New York State Oil and Gas Methane Emissions Inventory:

2018–2020 Update

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New York State Oil and Gas Methane Emissions Inventory: 2018–2020 Update

Final Report

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Abstract

Methane (CH_4) is a short-lived climate pollutant that is second to carbon dioxide (CO_2) in its contribution to global climate change. A significant source of anthropogenic CH_4 emissions is the production and consumption of oil and natural gas. This documentation is meant as a supplement to the 2017 New York State Oil and Gas Sector Methane Emissions Inventory documentation (NYSERDA, 2019) and provides details on updating the 2017 inventory through 2020. The goal of this project is to support CH_4 emissions reduction efforts in New York State by improving NYS's understanding of CH_4 emissions and CH_4 emissions-accounting methodologies for the oil and natural gas sector. Due to updates to pipeline emission factors and the addition of beyond the meter source categories (residential appliances, residential buildings, and commercial buildings), this 2018–2020 update estimates emissions in 2017 to be 44% higher (12,919,759 $MTCO_2e$, AR5 GWP_{20}) than the previous 2017 estimate (8,951,652 $MTCO_2e$). CH_4 emissions from oil and natural gas activity in NYS totaled 12,582,293 $MTCO_2e$ in 2018, 12,611,756 $MTCO_2e$ in 2019, and 12,460,067 $MTCO_2e$ in 2020. Results from this inventory show that, despite an increase in natural gas consumption, the trend in total CH_4 emissions has continued to decline since 2007, with an average annual decrease of 2.2% per year.

Keywords

methane, oil, natural gas, emissions, inventory, greenhouse gas inventory, emission factors, methane inventory, downstream emissions, upstream emissions, midstream emissions, natural gas production, New York State methane inventory

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Acronyms and Abbreviations

AR4	Fourth Assessment Report of the IPCC (2007)
AR5	Fifth Assessment Report of the IPCC (2014)
bbl	Barrels. 1 oil barrel = 42 U.S. gallons
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
EF	Emissions factor
EIA	Energy Information Administration
EPA	United States Environmental Protection Agency
ESOGIS	Empire State Organized Geologic Information System
FLIGHT	Facility Level Information on GreenHouse Gases Tool
g	Gram
Gg	Gigagram
GHG	Greenhouse gas
GHGRP	Greenhouse Gas Reporting Program
GWP	Global warming potential
GWP_{20}	Global warming potential (20 year)
GWP_{100}	Global warming potential (100 year)
IPCC	Intergovernmental Panel on Climate Change
Kg	Kilogram
LNG	Liquefied natural gas
Mcf	Thousand cubic feet
MMcf	Million cubic feet
MMT	Million metric ton (1 MMT = 1 teragram)
NAICS	North American Industry Classification System
NG	Natural Gas
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
Oil and Gas Tool	Nonpoint Oil and Gas Emission Estimation Tool
PHMSA	Pipeline and Hazardous Materials Safety Administration
psi	Pounds per square inch
SIT	State Inventory Tool
UNFCCC	United Nations Framework Convention on Climate Change

1 Introduction

1.1 Overview

This documentation is meant as a supplement to the 2017 New York State Oil and Gas Sector Methane Emissions Inventory documentation (NYSERDA, 2019) and provides details on updating the 2017 inventory through 2020. The goal of this project is to support methane (CH_4) emissions reduction efforts in New York State by improving NYS's understanding of CH_4 emissions and CH_4 emissions-accounting methodologies for the oil and natural gas sector, including upstream, midstream, and downstream sources, from the wellhead to beyond the meter. Consequently, the inventory updates implemented under this project incorporate findings from the most current empirical research and utilize the most accurate, current, and inventory-appropriate available data sources to develop an activity-driven, site-level, CH_4 emissions inventory.

Specific objectives of this project include (1) assessing NYS's 2017 oil and natural gas sector CH_4 emissions inventory for areas of improvement, (2) performing a literature review of latest data on fugitive oil and gas methane emissions in NYS, and (3) incorporating the latest data to create an updated CH_4 emissions inventory for the oil and natural gas sector in NYS through 2020.

The remainder of this document is organized by sections and presents an overview of updates applied to the 2017 inventory to create the 2018–2020 inventories (section 1), new activity data for 2018–2020 (section 2), methane emissions inventory development for updated and new source categories (section 3), an analysis and summary of the 2018–2020 CH_4 emissions inventories (section 4), a discussion of potential future inventory improvements (section 5), conclusions (section 6), and references (section 7).

2 Differences Between the 2017 and 2018–2020 Inventories

In addition to updating the 2017 inventory with activity data and emissions for 2018–2020, there are three main differences between the 2017 inventory and the 2018–2020 inventories discussed in this section:

- Updates to distribution emissions factors based on utility reported data (section 2.1).
- Addition of beyond the meter sources including residential appliances, residential buildings, and commercial buildings from 1990 to 2020 (section 2.2).
- Expressing methane emissions in terms of CO_2e using Fifth Assessment Report of the IPCC (AR5) Global warming potential (20 year) GWP_{20} (section 2.3).

2.1 Updates to Distribution Emissions Factors

A comparison of utility reported distribution pipeline emissions under the Environmental Protection Agency's (EPA) GHG Reporting Program (FLIGHT database) and the estimated distribution pipeline emissions in NYS's 2017 oil and natural gas sector inventory revealed discrepancies between utility reported emissions and the NYS estimated emissions for pipeline mains and services. To ensure that the NYS methane emissions inventory aligns with utility reported data, the pipeline emissions factors for mains and services were updated to match the emissions factors used by utilities. In addition, all emissions factor units were updated to kg/mile for consistency. Table 1 below shows a comparison of the emissions factors used in 2017 NYS inventory (yellow shading) to the updated emissions factors used in the 2018–2020 inventories (green shading). These updates resulted in a 33% increase in overall emissions from the oil and natural gas sector.

Table 1. Comparison of Distribution Pipeline Methane EFs Based on Utility Reported Emissions versus EFs Used in the NYS 2017 Oil and Natural Gas Sector Inventory

	2017 EF Units	Calculated from Utility Reported Data to GHGRP	2017 NYS Inventory EF		Updated EF Units	Calculated from Utility Reported Data to GHGRP	Updated NYS Inventory EF	
		2017	2017 Low	2017 High		2017	2017 Low	2017 High
Mains								
Cast Iron	kg/mile	4,583.2	1,157.3	4,597.4			1,157.3	4,597.4
Unprotected Steel	kg/mile	2,115.8	861.3	2,122.3			861.3	2,122.3
Protected Steel	kg/mile	58.8	96.7	96.7			58.8	96.7
Plastic	kg/mile	190.0	28.8	190.9			28.8	190.9
Copper	kg/service		4.9	4.9	kg/mile		496.0	496.0
Services								
Cast Iron	kg/mile		1,157.3	4,597.4			1,157.3	4,597.4
Unprotected Steel	kg/service	31.9	14.5	32.8	kg/mile	2,711.5	1,198.7	2,711.5
Protected Steel	kg/service	3.3	1.3	3.4	kg/mile	247.3	94.5	247.3
Plastic	kg/service	0.2	0.3	0.3	kg/mile	13.5	13.5	13.5
Copper	kg/service	5.0	4.9	4.9	kg/mile	496.0	496.0	496.0

2.2 Addition of Beyond the Meter Sources

New York State's 2017 methane emissions inventory estimated methane emissions from the oil and natural gas sector up to and including emissions from the meter but lacked end-use emission estimates beyond the meter. Since completing the 2017 inventory, more research has been published on end-use emissions beyond the meter which allowed emission estimates from this category. Including methane emissions from beyond the meter end-use processes may help to further reconcile discrepancies in emission estimates from top-down versus bottom-up approaches. For example, a recent top-down measurement study by Plant et al. (2019) indicates that downstream emissions in the northeastern United States are around 0.8% of consumption. For comparison, the 2019 bottom-up downstream emissions estimated for the 2019 NYS inventory are around 0.2% of consumption. This agrees well with the data on delivery and losses reported by natural gas utilities to EPA's FLIGHT database. Thus, in addition to the inherent methodological differences, the discrepancy between top-down studies such as Plant et al. and the NYS inventory could be partially due to missing end-use sources.

This section provides the results of a literature search on beyond the meter end-use methane emissions. The purpose of the literature review was to determine the universe of appliances and buildings that might be contributing to end-use methane emissions and the leak rates from those appliances and building plumbing.

To conduct the literature review, Energy Information Administration (EIA)was searched to identify the end uses of natural gas in the residential and commercial sectors.[1] With this information, the following key terms were identified and used to guide the literature review:

1. residential methane emissions end use
2. commercial methane emissions end use
3. residential methane leaks end use
4. commercial methane leaks end use
5. methane emissions from
    - cooking
    - furnaces
    - water heaters
    - refrigeration
    - drying clothes

The results of the literature review are presented in Table 2 and Table 3 and were used to develop the beyond-the-meter methane emission estimation methods presented in section 3.4.3 for residential buildings, residential appliances (section 3.4.2), and commercial buildings (hospitals and restaurants; section 3.4.3). Due to a lack of available data, emissions were not estimated for residential refrigeration or clothes driers. The addition of these beyond the meter sources increased the overall emissions in the oil and natural gas sector inventory by 9% over the 2017 inventory estimate (5% from residential buildings, 2.2% from residential appliances, and 1.8% from commercial buildings).

Table 2. Literature Review Results Containing Emissions Factors

Author	Year	Title	Summary	Appliance(s)		
Hong & Howarth	2016	Greenhouse gas emissions from domestic hot water: heat pumps compared to most commonly used systems	EF for residential NG tankless and storage water heaters estimated to be 0.82 to 4.02 kg/GJ water heated. This is a lifecycle emissions factor and includes emissions before the meter.	tankless water heaters storage water heaters	0.82 to 4.02 kg/GJ of water heated	U.S.
Fischer et al.	2018	An estimate of natural gas methane emissions from California homes	Post meter methane emissions from residential natural gas are estimated using measurements from a sample of homes (75 single family homes) and appliances. Whole house emissions are typically less than 1 g CH4/day. The authors estimate that methane emissions from residential natural gas are 35.7 Gg/yr.	post-meter	<1 g CH_4/day/housing unit	California
Merrin & Francisco	2019	Unburned methane emissions from residential natural gas appliances	EF = 0.38 g/kg of NG consumed for US residential appliances. Calculates total methane emissions and methane emissions per year for each appliance (furnace, boiler, water heater, tankless water heater, stove, oven).	furnace boiler storage water heater tankless water heater stove oven	furnace = 0.22 kg/appliance boiler = 0.32 kg/appliance storage water heater = 0.077 kg/appliance tankless water heater = 1.2 kg/appliance stove = 0.066 kg/appliance oven = 0.13 kg/appliance	72 sites in Boston and Indianapolis and 28 sites in IL and NY
Lebel	2020	Quantifying methane emissions from natural gas water heaters	Examined water heaters from 64 northern California homes. Tankless water heaters emitted 2.39 kg CH_4/yr and storage water heaters emitted 1.40 kg CH_4/yr. U.S. emissions from water heaters are estimated to be 82.3 Gg CH_4/yr.	storage water heaters tankless water heaters	storage water heaters = 1.40 kg/unit/yr tankless water heaters = 2.39 kg/unit/yr	California
Saint-Vincent & Pekney	2020	Beyond the meter: Unaccounted sources of methane emissions in the natural gas distribution sector	This study estimates that residential homes and appliances could release 9.1 Gg CH_4/year, with furnaces being the most leak-prone appliance. Reports an EF of 4.1 kg/TJ for the furnaces in the US **based on the Merrin & Francisco paper.** EFs from other countries: 4.3 kg CH_4/TJ consumed (UK heating units or furnaces), 2.3 kg CH_4/TJ consumed (Germany furnaces), 4.5 kg CH_4/TJ consumed (Japan furnaces), 1 kg CH4/TJ consumed (Switzerland). Type of furnace, efficiency, furnace technology, and age may affect EFs. Mentions that Hong and Howarth (summarized above) calculated an EF for residential NG tankless and storage water heaters to be between 0.60 and 4.02 kg/GJ.	furnaces	4.1 kg/TJ NG consumed	U.S.

Table 3. Literature Review Results Containing Activity Data

Author	Year	Title	Summary	Activity Data	Geography
EIA	2018	2015 Residential Energy Consumption Survey (RECS) Survey Data	Survey data provides information on the appliances used by households, including stoves, ovens, water heaters, furnaces, and boilers. Data are also included on end-use consumption by fuel in the U.S. and in the Northeast for space heating, water heating, air conditioning, refrigerators, and other. More detailed consumption data provides the site energy consumption of natural gas space heating, water heating, clothes dryers, cooking, pool heaters, and hot tub heaters in the Northeast. There are also housing characteristics tables.	Counts and consumption of appliances by fuel type in the Northeast	Northeast, Mid-Atlantic
EIA	2016	2012 Commercial Building Energy Consumption Survey (CBECS) Survey Data	Survey data provides information on building characteristics and consumption and expenditures in the United States.	Natural gas consumption by census region and number of building end-use appliances	U.S., some data tables by census region
EIA	2019	Use of natural gas	Identifies specific end uses (i.e., using natural gas for heating buildings and water, for drying clothes, to operate refrigeration and cooling equipment, for outdoor lighting).	N/A	U.S.
NYSERDA	2019	Single-Family Building Assessment–Residential Building Stock Assessment	Provides a profile of new and existing homes in NYS based on data from a representative sample of homes and reports changes in building and equipment stock since the 2015 RSBS, including changes in the saturation of energy-consuming equipment (electric, natural gas, and other fuels), building characteristics, and energy management practices. The RBSA also collected customer household and demographic information.	Counts of single-family homes by climate zone	New York State
U.S. Census Bureau	2018	Annual estimates of county housing units for States: 2010–2018	Provides total number of housing units by county.	Counts of housing units by county	New York State

2.3 Global Warming Potential

The selection of an appropriate unit for inventory calculations is an important consideration. Over two decades ago, the Intergovernmental Panel on Climate Change IPCC recommended the Global Warming Potential 100-year (GWP_{100}) for converting methane (CH_4) emissions to carbon dioxide equivalents (CO_2e) for the purpose of governmental inventory reporting to the United Nations Framework Convention on Climate Change (UNFCCC). While this gives a long-range perspective, using GWP_{100} discounts important, near-term climate impacts (Alvarez et al. 2012). Some researchers are now suggesting the use of the GWP_{20} as an appropriate metric or at least reporting inventories using both GWP_{100} and GWP_{20} conversions (Balcombe et al. 2018; Alvarez et al. 2012; Ocko et al. 2017).

In 2017, NYS used the IPCC GWP_{100} from the Assessment Report 4 (AR4) of the IPCC (IPCC 2006) to be consistent with the U.S. National Greenhouse Gas (GHG)Inventory, other national governmental inventories that follow UNFCCC protocols, and the EPA's State Inventory Tool (SIT) -based inventories reported by other states. The AR4 GWP_{100} for CH_4 is 25 and the GWP_{20} is 72, meaning that CH_4 is 25x more potent than carbon dioxide ($CO_{2\_}$) as a GHG over a 100-year time period, and is 72 times more potent over a 20-year time period. More recently, the IPCC significantly revised its GWP values in the 2013 Fifth Assessment Report [AR5 (Hartmann, Tank, and Rusticucci 2013)]. Under AR5, the GWP_{100} for CH_4 is 28 (a 12% increase) and the updated GWP_{20} is 84 (a 16.7% increase). The calculation of GWP with subsequent Assessment Reports is due in part to the changing concentration of GHGs in the atmosphere and updated modeling for their direct and indirect effects. Recent literature estimates indicate that the GWP for CH_4 may in fact be greater than reported in AR5 (Etminan et al. 2016). The 2021 Sixth Assessment Report differentiates CH_4 of fossil origin and non-fossil origin. Under AR6, the GWP_{20} was updated to 82.5 for fossil origin CH_4 and 80.8 for non-fossil origin CH_4 while the AR6 GWP_{100} is 29.8 for fossil CH_4 and 27.2 for non-fossil CH_4 (IPCC 2021). For this inventory update, NYS is reporting emissions using the AR5 GWP_{20} values to capture the near-term climate impacts of methane emissions most effectively.

3 Methane Emissions Inventory Development for Updated and Added Source Categories

3.1 Summary

This section contains a detailed accounting of the emissions inventory development methodology for the sources updated or added since the 2017 inventory. All sources included in the inventory are listed in Table 4 (blue shading indicates an updated emissions factor and green shading indicates a new source category). For each updated or new source added since the 2017 inventory, the section contains the following subsections: (1) a source category description, (2) a discussion of EFs, (3) a discussion on activity data, (4) geospatial data and any allocation methodologies, (5) sample calculations, 6) limitations and uncertainties, and (7) potential areas of improvement. For sources not updated or added since 2017, please see the 2017 inventory documentation for details on the methodology (NYSERDA, 2019).

The general equation for emissions estimation is:

Equation 1 $$E = A \times EF$$

where:

- E = emissions
- A = activity
- EF = emissions factor

EFs in the published literature typically are averages of available data of acceptable quality and are assumed to represent long-term averages for similar facilities. However, variations among facilities, such as operational conditions and emissions controls, can significantly affect emissions. Whenever possible, the development of local, source specific EFs is highly desirable.

Table 4. Sources of CH_4 Emissions included in the 1990–2020 NYS Inventory

Category	Segment	Source
Upstream	Onshore Exploration	Drill Rigs
Upstream	Onshore Exploration	Fugitive Drilling Emissions
Upstream	Onshore Exploration	Oil Well: Mud Degassing
Upstream	Onshore Exploration	Gas Well: Mud Degassing
Upstream	Onshore Exploration	Oil Well: Completions
Upstream	Onshore Exploration	Gas Well: Completions
Upstream	Onshore Production	Oil Well: Conventional Production
Upstream	Onshore Production	Gas Well: Conventional Production
Upstream	Onshore Production	Oil Well: Unconventional Production
Upstream	Onshore Production	Gas Well: Unconventional Production
Upstream	Onshore Production	Oil: Abandoned Wells
Upstream	Onshore Production	Gas: Abandoned Wells
Midstream	Gathering and Boosting	Oil: Gathering and Processing
Midstream	Gathering and Boosting	Gas: Gathering and Processing
Midstream	Gathering and Boosting	Gathering Pipeline
Midstream	Crude Oil Transmission	Oil: Truck Loading
Midstream	Natural Gas Transmission and Compression	Gas: Truck Loading
Midstream	Natural Gas Processing	Gas Processing Plant
Midstream	Natural Gas Transmission and Compression	Transmission Pipeline
Midstream	Natural Gas Transmission and Compression	Gas Transmission Compressor Stations
Midstream	Underground Natural Gas Storage	Gas Storage Compressor Stations
Midstream	Underground Natural Gas Storage	Storage Reservoir Fugitives
Midstream	LNG Storage	LNG Storage Compressor Stations
Midstream	LNG Import/Export	LNG Terminal
Downstream	Natural Gas Distribution	Cast Iron Distribution Pipeline: Main
Downstream	Natural Gas Distribution	Cast Iron Distribution Pipeline: Services
Downstream	Natural Gas Distribution	Unprotected Steel Distribution Pipeline: Main
Downstream	Natural Gas Distribution	Unprotected Steel Distribution Pipeline: Services
Downstream	Natural Gas Distribution	Protected Steel Distribution Pipeline: Main
Downstream	Natural Gas Distribution	Protected Steel Distribution Pipeline: Services
Downstream	Natural Gas Distribution	Plastic Distribution Pipeline: Main
Downstream	Natural Gas Distribution	Plastic Distribution Pipeline: Services
Downstream	Natural Gas Distribution	Copper Distribution Pipeline: Main
Downstream	Natural Gas Distribution	Copper Distribution Pipeline: Services
Downstream	Natural Gas Distribution	Meters
Downstream	Beyond the meter	Residential Natural Gas Appliances
Downstream	Beyond the meter	Residential Buildings
Downstream	Beyond the meter	Commercial Buildings

3.2 Emissions Factor Confidence

While this section is also included in the 2017 inventory, it is repeated here to provide context on how EFs were rated for updated and new sources in the 2018–2020 inventory. EFs used in this inventory are derived from a comprehensive search of the literature and selected based on expert judgment and best available data. In most cases, EFs are transferred from studies performed at sites outside of NYS, which have varying methodologies and are not all peer reviewed. In addition, some of the EFs applied in this inventory are derived from empirical studies or engineering estimates performed well in the past and may not reflect current conditions in NYS. As such, it is important to describe the certainty of the EF as it is applied to NYS. In order to address EF certainty, this section outlines the four metrics used to evaluate the EF applied: geography, recency, study methodology, and publication status. Each metric is presented equally and independently with no judgments as to weighting of the four categories.

3.2.1 Geography

Geography is an important consideration when evaluating EFs. Selecting EFs that most closely reflect local conditions will result in the most robust estimates, as they are likely to share similar local environmental conditions and regulations, which can influence average EFs. Site-level EFs show significant geographic variation varying from 0.4% of production in the Marcellus Basin to 9.1% of production in the West Arkoma Basin, highlighting the need to select EFs that are as geographically local as possible.

NYS	Marcellus/Appalachian Basin	Rest of the Country

3.2.2 Recency

Many of the EFs employed in the EPA Oil and Gas Tool and SIT are derived from older studies, with some values originating from studies first published in 1977. The oil and natural gas sector has changed a good deal since that time, transitioning toward plastic pipelines, and centrifugal compressors with greater throughput and lower leak rates than reciprocating compressors, . As such, it is important to use EFs that most closely reflect the current state of the industry when evaluating the inventory.

Study Age ≤ 5 Years	5 > Study Age ≤ 15 Years	15 < Study Age

3.2.3 Study Methodology

The EFs in this inventory are derived using a variety of methodologies. At their simplest, EF estimates are derived from engineering estimates, which take assumptions about equipment throughputs and leak rates to estimate EFs in the absence of empirical observations. More sophisticated methodologies apply component- or site-level sampling methods to empirically observed emissions rates. Empirical observations of EFs represent best available practices, as they reflect real-world operations and uncertainties that may not be captured by engineering estimates.

Empirical Observation	Engineering Estimate

3.2.4 Publication Status

EFs in this inventory are derived from two primary sources: grey and peer-reviewed literature. Grey literature estimates are typically from government publications and reports, which are prepared by experts and in many cases provide a wealth of information on clearly documented EFs, but do not undergo a formal external peer review. The second source of EFs is the peer-reviewed literature. These EFs are subject to peer-review prior to publication, indicating that they have been thoroughly vetted, are derived using robust scientific methodologies, and represent the best available data.

Peer-Reviewed	Grey Literature

3.2.5 Summary Table

Table 5 summarizes the EF confidence assessment by CH_4 emissions sources for EFs updated or added in developing the 2018–2020 NYS inventory.

Table 5. Emission Factor Confidence Assessment for Emission Factors Used in the Updated 2018–2020 New York State Inventory

Emissions Source	EF			EF Unit	Geography	Recency	Methodology	Status	Source
	Low	Mid	High						
Cast Iron Distribution Pipeline: Main	1.1573	1.1573	4.5974	$MTCH_4\ mile^{-1}\ yr^{-1}$					Lamb et al. 2015; EPA 2018b; EPA, 2021
Cast Iron Distribution Pipeline: Services	1.1573	1.1573	4.5974	$MTCH_4\ mile^{-1}\ yr^{-1}$					Lamb et al. 2015; EPA 2018b; EPA, 2021
Unprotected Steel Distribution Pipeline: Main	0.8613	0.8613	2.1223	$MTCH_4\ mile^{-1}\ yr^{-1}$					Lamb et al. 2015; EPA 2018b; EPA, 2021
Unprotected Steel Distribution Pipeline: Services	1.1987	1.1987	2.7116	$MTCH_4\ mile^{-1}\ yr^{-1}$					Lamb et al. 2015; EPA 2018b; EPA, 2021
Protected Steel Distribution Pipeline: Main	0.0589	0.0589	0.0967	$MTCH_4\ mile^{-1}\ yr^{-1}$					Lamb et al. 2015; EPA 2018b; EPA, 2021
Protected Steel Distribution Pipeline: Services	0.0946	0.0946	0.2474	$MTCH_4\ mile^{-1}\ yr^{-1}$					Lamb et al. 2015; EPA 2018b; EPA, 2021
Plastic Distribution Pipeline: Main	0.0288	0.0288	0.1909	$MTCH_4\ mile^{-1}\ yr^{-1}$					Lamb et al. 2015; EPA 2018b; EPA, 2021
Plastic Distribution Pipeline: Services	0.0136	0.0136	0.0136	$MTCH_4\ mile^{-1}\ yr^{-1}$					Lamb et al. 2015; EPA 2018b; EPA, 2021
Copper Distribution Pipeline: Main	-	-	-	-	-	-	-	-	Note: There are no copper distribution mains in NYS.
Copper Distribution Pipeline: Services	0.4960	0.4960	0.4960	$MTCH_4\ mile^{-1}\ yr^{-1}$					Lamb et al. 2015; EPA 2018b; EPA, 2021

Table 5 continued

Emissions Source	EF			EF Unit	Geography	Recency	Methodology	Status	Source
	Low	Mid	High						
Residential Appliances – NG Furnace	0.14	0.22	0.51	kg CH_4 appliance^{-1} year^{-1}					Merrin and Francisco 2019
Residential Appliances – NG Boiler	0.15	0.32	0.75	kg CH_4 appliance^{-1} year^{-1}					Merrin and Francisco 2019
Residential Appliances – NG Storage Water Heater	0.02	0.077	0.084	kg CH_4 appliance^{-1} year^{-1}					Merrin and Francisco 2019
Residential Appliances – NG Tankless Water Heater	0.98	1.2	41	kg CH_4 appliance^{-1} year^{-1}					Merrin and Francisco 2019
Residential Appliances – NG Stove	0.04	0.056	0.071	kg CH_4 appliance^{-1} year^{-1}					Merrin and Francisco 2019
Residential Appliances – NG Oven	0.11	0.13	0.14	kg CH_4 appliance^{-1} year^{-1}					Merrin and Francisco 2019
Residential Buildings	0.0011	0.0018	0.0035	MTCH_4 housing unit^{-1} year^{-1}					Fischer et al. 2018a, Fischer et al. 2018b
Commercial Buildings -Hospitals	93.82	202.385	310.95	kg CH_4 hospital^{-1} year^{-1}					Sweeney et al. 2020
Commercial Buildings - Restaurants	0.0381	0.0480	0.0592	MTCH_4 restaurant^{-1} year^{-1}					Sweeney et al. 2020

3.3 Activity Data Summary

Activity data descriptions and data sources by emissions sources, along with flags for whether activity data were based on assumptions, whether an allocation method was applied to obtain county-level activity, and whether data cleansings were performed to remove suspected outliers, are presented in Table 6.

Table 6. Activity Data Summary for Activity Data Used in the 2018–2020 New York State Inventory

Emissions Source	Activity Data Description	Activity Data Based on Assumption	Allocation Method Applied	Data Cleansing Performed	Source
Drill Rigs	Drilling days	X		X	DEC 2021; ESOGIS 2021
Fugitive Drilling Emissions	Count of well completions				DEC 2021; ESOGIS 2021
Oil Well: Mud Degassing	Drilling days for oil wells	X		X	DEC 2021; ESOGIS 2021
Gas Well: Mud Degassing	Drilling days for gas wells	X		X	DEC 2021; ESOGIS 2021
Oil Well: Completions	Count of oil well completions				DEC 2021; ESOGIS 2021
Gas Well: Completions	Count of gas well completions				DEC 2021; ESOGIS 2021
Oil Well: Conventional Production	Mcf of associated gas production				DEC 2021; ESOGIS 2021
Gas Well: Conventional Production	Mcf of gas production				DEC 2021; ESOGIS 2021
Oil Well: Unconventional Production	Mcf of associated gas production	No activity in NYS			
Gas Well: Unconventional Production	Mcf of gas production	No activity in NYS			
Gas: Abandoned Wells	Count of abandoned gas wells				DEC 2021; ESOGIS 2021
Oil: Abandoned Wells	Count of abandoned oil wells	X			DEC 2021; ESOGIS 2021

Table 6 continued

Emissions Source	Activity Data Description	Activity Data Based on Assumption	Allocation Method Applied	Data Cleansing Performed	Source
Oil: Gathering and Processing	Mcf of associated gas production				DEC 2021; ESOGIS 2021
Gas: Gathering and Processing	Mcf of natural gas production				DEC 2021; ESOGIS 2021
Gathering Pipeline	Miles of pipeline	X	X		PHMSA 2021
Oil: Truck Loading	Bbls of crude oil loaded into trucks		X	X	ESOGIS 2021
Gas: Truck Loading	Mcf of gas loaded into trucks	No activity in NYS			
Gas Processing Plant	Count of gas processing plants	No activity in NYS			
Transmission Pipeline	Miles of pipeline		X	X	PHMSA 2021
Gas Transmission Compressor Stations	Count of gas transmission compressor stations	X			PHMSA 2021, NYSDEC permitting database
Gas Storage Compressor Stations	Count of gas storage compressor stations				NYSDEC permitting database
Storage Reservoir Fugitives	TBD—no data available				
LNG Storage Compressor Stations	Count of LNG Storage Compressor Stations				NYSDEC database
LNG Terminal	Count of terminals	No activity in NYS			
Cast Iron Distribution Pipeline: Main	Miles of pipeline		X	X	PHMSA 2021
Cast Iron Distribution Pipeline: Services	Miles of pipeline		X	X	PHMSA 2021
Unprotected Steel Distribution Pipeline: Main	Miles of pipeline		X		PHMSA 2021

Table 6 continued

Emissions Source	Activity Data Description	Activity Data Based on Assumption	Allocation Method Applied	Data Cleansing Performed	Source
Unprotected Steel Distribution Pipeline: Services	Miles of pipeline		X	X	PHMSA 2021
Protected Steel Distribution Pipeline: Main	Miles of pipeline		X	X	PHMSA 2021
Protected Steel Distribution Pipeline: Services	Miles of pipeline		X	X	PHMSA 2021
Plastic Distribution Pipeline: Main	Miles of pipeline		X		PHMSA 2021
Plastic Distribution Pipeline: Services	Miles of pipeline		X		PHMSA 2021
Copper Distribution Pipeline: Main	Miles of pipeline	No activity in NYS			
Copper Distribution Pipeline: Services	Miles of pipeline		X	X	PHMSA 2021
Meters: Residential	Count of services		X		PHMSA 2021
Meters: Commercial	Count of services		X		PHMSA 2021
Residential Appliances	Count of appliances	X			EIA 2018; U.S. Census Bureau 2021a
Residential Buildings	Count of buildings				U.S. Census Bureau 2021a
Commercial Buildings	Count of buildings	X			U.S. Census Bureau 2021b

3.4 Updated and New Methane Emissions Sources

3.4.1 Distribution Pipelines

3.4.1.1 Source Category Description

Distribution pipelines are a system comprised of mains and service lines that are used by distribution companies to deliver natural gas to homes and businesses. Mains are the step between high-pressure transmission lines and low-pressure service lines. Materials used for these pipes include steel, cast iron, plastic, and copper. Pressures can vary considerably but can be as high as 200 psi. Service pipelines connect to a meter and deliver natural gas to individual customers. Materials used for service pipes include plastic, steel, cast iron, or copper. Pressure of the gas in these pipes is low at around 6 psi.

3.4.1.2 Emissions Factors

The emissions factors for distribution pipeline mains and services have been updated to correct a unit error for the service pipeline emissions factors and discrepancies between reported emissions and estimated emissions for pipeline mains (see section 2.1).

<table>
<tr><th colspan="2">Source Category</th><th colspan="2">Cast Iron</th><th colspan="2">Unprotected Steel</th><th colspan="2">Protected Steel</th><th>Plastic</th><th>Copper</th></tr>
<tr><td rowspan="2">Default EF ($MTCH_4$ $mile^{-1}$ yr^{-1})</td><td>Main</td><td colspan="2">4.5974</td><td colspan="2">2.1223</td><td colspan="2">0.0588</td><td>0.1909</td><td>0.4960</td></tr>
<tr><td>Services</td><td colspan="2">4.5974</td><td colspan="2">2.7115</td><td colspan="2">0.2473</td><td>0.0135</td><td>0.4960</td></tr>
<tr><td>Source</td><td colspan="9">Lamb et al. 2015; EPA 2018a; EPA 2021</td></tr>
<tr><td>EF Confidence</td><td colspan="2">Geography
NYS</td><td colspan="2">Recency
≤ 5 Years</td><td colspan="2">Methodology
Empirical
Observation</td><td colspan="3">Status
Peer-Reviewed</td></tr>
<tr><td>Source Description</td><td colspan="9">The EFs used for distribution mains and services are derived from utility reported data to the GHGRP (see section 2.1). As described elsewhere in the literature, consideration of high-emitting sources leads to a skewed distribution of leak rates, with a few sources accounting for the majority of emissions.</td></tr>
</table>

Note: The EF for cast iron services is assumed to be equal to the EF for cast iron mains.

3.4.1.3 Activity Data

Activity data for main and service distribution pipelines are miles of pipeline-by-pipeline material type. Operator-level data on the pipeline mileage by type was pulled from the PHMSA Pipeline Mileage and Facilities database. To correct for potential outliers in the PHMSA data, likely due to incomplete reporting, the following data adjustments were made:

- Cast Iron Mains: 1991 is the average of 1990 and 1992 PHMSA data.
- Cast Iron Services: 1990 to 2003 are based on a trendline from 2004 to 2017 PHMSA data.
- Unprotected Steel Services: 1991, 1998, and 2009 are the average of PHMSA data in adjacent years.
- Protected Steel Mains: 1994 to 1996 are based on a linear trend using 1993 and 1997 PHMSA data.
- Protected Steel Services: 1998 and 2009 are the average of PHMSA data in adjacent years.
- Copper Services: 1991 to 1992 are based on a linear trend using 1990 and 1993 PHMSA data; 1998, 2001, and 2010 are the average of PHMSA data in adjacent years.

CH_4 emissions were calculated as the miles of pipeline, by pipeline type, times the EFs discussed above. The MTs of CH_4 were converted to $MTCO_2e$ by applying the $GWP_{AR5, 20}$ factor of 84.

3.4.1.4 Geospatial Data and Allocation Methodology

The operator-level miles of distribution pipelines reported in the PHMSA database were allocated to the county-level based on the number of services. The methodology for estimating the number of services is discussed in section 3.4.2.4.

3.4.1.5 Sample Calculations

$$CH_4 \text{ emissions } (MTCO_2e) = \text{pipeline miles}_{type} \times AF \times EF \times GWP_{AR5, 20}$$

where:

- pipeline miles_{type} = State-level miles of distribution pipeline by pipeline material type
- AF = allocation factor based on the ratio of the number of county natural gas services (residential and commercial) to the number of State natural gas services (residential and commercial).
- EF = CH_4 EF ($MTCH_4$ $mile^{-1}$ yr^{-1})
- $GWP_{AR5, 20}$ = GWP = 84

For example, according to the PHMSA data, there were 4,203 miles of unprotected steel distribution service pipeline in NYS in 2019. From the allocation method, the total number of natural gas services in Albany County in 2019 was 118,660, and the total number natural gas services in NYS in 2019 was 4,951,148. Applying the allocation factor, 100.72 miles of unprotected steel distribution service pipeline were located in Albany County in 2019, resulting in 22,941 $MTCO_2e$ as shown below.

Unprotected steel distribution pipeline CH_4 ($MTCO_2e$) = 4,203 x 118,660/4,951,148 x 2.7115 x 84

Unprotected steel distribution pipeline CH_4 ($MTCO_2e$) = 22,941 $MTCO_2e$

3.4.1.6 Limitations and Uncertainties

These per-mile emissions rates are based on utility-reported values to GHGRP. The utility-reported values are calculated using emissions factors that may be outdated and are not based on actual emissions.

3.4.1.7 Potential Areas of Improvement

Performing a survey of actual miles of pipeline-by-pipeline type at the county-level would reduce errors associated with allocating state-level pipeline mileage to the county-level using natural gas services.

3.4.2 Residential Appliances

3.4.2.1 Source Category Description

Natural gas is a common fuel for many residential appliances. This category covers natural gas in appliance exhaust for furnaces, boilers, storage water heaters, tankless water heaters, stoves, and ovens. During ignition and extinguishment, appliance exhaust typically exhibits a brief methane concentration spike compared to the low concentration of methane in exhaust during steady-state operation. The methane emissions from residential appliances in this category reflect the appliance exhaust during ignition, extinguishment, and steady-state operation.

3.4.2.2 Emissions Factors

Source Category	**Residential Appliances**			
Default EF (MTCH4 appliance-1 yr-1)	Furnace	0.00022	(0.00014 – 0.00051)	
	Boiler	0.00032	(0.00015 – 0.00075)	
	Storage Water Heater	0.000077	(0.00002 – 0.000084)	
	Tankless Water Heater	0.0012	(0.00098 – 0.041)	
	Stove	0.000056	(0.00004 – 0.000071)	
	Oven	0.00013	(0.00011 – 0.00014)	
Source	Merrin and Francisco 2019			
EF Confidence	**Emissions Source**	**Activity Data Description**	**Activity Data Based on Assumption**	**Allocation Method Applied**
Source Description	Merrin and Francisco (2019) sampled methane concentrations in exhaust from residential natural gas appliances at 72 sites in Boston and Indianapolis and 28 sites in Illinois and New York State. Testing utilized a Picarro G4301 cavity ringdown spectroscopy portable gas concentration analyzer. The authors studied furnaces, boilers, storage water heaters, tankless water heaters, stoves, and ovens. To calculate the annual emissions per appliance-by-appliance type, Merrin and Francisco (2019) used average measured emission factors combined with calculated exhaust flow and appliance usage assumptions based on national usage data from EIA's 2015 Residential Energy Consumption Survey (EIA, 2018). After calculating an absolute emission quantity for ignition and extinguishment spikes and an emission factor during steady state operation, annual per appliance emissions were calculated using the following equation: $Appliance\ annual\ emissions\ (kg) = (ignition\ emission\ (kg/activation) + extinguisment\ emission\ (kg/activation)) * \frac{activations}{year} + steady\ state\ emission\ rate\ \left(\frac{kg}{hr}\right) * annual\ runtime\ \left(\frac{hr}{yr}\right)$ The methane emissions factors by appliance type were comparable regardless of location. As the authors note, climate differences will affect usage and total emissions, but appliances are mass-produced and distributed widely so location is unlikely to influence emission factors. Several sources of uncertainty during the data collection include instrument limitations, sample size, exhaust-flow rate assumptions/calculations and limited appliance observation. To account for the uncertainty, Merrin and Francisco report per alliance annual emissions values as well as 97.5% confidence interval ranges.				

Two recent studies reference Merrin and Francisco's work. Lebel et al. (2020) developed emissions factors from natural gas water heaters in northern California and compared the emissions factors to those developed by Merrin and Francisco. While the EFs developed by Lebel et al. are higher than those developed by Merrin and Francisco for water heaters, Lebel et al. (2020) notes that Merrin and Francisco did not measure pilot lights due to their sampling protocol. However, EF values were similar for the components that both studies measured, indicating that EFs are comparable regardless of location/ climate. Saint-Vincent and Pekney (2020) compared the Merrin and Francisco emission factor for furnaces to emission factors used in other countries. They use the EF for furnaces developed by Merrin and Francisco and convert it to units of kg/TJ. Saint-Vincent and Pekney (2020) state that considering steady-state usage and the off state is important when estimating emissions, and the authors note that Merrin and Francisco's EFs consider steady-state usage in addition to ignition.

3.4.2.3 Activity Data

The activity data are the county-level number of appliances by appliance type. The number of appliances by appliance type in the Middle Atlantic, which consists of New Jersey, New York State, and Pennsylvania,[2] is estimated using information from the 2015 Residential Energy Consumption Survey (RECS; Tables HC3.7, HC6.7, and HC8.7). The RECS reports data on the number of housing units using stoves, ovens, furnaces, boilers, and water heaters, including data on the most used fuel for each appliance type in the Middle Atlantic region. Table 7 shows the estimated number of appliances by appliance type in the Middle Atlantic region in 2015.

Table 7. Number of Natural Gas Appliances in the Mid-Atlantic Region by Appliance Type

	(million)
Tankless Water Heater	0.17
Storage Water Heater	5.86
Furnace	5.6
Boiler	3.2
Stove	8.44
Oven	7.85

The fraction of housing units with appliance type presented in Table 8 is calculated by dividing the total number of appliances by the total number of housing units in the Middle Atlantic in 2015 from RECS (15.4 million).

Table 8. Fraction of Housing Units with Appliance Type by Appliance

Natural Gas Appliance	Fraction of Housing Units with Appliance Type
Furnace	0.361290323
Boiler	0.206451613
Storage Water Heater	0.378064516
Tankless Water Heater	0.010967742
Stove	0.544516129
Oven	0.506451613

NYSERDA's Single Family Building Assessment Report[3] and the U.S. Census Bureau[4] are used to develop the fraction of housing units by housing unit type across the three climate zones in NYS. These fractions are presented in Table 9.

Table 9. Fraction of Units in Each Climate Zone by Housing Unit Type

Housing Unit Type	Fraction of Units in Climate Zone 4	Fraction of Units in Climate Zone 5	Fraction of Units in Climate Zone 6
Single-family total			
Climate Zone 4	0.181274		
Climate Zone 5		0.146721	
Climate Zone 6			0.066557
Apartments in buildings with 2-4 units	0.285904	0.297971	0.325964
Apartments in buildings with 5 or more units	0.480839	0.501132	0.548213
Mobile homes	0.051983	0.054176	0.059266
Total	1	1	1

The correction factors in Table 10 are then applied to take into account that some counties do not have natural gas service.

Table 10. Correction Factor to Account for Counties without Natural Gas Service

Housing Unit Type	Total Housing Units in 2018	Total Housing Units in Counties with Natural Gas Service in 2018	Total Housing Units in Counties without Natural Gas Service in 2018	Ratio of Total Housing Units to Housing Units with Natural Gas Service
Single-family total	1,316,657	1,292,847	23,810	1.018417022
Other housing types	7,047,277	6,795,613	251,664	1.037033245

The county-level number of appliances by appliance type and housing type is then calculated by multiplying the county-level number of houses from the U.S. Census Bureau by the fraction of housing units with the appliance, the fraction of housing unit type by climate zone, and the correction factor.

3.4.2.4 Geospatial Data and Allocation Methodology

No allocation methodology was necessary for years 2000–2020 since county-level number of housing units were available from the Census. For years 1990–1999, the ratio of county to state total housing units in 2000 was applied to distribute state-level numbers to county-level.

3.4.2.5 Sample Calculations

Equation 2

$$\mathbf{CH_4\ emissions\ (MTCO_2e) = \sum Housing\ units_{county} \times fraction\ of\ housing\ units_{appliance} \times housing\ unit\ type\ fraction_{climate\ zone} \times CF_{ng\ service} \times EF_{appliance} \times GWP_{AR5,\ 20}}$$

where:

- Housing units$_{county}$ = total number of housing units in county
- Fraction of housing units$_{appliance}$ = fraction of housing units with natural gas appliance
- Housing unit type fraction$_{climate}$ = fraction of housing unit type by climate zone
- $CF_{ng\ service}$ = correction factor to account for counties without natural gas service
- $EF_{appliance}$ = CH_4 emissions factor by appliance ($MTCH_4$ appliance^{-1} yr^{-1})
- $GWP_{AR5,\ 20}$ = GWP = 84

For example, there were 7,760 natural gas furnaces in single-family homes in Albany County in 2019, resulting in 143 $MTCO_2e$ as shown below.

$$\textbf{Gas furnace } CH_4\ (MTCO_2e) = 142{,}895 \times 0.36129 \times 0.146721 \times 1.0185 \times 0.00022 \times 84$$

$$\textbf{Gas furnace } CH_4\ (MTCO_2e) = 143\ MTCO_2e$$

To calculate total emissions for all housing units with furnaces, repeat the calculation for each housing type and sum the emissions. The total CH_4 emissions from residential natural gas furnaces in Albany County in 2019 is 992 $MTCO_2e$.

3.4.2.6 Limitations and Uncertainties

There are several limitations to the current draft emissions estimates due to unavailable data. The inventory is currently missing emissions from natural gas clothes dryers because data on emissions from residential natural gas clothes dryers are not readily available. The impact of excluding natural gas clothes dryers is likely minimal. A study by Fisher et al. (2018) indicates that pilot lights are a main source of end-use methane emissions and natural gas dryers do not have pilot lights. Furthermore, Merrin and Francisco (2019) note that > 96% of residential natural gas consumption is used for space heating, water heating, and cooking, so end use emissions from other appliances, such as natural gas dryers, should be minimal.

3.4.2.7 Potential Areas of Improvement

The appliance estimates are based on Mid-Atlantic survey results from RECS. A NYS-specific survey could improve the accuracy of the appliance count estimates. For example, NYSERDA's Single Family Building Assessment Report has some information on the penetration rate of some natural gas appliance types. These rates could be used to adjust the Mid-Atlantic survey results.

3.4.3 Residential Buildings

3.4.3.1 Source Category Description

In addition to emissions from appliances discussed above in section 3.4.2, post-meter fugitive methane emissions in residential buildings occur from plumbing connections and pilot lights. This source category estimates the leakage of methane from residential building pipes, pipe connections and pilot lights from quiescent appliances (e.g., termed quiescent whole-house emissions).

3.4.3.2 Emissions Factors

Source Category	**Residential Buildings**			
Default EF ($MTCH_4$ housing unit^{-1} yr^{-1})	0.00181 (0.0010596 – 0.0035267)			
Source	Fischer et al. 2018a, Fischer et al. 2018b			
EF Confidence	Geography Rest of Country	Recency ≤ 5 Years	Methodology Empirical Observation	Status Peer-Reviewed
Source Description	Fischer et al. measured CH4 emissions from pipe leaks and pilot lights in 75 single-family California homes when appliances were not operating and quantified emissions using a Bayesian statistical sampling procedure. The emissions factor for this is calculated by dividing the quiescent whole-house emissions (Table 12 in Fisher et al. 2018a) by the number of housing units in California (12.93 million). The estimate for mean whole-house emissions is 23.4 (13.7 – 45.6, 95% confidence) Gg CH4/yr when using only measurements from houses where the prescribed calibration flow is obtained. Pilot light emissions account for roughly 25% of the quiescent whole-house emissions.			

3.4.3.3 Activity Data

The activity data for residential buildings is housing units with natural gas service. State-level data on the distribution of meter counts was pulled from the PHMSA Pipeline Mileage and Facilities database,[5] U.S. Census Bureau reported household utility gas counts, and EIA reported residential, commercial, and industrial customer counts.

3.4.3.4 Geospatial Data and Allocation Methodology

Residential meters were allocated to the county-level using census-reported counts of utility gas as the primary home heating fuel. These data were available from 2006–2020 at the census tract level. These meter counts were then geospatially allocated by census tract to the county and gas utility service areas, based on the most recently available geospatial distribution of service areas.[6] Finally, due to an under-counting of homes with utility gas in the one-year census data, census counts were scaled by the total residential meter count reported by EIA.[7] Census data were not readily available for years 1990–2006, so the distribution of meters by census block in 2006 was used as the baseline, and the same methodology was applied to scale the total residential meter count using EIA reported data for those years. The number of homes with utility gas as the primary heat source was reported in the U.S. Census Bureau's American Community Survey.[8]

3.4.3.5 Sample Calculations

Equation 3 $$CH_4 \text{ emissions } (MTCO_2e) = \text{housing units}_{ng} \times EF \times GWP_{AR5,\,20}$$

where:

- Housing units_{ng} = number of housing units with natural gas service
- EF = CH_4 EF ($MTCH_4$ housing unit^{-1} yr^{-1}) = 0.00181
- $GWP_{AR5,\,20}$ = GWP = 84

For example, there were 13,242 housing units in Cattaraugus County in 2019, resulting in 2,013 $MTCO_2e$ as shown below.

$$\text{Residential building } CH_4 \ (MTCO_2e) = 13{,}242 \times 0.00181 \times 84$$

$$\text{Residential building } CH_4 \ (MTCO_2e) = 2{,}013 \ MTCO_2e.$$

3.4.3.6 Limitations and Uncertainties

Fischer et al. (2018a) assumed methane emissions from multifamily housing can be estimated based on results from single-family homes, because they share many similar characteristics for natural gas plumbing and appliances. The authors did not find a significant ($p < 0.1$) relationship between whole-house leakage and house age.

3.4.3.7 Potential Areas of Improvement

Data on county-level housing units for NYS from 1990 to 2005 are needed for more accurate estimates of emissions from residential buildings for those years.

3.4.4 Commercial Buildings

3.4.4.1 Source Category Description

Post-meter fugitive methane leaks from commercial buildings are a result of gas appliance and pipeline leaks. Since combustion emissions from gas appliances are covered elsewhere in the NYS GHG inventory, this source category focuses solely on pipeline leaks. While many different building types are likely to have pipeline methane leaks, only hospitals and restaurants are covered in this category due to data limitations.

3.4.4.2 Emissions Factors

Source Category	**Commercial Buildings**			
Default EF ($MTCH_4$ building^{-1} yr^{-1})	Hospitals 0.202385 (0.09382 – 0.31095) Restaurants 0.0480325 (0.0381091 – 0.0591932)			
Source	Sweeney et al. 2020			
EF Confidence	Geography Rest of Country	Recency ≤ 5 Years	Methodology Empirical Observation	Status Grey Literature
Source Description	This study developed and validated measurement techniques for fugitive emissions from piping components and combustion equipment in the field for 20 foodservice sites and two inpatient hospitals in California. The project team collected samples from gas-fired appliances and accessible gas piping components at each site and completed an inventory of all gas appliances and visible piping components. The field data was fed into a series of probabilistic and statistical analyses that researchers then input into a Monte Carlo simulation to develop annual emissions by building type. The hospital emissions factors are calculated from data presented on page 138 of the Sweeney et al. report while restaurant emissions factors are derived from scenario 3.			

3.4.4.3 Activity Data

The activity data for commercial buildings are county-level counts of buildings by building type. County-level data on hospitals and restaurants was pulled from the United States Census Bureau's County Business Patterns Datasets. Data on the number of buildings in each county from 1998 to 2011 was pulled for North American Industry Classification System (NAICS) codes; for example, 622 (hospitals), 722110 (full-service restaurants), 722211 (limited-service restaurants), and 722212 (cafeterias, grill buffets, and buffets). From 2012 to 2019, data was pulled for the number of buildings for NAICS codes 622, 722511 (full-service restaurants), 722513 (limited-service restaurants), and 722514 (cafeterias, grill buffets, and buffets). The individual restaurant counts were summed to a total restaurant count per county. County-level data is not available for these NAICS codes before 1998, so the data were held constant from 1990 to 1998.

3.4.4.4 Geospatial Data and Allocation Methodology

No allocation methodology was necessary since the U.S. Census Bureau reports building counts by type at the county level.

3.4.4.5 Sample Calculations

Equation 4 **CH_4 emissions ($MTCO_2e$) = ∑commercial buildings$_{type}$ x EF x GWP$_{AR5,\ 20}$**

where:

- commercial buildings$_{type}$ = number of commercial buildings by building type.
- EF_{type} = CH_4 EF by building type ($MTCH_4$ building^{-1} yr^{-1}).
- $GWP_{AR5,\ 20}$ = GWP = 84

For example, there were 135 restaurants in Cattaraugus County in 2019, resulting in 545 $MTCO_2e$ as shown below.

Restaurant CH_4 ($MTCO_2e$) = 135 x 0.0480325 x 84

Restaurant CH_4 ($MTCO_2e$) = 545 $MTCO_2e$

To calculate emissions for this source category, repeat the calculation for each commercial building type and sum the emissions from each commercial building type.

3.4.4.6 Limitations and Uncertainties

Due to data limitations, this category only includes a limited subset of commercial buildings with natural gas service (i.e., hospitals and restaurants).

3.4.4.7 Potential Areas of Improvement

Since there is not activity data available before 1998 and data is held constant through 1998, more accurate county-level data on commercial buildings prior to 1998 would improve these estimates.

The estimates for this category could be improved with emissions factors and further data on foodservice, healthcare, and other commercial building types, such as offices, schools, and retail establishments.

4 Results

This section presents an analysis of the inventory detailing activity-driven CH_4 emissions for the oil and natural gas sector in NYS. Following best practices described by IPCC guidelines and the EPA, this analysis identifies and describes CH_4 emissions by source category and provides a geospatially resolved breakdown of emissions by county in NYS. In addition, the overall trends in CH_4 emissions captured by the inventory for 1990 to 2020 are presented.

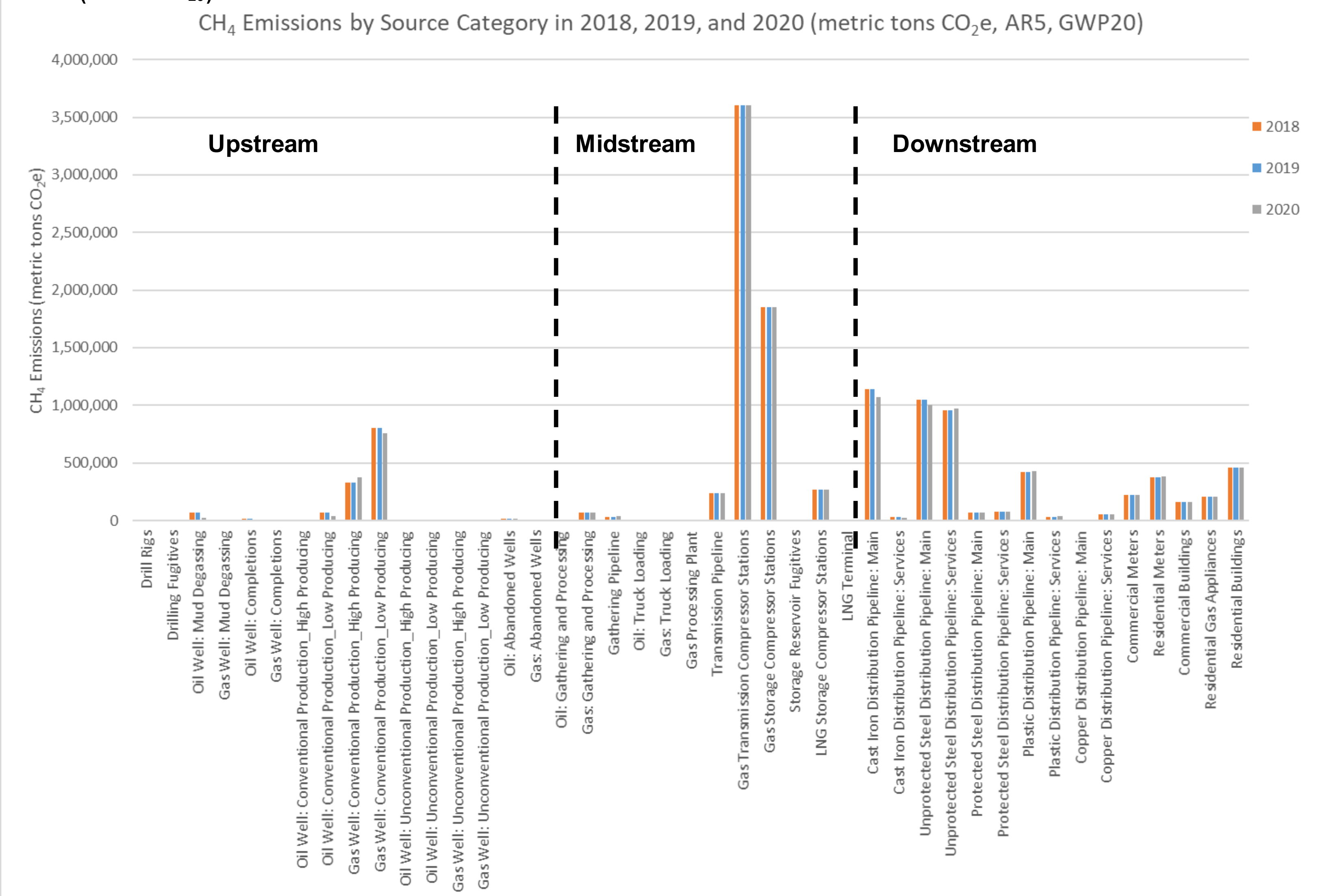
4.1 Total Emissions

CH_4 emissions from oil and natural gas activity in NYS in 2018 totaled 149,789 million tons of methane $MTCH_4$, equivalent to 12,582,293 $MTCO_2e$ (values given in AR5 GWP_{20} unless otherwise noted). Methane emissions totaled 12,611,756 $MTCO_2e$ (150,140 $MTCH_4$) in 2019 and 12,460,067 $MTCO_2e$ (148,334 $MTCH_4$) in 2020. Compared to the NYS 2017 oil and natural gas sector methane emission inventory, this 2018–2020 update estimates CH_4 emissions in 2017 to be 44% higher (12,919,759 $MTCO_2e$) than the previous 2017 estimate (8,951,652 $MTCO_2e$ in 2017). This difference is primarily due to the pipeline EF updates and the addition of beyond the meter source categories (residential appliances, residential buildings, and commercial buildings).

4.2 Emissions in Years 2018, 2019, and 2020 by Upstream, Midstream, and Downstream Stages

Figure 1 shows CH_4 emissions by source category broken out by upstream, midstream, and downstream source categories using AR5 GWP_{20} units. Downstream emissions totaled 5.354 $MMTCO_2e$ in 2018, accounting for 42.6% of total emissions. These data are also shown in Table 11. Cast iron distribution mains are the largest single-source category, followed by unprotected steel distribution mains, and unprotected steel distribution service mains. Midstream emissions totaled 6.057 $MMTCO_2e$ in 2018, accounting for 48.1% of emissions, with compressors (storage and transmission) comprising the largest source categories in the inventory. In fact, storage and transmission compressor stations are the two largest single-source categories identified in NYS. Upstream sources, dominated by conventional gas wells, emitted 1.171 $MMTCO_2e$ in 2018, accounting for 9.3% of total CH_4 emissions. In 2019, downstream emissions totaled 5.241 $MMTCO_2e$ (41.6% of total emissions), midstream emissions totaled 6.059 $MMTCO_2e$ (48%), and upstream emissions totaled 1.311 $MMTCO_2e$ (10.4%). In 2020, downstream emissions totaled 5.165 $MMTCO_2e$ (41.4%), midstream emissions totaled 6.067 $MMTCO_2e$ (48.7%), and upstream emissions totaled 1.228 $MMTCO_2e$ (9.9%). These results reflect the fact that NYS is largely a consumer of natural gas. As such, the midstream and downstream source categories are expected to drive the majority of CH_4 emissions in NYS.

Figure 1. Methane Emissions by Source Category and Grouped by Upstream, Midstream, and Downstream Stages in New York State (AR5 GWP_{20}).



4.3 Emissions by Source Category in Year 2018, 2019, and 2020

As shown in Figure 1, the 65 gas transmission compressor stations are the largest single source category in NYS, accounting for 3.602 $MMTCO_2e$, or approximately 29% of total CH_4 emissions in 2018, 2019, and 2020. The 26 gas storage compressor stations are the second largest source category, accounting for 1.85 $MMTCO_2e$ in 2018, 2019, and 2020, or approximately 15% of total CH_4 emissions each year. Taken together, the top five emitting source categories in this inventory (gas transmission compressor stations, gas storage compressor stations, cast iron distribution mains, unprotected steel distribution mains, and unprotected steel distribution services) account for approximately 68% of total CH_4 emissions from the oil and gas sector, highlighting the importance of compressor stations, gas wells, and iron/steel distribution pipelines to the whole NYS CH_4 inventory. Considering gas pipelines, emissions from gathering pipelines account for 0.3% of total emissions, transmission pipelines account for 1.9%, distribution mains account for 20% to 22% of emissions, and distribution service lines account for 9.1% to 9.6% of the total.

Table 11. Methane Emissions by Source Category in New York State from 1990 to 2000 ($MTCO_2e$; AR5 GWP_{20})

Category	Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Upstream	Drill Rigs	11	13	12	9	7	5	8	5	5	6	7
	Drilling Fugitives	656	792	613	538	394	293	495	284	263	319	372
	Oil Well: Mud Degassing	12,757	22,845	42,232	11,510	19,606	15,799	34,705	21,291	4,595	12,517	8,994
	Gas Well: Mud Degassing	58,731	44,333	35,536	45,340	26,324	14,508	18,600	14,661	26,696	25,339	32,188
	Oil Well: Completions	4,855	7,283	9,710	3,570	4,855	4,712	9,996	4,570	1,142	3,427	2,142
	Gas Well: Completions	16,422	18,136	10,139	13,566	7,426	4,284	5,712	4,712	5,998	4,284	6,997
	Oil Well: Conventional Production—High Producing	5,668	5,899	6,231	3,443	2,497	4,017	3,081	1,981	1,848	2,146	2,100
	Oil Well: Conventional Production—Low Producing	3,242	3,475	2,888	3,878	5,190	4,811	4,268	4,399	4,190	4,473	6,764
	Gas Well: Conventional Production—High Producing	980,596	905,270	907,803	825,749	679,838	600,552	528,637	475,077	454,555	416,560	466,150
	Gas Well: Conventional Production—Low Producing	685,722	776,635	816,216	837,269	865,378	849,507	873,769	829,494	842,571	855,434	854,413
	Oil Well: Unconventional Production—High Producing	0	0	0	0	0	0	0	0	0	0	0
	Oil Well: Unconventional Production—Low Producing	0	0	0	0	0	0	0	0	0	0	0
	Gas Well: Unconventional Production—High Producing	0	0	0	0	0	0	0	0	0	0	0
	Gas Well: Unconventional Production—Low Producing	0	0	0	0	0	0	0	0	0	0	0
	Oil: Abandoned Wells	13,113	13,113	13,113	13,113	13,113	13,113	13,113	13,113	13,113	13,113	13,113
	Gas: Abandoned Wells	3,060	3,119	3,377	3,487	3,650	3,635	3,716	3,716	3,546	3,760	4,461

Table 11 continued

Category	Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Midstream	Oil: Gathering and Processing	691	723	731	501	464	597	482	380	359	400	493
	Gas: Gathering and Processing	124,848	121,367	123,299	116,189	103,150	94,740	88,756	81,647	80,201	77,041	81,836
	Gathering Pipeline	112,896	88,256	62,720	87,808	227,584	231,616	357,056	282,464	207,872	202,048	201,600
	Oil: Truck Loading	187	192	182	151	135	137	139	124	98	93	95
	Gas: Truck Loading	0	0	0	0	0	0	0	0	0	0	0
	Gas Processing Plant	0	0	0	0	0	0	0	0	0	0	0
	Transmission Pipeline	214,861	215,787	216,713	217,640	218,566	219,492	220,418	221,344	222,270	223,196	224,123
	Gas Transmission Compressor Stations	3,320,520	3,320,520	3,320,520	3,320,520	3,320,520	3,320,520	3,320,520	3,320,520	3,320,520	3,320,520	3,320,520
	Gas Storage Compressor Stations	1,209,516	1,209,516	1,209,516	1,209,516	1,209,516	1,494,108	1,565,256	1,636,404	1,636,404	1,636,404	1,636,404
	Storage Reservoir Fugitives	0	0	0	0	0	0	0	0	0	0	0
	LNG Storage Compressor Stations	271,525	271,525	271,525	271,525	271,525	271,525	271,525	271,525	271,525	271,525	271,525
	LNG Terminal	0	0	0	0	0	0	0	0	0	0	0

Table 11 continued

Category	Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Downstream	Cast Iron Distribution Pipeline: Main	2,619,084	2,604,988	2,590,892	2,546,481	2,509,794	2,471,948	2,440,668	2,410,159	2,367,293	2,286,967	2,191,194
	Cast Iron Distribution Pipeline: Services	55,807	55,807	55,247	52,208	52,009	51,552	51,538	56,305	56,575	56,219	56,165
	Unprotected Steel Distribution Pipeline: Main	2,208,983	1,910,910	2,183,668	2,113,072	2,220,214	1,944,069	2,016,626	2,068,860	2,001,117	1,956,548	1,906,454
	Unprotected Steel Distribution Pipeline: Services	2,045,438	1,967,089	1,888,740	1,793,243	1,840,291	1,784,631	1,678,859	1,682,500	1,711,077	1,739,654	1,802,264
	Protected Steel Distribution Pipeline: Main	67,037	68,040	69,544	70,785	70,628	70,471	70,314	70,157	68,921	69,094	69,623
	Protected Steel Distribution Pipeline: Services	131,417	131,300	137,079	137,968	124,023	127,497	122,451	121,603	120,054	118,506	110,815
	Plastic Distribution Pipeline: Main	109,555	114,077	135,533	148,345	158,303	166,834	175,445	184,554	205,769	213,354	227,882
	Plastic Distribution Pipeline: Services	9,555	9,950	11,821	12,938	13,807	14,551	15,302	16,097	17,947	18,608	19,876
	Copper Distribution Pipeline: Main	0	0	0	0	0	0	0	0	0	0	0
	Copper Distribution Pipeline: Services	87,664	86,825	85,986	85,146	84,509	83,419	83,037	83,125	82,770	82,415	82,116
	Commercial Meters	164,089	129,858	148,636	168,931	173,271	174,277	174,573	180,146	188,582	189,874	202,421
	Residential Meters	306,829	277,133	320,780	321,822	331,616	327,391	329,499	335,829	338,702	339,824	353,527
	Commercial Buildings	103,942	103,942	103,942	103,942	103,942	103,942	103,942	103,942	103,942	102,552	104,532
	Residential Gas Appliances	162,547	161,981	161,328	160,666	160,044	160,656	160,888	159,928	159,515	172,007	184,500
	Residential Buildings	370,188	334,360	387,020	388,277	400,094	394,996	397,539	405,176	408,643	409,996	426,529

Table 12. Methane Emissions by Source Category in New York State from 2001 to 2011 ($MTCO_2e$; AR5 GWP_{20})

Category	Source	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Upstream	Drill Rigs	9	7	6	11	16	32	38	36	17	27	19
	Drilling Fugitives	525	407	315	635	932	1,856	2,214	2,013	1,042	1,466	1,015
	Oil Well: Mud Degassing	12,648	10,306	16,127	30,525	46,390	88,732	95,778	92,845	46,806	113,699	96,784
	Gas Well: Mud Degassing	47,747	29,628	20,482	42,954	61,051	119,038	162,430	151,620	70,548	65,996	32,429
	Oil Well: Completions	3,713	2,570	3,998	7,997	13,566	25,704	27,132	23,419	13,566	29,131	23,848
	Gas Well: Completions	11,852	7,568	4,284	9,568	15,422	33,701	43,840	40,127	19,421	17,564	8,282
	Oil Well: Conventional Production—High Producing	1,212	1,490	837	1,793	1,641	4,989	4,648	7,853	3,170	2,685	3,480
	Oil Well: Conventional Production—Low Producing	23,096	22,006	25,390	26,060	45,727	86,161	94,675	86,202	79,529	89,783	87,119
	Gas Well: Conventional Production—High Producing	978,008	1,307,620	1,401,114	2,065,194	2,704,861	2,556,182	2,484,830	2,197,255	1,926,334	1,553,667	1,389,783
	Gas Well: Conventional Production—Low Producing	868,761	869,182	887,956	884,437	872,319	884,720	908,365	897,085	900,421	917,818	933,066
	Oil Well: Unconventional Production—High Producing	0	0	0	0	0	0	0	0	0	0	0
	Oil Well: Unconventional Production—Low Producing	0	0	0	0	0	0	0	0	0	0	0
	Gas Well: Unconventional Production—High Producing	0	0	0	0	0	0	0	0	0	0	0
	Gas Well: Unconventional Production—Low Producing	0	0	0	0	0	0	0	0	0	0	0
	Oil: Abandoned Wells	13,436	11,283	12,922	13,394	13,493	12,550	13,179	13,535	13,535	13,676	13,386
	Gas: Abandoned Wells	4,217	4,166	4,166	4,210	3,996	4,328	4,711	4,969	4,962	5,161	5,257

Table 12 continued

Category	Source	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Midstream	Oil: Gathering and Processing	1,101	1,082	1,162	1,284	2,106	4,153	4,482	4,434	3,693	4,082	4,047
	Gas: Gathering and Processing	132,384	164,559	174,479	239,118	301,009	287,031	281,076	252,540	226,251	190,633	175,293
	Gathering Pipeline	146,944	172,480	175,168	171,584	171,136	168,717	229,152	239,053	245,862	155,456	160,205
	Oil: Truck Loading	75	74	73	82	90	140	170	174	150	171	169
	Gas: Truck Loading	0	0	0	0	0	0	0	0	0	0	0
	Gas Processing Plant	0	0	0	0	0	0	0	0	0	0	0
	Transmission Pipeline	225,049	227,746	227,746	227,746	227,746	228,787	228,787	236,912	236,912	236,912	236,912
	Gas Transmission Compressor Stations	3,320,520	3,376,800	3,376,800	3,376,800	3,376,800	3,376,800	3,376,800	3,601,920	3,601,920	3,601,920	3,601,920
	Gas Storage Compressor Stations	1,707,552	1,707,552	1,778,700	1,778,700	1,778,700	1,778,700	1,778,700	1,778,700	1,849,848	1,849,848	1,849,848
	Storage Reservoir Fugitives	0	0	0	0	0	0	0	0	0	0	0
	LNG Storage Compressor Stations	271,525	271,525	271,525	271,525	271,525	271,525	271,525	271,525	271,525	271,525	271,525
	LNG Terminal	0	0	0	0	0	0	0	0	0	0	0

Table 12 continued

Category	Source	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Downstream	Cast Iron Distribution Pipeline: Main	2,153,349	2,109,710	2,068,002	2,027,840	1,984,973	1,964,892	1,932,067	1,891,131	1,842,086	1,791,883	1,753,651
	Cast Iron Distribution Pipeline: Services	55,745	54,829	54,782	54,782	58,560	58,678	56,912	56,541	52,360	49,652	48,150
	Unprotected Steel Distribution Pipeline: Main	1,889,161	1,816,247	1,757,061	1,708,570	1,675,964	1,661,738	1,624,158	1,641,985	1,546,270	1,511,882	1,469,453
	Unprotected Steel Distribution Pipeline: Services	1,690,308	1,742,026	1,712,862	1,666,911	1,636,875	1,602,987	1,555,770	1,528,620	1,452,863	1,377,106	1,367,437
	Protected Steel Distribution Pipeline: Main	69,989	70,983	71,616	71,670	71,030	71,756	71,773	71,595	70,655	70,748	70,851
	Protected Steel Distribution Pipeline: Services	108,163	93,457	92,931	88,922	88,287	88,433	85,670	85,809	80,830	75,851	86,046
	Plastic Distribution Pipeline: Main	238,770	249,931	261,893	272,012	281,316	287,799	294,287	304,938	316,461	323,986	330,865
	Plastic Distribution Pipeline: Services	20,825	21,799	22,842	23,725	24,160	24,784	25,267	25,653	26,201	26,464	27,968
	Copper Distribution Pipeline: Main	0	0	0	0	0	0	0	0	0	0	0
	Copper Distribution Pipeline: Services	81,589	81,063	80,404	80,856	79,833	78,818	78,025	76,802	75,509	75,119	76,468
	Commercial Meters	192,775	197,076	210,573	203,782	207,735	216,005	214,003	208,068	207,996	206,062	214,003
	Residential Meters	341,062	349,855	352,305	356,824	357,201	358,835	360,727	363,274	362,308	359,830	374,433
	Commercial Buildings	107,166	111,262	114,935	117,893	120,510	121,646	124,567	127,397	132,463	137,567	140,763
	Residential Gas Appliances	185,833	186,914	188,041	189,051	190,144	191,433	192,517	193,585	194,600	194,757	195,748
	Residential Buildings	411,490	422,099	425,055	430,507	430,962	432,933	435,216	438,289	437,123	434,134	451,753

Table 13. Methane Emissions by Source Category in New York State from 2012 to 2020 ($MTCO_2e$; AR5 GWP_{20})

Category	Source	2012	2013	2014	2015	2016	2017	2018	2019	2020
Upstream	Drill Rigs	13	11	13	3	2	1	0	11	4
	Drilling Fugitives	687	600	705	188	131	83	4	600	214
	Oil Well: Mud Degassing	81,138	68,622	86,084	14,070	13,676	13,151	35,799	70,416	23,217
	Gas Well: Mud Degassing	8,512	5,777	3,917	481	0	0	0	0	0
	Oil Well: Completions	19,992	17,564	21,706	5,998	4,284	2,713	143	18,421	6,712
	Gas Well: Completions	1,428	1,714	714	143	0	0	0	0	0
	Oil Well: Conventional Production—High Producing	788	2,253	1,378	896	592	910	2,628	3,729	608
	Oil Well: Conventional Production—Low Producing	100,094	98,104	101,889	80,160	73,506	76,993	59,880	66,139	39,833
	Gas Well: Conventional Production—High Producing	1,099,669	929,351	775,172	646,827	458,357	363,323	300,979	327,774	377,009
	Gas Well: Conventional Production—Low Producing	949,696	1,002,577	981,714	914,510	872,105	808,229	756,590	802,692	758,761
	Oil Well: Unconventional Production—High Producing	0	0	0	0	0	0	0	0	0
	Oil Well: Unconventional Production—Low Producing	0	0	0	0	0	0	0	0	0
	Gas Well: Unconventional Production—High Producing	0	0	0	0	0	0	0	0	0
	Gas Well: Unconventional Production—Low Producing	0	0	0	0	0	0	0	0	0
	Oil: Abandoned Wells	12,227	13,369	12,045	13,618	14,032	10,530	10,505	15,580	16,159
	Gas: Abandoned Wells	5,228	5,220	5,205	5,264	5,287	4,748	4,704	5,736	5,773

Table 13 continued

Category	Source	2012	2013	2014	2015	2016	2017	2018	2019	2020
Midstream	Oil: Gathering and Processing	4,336	4,394	4,470	3,498	3,186	3,365	2,804	3,178	1,754
	Gas: Gathering and Processing	147,697	133,331	117,402	102,020	81,829	69,839	61,559	66,135	69,069
	Gathering Pipeline	143,942	37,139	52,058	37,318	32,928	36,422	32,941	30,231	36,176
	Oil: Truck Loading	162	165	160	129	101	83	84	84	76
	Gas: Truck Loading	0	0	0	0	0	0	0	0	0
	Gas Processing Plant	0	0	0	0	0	0	0	0	0
	Transmission Pipeline	236,912	238,631	238,631	238,631	238,631	238,631	236,599	236,860	236,235
	Gas Transmission Compressor Stations	3,601,920	3,601,920	3,601,920	3,601,920	3,601,920	3,601,920	3,601,920	3,601,920	3,601,920
	Gas Storage Compressor Stations	1,849,848	1,849,848	1,849,848	1,849,848	1,849,848	1,849,848	1,849,848	1,849,848	1,849,848
	Storage Reservoir Fugitives	0	0	0	0	0	0	0	0	0
	LNG Storage Compressor Stations	271,525	271,525	271,525	271,525	271,525	271,525	271,525	271,525	271,525
	LNG Terminal	0	0	0	0	0	0	0	0	0

Table 13 continued

Category	Source	2012	2013	2014	2015	2016	2017	2018	2019	2020
Downstream	Cast Iron Distribution Pipeline: Main	1,705,764	1,642,817	1,577,938	1,529,279	1,396,046	1,320,741	1,225,949	1,137,998	1,070,805
	Cast Iron Distribution Pipeline: Services	45,781	39,072	41,548	34,814	31,887	24,341	21,089	27,577	23,924
	Unprotected Steel Distribution Pipeline: Main	1,397,787	1,345,695	1,304,229	1,270,428	1,224,184	1,162,627	1,091,930	1,046,020	998,506
	Unprotected Steel Distribution Pipeline: Services	1,339,788	1,210,824	1,199,886	1,113,670	1,047,384	1,003,169	963,321	957,221	970,999
	Protected Steel Distribution Pipeline: Main	71,756	71,082	71,751	71,411	71,406	71,698	71,465	70,996	70,761
	Protected Steel Distribution Pipeline: Services	81,328	85,293	88,119	76,533	74,696	92,929	72,824	74,244	79,262
	Plastic Distribution Pipeline: Main	338,655	350,521	360,817	371,089	384,186	395,580	407,698	419,415	429,437
	Plastic Distribution Pipeline: Services	28,332	29,239	30,337	31,040	31,624	31,527	33,136	33,702	38,318
	Copper Distribution Pipeline: Main	0	0	0	0	0	0	0	0	0
	Copper Distribution Pipeline: Services	74,728	72,057	73,305	68,320	63,336	60,551	56,351	54,792	54,792
	Commercial Meters	210,675	210,353	215,184	218,086	218,194	219,868	221,379	222,077	222,756
	Residential Meters	368,901	368,219	370,039	370,842	370,449	374,454	375,917	378,722	381,563
	Commercial Buildings	144,071	147,658	149,268	151,154	153,010	158,246	158,246	158,246	158,727
	Residential Gas Appliances	196,319	196,837	197,510	198,073	198,951	199,934	200,932	202,941	204,971
	Residential Buildings	445,078	444,255	446,451	447,419	446,945	451,778	453,542	456,927	460,354

4.4 Emissions by County and Economic Region in Year 2018, 2019, and 2020

Figure 2 shows the distribution of emissions by county in NYS. County-level emissions do not change significantly each year, so the map applies to all three years. The counties with the largest emissions correspond to the high oil and natural gas exploration and production areas in the west of the State, and to areas of high population and corresponding gas services around New York City and Long Island. As shown in Figure 2, Erie County had the highest total CH_4 emissions, accounting for 10.1% of statewide CH_4 emissions from the oil and natural gas sector in 2018, 10.3% in 2019, and 10.7% in 2020, followed by Kings County (7.8 to 8% between 2018 and 2020). Erie County had the third-highest gas production in NYS in 2019, as well as the largest miles of transmission pipeline (379 miles in 2018 and 2019 and 378 miles in 2020) and second-highest number of compressor stations (five gas transmission compressor stations and six gas storage compressor stations), resulting in high-midstream emissions. Kings County ranked highest in miles of all types of distribution pipeline mains and services, residential buildings, and residential meters and second highest in commercial meters, resulting in high-downstream emissions. The top five counties (Erie, Kings, Steuben, Queens, Chautauqua) account for approximately 38% of statewide CH_4 emissions from 2018 to 2020. Data for each county are shown in Figure 3 and annual total emissions by county are shown in Table 14 through Table 16.

Figure 2. Map of Methane Emissions by County in New York State in 2018, 2019, and 2020 (AR5 GWP_{20})

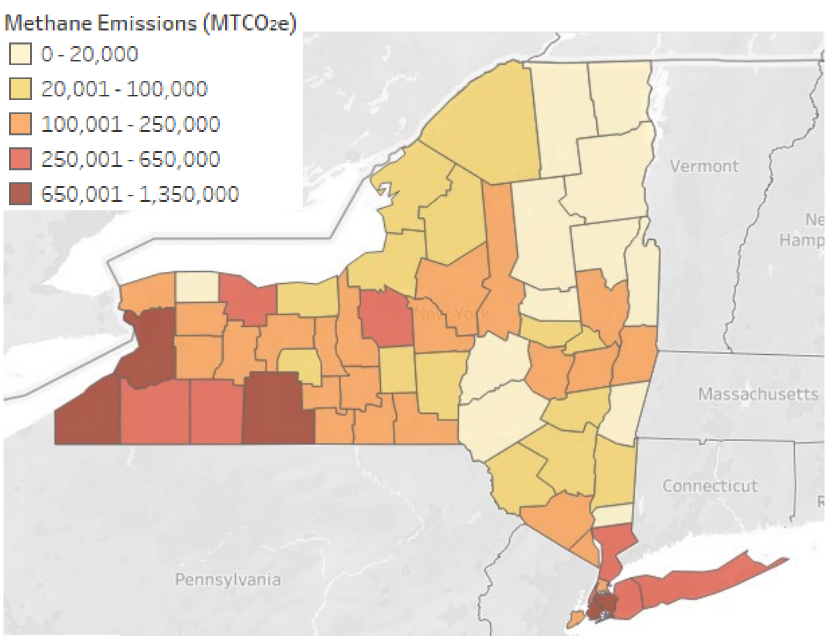


Figure 3. Methane Emissions by County in New York State in 2018, 2019, and 2020 (AR5 GWP_{20})

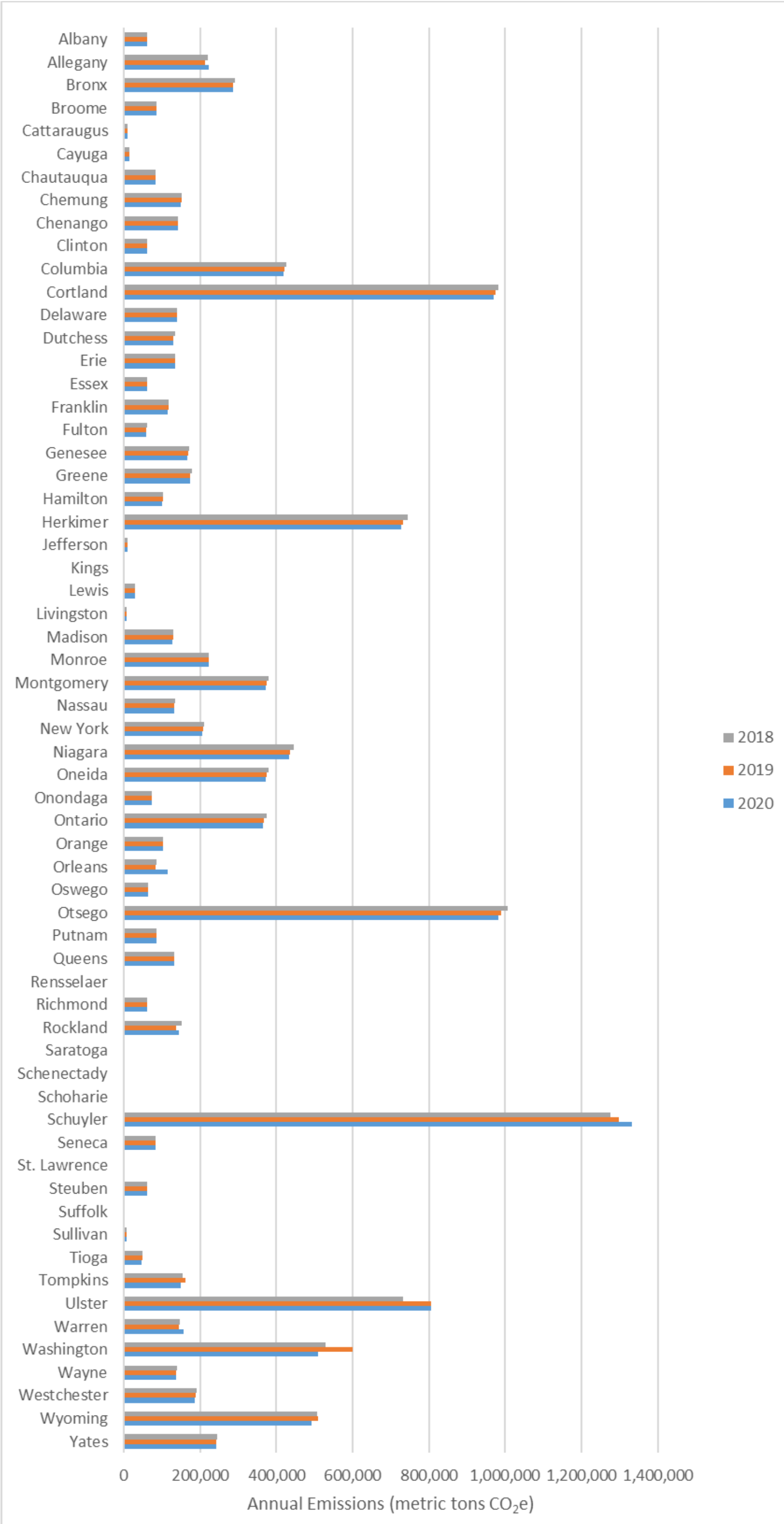


Table 14. Methane Emissions by County in New York State from 1990 to 2000 ($MTCO_2e$; AR5 GWP_{20})

County Name	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Albany	321,522	310,202	318,053	313,454	316,834	307,901	306,359	307,607	306,135	304,304	303,355
Allegany	447,355	444,407	467,876	443,359	456,178	446,676	442,446	454,074	441,385	440,587	439,668
Bronx	290,064	273,932	284,834	278,590	283,244	270,590	269,227	271,145	269,368	266,841	266,247
Broome	189,356	182,398	187,448	184,159	186,336	180,334	179,393	180,151	179,058	178,586	177,302
Cattaraugus	402,599	405,991	474,819	465,022	443,064	497,083	482,923	515,803	517,980	521,522	524,431
Cayuga	291,618	270,646	237,681	224,227	229,547	226,077	240,032	234,304	227,922	219,802	209,680
Chautauqua	1,405,888	1,437,279	1,404,222	1,385,040	1,426,058	1,338,689	1,418,110	1,295,952	1,214,840	1,168,039	1,119,632
Chemung	123,290	119,964	122,447	120,818	121,882	119,496	118,981	120,542	118,885	124,778	128,985
Chenango	17	17	17	17	17	17	17	17	17	17	17
Clinton	10,292	9,535	9,847	9,965	10,095	9,719	9,606	9,634	9,622	9,560	9,563
Columbia	1,470	1,476	1,482	1,488	1,495	1,501	1,507	1,513	1,520	1,526	1,532
Cortland	60,058	60,075	60,091	60,107	60,124	60,140	60,156	60,172	60,189	61,509	60,229
Delaware	1,230	1,235	1,241	1,246	1,251	1,257	1,262	1,267	1,280	1,285	1,290
Dutchess	90,491	88,084	89,126	89,404	89,841	88,812	88,726	89,096	89,163	89,055	89,399
Erie	1,569,365	1,527,688	1,571,055	1,586,747	1,548,904	1,582,592	1,565,497	1,557,110	1,548,397	1,521,990	1,518,745
Essex	2,752	2,663	2,733	2,672	2,701	2,617	2,607	2,615	2,597	2,592	2,658
Franklin	3,567	3,322	3,427	3,445	3,489	3,371	3,341	3,339	3,364	3,356	3,381
Fulton	17	17	17	17	17	17	17	17	17	17	17
Genesee	228,487	217,244	208,764	206,150	211,163	208,097	209,571	206,320	201,605	196,749	191,409
Greene	62,481	62,192	62,310	62,384	62,436	62,332	62,319	62,372	62,423	62,463	62,522
Hamilton	498	486	494	486	490	479	479	479	476	475	486
Herkimer	83,672	82,494	83,354	82,858	83,239	82,237	82,080	82,242	82,077	81,906	81,887
Jefferson	99,937	97,729	99,275	98,370	99,037	97,278	97,031	97,311	97,042	96,727	96,616
Kings	1,494,777	1,424,258	1,476,596	1,440,467	1,462,979	1,402,631	1,394,599	1,403,818	1,394,849	1,382,308	1,377,452
Lewis	63,112	62,899	63,030	63,025	63,092	62,943	62,945	62,976	63,021	63,008	63,051
Livingston	116,970	115,011	118,334	114,073	115,621	112,545	112,762	107,697	107,634	104,521	107,135
Madison	90,725	89,318	90,438	87,183	90,463	90,589	89,577	91,331	96,674	105,277	101,609

Table 14 continued

County Name	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Monroe	570,647	543,221	563,071	550,089	558,626	535,560	532,063	535,160	531,292	526,599	524,458
Montgomery	82,679	81,418	82,307	81,810	82,197	81,204	81,057	81,246	81,069	80,877	80,760
Nassau	564,011	531,473	550,695	543,766	551,926	530,998	526,967	529,794	527,942	523,649	523,326
New York	670,428	620,948	645,804	643,773	654,186	629,895	625,522	632,940	633,444	627,612	632,276
Niagara	211,040	203,048	208,861	205,078	207,603	200,870	199,766	200,685	199,456	197,895	197,088
Oneida	179,824	173,259	177,884	175,061	177,051	171,699	170,739	171,443	170,462	169,303	168,877
Onondaga	504,052	486,290	498,988	491,003	496,474	481,641	479,191	481,090	478,597	475,587	474,514
Ontario	184,978	182,183	185,007	183,274	183,824	182,090	181,547	182,356	181,667	180,691	180,883
Orange	165,558	159,342	163,321	161,443	163,148	158,660	158,196	158,978	158,600	157,678	157,745
Orleans	12,752	12,046	12,529	12,245	12,450	11,906	11,816	11,908	11,801	11,679	11,650
Oswego	47,468	44,923	46,763	45,598	46,376	44,255	43,944	44,262	43,905	43,477	43,383
Otsego	1,600	1,607	1,614	1,620	1,627	1,634	1,641	1,647	1,654	1,661	1,668
Putnam	10,497	9,700	10,011	10,172	10,303	10,151	10,195	10,401	10,513	10,550	10,729
Queens	1,115,040	1,060,089	1,099,667	1,073,852	1,090,843	1,045,895	1,039,595	1,046,045	1,039,479	1,030,161	1,026,945
Rensselaer	128,083	124,340	127,026	125,321	126,477	123,375	122,929	123,330	122,815	122,247	121,924
Richmond	285,869	271,007	282,112	274,372	279,154	266,297	264,506	266,313	264,237	261,618	260,668
Rockland	235,917	225,964	232,843	228,796	231,750	223,923	222,687	223,991	223,177	221,476	221,023
St. Lawrence	92,312	87,307	90,815	88,666	90,171	86,238	85,738	86,378	85,823	85,078	84,874
Saratoga	154,319	149,280	152,987	150,513	152,111	147,855	147,205	147,659	146,770	145,805	145,310
Schenectady	59,859	59,874	59,890	59,905	59,920	59,936	59,951	59,966	59,982	59,997	60,012
Schoharie	135,751	135,535	135,707	135,646	135,724	135,566	136,183	135,612	136,083	136,365	137,851
Schuyler	190,854	179,420	160,169	146,184	149,885	139,160	153,314	152,130	135,490	137,718	139,957
Seneca	142,446	139,295	140,231	142,429	143,106	142,373	142,461	142,881	142,934	142,909	143,262
Steuben	436,396	421,509	443,609	438,050	434,572	583,663	681,421	651,298	678,502	709,355	828,771
Suffolk	563,446	536,300	551,827	547,030	553,604	537,111	534,796	538,699	538,167	535,945	537,110
Sullivan	61,859	61,759	61,851	61,786	61,828	61,741	61,732	61,752	61,736	61,792	61,831

Table 14 continued

County Name	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Tioga	76,133	74,714	75,308	74,348	74,597	73,988	73,916	74,073	74,873	73,930	74,853
Tompkins	168,716	166,016	167,937	166,832	167,673	165,522	165,150	165,487	165,620	165,708	164,629
Ulster	95,183	92,833	94,160	93,806	94,372	92,702	92,424	92,748	92,797	92,645	92,663
Warren	22,293	20,944	21,762	21,426	21,773	20,831	20,648	20,742	20,650	20,566	20,482
Washington	13,049	12,361	12,841	12,541	12,747	12,174	12,112	12,219	12,132	12,057	12,039
Wayne	98,144	96,096	97,674	96,711	97,338	95,885	95,473	95,894	95,513	95,325	95,235
Westchester	423,761	400,962	414,883	409,137	415,058	399,793	397,203	399,652	398,536	395,664	395,398
Wyoming	265,468	270,323	264,290	252,078	254,338	253,445	247,356	248,801	245,941	242,767	239,582
Yates	59,970	59,111	59,836	60,011	59,854	60,147	59,918	59,613	59,477	63,039	62,118

Table 15. Methane Emissions by County in New York State from 2001 to 2010 ($MTCO_2e$, AR5 GWP_{20})

County Name	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Albany	298,621	297,946	295,414	292,612	290,626	289,610	286,864	286,275	280,923	276,894
Allegany	449,859	503,457	510,502	515,203	523,621	539,134	546,390	558,395	550,200	547,195
Bronx	259,806	259,887	256,771	252,560	249,809	248,100	244,594	243,960	237,533	232,494
Broome	174,807	175,287	192,176	178,274	172,402	168,380	166,741	166,381	162,546	159,826
Cattaraugus	520,276	512,064	489,515	494,667	540,473	640,504	669,379	640,538	593,137	676,363
Cayuga	202,149	199,564	190,176	184,151	159,460	186,944	186,343	188,565	205,855	205,258
Chautauqua	1,106,708	1,067,449	1,048,043	1,042,326	1,055,603	1,117,166	1,187,693	1,211,408	1,152,120	1,068,904
Chemung	542,783	953,298	926,287	871,965	1,444,492	1,367,997	1,246,235	951,082	737,158	655,272
Chenango	17	17	17	989	1,925	668	11,735	44,676	131,739	142,618
Clinton	9,374	9,344	9,392	9,111	9,065	9,154	9,099	9,058	8,806	8,626
Columbia	1,538	1,557	1,557	1,557	1,557	1,564	1,564	1,619	1,619	1,619
Cortland	60,245	60,285	61,706	61,274	61,060	60,311	60,939	60,454	60,454	60,454
Delaware	1,296	1,311	1,311	1,797	1,311	1,317	1,317	1,364	1,364	1,364
Dutchess	88,749	88,978	89,392	88,928	88,918	89,040	88,836	88,545	87,892	87,303
Erie	1,486,629	1,487,477	1,478,187	1,471,061	1,482,235	1,507,836	1,520,616	1,548,472	1,560,681	1,585,488
Essex	2,593	2,623	2,603	2,624	2,578	2,550	2,538	2,533	2,450	2,464
Franklin	3,293	3,274	3,270	3,187	3,158	3,208	3,130	3,133	3,048	2,971
Fulton	17	17	17	17	17	17	17	17	17	17
Genesee	183,502	186,357	177,228	180,897	173,593	174,805	196,594	185,176	175,703	175,253
Greene	62,446	62,533	62,530	62,477	62,461	62,511	62,506	62,532	62,405	62,370
Hamilton	492	504	503	486	486	489	500	502	481	477
Herkimer	81,411	81,358	81,040	80,745	80,436	80,319	80,045	136,403	135,886	135,484
Jefferson	95,654	95,627	95,037	94,410	94,049	93,854	93,572	93,410	92,346	91,609
Kings	1,347,448	1,342,947	1,325,034	1,308,209	1,293,754	1,284,358	1,268,159	1,265,781	1,233,640	1,209,209
Lewis	62,995	63,032	62,965	62,878	62,880	62,867	62,889	62,913	62,843	62,788
Livingston	102,851	100,972	99,871	103,756	101,321	99,441	101,824	99,553	97,284	94,918
Madison	105,970	105,685	105,716	104,699	103,907	108,242	117,742	137,606	160,886	141,023

Table 15 continued

County Name	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Monroe	512,751	510,121	503,152	496,000	490,043	486,605	480,053	478,203	464,557	454,460
Montgomery	80,244	80,203	79,888	79,581	79,844	79,328	79,011	79,002	78,398	77,976
Nassau	511,451	507,687	503,437	495,651	491,381	489,293	481,648	478,003	464,788	454,785
New York	617,001	606,597	604,422	592,358	585,787	586,046	575,240	570,143	554,022	541,280
Niagara	193,667	192,960	190,625	188,498	186,670	185,518	183,693	239,571	235,558	232,666
Oneida	165,998	165,580	163,979	162,238	161,332	159,999	158,414	158,060	154,885	152,565
Onondaga	466,720	465,981	460,697	457,035	452,998	452,854	448,062	445,041	436,105	429,648
Ontario	179,004	179,077	179,315	179,423	177,193	177,706	176,134	237,521	232,830	230,498
Orange	155,495	155,500	154,708	153,307	152,530	152,232	151,076	150,472	147,769	145,682
Orleans	11,362	11,287	11,129	10,938	10,776	10,715	10,544	10,463	10,133	9,850
Oswego	42,192	42,044	41,426	42,299	40,209	39,896	39,295	39,168	37,865	36,887
Otsego	1,674	1,694	1,694	1,694	1,694	1,702	2,871	1,761	2,372	1,761
Putnam	10,475	10,585	10,763	10,529	10,569	10,632	10,584	10,472	10,181	9,971
Queens	1,004,617	1,001,801	989,036	975,567	965,089	958,245	945,598	942,456	917,060	897,720
Rensselaer	120,197	120,061	119,215	118,375	117,680	117,267	116,458	116,279	114,415	113,043
Richmond	254,238	253,043	248,984	245,428	242,527	240,507	236,878	235,957	228,372	222,807
Rockland	217,038	216,190	214,191	211,742	210,024	208,979	206,727	206,010	201,194	197,670
St. Lawrence	83,068	82,756	81,807	80,671	79,880	79,566	78,478	78,019	75,670	73,876
Saratoga	143,102	142,661	141,354	140,128	139,225	138,605	137,344	137,111	134,596	132,712
Schenectady	60,028	60,073	60,073	60,073	60,073	60,090	60,090	60,224	60,224	60,224
Schoharie	136,696	137,791	135,516	208,892	333,370	338,773	267,321	206,596	197,628	171,881
Schuyler	139,023	142,649	138,270	139,316	133,967	142,109	168,780	219,687	202,485	184,157
Seneca	142,643	142,824	143,050	142,963	142,887	142,713	142,475	143,158	142,557	142,166
Steuben	1,014,712	1,002,203	1,263,622	2,007,309	2,019,118	1,853,326	1,925,051	1,869,295	1,687,657	1,392,195
Suffolk	527,289	527,420	525,359	518,046	515,162	514,131	508,983	505,729	494,574	486,475
Sullivan	61,826	61,893	61,841	61,856	61,869	61,880	61,883	61,973	61,928	61,916

Table 15 continued

County Name	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Tioga	147,088	149,828	145,063	145,424	144,088	147,175	146,228	145,073	143,570	144,769
Tompkins	163,793	163,463	163,420	162,606	162,290	161,318	161,660	161,259	159,538	158,635
Ulster	91,832	92,059	92,017	91,489	91,245	91,251	90,714	90,537	89,584	88,900
Warren	19,987	19,860	19,586	19,317	19,064	18,997	18,801	18,654	18,216	17,790
Washington	11,788	11,804	11,596	11,432	11,286	11,242	11,115	11,001	10,701	10,461
Wayne	94,471	94,377	95,085	93,984	94,375	102,003	96,635	94,134	94,095	91,056
Westchester	386,629	385,228	382,322	376,526	373,054	371,658	366,682	364,432	354,718	347,250
Wyoming	235,984	235,222	234,153	236,120	238,416	243,024	241,169	236,897	236,291	234,921
Yates	60,986	59,933	59,495	59,280	59,168	58,814	59,936	63,191	59,685	59,349

Table 16. CH_4 Emissions by County in New York State from 2011 to 2020 ($MTCO_2e$, AR5 GWP_{20})

County Name	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Albany	276,078	271,956	266,377	263,993	259,761	254,045	250,525	245,324	242,662	240,860
Allegany	546,196	571,621	545,408	552,597	524,097	514,874	514,830	507,632	508,993	491,308
Bronx	231,534	226,544	218,755	216,099	210,471	202,685	197,736	190,528	187,030	184,830
Broome	159,274	156,648	153,044	151,409	148,577	144,801	142,483	139,142	137,234	135,872
Cattaraugus	637,839	586,281	599,866	613,930	523,067	521,186	531,549	529,103	598,802	509,290
Cayuga	202,707	186,227	174,493	171,233	164,611	160,078	151,423	146,799	145,030	156,719
Chautauqua	1,055,978	1,040,748	1,014,245	971,654	910,591	847,030	766,466	731,797	806,074	746,005
Chemung	610,271	473,909	422,591	345,217	294,241	209,509	176,246	154,647	160,335	148,864
Chenango	137,651	111,485	93,295	79,134	68,150	59,025	50,039	49,886	47,624	46,035
Clinton	8,637	8,407	8,190	8,114	7,968	7,710	7,631	7,443	7,348	7,280
Columbia	1,619	1,619	1,630	1,630	1,630	1,630	1,613	1,600	1,601	1,597
Cortland	60,454	60,454	60,484	60,484	60,484	60,484	60,484	60,448	60,453	60,442
Delaware	1,364	1,356	1,366	1,366	1,366	1,366	1,366	1,354	1,356	1,352
Dutchess	87,291	86,773	86,007	85,788	85,297	84,609	84,178	83,493	83,144	82,891
Erie	1,564,105	1,519,191	1,457,795	1,429,203	1,393,664	1,360,483	1,337,376	1,276,481	1,297,095	1,329,204
Essex	2,462	2,420	2,379	2,359	2,316	2,268	2,198	2,152	2,132	2,118
Franklin	2,980	2,890	2,796	2,763	2,710	2,630	2,565	2,504	2,479	2,464
Fulton	17	17	17	17	17	17	0	0	0	0
Genesee	174,383	171,081	163,266	162,729	150,511	147,245	145,350	151,013	136,303	145,028
Greene	62,365	62,304	62,241	62,184	62,091	62,003	62,012	61,924	61,894	61,865
Hamilton	469	477	471	461	461	459	456	450	449	449
Herkimer	135,352	134,914	134,357	134,085	133,578	132,961	132,611	132,015	131,728	131,512
Jefferson	91,425	90,689	89,544	89,082	88,189	87,046	86,329	85,293	84,769	84,404
Kings	1,206,187	1,181,489	1,144,442	1,130,540	1,103,624	1,065,338	1,041,860	1,006,706	988,386	976,204
Lewis	62,790	62,739	62,662	62,618	62,566	62,492	62,417	62,314	62,282	62,249
Livingston	93,745	92,447	90,090	90,709	87,973	87,891	87,693	85,281	82,163	114,047
Madison	158,533	136,830	127,760	121,930	117,444	112,291	105,152	103,090	102,544	102,655

Table 16 continued

County Name	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Monroe	452,493	442,799	428,308	422,327	411,426	396,777	387,718	374,566	367,240	362,137
Montgomery	77,841	77,443	76,771	76,502	75,996	75,362	74,911	74,304	73,988	73,755
Nassau	452,960	443,223	429,514	424,489	414,246	400,335	392,234	379,789	373,563	369,514
New York	540,259	527,794	510,026	504,358	490,744	471,355	460,932	445,207	437,114	431,864
Niagara	232,101	229,144	224,747	223,100	219,934	215,630	213,035	209,171	206,962	205,379
Oneida	152,023	149,774	146,332	145,059	142,526	139,043	137,066	134,011	132,400	131,678
Onondaga	428,287	422,048	412,838	409,192	402,135	392,566	386,769	378,368	373,917	370,846
Ontario	230,222	229,567	227,942	226,966	226,060	223,903	224,002	222,581	222,416	223,131
Orange	145,201	143,143	140,269	139,223	137,345	134,508	132,686	130,028	128,628	127,673
Orleans	9,828	9,570	9,201	9,066	8,798	8,435	8,204	7,888	7,705	7,576
Oswego	36,783	35,909	34,513	34,045	33,007	31,598	30,719	29,526	28,874	28,431
Otsego	1,761	1,761	1,773	1,773	1,790	1,790	1,790	1,775	1,777	1,773
Putnam	9,857	9,617	9,436	9,442	9,328	9,082	8,899	8,686	8,579	8,502
Queens	894,669	876,106	848,412	838,282	817,346	788,713	770,984	744,548	731,309	722,736
Rensselaer	112,827	111,454	109,492	108,611	107,185	105,171	103,966	102,174	101,242	100,605
Richmond	221,839	216,339	208,273	205,102	199,029	190,778	185,678	178,249	174,255	171,527
Rockland	197,099	193,522	188,627	186,710	183,326	178,334	175,215	170,630	168,272	166,701
St. Lawrence	73,628	71,904	69,273	68,426	66,557	63,982	62,369	60,033	58,804	57,985
Saratoga	132,274	130,506	127,770	126,659	124,555	121,872	120,109	117,646	116,249	115,258
Schenectady	60,224	60,224	60,253	60,253	60,253	60,253	60,236	60,202	60,207	60,196
Schoharie	172,039	165,834	159,281	159,929	157,091	136,910	134,943	134,804	134,747	134,719
Schuyler	169,546	159,536	152,103	148,513	143,340	142,061	135,118	135,536	129,314	129,437
Seneca	142,244	142,369	141,426	141,371	140,592	139,742	139,531	138,643	138,299	138,043
Steuben	1,288,893	1,214,563	1,151,634	1,139,821	1,090,985	1,032,931	1,005,280	983,320	973,981	969,533
Suffolk	485,134	477,421	466,175	462,277	453,762	442,217	435,394	425,149	419,788	416,176
Sullivan	61,904	61,825	61,806	61,790	61,777	61,690	61,638	61,568	61,550	61,534

Table 16 continued

County Name	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Tioga	143,268	145,275	142,587	142,428	142,823	141,753	141,499	141,094	140,854	140,689
Tompkins	158,410	157,512	156,124	155,597	154,585	153,135	152,242	150,935	150,253	149,757
Ulster	88,781	88,114	87,130	86,900	86,148	85,212	84,656	83,778	83,315	82,989
Warren	17,671	17,257	16,628	16,355	15,904	15,310	14,947	14,419	14,137	13,946
Washington	10,415	10,199	9,788	9,586	9,288	8,964	8,744	8,426	8,257	8,143
Wayne	91,631	90,404	89,163	88,615	87,802	86,837	86,161	85,214	84,540	84,035
Westchester	346,070	338,720	328,493	324,871	317,378	307,187	300,944	291,864	287,312	284,348
Wyoming	232,810	233,510	226,749	224,359	221,568	218,877	218,940	219,534	211,997	223,406
Yates	59,279	58,876	59,607	59,608	59,124	59,770	59,613	60,208	59,998	60,498

NYS has 10 distinct economic regions, as defined by NYS Empire State Development and shown in Figure 4. The CH_4 emissions for these regions are presented in Table 17. CH_4 emissions between 2018 and 2020 were greatest in Western New York (26 to 27%) and New York City (20%). The Western New York region has a large portion of oil and natural gas exploration and development, as well as a high density of pipelines. The New York City region has no oil or natural gas development, but does have a high number of distribution lines, natural gas services, and meters providing end-user populations with commercial and residential gas services.

Figure 4. New York Economic Regions as Identified by Empire State Development

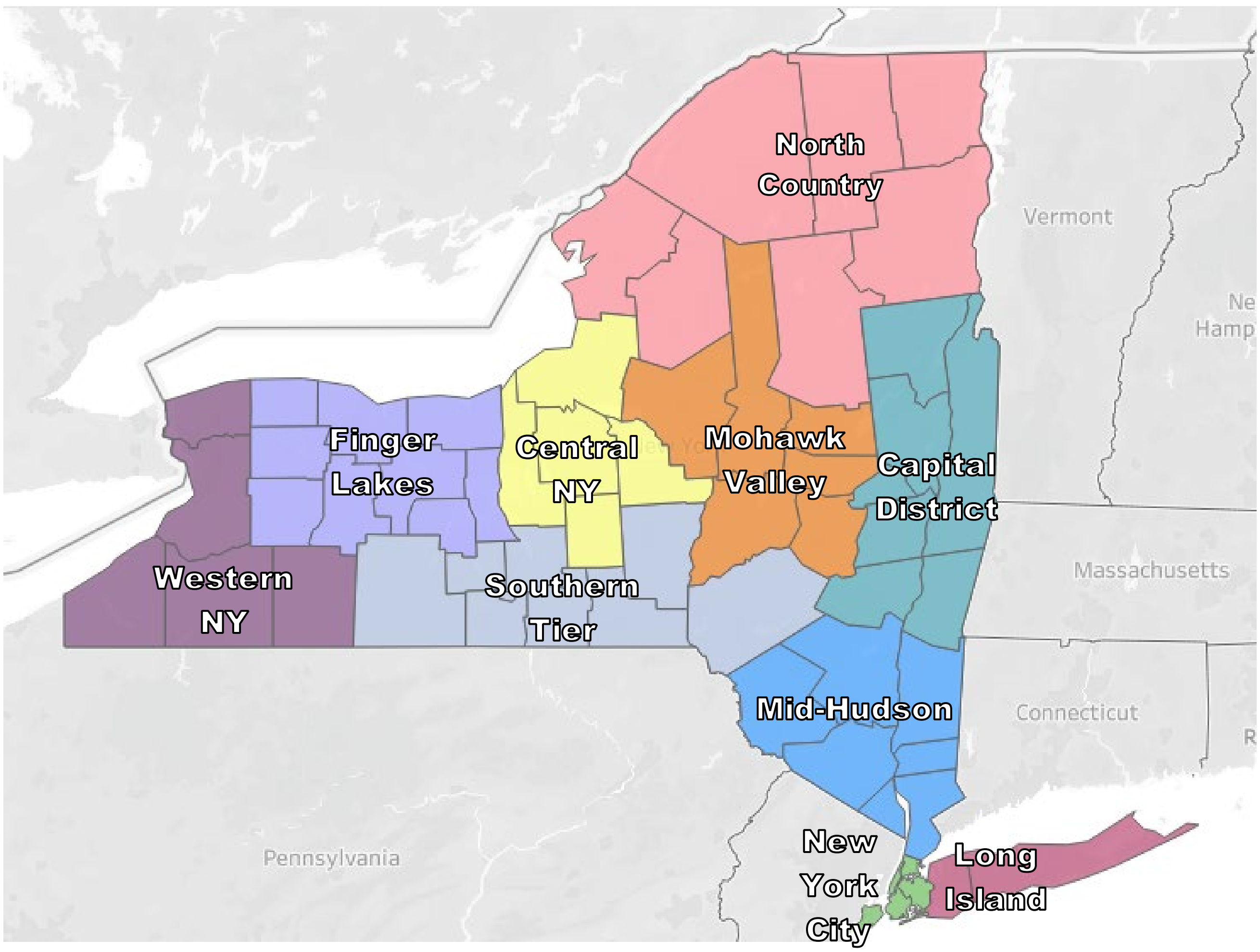


Figure 5. Methane Emissions by Economic Region in New York State in 2018 (AR5 GWP_{20})

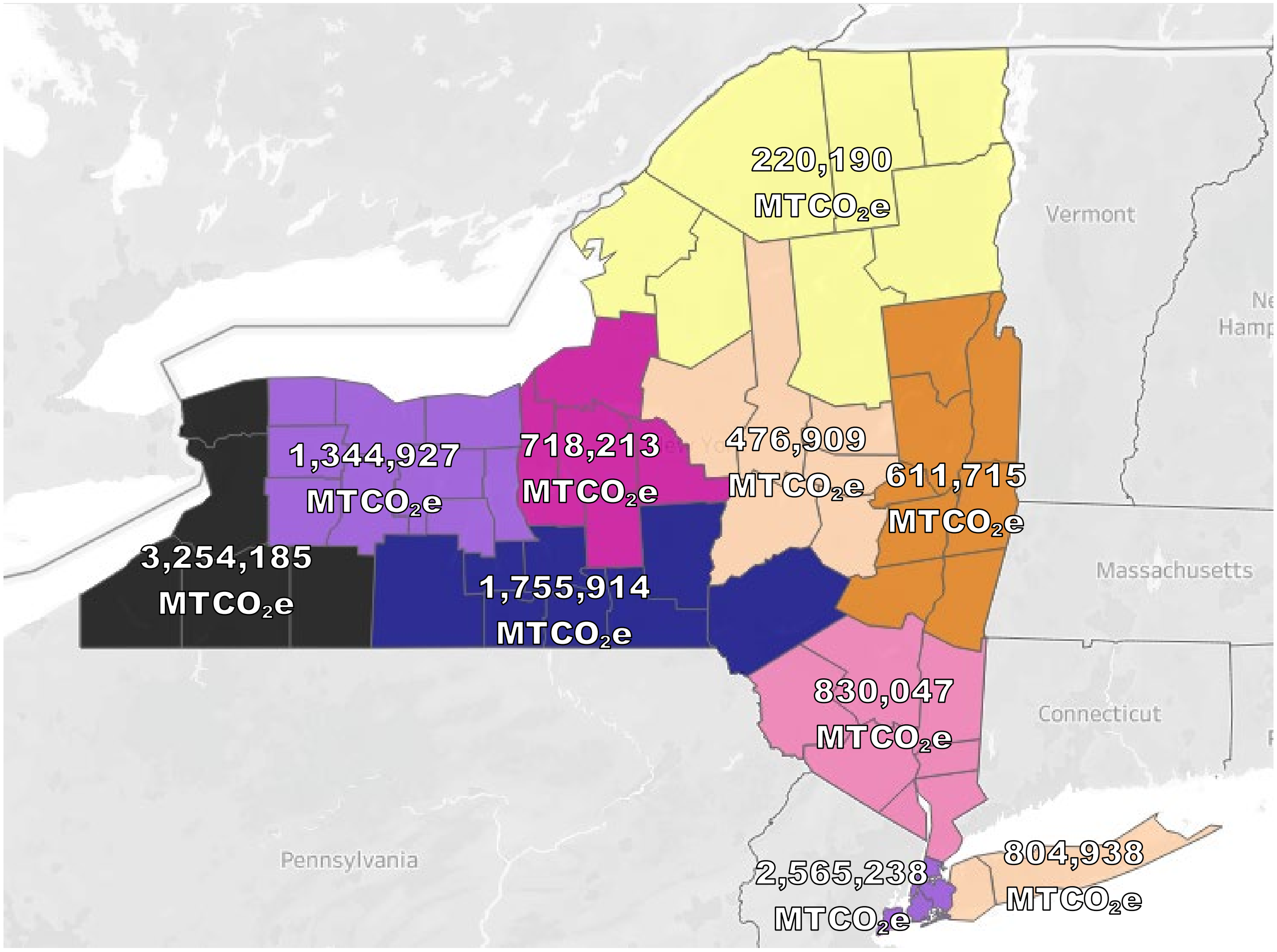


Figure 6. CH_4 Emissions by Economic Region in NYS in 2019 (AR5 GWP_{20})

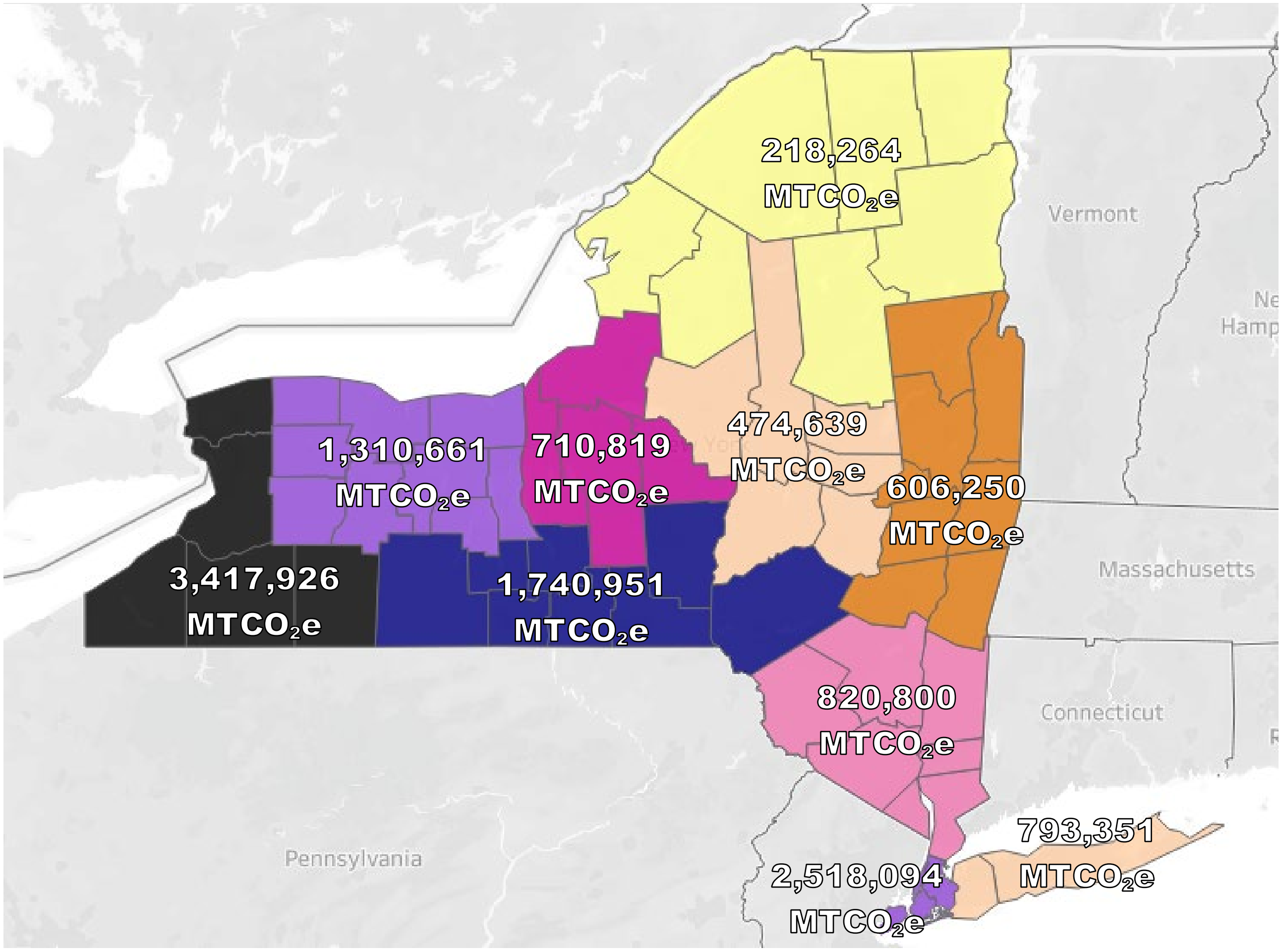


Figure 7. CH_4 Emissions by Economic Region in NYS in 2020 (AR5 GWP_{20})

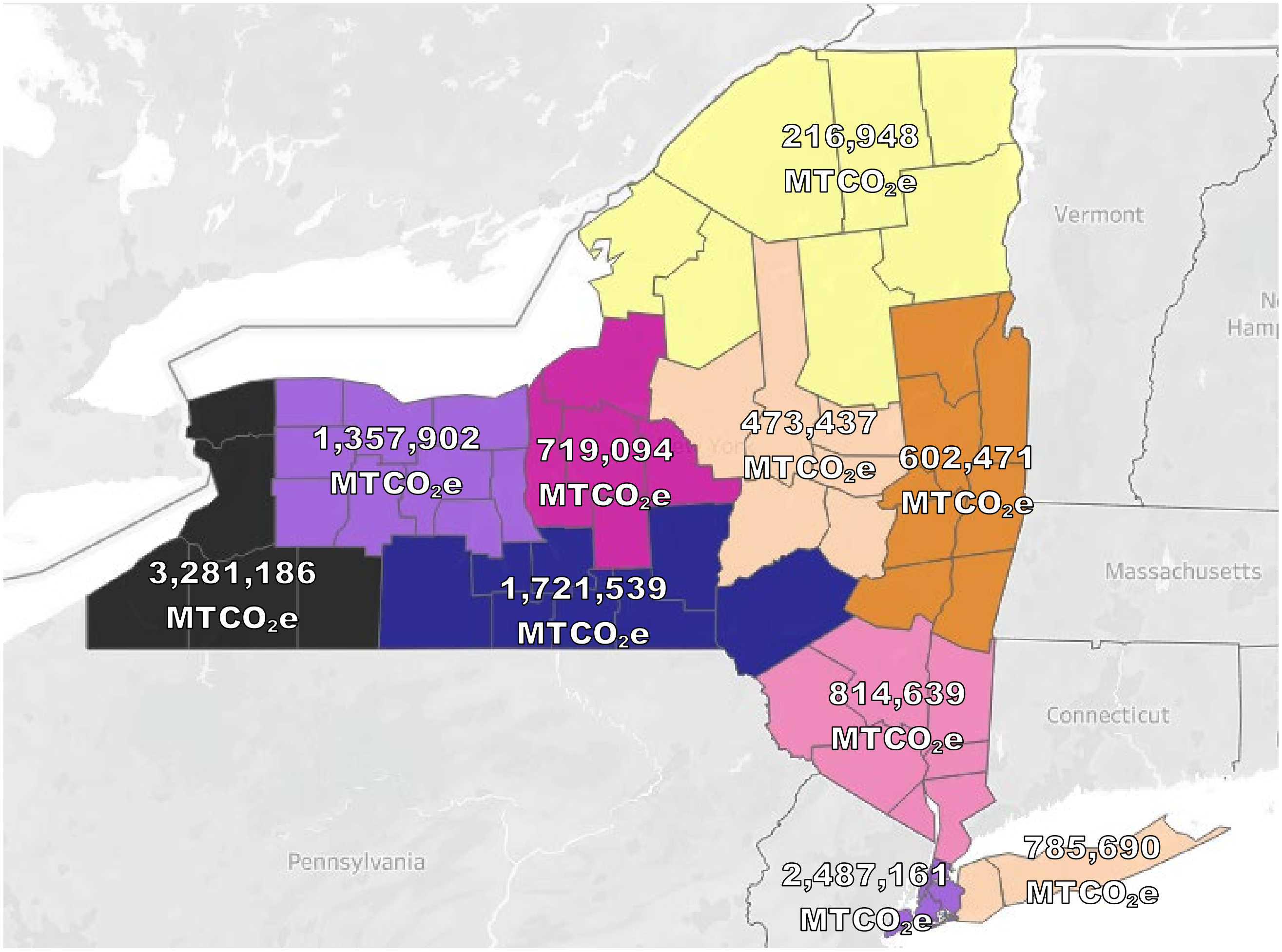


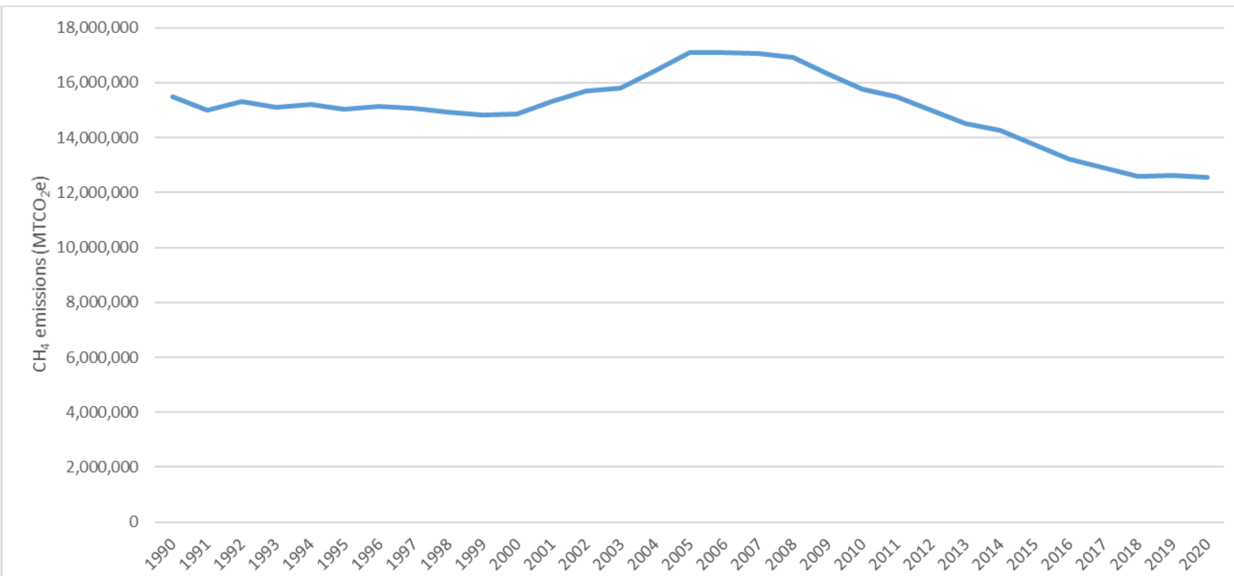
Table 17. CH_4 Emissions by Economic Region in NYS in 2018, 2019, and 2020

		% of Statewide CH4 Emissions		
Upstate/Downstate	**Region**	**2018**	**2019**	**2020**
Upstate	Western New York	25.9%	27.1%	26.3%
Upstate	Finger Lakes	10.7%	10.4%	10.9%
Upstate	Southern Tier	14.0%	13.8%	13.8%
Upstate	Central New York	5.7%	5.6%	5.8%
Upstate	North Country	1.7%	1.7%	1.7%
Upstate	Mohawk Valley	3.8%	3.8%	3.8%
Upstate	Capital District	4.9%	4.8%	4.8%
Downstate	Hudson Valley	6.6%	6.5%	6.5%
Downstate	New York City	20.4%	20.0%	20.0%
Downstate	Long Island	6.4%	6.3%	6.3%

4.5 Emissions Time Series

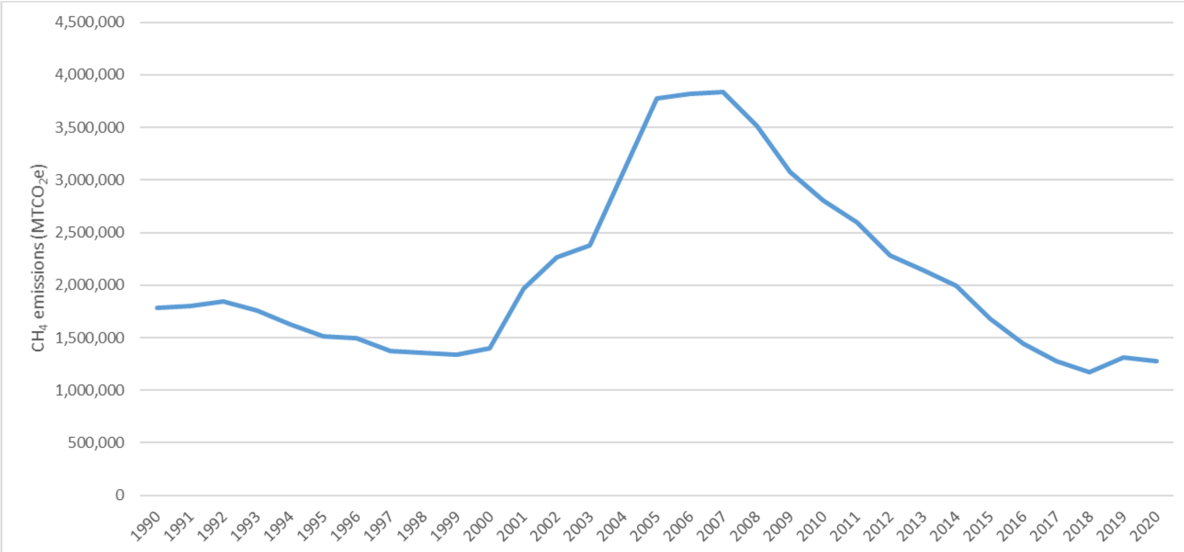
Figure 8 shows total CH_4 emissions in NYS from 1990 to 2020. As noted previously, retrospective emissions are estimated by applying current methodologies and EFs to past activity data. Figure 8 shows that total CH_4 emissions followed a generally increasing trend from 1990 until peaking at 17.063 $MMTCO_2e$ in 2007. Since 2007 CH_4 emissions decreased each year, except for a slight increase between 2018 and 2019. Total CH_4 emissions have decreased 27% since their peak in 2007. This trend is described in more detail below.

Figure 8. Total Methane Emissions in New York State from 1990 to 2020 (AR5 GWP_{20})



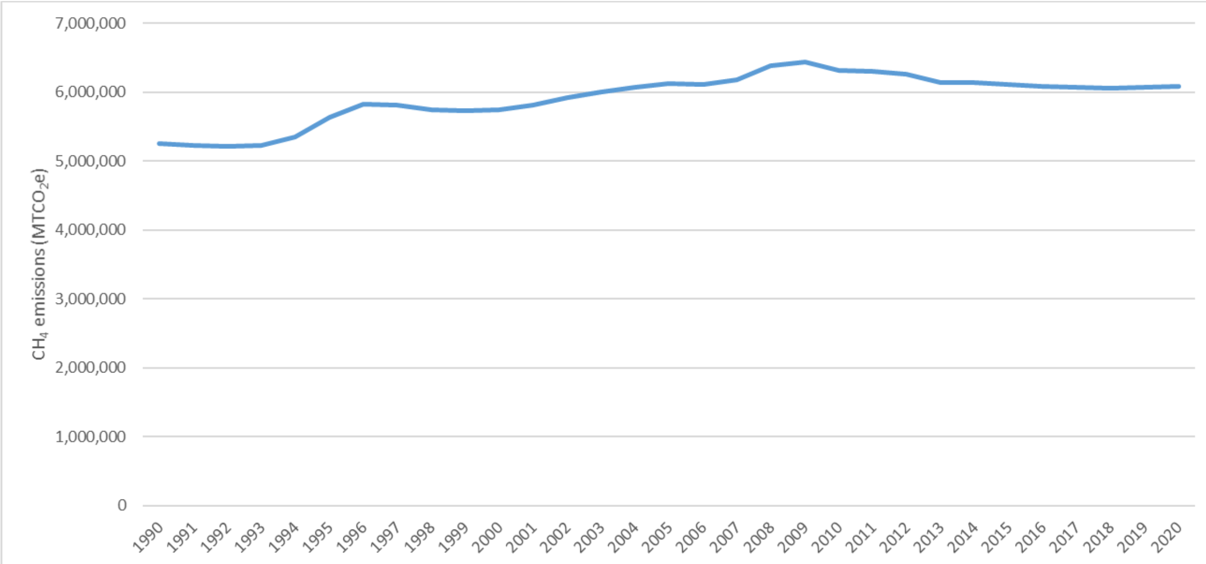
Total emissions are the sum of upstream (Figure 9), midstream (Figure 10), and downstream (Figure 11) emissions. Upstream emissions (Figure 9), though smaller in magnitude than midstream and downstream emissions, have shown greater variation over time, more closely mirroring the cyclical nature of oil and gas exploration, along with well completions in NYS. Upstream CH_4 emissions peaked at 3.842 $MMTCO_2e$ in 2007, corresponding with the observed peak in natural gas production and well completions, which both correspond with peak natural gas prices, and which have declined since 2007. Correspondingly, well completions and natural gas production have declined since the peak production observed in 2007, resulting in an overall decline in emissions associated with upstream source categories. Overall upstream emissions decreased 31.2% from 1990 to 2020, and by 68% from 2007 to 2020.

Figure 9. Upstream Methane Emissions in New York State from 1990 to 2020 (AR5 GWP_{20})



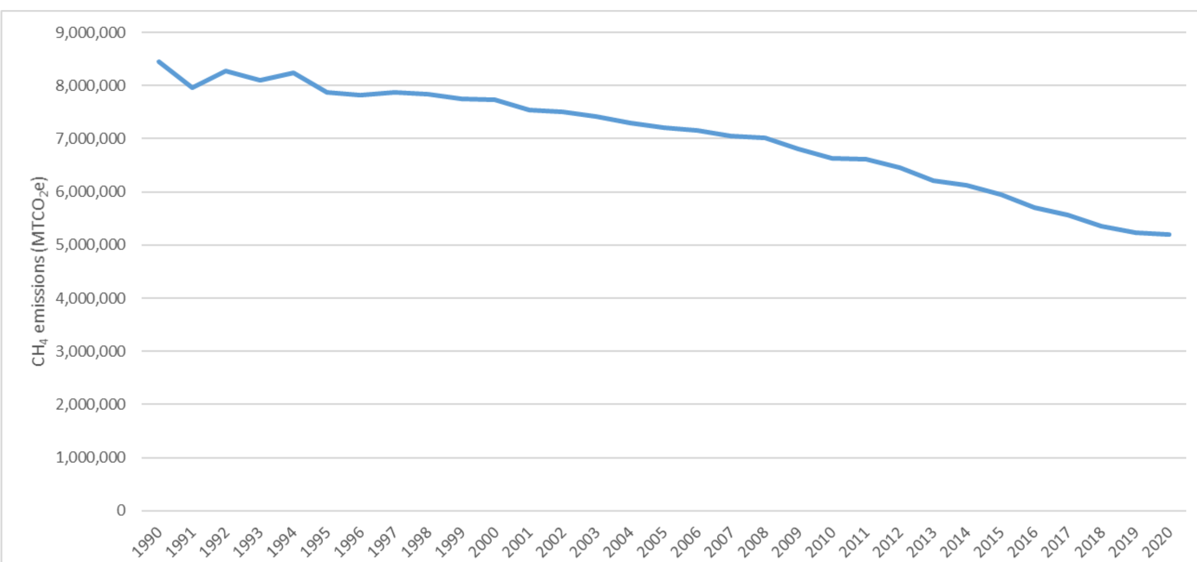
Midstream CH_4 emissions (Figure 10) increased from 1990 to 2020 by 15.4%. However, since 2009 midstream emissions have declined by 5.7% as a result of declining natural gas production, and subsequent midstream throughput, in NYS. As shown in Figure 1, midstream CH_4 emissions are largely a function of transmission and storage compressor stations and transmission pipelines. NYS Department of Environmental Conservation (DEC) data show increasing compressor counts and throughput in NYS, resulting in generally increasing midstream CH_4 emissions. Although natural gas production in NYS has declined since 2006, natural gas consumption in NYS has increased, rising by 21.5% from 1,080,215 million cubic feet (MMcf) in 2005 to 1,312,031 MMcf in 2019 (EIA 2021). Correspondingly, driven by consumption, emissions in NYS from transmission compressor stations have risen to accommodate increased natural gas throughput.

Figure 10. Midstream Methane Emissions in New York State from 1990 to 2020 (AR5 GWP_{20})



Downstream CH_4 emissions (Figure 11) decreased by 38.8% from 1990 to 2020. The two largest source categories in downstream emissions—cast iron and unprotected steel distribution main pipeline mileages—have both decreased since 1990, as they have been largely replaced with plastic distribution mains. Plastic mains have much lower leak rates and therefore a lower EF, resulting in the downward trend observed in Figure 11. Additionally, increasing consumption in NYS has driven increases in the number of residential services and meters, though this growth is outweighed by the transition from cast iron and unprotected steel distribution lines to plastic.

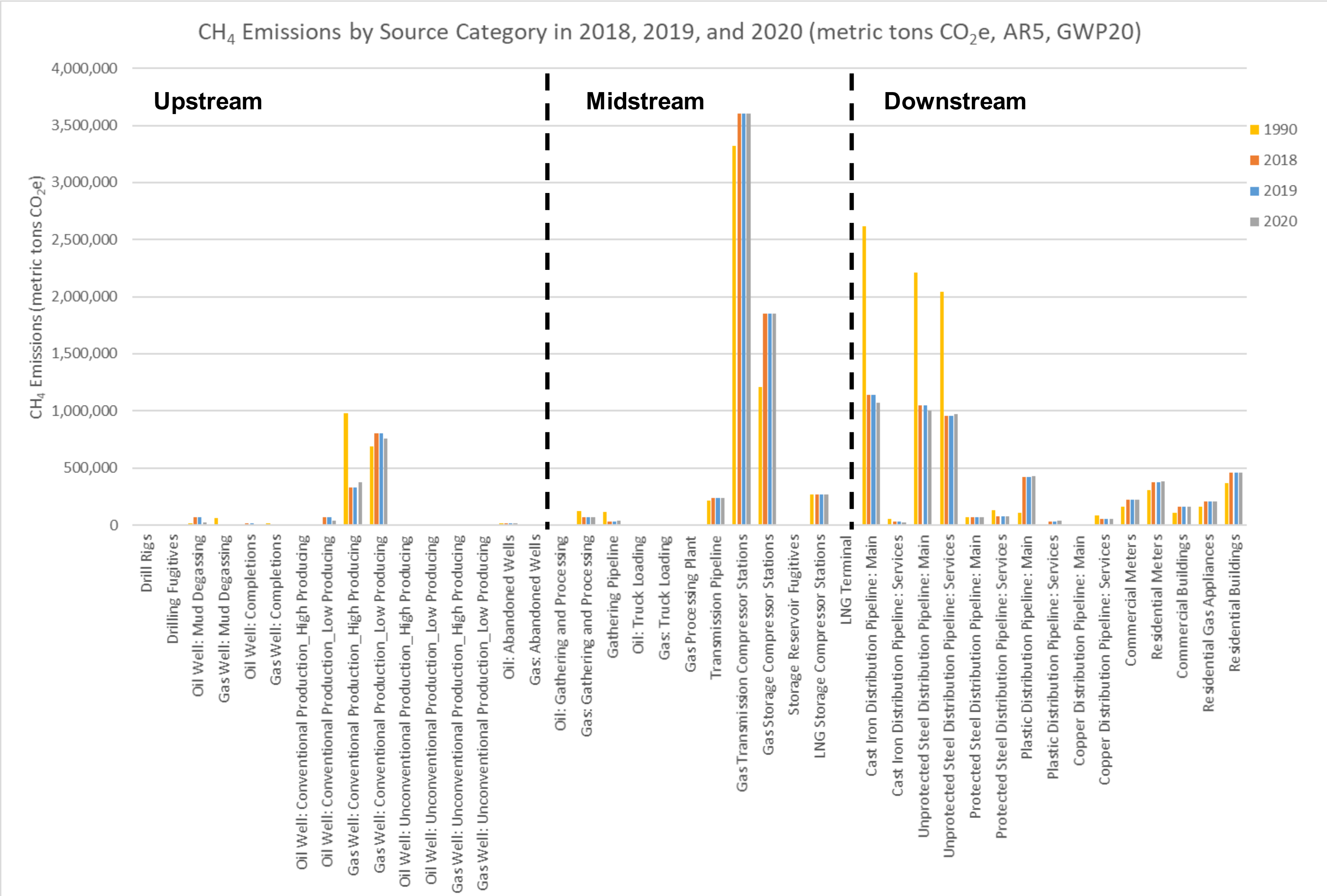
Figure 11. Downstream Methane Emissions in New York State from 1990 to 2020 (AR5 GWP_{20})



4.6 Source Category Comparison Summary: 1990 to 2018, 2019, and 2020

While most upstream source category emissions decreased between 1990 and 2020, some sources increased in 2020 after decreasing in 2018 and 2019 (Figure 12). Emissions from low-producing oil wells in 2020 were 1,128.6% above 1990 levels and low-producing gas wells were 10.7% above 1990 levels; levels for both sources were greater than 1990 in 2018 and 2019 as well. The largest upstream decrease in emissions between 1990 and 2020 was from conventional oil production from high-producing wells (-89.3%), which follows the decreasing completion and production patterns. The midstream source categories saw increases in emissions from transmission pipelines (+10.1% between 1990 and 2018, +10.2% between 1990 and 2019, and +9.9% between 1990 and 2020) due to increases in overall pipeline mileages in NYS over that time period; as well as large increases in CH_4 emissions from transmission (+8.5%) and gas storage compressor stations (+52.9%), resulting from increases in the number of compressor stations during that time period in order to accommodate increased pipeline capacity. Increases in pipeline and storage capacity and associated compressors reflect trends toward increasing natural gas consumption in NYS, as identified by EIA (2021). In the downstream source categories, there was a large shift away from cast iron and unprotected steel distribution mains toward lower emitting plastic pipes, resulting in a net decrease in downstream emissions. Emissions from cast iron and unprotected steel distribution mains decreased by 59.1% and 54.8% in 2020 compared to 1990, respectively, and emissions from plastic pipelines increased by 292%. Although there was an increase in plastic distribution main and services, along with residential and commercial meter emissions, they were offset by larger reductions in emissions from replacing cast iron and unprotected steel pipelines.

Figure 12. Comparison of Source Category Methane Emissions from 1990 and 2018, 2019, and 2020 in New York State, Using AR5 GWP_{20} Conversion Factors for Methane



4.6.1 Emissions Inventory Uncertainty

Using the uncertainty bounds associated with the EFs, the following figures present the total time series emissions, including upper and lower confidence bounds. Comparing Figure 13, Figure 15, and Figure 16 reveals that the lower bound on the uncertainty estimate is driven by midstream and downstream emissions. This is because for the upstream EFs, it was determined that selecting the lower-bound value represented the most applicable value to NYS based on the differences in production between NYS, West Virginia, and Pennsylvania where the EF studies were conducted. So, the best estimate and the lower-bound estimate are the same for that segment.

Upper-bound emissions estimates were determined by selecting the upper bound EF provided by the sources chosen for the best estimate EFs. As such, upper-bound emissions estimates may be thought of as representing the upper limit of emissions for NYS, based on EFs from other states which employ high-emitting techniques in the oil and natural gas sector. These upper-bound estimates also reflect literature estimates of EFs for many source categories with identified high-emitting sources. As such, these EFs also likely capture the possible range of uncertainty that arises from taking into consideration the high-emitting sources in NYS.

Figure 13. Total Emissions including Upper and Lower Bounds (AR5 GWP_{20})

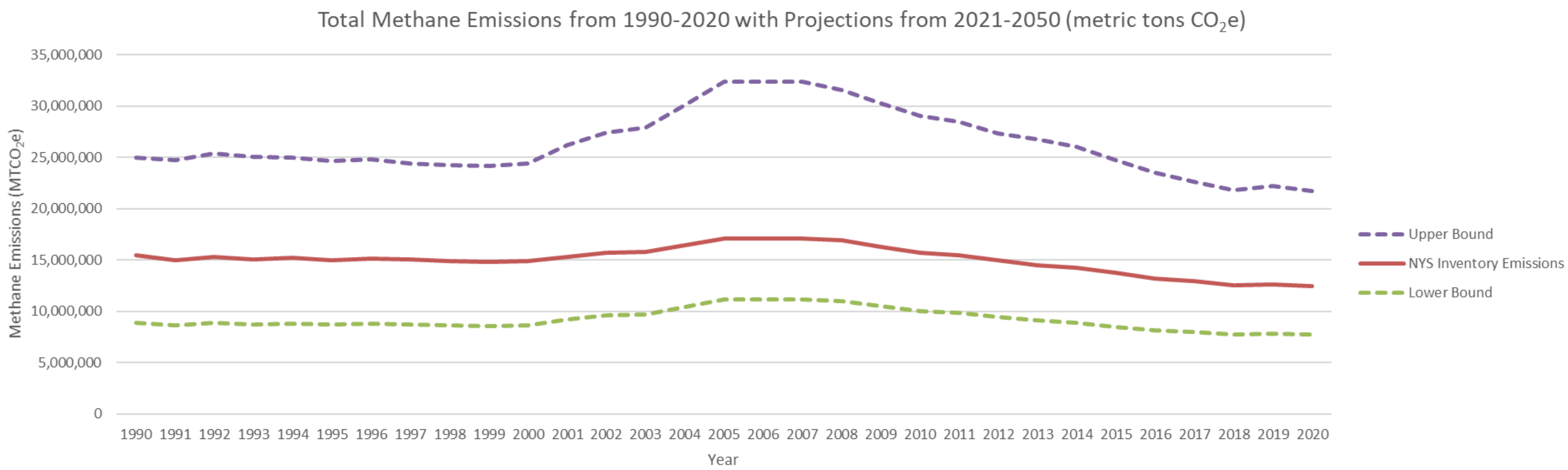


Figure 14. Upstream Emissions including Upper and Lower Bounds (AR5 GWP_{20})

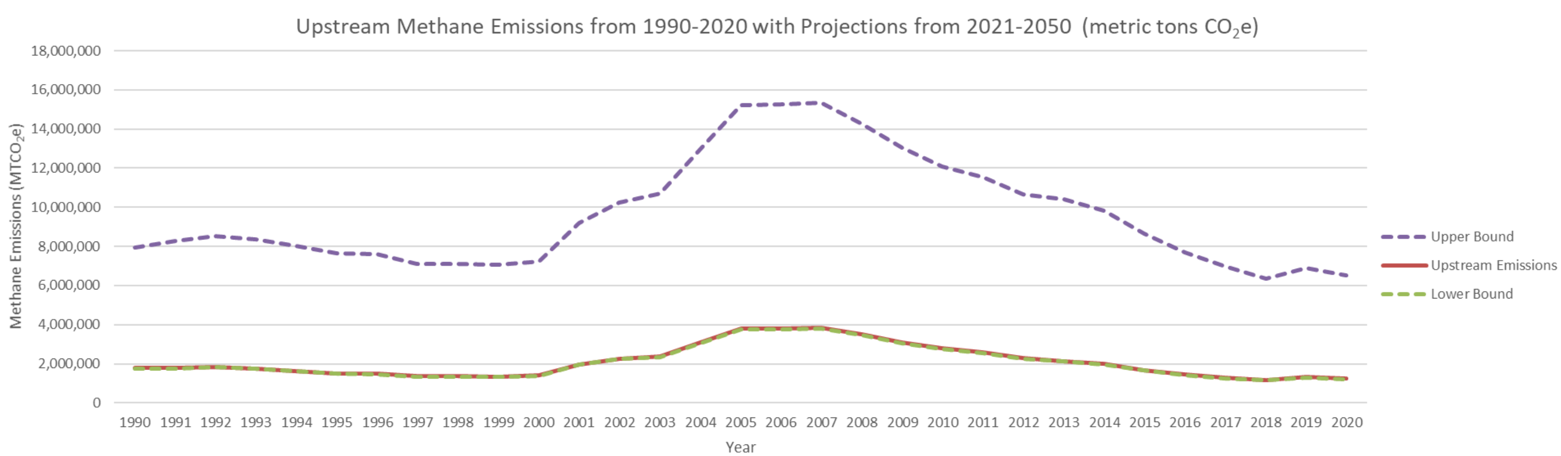


Figure 15. Midstream Emissions including Upper and Lower Bounds (AR5 GWP_{20})

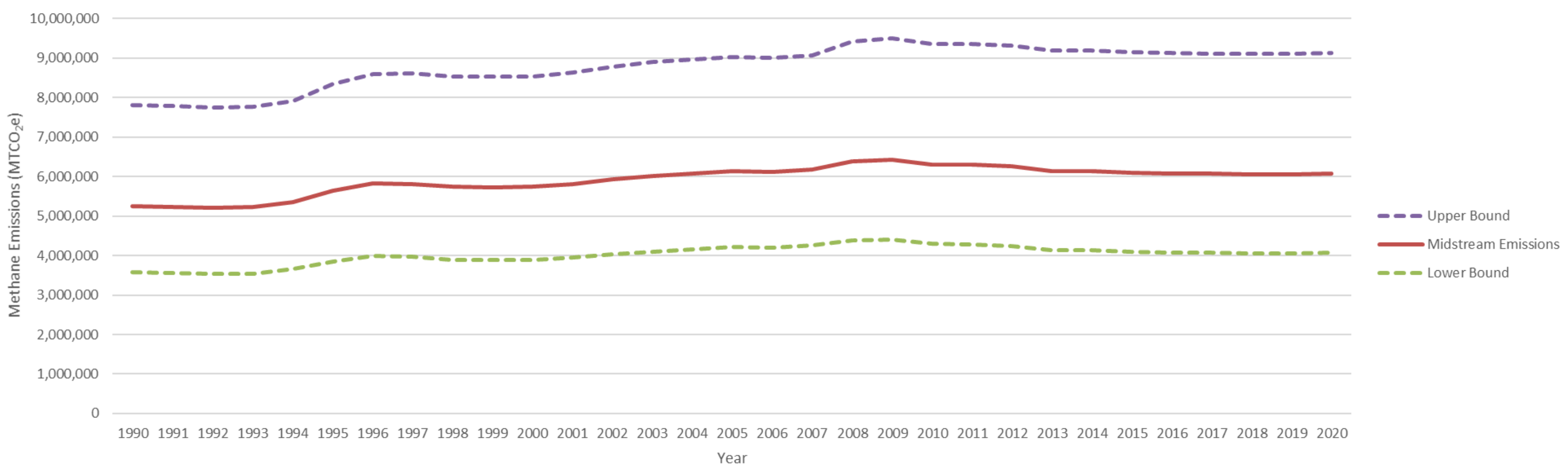
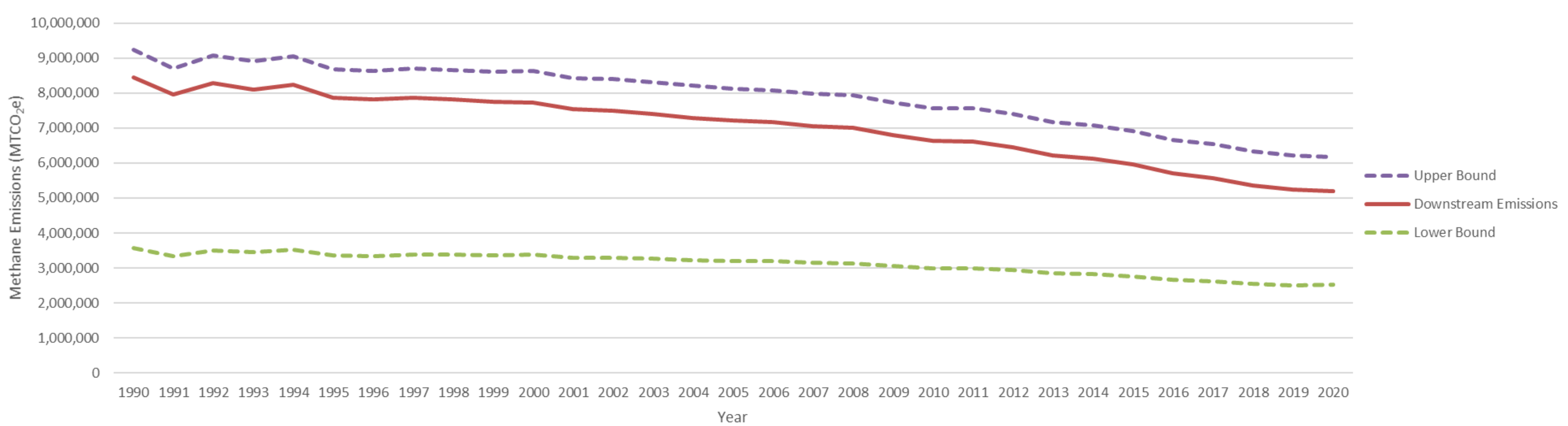


Figure 16. Downstream Emissions including Upper and Lower Bounds (AR5 GWP_{20})



4.7 Comparing AR4 and AR5 Emissions Estimates

As discussed in section 2.3, methane is a short-lived climate pollutant with a lifetime of approximately 12 years and selection of alternate GWPs depending on AR4 or AR5, and short-term or long-term climate effects, can yield markedly different results. The CH_4 emissions estimates presented throughout this report are the AR5 GWP_{20} estimates. Under AR4, GWP_{100} for CH_4 is 25, and GWP_{20} is 72. AR4 estimates from 2007 were updated in 2014 in IPCC's AR5, which increased the GWP_{100} to 28, and GWP_{20} to 84. Under AR6, GWP_{20} was decreased to 82.5 for fossil origin CH_4 and 80.8 for non-fossil origin CH_4 while GWP_{100} was changed to 29.8 for fossil CH_4 and 27.2 for non-fossil CH_4 (IPCC 2021). This section describes the 2018, 2019, and 2020 emissions estimated in the context of both AR4 and AR5 GWPs.

As shown in Table 18, changing the GWP from AR4 GWP_{100} to AR5 GWP_{20} increases CH_4 emissions from 3.74 $MMTCO_2e$ to 12.58 $MMTCO_2e$ for the oil and natural gas sector in 2018, from 3.75 $MMTCO_2e$ to 12.61 $MMTCO_2e$ in 2019, and from 3.71 $MMTCO_2e$ to 12.58 $MMTCO_2e$ in 2020.

Table 18. Comparison of AR4 and AR5 GWP_{100} and GWP_{20} Values Applied to the 2018, 2019, and 2020 Emissions from the Oil and Natural Gas Sector ($MTCO_2e$)

	AR4 GWP_{100}	AR4 GWP_{20}	AR5 GWP_{100}	AR5 GWP_{20}
CH_4 GWP (CO_2e)	**25**	**72**	**28**	**84**
2018 Oil and Gas CH_4 ($MMTCO_2e$)	3,744,730	10,784,823	4,194,098	12,582,293
2019 Oil and Gas CH_4 ($MMTCO_2e$)	3,753,499	10,810,076	4,203,919	12,611,756
2020 Oil and Gas CH_4 ($MMTCO_2e$)	3,708,353	10,680,057	4,153,356	12,460,067

5 Future Improvements

Emissions inventory development is a continuous process that requires making improvements as better data on emissions factors and emission source activity become available. In addition, as discussed in section 2.2, measurements of atmospheric methane concentration can be used to assess the completeness/accuracy of the emissions inventory. Below is a list of actions that NYS is currently taking to potentially improve future inventories:

- Continuing to review literature to identify new data on emissions factors and emission source activity.
- Identifying additional sources of methane emissions to include in the NYS oil and natural gas sector methane emissions inventory:
  - Residential refrigeration and clothes dryers.
  - Commercial buildings beyond restaurants and hospitals. Currently, data on methane leaks in other commercial buildings is lacking. The inventory does not currently use the data from restaurants and hospitals as a surrogate for other commercial buildings because it is thought that restaurants and hospitals will have a different emissions profile than office buildings and other commercial buildings. To understand the potential missing emissions, applying the average hospital/restaurant emissions factor to all other commercial buildings results in emissions of around 1 million $MTCO_2e$ (AR5, GWP20) or roughly 8% of the current 2020 inventory. However, this is likely an overestimate.
  - Industrial buildings.
- Investigating the impacts of cast iron pipeline reconditioning on emissions estimates from existing cast iron pipeline infrastructure.
- Assessing whether NYS's usage of a higher natural gas odorant concentration results in a larger number of leak detection and repairs in buildings, and therefore lower emissions, than states that require lower odorant concentrations.
- As data become available, comparing top-down measurements of methane emissions to the bottom-up inventory values to verify inventory and identify further areas for potential improvement.

6 Conclusions

On December 15, 2020, Governor Andrew M. Cuomo announced the finalization of regulations to reduce greenhouse gas emissions statewide and implement the Climate Leadership and Community Protection Act (Climate Act). Under the Climate Act, NYS has committed to reducing GHG emissions 40% by 2030 and 85% by 2050, from 1990 levels. While most efforts have focused on the reduction of carbon dioxide (CO_2) emissions, the dominant cause of the rise in global average temperature, NYS is now turning its attention to CH_4. Consequently, there is a need to better understand CH_4 emissions from the oil and natural gas sector so that NYS will be better positioned to create effective policies to achieve the GHG reduction commitments under the Climate Act.

The 2018–2020 inventories incorporate findings from the most current empirical research and utilize the most accurate, current, and inventory-appropriate available data sources. Methane emissions from oil and natural gas activity in NYS in 2019 totaled 12,611,756 $MTCO_2e$ (150,140 $MTCH_4$). Compared to the NYS 2017 oil and natural gas sector methane emission inventory, this 2018–2020 update estimates methane emissions in 2017 to be 44% higher (12,919,759 $MTCO_2e$) than the previous 2017 estimate (8,951,652 $MTCO_2e$ in 2017). This difference is primarily due to the pipeline EF updates and the addition of beyond the meter source categories (residential appliances, residential buildings, and commercial buildings) and less due to changes in activity data.

Largely driven by decreases in high-producing well activity, and transition away from more leak-prone cast iron and unprotected steel pipelines to plastic, results from this inventory show that, despite an increase in natural gas consumption, the trend in total CH_4 emissions has continued to decline since 2007, with an average annual decrease of 2.2% per year. This trend agrees with observed large-scale nationwide energy shifts. The largest methane emissions source categories identified in the 2019 NYS inventory include: transmission compressor stations (3.602 $MMTCO_2e$ or 28.6% CH_4 emissions in the oil and natural gas sector); natural gas storage compressor stations (1.850 $MMTCO_2e$ or 14.7%); cast iron distribution pipeline mains (1.138 $MMTCO_2e$ or 9.0%); unprotected steel distribution pipeline mains (1.046 $MMTCO_2e$ or 8.3%); unprotected steel distribution pipeline services (0.957 $MMTCO_2e$ or 7.6%); low producing conventional gas wells (0.803 $MMTCO_2e$ or 6.4%); and residential buildings (0.457 $MMTCO_2e$ or 3.6%).

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