# 2022

# Pennsylvania Greenhouse Gas Inventory Report

**October 6, 2022**

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

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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 by 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.

Greenhouse gas emissions data presented in this inventory help track overall emissions trends over time. Executive Order 2019-01, signed by Governor Wolf on January 8, 2019, 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 2019, Pennsylvania has achieved a nearly 18 percent reduction in net GHG emissions compared to 2005; however, during the last two data years (2018 and 2019), GHG emissions rose slightly in the Commonwealth. An additional reduction of 24.28 million metric tons of carbon dioxide equivalent ($MMTCO_2e$) from 2019 levels is required to reach the 2025 goal and 180.64 $MMTCO_2e$ to reach the 2050 goal. This underscores the need for 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 duration of severe weather events all have a role in the trends observed in the Commonwealth's GHG emissions.

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.

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[1] IPCC 2014: https://www.ipcc.ch/report/ar5/syr/

[2] DEP, 2021: www.depgreenport.state.pa.us/elibrary/GetDocument?docId=3667348&DocName=PENNSYLVANIA_CLIMATE_IMPACTS ASSESSMENT_2021.PDF <span_style%3D"color:green%3b"> <span style%3D"color:blue%3b">%28NEW%29 4/30/2023

[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

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 2019 data, the National Inventory report disaggregated energy use and GHG emission totals to the state level.[6] This shift ensures consistency with the national inventory, adherence to international standards, and methodological consistency. It also ensures that the state inventory covers the same time series, as well as anthropogenic sources and sinks for GHGs in the national inventory. This access to new estimates in various sectors resulted in some changes to the historic data from previous Commonwealth GHG inventory reports. Most of these changes were small, but some highlighted significant discrepancies in categories such as Ozone Depleting Substances (ODS) substitute emissions and international bunker fuels.

While the complete inventory presented in this report includes GHG emissions data from 2005 through 2019, fuel consumption data is available from the U.S, Energy Information Administration's (EIA) State Energy Data System (SEDS) for 2020[7] and has been included in relevant tables and figures below. It should be noted that due to impacts from COVID-19 related shutdowns, data from 2020 may be anomalous.

As shown in Table 1, the total statewide gross GHG emissions for Pennsylvania in 2019, the latest year with complete data available from the SIT, were 266.01 $MMTCO_2e$. This is an increase of 0.15 $MMTCO_2e$ from 2018. Pennsylvania's forestry and land use sector provides a carbon sink for GHG emissions, absorbing 27.47 $MMTCO_2e$ in 2019 and lowering the Commonwealth's net GHG emission for 2019 to 238.55 $MMTCO_2e$. Table 1 also shows a relative decrease of 17.5 percent in the gross emission totals and 17.6 percent in the net emission totals for 2019 relative to 2005.

Also shown in Table 1, the sectors with the largest contribution to the Commonwealth's GHG emissions are the industrial, electricity production and transportation sectors. Increased emissions were seen across all three of these sectors between 2018 and 2019. The industrial sector was once again the highest GHG producing sector in the state in 2019, producing 32 percent of the Commonwealth's emissions. Emissions from the industrial sector have been trending upward since 2016 with an increase of eight percent between 2016 and 2019. Emissions from the electricity production sector increased slightly in 2019, ending the downward trend observed over the past decade. The relative change for each of these sectors between 2005 and 2019 was an increase of 8.44 $MMTCO_2e$ (10.8 percent) for the industrial sector, a decrease of 50.66 $MMTCO_2e$ (40.3 percent) for the electricity production sector, and a decrease of 9.54 $MMTCO_2e$ (13.8 percent) for the transportation sector. Together, these three sectors annually account for approximately 83 percent of Pennsylvania's gross GHG emissions.

[6] State GHG Emissions and Removals | US EPA

[7] 2020 data from SEDS released 7/24/2022. U.S. Energy Information Administration - EIA - Independent Statistics and Analysis

The residential, and commercial sectors experienced decreases in emissions between 2018 and 2019 as well as overall declines in GHG emissions since 2005. The residential and commercial sectors had decreases in GHG emissions of 4.38 and 0.98 $MMTCO_2e$ (18.3 and 7.7 percent), respectively, since 2005. Emissions from the commercial sector, however, have trended upward since 2016 with an 11 percent increase between 2016 and 2019. GHG emissions from the agricultural sector decreased slightly between 2018 and 2019 but have increased overall 1.39 $MMTCO_2e$ (16.8 percent) since 2005.

GHG emissions from the waste management sector experienced a 0.83 $MMTCO_2e$ (17.9 percent) decrease from 2005 to 2019. During this same period, the GHG emissions sequestered in the forestry and land use sector have decreased by 5.57 $MMTCO_2e$ (16.9 percent).

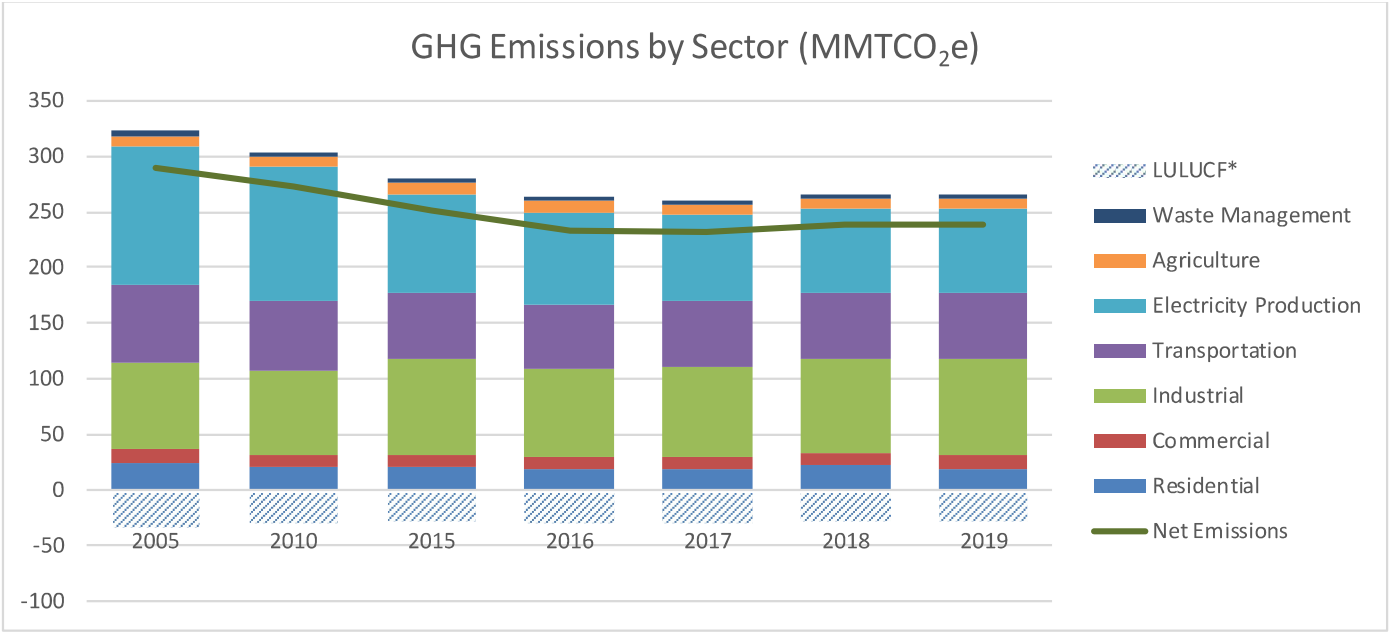
A brief discussion of each individual sector will occur later in the document. The discussions will focus on the trends of various components within each sector, such as fuel mix or subgroups of the sector.

**Table 1 - GHG Emissions by Sector ($MMTCO_2e$)**

| Sector / Emission Sources ($MMTCO_2e$) | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| **Residential** | **23.90** | **20.21** | **20.75** | **18.48** | **18.53** | **21.65** | **19.52** |
| **Commercial** | **12.86** | **10.53** | **11.44** | **10.57** | **10.85** | **12.12** | **11.88** |
| **Industrial** | **77.95** | **75.82** | **84.90** | **79.12** | **81.46** | **84.36** | **86.38** |
| Combustion of Fossil Fuels | 46.34 | 40.01 | 50.15 | 45.49 | 47.29 | 49.94 | 49.75 |
| Industrial Process | 13.05 | 12.52 | 12.42 | 12.23 | 11.91 | 11.66 | 12.39 |
| Coal Mining and Abandoned Mines | 9.82 | 11.99 | 10.06 | 9.25 | 10.07 | 10.54 | 11.91 |
| Natural Gas and Oil Systems | 8.74 | 11.30 | 12.27 | 12.15 | 12.19 | 12.22 | 12.33 |
| **Transportation** | **69.25** | **62.98** | **60.01** | **58.95** | **59.48** | **59.34** | **59.71** |
| Petroleum | 67.54 | 60.36 | 57.59 | 56.70 | 57.04 | 56.75 | 57.36 |
| Natural Gas | 1.71 | 2.62 | 2.42 | 2.25 | 2.44 | 2.59 | 2.34 |
| **Electricity Production** | **125.75** | **120.80** | **88.56** | **82.63** | **77.04** | **74.85** | **75.09** |
| Coal | 117.14 | 106.95 | 63.98 | 54.87 | 47.99 | 44.77 | 38.07 |
| Petroleum | 4.19 | 0.51 | 0.45 | 0.25 | 0.22 | 0.58 | 0.16 |
| Natural Gas | 4.42 | 13.34 | 24.13 | 27.51 | 28.82 | 29.50 | 36.86 |
| **Agriculture** | **8.23** | **9.26** | **9.93** | **9.88** | **9.97** | **10.04** | **9.62** |
| Enteric Fermentation | 3.37 | 3.44 | 3.43 | 3.51 | 3.57 | 3.59 | 3.51 |
| Manure Management | 1.68 | 1.93 | 2.17 | 2.26 | 2.22 | 2.31 | 2.24 |
| Agricultural Soil Management | 3.13 | 3.49 | 4.20 | 3.90 | 3.98 | 3.99 | 3.71 |
| Liming of Soils | 0.03 | 0.38 | 0.08 | 0.16 | 0.15 | 0.11 | 0.11 |
| Urea Fertilization | 0.02 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Burning of Agricultural Crop Waste | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Waste Management** | **4.65** | **3.40** | **3.62** | **3.68** | **3.70** | **3.81** | **3.82** |
| Solid Waste and Combustion | 3.58 | 2.25 | 2.45 | 2.51 | 2.53 | 2.63 | 2.64 |
| Wastewater | 1.07 | 1.15 | 1.16 | 1.17 | 1.17 | 1.18 | 1.18 |
| **Total Statewide Gross Emissions (Prod.)** | **322.58** | **303.01** | **279.20** | **263.31** | **261.03** | **266.16** | **266.01** |
| *Change relative to 2005* | | *-6.1%* | *-13.4%* | *-18.4%* | *-19.1%* | *-17.5%* | *-17.5%* |
| **Forestry and Land Use** | **-33.04** | **-30.56** | **-28.55** | **-29.31** | **-28.92** | **-28.36** | **-27.47** |
| **Total Statewide Net Emissions (Prod w/ Sinks)** | **289.55** | **272.46** | **250.64** | **234.00** | **232.11** | **237.81** | **238.55** |
| *Change relative to 2005* | | *-5.9%* | *-13.4%* | *-19.2%* | *-19.8%* | *-17.9%* | *-17.6%* |

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 2, 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 2 - GHG Emissions by Gas ($MMTCO_2e$)**

| Emissions ($MMTCO_2E$) | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| **Gross $CO_2$** | 292.15 | 265.54 | 241.93 | 227.06 | 223.83 | 228.44 | 227.16 |
| **Net $CO_2$** | 259.07 | 234.90 | 213.15 | 197.51 | 194.71 | 199.91 | 199.54 |
| CO2 from Fossil Fuel Combustion | 281.40 | 256.44 | 232.78 | 217.98 | 215.04 | 219.85 | 217.94 |
| Industrial Processes | 9.12 | 7.27 | 7.41 | 7.21 | 6.92 | 6.67 | 7.29 |
| Waste | 1.58 | 1.43 | 1.61 | 1.67 | 1.68 | 1.78 | 1.78 |
| Agriculture | 0.05 | 0.40 | 0.13 | 0.20 | 0.19 | 0.15 | 0.15 |
| LULUCF | (33.08) | (30.64) | (28.77) | (29.55) | (29.12) | (28.53) | (27.62) |
| **$CH_4$** | 26.56 | 30.57 | 29.97 | 29.15 | 30.02 | 30.65 | 31.96 |
| Stationary Combustion | 0.39 | 0.42 | 0.51 | 0.44 | 0.44 | 0.50 | 0.48 |
| Mobile Combustion | 0.13 | 0.10 | 0.07 | 0.07 | 0.06 | 0.06 | 0.06 |
| Coal Mining | 9.82 | 11.99 | 10.06 | 9.25 | 10.07 | 10.54 | 11.91 |
| Natural Gas and Oil Systems | 8.75 | 11.31 | 12.27 | 12.15 | 12.20 | 12.22 | 12.32 |
| Enteric Fermentation | 4.45 | 4.78 | 4.96 | 5.12 | 5.14 | 5.23 | 5.12 |
| Forest Fires | 0.01 | 0.03 | 0.14 | 0.16 | 0.12 | 0.10 | 0.08 |
| Waste | 1.96 | 0.80 | 0.81 | 0.82 | 0.82 | 0.82 | 0.83 |
| Wastewater | 1.06 | 1.13 | 1.15 | 1.16 | 1.16 | 1.17 | 1.16 |
| **$N_2O$** | 6.14 | 5.96 | 6.22 | 5.82 | 5.82 | 5.80 | 5.43 |
| Stationary Combustion | 0.84 | 0.75 | 0.59 | 0.51 | 0.48 | 0.48 | 0.44 |
| Mobile Combustion | 1.49 | 1.04 | 0.66 | 0.62 | 0.58 | 0.54 | 0.52 |
| Industrial Processes | - | - | - | - | - | - | - |
| Forest Fires | 3.73 | 4.08 | 4.85 | 4.56 | 4.63 | 4.65 | 4.35 |
| N2O from Settlement Soils | 0.04 | 0.05 | 0.08 | 0.09 | 0.08 | 0.08 | 0.08 |
| Waste | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Wastewater | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **HFC, PFC, $SF_6$ and $NF_3$ Emissions** | 3.93 | 5.25 | 5.01 | 5.02 | 4.99 | 5.00 | 5.10 |
| Industrial Processes | 3.93 | 5.25 | 5.01 | 5.02 | 4.99 | 5.00 | 5.10 |
| **Indirect $CO_2$ from Electricity Consumption*** | 89.46 | 84.58 | 64.65 | 59.36 | 55.83 | 55.72 | 52.80 |
| **Gross Emissions** | **328.79** | **307.32** | **283.12** | **267.06** | **264.66** | **269.89** | **269.66** |
| **Sinks** | **(33.08)** | **(30.64)** | **(28.77)** | **(29.55)** | **(29.12)** | **(28.53)** | **(27.62)** |
| **Net Emissions (Sources and Sinks)** | **295.71** | **276.68** | **254.35** | **237.50** | **235.54** | **241.36** | **242.04** |

* 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 1 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 84 percent of GHG emission, in terms of $MMTCO_2e$, followed by $CH_4$ at 12 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 2019.

**Figure 2 – GHG Emissions by Gas, 2019 ($MMTCO_2e$)**

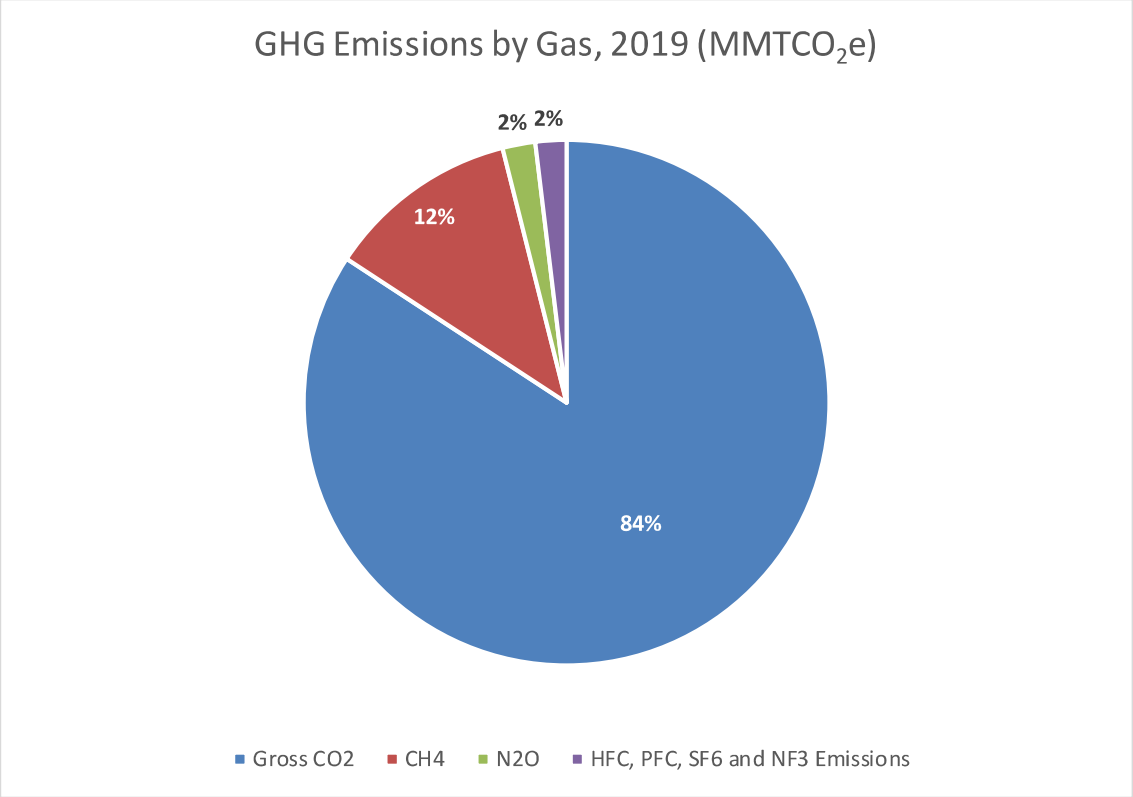
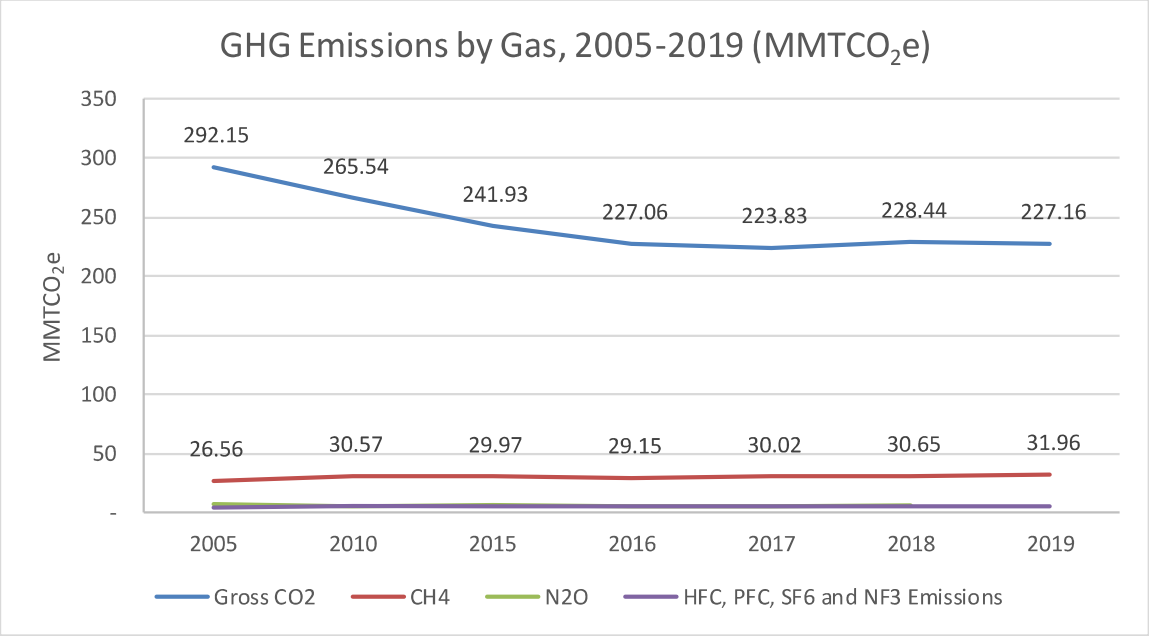



**Figure 3 – GHG Emissions by Gas, 2005-2019 ($MMTCO_2e$)**



# 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 2019, are natural gas, heating oil, propane, and kerosene. Table 3 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 increased in 2019 relative to 2018. No electricity consumption is included in these values.

**Table 3– Residential Sector Fuel Consumption by Year (BBtu)**

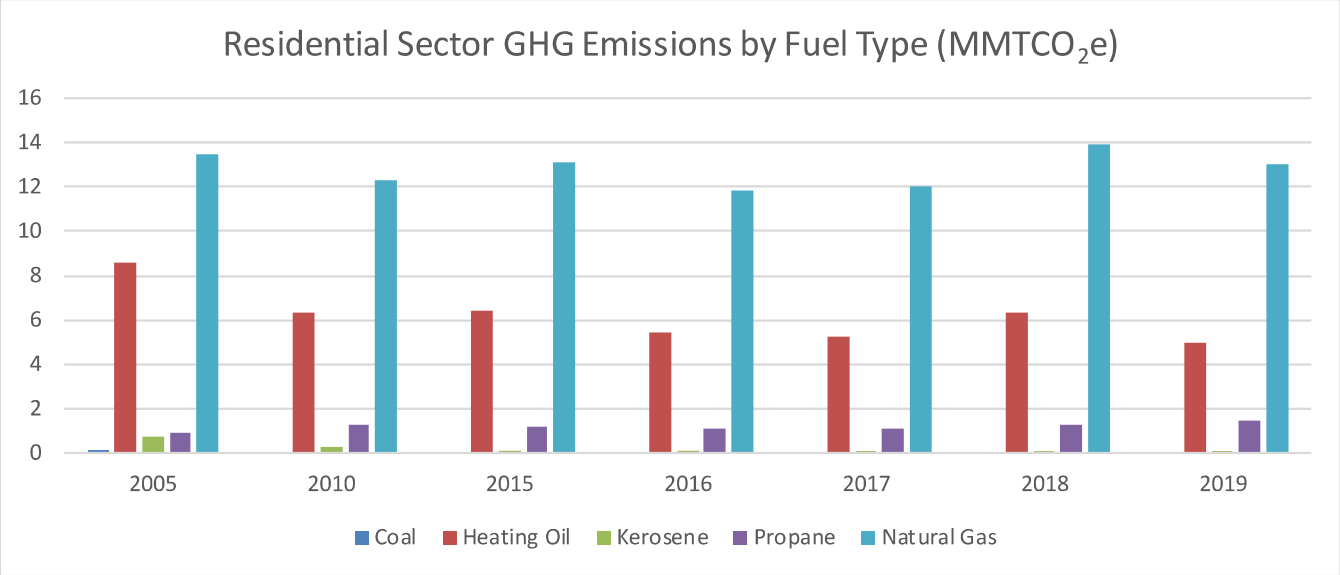
| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020[8] |
|---|---|---|---|---|---|---|---|---|
| **Coal**[9] | 1,253 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Heating Oil** | 115,753 | 85,432 | 86,789 | 73,049 | 71,250 | 86,087 | 66,666 | 59,300 |
| **Kerosene** | 10,330 | 4,211 | 1,350 | 1,513 | 921 | 930 | 1,056 | 1,000 |
| **Propane** | 15,122 | 20,812 | 18,230 | 16,909 | 17,668 | 20,768 | 23,752 | 18,625 |
| **Natural Gas** | 255,038 | 231,854 | 247,059 | 224,764 | 228,190 | 262,667 | 245,942 | 230,053 |
| **Total** | **397,496** | **342,309** | **353,428** | **316,235** | **318,029** | **370,452** | **337,416** | **308,978** |

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.

[8] 2020 data was compiled from U.S. Energy Information Administration's State Energy Data System (SEDS), released 7/24/2022. 2020 data is not available for all sectors presented in this inventory and will be presented in full in the 2023 Pennsylvania Greenhouse Gas Inventory Report.

[9] 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 2019, are natural gas, heating oil, motor gasoline, propane, coal, kerosene, and residual fuel. Table 4 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 4- Commercial Sector Fuel Consumption (BBtu)**

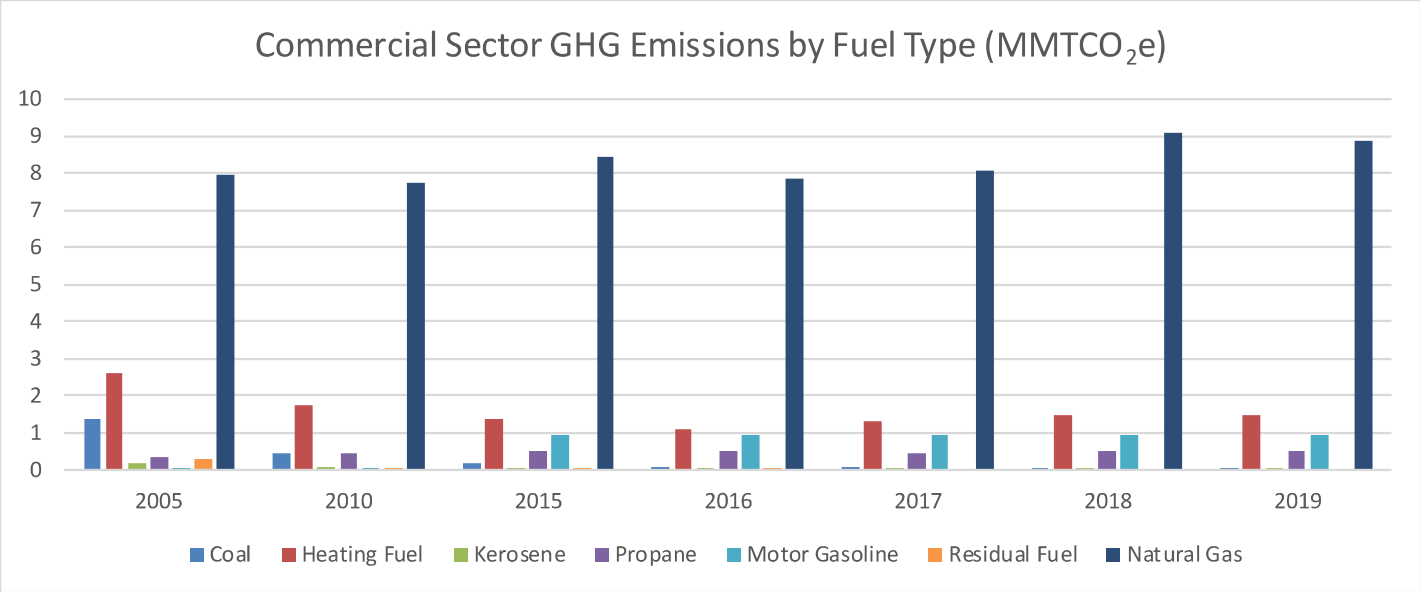
| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020[10] |
|---|---|---|---|---|---|---|---|---|
| **Coal** | 14,407 | 4,729 | 1,963 | 1,031 | 645 | 362 | 311 | 224 |
| **Heating Oil** | 35,632 | 23,625 | 18,765 | 15,272 | 17,907 | 20,328 | 19,943 | 13,707 |
| **Kerosene** | 2,610 | 755 | 144 | 222 | 143 | 179 | 217 | 176 |
| **Propane** | 5,480 | 6,853 | 7,829 | 8,135 | 7,225 | 8,409 | 8,019 | 7,966 |
| **Motor Gasoline[11]** | 462 | 428 | 13,062 | 13,142 | 13,331 | 13,533 | 13,620 | 14,747 |
| **Residual Fuel** | 3,934 | 570 | 53 | 127 | 3 | 5 | - | - |
| **Natural Gas** | 150,849 | 146,902 | 159,442 | 148,851 | 152,220 | 171,616 | 167,984 | 154,048 |
| **Total** | **213,374** | **183,862** | **201,258** | **186,780** | **191,474** | **214,432** | **210,094** | **190,868** |

[10] Ibid.

[11] 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 over 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 2019 are natural gas, coal/coke, heating oil, and various other fuels. Table 5 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 5 – Industrial Sector Fuel Consumption (BBtu)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020[12] |
|---|---|---|---|---|---|---|---|---|
| **Coking Coal** | 182,475 | 134,939 | 172,216 | 130,860 | 149,838 | 162,218 | 158,335 | 105,660 |
| **Other Coal** | 67,654 | 51,240 | 35,377 | 28,876 | 17,257 | 13,516 | 12,035 | 12,323 |
| **Asphalt and Road Oil** | 60,964 | 46,840 | 47,228 | 46,510 | 47,515 | 43,561 | 45,301 | 37,252 |
| **Aviation Gasoline Blending Components** | 390 | -11 | -12 | -9 | -6 | -50 | -28 | -12 |
| **Heating Oil** | 33,055 | 34,088 | 51,101 | 36,780 | 41,820 | 43,320 | 43,822 | 32,112 |
| **Kerosene** | 663 | 281 | 68 | 82 | 58 | 79 | 63 | 60 |
| **Propane** | 22,823 | 29,562 | 20,734 | 21,201 | 20,946 | 21,252 | 20,765 | 5,948 |
| **Lubricants[13]** | 14,716 | 5,910 | 7,060 | 6,970 | 6,461 | 6,101 | 5,966 | 5,303 |
| **Motor Gasoline** | 9,486 | 9,712 | 7,055 | 7,004 | 7,079 | 7,163 | 7,150 | 7,748 |
| **Misc. Petro Products** | 1,493 | 1,795 | 2,508 | 2,540 | 2,593 | 2,582 | 2,349 | 2,226 |
| **Petroleum Coke** | 36,889 | 26,859 | 25,424 | 24,379 | 24,432 | 22,396 | 12,613 | 7,802 |
| **Residual Fuel** | 12,039 | 4,272 | 565 | 770 | 598 | 477 | 580 | 705 |
| **Still Gas** | 70,200 | 67,173 | 49,515 | 50,075 | 51,235 | 51,797 | 35,455 | 20,781 |
| **Special Naphthas** | 3,265 | 1,653 | 6,891 | 6,496 | 6,883 | 6,314 | 6,559 | 5,937 |
| **Unfinished Oils[14]** | 131 | 1,276 | -589 | 268 | 2,472 | 992 | 3,142 | 2,818 |
| **Waxes** | 1,871 | 894 | 722 | 751 | 625 | 764 | 641 | 566 |
| **Natural Gas** | 197,525 | 228,806 | 404,961 | 418,060 | 432,717 | 475,033 | 516,241 | 490,266 |
| **Total** | **715,639** | **645,289** | **830,824** | **781,613** | **812,523** | **857,515** | **870,989** | **737,495** |

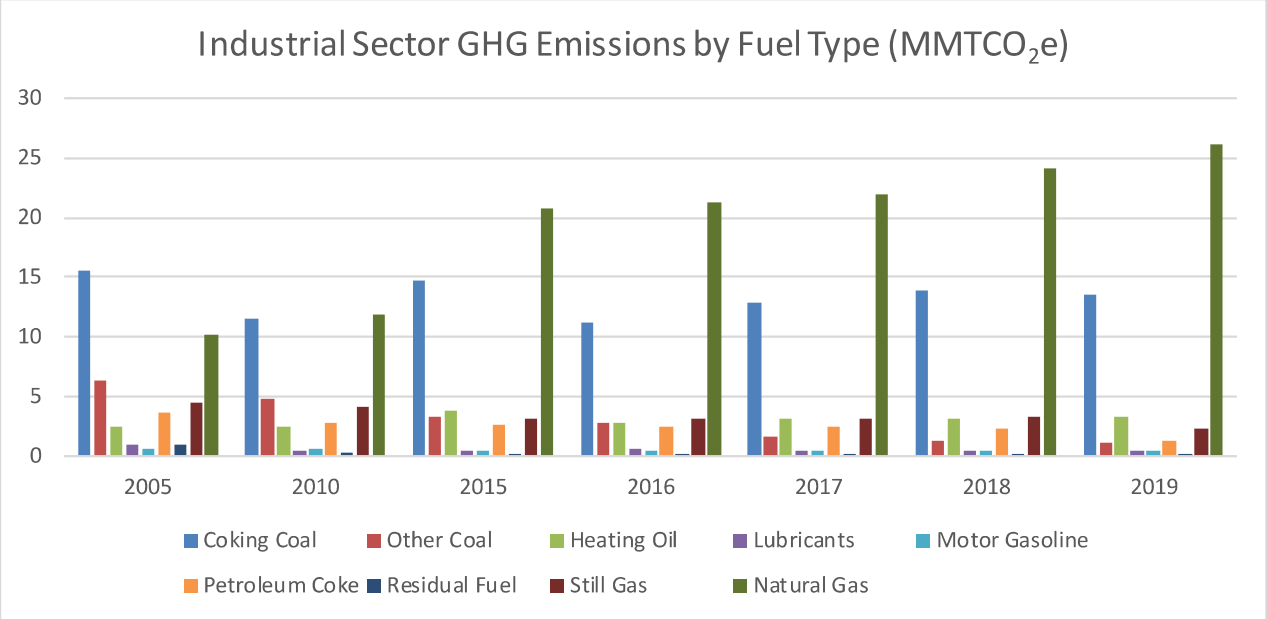
As in the residential and commercial sectors, each fuel used in the industrial sector emits GHGs at different rates. Figure 6 shows the GHG emissions ($MMTCO_2e$) attributed to each fuel used in the industrial sector. The emissions related to electricity within the industrial sector are accounted for in the electricity production sector.

[12] Ibid.

[13] 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

[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)

**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 6 shows the GHG emissions ($MMTCO_2e$) attributed to each of the processes included within the industrial sector.

**Table 6– Industrial Sector Process Emissions ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| *$CO_2$ Emissions* | | | | | | | |
| **Cement Manufacture** | 3.13 | 1.65 | 1.85 | 1.83 | 1.74 | 1.61 | 1.80 |
| **Lime Manufacture** | 0.85 | 0.85 | 0.73 | 0.69 | 0.62 | 0.65 | 0.71 |
| **Limestone and Dolomite Use** | 0.55 | 0.87 | 0.95 | 0.80 | 0.67 | 0.51 | 0.90 |
| **Soda Ash** | 0.11 | 0.09 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| **Iron & Steel Production** | 4.48 | 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 |
| *HFC, PFC, $SF_6$, and $NF_3$ Emissions* | | | | | | | |
| **ODS Substitutes**[15] | 3.56 | 5.00 | 4.84 | 4.85 | 4.82 | 4.83 | 4.93 |
| **Semiconductor Manufacturing** | 0.03 | 0.02 | 0.02 | 0.02 | 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 |
| **Total** | **13.05** | **12.52** | **12.42** | **12.23** | **11.91** | **11.66** | **12.39** |

[15] There is a significant difference in current ODS substitutes data from previous GHG inventory reports due to a change in the calculation methodology for EPA SIT data.

## 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 7 shows the GHG emissions ($MMTCO_2e$) attributed to underground and surface coal mining, coal processing, and abandoned underground mines.

**Table 7– $CH_4$ from Coal Mining-Related Process Emissions ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| **Underground Mining** | 6.51 | 9.39 | 8.00 | 7.38 | 8.09 | 8.57 | 9.93 |
| **Surface Mining** | 0.73 | 0.61 | 0.35 | 0.24 | 0.31 | 0.30 | 0.31 |
| **Underground Processing** | 1.16 | 1.01 | 0.93 | 0.88 | 0.93 | 0.95 | 0.95 |
| **Surface Processing** | 0.12 | 0.10 | 0.06 | 0.04 | 0.05 | 0.05 | 0.05 |
| **Abandoned Mines** | 1.30 | 0.87 | 0.73 | 0.71 | 0.70 | 0.68 | 0.67 |
| **Total** | **9.82** | **11.99** | **10.06** | **9.25** | **10.07** | **10.54** | **11.91** |

## 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[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. Table 8 shows the GHG emissions ($MMTCO_2e$) attributed to natural gas production, transmission and distribution, and oil production.

**Table 8 – $CH_4$ from Natural Gas Production Process Emissions ($MMTCO_2e$)**

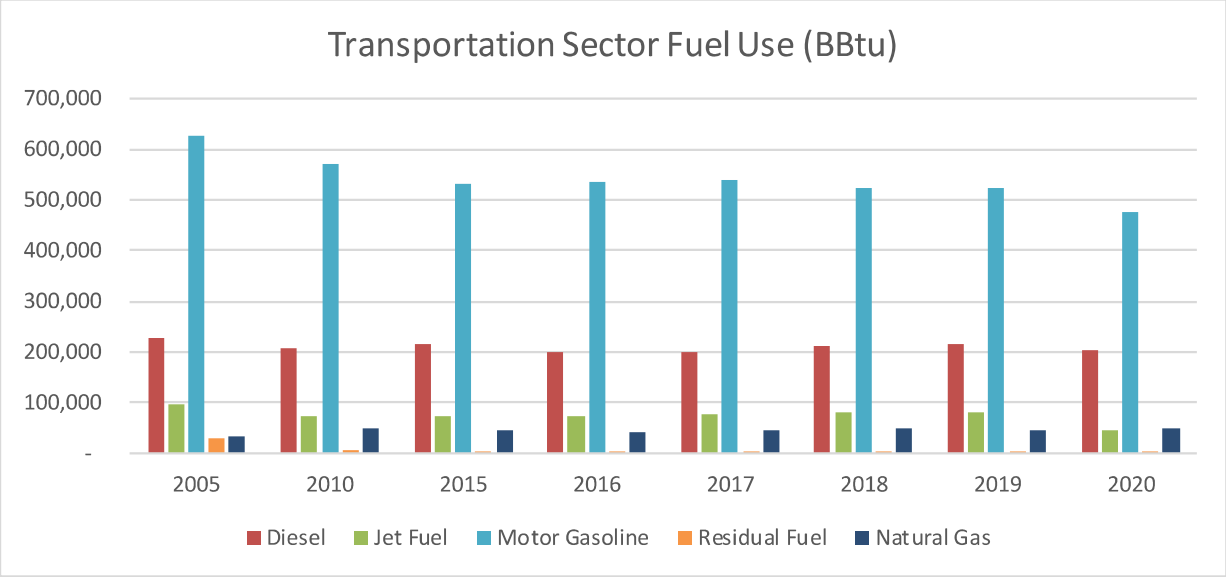
| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| **Natural Gas Production** | 4.81 | 7.26 | 8.14 | 8.00 | 8.01 | 8.01 | 8.11 |
| **Natural Gas Transmission** | 1.92 | 1.97 | 1.98 | 2.00 | 2.02 | 2.06 | 2.07 |
| **Natural Gas Distribution** | 1.97 | 2.02 | 2.07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

[16] 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

## 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 2019, 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 9 shows the GHG emission ($MMTCO_2e$) attributed to each fuel used in the transportation sector.

**Table 9– Transportation Sector Emissions by Fuel Consumption ($MMTCO_2e$)**

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

## 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-eight percent of the statewide gross emissions in 2019 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

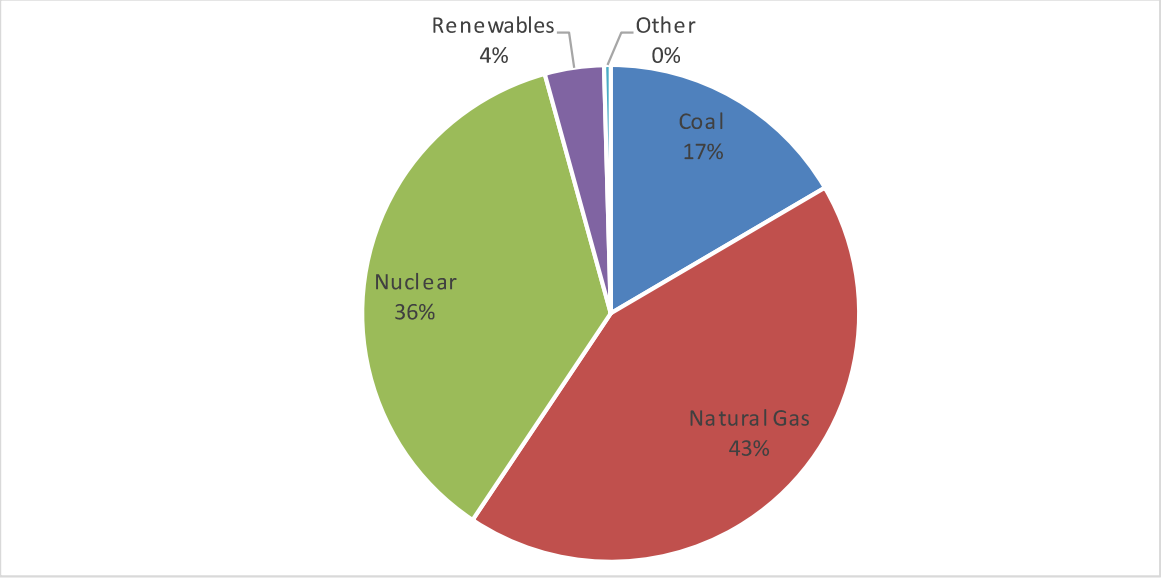
different ways within the Commonwealth. The three primary forms of electricity generation in Pennsylvania are natural gas, nuclear, and coal.

The largest changes in the production of electricity since 2005 have occurred in the use of coal and natural gas. From 2018 to 2019, electricity generation from coal continued its decline from 20.5 percent of total generation to 16.6 percent, while electricity generation from natural gas increased from 35.5 percent of total generation to 42.8 percent. Table 10 and Figure 8 give the relative percentages of each fuel used to generate electricity in Pennsylvania.

**Table 10– Electricity Generation by Fuel Type (%)[17]**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020[18] |
|---|---|---|---|---|---|---|---|---|
| **Coal** | 55.5 | 48.0 | 30.1 | 25.4 | 22.3 | 20.5 | 16.6 | 10.2 |
| **Nuclear** | 35.0 | 33.9 | 37.5 | 38.6 | 39.0 | 38.8 | 36.3 | 33.2 |
| **Natural Gas** | 5.0 | 14.7 | 27.7 | 31.6 | 33.9 | 35.5 | 42.8 | 52.5 |
| **Petroleum** | 2.3 | 0.2 | 0.3 | 0.2 | 0.2 | 0.3 | 0.1 | 0.0 |
| **Biomass** | 0.9 | 1.0 | 1.1 | 1.1 | 1.1 | 1.1 | 0.9 | 0.8 |
| **Hydroelectric** | 1.0 | 1.0 | 1.2 | 1.1 | 1.5 | 2.0 | 1.5 | 1.2 |
| **Solar** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| **Wind** | 0.1 | 0.8 | 1.6 | 1.6 | 1.7 | 1.7 | 1.4 | 1.6 |
| **Other** | 0.3 | 0.3 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 |

**Figure 8– Electricity Generation by Type for 2019**




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 11 shows the amount of each of these fuels consumed (BBtu) for electricity generation in Pennsylvania.

[17] U.S. Energy Information Administration (EIA). 2022. Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923). Accessed 106/121/2022. https://www.eia.gov/electricity/data/state/
[18] Ibid.

**Table 11– Fuel Use for Electricity Generation (BBtu)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020[19] |
|---|---|---|---|---|---|---|---|---|
| **Coal** | 1,224,911 | 1,119,758 | 669,244 | 574,070 | 501,784 | 467,959 | 398,101 | 256,047 |
| **Natural Gas** | 83,531 | 252,182 | 456,219 | 520,118 | 544,924 | 557,750 | 696,798 | 859,161 |
| **Oil** | 51,783 | 6,810 | 6,008 | 3,369 | 2,985 | 7,847 | 2,222 | 1,015 |
| **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** |

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.

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

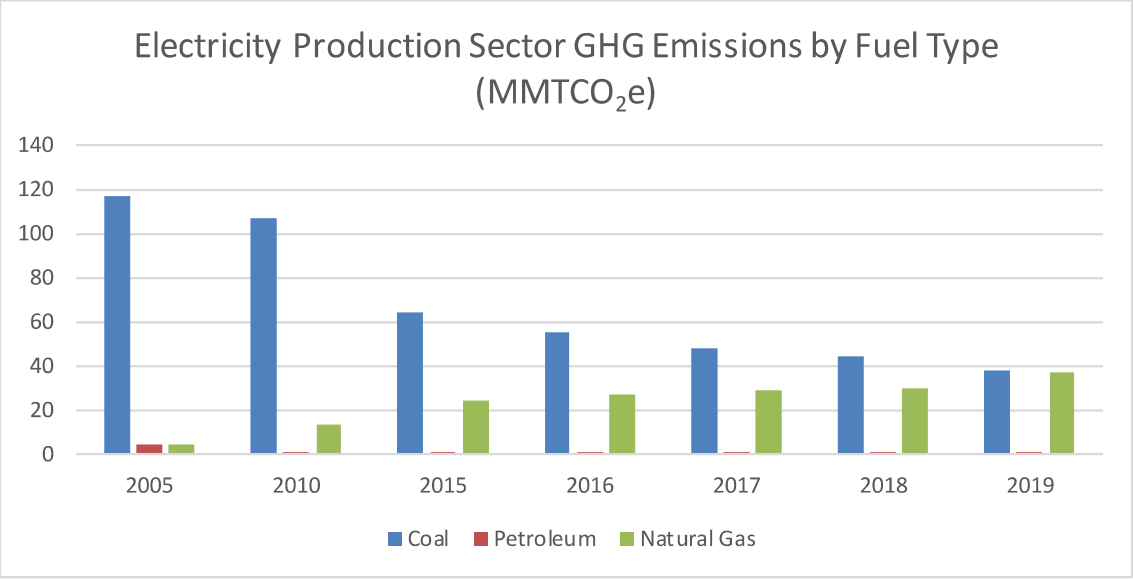



Table 12 gives the relative percentage of GHG emissions attributed to the three primary fossil fuels used in the electricity production sector.

[19] Ibid.

**Table 12– Contribution to GHG Emissions, Fuel Type, in the Electricity Sector (%)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| **Coal** | 93.2 | 88.5 | 72.2 | 66.4 | 62.3 | 59.8 | 50.7 |
| **Oil** | 3.3 | 0.4 | 0.5 | 0.3 | 0.3 | 0.8 | 0.2 |
| **Natural Gas** | 3.5 | 11.0 | 27.2 | 33.3 | 37.4 | 39.4 | 49.1 |

As noted in Table 10 and Table 12, for Pennsylvania's electricity generation sector in 2019, coal produced 50.7 percent of the GHG emissions while producing 16.6 percent of the electricity. Natural gas produced 49.1 percent of the GHG emissions while producing 42.8 percent of the electricity. Nuclear fuel, which produces no GHG emissions, was responsible for generating 36.3 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 13 shows the total consumption of electricity (TWh) within the residential, commercial, industrial, and transportation sectors.

**Table 13 – Electricity Consumption by Sector (TWh)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020[20] |
|---|---|---|---|---|---|---|---|---|
| **Residential** | 53.66 | 55.25 | 54.42 | 53.88 | 51.72 | 55.90 | 54.40 | 55.31 |
| **Commercial** | 45.78 | 47.37 | 43.75 | 43.54 | 42.62 | 43.22 | 40.14 | 35.38 |
| **Industrial** | 47.95 | 45.46 | 47.40 | 47.13 | 47.89 | 49.16 | 50.42 | 48.61 |
| **Transportation** | 0.88 | 0.89 | 0.78 | 0.79 | 0.75 | 0.70 | 0.62 | 0.43 |
| **Line Loss** | 6.41% | 5.82% | 4.97% | 4.49% | 4.49% | 4.88% | 5.10% | 5.10% |

Table 14 gives the total amount of electricity (TWh) consumed in Pennsylvania and the total amount of electricity (TWh) generated. The difference between the two values is the total amount of electricity (TWh) exported from Pennsylvania.

**Table 14– Electricity Generated, Consumed and Exported (TWh)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020[21] |
|---|---|---|---|---|---|---|---|---|
| **Electricity Consumed** | 151.56 | 151.75 | 150.67 | 150.53 | 148.33 | 154.37 | 150.40 | 144.86 |
| **Electricity Generated** | 218.09 | 229.75 | 214.57 | 215.07 | 213.64 | 215.39 | 229.00 | 230.14 |
| **Electricity Exported** | 52.86 | 68.26 | 54.93 | 55.49 | 56.61 | 52.57 | 70.48 | 77.81 |

## Agriculture Sector

At approximately ten $MMTCO_2e$ 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

[20] Ibid.
[21] Ibid.

fermentation, manure management, and soil management. Table 15 lists the number (1,000 head) of each type of farm animal accounted for in the SIT.

**Table 15– Animal Populations Contributing to GHG Emissions (1,000 Head)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| **Dairy Cows** | 566 | 540 | 530 | 530 | 525 | 525 | 505 |
| **Dairy Replacement Heifers** | 275 | 300 | 305 | 325 | 315 | 310 | 290 |
| **Beef Cows** | 154 | 160 | 150 | 170 | 185 | 215 | 225 |
| **Beef Replacement Heifers** | 40 | 40 | 55 | 60 | 65 | 60 | 65 |
| **Heifer Stockers** | 55 | 50 | 55 | 55 | 60 | 60 | 55 |
| **Steer Stockers** | 170 | 150 | 145 | 140 | 160 | 130 | 135 |
| **Feedlot Heifers** | 24 | 24 | 24 | 24 | 24 | 24 | 24 |
| **Feedlot Steer** | 44 | 46 | 46 | 46 | 46 | 46 | 46 |
| **Bulls** | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| **Sheep** | 100 | 94 | 86 | 94 | 93 | 96 | 95 |
| **Goats** | 52 | 54 | 52 | 52 | 53 | 53 | 53 |
| **Swine** | 1,088 | 1,133 | 1,165 | 1,163 | 1,195 | 1,280 | 1,270 |
| **Horses** | 115 | 118 | 101 | 95 | 88 | 82 | 88 |

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

**Table 16– GHG Emissions ($CH_4$), by Livestock Type, from Enteric Fermentation ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| **Dairy Cows** | 1.936 | 1.950 | 1.932 | 1.934 | 1.935 | 1.935 | 1.861 |
| **Dairy Replacement Heifers** | 0.440 | 0.495 | 0.503 | 0.536 | 0.519 | 0.511 | 0.478 |
| **Beef Cows** | 0.357 | 0.377 | 0.354 | 0.401 | 0.436 | 0.507 | 0.531 |
| **Beef Replacement Heifers** | 0.065 | 0.071 | 0.098 | 0.107 | 0.116 | 0.107 | 0.116 |
| **Heifer Stockers** | 0.082 | 0.075 | 0.083 | 0.083 | 0.091 | 0.091 | 0.083 |
| **Steer Stockers** | 0.245 | 0.217 | 0.210 | 0.203 | 0.232 | 0.189 | 0.196 |
| **Feedlot Heifers** | 0.024 | 0.026 | 0.026 | 0.026 | 0.026 | 0.026 | 0.026 |
| **Feedlot Steer** | 0.042 | 0.048 | 0.048 | 0.048 | 0.048 | 0.048 | 0.048 |
| **Bulls** | 0.060 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 |
| **Sheep** | 0.020 | 0.019 | 0.017 | 0.019 | 0.019 | 0.019 | 0.019 |
| **Goats** | 0.006 | 0.007 | 0.006 | 0.007 | 0.007 | 0.007 | 0.007 |
| **Swine** | 0.041 | 0.042 | 0.044 | 0.044 | 0.045 | 0.048 | 0.048 |
| **Horses** | 0.052 | 0.053 | 0.045 | 0.043 | 0.040 | 0.037 | 0.040 |
| **Total** | **3.370** | **3.442** | **3.427** | **3.511** | **3.575** | **3.586** | **3.513** |

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 17 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 17 – GHG Emissions ($CH_4$ and $N_2O$), by Livestock Type, from Manure Management ($MMTCO_2e$)**

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

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 18 below shows the estimated GHG emissions ($MMTCO_2e$) resulting from agriculture soils management.

**Table 18 – GHG Emissions ($N_2O$) from the Management of Agricultural Soils ($MMTCO_2e$)**

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

## 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 19 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 19 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 19– GHG Emissions Associated with Landfilling Operations ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| **Potential Landfill $CH_4$** | 8.81 | 9.78 | 9.93 | 9.97 | 10.02 | 10.07 | 10.15 |
| **$CH_4$ Avoided** | -6.62 | -8.89 | -9.03 | -9.07 | -9.11 | -9.15 | -9.23 |
| **Oxidation** | -0.22 | -0.09 | -0.09 | -0.09 | -0.09 | -0.09 | -0.09 |
| **Total $CH_4$ Emissions (Landfills)** | **1.97** | **0.80** | **0.81** | **0.82** | **0.82** | **0.82** | **0.83** |

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 20 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 20– GHG Emissions Associated with Waste Combustion ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| **$CO_2$** | 1.58 | 1.43 | 1.61 | 1.66 | 1.68 | 1.78 | 1.78 |
| **$N_2O$** | 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 |
| **Total** | **1.62** | **1.45** | **1.64** | **1.69** | **1.71** | **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 2019[22].

**Table 21– 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 |
| 2019 | 4.76 | 6.70 | 1.6 | 1.34 |
| 2018 | 4.96 | 8.35 | 2.2 | 1.56 |
| 2017 | 5.77 | 8.78 | 2.09 | 1.64 |
| 2016 | 7.11 | 9.28 | 2.21 | 1.73 |
| 2015 | 7.06 | 9.61 | 2.29 | 1.79 |
| 2014 | 15.34 | 14.85 | 3.53 | 2.77 |
| 2013 | 5.55 | 6.96 | 1.66 | 1.3 |
| 2012 | 7.71 | 15.97 | 3.81 | 2.99 |

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,

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

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 22 shows the GHG emissions ($MMTCO_2e$) attributed to the treatment of wastewater from municipal and industrial sources in the waste management sector.

**Table 22 – GHG Emissions Associated with Wastewater Treatment ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| **Municipal $CH_4$** | 0.99 | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 | 1.03 |
| **Municipal $N_2O$** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **Industrial $CH_4$** | 0.07 | 0.12 | 0.13 | 0.13 | 0.14 | 0.14 | 0.14 |
| **Total** | **1.07** | **1.15** | **1.16** | **1.17** | **1.17** | **1.18** | **1.18** |

Table 23 shows the GHG emissions ($MMTCO_2e$) totals for the solid waste and wastewater treatment portions of the waste management sector.

**Table 23– Total GHG Emissions ($CO_2$, $CH_4$, $N_2O$) from the Waste Management Sector ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| **Solid Waste** | 3.59 | 2.25 | 2.45 | 2.50 | 2.53 | 2.63 | 2.64 |
| **Wastewater** | 1.07 | 1.15 | 1.16 | 1.17 | 1.17 | 1.18 | 1.18 |
| **Total** | **4.65** | **3.40** | **3.62** | **3.67** | **3.70** | **3.81** | **3.82** |

## 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 2019, the forestry and land use sector sequestered 27.47 $MMTCO_2$ 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[23] and Pennsylvania's Department of Conservation & Natural Resources.

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

Table 24 shows the total GHG emissions produced (positive values) and emissions sequestered (negative values) ($MMTCO_2e$) totals for the forestry and land use sector.

**Table 24– Total GHG Emissions from the Forestry and Land Use Sector ($MMTCO_2e$)**

| | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| **Forest Carbon Flux** | -24.74 | -23.89 | -22.72 | -22.38 | -22.07 | -21.75 | -21.34 |
| **Urban Trees, Carbon** | -3.15 | -3.31 | -3.46 | -3.49 | -3.52 | -3.56 | -3.59 |
| **Landfilled Yard Trimmings and Food Scraps, Carbon** | -0.38 | -0.43 | -0.40 | -0.36 | -0.33 | -0.42 | -0.42 |
| **Forest Fires, $CH_4$ and $N_2O$** | 0.01 | 0.04 | 0.16 | 0.18 | 0.14 | 0.11 | 0.10 |
| **$N_2O$ from Settlement Soils** | 0.04 | 0.04 | 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 | -2.27 |
| **Total** | **-33.04** | **-30.56** | **-28.55** | **-29.31** | **-28.92** | **-28.36** | **-27.47** |

## 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. As this is the first report with some fuel data from 2020, it should be noted that due to impacts related to the COVID-19 pandemic and the consequent lockdowns, data presented for 2020 may be anomalous. The Intergovernmental Panel on Climate Change (IPCC) reports that carbon-based fossil fuel emissions were reduced significantly in the first half of 2020. The annual average $CO_2$ emissions in 2020 decreased relative to 2019 by an estimated 5.8 percent per the IPCC's Climate Change 2022 Mitigation of Climate Change Summary for Policymakers.[24] It was also noted in the summary report that the full GHG emissions impact of the COVID-19 pandemic could not be assessed due to a lack of data on non-$CO_2$ GHG emissions.

To date, Pennsylvania achieved a nearly 18 percent reduction in GHG emissions by 2019 compared to 2005. The two most recent years (2018 and 2019) has resulted in slight increase in total GHG emissions for Pennsylvania. This increase can primarily be attributed to an increase in natural gas use for both the industrial sector (Table 5) and the electricity generation sector (Tables 10-12). While $CH_4$ based emissions increased overall, $CO_2$ (Table 2), emissions decreased. This condition is the result of the continual reduction in coal-based electricity generation and overall use, and a decline in electricity generation from nuclear power with Three Mile Island being taken offline in September of 2019.[25] Nuclear power generation levels are expected to remain the same, and renewable electricity generation from sources such as wind and solar are expected to continue to increase going forward.

The industrial sector has not experienced a notable decline in greenhouse gas emissions since the baseline year of 2005. The decrease in emissions from operations such as coal mining has likely been replaced by emissions from natural gas production, resulting in a net increase in industrial emissions over the past 5-6 years. Industrial sector emissions in Pennsylvania mainly come directly from fossil fuel production, specifically coal and natural gas, and direct use of fossil fuels in industrial processes. Major decarbonization of this sector

[24] IPCC_AR6_WGIII_SummaryForPolicymakers.pdf (P. 6, B.1.4)
[25] Three Mile Island shuts down | ABC27

will require a large scale and long-term transition away from the use of fossil fuels towards low or no GHG emitting fuel sources such as hydrogen, electricity, and biofuels. More targeted actions including energy efficiency and partial fuel switching will be required to achieve industrial emissions reductions in the short-term. Future climate action plans for the commonwealth will likely focus on detailed analysis of the industrial sector and other sectors which may prove to be difficult to decarbonize.