# 2023

# Pennsylvania Greenhouse Gas Inventory Report

**July 18, 2023**

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pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

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# Executive Summary

In this inventory, the Pennsylvania Department of Environmental Protection (DEP) provides data on Greenhouse Gas Emissions (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 (EPA) State Inventory Tool (SIT). Preliminary data for 2021 from EIA estimates have also been included.

**Overall Key Findings:**

- In 2020, net emissions decreased by **12 percent from 2019 levels.** Gross GHG emissions were 232.05 $MMTCO_2e$ and net GHG emissions in 2020 were 203.16 $MMTCO_2e$.
- Statewide net emissions decreased **26.4 percent from 2005 baseline**. While this percent reduction achieves the 26 percent 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 **electricity production, industrial, and transportation sectors accounting for 82 percent** 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 was 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 towards Pennsylvania's 26 percent by 2025 emissions goal.

**Table 1 – Summary of Key Emissions Trends**

| | 2020 Emissions | % Change from 2019 | % Change from 2005 |
|---|---|---|---|
| Residential | 17.81 | ↓ -8.8% | ↓ -25.5% |
| Commercial | 10.67 | ↓ -10.2% | ↓ -17.0% |
| Industrial | 67.73 | ↓ -9.8% | ↑ 6.0% |
| Transportation | 51.79 | ↓ -13.8% | ↓ -25.2% |
| Electricity Production | 70.05 | ↓ -6.7% | ↓ -44.3% |
| Agriculture | 9.73 | ↓ -2.8% | ↑ 19.8% |
| Waste Management | 4.28 | → 0.3% | ↓ -16.5% |
| **Total Gross Emissions** | **232.05** | ↓ **-9%** | ↓ **-24.9%** |
| Forestry and Land Use | -28.89 | ↑ 4.4% | ↓ -12.5% |
| **Total Net Emissions** | **203.16** | ↓ **-10.9%** | ↓ **-26.4%** |

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# 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 percent over the same timeframes. 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 Department of Environmental Protection (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.

**PA GHG Emissions Reduction Goals (EO 2019-01)**

- 26% below 2005 levels by 2025
- 80% below 2005 levels by 2050

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 percent by 2025 from 2005 levels and 80 percent by 2050 from 2005 levels. The year 2005 is used as a reference point for emissions reductions in order to maintain consistency with goals set forth in the Paris Climate Agreement. As of 2020, Pennsylvania has achieved a 26.4 percent reduction in net GHG emissions compared to 2005. While this significant emissions reduction in 2020 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 percent 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 147.99 $MMTCO_2e$ is needed to reach the 2050 goal. This underscores the need for more and continued policies aimed at reducing Pennsylvania's GHG emissions.

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

[1] IPCC, 2023: https://www.ipcc.ch/report/ar6/syr/
[2] DEP, 2021: www.depgreenport.state.pa.us/elibrary/GetDocument?docId=3667348&DocName=PENNSYLVANIA CLIMATE IMPACTS ASSESSMENT 2021.PDF
[3] https://www.dep.pa.gov/Citizens/climate/Pages/CCAC.aspx
[4] https://www.theclimateregistry.org/
[5] https://www.dep.pa.gov/citizens/climate/Pages/PA-Climate-Action-Plan.aspx
[6] 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.

heatwaves) that influence energy use all have a role in the trends observed in the Commonwealth's GHG emissions.

**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 United States Environmental Protection Agency (EPA) State Inventory Tool (SIT). The SIT is an interactive 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 million metric tons of carbon dioxide equivalent ($MMTCO_2e$). A metric ton is equal to 2,204.6 pounds or approximately 1.1 short tons (US 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 GWP used by the SIT is 1.0 for $CO_2$, 25 for $CH_4$, and 298 for $N_2O$. The GWP of a GHG will vary depending on the time scale selected, and the default time scale for the SIT is 100 years. In order to provide consistency with previous updates and other state inventories that use the SIT, the default values were not changed in compiling the inventory. Where default data are not available, state-specific data is incorporated into the SIT modules where it is available.

For the current update to the 2020 data, 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.[7] The majority of methodology changes resulted in minor updates to prior values; however, there was a significant change to the calculations for the industrial sector that resulted in discrepancies to past inventory values. Updated calculations for the industrial sector corrected 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.

While the complete inventory presented in this report includes GHG emissions data from 2005 through 2020, fuel consumption data is available from the US Energy Information Administration's (EIA) State Energy Data System (SEDS) for 2021[8] and has been included in relevant tables and figures below.

As shown in Table 2, the total statewide gross GHG emissions for Pennsylvania in 2020, the latest year with complete data available from the SIT, were 232.05 $MMTCO_2e$. This is a decrease of 23.68 $MMTCO_2e$ from 2019. Pennsylvania's forestry and land use sector provides a carbon sink for GHG emissions, absorbing 28.89 $MMTCO_2e$ in 2020 and resulting in net GHG emission for 2020 to 203.16 $MMTCO_2e$. Compared to 2005

[7] 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) factsheet-crosswalk-between-ghg-by-state-and-sit.pdf (epa.gov)

[8] 2021 data from SEDS released 7/23/2023. U.S. Energy Information Administration – EIA – Independent Statistics and Analysis (U.S. Energy Information Administration - EIA - Independent Statistics and Analysis)

baseline, these represent a relative decrease of 24.9 percent in the gross emissions totals and 26.4 percent in the net emission totals.

Also shown in Table 1, above and Table 2, below, the sectors with the largest contribution to the Commonwealth's GHG emissions are the electricity production, industrial, and transportation sectors. Decreased emissions were seen across all three of these sectors between 2019 and 2020. The electricity production sector was the highest GHG producing sector in the state in 2020, producing 29 percent of the Commonwealth's emissions. The industrial sector experienced a 9.8 percent decrease from 2019 in 2020 reversing their previous upward trend between 2016 and 2019. This decrease may have resulted from COVID-19 related disruptions and emissions may increase in upcoming years. The relative change for each of these sectors between 2005 and 2020 was a decrease of 55.70 $MMTCO_2e$ (44.3 percent) for the electricity production sector, an increase of 3.84 $MMTCO_2e$ (6.0 percent) for the industrial sector, and a decrease of 17.46 $MMTCO_2e$ (25.2 percent) for the transportation sector. Together, these three sectors annually account for approximately 82 percent of Pennsylvania's gross GHG emissions.

The residential and commercial sectors experienced decreases in emissions between 2019 and 2020 as well as overall declines in GHG emissions since 2005. GHG emissions from the residential and commercial sectors decreased by 6.09 and 2.19 $MMTCO_2e$ (25.5 and 17.0 percent), respectively, since 2005. Emissions from the commercial sector had trended upwards prior to 2020, however, they experienced a 10.2 percent decrease between 2019-2020 which may have been influenced by COVID-19 disruptions. GHG emissions from the agricultural sector decreased slightly between 2019 and 2020 but have increased overall 1.61 $MMTCO_2e$ (19.8 percent) since 2005.

GHG emissions from the waste management sector experienced a 0.85 $MMTCO_2e$ (16.5 percent) decrease from 2005 to 2020. During this same period, the GHG emissions sequestered in the forestry and land use sector have decreased by 4.13 $MMTCO_2e$ (12.5 percent).

A brief discussion of each individual sector will occur later in the document. The discussions will focus on the trends of various components within each sector, such as fuel mix or subgroups of the sector.

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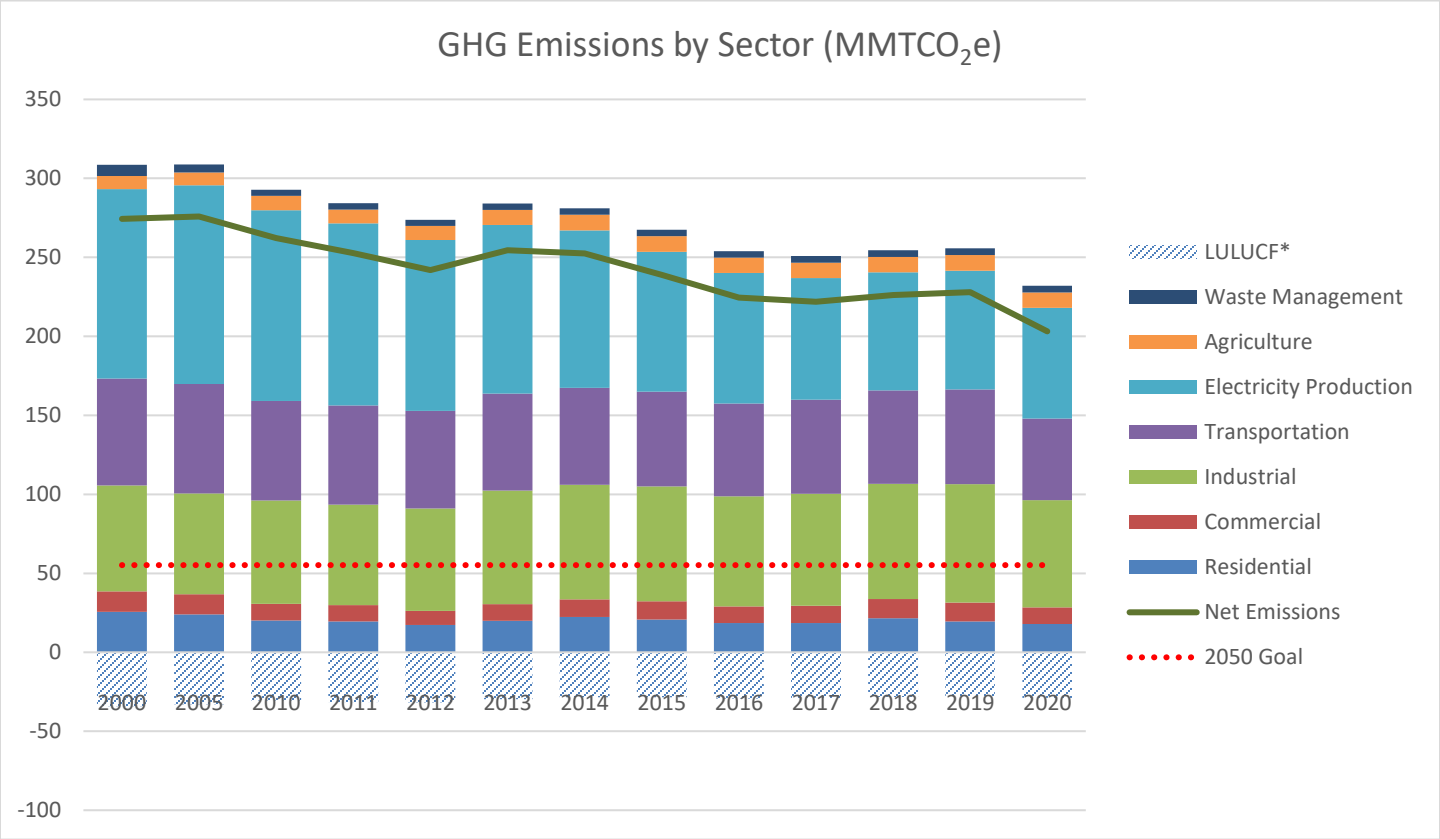
**Table 2 – GHG Emissions by Sector ($MMTCO_2e$)**

| Sector / Emission Sources ($MMTCO_2e$) | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| **Residential** | **23.90** | **20.21** | **20.75** | **18.48** | **18.53** | **21.65** | **19.52** | **17.81** |
| **Commercial** | **12.86** | **10.53** | **11.44** | **10.57** | **10.85** | **12.12** | **11.88** | **10.67** |
| **Industrial** | **63.89** | **65.34** | **72.85** | **69.59** | **71.05** | **72.84** | **75.05** | **67.73** |
| Combustion of Fossil Fuels[9] | 31.85 | 28.85 | 37.50 | 35.33 | 36.24 | 38.12 | 37.84 | 32.97 |
| Industrial Process | 12.98 | 12.44 | 12.32 | 12.16 | 11.86 | 11.27 | 12.27 | 12.12 |
| Coal Mining and Abandoned Mines | 10.32 | 12.74 | 10.76 | 9.95 | 10.76 | 11.23 | 12.61 | 10.38 |
| Natural Gas and Oil Systems | 8.74 | 11.30 | 12.27 | 12.15 | 12.19 | 12.22 | 12.33 | 12.26 |
| **Transportation** | **69.25** | **62.98** | **60.01** | **58.95** | **59.48** | **59.11** | **59.92** | **51.79** |
| Petroleum | 67.54 | 60.09 | 57.33 | 56.46 | 56.82 | 56.53 | 57.13 | 49.17 |
| Natural Gas | 1.71 | 2.62 | 2.42 | 2.25 | 2.44 | 2.59 | 2.79 | 2.62 |
| **Electricity Production** | **125.75** | **120.80** | **88.56** | **82.63** | **77.04** | **74.85** | **75.09** | **70.05** |
| Coal | 117.14 | 106.95 | 63.98 | 54.87 | 47.99 | 44.77 | 38.07 | 24.53 |
| Petroleum | 4.19 | 0.51 | 0.45 | 0.25 | 0.22 | 0.58 | 0.16 | 0.08 |
| Natural Gas | 4.42 | 13.34 | 24.13 | 27.51 | 28.82 | 29.50 | 36.86 | 45.44 |
| **Agriculture** | **8.12** | **9.14** | **9.75** | **9.58** | **9.70** | **9.77** | **10.00** | **9.73** |
| Enteric Fermentation | 3.29 | 3.35 | 3.34 | 3.42 | 3.49 | 3.50 | 3.31 | 3.18 |
| Manure Management | 1.65 | 1.90 | 2.15 | 2.24 | 2.20 | 2.28 | 2.29 | 2.24 |
| Agricultural Soil Management | 3.13 | 3.49 | 4.15 | 3.73 | 3.80 | 3.82 | 4.19 | 4.09 |
| 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 |
| **Waste Management** | **5.12** | **3.85** | **4.07** | **4.13** | **4.17** | **4.26** | **4.26** | **4.28** |
| Solid Waste and Combustion | 3.36 | 2.02 | 2.21 | 2.27 | 2.29 | 2.39 | 2.39 | 2.40 |
| Wastewater | 1.76 | 1.83 | 1.86 | 1.86 | 1.88 | 1.87 | 1.87 | 1.88 |
| **Total Statewide Gross Emissions (Prod.)** | **308.89** | **292.84** | **267.42** | **253.93** | **250.81** | **254.59** | **255.73** | **232.05** |
| *Change relative to 2005* | | *-5.2%* | *-13.4%* | *-17.8%* | *-18.8%* | *-17.6%* | *-17.2%* | *-24.9%* |
| **Forestry and Land Use** | **-33.02** | **-30.54** | **-28.56** | **-29.29** | **-28.90** | **-28.33** | **-27.68** | **-28.89** |
| **Total Statewide Net Emissions (Prod w/ Sinks)** | **275.87** | **262.30** | **238.86** | **224.64** | **221.91** | **226.26** | **228.05** | **203.16** |
| *Change relative to 2005* | | *-4.9%* | *-13.4%* | *-18.6%* | *-19.6%* | *-18.0%* | *-17.3%* | *-26.4%* |

[9] There is a significant difference in current data for Combustion of Fossil Fuels from previous GHG inventory reports due to a change in the calculation methodology for EPA SIT data.

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 2, and Figure 3 present GHG emissions by gas in units of $MMTCO_2e$. As noted above, it is customary to present GHG emissions data in units of $MMTCO_2e$ so that emissions sources can be compared.

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

| Emissions ($MMTCO_2E$) | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| **Gross $CO_2$** | 277.62 | 253.93 | 228.80 | 216.47 | 212.38 | 216.23 | 215.26 | 193.09 |
| **Net $CO_2$** | 244.54 | 223.31 | 200.05 | 186.94 | 183.29 | 187.73 | 187.41 | 164.05 |
| CO2 from Fossil Fuel Combustion | 266.92 | 244.90 | 219.75 | 207.48 | 203.66 | 207.70 | 206.14 | 184.19 |
| Industrial Processes | 9.07 | 7.20 | 7.32 | 7.13 | 6.84 | 6.59 | 7.13 | 6.91 |
| 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 | (33.07) | (30.62) | (28.75) | (29.53) | (29.10) | (28.51) | (27.84) | (29.04) |
| **$CH_4$** | 26.95 | 31.19 | 30.55 | 29.76 | 30.64 | 31.25 | 32.51 | 30.00 |
| Stationary Combustion | 0.39 | 0.42 | 0.51 | 0.44 | 0.44 | 0.50 | 0.48 | 0.42 |
| Mobile Combustion | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Coal Mining | 10.32 | 12.74 | 10.76 | 9.95 | 10.76 | 11.23 | 12.61 | 10.37 |
| Natural Gas and Oil Systems | 8.75 | 11.31 | 12.27 | 12.15 | 12.21 | 12.22 | 12.32 | 12.27 |
| Enteric Fermentation | 4.35 | 4.66 | 4.85 | 5.01 | 5.04 | 5.13 | 4.94 | 4.77 |
| Forest Fires | 0.01 | 0.03 | 0.11 | 0.16 | 0.12 | 0.10 | 0.08 | 0.08 |
| Waste | 1.75 | 0.56 | 0.57 | 0.57 | 0.57 | 0.58 | 0.58 | 0.59 |
| Wastewater | 1.38 | 1.45 | 1.47 | 1.48 | 1.49 | 1.48 | 1.48 | 1.50 |
| **$N_2O$** | 5.58 | 5.52 | 5.98 | 5.50 | 5.53 | 5.54 | 5.88 | 5.66 |
| Stationary Combustion | 0.84 | 0.75 | 0.59 | 0.51 | 0.48 | 0.48 | 0.44 | 0.34 |
| Mobile Combustion | 0.57 | 0.24 | 0.12 | 0.11 | 0.10 | 0.07 | 0.09 | 0.08 |
| Industrial Processes | - | - | - | - | - | - | - | - |
| Forest Fires | 3.72 | 4.07 | 4.78 | 4.38 | 4.45 | 4.48 | 4.85 | 4.74 |
| N2O from Settlement Soils | 0.04 | 0.05 | 0.08 | 0.09 | 0.08 | 0.08 | 0.08 | 0.08 |
| Waste | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Wastewater | 0.38 | 0.38 | 0.38 | 0.39 | 0.39 | 0.39 | 0.38 | 0.38 |
| **HFC, PFC, $SF_6$ and $NF_3$ Emissions** | 3.91 | 5.24 | 5.00 | 5.03 | 5.02 | 5.03 | 5.14 | 5.21 |
| Industrial Processes | 3.91 | 5.24 | 5.00 | 5.03 | 5.02 | 5.03 | 5.14 | 5.21 |
| **Indirect $CO_2$ from Electricity Consumption*** | 89.46 | 84.58 | 64.65 | 59.36 | 55.83 | 55.72 | 52.80 | 46.68 |
| **Gross Emissions** | **314.06** | **295.88** | **270.33** | **256.76** | **253.57** | **258.06** | **258.79** | **233.96** |
| **Sinks** | **(33.07)** | **(30.62)** | **(28.75)** | **(29.53)** | **(29.10)** | **(28.51)** | **(27.84)** | **(29.04)** |
| **Net Emissions (Sources and Sinks)** | **280.99** | **241.58** | **254.35** | **227.23** | **224.47** | **229.55** | **230.94** | **204.92** |

* 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 errors.

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 percent of GHG emission, in terms of $MMTCO_2e$, followed by $CH_4$ at 13 percent (Figure 2). $CO_2$ has also seen the greatest reduction of GHGs reported in the SIT as shown in Figure 3. Sources of other GHGs have remained relatively stable from 2005 to 2020.

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

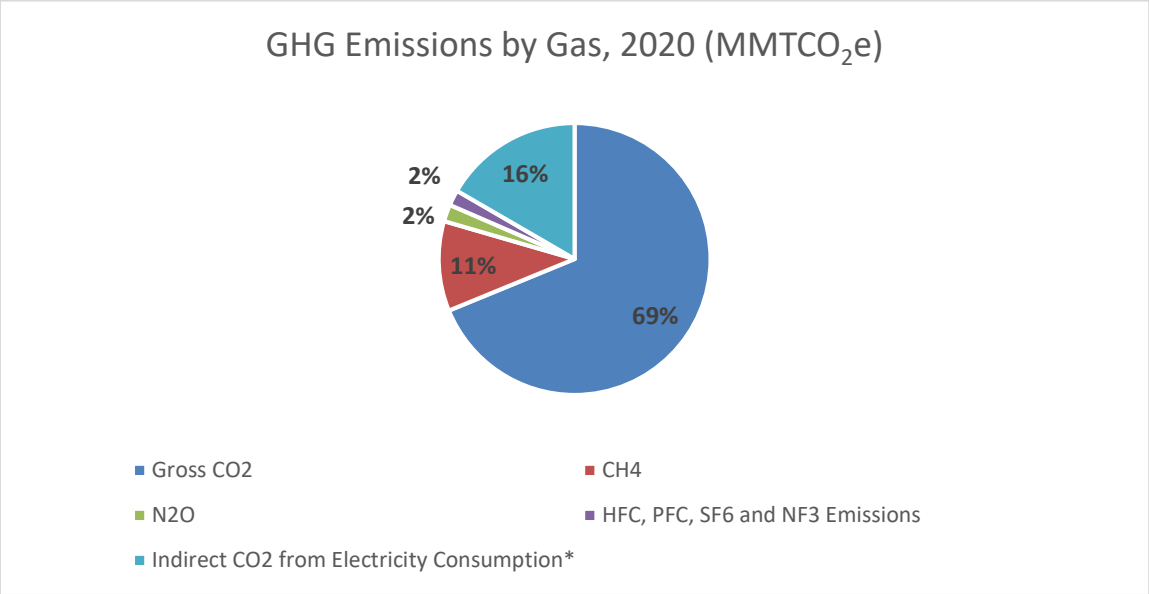
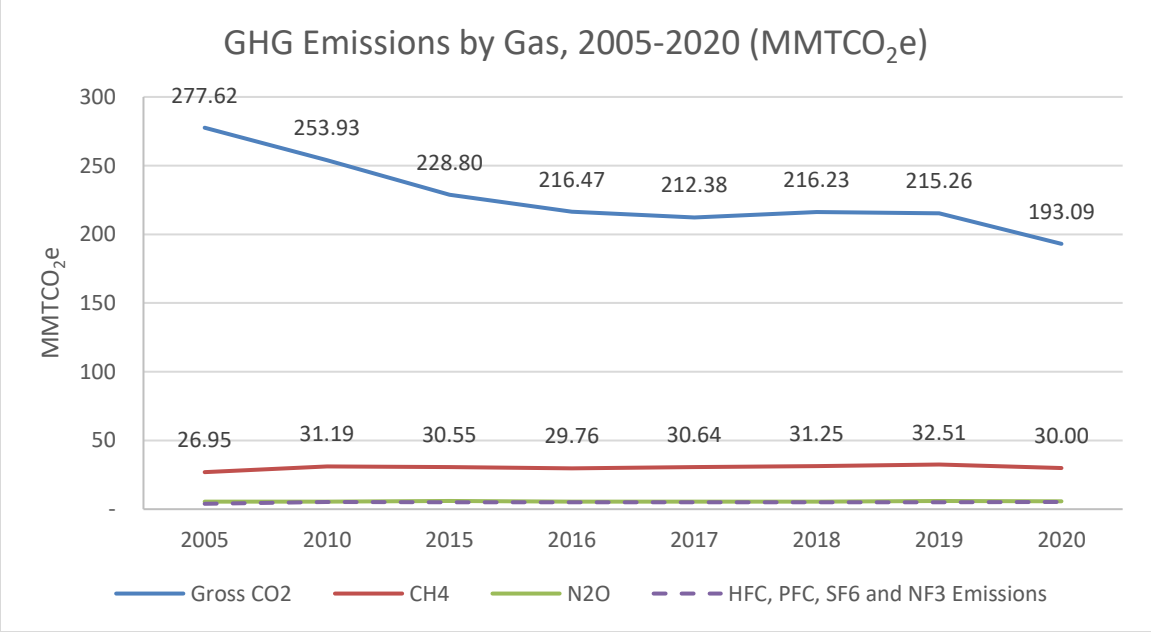



**Figure 3 – GHG Emissions by Gas, 2005-2020 ($MMTCO_2e$)**



# Greenhouse Gas Emissions by Sector

## Residential Sector

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 4 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.

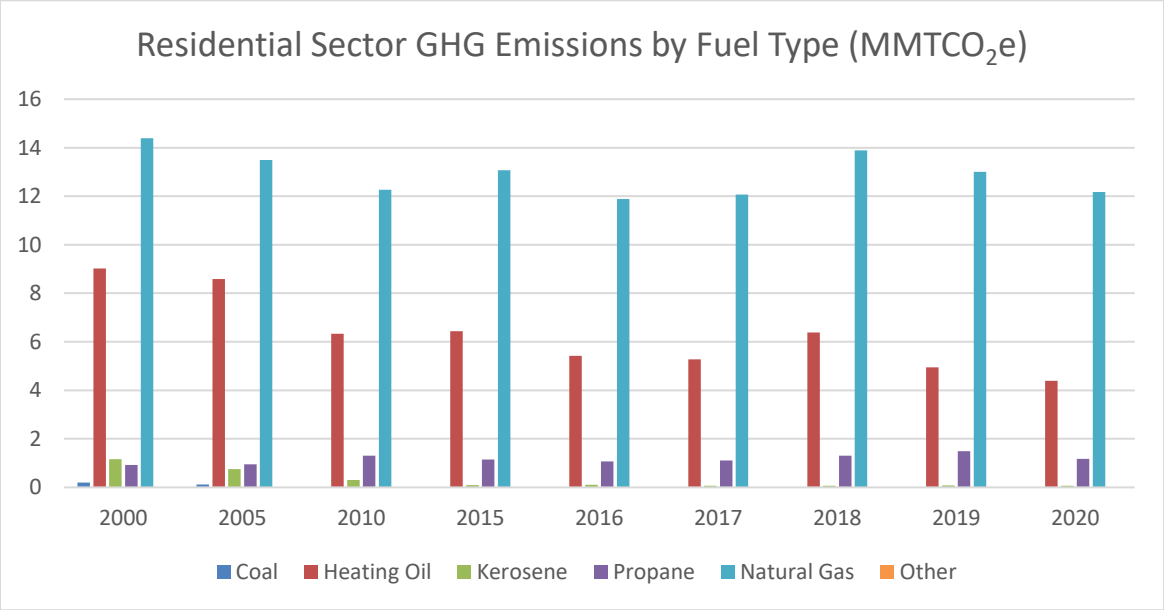
**Table 4 – Residential Sector Fuel Consumption by Year (BBtu)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021[10] |
|---|---|---|---|---|---|---|---|---|---|
| **Coal**[11] | 1,253 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **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 |
| **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 will emit GHGs at different rates.
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.

[10] 2021 data was compiled from U.S. Energy Information Administration's State Energy Data System (SEDS), released 6/23/2023. 2021 data is not available for all sectors presented in this inventory and will be presented in full in the 2024 Pennsylvania Greenhouse Gas Inventory Report.
[11] 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

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, heating oil, propane, coal, kerosene, and residual fuel. Table 5 shows the amount of each fuel used (billion Btu) in commercial buildings within the Commonwealth. Several factors will 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. No electricity consumption is included in these values.

**Table 5 – Commercial Sector Fuel Consumption (BBtu)**

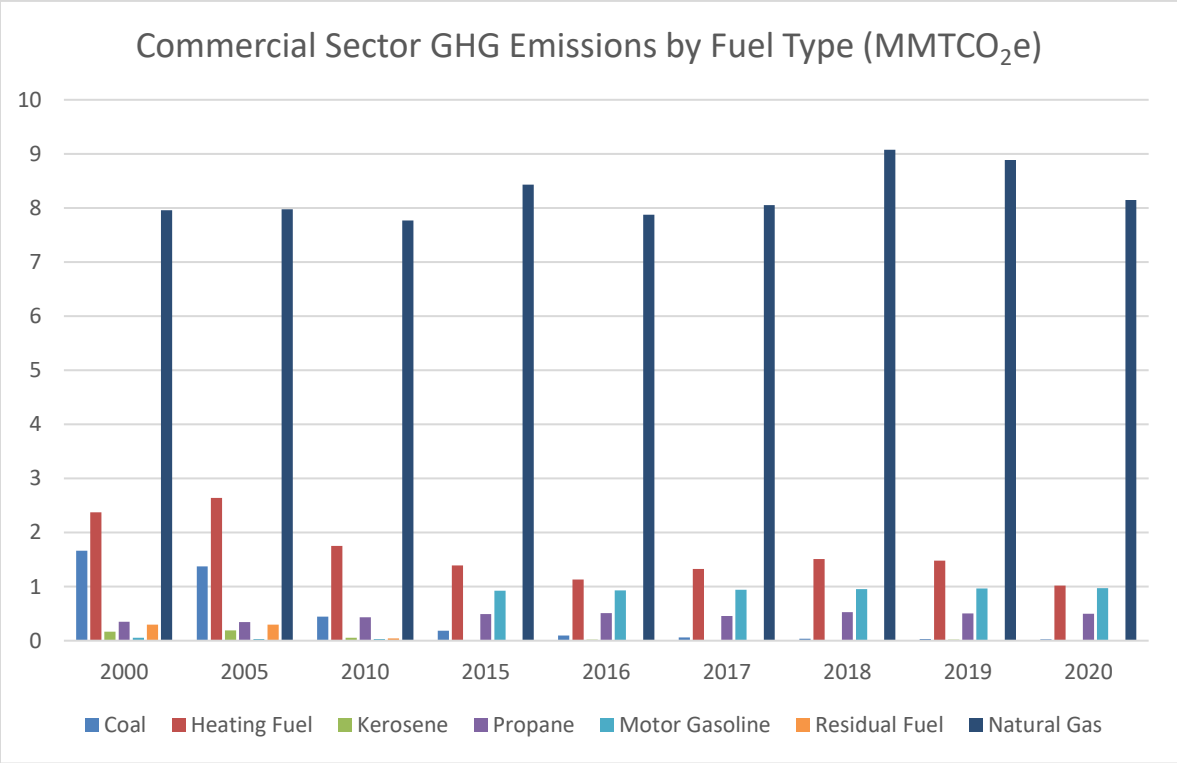
| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021[12] |
|---|---|---|---|---|---|---|---|---|---|
| **Coal** | 14,407 | 4,729 | 1,963 | 1,031 | 645 | 362 | 311 | 224 | 171 |
| **Heating Oil** | 35,632 | 23,625 | 18,765 | 15,272 | 17,907 | 20,328 | 19,943 | 13,707 | 18,203 |
| **Kerosene** | 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[13]** | 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 |
| **Total** | **213,374** | **183,862** | **201,258** | **186,780** | **191,474** | **214,432** | **210,092** | **189,845** | **202,219** |

[12] Ibid.

[13] 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.

As in the residential sector, each fuel used in commercial buildings will have different rates of GHG emissions. 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

Greenhouse gas 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.

### 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. Table 6 shows the amount of each fuel used (BBtu) in the industrial sector within the Commonwealth. Several factors will influence the amount of a 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 6 – Industrial Sector Fuel Consumption (BBtu)[14]**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021[15] |
|---|---|---|---|---|---|---|---|---|---|
| **Coking Coal** | 182,475 | 134,939 | 172,216 | 130,860 | 149,838 | 162,218 | 158,335 | 105,660 | 164,596 |
| **Other Coal** | 67,654 | 51,240 | 35,377 | 28,876 | 17,257 | 13,516 | 12,035 | 12,323 | 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 |
| **Heating Oil** | 33,055 | 34,088 | 51,101 | 36,780 | 41,820 | 43,320 | 43,822 | 32,112 | 42,942 |
| **Kerosene** | 663 | 281 | 68 | 82 | 58 | 79 | 63 | 60 | 62 |
| **Propane** | 22,823 | 29,562 | 20,734 | 21,201 | 20,946 | 21,252 | 20,765 | 5,948 | 6,519 |
| **Lubricants[16]** | 14,716 | 5,910 | 7,060 | 6,970 | 6,461 | 6,101 | 5,966 | 5,303 | 5,257 |
| **Motor Gasoline** | 9,486 | 9,712 | 7,055 | 7,004 | 7,079 | 7,163 | 7,150 | 7,748 | 7,648 |
| **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 |
| **Residual Fuel** | 12,039 | 4,272 | 565 | 770 | 598 | 477 | 580 | 705 | 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[17]** | 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** | 197,525 | 228,806 | 404,961 | 418,060 | 432,717 | 475,033 | 516,241 | 490,266 | 534,223 |
| **Total** | **715,639** | **645,289** | **830,824** | **781,613** | **812,523** | **857,515** | **870,989** | **737,495** | **844,093** |

As in the residential and commercial sectors, each fuel used in the industrial sector emits GHGs at different rates. Figure 6 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.[18]

[14] Includes non-energy fuel consumption

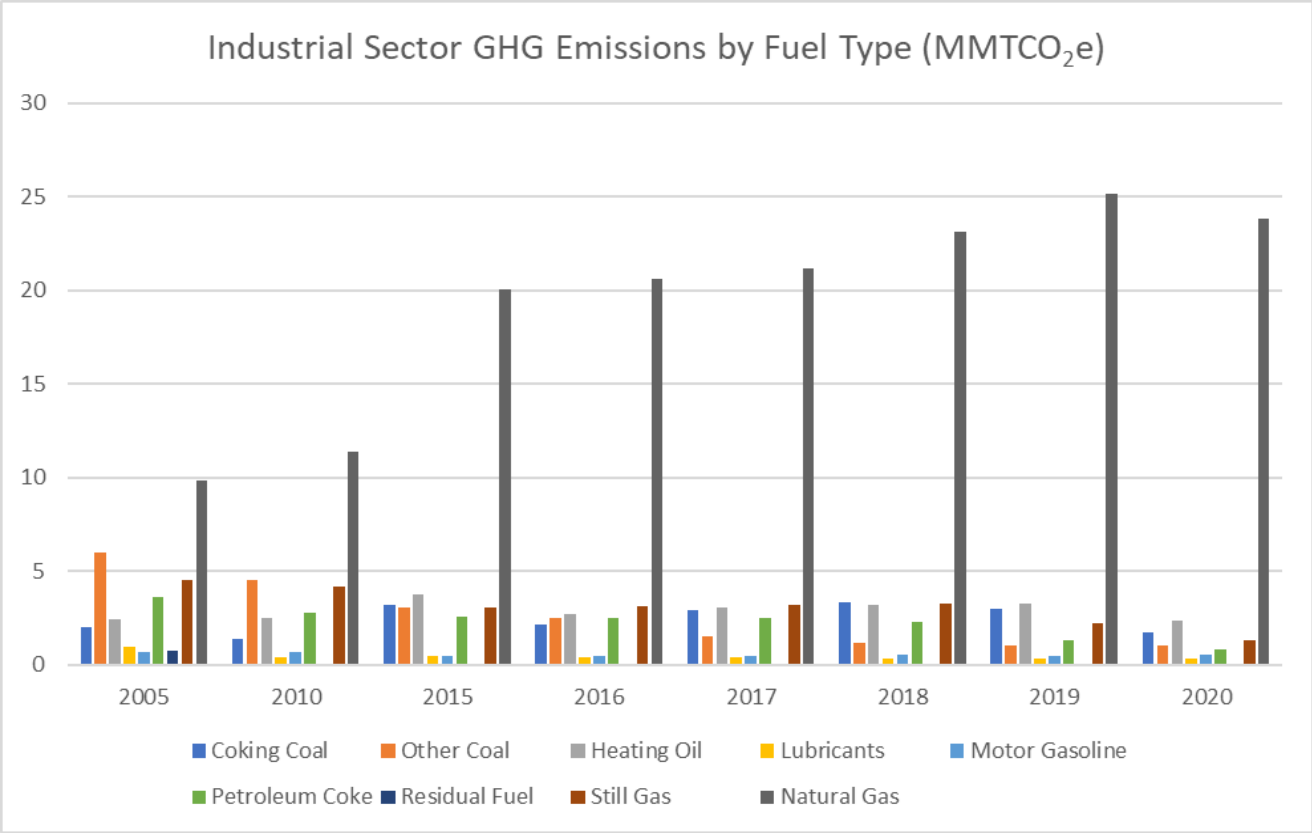
[15] Ibid.

[16] EIA's State Energy Data System (SEDS) modified the methodology for deriving lubricants consumption in data year 2016. https://www.eia.gov/state/seds/seds-data-changes.php?sid=US#2016

[17] 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)

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

**Figure 6 – 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 ODS, and electric power transmission and distribution systems. Table 7 shows the GHG emissions ($MMTCO_2e$) attributed to each of the processes included within the industrial sector.

**Table 7 – Industrial Sector Process Emissions ($MMTCO_2e$)**

| | 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** | 0.55 | 0.87 | 0.95 | 0.80 | 0.67 | 0.51 | 0.90 | 0.68 |
| **Soda Ash** | 0.11 | 0.09 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.07 |
| **Iron & Steel Production** | 4.48 | 3.80 | 3.80 | 3.80 | 3.80 | 3.80 | 3.80 | 3.80 |
| **Urea Consumption** | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| *HFC, PFC, $SF_6$, and $NF_3$ Emissions* | | | | | | | | |
| **ODS Substitutes** | 3.56 | 5.00 | 4.84 | 4.85 | 4.82 | 4.83 | 4.93 | 5.06 |
| **Semiconductor Manufacturing** | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| **Electric Power Transmission and Distribution Systems** | 0.34 | 0.22 | 0.15 | 0.16 | 0.16 | 0.15 | 0.16 | 0.14 |
| **Total** | **13.05** | **12.52** | **12.42** | **12.23** | **11.91** | **11.66** | **12.39** | **12.12** |

## Coal Mining and Abandoned Coal Mines

The GHG emissions associated with underground and surface mining coal processing, and abandoned coal mines are accounted for in this section. 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. Table 8 shows the GHG emissions ($MMTCO_2e$) attributed to underground and surface coal mining, coal processing, and abandoned underground mines.

**Table 8 – $CH_4$ from Coal Mining-Related Process Emissions ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| **Underground Mining** | 6.64 | 9.58 | 8.16 | 7.53 | 8.25 | 8.74 | 10.13 | 8.25 |
| **Surface Mining** | 0.56 | 0.47 | 0.26 | 0.19 | 0.24 | 0.23 | 0.24 | 0.18 |
| **Underground Processing** | 1.18 | 1.03 | 0.95 | 0.90 | 0.95 | 0.97 | 0.97 | 0.70 |
| **Surface Processing** | 0.12 | 0.10 | 0.06 | 0.04 | 0.05 | 0.05 | 0.05 | 0.04 |
| **Abandoned Mines** | 1.82 | 1.56 | 1.33 | 1.30 | 1.27 | 1.25 | 1.23 | 1.21 |
| **Total** | **10.32** | **12.74** | **10.76** | **9.95** | **10.76** | **11.23** | **12.61** | **10.37** |

## Natural Gas and Oil Systems

The GHG emissions associated with natural gas production, transmission, and distribution are accounted for in this section; however, emissions from orphaned and abandoned oil and gas wells are not accounted for in this inventory. Emission factors are used in determining the total GHG emissions based on the number of natural gas wells, miles of transmission pipeline, and number and types of services used for distribution in the Commonwealth[19]. 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. Table 9 shows the GHG emissions ($MMTCO_2e$) attributed to natural gas production, transmission and distribution, and oil production.

**Table 9 – $CH_4$ from Natural Gas Production Process Emissions ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| **Natural Gas Production** | 4.81 | 7.26 | 8.14 | 8.00 | 8.01 | 8.01 | 8.11 | 8.02 |
| **Natural Gas Transmission** | 1.92 | 1.97 | 1.98 | 2.00 | 2.02 | 2.06 | 2.07 | 2.09 |
| **Natural Gas Distribution** | 1.97 | 2.02 | 2.07 | 2.08 | 2.09 | 2.09 | 2.09 | 2.10 |
| **Oil Production** | 0.04 | 0.05 | 0.08 | 0.07 | 0.07 | 0.06 | 0.06 | 0.05 |
| **Total** | **8.74** | **11.30** | **12.27** | **12.15** | **12.19** | **12.22** | **12.33** | **12.26** |

[19] Transmission and distribution pipeline data from the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administrations. https://www.phmsa.dot.gov/data-and-statistics/pipeline/gas-distribution-gas-gathering-gas-transmission-hazardous-liquids

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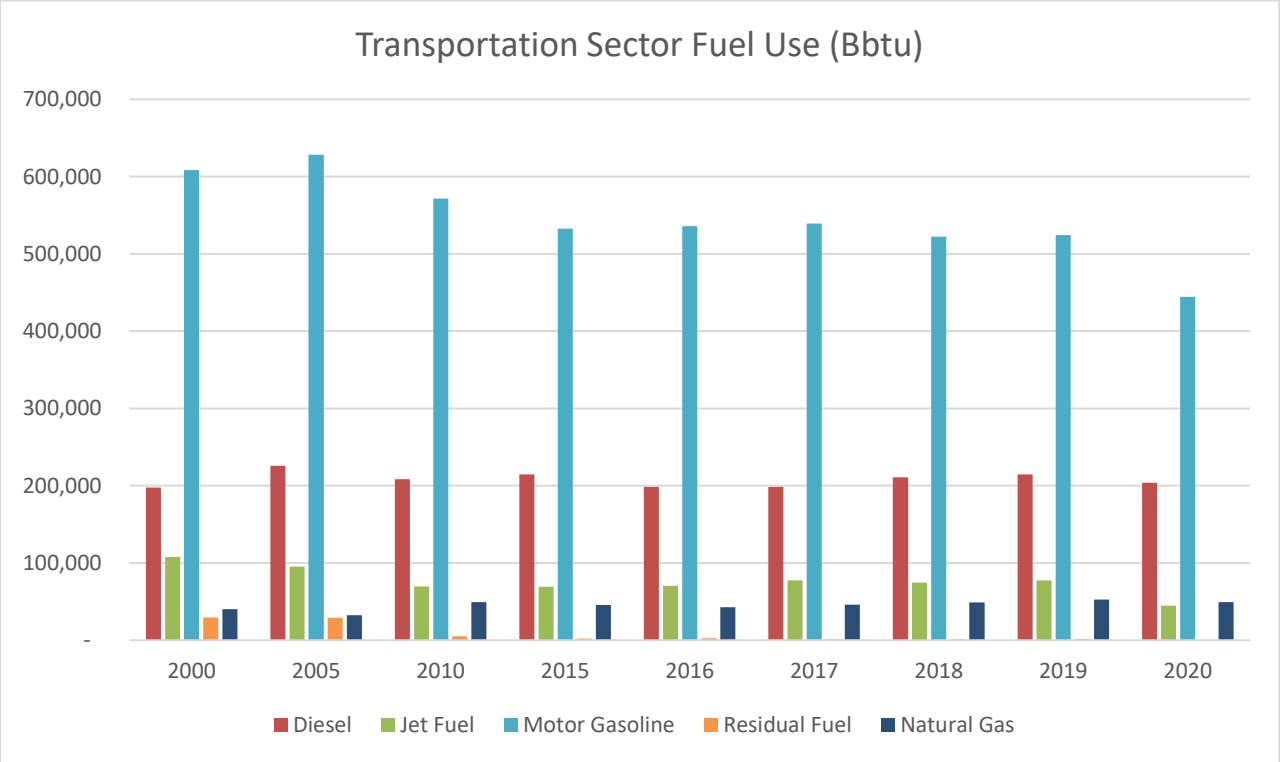
## Transportation Sector

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. Several factors will 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.

**Figure 7 – Transportation Sector Fuel Use (BBtu)**




As in the previous sectors, each fuel used in transportation will have different rates of GHG emissions. Table 10 shows the GHG emission ($MMTCO_2e$) attributed to each fuel used in the transportation sector.

**Table 10 – Transportation Sector Emissions by Fuel Consumption ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| **Diesel** | 16.73 | 15.43 | 15.90 | 14.70 | 14.72 | 15.63 | 15.90 | 15.06 |
| **Jet Fuel** | 6.89 | 5.40 | 5.39 | 5.41 | 5.58 | 5.72 | 5.93 | 3.24 |
| **Motor Gasoline** | 44.50 | 40.64 | 37.60 | 37.88 | 38.12 | 36.92 | 37.06 | 31.41 |
| **Natural Gas** | 1.71 | 2.62 | 2.42 | 2.25 | 2.44 | 2.59 | 2.34 | 2.62 |
| **Other** | 2.73 | 0.79 | 0.57 | 0.57 | 0.46 | 0.43 | 0.46 | 0.33 |
| **Total** | **72.56** | **64.89** | **61.89** | **60.81** | **61.33** | **61.29** | **61.70** | **52.66** |

## Electricity Production Sector

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 percent of total generation to 10.2 percent, while electricity generation from natural gas increased from 42.8 percent of total generation to 52.5 percent. Table 11 and Figure 8 give the relative percentages of each fuel used to generate electricity in Pennsylvania.

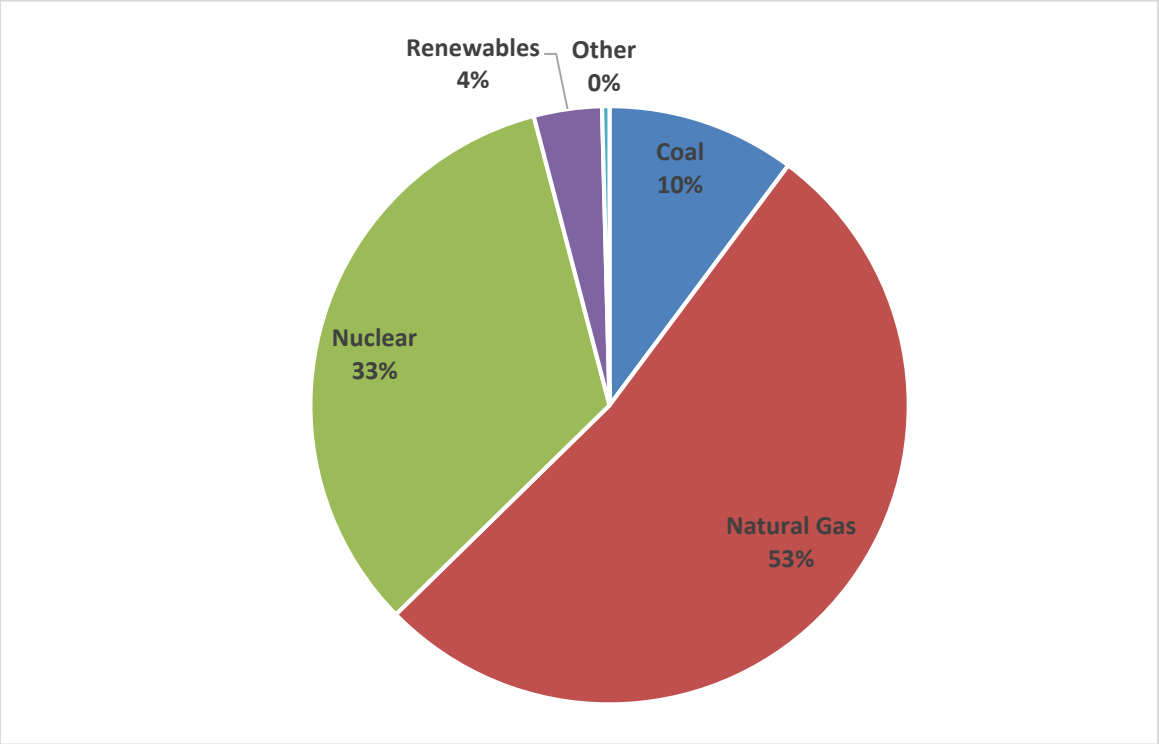
**Table 11 – Electricity Generation by Fuel Type (%)[20]**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021[21] |
|---|---|---|---|---|---|---|---|---|---|
| **Coal** | 55.5 | 48.0 | 30.1 | 25.4 | 22.3 | 20.5 | 16.6 | 10.2 | 12.1 |
| **Nuclear** | 35.0 | 33.9 | 37.5 | 38.6 | 39.0 | 38.8 | 36.3 | 33.2 | 31.5 |
| **Natural Gas** | 5.0 | 14.7 | 27.7 | 31.6 | 33.9 | 35.5 | 42.8 | 52.5 | 52.5 |
| **Petroleum** | 2.3 | 0.2 | 0.3 | 0.2 | 0.2 | 0.3 | 0.1 | 0.0 | 0.1 |
| **Biomass** | 0.9 | 1.0 | 1.1 | 1.1 | 1.1 | 1.1 | 0.9 | 0.8 | 0.7 |
| **Hydroelectric** | 1.0 | 1.0 | 1.2 | 1.1 | 1.5 | 2.0 | 1.5 | 1.2 | 1.3 |
| **Solar** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 |
| **Wind** | 0.1 | 0.8 | 1.6 | 1.6 | 1.7 | 1.7 | 1.4 | 1.6 | 1.4 |
| **Other** | 0.3 | 0.3 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 |

[20] U.S. Energy Information Administration (EIA). 2023. Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923). Accessed 3/2023. https://www.eia.gov/electricity/data/state/

[21] Ibid.

**Figure 8 – 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 12 shows the amount of each of these fuels consumed (BBtu) for electricity generation in Pennsylvania.

**Table 12 – Fuel Use for Electricity Generation (BBtu)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021[22] |
|---|---|---|---|---|---|---|---|---|---|
| **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 |
| **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. Figure 9 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.

[22] Ibid.

**Figure 9 – Electricity Production Sector GHG Emissions by Fuel Type ($MMTCO_2e$)**

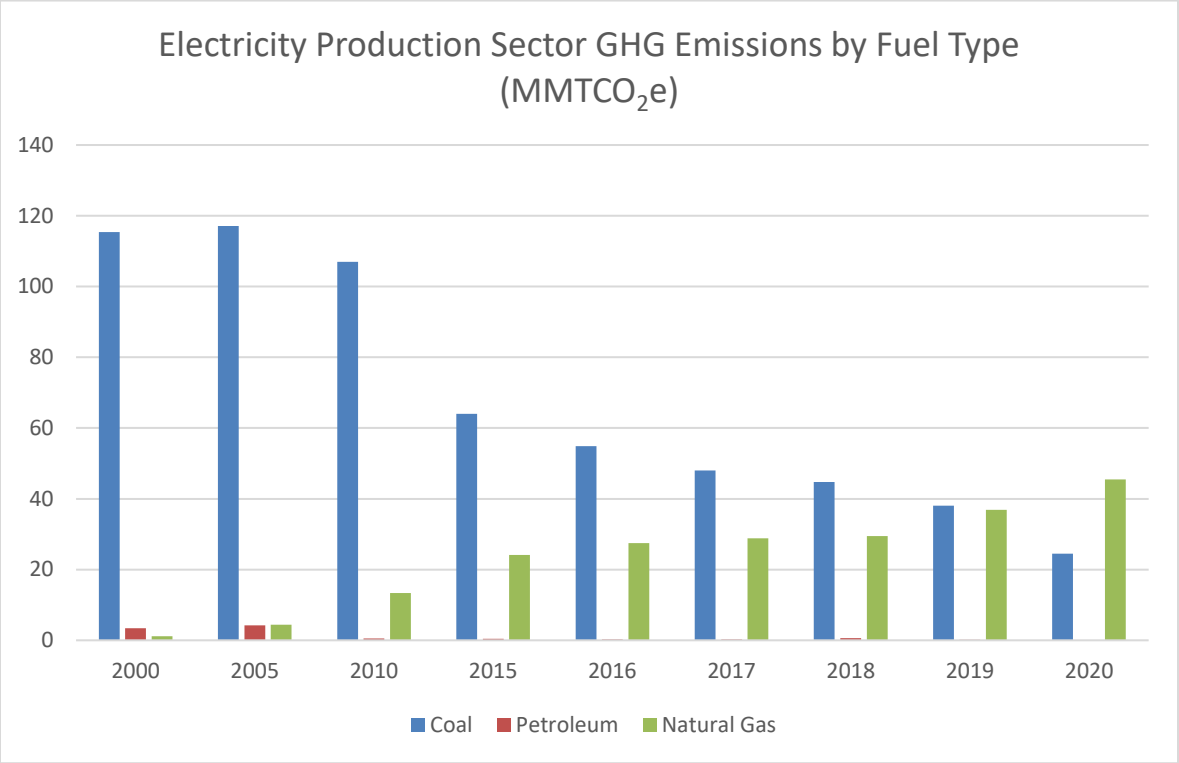



**Table 13 – Electricity Production Sector GHG Emissions by Fuel Type (MMTCO2e)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| **Coal** | 117.14 | 106.95 | 63.98 | 54.87 | 47.99 | 44.77 | 38.07 | 24.53 |
| **Oil** | 4.19 | 0.51 | 0.45 | 0.25 | 0.22 | 0.58 | 0.16 | 0.08 |
| **Natural Gas** | 4.42 | 13.34 | 24.13 | 27.51 | 28.82 | 29.50 | 36.86 | 45.44 |

Table 14 gives the relative percentage of GHG emissions attributed to the three primary fossil fuels used in the electricity production sector.

**Table 14 – Contribution to GHG Emissions, Fuel Type, in the Electricity Sector (%)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| **Coal** | 93.2 | 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 | 11.0 | 27.2 | 33.3 | 37.4 | 39.4 | 49.1 | 64.9 |

Table 14 shows for Pennsylvania's electricity generation sector in 2020, coal produced 35.0 percent of the GHG emissions while producing 10.2 percent of the electricity. Natural gas produced 64.9 percent of the GHG emissions while producing 52.5 percent of the electricity. Nuclear fuel, which produces no GHG emissions, was responsible for generating 33.2 percent 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 15 shows the total consumption of electricity (TWh) within the residential, commercial, industrial, and transportation sectors.

**Table 15 – Electricity Consumption by Sector (TWh)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021[23] |
|---|---|---|---|---|---|---|---|---|---|
| **Direct Use** | 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 |

Table 16 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 16 – Electricity Generated, Consumed and Exported (TWh)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021[24] |
|---|---|---|---|---|---|---|---|---|---|
| **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 |
| **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 |

## Agriculture Sector

At 9.73 MMTCO$_2$e annually, 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 groups consisting of enteric fermentation, manure management, and soil management. Table 17 lists the number (1,000 head) of each type of farm animal accounted for in the SIT.

[23] Ibid.
[24] Ibid.

**Table 17 – Animal Populations Contributing to GHG Emissions (1,000 Head)**

| | 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** | 1,088 | 1,133 | 1,165 | 1,163 | 1,195 | 1,280 | 1,270 | 1,398 |
| **Horses** | 115 | 118 | 101 | 95 | 88 | 82 | 88 | 69 |

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

**Table 18 – GHG Emissions ($CH_4$), by Livestock Type, from Enteric Fermentation ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| **Dairy Cows** | 1.889 | 1.900 | 1.895 | 1.903 | 1.907 | 1.901 | 1.909 | 1.782 |
| **Dairy Replacement Heifers** | 0.407 | 0.457 | 0.462 | 0.492 | 0.476 | 0.468 | 0.476 | 0.411 |
| **Beef Cows** | 0.355 | 0.375 | 0.352 | 0.399 | 0.435 | 0.506 | 0.436 | 0.519 |
| **Beef Replacement Heifers** | 0.063 | 0.065 | 0.089 | 0.097 | 0.105 | 0.097 | 0.084 | 0.077 |
| **Heifer Stockers** | 0.082 | 0.075 | 0.083 | 0.083 | 0.091 | 0.091 | 0.047 | 0.039 |
| **Steer Stockers** | 0.245 | 0.217 | 0.210 | 0.203 | 0.232 | 0.188 | 0.112 | 0.090 |
| **Feedlot Heifers** | 0.024 | 0.026 | 0.026 | 0.026 | 0.026 | 0.026 | 0.026 | 0.039 |
| **Feedlot Steer** | 0.042 | 0.048 | 0.048 | 0.048 | 0.048 | 0.048 | 0.048 | 0.070 |
| **Bulls** | 0.060 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.049 |
| **Sheep** | 0.020 | 0.019 | 0.017 | 0.019 | 0.019 | 0.019 | 0.019 | 0.019 |
| **Goats** | 0.006 | 0.007 | 0.006 | 0.007 | 0.007 | 0.007 | 0.007 | 0.007 |
| **Swine** | 0.041 | 0.042 | 0.044 | 0.044 | 0.045 | 0.048 | 0.048 | 0.052 |
| **Horses** | 0.052 | 0.053 | 0.045 | 0.043 | 0.040 | 0.037 | 0.040 | 0.031 |
| **Total** | **3.286** | **3.345** | **3.339** | **3.424** | **3.491** | **3.489** | **3.312** | **3.184** |

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 19 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 19 – GHG Emissions ($CH_4$ and $N_2O$), by Livestock Type, from Manure Management ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| **Dairy Cattle** | 1.092 | 1.353 | 1.583 | 1.661 | 1.626 | 1.661 | 1.595 | 0.696 |
| **Beef Cattle** | 0.055 | 0.057 | 0.058 | 0.059 | 0.060 | 0.060 | 0.061 | 0.060 |
| **Swine** | 0.308 | 0.320 | 0.305 | 0.311 | 0.305 | 0.347 | 0.347 | 0.251 |
| **Poultry** | 0.209 | 0.190 | 0.216 | 0.220 | 0.222 | 0.228 | 0.223 | 0.240 |
| **Other** | 0.013 | 0.011 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.008 |
| **Total** | **1.676** | **1.931** | **2.172** | **2.260** | **2.222** | **2.306** | **2.235** | **1.256** |

The third sub-group 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, and crop residue with the soil. Table 20 below shows the estimated GHG emissions ($MMTCO_2e$) resulting from agriculture soils management.

**Table 20 – GHG Emissions ($N_2O$) from the Management of Agricultural Soils ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| **Direct** | 2.43 | 2.46 | 2.75 | 2.81 | 2.92 | 2.88 | 2.72 | 2.59 |
| **Indirect** | 0.21 | 0.21 | 0.23 | 0.24 | 0.24 | 0.24 | 0.21 | 0.22 |
| **Leaching and Runoff** | 0.27 | 0.27 | 0.32 | 0.32 | 0.32 | 0.33 | 0.28 | 0.30 |
| **Total** | **2.91** | **2.94** | **3.30** | **3.37** | **3.48** | **3.44** | **3.21** | **3.11** |

## Waste Management Sector

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 percent 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.

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 21 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 21 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 21 – GHG Emissions Associated with Landfilling Operations ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| **Potential Landfill $CH_4$** | 8.56 | 9.51 | 9.66 | 9.70 | 9.75 | 9.79 | 9.88 | 9.96 |
| **$CH_4$ Avoided** | -6.62 | -8.89 | -9.03 | -9.07 | -9.11 | -9.15 | -9.23 | -9.30 |
| **Oxidation** | -0.19 | -0.06 | -0.06 | -0.06 | -0.06 | -0.06 | -0.06 | -0.07 |
| **Total $CH_4$ Emissions (Landfills)** | **1.75** | **0.56** | **0.57** | **0.57** | **0.57** | **0.58** | **0.58** | **0.59** |

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 previously were used in the calculation. Table 22 shows the GHG emissions ($MMTCO_2e$) attributable to the combustion of plastics, synthetic rubber, and synthetic fibers included in the waste combustion portion of the waste management sector.

**Table 22 – GHG Emissions Associated with Waste Combustion ($MMTCO_2e$)**

| | 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 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| **$CH_4$** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | **1.62** | **1.45** | **1.64** | **1.70** | **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 21 shows estimated $CO_2$ emissions avoided by recycling for the years 2012 through 2020.[25]

**Table 23 – GHG Emissions Avoided from Recycling**

| Year | Tons Recycled (in millions) | Equivalents (in millions) | | |
|---|---|---|---|---|
| | | Tons of $CO_2$ saved per year | Passenger Vehicles Taken off the Road for One Year | 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 |

[25] Statewide Recycling Data (pa.gov), values converted to metric tons here.

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

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 (red meat, poultry, pulp and paper, and fruit and vegetable production). The SIT was used to calculate the municipal and industrial wastewater GHG emissions. Production data was 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 24 shows the GHG emissions ($MMTCO_2e$) attributed to the treatment of wastewater from municipal and industrial sources in the waste management sector.

**Table 24 – GHG Emissions Associated with Wastewater Treatment ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| **Municipal $CH_4$** | 1.00 | 1.02 | 1.02 | 1.02 | 1.02 | 1.03 | 1.02 | 1.02 |
| **Municipal $N_2O$** | 0.38 | 0.38 | 0.38 | 0.39 | 0.39 | 0.39 | 0.38 | 0.38 |
| **Industrial $CH_4$** | 0.38 | 0.43 | 0.45 | 0.45 | 0.47 | 0.46 | 0.46 | 0.48 |
| **Total** | **1.76** | **1.83** | **1.86** | **1.86** | **1.88** | **1.87** | **1.87** | **1.88** |

Table 25 shows the GHG emissions ($MMTCO_2e$) totals for the solid waste and wastewater treatment portions of the waste management sector.

**Table 25 – 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** | 3.36 | 2.01 | 2.21 | 2.27 | 2.29 | 2.39 | 2.39 | 2.40 |
| **Wastewater** | 1.76 | 1.83 | 1.86 | 1.86 | 1.88 | 1.87 | 1.87 | 1.88 |
| **Total** | **5.12** | **3.84** | **4.07** | **4.13** | **4.17** | **4.26** | **4.26** | **4.28** |

## 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, the forestry and land use sector sequestered 28.89 $MMTCO_2$ 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 this sector, but those sources are now accounted for in the agricultural sector. Data from the SIT was the primary source of information for this section; however, forest fire acreage is collected from the National Interagency Fire Center[26] and Pennsylvania's Department of Conservation & Natural Resources.

Table 26 shows the total GHG emissions produced (positive values) and emissions sequestered (negative values) ($MMTCO_2e$) totals for the forestry and land use sector.

[26] https://www.nifc.gov/fireInfo/fireInfo_statistics.html

**Table 26 – Total GHG Emissions from the Forestry and Land Use Sector ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| **Forest Carbon Flux** | -24.72 | -23.89 | -22.69 | -22.35 | -22.04 | -21.72 | -21.40 | -21.40 |
| **Urban Trees, Carbon** | -3.15 | -3.31 | -3.46 | -3.49 | -3.52 | -3.56 | -3.59 | -3.62 |
| **Landfilled Yard Trimmings and Food Scraps, Carbon** | -0.39 | -0.44 | -0.40 | -0.36 | -0.33 | -0.42 | -0.42 | -0.36 |
| **Forest Fires, $CH_4$ and $N_2O$** | 0.01 | 0.04 | 0.12 | 0.18 | 0.14 | 0.11 | 0.10 | 0.10 |
| **$N_2O$ from Settlement Soils** | 0.04 | 0.04 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **Agricultural Soil Carbon Flux** | -4.81 | -3.01 | -2.20 | -3.32 | -3.20 | -2.80 | -2.43 | -3.66 |
| **Total** | **-33.02** | **-30.56** | **-28.56** | **-29.29** | **-28.90** | **-28.33** | **-27.68** | **-28.89** |

## Conclusion and Looking Forward

The 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 26.4 percent reduction in GHG emissions in 2020 compared to 2005. While this reduction 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.[27]

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 42.8 percent in 2019 to 52.5 percent in 2020, while coal-based electricity generation continues to decrease (Table 11). While the electricity production sector contributed the highest emissions in 2020, 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 truer measurement from which to assess progress towards Pennsylvania's 26 percent by 2025 emissions goal.

[27] 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.