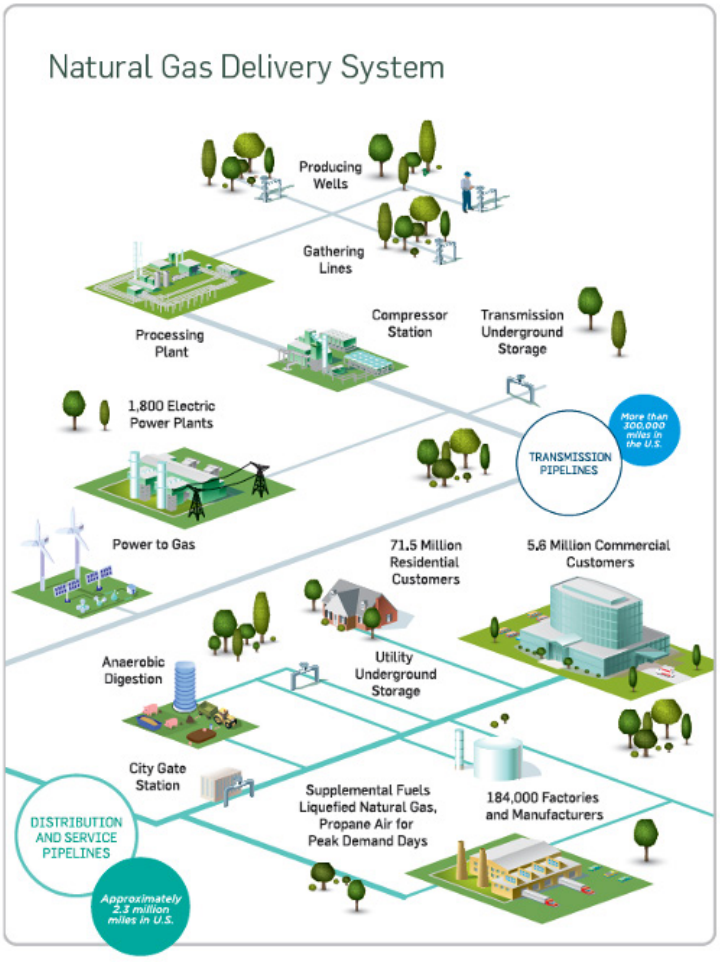
NO (Not Occurring)
*NO in 1990

Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, Table 3-77 Environmental Protection Agency

DISTRIBUTION SYSTEM CH_4 EMISSIONS

Three phases of the natural gas industry, as illustrated in Figure 12, are involved in delivering natural gas from the point of production to the consumer. Production companies explore, drill and extract natural gas from the ground. Transmission companies operate the pipelines that link the gas fields to major consuming areas. Distribution companies are the local utilities that deliver natural gas to the customer.

Figure 12: U.S. Natural Gas Delivery System



Source: American Gas Association, Delivering Natural Gas

Natural gas distribution systems (shown in teal in Figure 12), owned and operated by natural gas utilities, deliver natural gas to consumers through an extensive infrastructure of 2.3 million miles of pipeline, compressor stations, metering and regulating (M&R) facilities and other related equipment. Gas utilities predominantly serve households and businesses and provide about one-quarter of natural gas volumes consumed for electricity generation. In 2022, natural gas utilities delivered 53 percent of the natural gas consumed across the country.

The distribution segment, which includes the regular operation and maintenance of natural gas delivery infrastructure along with emissions released from accidents, accounts for 8.8 percent of estimated CH_4 emissions from the natural gas system. Categories of distribution sources of CH_4 emissions include leaks from natural gas pipelines, M&R stations, customer meters, upsets (i.e., mishaps such as excavation damage) and releases during routine maintenance.

Gas utility companies reduce CH_4 emissions each year through voluntary measures, which are discussed later in this report. Throughout much of the time series, these measures have been reported to EPA through two partnership programs: Methane Challenge (from 2016 to 2024) and Natural Gas STAR (from 1993 to 2022). Methane Challenge, set up to transparently report

systematic and comprehensive actions to reduce CH_4 emissions, has included natural gas distribution utility partners representing more than 80 percent of all U.S. natural gas customers.[6] EPA's Natural Gas STAR program encouraged natural gas and oil companies to adopt proven, cost-effective technologies and practices to improve operational efficiency and reduce CH_4 emissions.[7]

Overall, CH_4 emissions from the distribution segment have been declining since 1990, even as the size of the system has grown significantly. CH_4 emissions from distribution systems were 15.2 $MMTCO_2e$ in 2022, a decline of 70 percent from 1990 levels. This drop occurred as the industry added 480,227 miles of (main) pipelines to serve 23.4 million additional customers.[8]

Table 5 summarizes the breakdown in distribution-segment CH_4 emissions by source category. The majority of distribution CH_4 emissions are from pipeline leaks and M&R operations. Less than half, 34.8 percent, of distribution system CH_4 emissions are associated with pipeline leaks, and 8.4 percent of CH_4 emissions result from the operation of gas meters and regulators at city gates, which connect the transmission system with the distribution network. Customer meters account for 43.4 percent of distribution segment CH_4 emissions, and upsets and routine maintenance comprise nearly 13 percent.[9]

Table 5: 2022 CH_4 Emissions from the Natural Gas Distribution Segment

Source	CH_4 $MMTCO_2e$	Share
Pipeline Leaks	5.3	34.8%
Meter/Regulator (City Gates)	1.3	8.4%
Customer Meters	6.6	43.4%
Routine Maintenance	0.1	0.6%
Upsets	2.0	12.8%
Net Total Emissions	**15.2**	**100%**

Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022.

The historical reductions in this sector result from 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 13 reproduces the EPA estimates for pipeline leaks using EPA emission factors for pipeline main and activity (mileage) data from the U.S. Department of Transportation. The same figure shows the increasing trend in the miles of installed main and the simultaneous decreasing trend in emissions from the main pipeline. It illustrates the ever-decreasing environmental footprint of the natural gas industry's expanding service territory.

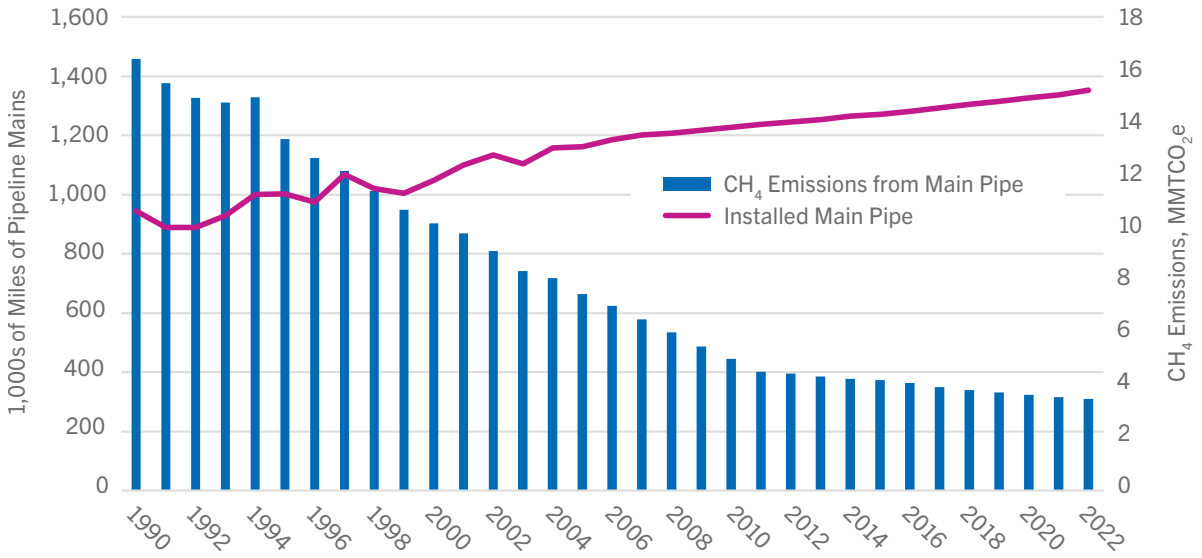
6 On April 24, 2024, the U.S. Environmental Protection Agency announced it would sunset the Methane Challenge Partnership program at the end of 2024. See https://www.epa.gov/natural-gas-star-program/methane-challenge-partnership-2016-2024.

7 In 2022, EPA ended the Natural Gas STAR Partnership and annual reporting elements of the program. See https://www.epa.gov/natural-gas-star-program/natural-gas-star-partnership-1993-2022.

8 The reported miles of main pipeline for 1990 is reflective of corrected data gathered by AGA. PHMSA corrected its annual gas distribution data for 1990 – see https://www.phmsa.dot.gov/data-and-statistics/pipeline/gas-distribution-gas-gathering-gas-transmission-hazardous-liquids, annual_gas_distribution_1990.xlsx (corrected June 3, 2024).

9 A pipeline leak is 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. For additional information on the source of the current leak grading system please see ANSI Z380.1, Guide for Gas Transmission, Distribution and Gathering Piping Systems, specifically in Guide Material Appendix (GMA) G-192-11 section 5 on Leak Investigation and Classification.

Figure 13: Distribution System Main Pipeline — Activity and CH_4 Emissions



Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022. Annex Table 3.6.1 Environmental Protection Agency

POST-METER CH_4 EMISSIONS

The post-meter subsegments include CH_4 emissions from:

- Residential and commercial appliances — Leak emissions from natural gas-fired furnaces, water heaters, stoves and ovens and barbeques/grills
- Leakage from internal piping at industrial plants and power stations
- Natural gas-fueled vehicles — Releases during fueling and depressurization of high-pressure systems

EPA added the post-meter segment to the Inventory in 2022. For the 2022 inventory and continuing through the 2024 Inventory, CH_4 emissions from the post-meter segment are estimated using activity-based emission factors listed in Table 6. In 2022, AGA requested that the EPA postpone adding residential post-meter emissions due to data gaps and uncertainties until further data and analysis can be developed and applied. AGA believes these concerns persist for the post-meter segment's emissions in the Inventory.[10]

In 2022, estimated CH_4 emissions from all post-meter sources totaled 13.4 $MMTCO_2e$ (effectively comprising all of the segment's GHG emissions). Post-meter emission factors were held constant over the 1990 to 2021 time series.

10 AGA identified five data gaps and uncertainties within EPA's analysis of post-meter emissions: 1) There are no consensus standard test methods or standard practices for measuring and determining the flow rate or volume of methane emissions from end-use natural gas appliances. Differences in the types of measurement equipment used, performance-related attributes of the equipment and standardization of the measurement protocols themselves should be addressed first before utilizing any individual study on these types of methane emissions. The standards development for testing protocols would be time-intensive work but essential to establish the credibility for estimating post-meter methane emissions. 2) The use of a limited set of studies conducted on a small sample of homes is unlikely to be representative of a national estimate. 3) There are considerable data gaps, large uncertainties and orders of magnitude differences among the available studies that EPA reviewed for these methane emissions estimates. 4) There were no repeated tests to determine the reproducibility of the methods referenced or whether emissions vary with time or environmental conditions such as seasonal temperature and weather changes. 5) EPA's estimated time series should reflect the phase-out of pilot lights from many natural gas applications. To the extent these studies indicated higher emissions for gas appliances with pilot lights, any inclusion of an estimate of post-meter emissions should reflect the fact that pilot lights have been largely phased out in gas appliances manufactured in the United States over the past 10 to 30 years, due to DOE's appliance energy efficiency standards under 10 C.F.R. Part 430.

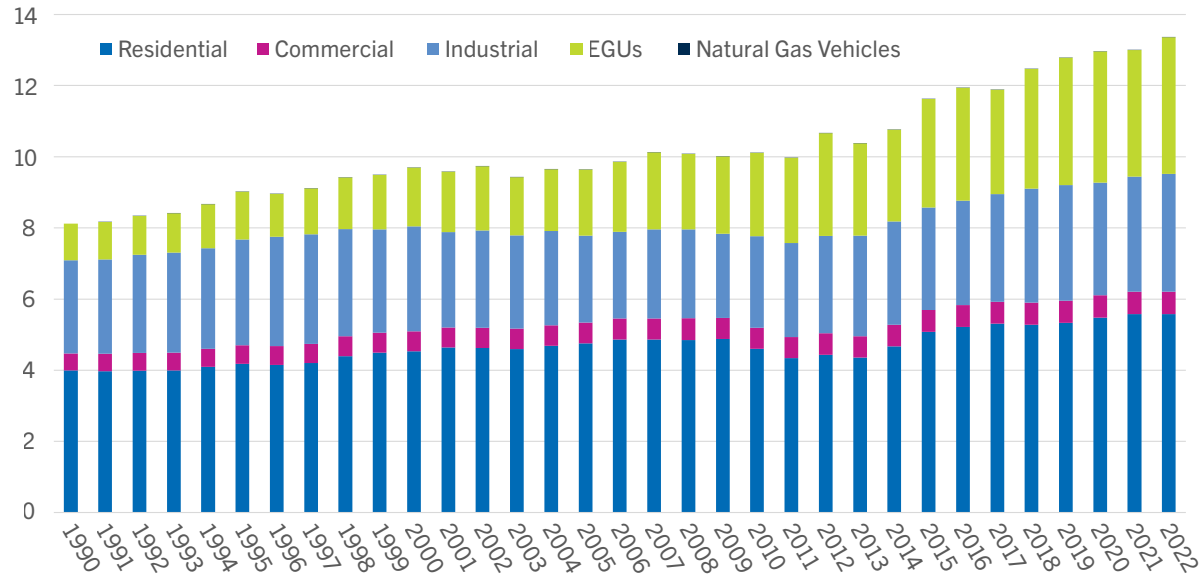
The post-meter segment accounted for less than 8 percent of CH_4 emissions from natural gas systems in 2022. Leak emissions from residential appliances, industrial facilities and power plants account for the majority (95 percent) of post-meter CH_4 emissions. CH_4 emissions from all post-meter sources increased by 60 percent from 1990 to 2022 but remained nearly constant between 2021 and 2022. The 2022 distribution of CH_4 emissions across post-meter sources is shown in Table 6, and trends in CH_4 emissions from the distribution and post-meter segments over the 1990 to 2022 time series are illustrated in Figure 14.

Table 6: 2022 U.S. CH_4 Emission Factors and Emissions for the Post-Meter Segment

Post-Meter Subsegment	Activity	CH_4 Emission Factor (EF)	EF Source	CH_4 $MMTCO_2e$
Residential	87,480,000 NG houses	2.3 kg/NG house	Fischer et al.	5.6
Commercial	5,619,484 appliances	4.0 kg/appliance	IPCC 2019	0.6
Industrial	10,438 BCF	11,327 kg/BCF	IPCC 2019	3.3
EGUs	12,118 BCF	11,327 kg/BCF	IPCC 2019	3.8
Natural Gas Vehicles	124,373 vehicles	0.3 kg/vehicle	IPCC 2019	0.001
Total				**13.4**

Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, Annex Tables 3.6-1, 3.6-2, 3.6-6 and 3.6-7 Environmental Protection Agency

Figure 14: Trends in CH_4 Emissions from Post-Meter Segment Sources ($MMTCO_2e$)



Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022. Annex Table 3.6.1 Environmental Protection Agency

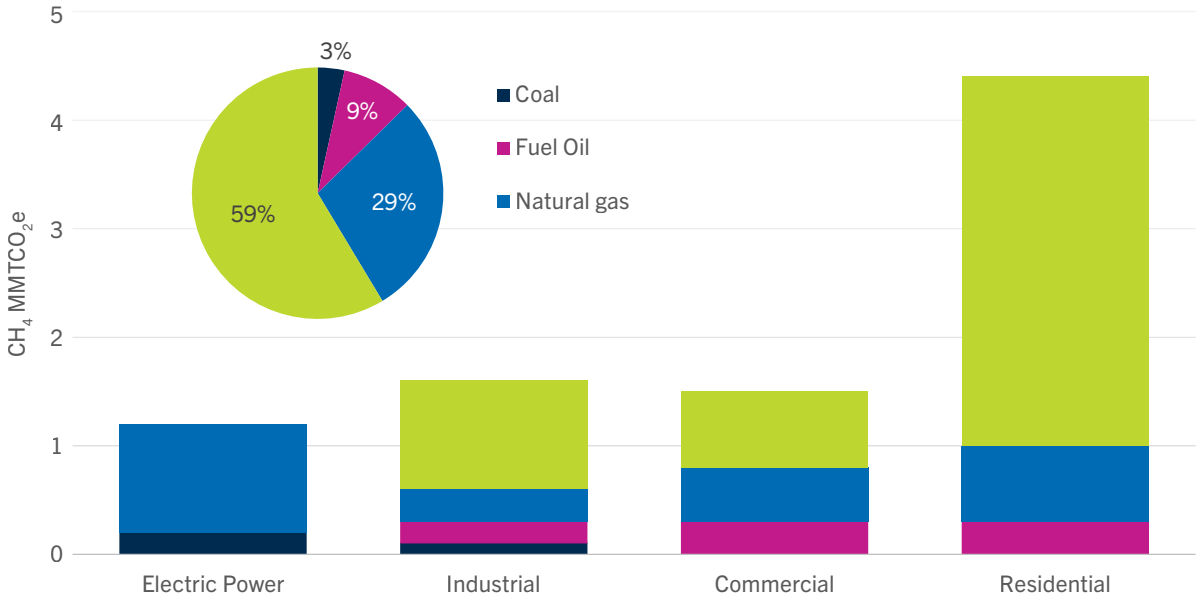
Fugitive emissions from residential appliances, which account for 43 percent of total post-meter CH_4 emissions in 2021, were estimated using an emission factor extracted from a single limited study conducted in California (Fischer et al.). The California study may not represent national activity for the residential appliance subsegment. EPA noted in the Inventory that it would continue to track studies that may include data that could be used to update the emission factor for residential post-meter emissions and to be used instead of IPCC default values for commercial, industrial and vehicle post-meter emissions. EPA may consider changes in emissions rates over the time series, such as applying default IPCC factors for residential emissions for earlier years.

CH_4 AND N_2O EMISSIONS FROM STATIONARY NATURAL GAS COMBUSTION

The direct combustion of fuels by stationary sources in the electric power, industrial, commercial and residential sectors represents the greatest share of U.S. GHG emissions. The combustion of fossil fuels, including coal, fuel oil and natural gas, primarily results in CO_2 emissions, but CH_4 and N_2O are also emitted. N_2O forms as a product of combustion. The combustion of natural gas may result in emissions of unburned CH_4 ("CH_4 slip"). CH_4 may also form in combustion reactions. CH_4 and N_2O emissions from combustion are a function of fuel characteristics, size and vintage of the combustion technology, pollution control equipment and operation and maintenance of the combustion equipment. CH_4 emissions from stationary combustion are primarily a function of the CH_4 content of the fuel and the combustion efficiency of the appliance.

In 2022, CH_4 emissions from natural gas stationary combustion accounted for 29 percent of total CH_4 emissions from direct fossil fuel combustion for all fuels (including natural gas, coal, fuel oil and wood) across all sectors. The residential and commercial sectors accounted for 28 percent (0.7 $MMTCO_2e$) and 20 percent (0.5 $MMTCO_2e$), respectively, of CH_4 emissions from natural gas combustion across all sectors. Between 1990 and 2022, CH_4 emissions from natural gas combustion increased by about 17 percent in the residential segment and increased by 25 percent in the commercial segment. From 2021 to 2022, CH_4 emissions remained constant for the commercial segment and increased by 16.7 percent for the residential segment. Figure 15 provides CH_4 emissions ($MMTCO_2e$) from fossil fuel combustion by segment (electric power, industrial, commercial and residential) and fuel type (natural gas, coal, fuel oil and wood) for the 1990 to 2022 time series. More detailed CH_4 emissions trends from natural gas combustion can be found in Table 7.

Figure 15: 2022 CH_4 Emissions from Fossil Fuel Combustion by Segment and Fuel Type ($MMTCO_2e$)



Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2022, Annex Table 3-8 Environmental Protection Agency

Table 7: CH_4 Emissions from Stationary Combustion ($MMTCO_2e$)

Sector/Fuel Type	1990	2000	2010	2018	2019	2020	2021	2022
Electric Power	**0.5**	0.7	1.1	1.4	1.4	1.4	1.4	1.3
Coal	0.4	0.4	0.4	0.3	0.2	0.2	0.2	0.2
Fuel Oil	+	+	+	+	+	+	+	+
Natural gas	0.1	0.2	0.7	1.1	1.2	1.2	1.2	1
Wood	+	+	+	+	+	+	+	+
Industrial	**2.1**	2.1	1.8	1.7	1.7	1.6	1.6	1.6
Coal	0.5	0.4	0.3	0.2	0.1	0.1	0.1	0.1
Fuel Oil	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2
Natural gas	0.2	0.2	0.2	0.2	0.3	0.2	0.3	0.3
Wood	1.2	1.3	1.1	1.1	1.1	1.1	1.1	1
Commercial	**1.2**	1.2	1.2	1.4	1.4	1.3	1.3	1.4
Coal	+	+	+	+	+	+	+	+
Fuel Oil	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3
Natural gas	0.4	0.4	0.4	0.5	0.5	0.4	0.5	0.5
Wood	0.5	0.6	0.6	0.7	0.7	0.7	0.7	0.7
Residential	**5.9**	4.5	5.3	5.1	5.3	3.6	3.6	4.3
Coal	0.3	0.1	NO	NO	NO	NO	NO	NO
Fuel Oil	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.3
Natural Gas	0.6	0.7	0.6	0.7	0.7	0.6	0.6	0.7
Wood	4.6	3.4	4.3	4.2	4.4	2.8	2.7	3.4
U.S. Territories	**+**	0.1	0.1	+	+	+	+	+
Coal	+	+	+	+	+	+	+	+
Fuel Oil	+	0.1	0.1	+	+	+	+	+
Natural Gas	NO	+	+	+	+	+	+	+
Wood	NE	NE	NE	NE	NE	NE	NE	NE
Total	**9.7**	**8.6**	**9.5**	**9.6**	**9.8**	**8**	**8**	**8.6**
Natural gas contribution	**13%**	**17%**	**20%**	**26%**	**28%**	**30%**	**33%**	**29%**

+ Does not exceed 0.05 MMT CO_2 Eq.
NO (Not Occurring)
NE (Not Estimated)
Note: Totals may not sum due to independent rounding.

Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2022, Table 3-8 Environmental Protection Agency.

In 2022, N_2O emissions from natural gas stationary combustion (3.8 $MMTCO_2e$) accounted for 15.4 percent of total N_2O emissions from direct fossil fuel combustion for all fuels (including natural gas, coal, fuel oil and wood) across all sectors. The residential and commercial sectors each accounted for 2.6 percent of N_2O emissions from natural gas combustion (0.1 $MMTCO_2e$ per sector). N_2O emissions trends from combustion across sectors are summarized in Table 8.

Table 8: N_2O Emissions from Stationary Combustion ($MMTCO_2e$)

Sector/Fuel Type	1990	2000	2010	2018	2019	2020	2021	2022
Electric Power	**18.2**	22.5	26.8	21.7	18.8	17.5	19	21.6
Coal	17.9	21.8	24.4	18.1	14.8	13.5	15.1	18.2
Fuel Oil	0.1	0.1	+	+	+	+	+	+
Natural gas	0.3	0.6	2.4	3.6	3.9	4	3.9	3.4
Wood	+	+	+	+	+	+	+	+
Industrial	**2.8**	2.8	2.4	2.2	2.2	2	2.1	2
Coal	0.7	0.5	0.4	0.2	0.2	0.2	0.2	0.2
Fuel Oil	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.3
Natural gas	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Wood	1.5	1.6	1.4	1.4	1.4	1.4	1.4	1.3
Commercial	**0.3**	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Coal	+	+	+	+	+	+	+	+
Fuel Oil	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Natural gas	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wood	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Residential	**0.9**	0.8	0.8	0.8	0.8	0.6	0.6	0.7
Coal	+	+	NO	NO	NO	NO	NO	NO
Fuel Oil	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1
Natural Gas	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wood	0.6	0.4	0.5	0.5	0.5	0.3	0.3	0.4
U.S. Territories	**+**	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Coal	+	+	+	+	+	+	+	+
Fuel Oil	+	0.1	0.1	+	+	+	+	+
Natural Gas	NO	+	+	+	+	+	+	+
Wood	NE	NE	NE	NE	NE	NE	NE	NE
Total	**22.3**	**26.5**	**30.4**	**25.1**	**22.2**	**20.5**	**22**	**24.7**
Natural gas contribution	**3.1%**	**3.8%**	**9.2%**	**15.9%**	**19.4%**	**21.5%**	**19.5%**	**15.4%**

+ Does not exceed 0.05 MMT CO_2 Eq.
NO (Not Occurring)
NE (Not Estimated)
Note: Totals may not sum due to independent rounding.

Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2022, Table 3-9 Environmental Protection Agency.

CALCULATION OF METHANE INTENSITY

Methane intensity is a measure of CH_4 emissions from a company asset or a natural gas supply chain segment relative to the natural gas (or CH_4) throughput for that asset or segment. The Natural Gas Sustainability Initiative (NGSI) CH_4 Emissions Intensity Protocol, Version 1.0, February 2021 (NGSI Protocol) details a methodology for companies to consistently calculate and report their methane intensity. NGSI is the result of a collaborative effort spearheaded by AGA and the Edison Electric Institute (EEI) with the investor community and experts from upstream, midstream and downstream natural gas companies.[11] The NGSI Protocol and accompanying segment-specific templates support voluntary reporting by companies operating within the natural gas supply chain in the United States from onshore production through distribution. NGSI is available to the public and free for companies to use, regardless of whether they are a member of AGA or EEI.

11 Natural Gas Sustainability Initiative (NGSI): https://www.aga.org/research-policy/natural-gas-esg-sustainability/natural-gas-sustainability-initiative-ngsi/

The NGSI Protocol may be used to estimate CH_4 intensity for an entire segment based on the segment's total CH_4 emissions and CH_4 throughput on a volume or mass basis. The CH_4 intensity metric for a segment is determined in terms of percent as follows:

$$CH_4\ Emissions\ (\%) = \frac{CH_4\ Emissions\ from\ Natural\ Gas}{Methane\ Content\ of\ the\ Natural\ Gas\ Throughput}$$

The numerator of the CH_4 intensity equation is the annual total CH_4 volume or mass emissions reported in the Inventory for a segment. CH_4 emissions reported in the Inventory in terms of mass (kt or MMT) may be converted to a volume basis using the density of CH_4 (0.0192 MMT/Bcf). In any case, the numerator and denominator must be in like units (mass or volume of CH_4). CH_4 emissions used in the numerator of the equation are not converted to CO_2e when calculating methane intensity.

For natural gas system segments upstream of transmission and storage, the portion of total CH_4 emissions is allocated to natural gas production, as opposed to other hydrocarbons that may be produced (e.g., crude oil, condensate), on an energy basis:

$$CH_4\ Intensity\ (\%) = \frac{CH_4\ Emissions\ (MMT) \times Gas\ Ratio}{Natural\ Gas\ Throughput\ (MMscf) \times CH_4\ Volume\ Fraction \times \frac{0.0000192\ MMT}{MMscf}}$$

For the transmission and storage, distribution and post-meter segments, CH_4 intensity is calculated as follows:

$$CH_4\ Intensity\ (\%) = \frac{CH_4\ Emissions\ (MMT)}{Natural\ Gas\ Throughput\ (MMscf) \times CH_4\ Volume\ Fraction \times \frac{0.0000192\ MMT}{MMscf}}$$

The equation above is derived from the equation for distribution segment CH_4 intensity set out in Section 7 of the 2021 NGSI Protocol. This equation is also used for the post-meter segment, which is not described in the 2021 NGSI Protocol.

Annual natural gas throughput data and statistics for natural gas systems, including the distribution and post-meter segments and petroleum systems (crude oil and condensate), are reported to and tracked by the Energy Information Administration (EIA). Annual data is available from 1997 through 2022.

Table 9 provides the CH_4 emissions intensity for the distribution and post-meter segments, including data supporting the quantification of the numerator and denominator of the CH_4 emissions intensity equation.

Table 9: 2022 CH_4 Intensity for the Distribution and Post-Meter Segments

	[1]		[2]		[3]		[1]*[2]/[3]	
	2022 CH_4 Emissions (MMT)		2022 CH_4 Throughput (MMT)		Gas Ratio		Methane Intensity (%)	U.S. Energy Information Administration (EIA) Source
Natural Gas System	6.2	*	516.4	/	0.68	=	0.81%	U.S. Natural Gas Gross Withdrawals
Distribution	0.5	*	466.9	/	n/a	=	0.12%	U.S. Total Natural Gas Deliveries
Post Meter	0.5	*	466.9	/	n/a	=	0.10%	Natural Gas Delivered to Consumers in the U.S.
Residential	0.2	*	79.4	/	n/a	=	0.25%	U.S. Natural Gas Residential Consumption
Commercial	0.0	*	56.1	/	n/a	=	0.04%	Natural Gas Deliveries to Commercial Consumers (Including Vehicle Fuel through 1996) in the U.S.
Industrial	0.1	*	136.5	/	n/a	=	0.09%	U.S. Natural Gas Industrial Consumption
Electric Generator Units	0.1	*	193.8	/	n/a	=	0.07%	U.S. Natural Gas Deliveries to Electric Power Consumers
Natural Gas Vehicles	3.70E-05	*	1.0	/	n/a	=	0.00%	U.S. Natural Gas Vehicle Fuel Consumption

DISCUSSION OF INDUSTRY ACTIVITIES

The American Gas Association and the natural gas industry are committed to reducing CH_4 emissions and improving the safety and environmental profile of the natural gas system. These collective commitments are formalized in the AGA Climate Change Position Statement and include:[12]

- Further reduce CH_4 emissions from natural gas utility systems
- Encourage and support energy efficiency
- Increase efficiencies in operating facilities
- Scale up and deploy advanced natural gas applications
- Invest in research, development and deployment of new emissions mitigation, delivery and end-use technologies
- Support renewable natural gas development and use
- Assessing the potential of renewable power to gas
- Modernize pipeline and other natural gas utility infrastructure
- Encourage and support programs to prevent third-party damage to utility infrastructure
- Transparently report emissions data
- Encourage and increase collaboration with natural gas producers and pipeline operators to help ensure that natural gas resources are developed and transported sustainably and responsibly

In addition to improvements in the accuracy of estimating emissions from natural gas systems, actual emission reductions are expected to continue. On average, the natural gas utility industry invests $95 million daily in infrastructure upgrades and energy efficiency that drive down greenhouse gas emissions from gas utility systems. Forty-two states and the District of Columbia have programs to facilitate accelerated replacement and modernization of natural gas distribution pipelines no longer fit for service.

12 "Climate Change Position Statement," American Gas Association, January 2020, Accessed at: https://www.aga.org/natural-gas/environment/climate-change-commitment/

Voluntary CH_4 emissions measurement and reduction initiatives for segments within the natural gas supply chain, including certification programs, guidelines and commitments, are increasingly being adopted by U.S. companies. Companies can quantify CH_4 emissions using a bottom-up approach consistent with EPA's GHGRP and augment and reconcile Inventory data as informed by top-down, site-level measurements. Using improved emission estimates, companies can determine the CH_4 intensity of their operations and superior performance, which may be "certified" by independent auditors. Certified gas is geologic natural gas differentiated by environmental performance criteria across the value chain.[13]

AGA and the natural gas industry are committed to supporting studies to collect accurate measurements of CH_4 emissions from natural gas system operations. In particular, additional studies are needed to quantify CH_4 emissions from the post-meter segment, as the emission factors supporting the Inventory are based on limited data from a single focused study. Further ongoing data collection and analysis from the government, academia and industry will help inform public understanding of natural gas CH_4 emissions and the role natural gas plays in reducing emissions and addressing climate change. As site or pipeline CH_4 emissions quantification improves, EPA and stakeholders must find ways to propagate such improvements into its U.S. GHGI emission calculation framework.

Improvements in technology, ongoing science and understanding of existing trends reported by EPA point to the 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.

CONCLUSION

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

The 2024 Inventory affirms a low CH_4 emissions profile for natural gas distribution systems shaped by a declining trend. Trends in natural gas system emissions are markers that signify directionally how new information better informs understanding of the GHG profile of the natural gas supply chain. New information will continue to refine the emissions estimates in the Inventory. It will offer industry, the public and policymakers a better understanding of where emissions occur and the levels of released CH_4. Better information helps focus attention on cost-effective opportunities identified in the data.

13 "Natural Gas Utility Industry Climate Change Commitments Industry Progress," American Gas Association, August 2022, https://www.aga.org/wp-content/uploads/2022/02/aga-climate-change-progress.pdf

Appendix A.1

Appendices available as reference for more detailed information for your convenience.

Table A.1: Calculation of Methane Intensity

	2022	Source
CH_4 Emissions from Natural Gas Systems (MMT)	6.18	EPA GHGI 2024
CH_4 Emissions from Distribution Segment (MMT)	0.54	EPA GHGI 2024
CH_4 Emissions from Post-Meter Segment (MMT)	0.48	EPA GHGI 2024
Residential (MMT)	0.20	EPA GHGI 2024
Commercial (MMT)	0.02	EPA GHGI 2024
Industrial (MMT)	0.12	EPA GHGI 2024
EGUs (MMT)	0.14	EPA GHGI 2024
Natural Gas Vehicles (MMT)	3.7E-05	EPA GHGI 2024
CH_4 Emissions from Natural Gas Systems, excluding Post-Meter (MMT)	**5.71**	EPA GHGI 2024
U.S. Natural Gas Gross Withdrawals (MMcf)	43,802,260	EIA 2022
Crude Oil Production (1,000s bbls)	4,107,585	EIA 2022
Lease Condensate Production (million bbls)	295	EIA 2022
U.S. Natural Gas Total Consumption (MMcf)	32,288,230	EIA 2022
Natural Gas Delivered to Consumers in the U.S. (MMcf)	29,193,090	EIA 2022
Natural Gas Delivered to LDCs in the U.S. (MMcf)	29,193,090	EIA 2022
Natural Gas Delivered to LDCs in the U.S.: Residential (MMcf)	4,964,165	EIA 2022
Natural Gas Delivered to LDCs in the U.S.: Commercial (MMcf)	3,509,075	EIA 2022
Natural Gas Delivered to LDCs in the U.S.: Industrial (MMcf)	8,536,882	EIA 2022
Natural Gas Delivered to LDCs in the U.S.: Power (MMcf)	12,117,975	EIA 2022
Natural Gas Delivered to LDCs in the U.S.: Natural Gas Vehicles (MMcf)	64,994	EIA 2022
CH_4 Total Consumption (MMcf)	26,896,096	NGSI Protocol v.1.0
CH_4 Delivered to LDCs in the U.S. (MMcf)	24,317,844	NGSI Protocol v.1.0
CH_4 Delivered to LDCs in the U.S.: Residential (MMcf)	4,135,149	NGSI Protocol v.1.0
CH_4 Delivered to LDCs in the U.S.: Commercial (MMcf)	2,923,059	NGSI Protocol v.1.0
CH_4 Delivered to LDCs in the U.S.: Industrial (MMcf)	7,111,223	NGSI Protocol v.1.0
CH_4 Delivered to LDCs in the U.S.: Power Plants (MMcf)	10,094,273	NGSI Protocol v.1.0
CH_4 Delivered to LDCs in the U.S.: Natural Gas Vehicles (MMcf)	54,140	NGSI Protocol v.1.0
CH_4 Total Consumption (MMT)	516	NGSI Protocol v.1.0
CH_4 Delivered to LDCs in the U.S. (MMT)	467	NGSI Protocol v.1.0
CH_4 Delivered to LDCs in the U.S.: Residential (MMT)	79	NGSI Protocol v.1.0
CH_4 Delivered to LDCs in the U.S.: Commercial (MMT)	56	NGSI Protocol v.1.0
CH_4 Delivered to LDCs in the U.S.: Industrial (MMT)	137	NGSI Protocol v.1.0
CH_4 Delivered to LDCs in the U.S.: Power Plants (MMT)	194	NGSI Protocol v.1.0
CH_4 Delivered to LDCs in the U.S.: Natural Gas Vehicles (MMT)	1	NGSI Protocol v.1.0
CH_4 Total Consumption Excluding Post-Meter (MMT)	50	NGSI Protocol v.1.0
BTU equivalent for U.S. Natural Gas Gross Withdrawals (MMBtu)	54,095,802,215	NGSI Protocol v.1.0
BTU equivalent for U.S. crude oil production (MMBtu)	25,214,786,600	NGSI Protocol v.1.0
BTU equivalent for lease condensate (MMBtu)	24,281,284	NGSI Protocol v.1.0
Gas Ratio (GR) energy basis (dimensionless)	0.68	NGSI Protocol v.1.0
CH_4 emissions intensity (%), Natural Gas Systems (Production)	0.82%	NGSI Protocol v.1.0
CH_4 emissions intensity (%), Distribution	0.12%	NGSI Protocol v.1.0
CH_4 emissions intensity (%), Post-Meter	0.10%	NGSI Protocol v.1.0
CH_4 emissions intensity (%), Post-Meter: Residential	0.25%	NGSI Protocol v.1.0
CH_4 emissions intensity (%), Post-Meter: Commercial	0.04%	NGSI Protocol v.1.0
CH_4 emissions intensity (%), Post-Meter: Industrial	0.09%	NGSI Protocol v.1.0
CH_4 emissions intensity (%), Post-Meter: Power	0.07%	NGSI Protocol v.1.0
CH_4 emissions intensity (%), Post-Meter: Natural Gas Vehicles	0.004%	NGSI Protocol v.1.0
CH_4 emissions intensity (%), Natural Gas Systems (Production), excluding Post-Meter	**11.525%**	**NGSI Protocol v.1.0**
CH_4 Fraction of Natural Gas (%v)	83.3%	NGSI Protocol v.1.0
BTU Equivalent of Natural Gas (MMBtu/Mscf)	1.235	NGSI Protocol v.1.0
BTU Equivalent of Crude Oil (MMBtu/bbl)	5.8	NGSI Protocol v.1.0
CH_4 Density (MT/Mscf)	0.0192	NGSI Protocol v.1.0
CH_4 Density (MMT/MMscf)	0.0000192	Conversion

Appendix A.1

Table compiled by the American Gas Association

Acronyms for table A.1: Calculation of Methane Intensity	
Bbls	Barrel
BTU	British Thermal Unit
CH_4	Methane
EIA	Energy Information Administration
EPA GHGI	Environmental Protection Agency Greenhouse Gas Inventory
MMBtu	One Million British Thermal Units
MMcf	One Million Cubic Feet
MMscf	One Million Standard Cubic Feet
MMT	One Million Metric Tons
Mscf	One Thousand Standard Cubic Feet
NGSI Protocol	Natural Gas Sustainability Initiative Methane Emissions Intensity Protocol

Appendix A.2

Table A.2: 2022 CH_4 Emission Factors and Activity Data for the Natural Gas Distribution and Post-Meter Segments

Distribution and Post-Meter (2022)	Emission Factors		Activity Data	
Normal Fugitives				
Pipeline Leaks				
Mains - Cast Iron	1,157.3	kg/mile	17,004	Miles
Mains - Unprotected Steel	861.3	kg/mile	41,415	Miles
Mains - Protected Steel	96.7	kg/mile	470,936	Miles
Mains - Plastic	28.8	kg/mile	823,029	Miles
Services - Unprotected Steel	14.5	kg/service	2,216,126	Services
Services - Protected Steel	1.3	kg/service	12,117,541	Services
Services - Plastic	0.3	kg/service	54,389,134	Services
Services - Copper	4.9	kg/service	579,216	Services
Meter/Regulator (City Gates)				
M&R > 300	2,142.7	kg/station	4,281	Stations
M&R 100-300	995.4	kg/station	15,623	Stations
M&R < 100	727.2	kg/station	8,350	Stations
Reg > 300	868.9	kg/station	4,680	Stations
R-Vault > 300	50.6	kg/station	3,413	Stations
Reg 100-300	143.4	kg/station	14,159	Stations
R-Vault 100-300	50.6	kg/station	11,867	Stations
Reg 40-100	163.7	kg/station	42,489	Stations
R-Vault 40-100	50.6	kg/station	8,327	Stations
Reg < 40	22.4	kg/station	18,017	Stations
Customer Meters				
Residential	1.5	kg/meter	57,566,726	Outdoor meters
Commercial	23.4	kg/meter	5,619,484	Meters
Industrial	105.0	kg/meter	181,947	Meters
Routine Maintenance				
Pressure Relief/Valve Relief	**0.9**	**kg/mile**	**1,352,384**	**Miles main**
Pipeline Blowdown	0.8	kg/mile	2,321,509	Miles
Upsets				
Mishaps	30.0	kg/mile	2,321,509	Miles

Source: EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, Annex Tables 3.6-2 and 3.6-7, Environmental Protection Agency

Appendix A.3

Table A.3: 2021 Activity Data and Data Sources/Methodology for Natural Gas Systems Distribution and Post-Meter Segments

Segment/Source	Units	Data Source(s)/Methodology
Distribution		
Pipeline Leaks		
Mains - Cast Iron	Miles	Material-specific mileage of distribution mains in year N (PHMSA 2021b). 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 mains (all pipeline material types)
Services - Unprotected Steel	Services	Material-specific counts of distribution services in year N (PHMSA 2021b). 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]. 2011-2020: 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 2021g)] * [Weighted average percentage of meters outdoors (GRI/EPA 1996)]. Refer to EPA 2016d for additional detail.
Commercial	Meters	Total number of commercial and industrial natural gas consumers in year N (EIA 2021g). Refer to EPA 2021a for additional detail.
Industrial	Meters	
Routine Maintenance		
Pressure Relief/Valve Relief 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 pipelines (mains + services) (PHMSA 2020b)
Post-Meter		
Residential	NG houses	National counts of residential housing units that use natural gas as a fuel in year N (U.S. Census Bureau 2021).
Commercial	Appliances	Total number of commercial natural gas consumers in year N (EIA 2021g) * Average appliances per commercial meter (EIA 2021i).
Industrial & EGUs	BCF	Annual natural gas consumption in the industrial and power utilities sectors (EIA 2021d).
NG Vehicles	CNG vehicles	National counts of CNG vehicles from MOVES3 (EPA 2021d).

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, Annex Table 3.6-8, Environmental Protection Agency

Appendix A.4

Table A.4: Installed Pipeline Main and CH_4 Emissions from Main Pipe, 1990-2022

Year	Installed Main Pipe (Thousand Miles)	CH_4 Emissions from Main Pipe ($MMTCO_2e$)
1990	944.2	16.41
1991	888.4	15.49
1992	888.9	14.94
1993	928.8	14.74
1994	1000.4	14.95
1995	1001.7	13.37
1996	975.2	12.63
1997	1068.8	12.15
1998	1019.8	11.39
1999	1004.9	10.66
2000	1048.5	10.17
2001	1099.1	9.77
2002	1133.6	9.11
2003	1104.7	8.35
2004	1158.2	8.07
2005	1162.6	7.47
2006	1185.3	7.01
2007	1201.1	6.51
2008	1207.6	6.02
2009	1218.1	5.48
2010	1228.3	5.01
2011	1237.6	4.51
2012	1246.0	4.44
2013	1253.7	4.33
2014	1264.9	4.24
2015	1271.6	4.21
2016	1281.7	4.10
2017	1293.1	3.93
2018	1304.2	3.82
2019	1315.5	3.73
2020	1325.9	3.65
2021	1337.3	3.56
2022	1352.4	3.49

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, Annex Table 3.6-1 and Table 3.6-7, Environmental Protection Agency

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