Pennsylvania Greenhouse Gas Inventory Report

2023

December 15, 2023

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Table of Contents

List of Figures and Tables

Figures

Tables

Executive Summary

In this inventory, the Pennsylvania Department of Environmental Protection (DEP) provides data on greenhouse gas (GHG) emissions in the state from 2005 to 2020 and tracks progress toward the GHG emission-reduction targets. The data provided in this report were primarily obtained from the United States Environmental Protection Agency (U.S. EPA) State Inventory Tool (SIT) and the U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks by State report, which disaggregates the national inventory emissions to the state level. Preliminary data for 2021 from United States Energy Information Administration (U.S. EIA) estimates have also been included.

Overall Key Findings:

- In 2020, net emissions decreased by **10.4% from 2019 levels.** Gross GHG emissions were **238.74 million metric tons of carbon dioxide equivalent (MMTCO$_2$e)** and net GHG emissions in 2020 were **213.94 MMTCO$_2$e**.
- Statewide net emissions **decreased 25.9% from 2005 baseline**. While Pennsylvania is on track to achieve the 26% by 2025 GHG emissions reduction goal, this achievement is likely fleeting and not durable, as the temporary impacts from the COVID-19 pandemic on the economy appear to be a main driver of the decrease.
- The sectors with the **largest contribution** to the Commonwealth's GHG emissions are the **industrial, electricity production, and transportation sectors accounting for 82%** of all gross GHG emissions in 2020.

This report provides an overview of key emission trends by sector and further analysis within each sector. In 2020, most sectors experienced a decrease in emissions compared to 2019. As shown in Table 1 below, the transportation, commercial and industrial sectors experienced the largest decreases from the prior year; however, these decreases were likely influenced by less economic and transportation activity during the COVID-19 pandemic. In comparison to the baseline 2005 emissions levels, the electricity production sector continues to reduce emissions year over year primarily due to generation fuel sources switching from coal to natural gas. Despite reductions in 2020 from 2019 both industrial and agriculture sector emissions are still higher than at the 2005 baseline.

The 2020 GHG emission data were in some cases skewed by the COVID-19 pandemic and resulted in unexpected major emissions decreases. Recent energy generation, use, and emissions indicators point to potential increases in the emissions reported in this inventory report as the economy rebounds from the pandemic. The 2021 and 2022 GHG Emissions Inventories will likely be a truer measurement from which to assess progress toward Pennsylvania's 26% by 2025 emissions goal.

Table 1 – Summary of Key Emissions Trends

	2020 Emissions		% Change from 2019		% Change from 2005
Residential	18.14	⬇	-8.9%	⬇	-25.2%
Commercial	10.76	⬇	-10.1%	⬇	-17.1%
Industrial	73.56	⬇	-9.7%	⬆	5.1%
Transportation	52.25	⬇	-13.7%	⬇	-26.2%
Electricity Production	70.22	⬇	-6.8%	⬇	-44.4%
Agricultural	9.37	⬇	-6.9%	⬆	13.8%
Waste Management	4.25	⬆	0.6%	⬇	-20.5%
Forestry and Land Use Non-CO_2 Emissions	0.19	⬇	-0.1%	⬇	110.6%
Total Gross Emissions	**238.74**	⬇	**-9.5%**	⬇	**-24.9%**
Forestry and Land Use Net Carbon Flux	-24.79	⬇	-0.5%	⬇	-15.6%
Total Net Emissions	**213.94**	⬇	**-10.4%**	⬇	**-25.9%**

Table Key: ⬇ = Decrease in emissions; ⬆ = Increase in emissions

Greenhouse Gas Inventory Overview

Global climate is changing due to increased concentrations of greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), and Nitrous Oxide (N_2O) in Earth's atmosphere during the last century.[1] Pennsylvania's Climate Impacts Assessment[2] projects that the average annual temperature in Pennsylvania will increase 5.9°F by midcentury from the baseline period (1971-2000), and average annual precipitation will increase by 8% over the same timeframe. The Climate Impacts Assessment provides details on how these changes impact Pennsylvanians. These changes in GHG concentrations and global climate have been linked to human activities and are long-lasting, as most GHGs take decades to break down and leave the atmosphere.

The Pennsylvania Climate Change Act (Act 70 of 2008, or Act) requires the DEP to:

- Administer a Climate Change Advisory Committee;[3]
- Set up a voluntary registry of GHG emissions;[4]
- Prepare a Climate Change Impacts Assessment and provide an update once every three years;
- Prepare a Climate Change Action Plan[5] and provide an update once every three years; and
- Develop an inventory of GHGs and update this inventory annually.

[1] Intergovernmental Panel on Climate Change (IPCC). 2023. AR 6 Synthesis Report. https://www.ipcc.ch/report/ar6/syr/.

[2] Pennsylvania Department of Environmental Protections (DEP). 2021. Pennsylvania Climate Impacts Assessment. www.depgreenport.state.pa.us/elibrary/GetDocument?docId=3667348&DocName=PENNSYLVANIA CLIMATE IMPACTS ASSESSMENT 2021.PDF.

[3] DEP. 2023. Climate Change Advisory Committee (CCAC) Home Page. Accessed 20 October 2023. https://www.dep.pa.gov/Citizens/climate/Pages/CCAC.aspx.

[4] The Climate Registry. Website Home Page. Accessed 20 October 2023. https://www.theclimateregistry.org/.

[5] DEP. 2021. Pennsylvania Climate Action Plan. https://www.dep.pa.gov/citizens/climate/Pages/PA-Climate-Action-Plan.aspx.

Greenhouse gas emissions data presented in this inventory help track overall emissions trends over time. Executive Order 2019-01 sets GHG emissions reduction goals at 26% by 2025 from 2005 levels and 80% by 2050 from 2005 levels. The year 2005 is used as a reference point for emissions reductions to maintain consistency with goals set forth in the Paris Climate Agreement. As of 2020, Pennsylvania has achieved a 25.9% reduction in net GHG emissions compared to 2005. While this significant emissions reduction in 2020 nearly achieves the 2025 emissions reduction goal, this reduction was likely partially driven by the impacts from the COVID-19 pandemic and may not be durable. In the national 2021 Inventory of U.S. Greenhouse Gas Emissions and Sinks, overall nationwide emissions increased by 5.2% between 2020 and 2021 - driven by economic activity rebounding after the height of the COVID-19 pandemic.[6] Pennsylvania's emissions, significantly reduced in 2020, will likely follow a similar pattern to the national trend with expected increases in emissions in 2021 from 2020 levels. Even if the reductions seen in 2020 are durable, an additional reduction of 156.22 MMTCO_2e is needed to reach the 2050 goal. This underscores the need for more and continued policies aimed at reducing Pennsylvania's GHG emissions.

PA GHG Emissions Reduction Goals

26% below 2005 levels by 2025

80% below 2005 levels by 2050

Pennsylvania has several sectors which contribute to GHG emissions, and each of these sectors has undergone fluctuations in GHG emissions since the year 2005. Changes in the amount and type of fuel consumption, growth and contraction in the economy, and changing weather patterns (i.e., increased average temperatures heatwaves) that influence energy use all have a role in the trends observed in the Commonwealth's GHG emissions.

GHG Inventory Summary

Key Findings:

- Gross GHG emissions were **238.74 MMTCO_2e** and net GHG emissions in 2020 were **213.94 MMTCO_2e** (Table 2). This represents a decrease of **24.95 MMTCO_2e** or **10.4%** from 2019 levels.
- Pennsylvania's forestry and land use sector was a net carbon sink, absorbing **24.79 MMTCO_2e** in 2020.
- Statewide **net emissions decreased 25.9% relative and gross emissions decreased 24.9% to Pennsylvania's 2005 baseline**. While Pennsylvania is on track to achieve the 26% by 2025 GHG emissions reduction goal, this achievement is likely fleeting and not durable, as the temporary impacts from the COVID-19 pandemic on the economy appear to be a main driver of the decrease.
- The sectors with the **largest contribution** to the Commonwealth's GHG emissions are the **industrial, electricity production, and transportation sectors, accounting for 82%** of all gross GHG emissions in 2020 (Figure 1). Electricity production emissions decreased 44.4%, industrial sector emissions increased 5.1%, and transportation sector emissions decreased 26.2% between 2005 and 2020.
- The industrial sector emissions had slightly declined between 2005 to 2015, however, the sector had been trending upward between 2016 and 2019. In 2020, there was a **decrease** that may have resulted from COVID-19 related disruptions and therefore likely will increase in upcoming years and revert to previous trends.
- Residential and commercial sector emissions **decreased** between 2019 and 2020 and declined overall since 2005, by 25.2% and 17.1% respectively. Emissions from the commercial sector had trended upwards prior to 2020, however, they experienced a 10.1% decrease between 2019 and 2020, which may have been influenced by COVID-19 disruptions.
- Emissions from the agricultural sector **decreased slightly** between 2019 and 2020 but have **increased overall since 2005** by 13.8%.
- Waste management sector emissions **decreased** by 20.5% from 2005 and 2020.
- Forestry and land use sector emissions **decreased** 15.6% from 2005 and 2020.

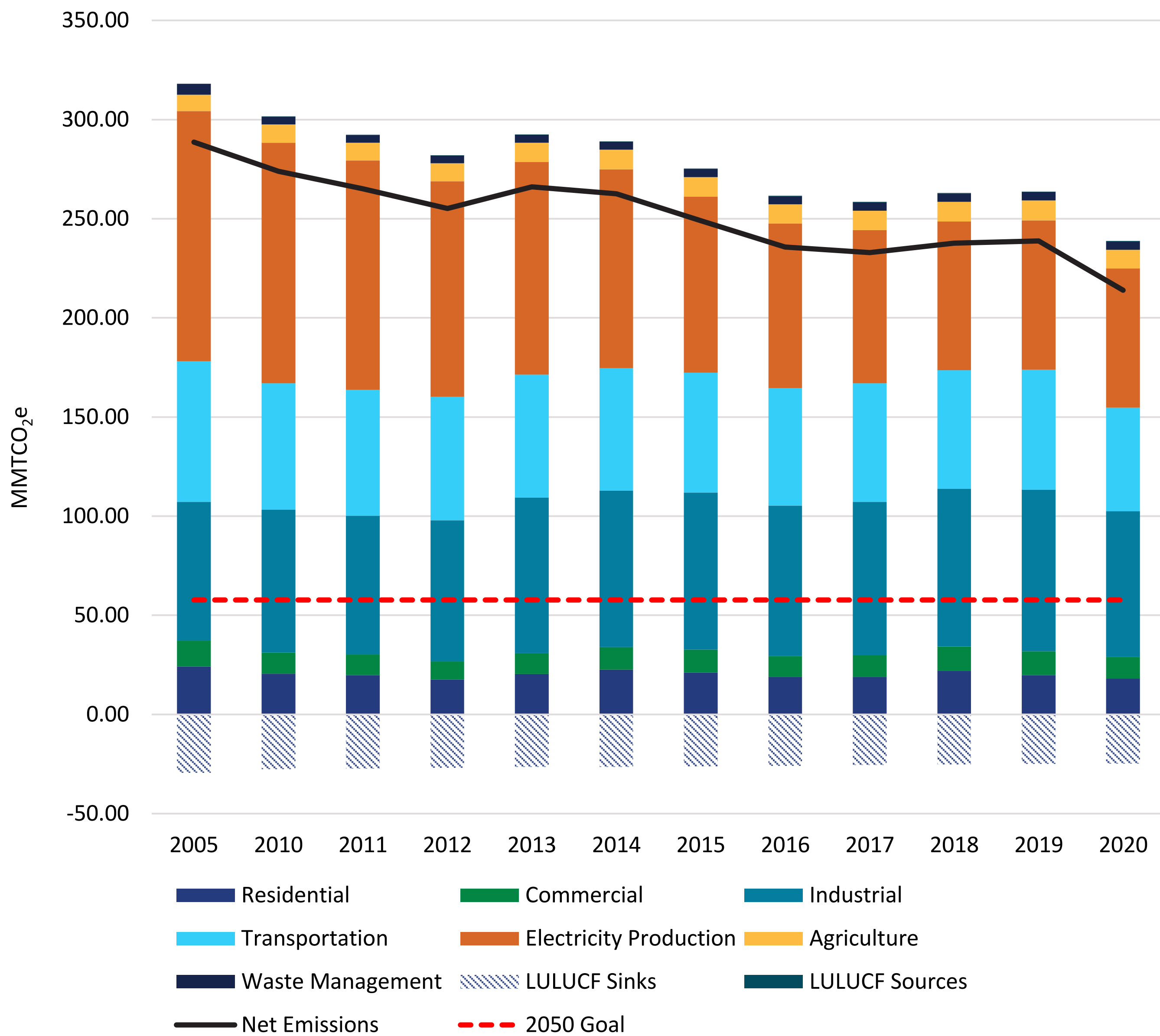
[6] U.S. Environmental Protection Agency (EPA). 2023. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021. U.S. Environmental Protection Agency, EPA 430-R-23-002. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-andsinks-1990-2021.

Table 2 – GHG Emissions by Sector (MMTCO2e)

Sector / Emission Sources ($MMTCO_2e$)	2005	2010	2015	2016	2017	2018	2019	2020
Residential	**24.25**	**20.58**	**21.15**	**18.81**	**18.86**	**22.07**	**19.91**	**18.14**
Commercial	**12.98**	**10.63**	**11.53**	**10.66**	**10.94**	**12.22**	**11.97**	**10.76**
Industrial	**69.97**	**72.00**	**79.25**	**75.86**	**77.35**	**79.62**	**81.48**	**73.56**
Combustion of Fossil Fuels	32.05	29.04	37.68	35.50	36.33	38.24	37.96	32.89
Industrial Process	14.18	13.61	13.33	13.17	12.85	12.64	13.13	12.86
Coal Mining and Abandoned Mines	11.56	14.27	12.06	11.15	12.05	12.58	14.13	11.62
Natural Gas and Oil Systems	12.18	15.07	16.18	16.05	16.12	16.15	16.27	16.20
Transportation	**70.84**	**63.74**	**60.41**	**59.33**	**59.83**	**59.66**	**60.55**	**52.25**
Petroleum	67.66	60.11	57.34	56.46	56.81	56.53	57.19	49.17
Natural Gas	1.71	2.63	2.42	2.25	2.45	2.59	2.79	2.62
Non-CO_2 Emissions	1.46	1.01	0.66	0.62	0.58	0.54	0.58	0.46
Electricity Production	**126.31**	**121.35**	**88.87**	**82.91**	**77.30**	**75.10**	**75.30**	**70.22**
Coal	117.14	106.95	63.98	54.87	47.99	44.77	38.07	24.53
Petroleum	4.20	0.51	0.45	0.25	0.22	0.58	0.16	0.08
Natural Gas	4.43	13.39	24.14	27.52	28.84	29.52	36.86	45.46
Non-CO_2 Emissions	0.55	0.50	0.31	0.27	0.24	0.23	0.21	0.15
Agriculture	**8.23**	**9.25**	**9.81**	**9.70**	**9.81**	**9.89**	**10.06**	**9.37**
Enteric Fermentation	3.68	3.75	3.74	3.84	3.91	3.92	3.71	3.57
Manure Management	1.72	1.99	2.26	2.36	2.32	2.41	2.41	2.35
Agricultural Soil Management	2.79	3.10	3.69	3.32	3.38	3.40	3.73	3.24
Liming of Soils	0.03	0.38	0.08	0.16	0.15	0.11	0.15	0.15
Urea Fertilization	0.02	0.03	0.04	0.04	0.05	0.05	0.06	0.06
Burning of Agricultural Crop Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forestry and Land Use	**0.09**	**0.12**	**0.22**	**0.28**	**0.23**	**0.21**	**0.19**	**0.19**
Non-CO_2 Emissions	0.09	0.12	0.22	0.28	0.23	0.21	0.19	0.19
Waste Management	**5.35**	**3.88**	**4.07**	**4.10**	**4.13**	**4.23**	**4.23**	**4.25**
Solid Waste and Combustion	3.70	2.16	2.32	2.35	2.36	2.46	2.47	2.47
Wastewater	1.64	1.72	1.75	1.75	1.77	1.76	1.76	1.78
Total Statewide Gross Emissions (Prod.)	**318.01**	**301.55**	**275.31**	**261.65**	**258.46**	**262.98**	**263.68**	**238.74**
Change relative to 2005		*-5.2%*	*-13.4%*	*-17.7%*	*-18.7%*	*-17.3%*	*-17.1%*	*-24.9%*
Forestry and Land Use Carbon Flux	**-29.38**	**-27.63**	**-26.25**	**-25.90**	**-25.55**	**-25.26**	**-24.91**	**-24.79**
Total Statewide Net Emissions (Prod w/ Sinks)	**288.63**	**273.93**	**249.06**	**235.75**	**232.91**	**237.73**	**238.77**	**213.94**
Change relative to 2005		*-5.1%*	*-13.7%*	*-18.3%*	*-19.3%*	*-17.6%*	*-17.3%*	*-25.9%*

Figure 1 displays the total contribution to the Commonwealth's GHG emissions for the residential, commercial, industrial, transportation, electricity production, agriculture, and waste management sectors.

Figure 1 – GHG Emissions by Sector ($MMTCO_2e$)



* LULUCF – Land Use, Land Use Change, and Forestry

Table 3, Figure 1, and Figure 2 present GHG emissions by gas in units of $MMTCO_2e$.

Table 3 – GHG Emissions by Gas ($MMTCO_2e$)

Emissions ($MMTCO_2e$)	2005	2010	2015	2016	2017	2018	2019	2020
Gross CO_2	275.81	253.57	228.16	215.82	211.65	215.48	214.34	192.83
Net CO_2	246.43	225.95	201.91	189.92	186.11	190.22	189.43	168.03
CO_2 from Fossil Fuel Combustion	263.90	243.28	218.00	205.72	201.85	205.83	204.27	183.08
Industrial Processes	10.28	8.47	8.42	8.24	7.93	7.71	8.09	7.75
Waste	1.58	1.43	1.61	1.67	1.68	1.78	1.78	1.78
Agriculture	0.05	0.40	0.12	0.19	0.20	0.16	0.21	0.22
LULUCF	-29.38	-27.63	-26.25	-25.90	-25.55	-25.26	-24.91	-24.79
Natural Gas and Oil Systems	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CH_4	32.53	37.24	36.49	35.60	36.58	37.28	38.69	35.88
Stationary Combustion	0.39	0.44	0.53	0.46	0.46	0.53	0.50	0.44
Mobile Combustion	0.14	0.10	0.07	0.07	0.07	0.06	0.07	0.06
Coal Mining	11.56	14.27	12.06	11.15	12.05	12.58	14.13	11.62
Natural Gas and Oil Systems	12.17	15.07	16.18	16.05	16.11	16.15	16.27	16.20
Agriculture	4.87	5.22	5.43	5.61	5.65	5.74	5.54	5.34
LULUCF	0.05	0.08	0.15	0.20	0.16	0.14	0.12	0.12
Waste	2.04	0.68	0.67	0.65	0.65	0.66	0.66	0.67
Wastewater	1.30	1.38	1.41	1.41	1.43	1.42	1.41	1.44
Industrial Processes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N_2O	5.92	5.74	5.91	5.45	5.45	5.44	5.75	5.07
Stationary Combustion	0.68	0.62	0.47	0.41	0.38	0.38	0.34	0.27
Mobile Combustion	1.32	0.91	0.59	0.55	0.51	0.48	0.51	0.40
Industrial Processes	0.16	0.15	0.15	0.15	0.15	0.15	0.14	0.15
Agriculture	3.31	3.62	4.25	3.90	3.96	3.99	4.32	3.82
LULUCF	0.03	0.04	0.07	0.08	0.07	0.07	0.07	0.07
Waste	0.09	0.06	0.04	0.03	0.03	0.03	0.03	0.03
Wastewater	0.34	0.34	0.34	0.34	0.34	0.35	0.34	0.34
HFC, PFC, SF_6 and NF_3 Emissions	3.74	4.99	4.75	4.78	4.77	4.79	4.89	4.95
Industrial Processes	3.74	4.99	4.75	4.78	4.77	4.79	4.89	4.95
Indirect CO_2 from Electricity Consumption*	89.46	84.58	64.65	59.36	55.83	55.72	52.80	46.68
Gross Emissions	**318.01**	**301.55**	**275.31**	**261.65**	**258.46**	**262.98**	**263.68**	**238.74**
Sinks	**-29.38**	**-27.63**	**-26.25**	**-25.90**	**-25.55**	**-25.26**	**-24.91**	**-24.79**
Net Emissions (Sources and Sinks)	**288.63**	**273.93**	**249.06**	**235.75**	**232.91**	**237.73**	**238.77**	**213.94**

* Emissions from Electricity Consumption are not included in totals in order to avoid double counting with Fossil Fuel Combustion estimates.

Note: Totals shown here are slightly different than totals shown in Table 2 due to differences in accounting and rounding.

The vast majority of GHG emissions are comprised of CO_2 resulting from the combustion of fossil fuels including coal, petroleum products, and natural gas. In total, CO_2 comprises 83% of GHG emission, in terms of $MMTCO_2e$, followed by CH_4 at 13% (Figure 2). CO_2 has also seen the greatest reduction of GHGs (Figure 3), which is primarily due to a decrease in emissions from fossil fuel combustion. Sources of other GHGs have remained relatively stable from 2005 to 2020.

Figure 2 – GHG Emissions by Gas, 2020 ($MMTCO_2e$)

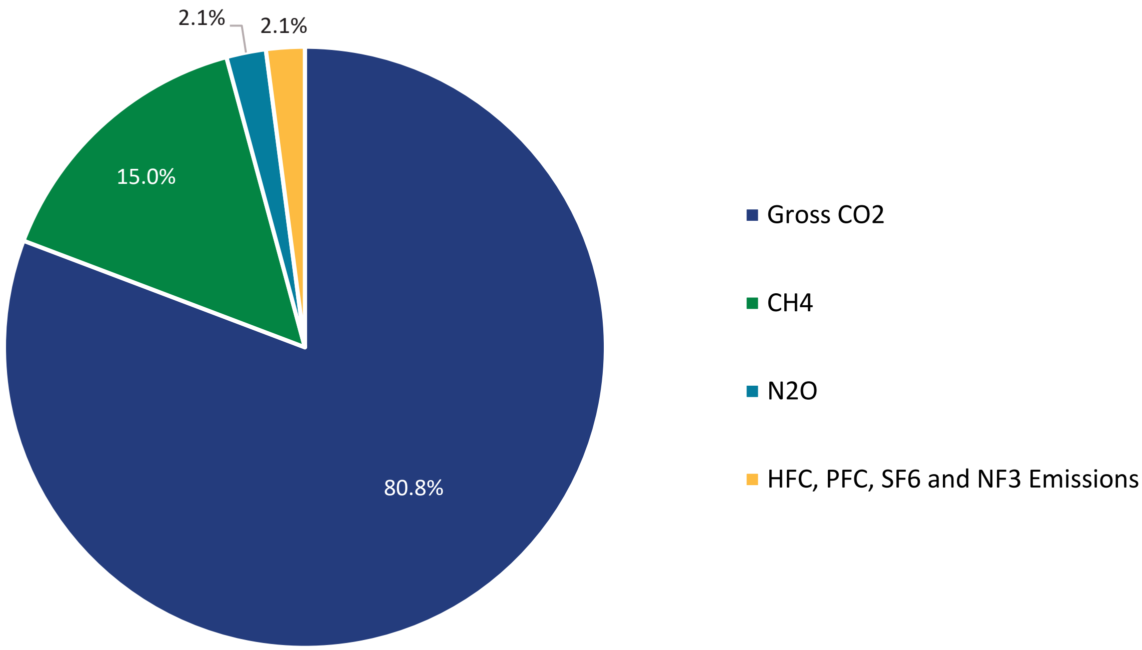
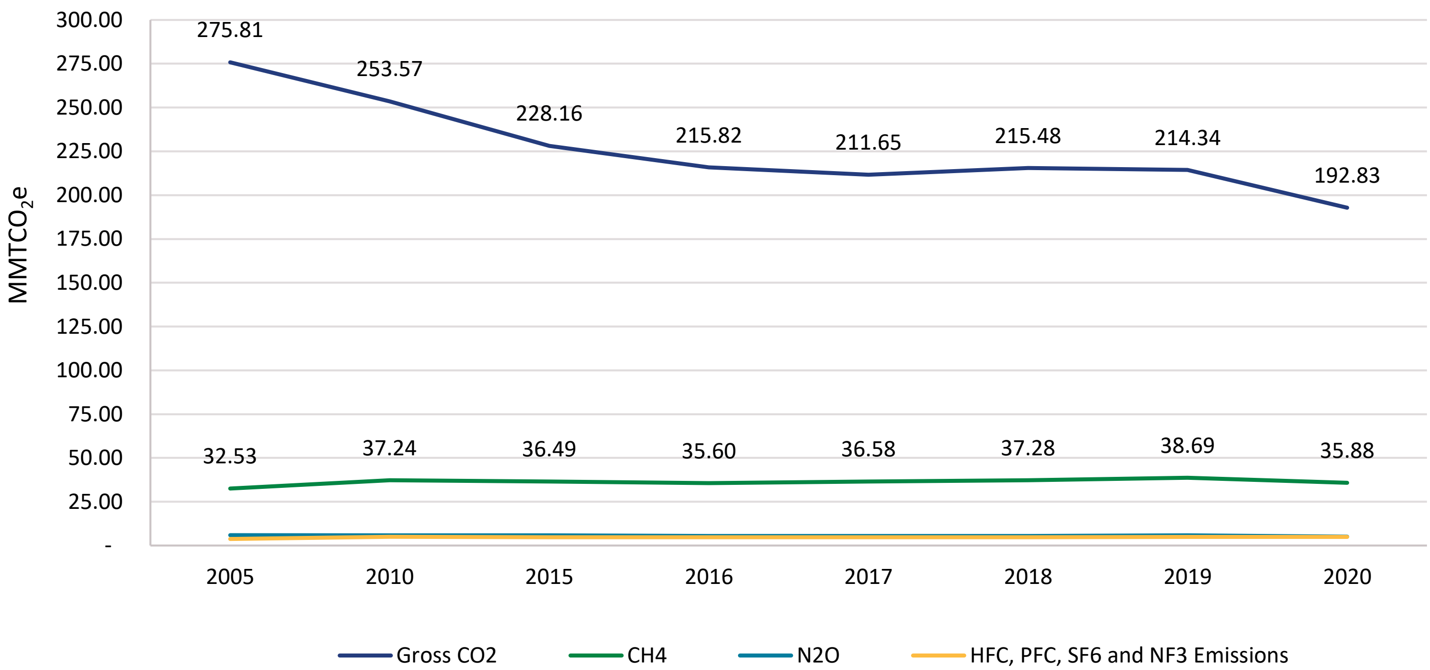


Figure 3 – GHG Emissions by Gas, 2005-2020 ($MMTCO_2e$)



Greenhouse Gas Emissions by Sector

Residential Sector

In 2020, emissions from the residential sector were 18.14 $MMTCO_2e$. Table 4 shows greenhouse gas emissions from this sector by fuel type.

Table 4 – Residential Sector GHG Emissions by Fuel Type ($MMTCO_2e$)

Fuel Type	2005	2010	2015	2016	2017	2018	2019	2020
Coal	0.13	-	-	-	-	-	-	-
Petroleum	10.42	8.01	7.73	6.63	6.50	7.81	6.55	5.68
Natural Gas	13.56	12.34	13.11	11.93	12.11	13.94	13.05	12.21
Other	0.14	0.23	0.31	0.25	0.25	0.32	0.30	0.26
Total	**24.25**	**20.58**	**21.15**	**18.81**	**18.86**	**22.07**	**19.91**	**18.14**

The emissions attributed to the residential sector result from fuels combusted to provide heat and hot water to residential homes within the Commonwealth. These fuels, in order of decreasing use in 2020, are natural gas, heating oil, propane, and kerosene. Table 5 shows the amount of each fuel used (BBtu, or billion British thermal units) in residential homes within the Commonwealth. Several factors influence the amount of a fuel being used, including the severity of the weather, efficiency of the heating or hot water system, and the price and availability of a particular fuel. Fuel consumption decreased in 2020 relative to 2019. No electricity consumption is included in these values.

Table 5 – Residential Sector Fuel Consumption by Year (BBtu)

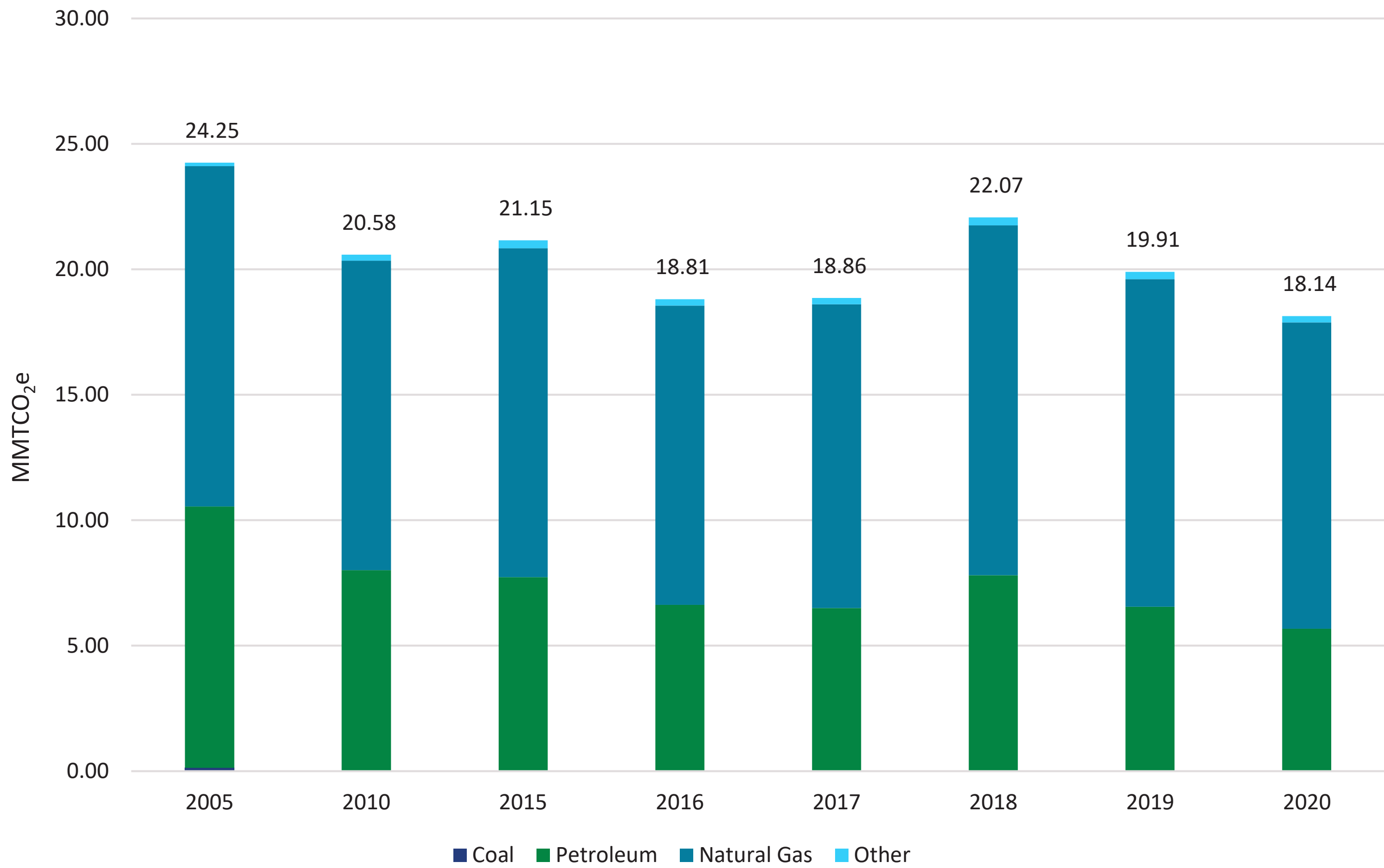
Fuel Type	2005	2010	2015	2016	2017	2018	2019	2020	2021[7]
Coal[8]	1,253	-	-	-	-	-	-	-	-
Heating Oil	115,753	85,432	86,789	73,049	71,250	86,087	66,666	59,300	74,997
Kerosene	10,330	4,211	1,350	1,513	921	930	1,056	1,000	1,060
Propane	15,122	20,812	18,230	16,909	17,668	20,768	23,752	18,625	18,812
Natural Gas	255,038	231,854	247,059	224,764	228,190	262,667	245,940	230,053	235,221
Other	-	-	-	-	-	-	-	-	
Total	**397,496**	**342,309**	**353,428**	**316,235**	**318,029**	**370,452**	**337,414**	**308,978**	**330,090**

Each fuel used in residential homes emits GHGs at different rates. Emissions from this sector were calculated in the SIT CO_2FFC module by multiplying the total fuel consumption for each fuel type by the emissions factor for that fuel type. Non-CO_2 emissions (e.g., CH_4 and N_2O) produced during fuel combustion were calculated in the SIT Stationary Combustion Module.

Figure 4 shows the GHG emission ($MMTCO_2e$) attributed to each fuel used in the residential sector. The emissions related to electricity use for residential homes using electricity for heating or cooling purposes are accounted for in the electricity production sector.

[7] 2021 data were compiled from U.S. Energy Information Administration's State Energy Data System (SEDS), released 6/23/2023. 2021 data are not available for all sectors presented in this inventory and will be presented in full in the 2024 Pennsylvania Greenhouse Gas Inventory Report.
[8] The U.S. Energy Information Administration, which is the source of default fuel consumption data used in the SIT, assumes that coal use for residential heating is zero from 2008 on.

Figure 4 – Residential Sector GHG Emissions by Fuel Type ($MMTCO_2e$)



Commercial Sector

In 2020, emissions from the commercial sector were 10.76 $MMTCO_2e$. Table 6 shows greenhouse gas emissions from this sector by fuel type.

Table 6 – Commercial Sector GHG Emissions by Fuel Type ($MMTCO_2e$)

Fuel Type	2005	2010	2015	2016	2017	2018	2019	2020
Coal	1.39	0.45	0.19	0.10	0.06	0.03	0.03	0.02
Petroleum	3.55	2.33	2.84	2.61	2.75	3.02	2.98	2.52
Natural Gas	8.02	7.82	8.46	7.90	8.08	9.11	8.91	8.18
Other	0.02	0.03	0.05	0.05	0.05	0.05	0.04	0.05
Total	**12.98**	**10.63**	**11.53**	**10.66**	**10.94**	**12.22**	**11.97**	**10.76**

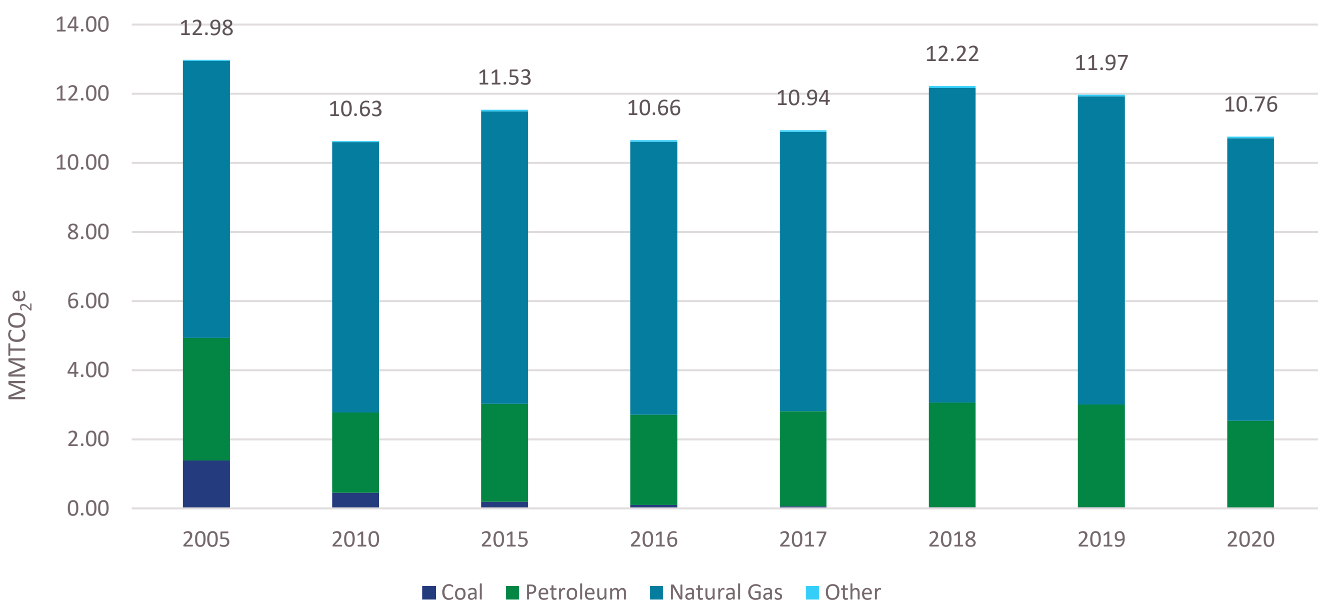
The emissions attributed to the commercial sector result from fuels that are combusted to provide heat and hot water to commercial buildings within the Commonwealth. These fuels, in order of decreasing use in 2020, are natural gas, motor gasoline, heating oil, propane, coal, and kerosene. Table 7 shows the amount of each fuel used (BBtu) in commercial buildings within the Commonwealth. Several factors will influence the amount of fuel being used, including the severity of the weather, efficiency of the heating or hot water system, and the price and availability of a particular fuel. No electricity consumption is included in these values.

Table 7 – Commercial Sector Fuel Consumption (BBtu)

	2005	2010	2015	2016	2017	2018	2019	2020	2021[9]
Coal	14,407	4,729	1,963	1,031	645	362	311	224	171
Heating Oil	35,632	23,625	18,765	15,272	17,907	20,328	19,943	13,707	18,203
Kerosene	2,610	755	144	222	143	179	217	176	166
Propane	5,480	6,853	7,829	8,135	7,225	8,409	8,019	7,966	8,367
Motor Gasoline[10]	462	428	13,062	13,142	13,331	13,533	13,620	13,724	14,910
Residual Fuel	3,934	570	53	127	3	5	-	-	3
Natural Gas	150,849	146,902	159,442	148,851	152,220	171,616	167,982	154,048	160,399
Other	-	-	-	-	-	-	-	-	-
Total	**213,374**	**183,862**	**201,258**	**186,780**	**191,474**	**214,432**	**210,092**	**189,845**	**202,219**

As in the residential sector, each fuel used in commercial buildings emits GHGs at different rates. Emissions from this sector were also calculated in the SIT CO_2FFC module by multiplying the total fuel consumption for each fuel type by the emissions factor for that fuel type. Non-CO_2 emissions (e.g., CH_4 and N_2O) produced during fuel combustion were calculated in the SIT Stationary Combustion Module. Figure 5 shows the GHG emissions ($MMTCO_2e$) attributed to each fuel used in the commercial sector. The emissions from burning firewood to heat commercial buildings are accounted for in the forestry and land use sector. The emissions related to electricity use for commercial buildings using electricity for heating or cooling purposes are accounted for in the electricity production sector.

Figure 5 – Commercial Sector GHG Emissions by Fuel Type ($MMTCO_2e$)



Industrial Sector

In 2020, emissions from the industrial sector were 73.56 $MMTCO_2e$. GHG emissions from the industrial sector differ from the residential and commercial sectors in that these emissions come from four separate subgroups: combustion of fossil fuels, industrial processes, activities involving coal mining and abandoned coal mines, and activities involving natural gas and oil systems. Within the four subgroups, combustion of fossil fuels consistently accounts annually for approximately half of the GHG emissions from the industrial sector.

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[9] 2021 data were compiled from U.S. Energy Information Administration's State Energy Data System (SEDS), released 6/23/2023. 2021 data are not available for all sectors presented in this inventory and will be presented in full in the 2024 Pennsylvania Greenhouse Gas Inventory Report.

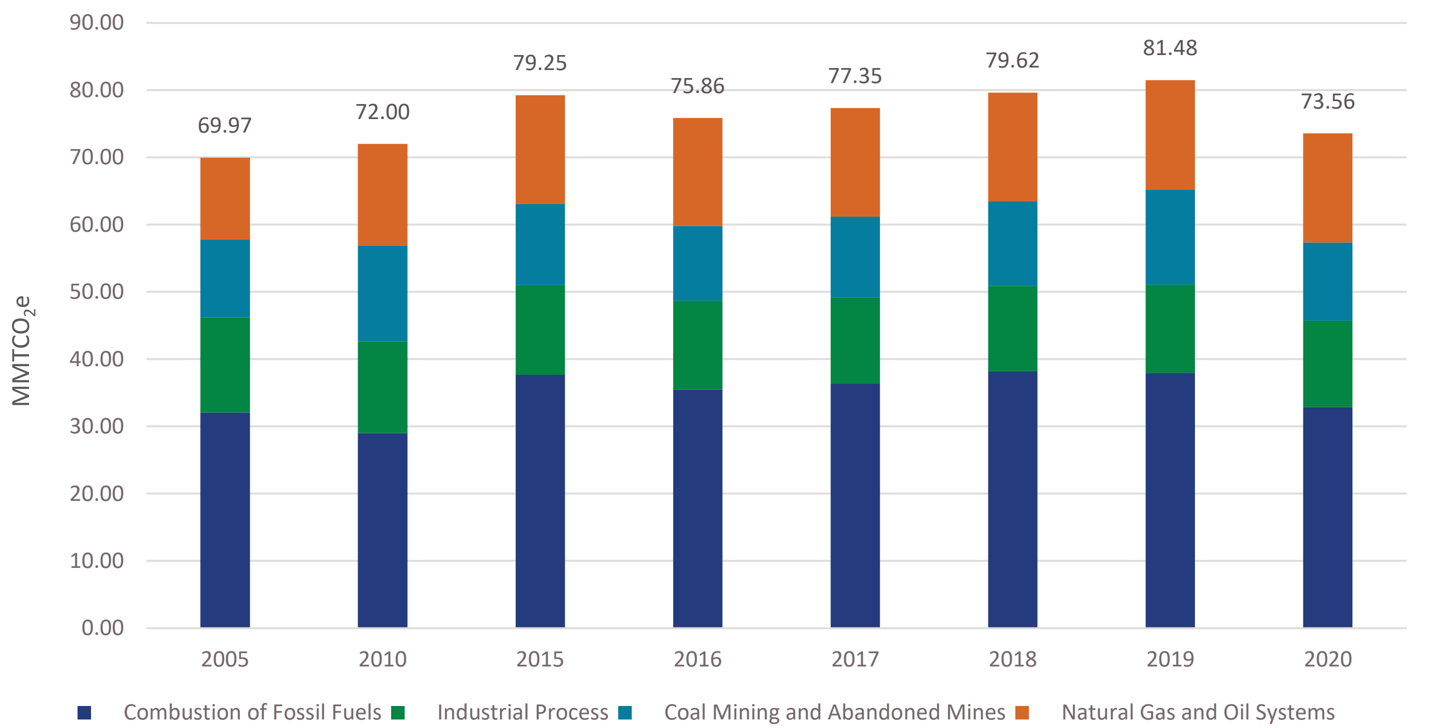
[10] Beginning in 2015, the Federal Highway Administration (FHWA) has revised its methods of estimating non-highway use of motor gasoline. Therefore, estimates for motor gasoline consumption by sector from 2015 forward are not compatible with data before 2015.

Table 8 shows greenhouse gas emissions from this sector by subgroup.

Table 8 – Industrial Sector GHG Emissions by Subgroup (MMTCO$_2$e)

	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Combustion of Fossil Fuels	32.05	29.04	29.50	31.32	35.61	37.17	37.68	35.50	36.33	38.24	37.96	32.89
Industrial Process	14.18	13.61	14.33	13.35	14.40	13.32	13.33	13.17	12.85	12.64	13.13	12.86
Coal Mining and Abandoned Mines	11.56	14.27	11.16	11.15	12.96	12.23	12.06	11.15	12.05	12.58	14.13	11.62
Natural Gas and Oil Systems	12.18	15.07	14.97	15.43	15.46	16.17	16.18	16.05	16.12	16.15	16.27	16.20
Total	**69.97**	**72.00**	**69.96**	**71.23**	**78.43**	**78.89**	**79.25**	**75.86**	**77.35**	**79.62**	**81.48**	**73.56**

Figure 6 – GHG Emissions from Industrial Sector by Source (MMTCO$_2$e)



Combustion of Fossil Fuels in the Industrial Sector

The emissions attributed to the industrial sector result from fuels combusted to heat and cool industrial buildings and equipment within the Commonwealth. These fuels, in order of decreasing use in 2020 are natural gas, coal/coke, heating oil, and various other fuels. In 2020, emissions from the combustion of fossil fuels in the industrial sector were 32.89 MMTCO2e.

Table 9 shows the amount of each fuel used (BBtu) in the industrial sector within the Commonwealth. Several factors will influence the amount of each fuel being used, including the severity of the weather, efficiency of the heating or cooling system, and the price and availability of a particular fuel.

Table 9 – Industrial Sector Fuel Consumption (BBtu)[11]

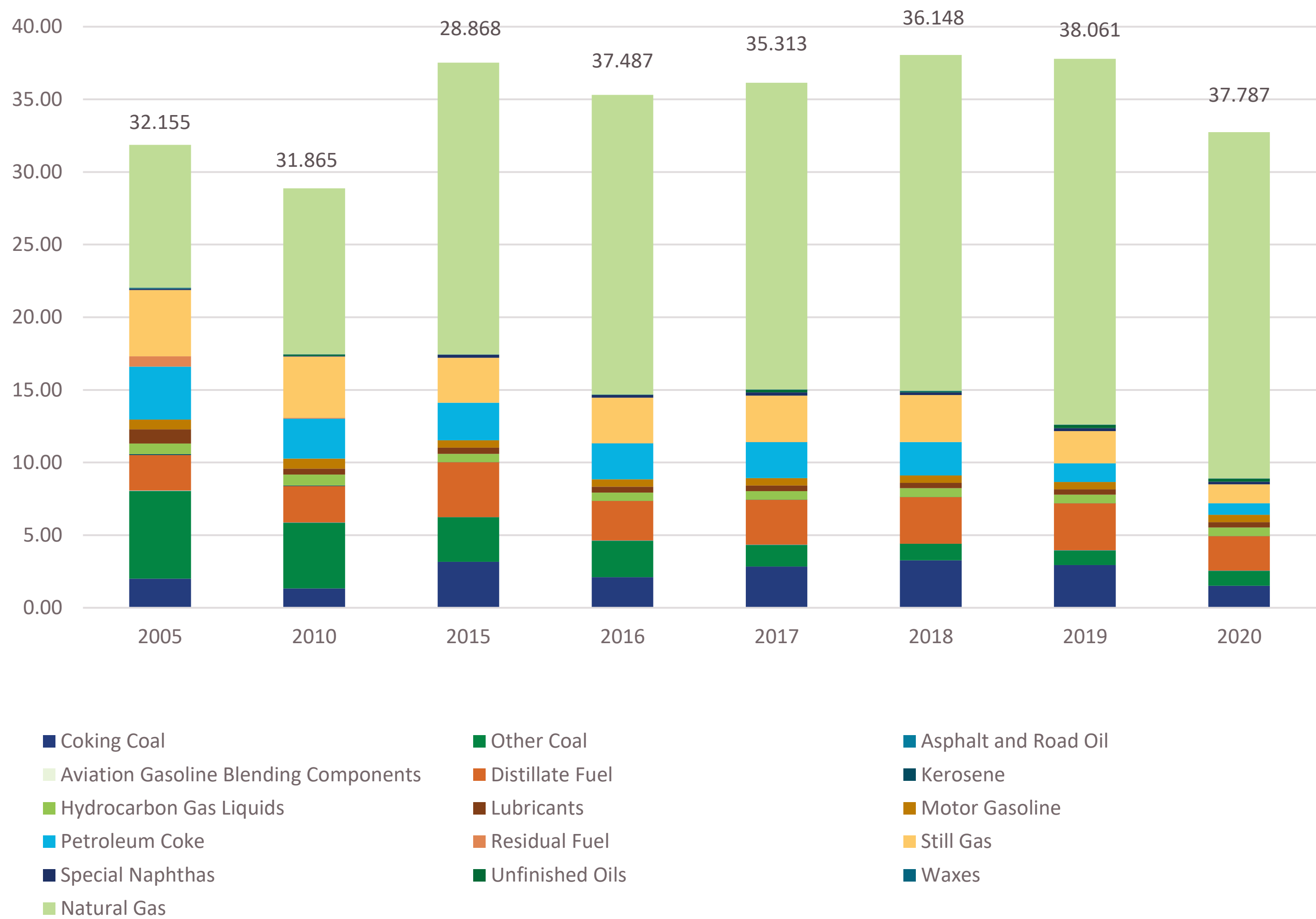
	2005	2010	2015	2016	2017	2018	2019	2020	2021[12]
Coking Coal	23,835	15,755	37,479	24,872	33,672	38,555	34,734	17,870	152,971*
Other Coal	63,541	47,710	32,165	26,410	15,551	11,940	10,518	10,769	11,624
Asphalt and Road Oil	60,964	46,840	47,228	46,510	47,515	43,561	45,301	37,252	42,158
Aviation Gasoline Blending Components	390	-11	-12	-9	-6	-50	-28	-12	-13
Crude Oil	-	-	-	-	-	-	-	-	-
Heating Oil	32,990	33,972	51,037	36,747	41,792	43,301	43,808	32,102	42,942
Feedstocks, Naphtha less than 401°F	-	-	-	-	-	-	-	-	-
Feedstocks, Other Oils greater than 401°F	-	-	-	-	-	-	-	-	-
Kerosene	663	281	68	82	58	79	63	60	62
Propane	22,823	29,624	20,722	21,166	20,819	21,164	20,711	21,922	6,519
Lubricants[13]	14,716	5,920	6,572	6,106	5,787	5,423	5,303	5,303	5,257
Motor Gasoline	9,486	9,712	7,055	7,004	7,079	7,163	7,150	7,211	7,648
Motor Gasoline Blending Components	-	-	-	-	-	-	-	-	-
Misc. Petro Products	1,493	1,795	2,508	2,540	2,593	2,582	2,349	2,226	2,227
Petroleum Coke	36,889	26,859	25,424	24,379	24,432	22,396	12,613	7,802	8,299
Pentanes Plus	-	-	-	-	-	-	-	-	-
Residual Fuel	9,551	920	-	31	33	-	-	-	564
Still Gas	70,200	67,173	49,515	50,075	51,235	51,797	35,455	20,781	22,566
Special Naphthas	3,265	1,653	6,891	6,496	6,883	6,314	6,559	5,937	5,572
Unfinished Oils[14]	131	1,276	-589	268	2,472	992	3,142	2,818	749
Waxes	1,871	894	722	751	625	764	641	566	725
Natural Gas	189,474	220,566	391,825	404,350	415,753	456,088	495,875	470,239	534,223
Other	-	-	-	-	-	-	-	-	-
Total	**542,282**	**510,940**	**678,609**	**657,778**	**676,293**	**712,069**	**724,195**	**642,845**	**844,093**

**The value from U.S. EIA represents total coking coal consumption, not industrial consumption of coking coal. This disaggregation will be done for the next GHG inventory.*

[11] Includes non-energy fuel consumption.
[12] 2021 data were compiled from U.S. Energy Information Administration's State Energy Data System (SEDS), released 6/23/2023. 2021 data are not available for all sectors presented in this inventory and will be presented in full in the 2024 Pennsylvania Greenhouse Gas Inventory Report.
[13] EIA's State Energy Data System (SEDS) modified the methodology for deriving lubricants consumption in data year 2016. Source: https://www.eia.gov/state/seds/seds-data-changes.php?sid=US#2016.
[14] Negative values represent storage of energy since oils are manufactured from other fuels. Negative emissions serve to correct the overestimation of emissions attributed to the parent fuel. Source: SIT.

As in the residential and commercial sectors, each fuel used in the industrial sector emits GHGs at different rates. Emissions from this sector were also calculated in the SIT CO_2FFC module by multiplying the total fuel consumption for each fuel type by the emissions factor for that fuel type. Non-CO_2 emissions (e.g., CH_4 and N_2O) produced during fuel combustion were calculated in the SIT Stationary Combustion Module. Figure 7 shows the GHG emissions ($MMTCO_2e$) attributed to each fuel used in the industrial sector. The emissions related to electricity within the industrial sector are accounted for in the electricity production sector.[15]

Figure 7 – Industrial Sector GHG Emissions by Fuel Type ($MMTCO_2e$)



Industrial Processes

Some of the industrial processes that are accounted for in this group include cement manufacturing, lime manufacturing, limestone and dolomite use, iron and steel production, substitutes for ozone-depleting substances (ODS), and electric power transmission and distribution systems. Emissions from these sources were estimated in the SIT Industrial Processes Module. Emissions from ferroalloy production, zinc production, carbon dioxide consumption, glass production, lead production, carbide production and consumption, caprolactam production, titanium dioxide production, petrochemical production, chlorodifluoromethane (HCFC-22) production, phosphoric acid production, and N_2O from production were estimated from the U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks by State report. Emissions from ferroalloy production, zinc production, carbon dioxide consumption, N_2O from product uses, glass production, lead production, carbide production and consumption were not included in previous inventories. Table 10 shows the GHG emissions ($MMTCO_2e$) attributed to each of the processes included within the industrial processes sector. In 2020, emissions from industrial processes were 12.86 $MMTCO_2e$.

[15] Values in this figure have changed from prior reports due to new SIT calculations.

Table 10 – Industrial Sector Process Emissions (MMTCO$_2$e)

	2005	2010	2015	2016	2017	2018	2019	2020
CO_2 Emissions								
Cement Manufacture	3.13	1.65	1.85	1.83	1.74	1.61	1.80	1.71
Lime Manufacture	0.85	0.85	0.73	0.69	0.62	0.65	0.71	0.64
Limestone and Dolomite Use	0.49	0.80	0.86	0.72	0.60	0.44	0.73	0.68
Soda Ash	0.11	0.09	0.08	0.08	0.08	0.08	0.08	0.07
Aluminum Production, CO_2	-	-	-	-	-	-	-	-
Iron & Steel Production	4.48	3.80	3.80	3.80	3.80	3.80	3.80	3.80
Ammonia Production	-	-	-	-	-	-	-	-
Urea Consumption	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Ferroalloy Production	0.18	0.24	0.45	0.50	0.51	0.57	0.38	0.29
Zinc Production	0.67	0.60	0.26	0.23	0.22	0.21	0.22	0.22
Carbon Dioxide Consumption	0.06	0.18	0.19	0.18	0.18	0.16	0.19	0.19
Glass Production	0.25	0.20	0.17	0.18	0.15	0.15	0.15	0.13
Lead Production	0.06	0.04	0.02	0.02	0.02	0.02	0.02	0.01
Carbide Production and Consumption	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caprolactam Production	-	-	-	-	-	-	-	-
Titanium Dioxide Production	-	-	-	-	-	-	-	-
Petrochemical Production	-	-	-	-	-	-	-	-
HCFC-22 Production	-	-	-	-	-	-	-	-
Phosphoric Acid Production	-	-	-	-	-	-	-	-
N_2O Emissions								
N_2O From Product Uses	0.16	0.15	0.15	0.15	0.15	0.15	0.14	0.15
CH_4 Emissions								
Ferroalloy Production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petrochemical Production	-	-	-	-	-	-	-	-
HFC, PFC, SF6 and NF3 Emissions								
ODS Substitutes	3.36	4.74	4.58	4.61	4.59	4.62	4.71	4.80
Semiconductor Manufacturing	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01
Magnesium Production	-	-	-	-	-	-	-	-
Electric Power Transmission and Distribution Systems	0.35	0.23	0.15	0.16	0.16	0.15	0.17	0.15
HCFC-22 Production	-	-	-	-	-	-	-	-
Aluminum Production, PFCs	-	-	-	-	-	-	-	-
Total	**14.18**	**13.61**	**13.33**	**13.17**	**12.85**	**12.64**	**13.13**	**12.86**

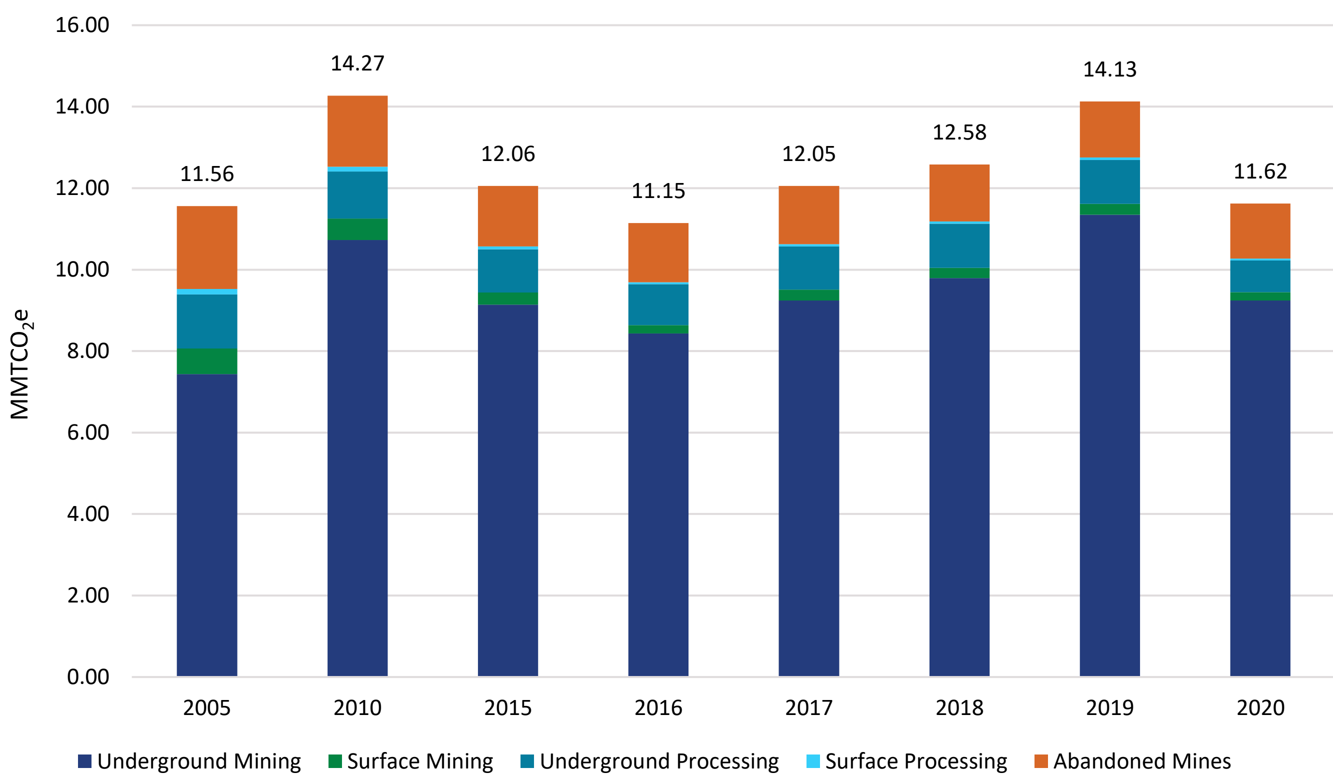
Coal Mining and Abandoned Coal Mines

In 2020, emissions from coal mining and related processes were 11.62 MMTCO$_2$e. The GHG emissions associated with underground and surface mining coal processing, and abandoned coal mines are accounted for in this section. Table 11 and Figure 8 show the GHG emissions (MMTCO$_2$e) attributed to underground and surface coal mining, coal processing, and abandoned underground mines.

Table 11 – CH_4 from Coal Mining-Related Process Emissions ($MMTCO_2e$)

	2005	2010	2015	2016	2017	2018	2019	2020
Underground Mining	7.44	10.73	9.14	8.43	9.24	9.79	11.35	9.24
Surface Mining	0.62	0.53	0.30	0.21	0.27	0.25	0.26	0.20
Underground Processing	1.33	1.16	1.07	1.01	1.06	1.08	1.08	0.78
Surface Processing	0.14	0.11	0.06	0.05	0.06	0.05	0.06	0.04
Abandoned Mines	2.04	1.75	1.49	1.46	1.43	1.40	1.37	1.35
Total	**11.56**	**14.27**	**12.06**	**11.15**	**12.05**	**12.58**	**14.13**	**11.62**

Figure 8 – CH4 from Coal Mining-Related Process Emissions ($MMTCO_2e$)



Emissions from coal mining and abandoned coal mines were calculated using the SIT Coal Module. Most emissions accounted for come from underground mining activity. The results are determined by measuring ventilation air from underground mines and applying emission factors for surface mines, abandoned mines, and coal processing.

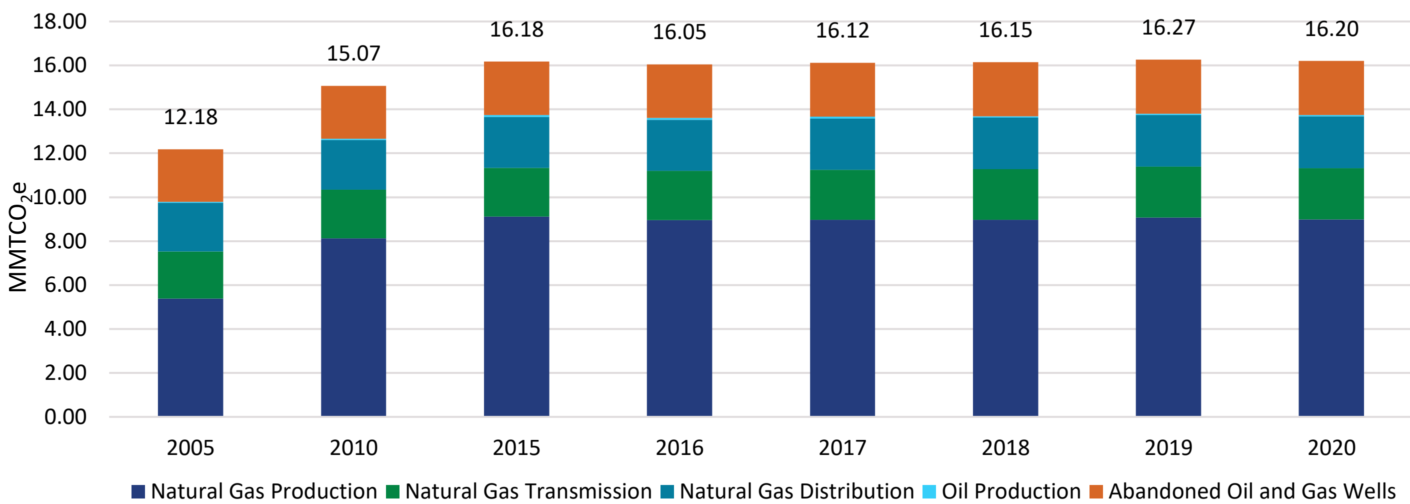
Natural Gas and Oil Systems

In 2020, emissions from natural gas and oil systems were 16.20 $MMTCO_2e$. Emissions from natural gas production, transmission, and distribution, oil production, and abandoned oil and gas wells are accounted for in this section and are shown in Table 12 and Figure 9.

Table 12 – CH_4 and CO_2 from Natural Gas Production Process Emissions ($MMTCO_2e$)

	2005	2010	2015	2016	2017	2018	2019	2020
Natural Gas Production	5.39	8.13	9.12	8.96	8.98	8.97	9.08	8.99
Natural Gas Transmission	2.14	2.21	2.22	2.24	2.27	2.31	2.32	2.34
Natural Gas Distribution	2.21	2.26	2.32	2.33	2.34	2.34	2.34	2.36
Oil Production	0.05	0.06	0.09	0.08	0.08	0.07	0.06	0.06
Abandoned Oil and Gas Wells	2.38	2.41	2.43	2.44	2.45	2.46	2.47	2.46
Total	**12.18**	**15.07**	**16.18**	**16.05**	**16.12**	**16.15**	**16.27**	**16.20**

Figure 9 – CH_4 and CO_2 from Natural Gas Production Process Emissions ($MMTCO_2e$)



Emissions from natural gas production, natural gas transmission, and natural gas distribution, and oil production were estimated using the SIT Natural Gas and Oil Module. In SIT, the total GHG emissions are determined based on the number of natural gas wells, miles of transmission pipeline, and number and types of services used for distribution in the Commonwealth.[16] The natural gas transmission data became available in 2001. An emission factor is also used to determine the GHG emissions based on the total oil production within the Commonwealth. Emissions from abandoned oil and gas wells are not estimated within SIT and were instead estimated from U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks by State report. The U.S. Inventory calculated emissions from abandoned oil and gas wells by estimating the number and type (plugged and unplugged) of abandoned oil and gas wells in each state using a combination of Enverus[17], a proprietary information regarding the oil and gas industry, and historical data, and multiplying the total count for each well type by its respective emissions factor. U.S. EPA established different emissions factors for wells in and outside of the Appalachia region due to their varied geographic qualities that impact the magnitude of leak rates. These well counts are estimates, and the uncertainty surrounding the number of abandoned oil and gas wells impacts the rigor of this analysis. More information about the methodology used to calculate emissions from oil and gas wells can be found tin the U.S. Inventory Methodology for Emissions Estimates by State.[18] Emissions from abandoned gas and oil wells were not included in previous inventories.

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[16] U.S. Department of Transportation (U.S. DOT) Pipeline and Hazardous Materials Safety Administration. 2023. Gas Distribution, Gas Gathering, Gas Transmission, Hazardous Liquids, Liquefied Natural Gas (LNG), and Underground Natural Gas Storage (UNGS) Annual Report Data. Last Updated 5 October 2023. https://www.phmsa.dot.gov/data-and-statistics/pipeline/gas-distribution-gas-gathering-gas-transmission-hazardous-liquids.

[17] https://www.enverus.com/

[18] EPA. 2022. Methodology Report: Inventory of U.S. Greenhouse Gas Emissions and Sinks by State: 1990–2020. U.S. Environmental Protection Agency, EPA 430-R-22-005. https://www.epa.gov/ghgemissions/state-ghg-emissionsand-removals

Transportation Sector

In 2020, emissions from the transportation sector were 52.25 $MMTCO_2e$. Table 13 shows greenhouse gas emissions from this sector by fuel type.

Table 13 – Transportation Sector Emissions by Fuel Consumption ($MMTCO_2e$)

Fuel Type	2005	2010	2015	2016	2017	2018	2019	2020
Coal	-	-	-	-	-	-	-	-
Petroleum	67.66	60.11	57.34	56.46	56.81	56.53	57.19	49.17
Natural Gas	1.71	2.63	2.42	2.25	2.45	2.59	2.79	2.62
Other	-	-	-	-	-	-	-	-
Non-CO_2 Emissions	1.46	1.01	0.66	0.62	0.58	0.54	0.58	0.46
Total	**70.84**	**63.74**	**60.41**	**59.33**	**59.83**	**59.66**	**60.55**	**52.25**

The emissions attributed to the transportation sector result from fuels combusted to provide transportation for various types of vehicles within the Commonwealth. In order of decreasing use in 2020, these fuels include gasoline, diesel, jet fuel, and natural gas (see Table 14). Several factors influence the amount of a fuel being used, such as the mode of transportation, efficiency of the vehicle, and the price and availability of a particular fuel. The emissions related to electricity use in transportation are accounted for in the electricity production sector.

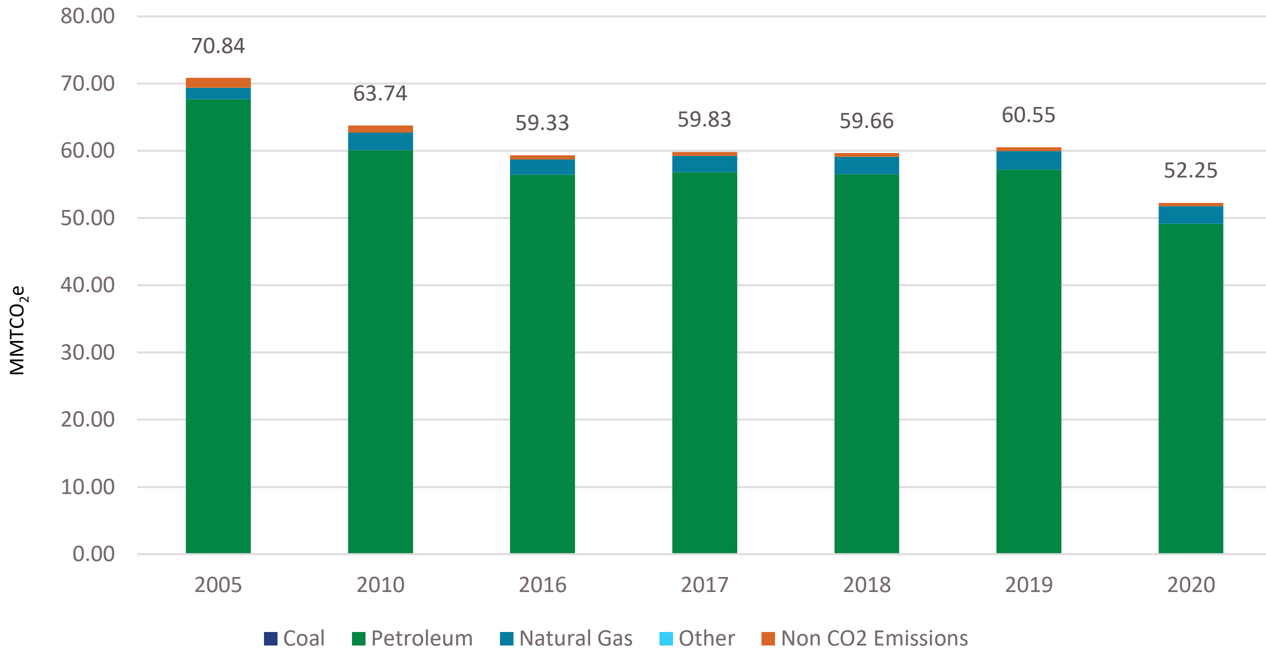
Table 14 – Transportation Sector Fuel Use (BBtu)

Fuel Type	2005	2010	2015	2016	2017	2018	2019	2020	2021
Aviation Gasoline	505	537	517	366	368	369	425	338	386
Diesel	225,678	208,177	214,410	198,257	198,552	210,825	214,525	203,729	199,697
Jet Fuel	95,404	69,561	69,271	70,357	72,639	74,608	77,595	44,795	52,689
Hydrocarbon Gas Liquids	755	94	222	240	575	345	257	92	398
Motor Gasoline	628,121	571,588	532,669	535,957	539,177	522,404	524,467	444,536	519,615
Residual Fuel	28,923	5,015	2,074	2,645	1,235	1,272	1,694	677	1,440
Natural Gas	32,312	49,517	45,700	42,547	46,208	48,893	52,681	49,479	55,374
Other	-	-	-	-	-	-	-	-	-
Total	**1,011,698**	**904,489**	**864,863**	**850,369**	**858,754**	**858,716**	**871,644**	**743,646**	**829,599**

As in the previous sectors, each fuel used in transportation will have different rates of GHG emissions. Emissions from this sector were calculated in the SIT CO_2FFC module by multiplying the total fuel consumption for each fuel type by the emissions factor for that fuel type. Non-CO_2 emissions (e.g., CH_4 and N_2O) produced during fuel combustion were calculated in the SIT Mobile Combustion Module.

Figure 10 shows the GHG emission ($MMTCO_2e$) attributed to each fuel used in the transportation sector.

Figure 10 – Transportation Sector Emissions by Fuel Consumption (MMTCO₂e)



Electricity Production Sector

In 2020, emissions from electricity production were 70.22 $MMTCO_2e$. Table 15 and Figure 11 show greenhouse gas emissions from this sector by fuel type.

Table 15 – Electricity Production Sector GHG Emissions by Fuel Type ($MMTCO_2e$)

Fuel Type	2005	2010	2015	2016	2017	2018	2019	2020
Coal	117.66	107.43	64.26	55.12	48.21	44.97	38.24	24.64
Petroleum	4.21	0.51	0.45	0.25	0.22	0.58	0.17	0.08
Natural Gas	4.43	13.40	24.16	27.55	28.87	29.55	36.90	45.50
Other	0.01	0.01	-	-	-	-	-	-
Total	**126.31**	**121.35**	**88.87**	**82.91**	**77.30**	**75.10**	**75.30**	**70.22**

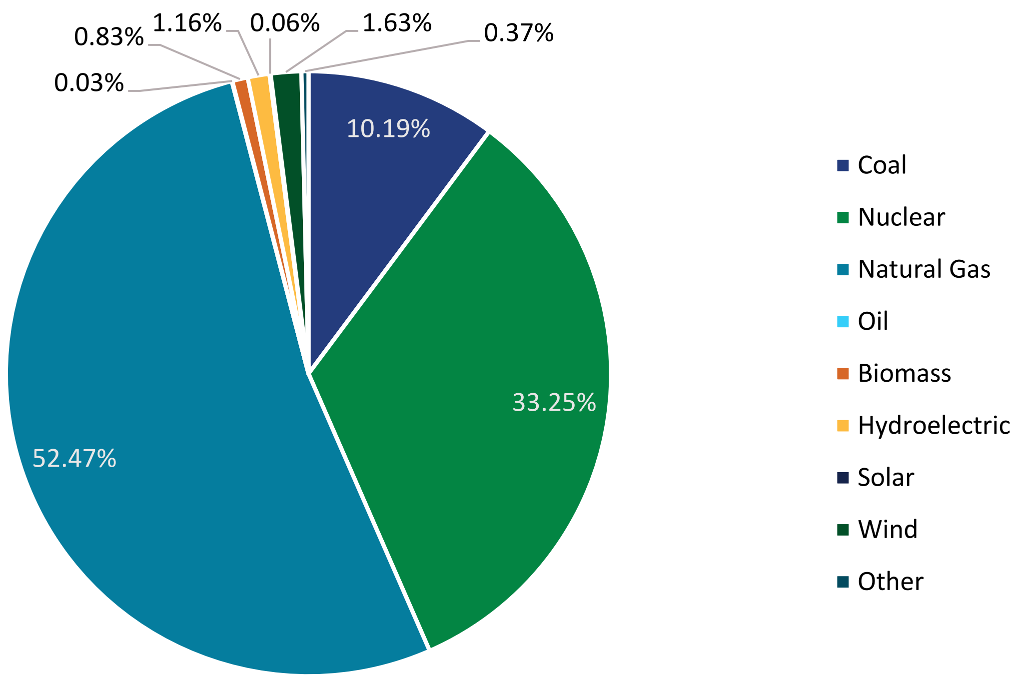
The emissions attributed to the electricity production sector result from fuels that are combusted to generate electricity within the Commonwealth. Electricity production is one of the largest contributors of GHG emissions in Pennsylvania. Twenty-nine percent of the statewide gross emissions in 2020 came from the electricity production sector; however, a sizable percentage of these emissions are associated with electricity that is produced and exported to meet the needs of surrounding states. Electricity is produced several different ways within the Commonwealth. The three primary forms of electricity generation in Pennsylvania are natural gas, nuclear, and coal.

The largest changes in the production of electricity since 2005 have occurred in the use of coal and natural gas. From 2019 to 2020, electricity generation from coal continued its decline from 16.6% of total generation to 10.2%, while electricity generation from natural gas increased from 42.8% of total generation to 52.5%. Table 16 and Figure 11 give the relative percentages of each fuel used to generate electricity in Pennsylvania.

Table 16 – Electricity Generation by Fuel Type (%)[19]

Fuel Type	2005	2010	2015	2016	2017	2018	2019	2020	2021
Coal	55.5%	48.0%	30.1%	25.4%	22.3%	20.5%	16.6%	10.2%	12%
Nuclear	35.0%	33.9%	37.5%	38.6%	39.0%	38.8%	36.3%	33.2%	31%
Natural Gas	5.0%	14.7%	27.7%	31.6%	33.9%	35.5%	42.8%	52.5%	52%
Oil	2.3%	0.2%	0.3%	0.2%	0.2%	0.3%	0.1%	0.0%	0%
Biomass	0.9%	1.0%	1.1%	1.1%	1.1%	1.1%	0.9%	0.8%	1%
Hydroelectric	1.0%	1.0%	1.2%	1.1%	1.5%	2.0%	1.5%	1.2%	1%
Solar	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0%
Wind	0.1%	0.8%	1.6%	1.6%	1.7%	1.7%	1.4%	1.6%	1%
Other	0.3%	0.3%	0.4%	0.3%	0.3%	0.3%	0.3%	0.4%	0%

Figure 11 – Electricity Generation by Type for 2020



Since electricity produced from nuclear fuel, hydroelectric, solar, and wind creates no direct GHG emissions, the primary fuels associated with GHG emissions from electricity production are coal and natural gas. Table 17 shows the amount of each of these fuels consumed (BBtu) for electricity generation in Pennsylvania.

[19] U.S. Energy Information Administration (U.S. EIA). 2023. Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923). Accessed March 2023. https://www.eia.gov/electricity/data/state/.

Table 17 – Fuel Use for Electricity Generation (BBtu)

Fuel Type	2005	2010	2015	2016	2017	2018	2019	2020	2021
Coal	1,224,911	1,119,758	669,244	574,070	501,784	467,959	398,101	256,047	320,427
Natural Gas	83,531	252,182	456,219	520,118	544,924	557,750	696,798	859,161	882,142
Oil	51,783	6,810	6,008	3,369	2,985	7,847	2,222	1,015	1,410
Electric Power Distillate Fuel	7,406	4,243	6,008	3,369	2,985	7,787	2,179	963	1,389
Electric Power Residual Fuel	44,377	2,567	-	-	-	60	43	52	21
Total	**1,360,225**	**1,378,750**	**1,131,471**	**1,097,557**	**1,049,693**	**1,033,556**	**1,097,121**	**1,116,223**	**1,203,979**

As in the previous sectors, each fuel used in electricity production emits GHGs at different rates. Emissions from this sector were also calculated in the SIT CO_2FFC module by multiplying the total fuel consumption for each fuel type by the emissions factor for that fuel type. Non-CO_2 emissions (e.g., CH_4 and N_2O) produced during fuel combustion were calculated in the SIT Stationary Combustion Module.

Figure 12 shows the GHG emission (MMTCO_2e) attributed to the three primary fossil fuels used in the electricity production sector. In 2020, emissions from natural gas-fired power plants surpassed emissions from coal-fired plants. While this fuel-switching has accelerated our emissions reduction to date, other strategies, like increased renewable energy generation, will be needed to continue to decrease emissions.

Figure 12 – Electricity Production Sector GHG Emissions by Fuel Type (MMTCO_2e)

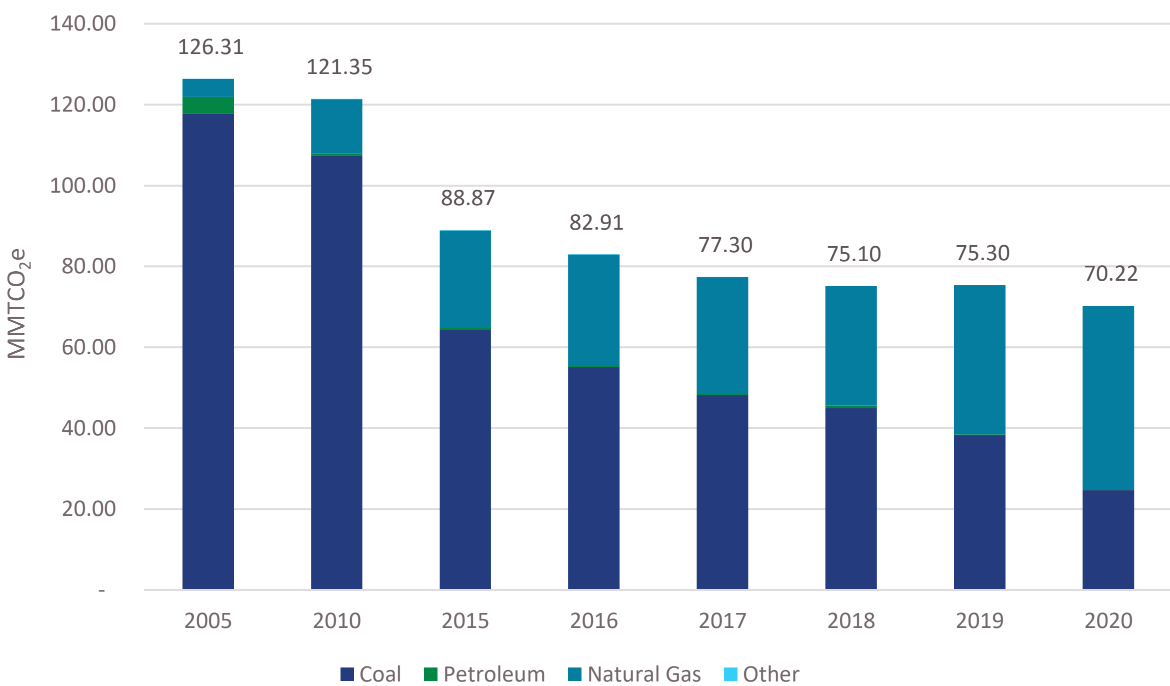


Table 18 gives the relative percentage of GHG emissions attributed to the three primary fossil fuels used in the electricity production sector.

Table 18 – Contribution to GHG Emissions, Fuel Type, in the Electricity Sector (%)

Fuel Type	2005	2010	2015	2016	2017	2018	2019	2020
Coal	93.1	88.5	72.2	66.4	62.3	59.8	50.7	35.0
Oil	3.3	0.4	0.5	0.3	0.3	0.8	0.2	0.1
Natural Gas	3.5	11.1	27.3	33.3	37.4	39.4	49.1	64.9

Table 18 shows for Pennsylvania's electricity generation by sector in 2020, coal produced 35.0% of the GHG emissions while producing 10.2% of the electricity. Natural gas produced 64.9% of the GHG emissions while producing 52.5% of the electricity. Nuclear fuel, which produces no GHG emissions, was responsible for generating 33.2% of the Commonwealth's electricity.

As has been noted in previous inventory reports, Pennsylvania has historically been, and is projected to remain, an exporter of electricity to neighboring states.

Table 19 shows the total consumption of electricity (TWh) within the residential, commercial, industrial, and transportation sectors.

Table 19 – Electricity Consumption by Sector (TWh)

	2005	2010	2015	2016	2017	2018	2019	2020	2021
Direct Use by Electricity Generation Sector	3.29	2.78	4.33	5.20	5.34	5.39	4.82	5.14	5.74
Residential	53.66	55.25	54.42	53.88	51.72	55.90	54.40	55.31	55.95
Commercial	45.78	47.37	43.75	43.54	42.62	43.22	40.14	35.38	36.99
Industrial	47.95	45.46	47.40	47.13	47.89	49.16	50.42	48.61	50.00
Transportation	0.88	0.89	0.78	0.79	0.75	0.70	0.62	0.43	0.41
Total	**151.56**	**151.75**	**150.67**	**150.53**	**148.33**	**154.37**	**150.40**	**144.86**	**149.09**

Table 20 presents the total amount of electricity (TWh) generated and consumed in Pennsylvania, as well as electricity exports. A small amount of electricity is lost during transmission or cannot be accounted for.

Table 20 – Electricity Generated, Consumed and Exported (TWh)

	2005	2010	2015	2016	2017	2018	2019	2020	2021
Electricity Generated	218.09	229.75	214.57	215.07	213.64	215.39	229.00	230.14	241.33
Electricity Consumed	151.56	151.75	150.67	150.53	148.33	154.37	150.40	144.86	149.08
Total electric industry retail sales	148.27	148.96	146.34	145.33	142.99	148.98	145.58	139.72	143.34
Direct use	3.29	2.78	4.33	5.20	5.34	5.39	4.82	5.14	5.74
Estimated Losses	9.91	9.20	7.30	7.58	7.78	7.68	7.89	7.78	6.74
Unaccounted	0.00	1.31	2.28	1.80	1.00	0.93	0.36	-0.21	0.92
Electricity Exported	52.86	68.26	54.86	55.43	56.52	52.46	70.34	77.71	84.59
Total international exports	0.32	0.35	0.03	-	-	0.01	-	-	-
Net interstate exports	52.55	67.92	54.83	55.43	56.52	52.45	70.34	77.71	84.59

Agriculture Sector

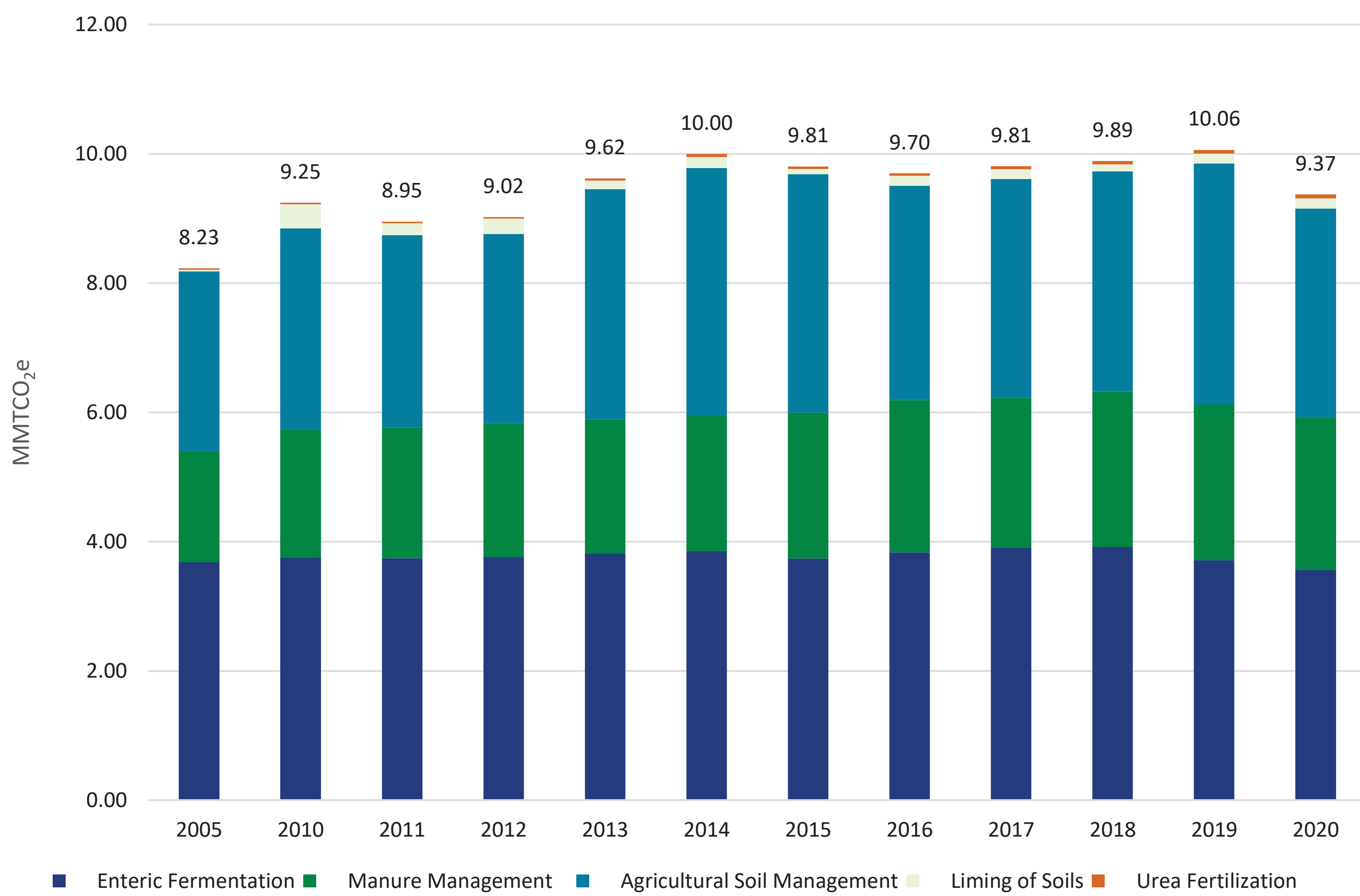
In 2020, emissions from the agriculture sector were 9.37 $MMTCO_2e$.

Table 21 and Figure 13 show greenhouse gas emissions from this sector by process.

Table 21 – Agricultural Sector GHG Emissions by Subgroup ($MMTCO_2e$)

Source	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Enteric Fermentation	3.68	3.75	3.74	3.76	3.81	3.85	3.74	3.84	3.91	3.92	3.71	3.57
Manure Management	1.72	1.99	2.03	2.07	2.07	2.10	2.26	2.36	2.32	2.41	2.41	2.35
Agricultural Soil Management	2.79	3.10	2.97	2.93	3.56	3.83	3.69	3.32	3.38	3.40	3.73	3.24
Liming of Soils	0.03	0.38	0.19	0.24	0.13	0.17	0.08	0.16	0.15	0.11	0.15	0.15
Urea Fertilization	0.02	0.03	0.02	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.06	0.06
Burning of Agricultural Crop Waste	-	-	-	-	-	-	-	-	-	-	-	-
Total	**8.23**	**9.25**	**8.95**	**9.02**	**9.62**	**10.00**	**9.81**	**9.70**	**9.81**	**9.89**	**10.06**	**9.37**

Figure 13 – GHG Emissions from Agricultural Sector by Source ($MMTCO_2e$)



The GHG emissions from the agriculture sector are significantly lower than emissions from the industrial, transportation, and electricity production sectors. Like the industrial sector, GHG emissions in the agriculture sector are broken down into smaller subgroups consisting of enteric fermentation, manure management, agricultural soil management, and liming and urea fertilization.

Emissions from the agriculture sector were estimated in the SIT Agriculture Module using the default activity data for animal population, crop cultivation, and fertilizer application. Table 22 lists the number (1,000 head) of each type of farm animal accounted for in the SIT.

Table 22 – Animal Populations Contributing to GHG Emissions (1,000 Head)

Animal Type	2005	2010	2015	2016	2017	2018	2019	2020
Dairy Cows	566	540	530	530	525	525	525	480
Dairy Replacement Heifers	275	300	305	325	315	310	315	272
Beef Cows	154	160	150	170	185	215	185	220
Beef Replacement Heifers	40	40	55	60	65	60	52	48
Heifer Stockers	55	50	55	55	60	60	31	26
Steer Stockers	170	150	145	140	160	130	77	62
Feedlot Heifers	24	24	24	24	24	24	24	36
Feedlot Steer	44	46	46	46	46	46	46	66
Bulls	25	25	25	25	25	25	25	20
Sheep	100	94	86	94	93	96	95	96
Goats	52	54	52	52	53	53	54	54
Swine	1088	1133	1165	1163	1195	1280	1270	1398
Horses	115	118	101	95	88	82	88	69

Enteric Fermentation

The enteric fermentation group includes animals that produce methane emissions due to their unique digestive process. Each type of farm animal has an associated methane emission factor associated with the enteric fermentation process. The total estimated GHG emissions from enteric fermentation is a summation of the product of the size of the statewide herd of each particular farm animal and the emission factor for that animal.

Table 23 shows the GHG emissions (MMTCO_2e) attributed to each animal in the agriculture sector due to enteric fermentation.

Table 23 – GHG Emissions (CH_4), by Livestock Type, from Enteric Fermentation ($MMTCO_2e$)

Animal Type	2005	2010	2015	2016	2017	2018	2019	2020
Dairy Cows	2.116	2.127	2.122	2.131	2.136	2.129	2.138	1.996
Dairy Replacement Heifers	0.456	0.512	0.517	0.551	0.533	0.525	0.533	0.460
Beef Cows	0.398	0.420	0.394	0.447	0.487	0.567	0.488	0.581
Beef Replacement Heifers	0.071	0.072	0.100	0.109	0.118	0.109	0.094	0.086
Heifer Stockers	0.092	0.084	0.093	0.093	0.101	0.101	0.053	0.043
Steer Stockers	0.274	0.243	0.235	0.228	0.260	0.211	0.126	0.101
Feedlot Heifers	0.027	0.030	0.030	0.030	0.030	0.030	0.030	0.043
Feedlot Steer	0.047	0.054	0.054	0.054	0.054	0.054	0.054	0.078
Bulls	0.067	0.068	0.068	0.068	0.068	0.068	0.068	0.055
Sheep	0.022	0.021	0.019	0.021	0.021	0.022	0.021	0.022
Goats	0.007	0.008	0.007	0.007	0.007	0.007	0.008	0.008
Swine	0.046	0.048	0.049	0.049	0.050	0.054	0.053	0.059
Horses	0.058	0.060	0.051	0.048	0.045	0.041	0.045	0.035
Total	**3.680**	**3.746**	**3.739**	**3.835**	**3.910**	**3.918**	**3.710**	**3.566**

Manure Management

The second agricultural subgroup is manure management. As with the enteric fermentation subgroup, each type of farm animal has an associated emission factor for the GHG emission (CH_4 and N_2O) based on the amount of manure that animal produces. The total GHG emissions from manure management are equal to the summation of the product of the statewide livestock herd size by animal and the emission factor for that animal. Table 24 shows the GHG emission ($MMTCO_2e$) attributed to each animal type in the agriculture sector from manure management. The "other" category includes sheep, goats, and horses.

Table 24 – GHG Emissions (CH_4 and N_2O), by Livestock Type, from Manure Management ($MMTCO_2e$)

Animal Type	2005	2010	2015	2016	2017	2018	2019	2020
Dairy Cattle	1.111	1.391	1.647	1.734	1.699	1.736	1.744	1.621
Beef Cattle	0.053	0.055	0.057	0.059	0.060	0.060	0.057	0.076
Swine	0.343	0.357	0.341	0.347	0.340	0.387	0.385	0.421
Poultry	0.195	0.178	0.202	0.205	0.208	0.214	0.215	0.228
Other	0.013	0.012	0.010	0.010	0.010	0.010	0.010	0.009
Total	**1.716**	**1.993**	**2.257**	**2.355**	**2.316**	**2.406**	**2.410**	**2.354**

Agricultural Soil Management

The third subgroup of the agriculture sector is the soil management group. GHG emissions (N_2O) from agricultural soils are calculated from the direct and indirect biochemical interactions of fertilizers, livestock manure, and crop residue with the soil. Direct N_2O emissions occur when fertilizer, manure, or crop residue is applied to soils and N_2O is released to the atmosphere. Indirect N_2O occurs when nitrogen is volatized to the atmosphere or through leaching and runoff.

N_2O emissions are calculated by multiplying the amount of fertilizer, livestock manure, and crop residue applied to soils by the direct and indirect N_2O emissions factors. The agricultural soils management subgroup also includes emissions from histosols in Pennsylvania. Histosols are soils rich in organic matter, and they produce N_2O emissions when drained for agricultural use. The total acreage of histosols within the Commonwealth is small, SIT does not contain default data on the area of histosols. Emissions from histosols were not included in previous inventories. Table 25 below shows the estimated GHG emissions ($MMTCO_2e$) resulting from agricultural soils management.

Table 25 – GHG Emissions (N_2O) from the Management of Agricultural Soils ($MMTCO_2e$)

	2005	2010	2015	2016	2017	2018	2019	2020
Direct	2.40	2.65	3.06	2.78	2.86	2.84	3.14	2.75
Indirect	0.38	0.45	0.63	0.53	0.52	0.57	0.59	0.48
Volatilization & Atmospheric Deposition	0.15	0.18	0.24	0.21	0.20	0.22	0.23	0.19
Leaching/Runoff	0.23	0.27	0.39	0.33	0.32	0.35	0.36	0.30
Total	**2.79**	**3.10**	**3.69**	**3.32**	**3.38**	**3.40**	**3.73**	**3.24**

Liming of Soils and Urea Fertilization

The fourth subgroup of the agriculture sector is liming of soils and urea fertilization. In 2020, these groups produced 0.15 and 0.06 $MMTCO_2e$ respectively, as shown in Table 26.

Table 26 – GHG Emissions from Liming of Soils and Urea Fertilization ($MMTCO_2e$)

	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Liming of Soils	0.03	0.38	0.19	0.24	0.13	0.17	0.08	0.16	0.15	0.11	0.15	0.15
Urea Fertilization	0.02	0.03	0.02	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.06	0.06

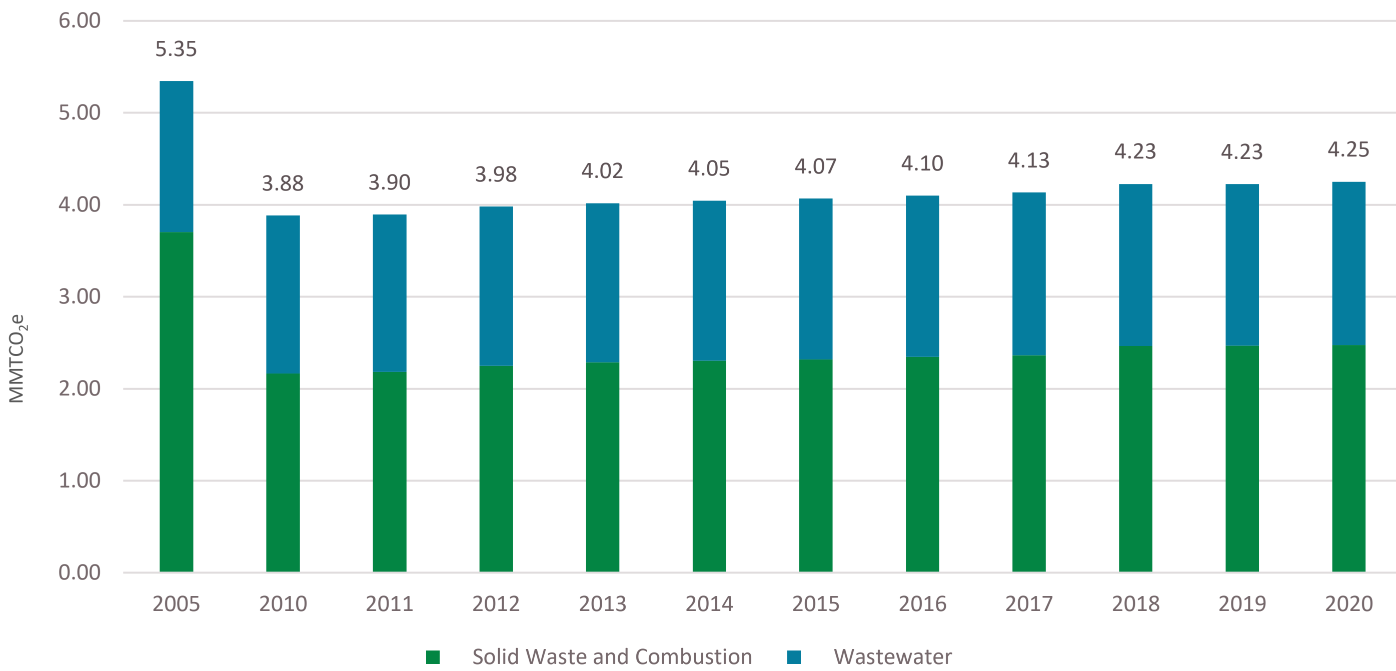
Waste Management Sector

In 2020, emissions from the waste management sector were 4.25 $MMTCO_2e$. GHG emissions in the waste management sector primarily come from the following three subgroups: landfill gas, solid waste combustion, and wastewater treatment. Landfill gas, which is approximately 50% methane, is generated by the decomposition of solid waste within a landfill. Some solid waste in the Commonwealth is combusted in waste-to-energy plants, thus avoiding the production of methane that would otherwise be produced in a landfill, but also resulting in the release of carbon dioxide. Both municipal wastewater treatment and industrial wastewater treatment are accounted for in the third subgroup. Emissions from waste management were calculated using the SIT Solid Waste Module. Table 27 and Figure 14 show greenhouse gas emissions from this sector by subgroup.

Table 27 – Wastewater Emissions by Subgroup ($MMTCO_2e$)

	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Solid Waste and Combustion	3.70	2.16	2.18	2.25	2.29	2.30	2.32	2.35	2.36	2.46	2.47	2.47
Wastewater	1.64	1.72	1.71	1.73	1.73	1.74	1.75	1.75	1.77	1.76	1.76	1.78
Total	**5.35**	**3.88**	**3.90**	**3.98**	**4.02**	**4.05**	**4.07**	**4.10**	**4.13**	**4.23**	**4.23**	**4.25**

Figure 14 – Waste Management Emissions by Source ($MMTCO_2e$)[20]



Landfill Gas

Default data in the SIT regarding the amount of landfilled solid waste in Pennsylvania was used to calculate the potential landfill methane emissions. The methane avoided value in Table 28 was calculated using data in the SIT and reflects the amount of methane that otherwise could have entered the atmosphere but was instead combusted in either a flare or a landfill gas to energy project. A small amount of oxidation occurs in landfills each year, which reduces the amount of methane emitted by approximately ten percent.

Table 28 shows the GHG emissions ($MMTCO_2e$) attributable to the potential landfill gas, the avoided methane emissions, and the avoided emissions due to solid waste oxidation.

Table 28 – GHG Emissions Associated with Landfilling Operations ($MMTCO_2e$)

	2005	2010	2015	2016	2017	2018	2019	2020
Potential Landfill CH_4	9.59	10.65	10.82	10.86	10.92	10.97	11.06	11.15
CH_4 Avoided	-7.42	-9.96	-10.11	-10.15	-10.20	-10.25	-10.34	-10.42
Oxidation	-0.22	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07
Total CH_4 Emissions (Landfills)	**1.96**	**0.63**	**0.64**	**0.64**	**0.64**	**0.65**	**0.65**	**0.66**

Solid Waste Combustion

The GHG emissions in the solid waste combustion subgroup result from the combustion of certain types of solid waste including plastics, synthetic rubber, and synthetic fibers. To avoid the potential for double counting, the emissions from the combustion of natural or biogenic materials such as cotton and paper are omitted because the combustion of these items returns CO_2 that was already part of the natural carbon cycle back into the atmosphere. Along with CO_2 emissions from waste combustion, this section accounts for N_2O and CH_4 gases that are generated in the waste combustion process. Data from the SIT for total solid waste combusted and the relative percentage of each of the materials listed

[20] Solid waste and combustion emissions rapidly decreased between 2000-2010 due to the widespread adoption of new methane capture/flaring techniques and the growth of voluntary EPA programs like the Landfill Methane Outreach Program (LMOP).

previously were used in the calculation. Table shows the GHG emissions (MMTCO$_2$e) attributable to the combustion of plastics, synthetic rubber, and synthetic fibers included in the waste combustion portion of the waste management sector. Emissions from composting and anaerobic digestion at biogas facilities were not included in previous inventories.

Table 29 – GHG Emissions Associated with Waste Combustion (MMTCO$_2$e)

	2005	2010	2015	2016	2017	2018	2019	2020
CO_2	1.58	1.43	1.61	1.67	1.68	1.78	1.78	1.78
N_2O	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03
CH_4	-	-	-	-	-	-	-	-
Total	**1.61**	**1.45**	**1.64**	**1.69**	**1.71**	**1.81**	**1.81**	**1.81**

Recycling diverts material from solid waste landfills that would otherwise be contributing to GHG emissions from this sector. While these avoided emissions are not accounted for in the SIT, they can be estimated based on tons of recycled materials.

Table 30 shows estimated CO_2 emissions avoided by recycling for the years 2012 through 2020.[21]

Table 30 – GHG Emissions Avoided from Recycling

Year	Tons Recycled (millions)	Tons CO_2 saved per year	Equivalent Passenger Vehicles Taken off the Road for One Year (millions)	Homes Worth of Electricity Use Per Year Saved
2020	4.99	7.11	1.55	1.29
2019	5.25	7.68	1.6	1.34
2018	5.47	9.11	1.98	1.65
2017	6.36	9.71	2.06	1.69
2016	7.84	10.23	2.21	1.73
2015	7.78	10.59	2.29	1.79
2014	16.91	16.37	3.53	2.77
2013	6.12	7.67	1.66	1.3
2012	8.50	17.6*	3.81	2.99

* Number is high due to unusual increase in amount recycled for Mixed Metals that year.

Wastewater Treatment

The GHG emissions from the wastewater portion of the waste management sector are a combination of municipal wastewater treatment (CH_4 and N_2O) and some types of industrial wastewater treatment (e.g., red meat, poultry, pulp and paper, and fruit and vegetable production). The SIT Wastewater Module was used to calculate the municipal and industrial wastewater GHG emissions. Production data were collected from the United States Department of Agriculture's National Agricultural Statistics Service for the poultry and fruit and vegetable industrial wastewater treatment sector, which was multiplied by the SIT-supplied emission factors to determine the total GHG emissions. Table shows the GHG emissions (MMTCO$_2$e) attributed to the treatment of wastewater from municipal and industrial sources in the waste management sector.

[21] Values converted to metric tons here: DEP. 2021. Statewide Recycling Data. Accessed 20 October 2023. https://www.dep.pa.gov/Business/Land/Waste/Recycling/Pages/Recycling-Reports-and-Studies.aspx.

Table 31 – GHG Emissions Associated with Wastewater Treatment ($MMTCO_2e$)

	2005	2010	2015	2016	2017	2018	2019	2020
Municipal CH_4	0.88	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Municipal N_2O	0.34	0.34	0.34	0.34	0.34	0.35	0.34	0.34
Industrial CH_4	0.43	0.49	0.50	0.51	0.52	0.51	0.51	0.53
Total	**1.64**	**1.72**	**1.75**	**1.75**	**1.77**	**1.76**	**1.76**	**1.78**

Table 32 shows the GHG emissions ($MMTCO_2e$) totals for the solid waste and wastewater treatment portions of the waste management sector.

Table 32 – Total GHG Emissions (CO_2, CH_4, N_2O) from the Waste Management Sector ($MMTCO_2e$)

	2005	2010	2015	2016	2017	2018	2019	2020
Solid Waste	3.70	2.16	2.32	2.35	2.36	2.46	2.47	2.47
Wastewater	1.64	1.72	1.75	1.75	1.77	1.76	1.76	1.78
Total	**5.35**	**3.88**	**4.07**	**4.10**	**4.13**	**4.23**	**4.23**	**4.25**

Forestry and Land Use Sector

The forestry and land use sector sequesters or absorbs CO_2, reducing the net GHG emission in the Commonwealth. In 2020, forestry and land use sector resulted in a net increase in carbon stocks of 24.60 $MMTCO_2e$ of GHG and includes forested lands and soils, trees located in urban settings, yard waste, and forest fires. Prior to the 2018 release of the SIT, liming and fertilization of agricultural soils were included in the forestry and land use sector, but those sources are now accounted for in the agricultural sector. Emissions and carbon sequestration from the forestry and land use sector was estimated using the SIT Land-Use, Land-Change, and Forestry (LULUCF) Module. Default data in the SIT LULUCF Module was the primary source of information for this section; however, forest fire acreage was collected from the National Interagency Fire Center and Pennsylvania's Department of Conservation & Natural Resources and multiplied by the default emissions factors for CH_4 and N_2O from forest fires in the LULUCF module.[22] Carbon stocks from Land Converted to Settlements, Wetlands Remaining Wetlands, Land Converted to Wetlands were not included in previous inventories. Table 33 shows the total GHG emissions produced (positive values) and emissions sequestered (negative values) ($MMTCO_2e$) totals for the forestry and land use sector.

[22] National Interagency Fire Center. 2023. Statistics Home Page. Last Updated 20 October 2023. https://www.nifc.gov/fireInfo/fireInfo_statistics.html.

Table 33 – Total GHG Emissions from the Forestry and Land Use Sector ($MMTCO_2e$)

	2005	2010	2015	2016	2017	2018	2019	2020
Forest Carbon Flux	-25.72	-24.86	-23.67	-23.34	-23.03	-22.71	-22.39	-22.08
Urban Trees, Carbon Flux	-3.15	-3.31	-3.46	-3.49	-3.52	-3.56	-3.59	-3.62
Landfilled Yard Trimmings and Food Scraps, Carbon Flux	-0.39	-0.44	-0.40	-0.36	-0.33	-0.42	-0.42	-0.42
Forest Fires, CH_4 and N_2O	0.01	0.04	0.14	0.20	0.15	0.12	0.10	0.10
N_2O from Settlement Soils	0.03	0.04	0.06	0.06	0.06	0.06	0.06	0.06
Agricultural Soil Carbon Flux	-2.23	-1.18	-0.92	-0.91	-0.87	-0.77	-0.72	-0.88
Land Converted to Settlements	2.12	2.16	2.20	2.21	2.21	2.21	2.21	2.21
Wetlands Remaining Wetlands	0.05	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Settlements Remaining Settlements: Changes in Organic Soil Carbon Stocks	-	-	-	-	-	-	-	-
Land Converted to Wetlands	-	-	-	-	-	-	-	-
Forest Land Remaining Forest Land: Drained Organic Soils	-	-	-	-	-	-	-	-
Grassland Remaining Grassland: Grassland Fires	-	-	-	-	-	-	-	-
Total[23]	**-29.29**	**-27.51**	**-26.03**	**-25.62**	**-25.31**	**-25.05**	**-24.73**	**-24.60**

[23] Note that totals presented in this row are equal to the sum of Forestry and Land Use emission and carbon flux rows shown in Table 3.

Conclusion and Looking Forward

The U.S. EPA's SIT is updated and rereleased annually, and as methods for compiling GHG emissions data are refined, estimates for previous years may change with each iteration of the inventory.

Pennsylvania has achieved a 25.9% reduction in GHG emissions in 2020 compared to 2005. While this reduction almost meets the 2025 goal, it is important to note that the data from 2020 may be anomalous. The data included in this report for 2020 includes impacts from COVID-19 pandemic and economic disruptions which affected business-as-usual activities for most sectors. These disruptions likely contributed to the significant reduction in GHG emissions between 2019-2020. Pennsylvania GHG emissions will likely increase in 2021 following observed national emissions trends.[24]

Most sectors experienced a decrease in emissions during 2020. The sectors experiencing the largest decreases were transportation, commercial and industrial. These sectors were likely impacted by the COVID-19 public health guidance, which limited travel. The decrease in emissions can be primarily attributed to a decrease in jet fuel and motor gasoline consumption in the transportation sector, as well as direct fossil fuel consumption in industrial processes.

The electricity production sector also experienced a decrease in emissions. Electricity generation fuel sources continued to shift with natural gas increasing from generating 43% of megawatt hours (MWh) in 2019 to 52% of MWh in 2020, while coal-based electricity generation continues to decrease (Table 16). While the electricity production sector contributed to about a third of net emissions, renewable electricity generation from sources such as wind and solar are expected to continue to increase going forward.

The data from 2020 represents impacts and disruptions from the COVID-19 pandemic that resulted in an unexpected major emissions decrease. Recent energy generation, use, and emissions indicators point to potential increases in emissions as the economy rebounds from the pandemic. The 2021 and 2022 GHG Inventories will likely be a more representative measurement from which to assess progress toward Pennsylvania's 26% by 2025 emissions goal.

[24] EPA. 2023. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021. U.S. Environmental Protection Agency, EPA 430-R-23-002. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-andsinks-1990-2021.

Appendix A: Acronyms and Abbreviations

BBTu – Billion British thermal units
CH_4 – Methane
CO_2 – Carbon dioxide
CO_2FFC – Carbon dioxide from fossil fuel combustion
DEP – Pennsylvania Department of Environmental Protection
FHWA – United States Federal Highway Administration
GHG – Greenhouse gas
GWP – Global warming potential
HCFC-22 – Chlorodifluoromethane
LNG – Liquefied natural gas
LULUCF – Land use, land-use change, and forestry
MWh – Megawatt hours
N_20 – Nitrous oxide
ODS – Ozone depleting substances
SIT – State Inventory Tool
TWh – Terawatt hour
UNGS – Underground natural gas storage
U.S. DOT – United States Department of Transportation
U.S. EIA – United States Energy Information Agency
U.S. EPA – United State Environmental Protection Agency

Appendix B: Inventory Methodology

The following sectors emit GHGs in Pennsylvania and are included in this inventory: residential, commercial, industrial, transportation, electricity production, agriculture, waste management, and forestry and land use. Data for this inventory were primarily obtained from the U.S. EPA SIT. Additional data for sources not estimated in SIT were obtained from the U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks by State.

Table 34 – Global Warming Potentials (GWPs) Used Previous and Current Reports

Gas	AR4 GWPs used in *previous* reports	AR5 GWPs used in current report
CO_2	1	1
CH_4	25	28
N_2O	298	265
HFC-23	14,800	12,400
HFC-32	675	677
HFC-125	3,500	3,170
HFC-134a	1,430	1,300
HFC-143a	4,470	4,800
NF_3	17,200	16,100
SF_6	22,800	23,500

Note: This and previous inventories use GWPs with a 100-year time horizon in accordance with Mandatory GHG Reporting (EPA 2021c).
Source: *IPCC Fifth Assessment Report* (2013).

U.S. EPA State Inventory Tools

SIT is an interactive Excel spreadsheet model designed to help states develop GHG emissions inventories and provides a streamlined way to update an existing inventory or complete a new inventory.

The SIT consists of 11 estimation modules applying a top-down approach to calculate GHG emissions and one module to synthesize estimates across all modules. The default data are gathered by federal agencies and incorporate reported data from private, state, and local sources covering fossil fuels, electricity consumption, agriculture, forestry, waste management, and industry. As is customary, the units for the GHG emissions are given in $MMTCO_2e$. A metric ton is equal to 2,204.6 pounds or approximately 1.1 short tons (U.S. tons). The GHGs the SIT typically accounts for are CO_2, CH_4, and N_2O. Each GHG has a different global warming potential (GWP), which is accounted for when converting emissions to $MMTCO_2e$. The default GWPs used by the SIT are 1 for CO_2, 28 for CH_4, and 265 for N_2O, which correspond to AR5 (Table 34) In previous inventories, AR4 GWPs were used, but to maintain consistency with the national inventory and the transition in SIT to use AR5, emissions results for Pennsylvania are now estimated using AR5 GWPs. The GWP of a GHG will vary depending on the time scale selected, and the default time scale for the SIT is 100 years.

Pennsylvania's GHG inventory was primarily produced using the default activity data included in each SIT module, with supplemental data included for categories that can be estimated in SIT but do not have default data (e.g., forest fires). To supplement the SIT, additional data for several emissions sources were obtained from the U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks by State report, as detailed in the following section.[25]

U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks by State

Alongside the national Inventory of U.S. Greenhouse Gas Emissions and Sinks, EPA publishes a dataset of national GHG emissions disaggregated by state.[26] While these emissions estimates are not intended to fully supplant official state-level GHG inventories, they are helpful for comparing results between state and the national inventory and for obtaining supplemental data to augment state inventories (e.g., for categories not estimated in SIT, categories best estimated with complex modeling tools, etc.).

Pennsylvania obtained emissions data for several additional source categories from 1990 to 2021 by state dataset from EPA. Data were obtained for the following sectors: natural gas and oil sector (abandoned oil and gas wells), forestry and

[25] GHG inventories produced exclusively using the SIT modules' default settings do not account for several categories of emissions, which are primarily excluded from the modules due to lack of readily available default data at the state level and significance of emissions. Unless the user estimates emissions from these sources using other approaches and integrates them into inventory totals, they will be excluded from the inventory, which may undercount emissions and impact other climate planning endeavors such as the development of a Climate Action Plan.

[26] Available for download here: https://www.epa.gov/system/files/other-files/2023-02/State-Level-GHG-data.zip. The latest version of the state-level emissions was published on September 7th, 2023.

land uses (carbon stocks from Land Converted to Settlements, Wetlands Remaining Wetlands, Land Converted to Wetlands), industrial processes (ferroalloy production, zinc production, carbon dioxide consumption, N_2O from product uses, glass production, lead production, carbide production and consumption), and solid waste (composting and anaerobic digestion at biogas facilities). Because the emissions source categories obtained from the U.S. Inventory by state disaggregation are not estimated within SIT, there is no double-counting, and these additional categories can be directly added to emissions results estimated by the SIT.[27]

Quality Assurance and Quality Control

Quality assurance and quality control measures were implemented during the inventory development process. These measures help to ensure the accuracy and consistency of emissions estimates over time. Quality assurance and quality control measures implemented during this inventory process include tracking and citing of default and external data sources, aggregating emissions results in Microsoft Excel workbooks, conducting multiple rounds of review for emissions results, and clearly documenting methodology.

Uncertainty of Emissions Estimates

Uncertainty is inherent in any emissions estimate for all GHG inventories. Uncertainty may stem from incomplete data, use of average emission factors rather than more granular emission factors, use of national-level data rather than more granular state-specific data, and user error. Additionally, emissions from certain sectors carry greater uncertainty than other sectors. For example, emissions from natural systems, such as CO_2 from agricultural soil carbon or carbon flux from forestry, are more difficult to comprehensively model and thus carry greater uncertainty than emissions from other sources, such as CO_2 from fuel combustion.

[27] U.S. EPA's crosswalk of SIT estimates and the U.S. Inventory by state disaggregation is available for download here: https://www.epa.gov/system/files/documents/2022-03/factsheet-crosswalk-between-ghg-by-state-and-sit.pdf

Appendix C: Summary of Updates to Emission Estimates in the 2020 Inventory Compared to Previous Reports

For the current update to include emissions from 2020, there were several changes to the SIT methodology across all sectors to enhance the accuracy of the inventory and bring the methodology more in line with that of the national GHG inventory.[28] SIT modules are updated in January each year but occasionally have mid-cycle updates in June.

GWP Update

The SIT was updated in June 2023 to use AR5 GWPs, consistent with the 1990-2021 publication of the U.S. Inventory of Greenhouse Gas Emissions and Sinks. The update to use AR5 GWP was applied across the time series. This GWP update generally increases CH_4 emissions and decreases N_2O emissions across the time series.

SIT Methodological Updates

The SIT modules are updated annually with new activity data, which can affect historical emissions estimates if the update is implemented across the entire time series. Specific SIT modules were also recently revised in June 2023 and include the following updates:

- The SIT CO_2FCC and Stationary modules were updated to correct a previous duplication of coking coal emissions within the combustion of fossil fuels and the industrial processes categories. This correction has resulted in a reduction in emissions reported within the industrial sector across all inventory years.
- The SIT LULUCF module was updated to include additional carbon pools agricultural soil carbon flux.
- The fraction of wastewater BOD5 (five-day biochemical oxygen demand) anaerobically digested automatically updates based on percent of population on not on septic in Wastewater Module.
- Annually variable carbon coefficients were added to the CO_2FFC module for Natural Gas and Distillate Fuel Oil.

Additional Emissions Sources

Several new sources of emissions were also included in the inventory for the first time, including new sources for the natural gas and oil sector (abandoned oil and gas wells), forestry and land uses (carbon stocks from Land Converted to Settlements, Wetlands Remaining Wetlands, Land Converted to Wetlands), industrial processes (ferroalloy production, zinc production, carbon dioxide consumption, N_2O from product uses, glass production, lead production, carbide production and consumption), solid waste (composting and anaerobic digestion at biogas facilities), and agriculture (histosols). The addition of these categories increased Pennsylvania's annual emissions estimates in 2020 by approximately 5% and increased emissions across the time series by an average of 4%. Figure 15 summarizes the combined impact of the above changes on the inventory.

[28] Crosswalk between the Inventory U.S. Greenhouse Gas Emissions and Sinks by U.S. State: 1990-2020 and the State Inventory Tool (SIT) (January 2022 edition). Source: factsheet-crosswalk-between-ghg-by-state-and-sit.pdf (epa.gov)

Figure 15 – Net Emissions Comparison Between Original Report and Updated Report