2021

DRAFT Pennsylvania Greenhouse Gas Inventory Report

August 2021

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Table of Contents

List of Figures and Tables

Figures

Tables

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% 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 & 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 reductions 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 U.S. Climate Alliance goals, and goals set forth in the Paris Climate Agreement. As of 2018, Pennsylvania has achieved a nearly 18 percent reduction in GHG emissions, compared to 2005, however, during the last two data years (2017 and 2018) GHG emissions rose slightly in the commonwealth. An additional reduction of 26.80 $MMTCO_2e$ from 2018 levels is required to reach the 2025 goal, and 183.20 $MMTCO_2e$ 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 since the year 2005. Changes in 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: 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.

---

[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)[6]. The GHGs typically accounted for in the SIT 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 for CO_2 is 1.0, CH_4 = 25, and N_2O = 298. The GWP of a GHG will vary depending on the time scale selected. The default time scale for the SIT is 100 years. In order to provide consistency with previous updates and other state inventories using 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.

As shown in Table 1, the total statewide gross GHG emissions for Pennsylvania in 2018, the latest year with complete data available from the SIT, were 269.10 $MMTCO_2e$. This is an increase of 4.41 $MMTCO_2e$ from 2017. Pennsylvania's Forestry and Land Use sector provides a carbon sink for GHG emissions, absorbing 27.98 $MMTCO_2e$ in 2018, and lowering the commonwealth's net GHG emission for 2018 to 241.12 $MMTCO_2e$. Table 1 also shows a relative decrease of 16.5 percent in the gross emission and 16.7 percent in the net emission totals for 2018 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. The industrial sector was the highest GHG producing sector in the state in 2018, producing 32 percent of the commonwealth's emissions. Emissions from the electricity production sector declined in 2018, continuing the trend observed over the past decade. The relative change for each of these sectors between 2005 and 2018 was an increase of 6.40 $MMTCO_2e$ (8.1 percent) for the industrial sector, a decrease of 47.88 $MMTCO_2e$ (39.6 percent) for the electricity production sector, and a decrease of 9.25 $MMTCO_2e$ (12.7 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 increases in emissions between 2017 and 2018, but overall declines in GHG emissions since 2005. The residential and commercial sectors had decreases in GHG emissions of 2.26, and 0.80 $MMTCO_2e$ (9.5 and 6.2 percent), respectively, since 2005. GHG emissions from the agricultural sector have increased 1.52 $MMTCO_2e$ (19.0 percent), between 2005 and 2018.

GHG emissions from the waste management sector experienced a 0.90 $MMTCO_2e$ (17.2 percent) decrease from 2005 to 2018. During this same period, the GHG emissions sequestered in the forest and land use sector have decreased by 4.55 $MMTCO_2e$ (14.3 percent).

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

[6] 1 short ton = .90718474 metric tons

Table 1 - GHG Emissions by Sector

Sector / Emission Sources ($MMTCO_2e$)	2005	2010	2015	2016	2017	2018
Residential	**23.91**	**20.21**	**20.75**	**18.48**	**18.53**	**21.65**
Commercial	**12.94**	**10.57**	**11.47**	**10.60**	**10.87**	**12.14**
Industrial	**78.57**	**73.75**	**85.35**	**79.58**	**81.99**	**84.98**
Combustion of Fossil Fuels	46.46	40.08	50.56	46.11	47.98	50.52
Industrial Process	14.03	13.64	14.19	13.85	13.67	13.52
Coal Mining and Abandoned Mines	10.71	12.80	10.70	9.88	10.68	11.14
Natural Gas and Oil Systems	7.38	7.23	9.89	9.74	9.65	9.80
Transportation	**72.61**	**64.68**	**59.93**	**60.73**	**64.33**	**63.37**
Petroleum	70.89	62.05	57.50	58.47	61.88	60.78
Natural Gas	1.71	2.63	2.42	2.26	2.45	2.59
Electricity Production	**120.97**	**116.59**	**86.03**	**80.50**	**75.15**	**73.09**
Coal	112.34	102.70	61.38	52.65	46.02	42.92
Petroleum	4.19	0.51	0.44	0.25	0.22	0.58
Natural Gas	4.43	13.38	24.20	27.59	28.91	29.59
Agriculture	**8.01**	**8.71**	**9.03**	**9.34**	**9.48**	**9.54**
Enteric Fermentation	3.37	3.44	3.43	3.51	3.58	3.59
Manure Management	1.68	1.93	2.17	2.26	2.22	2.31
Agricultural Soil Management	2.91	2.94	3.30	3.37	3.48	3.44
Liming of Soils	0.03	0.38	0.08	0.16	0.16	0.16
Urea Fertilization	0.02	0.03	0.05	0.05	0.05	0.05
Burning of Agricultural Crop Waste	0.00	0.00	0.00	0.00	0.00	0.00
Waste Management	**5.24**	**4.03**	**4.25**	**4.36**	**4.33**	**4.34**
Solid Waste and Combustion	3.55	2.26	2.45	2.50	2.53	2.53
Wastewater	1.69	1.78	1.80	1.86	1.81	1.81
Total Statewide Gross Emissions (Sources)	**322.25**	**298.54**	**276.81**	**263.59**	**264.69**	**269.10**
Change relative to 2005		*-7.4%*	*-14.1%*	*-18.2%*	*-17.9%*	*-16.5%*
Forestry and Land Use	-32.63	-30.40	-27.87	-28.59	-28.48	-27.98
Total Statewide Net Emissions (Sources w/ Sinks)	**289.62**	**268.14**	**248.94**	**235.00**	**236.21**	**241.12**
Change relative to 2005		*-7.4%*	*-14.0%*	*-18.9%*	*-18.4%*	*-16.7%*

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 ($MMTCO_2e$)

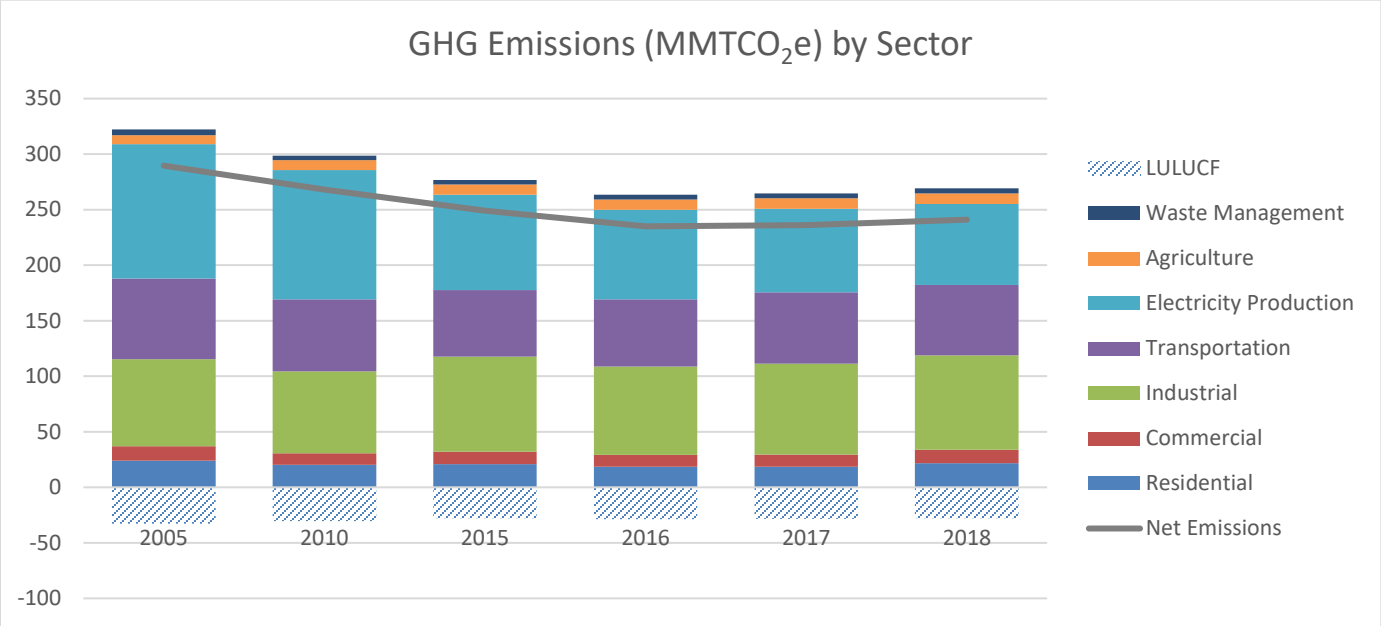


Table 2, Figure 2, and Figure 3 present GHG emissions by gas, in units of $MMTCO_2e$. As noted above, it is customary to present GHG emissions data in units of $MMTCO_2e$, so that emissions sources can be compared.

Table 2 - GHG Emissions by Gas ($MMTCO_2e$)

Gas/Emissions Source ($MMTCO_2e$)	2005	2010	2015	2016	2017	2018
Gross CO_2	287.63	261.22	237.89	225.32	225.67	229.41
Net CO_2	254.90	230.55	209.01	195.58	196.32	200.69
CO_2 from Fossil Fuel Combustion	276.88	252.12	228.74	216.41	216.87	220.78
Industrial Processes	9.12	7.27	7.41	7.05	6.93	6.76
Waste	1.58	1.43	1.61	1.66	1.68	1.68
Agriculture	0.05	0.40	0.13	0.20	0.20	0.20
Forestry and Land Use	(32.73)	(30.67)	(28.88)	(29.74)	(29.35)	(28.72)
CH_4	26.32	27.70	29.17	28.47	29.08	29.58
Stationary Combustion	0.39	0.42	0.51	0.44	0.44	0.50
Mobile Combustion	0.10	0.07	0.05	0.06	0.06	0.06
Coal Mining	10.71	12.80	10.70	9.88	10.68	11.14
Natural Gas and Oil Systems	7.38	7.24	9.90	9.75	9.82	9.80
Enteric Fermentation	3.37	3.44	3.43	3.51	3.57	3.59
Manure Management	1.08	1.34	1.53	1.60	1.57	1.65
Burning of Agricultural Crop Waste	0.00	0.00	0.00	0.00	0.00	0.00
Forest Fires	0.05	0.20	0.82	0.94	0.70	0.59
Waste	1.94	0.80	0.81	0.82	0.82	0.82
Wastewater	1.31	1.40	1.42	1.48	1.42	1.43
N_2O	6.05	5.37	5.46	5.48	5.52	5.46
Stationary Combustion	0.84	0.75	0.59	0.51	0.48	0.48
Mobile Combustion	1.25	0.61	0.32	0.32	0.32	0.30
Industrial Processes	-	-	-	-	-	-
Manure Management	0.60	0.59	0.64	0.66	0.65	0.66
Agricultural Soil Management	2.91	2.94	3.30	3.37	3.48	3.44
Burning of Agricultural Crop Waste	0.00	0.00	0.00	0.00	0.00	0.00
Forest Fires	0.01	0.03	0.13	0.15	0.11	0.10
N_2O from Settlement Soils	0.04	0.04	0.06	0.06	0.06	0.06
Waste	0.03	0.03	0.03	0.03	0.03	0.03
Wastewater	0.38	0.38	0.38	0.38	0.38	0.38
HFC, PFC, SF_6 and NF_3 Emissions	4.91	6.37	6.78	6.80	6.75	6.76
Industrial Processes	4.91	6.37	6.78	6.80	6.75	6.76
Indirect CO_2 from Electricity Consumption*	89.46	84.58	64.65	59.36	55.83	55.72
Gross Emissions	**324.90**	**300.67**	**279.30**	**266.07**	**267.03**	**271.21**
Sinks	**(32.73)**	**(30.67)**	**(28.88)**	**(29.74)**	**(29.35)**	**(28.72)**
Net Emissions (Sources and Sinks)	**292.18**	**270.00**	**250.42**	**236.33**	**237.68**	**242.49**

* 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 makes up 85 percent of GHG emissions, in terms of $MMTCO_2e$, followed by methane (CH_4) at 11 percent (Figure 2). Carbon dioxide (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 2018.

Figure 2 – GHG Emissions by Gas, 2018 ($MMTCO_2e$)

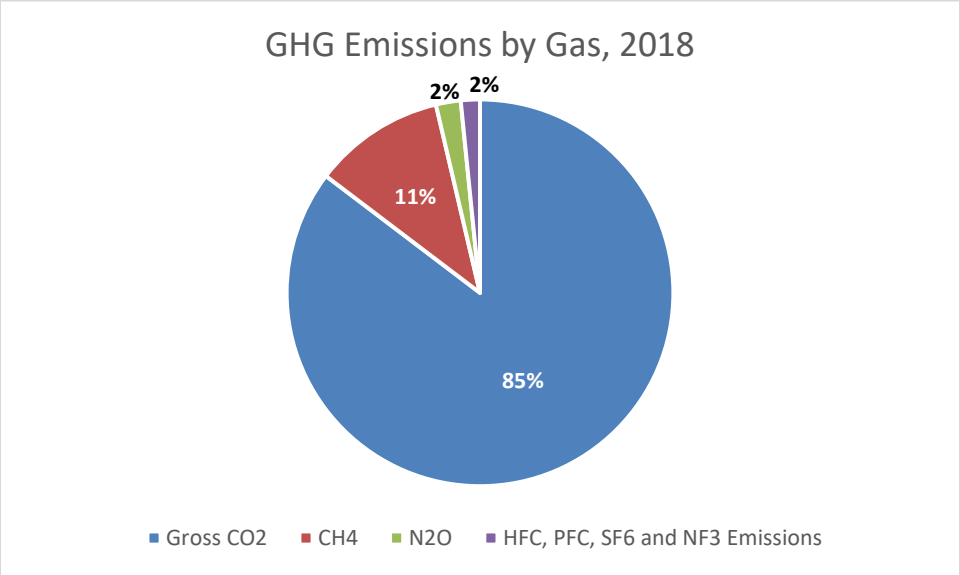
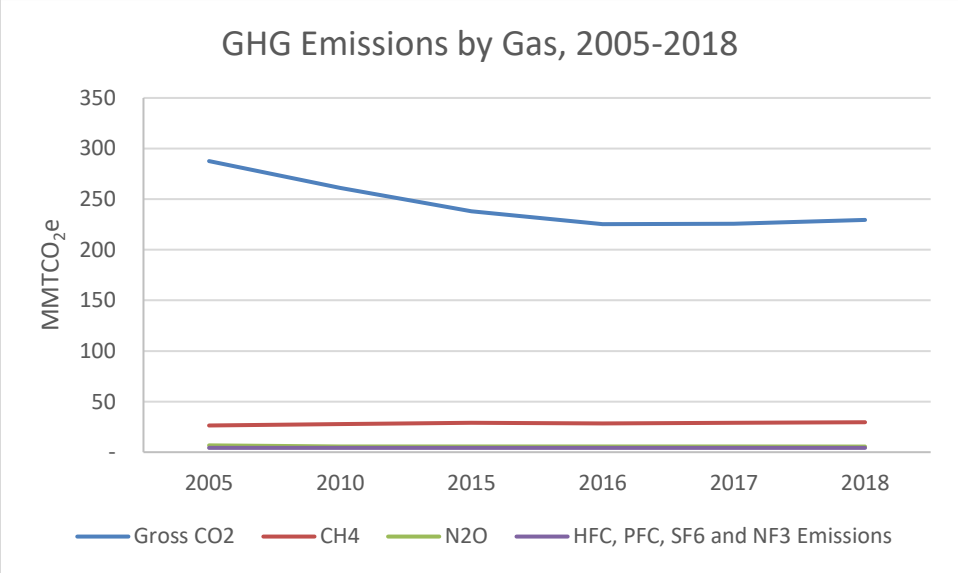


Figure 3 – GHG Emissions by Gas, 2005-2018 ($MMTCO_2e$)



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 2018, 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/hot water system, and the price/availability of a particular fuel. Fuel consumption increased in 2018 relative to 2017, possibly due to colder average temperatures during the winter months of 2018[7]. No electricity consumption is included in these values.

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

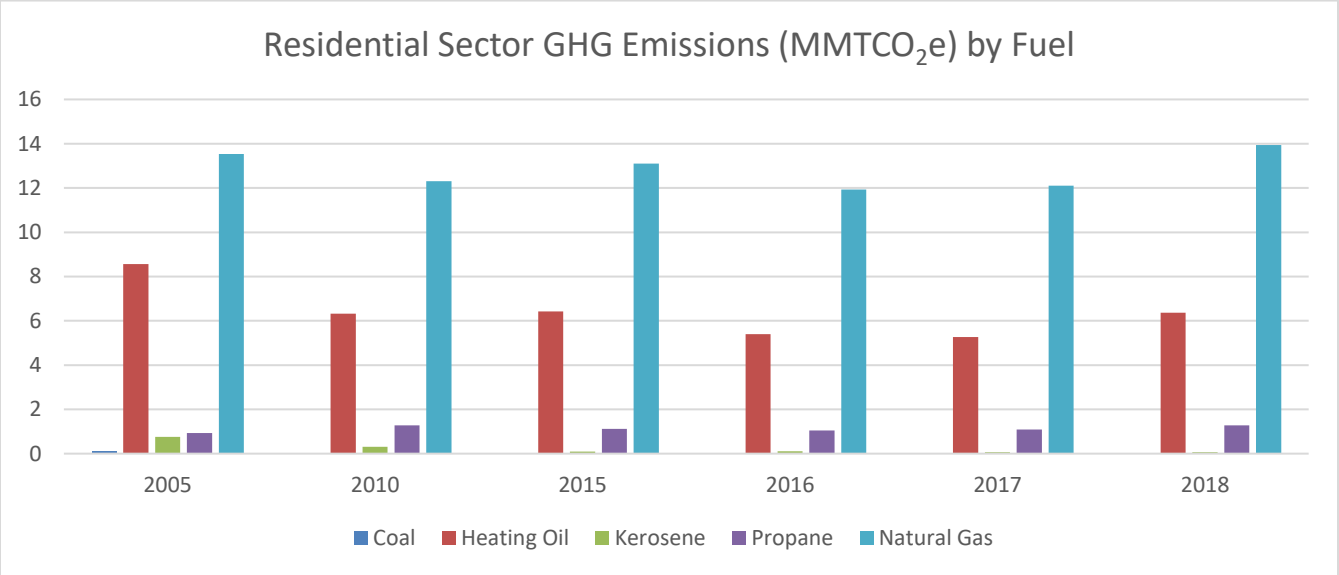
	2005	2010	2015	2016	2017	2018
Coal[8]	1,253	0	0	0	0	0
Heating Oil	115,753	85,432	86,789	73,049	71,250	86,087
Kerosene	10,330	4,211	1,350	1,513	921	930
Propane	15,122	20,812	18,230	16,909	17,668	20,768
Natural Gas	255,038	231,854	247,059	224,764	228,190	262,667

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 from burning firewood to heat residential homes are accounted for in the land use change sector. The emissions related to electricity use for residential homes using electricity for heating or cooling purposes are accounted for in the electricity production sector.

[7] National Temperature and Precipitation Maps | National Centers for Environmental Information (NCEI) (noaa.gov)

[8] The U.S. Energy Information Administration, which is the source of default fuel consumption data used in the SIT, assumes that coal use for residential heating is zero from 2008 on.

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



Commercial Sector

The emissions attributed to the commercial sector result from fuels combusted to provide heat and hot water to commercial buildings within the commonwealth. These fuels, in order of decreasing use in 2018, 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/hot water system, and the price/availability of a particular fuel. No electricity consumption is included in these values.

Table 4- Commercial Sector Fuel Consumption (BBtu)

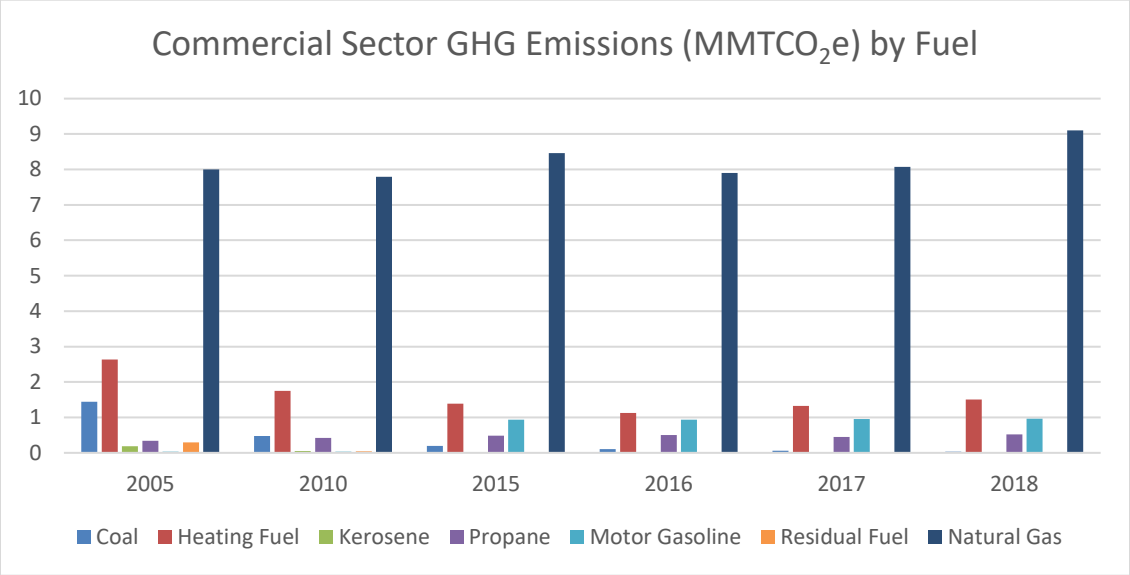
	2005	2010	2015	2016	2017	2108
Coal	14,407	4,729	1,963	1,031	645	362
Heating Oil	35,632	23,625	18,765	15,272	17,907	20,328
Kerosene	2610	755	144	222	143	179
Propane	5,480	6,853	7,829	8,135	7,225	8,409
Motor Gasoline[9]	462	428	13,062	13,142	13,331	13,533
Residual Fuel	3,934	570	53	127	3	5
Natural Gas	150,849	146,902	159,442	148,851	152,220	171,616

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

[9] 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.

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 the emissions come from four separate sub-groups: 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 sub-groups, 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 2018, 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/cooling system, and the price/availability of a particular fuel.

Table 5 – Industrial Sector Fuel Consumption (BBtu)

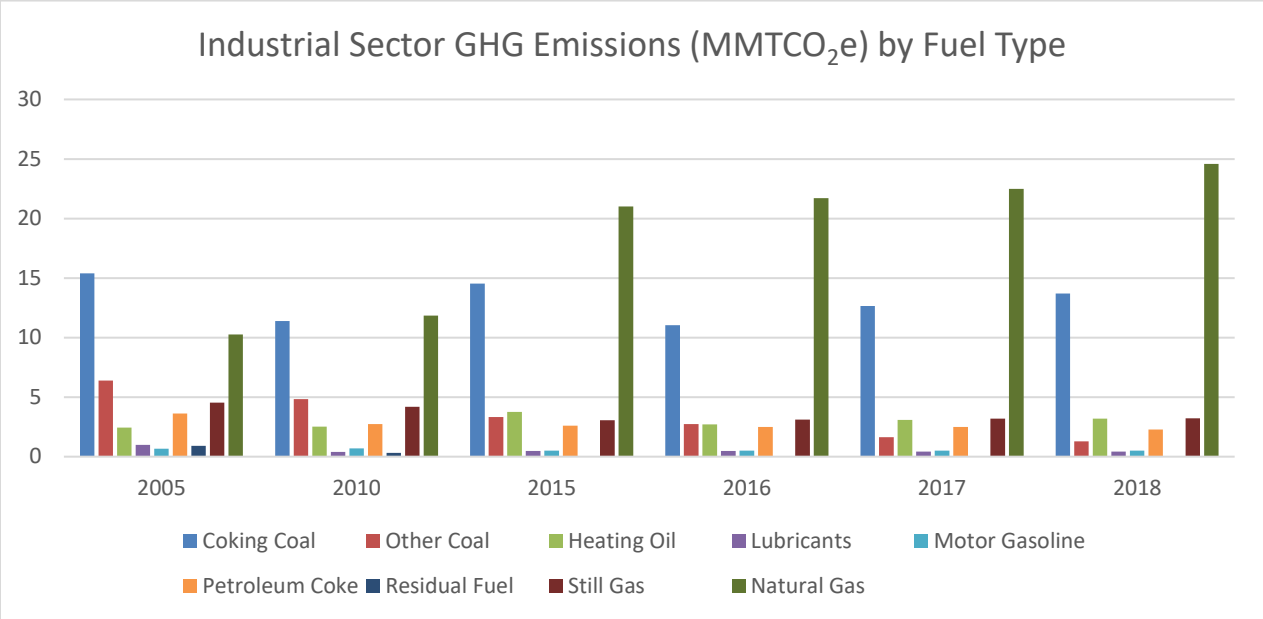
	2005	2010	2015	2016	2017	2018
Coking Coal	182,475	134,939	172,216	130,860	149,838	162,218
Other Coal	67,654	51,240	35,377	28,876	17,257	13,516
Asphalt and Road Oil	60,964	46,840	47,228	46,510	47,515	43,561
Aviation Gasoline Blending Components	390	-11	-12	-9	-6	-50
Heating Oil	33,055	34,088	51,101	36,780	41,820	43,320
Kerosene	663	281	68	82	58	79
Propane	23,620	26,755	19,312	19,312	19,312	19,312
Lubricants[10]	14,716	5,910	7,041	6,998	6,367	6,216
Motor Gasoline	9,486	9,712	7,055	7,004	7,079	7,163
Misc. Petro Products	1,493	1,795	2,508	2,540	2,639	2,628
Petroleum Coke	36,889	26,859	25,424	24,379	24,432	22,396
Residual Fuel	12,039	4,272	565	770	598	477
Still Gas	70,200	67,173	49,515	50,075	51,235	51,797
Special Naphthas	3,265	1,653	6,891	6,496	6,965	6,390
Unfinished Oils[11]	131	1,276	-589	268	2,472	992
Waxes	1,871	894	722	751	594	726
Natural Gas	197,525	228,806	404,961	418,060	432,717	472,312

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.

[10] 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

[11] 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 ozone-depleting substances (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
CO_2 Emissions						
Cement Manufacture	3.13	1.65	1.85	1.78	1.77	1.63
Lime Manufacture	0.85	0.85	0.73	0.69	0.62	0.62
Limestone and Dolomite Use	0.55	0.87	0.95	0.69	0.65	0.63
Soda Ash	0.11	0.09	0.08	0.08	0.08	0.08
Iron & Steel Production	4.48	3.80	3.80	3.80	3.80	3.80
Urea Consumption	0.00	0.00	0.01	0.01	0.01	0.01
HFC, PFC, SF_6 and NF_3 Emissions						
ODS Substitutes	4.53	6.13	6.61	6.62	6.57	6.58
Semiconductor Manufacturing	0.04	0.02	0.02	0.02	0.02	0.02
Electric Power Transmission and Distribution Systems	0.34	0.22	0.15	0.16	0.16	0.16
Total	**14.03**	**13.64**	**14.19**	**13.85**	**13.67**	**13.52**

Coal Mining and Abandoned Coal Mines

The GHG emissions associated with coal mining, both underground and surface mines, and processing coal are accounted for in this section. The GHG emissions coming from abandoned coal mines are also included. The majority of emissions accounted for come from underground mining activity. The results are determined by measurements of ventilation air from underground mines and by applying emission factors for surface mines, abandoned mines, and for 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
Underground Mining	6.64	9.48	8.00	7.38	8.09	8.57
Surface Mining	0.73	0.61	0.35	0.24	0.31	0.30
Underground Processing	1.16	1.01	0.93	0.88	0.93	0.95
Surface Processing	0.12	0.10	0.06	0.04	0.05	0.05
Abandoned Mines[12]	2.06	1.59	1.36	1.33	1.31	1.28
Total	**10.71**	**12.80**	**10.70**	**9.88**	**10.68**	**11.14**

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 orphan 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 the number and types of services used for distribution in the commonwealth[13]. 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 ($MMTCO_2e$)

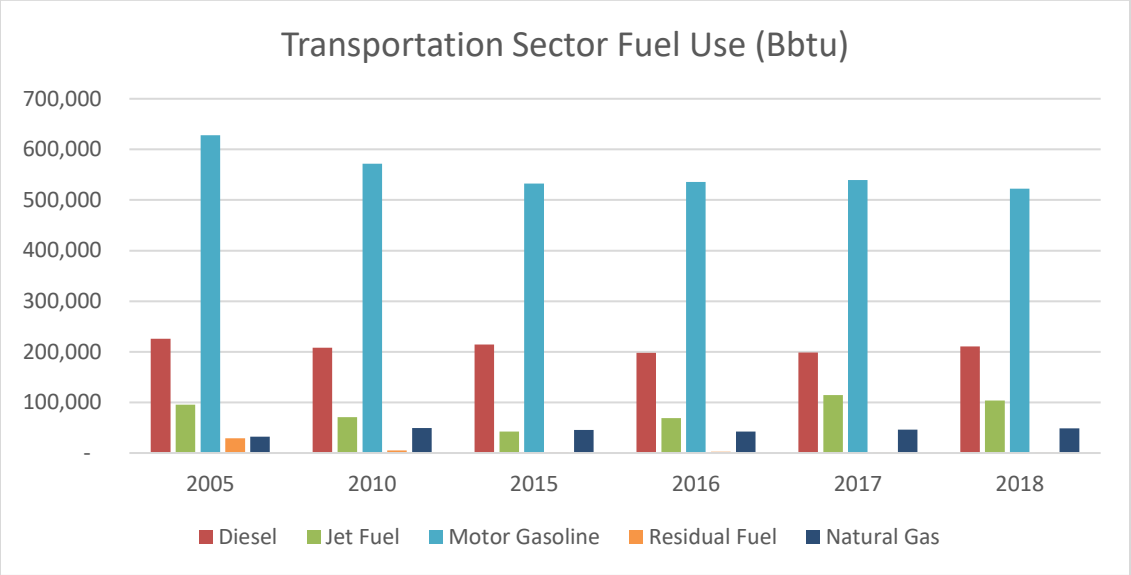
	2005	2010	2015	2016	2017	2018
Natural Gas Production	4.78	4.56	7.18	7.01	7.05	7.01
Natural Gas Transmission	1.92	1.97	1.98	2.00	2.02	2.06
Natural Gas Distribution[14]	0.64	0.65	0.66	0.66	0.67	0.67
Oil Production	0.04	0.05	0.08	0.07	0.07	0.06
Total	**7.38**	**7.23**	**9.90**	**9.74**	**9.81**	**9.80**

[12] The SIT was updated in 2018 to include data from five additional abandoned mines with closure dates beginning in 2000.
[13] 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
[14] Emissions for natural gas distribution were over-estimated in previous inventories due to a calculation error. This has been corrected, thus the apparent reduction in emissions from this source.

Transportation Sector

The emissions attributed to the transportation sector result from fuels combusted to provide transportation for various types of vehicles within the commonwealth. These fuels, in order of decreasing use in 201, are gasoline, diesel, jet fuel, and natural gas. Several factors will influence the amount of a fuel being used; including the mode of transportation, efficiency of the vehicle, and the price/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
Diesel	16.69	15.40	15.86	14.66	14.69	15.59
Jet Fuel	6.89	5.10	3.08	5.00	8.28	7.49
Motor Gasoline	44.60	40.78	38.01	38.24	38.47	37.27
Natural Gas	1.71	2.63	2.42	2.26	2.45	2.59
Other	2.73	0.79	0.57	0.57	0.46	0.44
Total	**72.63**	**64.70**	**59.94**	**60.74**	**64.35**	**63.38**

Electricity Production Sector

The emissions attributed to the electricity production sector result from fuels combusted to generate electricity within the commonwealth. The electricity production sector has historically been the largest contributor of GHG emissions, however, in 2017 the industrial sector became the largest contributor of GHG emissions. Nearly one third of the statewide gross emissions in 2018 came from the electricity production sector, however, a sizable percentage of these emissions are associated with electricity that is produced and

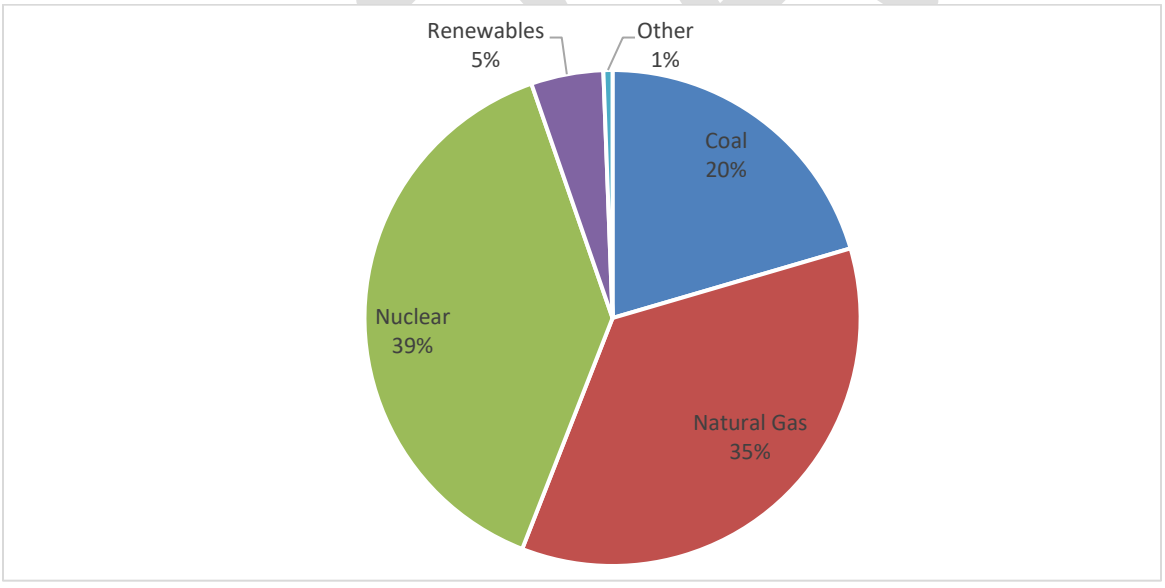
exported to meet the needs of surrounding states. Electricity is produced several different ways within the commonwealth. The three primary forms of electricity generation in Pennsylvania are nuclear, natural gas, and coal. Figure 6 shows the electricity generation in Pennsylvania by fuel for 2018.

The largest changes in the production of electricity since 2005 have occurred in the use of coal and natural gas. From 2017 to 2018, electricity generation from coal continued its decline from 22.3 percent of total generation to 20.5 percent, while electricity generation from natural gas increased from 33.9 percent of total generation to 35.5 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 (%)[15]

	2005	2010	2015	2016	2017	2018
Coal	55.5%	48.0%	30.1%	25.4%	22.3%	20.5%
Nuclear	35.0%	33.9%	37.5%	38.6%	38.9%	38.8%
Natural Gas	5.0%	14.7%	27.7%	31.6%	33.9%	35.5%
Petroleum	2.3%	0.2%	0.3%	0.2%	0.2%	0.3%
Biomass	0.9%	1.0%	1.1%	1.1%	1.1%	1.1%
Hydroelectric	1.0%	1.0%	1.2%	1.1%	1.5%	2.0%
Solar	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Wind	0.1%	0.8%	1.6%	1.6%	1.7%	1.7%
Other	0.3%	0.3%	0.4%	0.3%	0.3%	0.3%

Figure 8– Electricity Generation by Type (%) for 2018



[15] U.S. Energy Information Administration (EIA). 2018. Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923). Accessed 12/19/2018. https://www.eia.gov/electricity/data/state/

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.

Table 11– Fuel Use for Electricity Generation (BBtu)

	2005	2010	2015	2016	2017	2018
Coal	1,224,911	1,119,758	669,244	574,070	501,784	467,959
Natural Gas	83,531	252,182	456,219	520,118	544,924	557,750
Oil	51,783	6,810	6,008	3,369	2,985	7,847
Total	1,360,225	1,378,750	1,131,471	1,097,557	1,049,693	1,033,556

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 fuels used in the electricity production sector.

Figure 9– GHG Emissions by Fuel Type

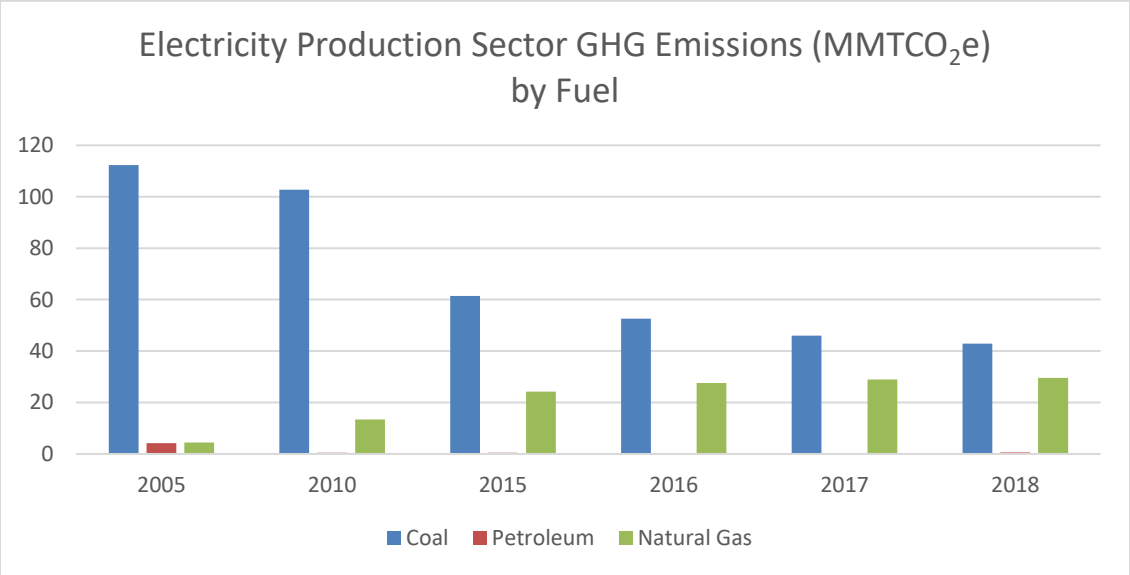


Table 12 gives the relative percentage of GHG emissions attributed to the three primary fuels used in the electricity production sector.

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

	2005	2010	2015	2016	2017	2018
Coal	92.9%	88.1%	71.3%	65.4%	61.2%	58.7%
Oil	3.5%	0.4%	0.5%	0.3%	0.3%	0.8%
Natural Gas	3.7%	11.5%	28.1%	34.3%	38.5%	40.5%

As noted in Table 10 and Table 12, for Pennsylvania's electricity generation sector in 2018 coal produced 58.7 percent of the GHG emissions while producing 20.5 percent of the electricity, natural gas produced 40.5 percent of the GHG emissions while producing 35.5 percent of the electricity, oil resources produced eight tenths of one percent of the GHG emissions while producing about three tenths of one percent of all electricity generated in the commonwealth. Nuclear fuel, which produces no GHG emissions, was responsible for generating 38.8 percent of the 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
Residential	53.66	55.25	54.42	53.88	51.72	55.90
Commercial	45.78	47.37	43.75	43.54	42.62	43.22
Industrial	47.95	45.46	47.40	47.13	47.89	49.16
Transportation	0.88	0.89	0.78	0.79	0.75	0.70
Line Loss	6.41%	5.82%	4.73%	4.49%	4.49%	4.88%
Total	**157.77**	**157.64**	**153.27**	**151.87**	**149.40**	**156.25**

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
Electricity Consumed	151.56	151.74	150.67	150.53	148.33	154.36
Electricity Generated	218.09	229.75	214.57	215.07	213.64	215.39
Electricity Exported	52.87	68.26	55.21	55.73	56.61	52.57

Agriculture Sector

At consistently less than eight $MMTCO_2e$ annually, the GHG emissions from the agriculture sector are significantly lower than emission from the industrial, transportation, and electricity production sectors. Like the industrial sector, GHG emissions in the agriculture sector are broken down into smaller groups: enteric

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
Dairy Cows	566	540	530	530	525	525
Dairy Replacement Heifers	275	300	305	325	315	310
Beef Cows	154	160	150	170	185	215
Beef Replacement Heifers	40	40	55	60	65	60
Heifer Stockers	55	50	55	55	60	60
Steer Stockers	170	150	145	140	160	130
Feedlot Heifers	24	24	24	24	24	24
Feedlot Steer	44	46	46	46	46	46
Bulls	25	25	25	25	25	25
Sheep	100	94	86	94	93	96
Goats	52	54	52	52	53	53
Swine	1088	1133	1165	1163	1195	1280
Horses	115	118	101	95	88	82

The enteric fermentation group includes animals that produce methane emissions as a result of 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 then 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
Dairy Cows	1.936	1.950	1.932	1.934	1.935	1.935
Dairy Replacement Heifers	0.440	0.495	0.503	0.536	0.519	0.511
Beef Cows	0.357	0.377	0.354	0.401	0.436	0.507
Beef Replacement Heifers	0.065	0.071	0.098	0.107	0.116	0.107
Heifer Stockers	0.082	0.075	0.083	0.083	0.091	0.091
Steer Stockers	0.245	0.217	0.210	0.203	0.232	0.189
Feedlot Heifers	0.024	0.026	0.026	0.026	0.026	0.026
Feedlot Steer	0.042	0.048	0.048	0.048	0.048	0.048
Bulls	0.060	0.061	0.061	0.061	0.061	0.061
Sheep	0.020	0.019	0.017	0.019	0.019	0.019
Goats	0.006	0.007	0.006	0.007	0.007	0.007
Swine	0.041	0.042	0.044	0.044	0.045	0.048
Horses	0.052	0.053	0.045	0.043	0.040	0.037
Total	**3.370**	**3.442**	**3.427**	**3.511**	**3.575**	**3.586**

The second sub-group of the agriculture sector is the manure management group. As with the enteric fermentation sub-group, 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 the 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 due to 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
Dairy Cattle	1.092	1.353	1.583	1.661	1.626	1.661
Beef Cattle	0.055	0.057	0.058	0.059	0.060	0.060
Swine	0.308	0.320	0.305	0.311	0.305	0.347
Poultry	0.209	0.190	0.216	0.220	0.222	0.228
Other	0.013	0.011	0.010	0.010	0.010	0.010
Total	**1.676**	**1.931**	**2.172**	**2.260**	**2.222**	**2.306**

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
Direct	2.43	2.46	2.75	2.81	2.92	2.88
Indirect	0.21	0.21	0.23	0.24	0.24	0.24
Leaching and Runoff	0.27	0.27	0.32	0.32	0.32	0.33
Total	**2.91**	**2.94**	**3.30**	**3.37**	**3.48**	**3.44**

Waste Management Sector

GHG emissions in the waste management sector primarily come from three sub-groups; 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, avoiding the production of methane that would otherwise be produced in a landfill, but also results in the release of carbon dioxide. Both municipal wastewater treatment and industrial wastewater treatment are accounted for in the third sub-group.

Data in the SIT regarding the amount of landfilled solid waste in the commonwealth 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 instead was combusted in either a flare or a landfill gas to energy project. A small amount (ten percent) of oxidation occurs in landfills each year, reducing the amount of methane emitted. 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
Potential Landfill CH_4	8.81	9.78	9.93	9.97	10.02	10.07
CH_4 Avoided	-6.65	-8.89	-9.03	-9.07	-9.11	-9.15
Oxidation	-0.22	-0.09	-0.09	-0.09	-0.09	-0.09
Total CH_4 Emissions (Landfills)[16]	**1.94**	**0.80**	**0.81**	**0.82**	**0.82**	**0.82**

The GHG emissions in the solid waste combustion sub-group result from the combustion of certain types of solid waste (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, paper, etc. are omitted because these items would decompose naturally and therefore, no additional CO_2 is emitted from the combustion of these materials. 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 was used in the calculation. Table 20 shows the GHG emissions ($MMTCO_2e$) attributable to the combustion of plastics, synthetic rubber, and synthetic fibers of 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
CO_2	1.58	1.43	1.61	1.66	1.68	1.68
N_2O	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
Total	**1.62**	**1.45**	**1.64**	**1.69**	**1.71**	**1.71**

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 and multiplied by the SIT-supplied emission factors to determine the total GHG emissions. Table 21 shows the GHG emissions ($MMTCO_2e$) attributed to the treatment of wastewater from municipal and industrial sources in the waste management sector.

Table 21 – GHG Emissions Associated with Wastewater Treatment ($MMTCO_2e$)

	2005	2010	2015	2016	2017	2018
Municipal CH_4	0.99	1.02	1.02	1.02	1.02	1.02
Municipal N_2O	0.38	0.38	0.38	0.38	0.38	0.38
Industrial CH_4	0.32	0.38	0.39	0.45	0.40	0.40
Total	**1.69**	**1.78**	**1.80**	**1.86**	**1.81**	**1.81**

Table 22 shows the GHG emissions ($MMTCO_2e$) totals for the solid waste and wastewater treatment portions of the waste management sector.

[16] The methodology used in the SIT to determine municipal solid waste generation was changed in 2018. This caused the default data to change for all years between 2009 and 2017. Prior to 2018, these values were held constant at 2008 levels.

Table 22– Total GHG Emissions (CO_2, CH_4, N_2O) from the Waste Management Sector ($MMTCO_2e$)

	2005	2010	2015	2016	2017	2018
Solid Waste	3.55	2.25	2.45	2.50	2.53	2.53
Wastewater	1.69	1.78	1.80	1.86	1.81	1.81
Total	**5.24**	**4.03**	**4.25**	**4.37**	**4.33**	**4.34**

Forestry and Land Use Sector

The forestry and land use sector is very important in its ability to sequester (absorb) carbon dioxide, reducing the net GHG emission in the commonwealth. In 2018, 27.98 $MMTCO_2$ of GHG was sequestered in the forestry and land use sector. This sector 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 was 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[17] and Pennsylvania's Department of Conservation & Natural Resources. Table 23 shows the total GHG emissions produced (positive values) and emissions sequestered (negative values) ($MMTCO_2e$) totals for the forestry and land use sector. Note that the 2020 SIT was updated with recently published data for the Land Use, Land Use Change, and Forestry (LULUCF) module, and therefore emissions results vary from previous iterations of this inventory report.

Table 23– Total GHG Emissions from the Forestry and Land Use Sector ($MMTCO_2e$)

	2005	2010	2015	2016	2017	2018
Forest Carbon Flux	-24.38	-23.92	-22.83	-22.57	-22.30	-22.03
Urban Trees, Carbon	-3.15	-3.31	-3.46	-3.49	-3.52	-3.56
Landfilled Yard Trimmings and Food Scraps, Carbon	-0.38	-0.43	-0.40	-0.36	-0.33	-0.33
Forest Fires, CH_4 and N_2O	0.05	0.23	0.95	1.09	0.81	0.68
N_2O from Settlement Soils	0.04	0.04	0.06	0.06	0.06	0.06
Agricultural Soil Carbon Flux	-4.81	-3.01	-2.20	-3.32	-3.20	-2.80
Total	**-32.63**	**-30.40**	**-27.87**	**-28.59**	**-28.48**	**-27.98**

It is important to note that the EPA's SIT is updated and re-released annually, and as methods for compiling GHG emissions data are refined, estimates for previous years may change with each iteration of the inventory.

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