August 15, 2023

# UNDERSTANDING GREENHOUSE GAS EMISSIONS FROM NATURAL GAS — EPA 2023 INVENTORY (1990–2021)

## KEY FINDINGS

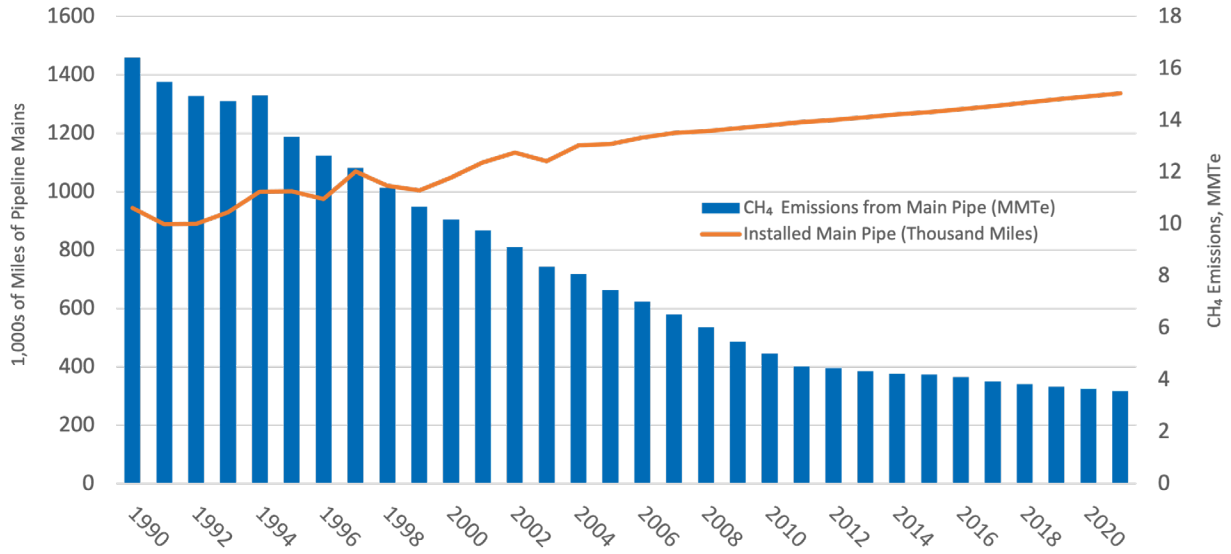
### Economy-Wide Emissions

- In 2021, net total U.S. GHG emissions were 5,586 MMTe.
- Overall, net emissions increased by six percent from 2020 to 2021, driven mainly by increased $CO_2$ emissions from fuel combustion due to economic activity rebounding after the height of the COVID-19 pandemic.
- Net GHG emissions in 2021 were 17 percent below 2005 levels due to a shift to less $CO_2$-intensive natural gas for generating electricity and a rapid increase in the use of renewable energy in the electric power sector.
- Transportation activities accounted for 29 percent of total U.S. GHG emissions in 2021.
- The electric power segment accounted for the second largest portion (25 percent), while emissions from industry accounted for the third largest share (24 percent) of total U.S. GHG emissions in 2021.
- The Land Use, Land-Use Change and Forestry (LULUCF) sector offset 12 percent of total U.S. GHG emissions in 2021.

### Natural Gas Systems

- Total GHG emissions ($CH_4$, $CO_2$, and $N_2O$) from U.S. natural gas systems in 2021 were 217.5 MMTe representing a decrease of 12 percent from 1990 and 2 percent from 2020, both primarily due to reductions in $CH_4$ emissions.
- The decrease in $CH_4$ emissions over the 1990 to 2021 time series is due primarily to the decrease in emissions from the following segments: Distribution (70 percent decrease), transmission and storage (30 percent decrease), processing (40 percent decrease), and exploration (94 percent decrease).
- U.S. dry gas production increased by 94 percent from 1990 to 2021, 62 percent from 2010 to 2021, and 3 percent from 2020 to 2021.
- Overall, natural gas systems emitted 181.4 MMTe of $CH_4$ in 2021, a 16 percent decrease compared to 1990 emissions and a two percent decrease compared to 2020.
- Of the overall U.S. GHG emissions for natural gas systems (217.5 MMTe), 83 percent are $CH_4$ emissions (181.4 MMTe), 17 percent are $CO_2$ emissions (36.2 MMTe), and less than 0.01 percent are $N_2O$ emissions (0.01 MMTe).

**$CH_4$ Emissions from Distribution System Main Pipeline — Emissions and Activity**




Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Annex Table 3.6-1 Environmental Protection Agency

- Distribution system $CH_4$ emissions in 2021 were 70 percent lower than 1990 levels and 1 percent lower than 2020 emissions, even as distribution system pipeline mileage increased 57% or by nearly 831,000 miles. Annual $CO_2$ emissions from this segment are less than 0.1 MMTe across the time series.
- Post-meter segment $CH_4$ emissions are associated with equipment owned and operated by consumers and include emissions from residential and commercial appliances, industrial facilities and power plants, and natural gas-fueled vehicles. These emissions, which EPA reports within the natural gas systems source category, accounted for approximately 7 percent of total emissions from natural gas systems in 2021.

# INTRODUCTION

Climate change is a defining challenge globally. Natural gas, gas utilities, and the delivery infrastructure are essential to meeting our nation's greenhouse gas (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 U.S. with an opportunity to address our 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.

Efficient natural gas technologies are low-cost, low-emission options for building energy needs, home comfort, industrial processes, and electricity generation. Natural gas is a low-carbon fuel relative to coal and oil, resulting in less carbon dioxide ($CO_2$) for the same amount of valuable energy. A better understanding of 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 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: 1990-2021* in April 2023 (2023 GHGI). The 2023 GHGI updates the *U.S. Greenhouse Gas Emissions and Sinks: 1990-2020* published in April 2022 (2022 GHGI) and incorporates new data from GHG emissions studies and the EPA's Greenhouse Gas Reporting Program (GHGRP).[1]

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

# OVERVIEW

Six emission subcategories (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 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 1,337,012 miles of distribution mains in 2021, an increase of 392,855 miles since 1990.[2] Distribution system $CH_4$ and $CO_2$ emissions, primarily from leaks from pipelines and stations, accounted for 8 percent of $CH_4$ emissions and less than 1 percent of $CO_2$ emissions from natural gas systems. Increasing plastic piping, which has lower emissions than other pipe materials and upgrades at metering and regulating (M&R) stations, has reduced $CH_4$ and $CO_2$ emissions from distribution systems. Distribution system $CH_4$ emissions in 2021 were 70 percent lower than 1990 levels and 1 percent lower than 2020 emissions. Distribution system $CO_2$ emissions in 2021 were 70 percent lower than 1990 levels and 1 percent lower than 2020 emissions. Annual $CO_2$ emissions from this segment are less than 0.1 million metric tons of $CO_2$-equivalent emissions (MMTe) across the time series.

$CH_4$ emissions from the post-meter segment,[3] newly added in the previous Inventory (2022 GHGI), accounted for approximately 7 percent of emissions from natural gas systems in 2021. Post-meter $CH_4$ emissions increased by 60 percent from 1990 to 2021 and by less than 1 percent from 2020 to 2021 due to the number of residential houses using natural gas and increased natural gas consumption at industrial facilities and power plants. $CO_2$ emissions from post-meter account for less than 0.01 percent of total $CO_2$ emissions from natural gas systems.

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. Additionally, 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, including $CH_4$.

1 The Greenhouse Gas Reporting Program (GHGRP) collects detailed annual emissions data from the largest GHG emitting facilities in the U.S. See https://www.epa.gov/ghgreporting.

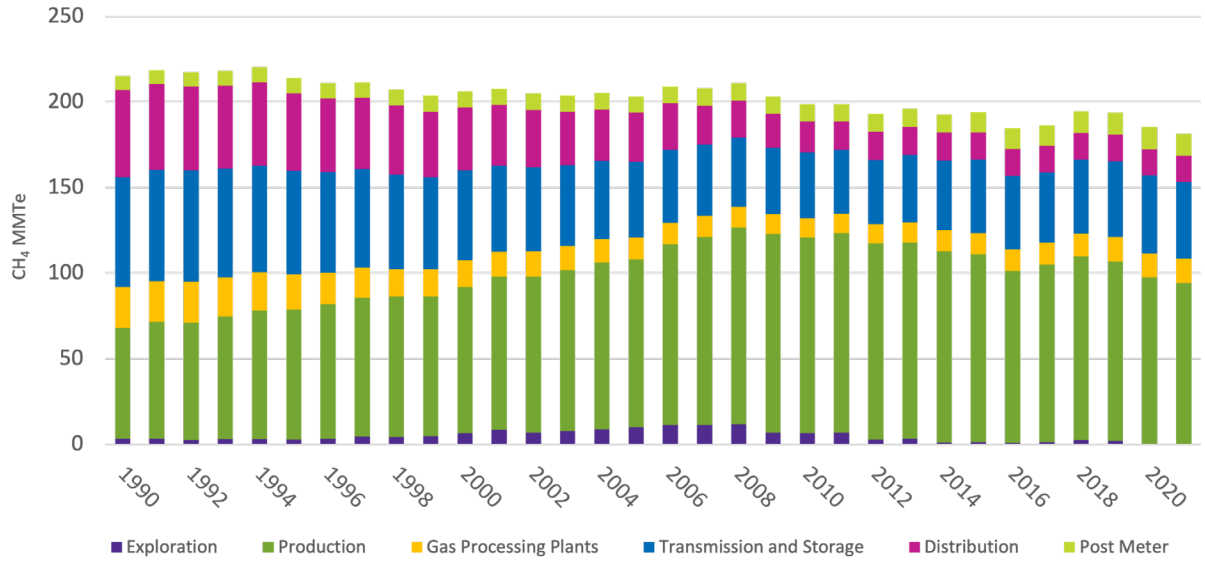
2 Gas Distribution Annual Data. Pipeline and Hazardous Materials Safety Administration, U.S. Department of Transportation, Washington, DC. Available online at: https://www.phmsa.dot.gov/data-andstatistics/pipeline/annual-report-mileage-gas-distribution-systems.

3 Post-meter includes leak emissions from residential and commercial appliances, industrial facilities and power plants, and natural gas fueled vehicles.

As companies and the country continue to modernize the natural gas infrastructure base while connecting homes and businesses, there will be new opportunities to achieve low-cost carbon emissions reductions by leveraging existing infrastructure, the nation's abundant natural gas resource, and renewable fuels such as hydrogen and renewable natural gas.

Figure 1 illustrates the trend in $CH_4$ emissions over the 1990 to 2021 time series in terms of million metric tons $CO_2e$ (MMTe).

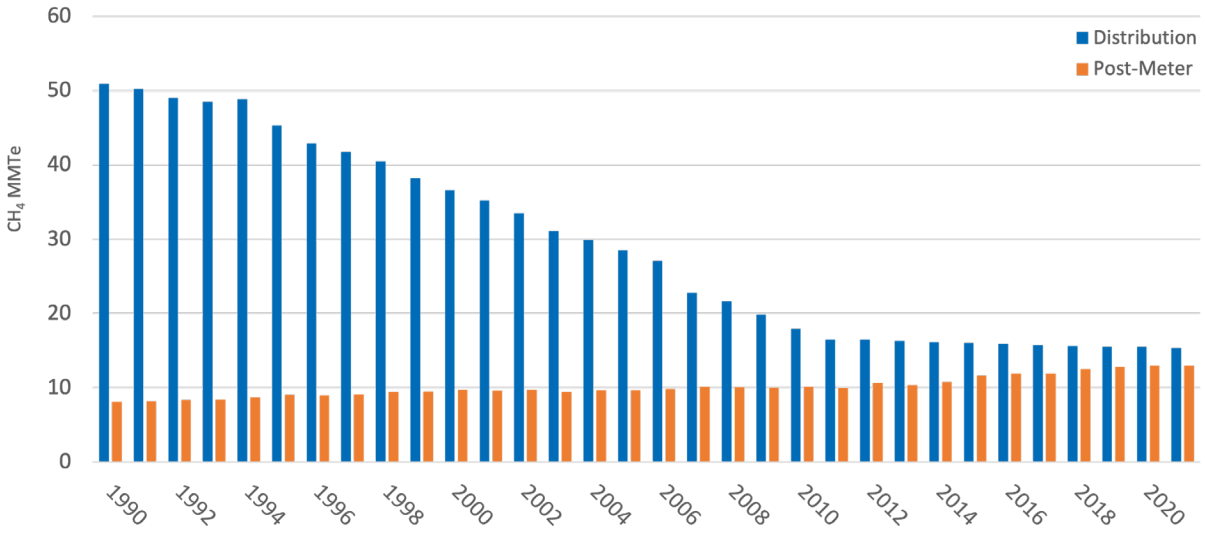
**Figure 1: $CH_4$ Emissions from Natural Gas Systems over the 1990 to 2021 Time Series (MMTe)**




Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Annex Table 3.6-1 Environmental Protection Agency

Trends in $CH_4$ emissions (MMTe) from the distribution and post-meter segments are illustrated in Figure 2.

**Figure 2: $CH_4$ Emissions from Natural Gas Distribution and Post-Meter Segments (MMTe)**




Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, 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 and calculation methodologies impact the current and future annual Inventories and may result in recalculating the previous Inventory's time series (e.g., 1990-2021). For this year's 2023 GHGI, the most notable change impacting the quantification of $CH_4$ emissions from segments within the natural gas systems was an update to the GWP for $CH_4$ and $N_2O$.

The GWPs used to calculate GHG emissions estimates expressed in terms of $CO_2e$ have been revised to reflect updated science. The current 2023 GHGI has been updated to use the 100-year GWPs provided in the IPCC Fifth Assessment Report (AR5). Inventories preceding this year's report (2022 GHGI and prior) used the GWPs provided in the IPCC Fourth Assessment Report (AR4). The former and updated GWPs for $CH_4$ and $N_2O$ are compared in Table 1.

**Table 1: Revised Global Warming Potentials (100-Year Time Horizon) – $CH_4$ and $N_2O$**

| Gas | AR4 GWP | AR5 GWP (current) |
|---|---|---|
| $CO_2$ | 1 | 1 |
| $CH_4$ | 25 | 28 |
| $N_2O$ | 298 | 265 |

The GWP is a multiplier against the mass emissions of each GHG, and any change in the GWP results in a proportional increase or decrease in emissions of that gas in terms of $CO_2e$.

For the 2023 GHGI, EPA also updated $CH_4$ emission calculations for several emission sources in the onshore production segment, including pneumatic controllers, equipment leaks, chemical injection pumps, storage tanks, and liquids unloading. For each emissions source, EPA modified the calculation methodology to use GHGRP data to develop basin-specific activity or emission factors.

Table 2 compares $CH_4$ emissions (MMTe) reported for natural gas system segments for the 2020 base year in the 2022 GHGI and recalculated emissions for the 2020 base year reported in the 2023 GHGI. For the 2020 base year, the combined impact of revisions to 2020 $CH_4$ emissions from natural gas system segments reported in the 2023 GHGI compared to the previous 2022 GHGI is an increase from 164.9 to 185.3 MMTe, or 12.4 percent, primarily resulting from the 12 percent increase in the GWP for $CH_4$.

**Table 2: Summary of Changes to Natural Gas System $CH_4$ Emissions from Previous Year (Net MMTe)**

| Segment | Prior Inventory (2020) | Recalculated Inventory (2020) | Change (%) |
|---|---|---|---|
| Exploration | 0.21 | 0.24 | 19% |
| Production | 86.39 | 97.29 | 13% |
| Gas Processing | 12.36 | 13.87 | 12% |
| Transmission and Storage | 40.62 | 45.49 | 12% |
| Distribution | 13.86 | 15.49 | 12% |
| Post Meter | 11.48 | 12.96 | 13% |
| **Total** | **164.9** | **185.3** | **12.4%** |

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Environmental Protection Agency

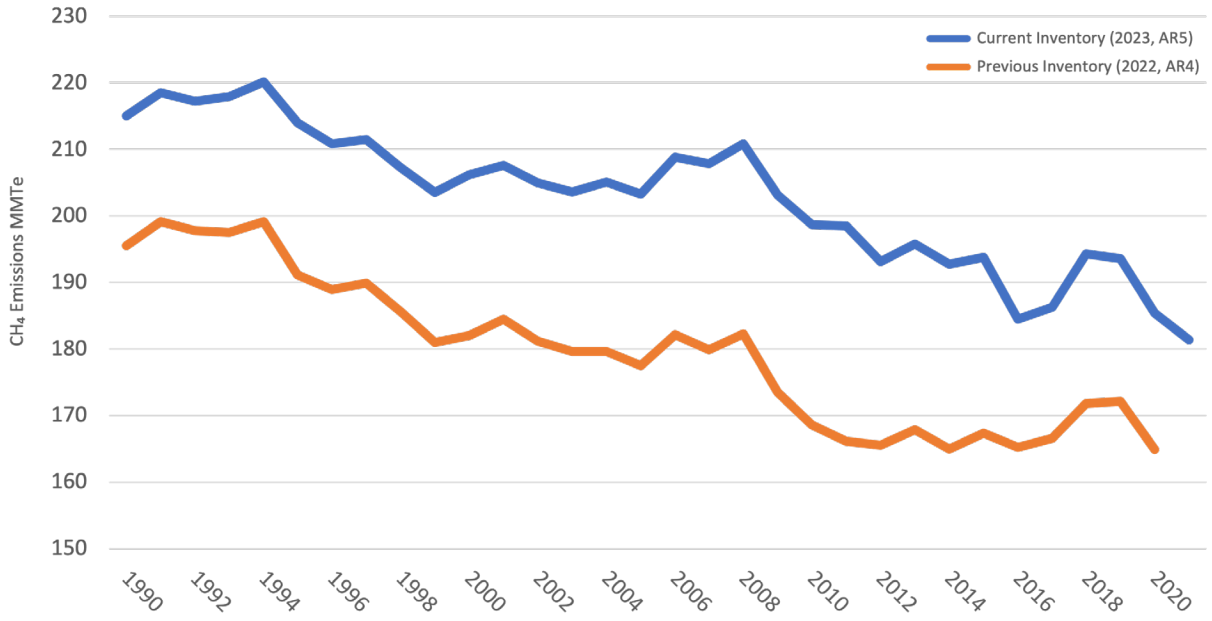
# RECALCULATIONS IN THE 2023 INVENTORY

In this year's 2023 GHGI, recalculations in natural gas systems include:

- Recalculations across the 1990 through 2021 time series to reflect the updated GWPs for $CH_4$ and $N_2O$
- Methodological updates to five onshore production segment sources — pneumatic controllers, equipment leaks, chemical injection pumps, storage tanks, and liquids unloading
- Recalculations due to GHGRP submission revisions

Figure 3 illustrates the quantitative impacts of EPA's recalculation of the $CH_4$ Inventory for the time series 1990 through 2021 for Natural Gas Systems resulting from the increase in the GWP for $CH_4$ from 25 to 28 (12 percent increase)

**Figure 3: Impacts of Recalculation of Net $CH_4$ Emissions from Natural Gas Systems**



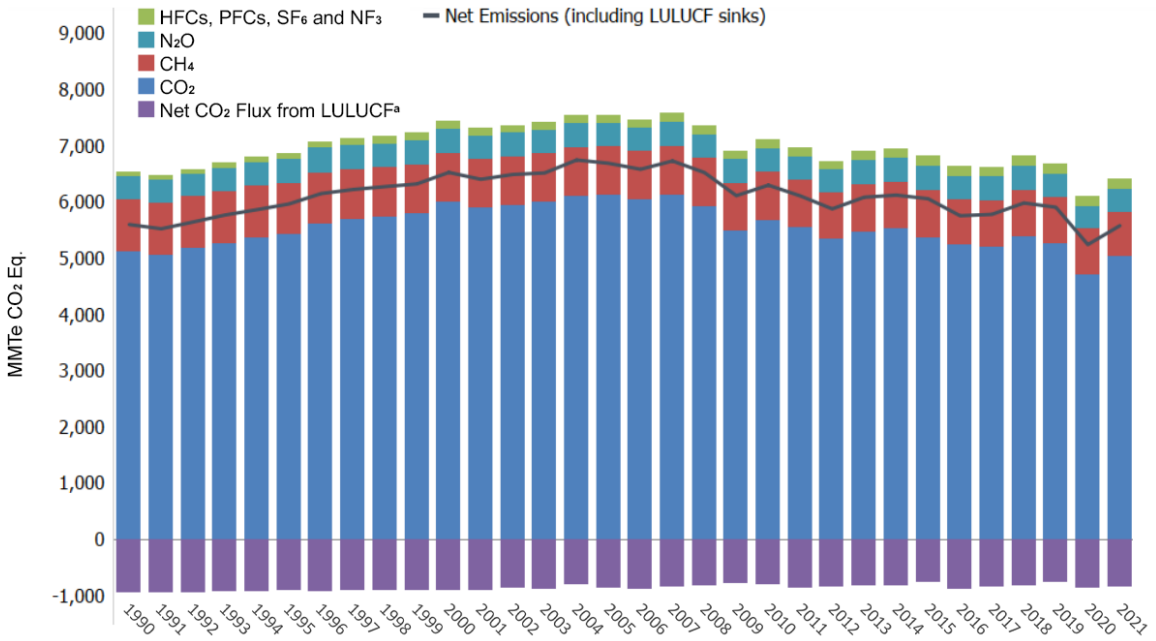

Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Annex Table 3.6-1 Environmental Protection Agency

# SUMMARY AND ANALYSIS OF EPA INVENTORY

The trends in U.S. GHG emissions by gas for the 1990 through 2020 time series are illustrated in Figure 4 in terms of MMTe. Overall, from 1990 to 2021, total emissions of $CO_2$ decreased by two percent, total emissions of $CH_4$ decreased by 16 percent, and total emissions of $N_2O$ decreased by three percent. During the same period, emissions of fluorinated gases rose by 105 percent.[4] 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 were estimated to offset 12 percent of total gross emissions in 2021.

4 Fluorinated gases including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6), and nitrogen trifluoride (NF3)

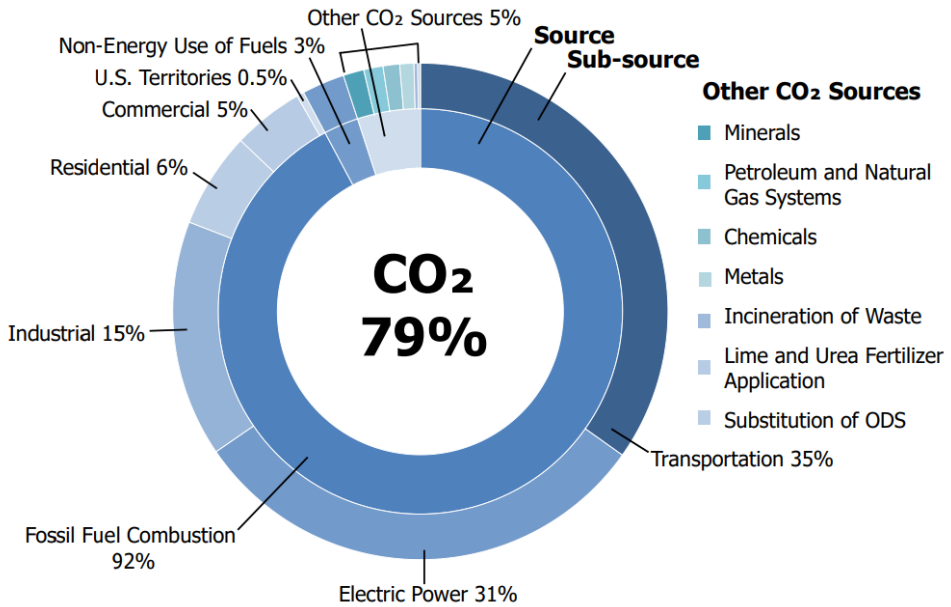
## Figure 4: U.S. GHG Emissions and Sinks by Gas (MMTe)




Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Environmental Protection Agency

$CO_2$ accounted for 79 percent of total U.S. emissions in 2021. $CO_2$ emissions have decreased 18 percent since 2005 and two percent since 1990. Fossil fuel combustion was the largest source, accounting for 92 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 12 percent of total U.S. emissions in 2021, shown by Figure 5.

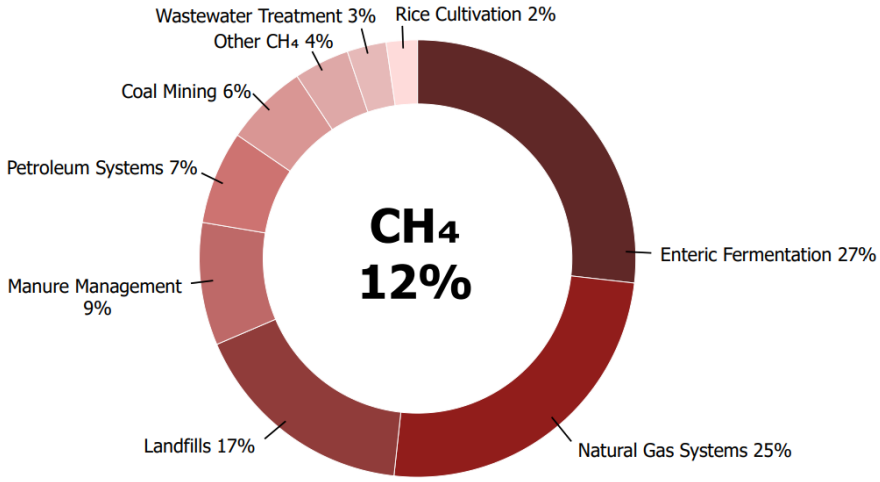
## Figure 5: 2021 U.S. Sources of $CO_2$ Emissions




Source: Data Highlights — Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Environmental Protection Agency

$CH_4$ accounted for 12 percent of emissions in 2021. $CH_4$ emissions have decreased by eight percent since 2005, 16 percent since 1990, and two percent from 2020 to 2021. 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 6 provides a breakdown of U.S. sources of $CH_4$ emissions in 2021.

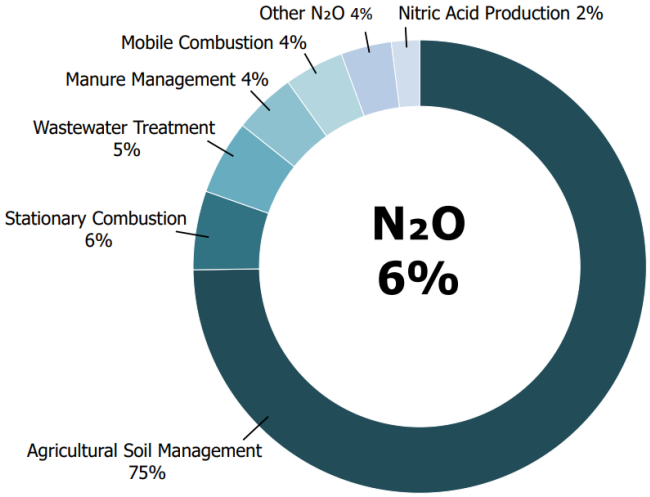
**Figure 6: 2021 U.S. Sources of $CH_4$ Emissions**




Source: Data Highlights — Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Environmental Protection Agency

Nitrous Oxide ($N_2O$) accounted for six percent of total U.S. GHG emissions in 2021. $N_2O$ emissions have decreased by five percent since 2005 and three percent since 1990 but have increased by one percent in 2021. In 2021, emissions were influenced by changes in emissions from agricultural soils due to interannual weather patterns, fertilizer use, and crop production; fluctuations in livestock populations; a small decrease of $N_2O$ emissions from stationary combustion; and impacts of national emission control standards on mobile combustion in on-road vehicles. Figure 7 provides a breakdown of U.S. $N_2O$ emission sources in 2021.

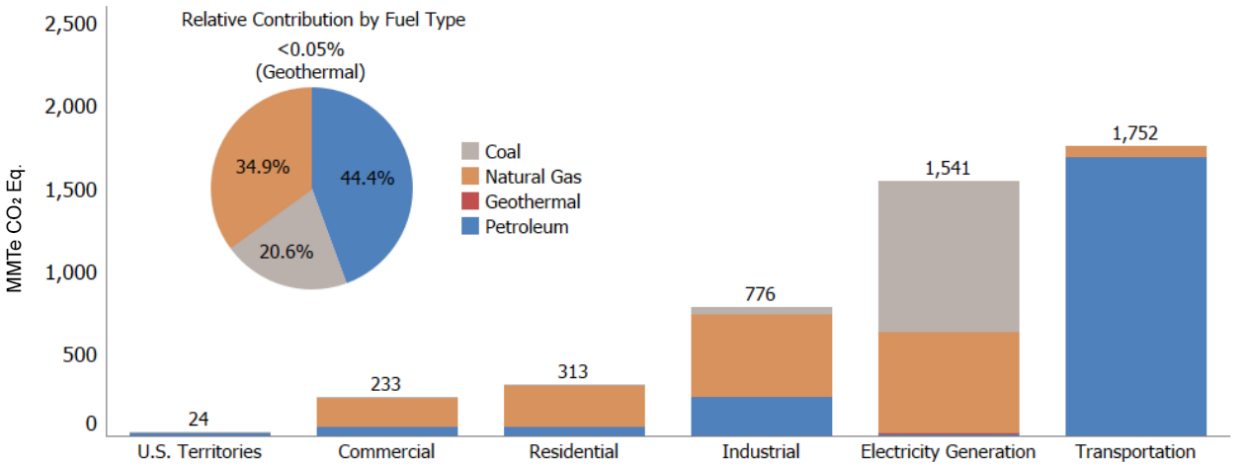
**Figure 7: 2021 U.S. Sources of $N_2O$ Emissions**




Source: Data Highlights — Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Environmental Protection Agency

Figure 8 illustrates the distribution of $CO_2$ emissions between sectors by fuel type in 2021.

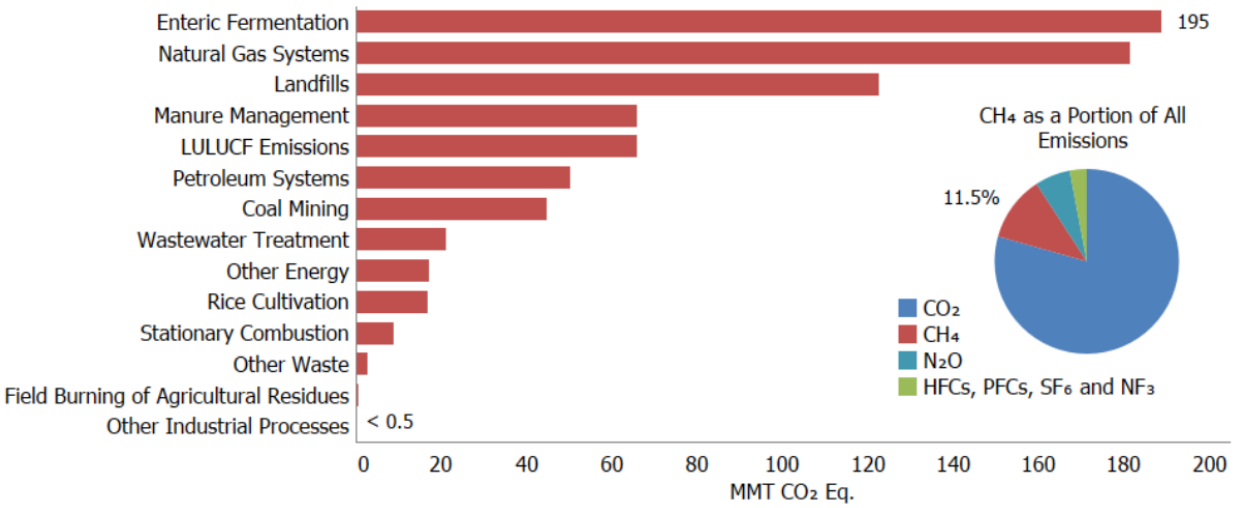
**Figure 8: 2021 $CO_2$ Emissions from Fossil Fuel Combustion by Sector and Fuel Type (MMTe)**




Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Environmental Protection Agency

As shown in Figure 9, the main anthropogenic sources of $CH_4$ in the U.S. include enteric fermentation from domestic livestock, natural gas systems, landfills, domestic livestock manure management, coal mining, and petroleum systems.

**Figure 9: 2021 Sources of $CH_4$ Emissions**




Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Environmental Protection Agency

Natural gas systems were the second largest anthropogenic source category of $CH_4$ emissions in the U.S. in 2021, accounting for 181.4 MMTe of $CH_4$ (22.9 percent of total $CH_4$ emissions and 2.9 percent of total gross emissions). Emissions decreased by 33.7 MMTe (15.7 percent) since 1990 largely due to decreases in emissions from distribution, transmission, and storage.

The third largest contributor to GHG emissions, $N_2O$, accounted for 6 percent of total U.S. emissions in 2021. $N_2O$ emissions have decreased by 5 percent since 2005 and 3 percent since 1990 but have increased by 1 percent in 2021.

# NATURAL GAS SYSTEM $CH_4$ 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. The EPA categorizes the natural gas system into six segments: exploration, production (includes gathering and boosting), processing, transmission and storage, distribution, and post-meter.

By the categorical conventions used in the Inventory, natural gas systems represent the second largest source category for $CH_4$ in the U.S., accounting for 25 percent of all $CH_4$ emissions in 2021. In 2021, natural gas system $CH_4$ emissions equaled 164.9 MMTe or 2.8 percent of total U.S. GHGs.

2021 and historical $CH_4$ emissions from natural gas systems by segment are summarized in Table 3. In 2021 the production segment accounted for the largest share of natural gas system $CH_4$ emissions (51.9 percent) followed by transmission and storage (24.5 percent), distribution (8.5 percent), gas processing (7.9 percent) and the post-meter segment (7.1 percent).

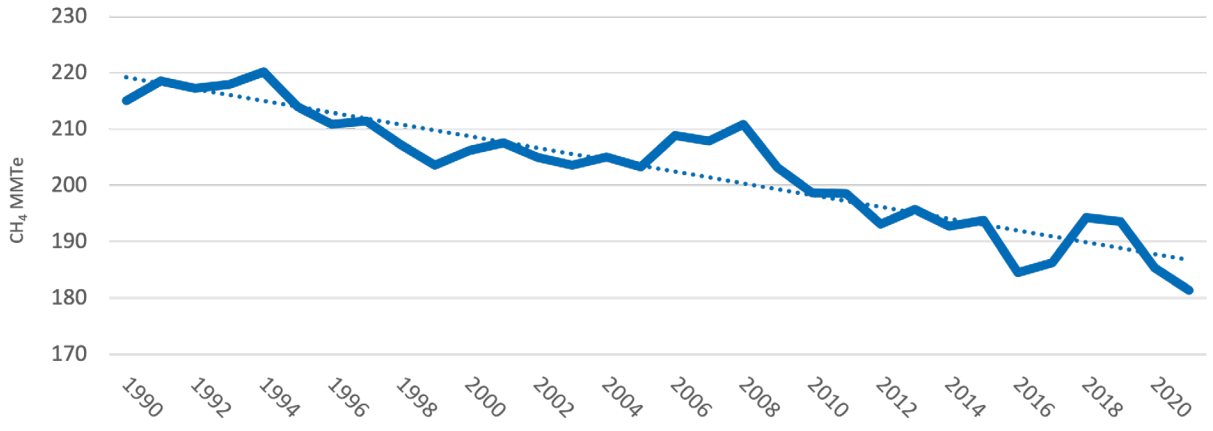
**Table 3: $CH_4$ Emissions from Natural Gas Systems (MMTe)**

| Segment | 1990 | 2000 | 2010 | 2020 | 2021 | 1990-2021 | Share of Natural Gas System Emissions, 2021 |
|---|---|---|---|---|---|---|---|
| Exploration | 3.3 | 6.5 | 6.6 | 0.2 | 0.2 | -94% | 0.1% |
| Production | 64.7 | 85.5 | 114.2 | 97.3 | 94.1 | 45% | 51.9% |
| Gas Processing | 23.9 | 15.5 | 11.3 | 13.9 | 14.3 | -40% | 7.9% |
| Transmission and Storage | 64.1 | 52.4 | 38.5 | 45.5 | 44.5 | -30% | 24.5% |
| Distribution | 50.9 | 36.6 | 17.9 | 15.5 | 15.3 | -70% | 8.5% |
| Post Meter | 8.1 | 9.7 | 10.1 | 13.0 | 13.0 | 60% | 7.1% |
| **Total** | **215** | **206** | **199** | **185** | **181** | **-16%** | **100%** |

Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Annex Table 3.6-1 Environmental Protection Agency

Figure 10 illustrates the trend, including a linear trendline, in total $CH_4$ emissions from natural gas systems during the time series 1990 through 2021 expressed in terms of MMTe.

**Figure 10: Trends in Total $CH_4$ Emissions from Natural Gas Systems, 1990 to 2021 (MMTe)**




Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Annex Table 3.6-1 Environmental Protection Agency

# NATURAL GAS SYSTEM $CO_2$ 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 32.2 to 36.2 MMTe, a 12.3 percent rise from 1990 to 2021. $N_2O$ emissions are 55 percent lower than their peak in 2015 and 12 percent lower than in 2020. Table 4 and Table 5 summarize $CO_2$ and $N_2O$ emissions, respectively, across the time series from 1990 to 2021.

The increased use of plastic materials for gas distribution pipelines has helped reduce $CH_4$ and $CO_2$ emissions in the natural gas distribution systems stage. $CO_2$ emissions from this sector are less than 0.1 MMTe across the time series.

**Table 4: $CO_2$ Emissions from Natural Gas Systems (MMTe)**

| Segment | 1990 | 2000 | 2010 | 2020 | 2021 |
|---|---|---|---|---|---|
| Exploration | 0.3 | 0.6 | 1.5 | 0.1 | 0.0 |
| Production | 3.3 | 4.1 | 5.7 | 8.9 | 9.1 |
| Gas Processing Plants | 28.3 | 20.4 | 18.6 | 25.4 | 26.1 |
| Transmission and Storage | 0.2 | 0.2 | 0.2 | 2.1 | 0.9 |
| Distribution | 0.05 | 0.04 | 0.02 | 0.02 | 0.02 |
| Post Meter | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 |
| **Total** | **32.2** | **25.3** | **25.9** | **36.5** | **36.2** |

Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Annex Table 3.6-10 Environmental Protection Agency

**Table 5: $N_2O$ Emissions from Natural Gas Systems (MMTe)**

| Segment | 1990 | 2000 | 2010 | 2020 | 2021 |
|---|---|---|---|---|---|
| Exploration | 0.0004 | 0.0006 | 0.0012 | 0.00005 | 0.00001 |
| Production | 0.0038 | 0.0048 | 0.0065 | 0.0033 | 0.0029 |
| Gas Processing Plants | 0.0000 | 0.0019 | 0.0043 | 0.0043 | 0.0043 |
| Transmission and Storage | 0.0002 | 0.0003 | 0.0003 | 0.0010 | 0.0004 |
| Distribution | NE | NE | NE | NE | NE |
| Post Meter | NE | NE | NE | NE | NE |
| **Total** | **0.004** | **0.008** | **0.012** | **0.009** | **0.008** |

Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Annex Table 3.6-14 Environmental Protection Agency

# DISTRIBUTION SYSTEM $CH_4$ EMISSIONS

Natural gas distribution systems (Figure 11), 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, meter and regulating 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 2021, natural gas utilities delivered 53 percent of the natural gas consumed across the country.

The distribution stage, which includes the regular operation and maintenance of natural gas delivery infrastructure along with emissions released from accidents, accounts for 8.5 percent of estimated $CH_4$ emissions from the natural gas system. Categories of distribution $CH_4$ 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 $CH_4$ emissions each year through voluntary measures, including those reported to the EPA through its Natural Gas STAR and $CH_4$ Challenge programs.

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 13 MMTe in 2021, a decline of 70 percent from 1990 levels. This drop occurred as the industry added 815,100 miles of pipelines to serve 22.3 million more customers.

Three segments of the natural gas industry illustrated in Figure 11 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.

Table 6 summarizes the breakdown in distribution-stage $CH_4$ emissions by source category. The majority of distribution $CH_4$ emissions are from pipeline leaks and meter/regulator operations. Less than half, 35.5 percent, of distribution system $CH_4$ emissions are associated with pipeline leaks, and eight percent of $CH_4$ emissions result from the operation of gas meters and regulators at city gates, which connects the transmission system with the distribution network. Customer meters account for 43 percent of distribution system-stage $CH_4$ emissions, and upsets and routine maintenance comprise 13 percent.[5]

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.

**Table 6: 2021 $CH_4$ Emissions from the Natural Gas Distribution Segment**

| Source | $CH_4$ MMTe | Share |
|---|---|---|
| Pipeline Leaks | 5.4 | 35.5% |
| Meter/Regulator (City Gates) | 1.3 | 8.2% |
| Customer Meters | 6.6 | 43.0% |
| Routine Maintenance | 0.1 | 0.6% |
| Upsets | 1.9 | 12.6% |
| **Net Total Emissions** | **15.3** | **100%** |

5 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. 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 12 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 miles of installed main and the simultaneous decreasing trend in emissions from the main pipeline. It illustrates the environmental footprint of the natural gas industry's expanding service territory.

**Figure 11: U.S. Natural Gas Delivery System**

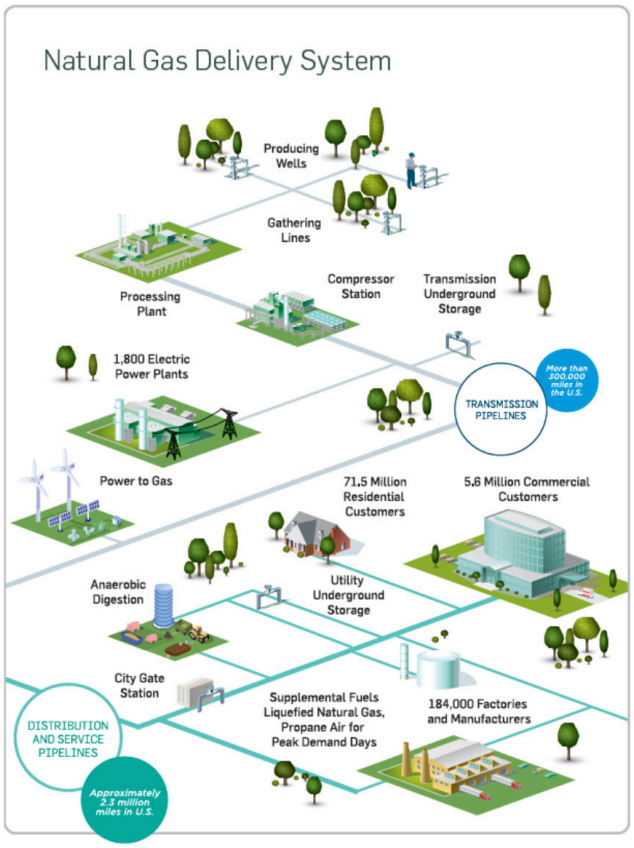
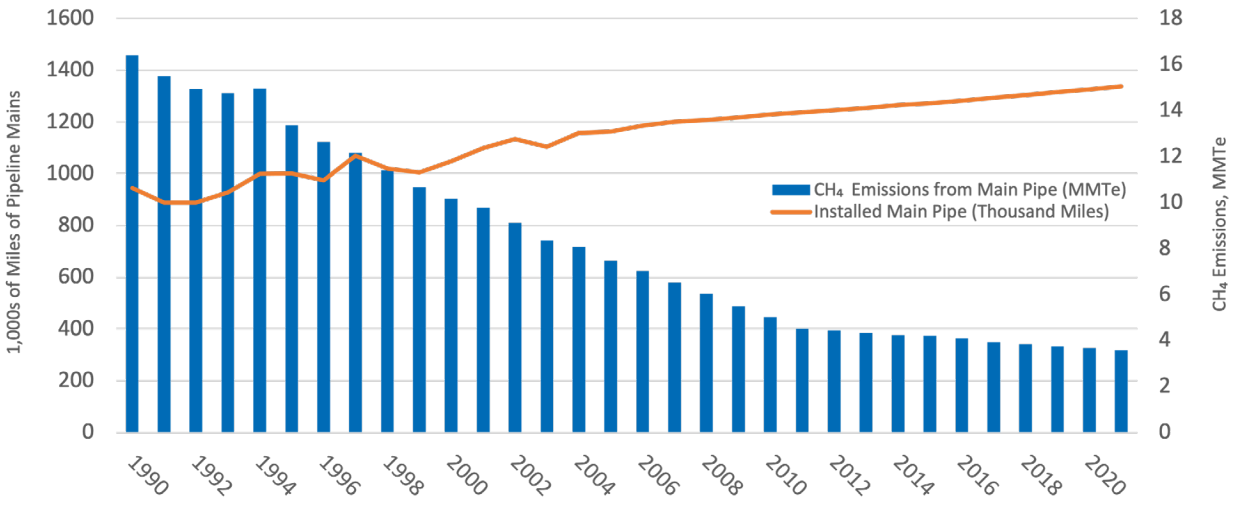



**Figure 12: $CH_4$ Emissions from Distribution System Main Pipeline — Emissions and Activity**




Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, 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 — Leakage 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 post-meter segment to the Inventory in 2022 and is estimated using activity-based emission factors listed in Table 7. At the time, AGA requested that EPA postpone adding residential post-meter emissions due to data gaps and uncertainties and until further data and analysis can be developed and applied. AGA believes these concerns persist concerning the post-meter segment.[6]

In 2021, estimated $CH_4$ emissions from all post-meter sources totaled 13 MMTe. Post-meter emission factors were held constant over the 1990-2021 time series.

**Table 7: 2021 U.S. $CH_4$ Emission Factors and Emissions for the Post-Meter Segment**

| Post-Meter Subsegment | Activity | | $CH_4$ Emission Factor (EF) | | EF Source | $CH_4$ MMTe |
|---|---|---|---|---|---|---|
| Residential | 87,480,000 | NG houses | 2.3 | kg/NG house | Fischer et al. | 5.6 |
| Commercial | 5,611,726 | appliances | 4.0 | kg/appliance | IPCC 2019 | 0.6 |
| Industrial | 10,042 | BCF | 11,327 | kg/BCF | IPCC 2019 | 3.2 |
| EGUs | 11,271 | BCF | 11,327 | kg/BCF | IPCC 2019 | 3.6 |
| Natural Gas Vehicles | 115,885 | vehicles | 0.3 | kg/vehicle | IPCC 2019 | 0.001 |
| **Total** | | | | | | **13.0** |

Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Annex Tables 3.6-1, 3.6-2, 3.6-6 and 3.6-7 Environmental Protection Agency

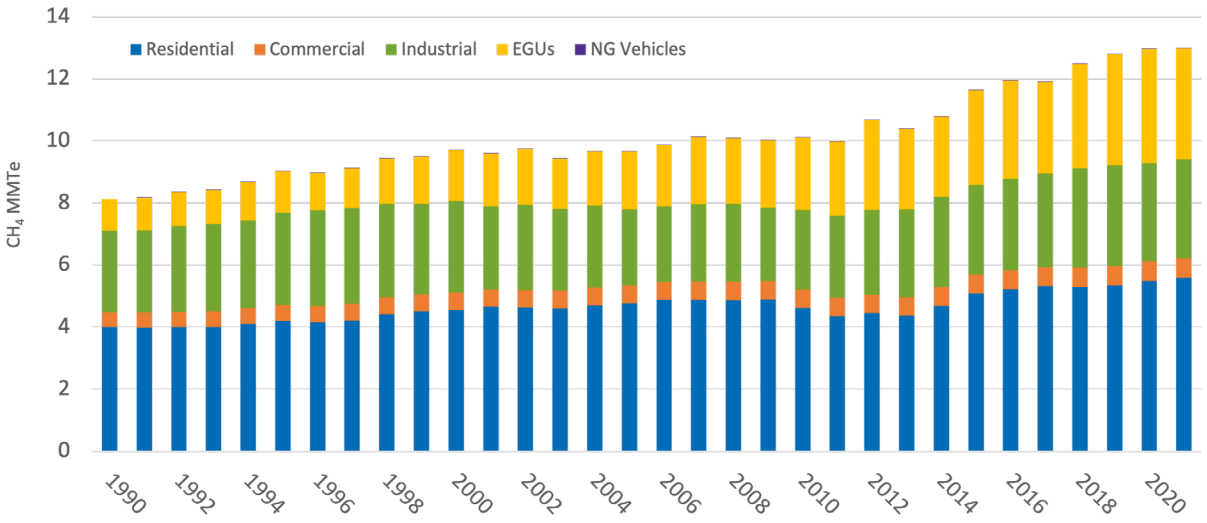
The post-meter segment accounted for approximately 7 percent of $CH_4$ emissions from natural gas systems in 2021. Leak emissions from residential appliances, industrial facilities, and power plants account for the majority (95 percent) of post-meter $CH_4$ emissions. $CH_4$ emissions from all post-meter sources increased by 60 percent from 1990 to 2021 and remained constant between 2020 and 2021. Trends in $CH_4$ emissions from the distribution and post-meter segments over the 1990 to 2021 time series are illustrated in Figure 13, and the 2021 distribution of $CH_4$ emissions across post-meter sources is shown in Table 7.

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

6 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 U.S. estimate. 3- There are considerable data gaps, large uncertainties, and orders of magnitude difference 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 to determine whether emissions vary with time or environmental conditions such as seasonal temperature and weather changes. 5- EPA estimated time series should reflect the phase out of pilot lights from many natural gas appliacations. To the extent thesestudies 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 U.S. over the past 10 to 30 years, due to DOE's appliance energy efficiency standards under 10 C.F.R. Part 430.

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.

**Figure 13: Trends in $CH_4$ Emissions from Post-Meter Segment Sources (MMTe)**



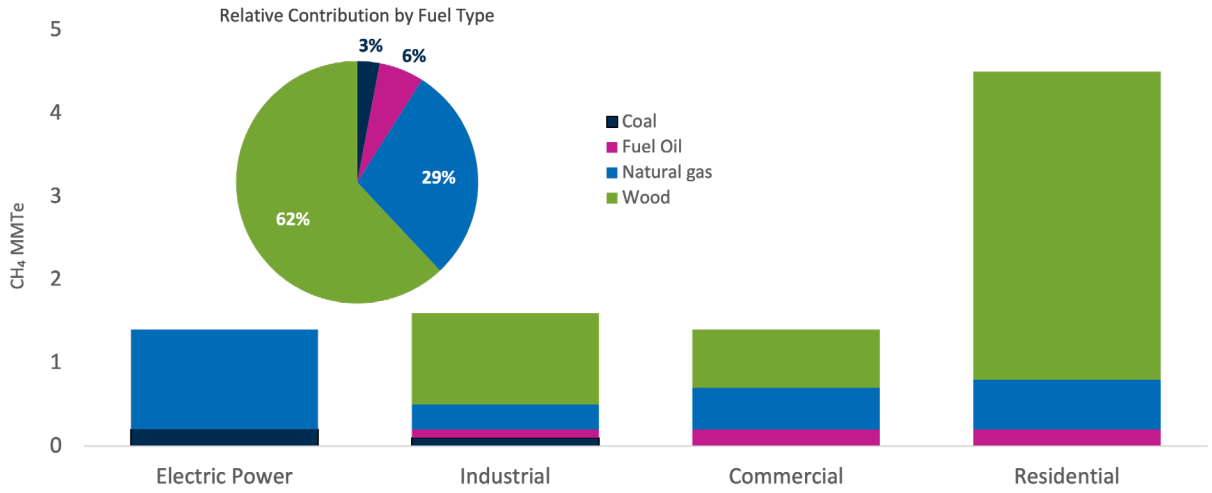

Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Annex Table 3.6-1 Environmental Protection Agency

# $CH_4$ 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. Combustion of fossil fuels, including coal, fuel oil, and natural gas, primarily results in emissions of $CO_2$, 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 2021, $CH_4$ emissions from natural gas stationary combustion accounted for 6.7 percent and 5.6 percent of the direct fossil fuel (including natural gas, coal, fuel oil, and wood) $CH_4$ emissions from the residential and commercial sectors, respectively. Between 1990 and 2021, $CH_4$ emissions from natural gas combustion in the residential segment decreased by 22 percent and increased by 8.3 percent in the commercial segment. From 2020 to 2021, $CH_4$ emissions remained constant for the commercial segment and increased by 4.5 percent for the residential segment. Figure 14 provides $CH_4$ emissions (MMTe) 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 2021 time series. More detailed emissions from natural gas combustion can be found in Table 8.

## Figure 14: 2021 $CH_4$ Emissions From Fossil Fuel Combustion by Segment and Fuel Type (MMTe)




Source: Derived from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2021, Annex Table 3-8 Environmental Protection Agency.

## Table 8: $CH_4$ Emissions from Stationary Combustion (MMTe)

| Sector/Fuel Type | 1990 | 2000 | 2010 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|
| **Electric Power** | **0.5** | 0.7 | 1.1 | 1.2 | 1.4 | 1.4 | 1.4 | 1.4 |
| Coal | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 |
| Fuel Oil | + | + | + | + | + | + | + | + |
| Natural gas | 0.1 | 0.2 | 0.7 | 1 | 1.1 | 1.2 | 1.2 | 1.2 |
| Wood | + | + | + | + | + | + | + | + |
| **Industrial** | **2** | 2.1 | 1.8 | 1.7 | 1.7 | 1.7 | 1.6 | 1.6 |
| Coal | 0.5 | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 |
| Fuel Oil | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 |
| Natural gas | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 | 0.3 |
| Wood | 1.2 | 1.3 | 1.1 | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 |
| **Commercial** | **1.2** | 1.2 | 1.2 | 1.3 | 1.4 | 1.4 | 1.3 | 1.3 |
| Coal | + | + | + | + | + | + | + | + |
| Fuel Oil | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Natural gas | 0.4 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 0.4 | 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 | 4.2 | 5.1 | 5.3 | 4.4 | 4.6 |
| Coal | 0.3 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fuel Oil | 0.4 | 0.4 | 0.3 | 0.2 | 0.3 | 0.3 | 0.2 | 0.2 |
| Natural Gas | 0.6 | 0.7 | 0.6 | 0.6 | 0.7 | 0.7 | 0.6 | 0.6 |
| Wood | 4.6 | 3.4 | 4.3 | 3.4 | 4.2 | 4.4 | 3.5 | 3.7 |
| **U.S. Territories** | **+** | 0.1 | 0.1 | 0 | 0 | 0 | 0 | 0 |
| Coal | + | + | + | + | + | + | + | + |
| Fuel Oil | + | 0.1 | 0.1 | + | + | + | + | + |
| Natural Gas | NO | + | + | + | + | + | + | + |
| Wood | NE | NE | NE | NE | NE | NE | NE | NE |
| **Total** | **9.6** | **8.6** | **9.5** | **8.6** | **9.6** | **9.8** | **8.8** | **8.9** |
| **Natural gas contribution** | **14%** | **17%** | **20%** | **26%** | **26%** | **28%** | **27%** | **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.

# CALCULATION OF $CH_4$ INTENSITY

$CH_4$ emissions 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) *CH4 Emissions Intensity Protocol*, Version 1.0, February 2021 (NGSI Protocol) details a methodology for companies to calculate and report $CH_4$ emissions intensity consistently. The NGSI initiative is the result of a collaborative effort spearheaded by the AGA and Edison Electric Institute (EEI) with the investor community and experts from upstream, midstream, and downstream natural gas companies.[7] The NGSI Protocol is intended to support voluntary reporting by companies operating within the natural gas supply chain in the United States from onshore production through distribution. NGSI is a voluntary, industry-led initiative to advance innovative efforts to address environmental, social, and governance (ESG) issues throughout the natural gas supply chain.

The NGSI Protocol may be used to estimate $CH_4$ intensity for an entire segment based on segment 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:

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

The numerator of the $CH_4$ intensity equation is the annual total $CH_4$ volume or mass emissions reported in the Inventory for the system or segment/source. Mass emissions of $CH_4$ reported in the Inventory in terms of mass (kt or MMT) may be converted to 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 $CO_2e$.

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.

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

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

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

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 for natural gas systems, including the distribution and post-meter segments, is reported to and tracked by the Energy Information Administration (EIA). Data is available from 1997 through 2021.

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

The $CH_4$ emissions numerator is extracted from the 2023 GHGI and converted to terms of million metric tons (MMT). The $CH_4$ emissions are in mass terms (MMT), not $CO_2e$ (MMTe). For the denominator of the $CH_4$ emissions intensity equation, the annual U.S. natural gas volume throughput for each segment, reported in units of million standard cubic feet (MMscf) based on data from EIA, is then converted to a $CH_4$ volume throughput using an assumed $CH_4$ volume fraction of natural gas (84.3%v $CH_4$) following the NGSI Protocol. The annual $CH_4$ volume throughput quantity was converted to a mass basis expressed in terms of million metric tons (MMT).

Table 9 provides the $CH_4$ emissions intensity calculations, including data supporting the quantification of the numerator and denominator of the $CH_4$ emissions intensity equation.

**Table 9: 2021 $CH_4$ Intensity for the Distribution and Post-Meter Segments**

| | [1] | [2] | [3] | [1]*[2]/[3] | |
|---|---|---|---|---|---|
| Segment/Source | 2021 $CH_4$ Emissions (MMT) | 2021 $CH_4$ Throughput (MMT) | Gas Ratio | Methane Intensity (%) | U.S. Energy Information Administration (EIA) Source |
| Natural Gas System | 6.5 | 666.4 | 0.68 | 0.66% | U.S. Natural Gas Gross Withdrawals |
| Distribution | 0.5 | 442.0 | n/a | 0.12% | U.S. Total Natural Gas Deliveries |
| Post Meter | 0.5 | 442.0 | n/a | 0.10% | Natural Gas Delivered to Consumers in the U.S. |
| Residential | 0.2 | 75.4 | n/a | 0.26% | U.S. Natural Gas Residential Consumption |
| Commercial | 0.02 | 52.8 | n/a | 0.04% | Natural Gas Deliveries to Commercial Consumers (Including Vehicle Fuel through 1996) in the U.S. |
| Industrial | 0.11 | 132.7 | n/a | 0.09% | U.S. Natural Gas Industrial Consumption |
| Electric Generator Units | 0.13 | 180.3 | n/a | 0.07% | U.S. Natural Gas Deliveries to Electric Power Consumers |
| Natural Gas Vehicles | 3.5E-05 | 0.9 | n/a | 0.004% | 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:[8]

- Further reducing $CH_4$ emissions from 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
- Supporting renewable natural gas development and use and assessing the potential of renewable power to gas
- Modernize pipeline and other natural gas utility infrastructure
- Encourage and support third-party damage prevention programs
- Utilize recognized best practices to reduce $CH_4$ and 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

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

In addition to improvements in estimated emissions from natural gas systems, actual 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 a program to facilitate accelerated replacement and modernization of natural gas distribution pipelines no longer fit for service.

EPA's $CH_4$ Challenge program, set up to transparently report systematic and comprehensive actions to reduce $CH_4$ emissions, has natural gas distribution utility partners representing more than 80 percent of all U.S. natural gas customers. EPA's Natural Gas STAR program encourages natural gas and oil companies to adopt proven, cost-effective technologies and practices that improve operational efficiency and reduce $CH_4$ emissions.

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 Inventories 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 may be "certified" by independent auditors. Certified gas is geologic natural gas differentiated by environmental performance criteria across the value chain.[9]

AGA and the natural gas industry are committed to supporting studies to collect accurate measurements of $CH_4$ emissions from natural gas system operations. 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 analysis characterized new estimates for $CH_4$ emissions and the implications for the GHG profile of natural gas. The updated EPA Inventory affirms a low $CH_4$ emissions profile for natural gas distribution systems shaped by a declining trend.

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 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 GHG emissions.

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.

9 Natural Gas Utility Industry Climate Change Commitments Industry Progress," American Gas Association, August 2022, Accessed at: https://www.aga. org/globalassets/research--insights/reports/aga_icfstudy_climatechangeposition_updated_08.22.2022.pdf

# Appendix A.1

## Table A.1: Calculation of Methane Intensity

| | 2021 | Source |
|---|---|---|
| $CH_4$ Emissions from Natural Gas Systems (MMT) | 6.48 | EPA GHGI 2023 |
| $CH_4$ Emissions from Distribution Segment (MMT) | 0.55 | EPA GHGI 2023 |
| $CH_4$ Emissions from Post-Meter Segment (MMT) | 0.46 | EPA GHGI 2023 |
| Residential (MMT) | 0.20 | EPA GHGI 2023 |
| Commercial (MMT) | 0.02 | EPA GHGI 2023 |
| Industrial (MMT) | 0.11 | EPA GHGI 2023 |
| EGUs (MMT) | 0.13 | EPA GHGI 2023 |
| Natural Gas Vehicles (MMT) | 3.5E-05 | EPA GHGI 2023 |
| **$CH_4$ Emissions from Natural Gas Systems, excluding Post-Meter (MMT)** | **6.01** | |
| U.S. Natural Gas Gross Withdrawals (MMcf) | 41,666,118 | EIA 2021 |
| Crude Oil Production (1,000s bbls) | 4,107,585 | EIA 2021 |
| Lease Condensate Production (million bbls) | 295 | EIA 2021 |
| U.S. Natural Gas Total Consumption (MMcf) | 30,664,951 | EIA 2021 |
| Natural Gas Delivered to Consumers in the U.S. (MMcf) | 27,634,144 | EIA 2021 |
| Natural Gas Delivered to LDCs in the U.S. (MMcf) | 27,634,144 | EIA 2021 |
| Natural Gas Delivered to LDCs in the U.S.: Residential (MMcf) | 4,716,208 | EIA 2021 |
| Natural Gas Delivered to LDCs in the U.S.: Commercial (MMcf) | 3,298,222 | EIA 2021 |
| Natural Gas Delivered to LDCs in the U.S.: Industrial (MMcf) | 8,294,683 | EIA 2021 |
| Natural Gas Delivered to LDCs in the U.S.: Power (MMcf) | 11,270,552 | EIA 2021 |
| Natural Gas Delivered to LDCs in the U.S.: Natural Gas Vehicles (MMcf) | 54,479 | EIA 2021 |
| $CH_4$ Total Consumption (MMcf) | 34,707,876 | NGSI Protocol v.1.0 |
| $CH_4$ Delivered to LDCs in the U.S. (MMcf) | 23,019,242 | NGSI Protocol v.1.0 |
| $CH_4$ Delivered to LDCs in the U.S.: Residential (MMcf) | 3,928,601 | NGSI Protocol v.1.0 |
| $CH_4$ Delivered to LDCs in the U.S.: Commercial (MMcf) | 2,747,419 | NGSI Protocol v.1.0 |
| $CH_4$ Delivered to LDCs in the U.S.: Industrial (MMcf) | 6,909,471 | NGSI Protocol v.1.0 |
| $CH_4$ Delivered to LDCs in the U.S.: Power Plants (MMcf) | 9,388,370 | NGSI Protocol v.1.0 |
| $CH_4$ Delivered to LDCs in the U.S.: Natural Gas Vehicles (MMcf) | 45,381 | NGSI Protocol v.1.0 |
| $CH_4$ Total Consumption (MMT) | 666 | NGSI Protocol v.1.0 |
| $CH_4$ Delivered to LDCs in the U.S. (MMT) | 442 | NGSI Protocol v.1.0 |
| $CH_4$ Delivered to LDCs in the U.S.: Residential (MMT) | 75 | NGSI Protocol v.1.0 |
| $CH_4$ Delivered to LDCs in the U.S.: Commercial (MMT) | 53 | NGSI Protocol v.1.0 |
| $CH_4$ Delivered to LDCs in the U.S.: Industrial (MMT) | 133 | NGSI Protocol v.1.0 |
| $CH_4$ Delivered to LDCs in the U.S.: Power Plants (MMT) | 180 | 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) | 224 | NGSI Protocol v.1.0 |
| BTU equivalent for U.S. Natural Gas Gross Withdrawals (MMBtu) | 51,457,655,730 | NGSI Protocol v.1.0 |
| BTU equivalent for U.S. crude oil production (MMBtu) | 23,823,993,000 | NGSI Protocol v.1.0 |
| BTU equivalent for lease condensate (MMBtu) | 1,711,000 | 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) | 0.66% | 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 | 0.26% | 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** | **1.97%** | **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 |

Source: EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, EIA (2021); and Natural Gas Sustainability Initiative (NGSI) Methane Emissions Intensity Protocol, version 1.0 (2021).

# Appendix A.2

**Table A.2: 2021 $CH_4$ Emission Factors and Activity Data for the Natural Gas Distribution and Post-Meter Segments**

| Distribution and Post-Meter (2021) | Emission Factors | | Activity Data | |
|---|---|---|---|---|
| **Normal Fugitives** | | | | |
| Pipeline Leaks | | | | |
| Mains - Cast Iron | 1,157.3 | kg/mile | 19,980 | Miles |
| Mains - Unprotected Steel | 861.3 | kg/mile | 48,244 | Miles |
| Mains - Protected Steel | 96.7 | kg/mile | 460,708 | Miles |
| Mains - Plastic | 28.8 | kg/mile | 787,868 | Miles |
| Services - Unprotected Steel | 14.5 | kg/service | 2,615,703 | Services |
| Services - Protected Steel | 1.3 | kg/service | 12,297,772 | Services |
| Services - Plastic | 0.3 | kg/service | 52,272,704 | Services |
| Services - Copper | 4.9 | kg/service | 655,762 | Services |
| **Meter/Regulator (City Gates)** | | | | |
| M&R > 300 | 2,142.7 | kg/station | 4,175 | Stations |
| M&R 100-300 | 995.4 | kg/station | 15,235 | Stations |
| M&R < 100 | 727.2 | kg/station | 8,143 | Stations |
| Reg > 300 | 868.9 | kg/station | 4,564 | Stations |
| R-Vault > 300 | 50.6 | kg/station | 3,972 | Stations |
| Reg 100-300 | 143.4 | kg/station | 13,808 | Stations |
| R-Vault 100-300 | 50.6 | kg/station | 12,491 | Stations |
| Reg 40-100 | 163.7 | kg/station | 41,435 | Stations |
| R-Vault 40-100 | 50.6 | kg/station | 8,897 | Stations |
| Reg < 40 | 22.4 | kg/station | 17,570 | Stations |
| **Customer Meters** | | | | |
| Residential | 1.5 | kg/meter | 56,719,359 | Outdoor meters |
| Commercial | 23.4 | kg/meter | 5,626,925 | Meters |
| Industrial | 105.0 | kg/meter | 184,011 | Meters |
| Routine Maintenance | | | | |
| **Pressure Relief/Valve Relief** | **1.0** | **kg/mile** | **1,316,800** | **Miles main** |
| Pipeline Blowdown | 2.0 | kg/mile | 2,284,348 | Miles |
| **Upsets** | | | | |
| Mishaps | 30.6 | kg/mile | 2,284,348 | Miles |

Source: EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, 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: 1990-2021, Annex Table 3.6-8, Environmental Protection Agency

# Appendix A.4

**Table A.4: Installed Pipeline Main and $CH_4$ Emissions from Main Pipe, 1990-2021**

| Year | Installed Main Pipe (Thousand Miles) | $CH_4$ Emissions from Main Pipe (MMTe) |
|---|---|---|
| 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 | 3.94 |
| 2018 | 1304.3 | 3.84 |
| 2019 | 1315.5 | 3.74 |
| 2020 | 1325.9 | 3.66 |
| 2021 | 1337.0 | 3.57 |

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Annex Table 3.6-1 and Table 3.6-7

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## NOTICE