Pennsylvania Greenhouse Gas Inventory
2016

Table of Contents

List of Tables

List of Figures

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Greenhouse Gas Inventory

Pennsylvania has several sectors which contribute to Greenhouse Gas (GHG) emissions, and each of these sectors has undergone fluctuations since 2000. Changes in the amount and type of fuel consumption, growth and slow-downs 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 have a GHG emission total associated with them within the Commonwealth: residential, commercial, industrial, transportation, electricity production, agriculture, waste management, forestry, and land use. Data for this inventory were primarily obtained from the EPA State Inventory Tool (SIT). SIT is an interactive spreadsheet model designed to help states develop GHG emissions inventories and provides a streamlined way to update an existing inventory or complete a new inventory.

The SIT consists of 11 estimation modules applying 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 (MMTCO2e). A metric ton is equal to 2,204.6 pounds or approximately 1.1 short tons (US tons). The greenhouse gases typically accounted for in the SIT are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Each GHG has a different global warming potential (GWP), which is accounted for when converting emissions to MMTCO2e. 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.

As shown in Table 1, the total statewide gross GHG emissions for Pennsylvania in 2013, the latest year with complete data available from the SIT, were 305.75 MMTCO2e. Pennsylvania's Forestry and Land Use sector provides a carbon sink for GHG emissions, absorbing approximately 34.36 MMTCO2e in 2013, and lowering the Commonwealth's net GHG emission for 2013 to 271.39 MMTCO2e. Table 1 also shows a relative decrease of 7.01 percent in the gross emission and 11.58 percent in the net emission totals for 2013 relative to 2000.

Also shown in Table 1, the sectors with the largest contribution to the Commonwealth's GHG emissions are the transportation, industrial, and electricity production sectors. The relative change for each of these sectors between 2000 and 2013 was a decrease of 11.50 MMTCO2e for the transportation sector, an increase of 5.16 MMTCO2e for the industrial sector, and a decrease of 12.26 MMTCO2e for the electricity production sector. Together, these three sectors annually account for over 85 percent of Pennsylvania's GHG emissions.

The residential, commercial, and agriculture sectors also experienced declines in GHG emissions during the time period from 2000 to 2013. The residential, commercial, and agriculture sectors

had decreases in GHG emissions of approximately 5.57, 2.45, and 0.26 MMTCO2e, respectively, during this time period.

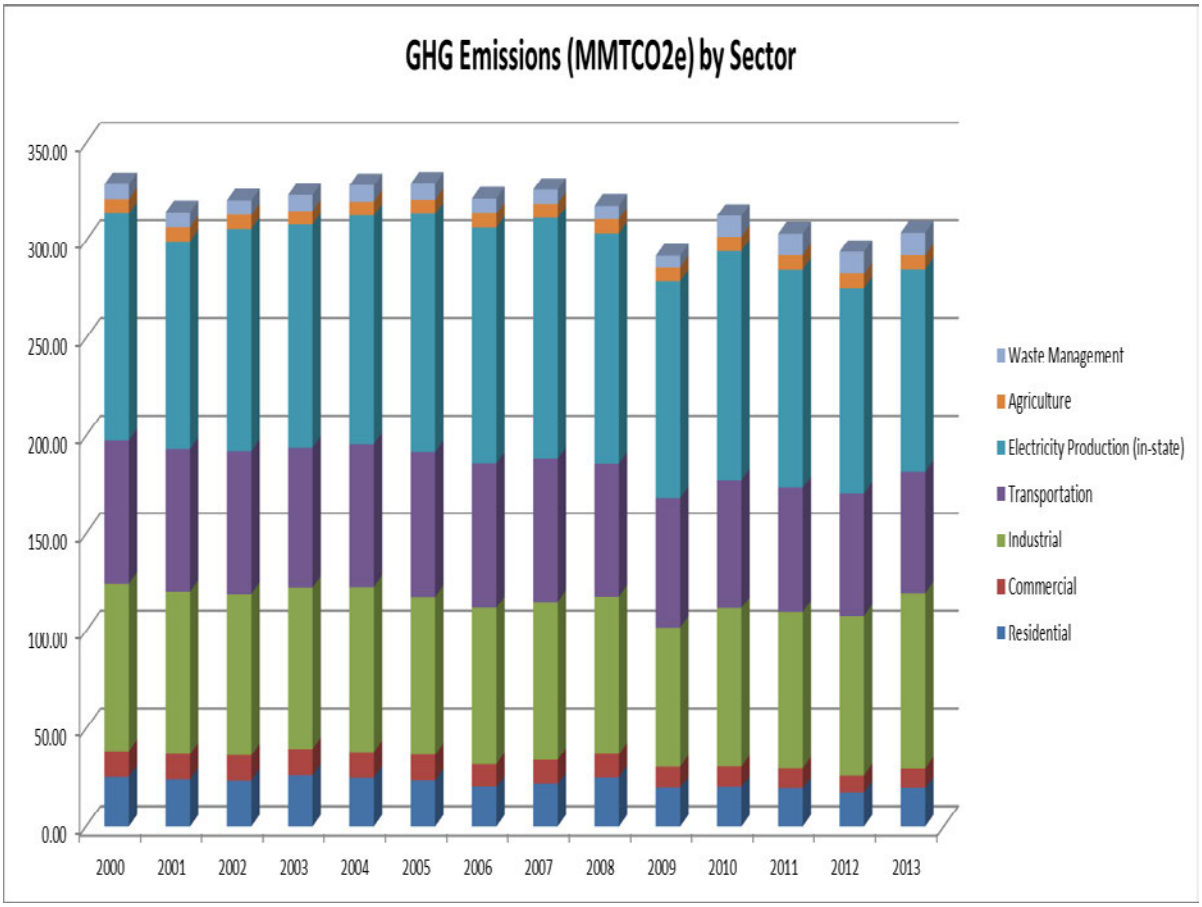
GHG emissions from the waste management sector experienced an approximately 3.83 MMTCO2e increase from 2000 to 2013. During this same period, the GHG emissions sequestered in the forest and land use sector have increased by approximately 12.48 MMTCO2e.

Table 1 – GHG Emissions by Sector

Sector / Emission Source ($MMTCO_2e$)	2000	2005	2009	2010	2011	2012	2013
Residential	**25.93**	**24.12**	**20.13**	**20.45**	**19.68**	**17.51**	**20.36**
Commercial	**13.02**	**13.00**	**10.90**	**10.63**	**10.39**	**9.12**	**10.57**
Industrial	**84.72**	**79.97**	**70.65**	**80.44**	**79.29**	**80.69**	**89.88**
Combustion of Fossil Fuels	49 08	46 57	35 66	40 67	41 12	42 59	49 59
Industrial Process	16 02	14 26	12 70	18 51	18 65	18 46	18 97
Coal Mining and Abandoned Coal Mines	12 78	9 40	11 53	11 78	9 11	9 10	10 63
Natural Gas and Oil Systems	6 85	9 74	10 76	9 48	10 41	10 54	10 69
Transportation	**73.75**	**74.74**	**66.50**	**65.90**	**63.85**	**62.86**	**62.25**
Petroleum	71 62	73 03	64 21	63 28	61 01	60 79	60 12
Natural Gas	2 13	1 71	2 30	2 62	2 84	2 07	2 13
Electricity Production (in-state)	**116.12**	**121.56**	**110.94**	**117.12**	**111.92**	**105.22**	**103.86**
Coal	111 04	112 34	98 23	102 70	94 32	82 93	83 08
Petroleum	3 37	4 19	0 70	0 51	0 40	0 26	0 29
Natural Gas	1 13	4 43	11 48	13 37	16 70	21 57	20 04
N2O	0 55	0 56	0 49	0 51	0 47	0 42	0 42
CH4	0 04	0 04	0 04	0 04	0 04	0 03	0 03
Agriculture	**7.38**	**7.19**	**7.37**	**7.29**	**7.31**	**7.40**	**7.12**
Enteric Fermentation	3 51	3 37	3 46	3 49	3 51	3 52	3 45
Manure Management	1 18	1 26	1 24	1 24	1 25	1 25	1 23
Agricultural Soil Management	2 67	2 55	2 65	2 55	2 54	2 61	2 43
Burning of Agricultural Crop Waste	0 01	0 01	0 01	0 01	0 01	0 01	0 01
Waste Management	**7.88**	**8.51**	**5.94**	**11.00**	**11.27**	**11.51**	**11.71**
Solid Waste and Combustion	6 23	6 85	4 24	9 28	9 55	9 79	9 99
Wastewater	1 66	1 66	1 70	1 72	1 72	1 73	1 73
Total Statewide Gross Emissions (Prod)	**328.81**	**329.10**	**292.43**	**312.84**	**303.69**	**294.32**	**305.75**
Increase relative to 2000		0 09%	-11 06%	-4 86%	-7 64%	-10 49%	-7 01%
Forestry and Land Use	-21 88	-34 25	-34 21	-34 11	-34 29	-34 31	-34 36
Total Statewide Net Emissions (Prod. with sinks)	**306.93**	**294.85**	**258.22**	**278.73**	**269.40**	**260.00**	**271.39**
Increase relative to 2000		-3 93%	-15 87%	-9 19%	-12 23%	-15 29%	-11 58%

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 (MMTCO2e)



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.

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 2013, are Natural Gas, Heating Oil, Propane, and Kerosene. Table 2 shows the amount of each fuel used (billion Btu) in residential homes within the Commonwealth. Several

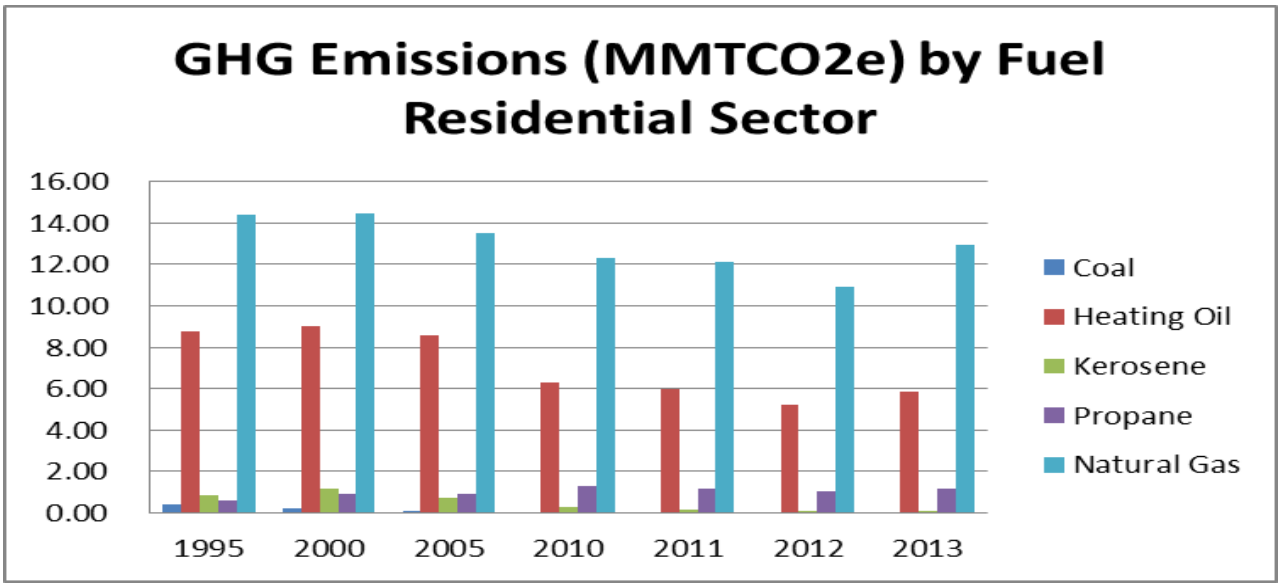
factors will have an effect on the amount of a fuel being used or including the severity of the weather, efficiency of the heating/hot water system, and the price/availability of a particular fuel. No electricity consumption is included in these values.

Table 2 – Residential Sector Fuel Consumption (Billion Btu)

	1990	1995	2000	2005	2010	2011	2012	2013
Coal	6,570	3,836	2,154	1,253	0	0	0	0
Heating Oil	117,704	118,190	121,678	115,753	85,476	80,652	70,867	79,446
Kerosene	7,810	11,702	15,822	10,330	4,211	2,572	1,076	1,152
Propane	8,286	10,107	14,687	15,102	20,815	19,264	16,902	18,976
Natural Gas	249,467	271,374	271,994	255,038	231,854	228,119	205,991	243,834

Each fuel used in residential homes will have different rates of GHG emissions. Figure 2 shows the GHG emission (MMTCO2e) 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.

Figure 2 - Residential Sector GHG Emissions by Fuel Type (MMTCO2e)



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

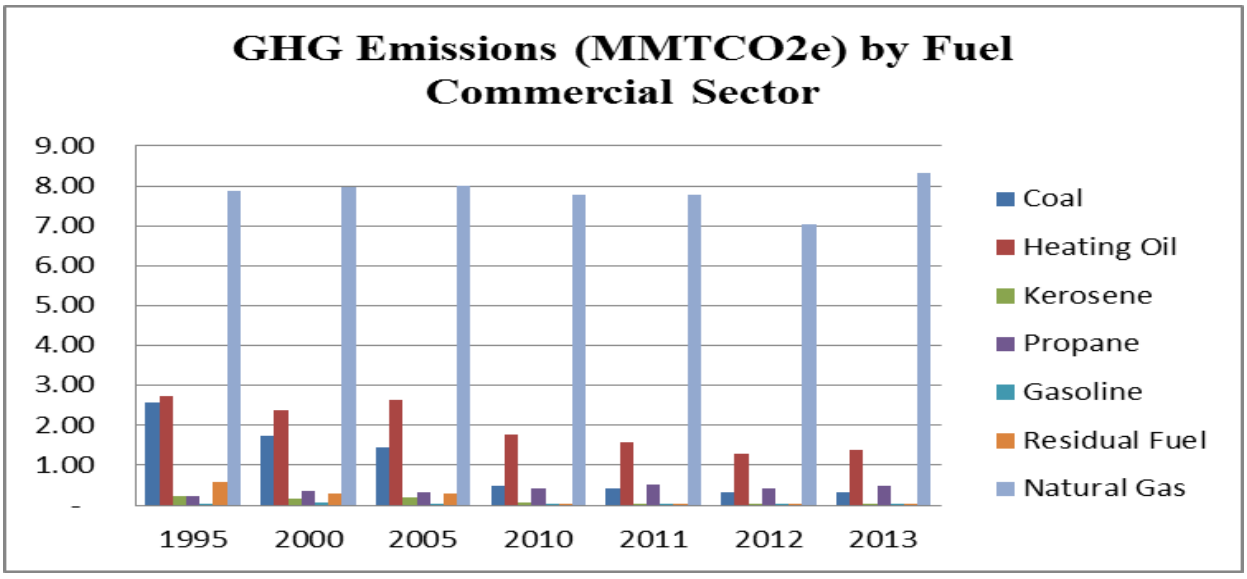
decreasing use in 2013, are natural gas, heating oil, propane, coal, gasoline, residual oil, and kerosene. Table 3 shows the amount of each fuel used (billion Btu) in commercial buildings within the Commonwealth. Several factors will have an effect on the amount of a fuel being used or including the 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 3 - Commercial Sector Fuel Consumption (Billion Btu)

	1990	1995	2000	2005	2010	2011	2012	2013
Coal	26,279	25,669	17,427	14,407	4,729	4,343	3,286	3,073
Distillate Fuel	38,676	36,862	31,978	35,632	23,638	21,063	17,103	18,557
Kerosene	851	2,992	2,307	2,610	755	198	67	58
LPG	3,143	3,834	5,571	5,473	6,865	7,907	6,540	7,713
Motor Gasoline	3,683	453	761	463	429	426	421	434
Residual Fuel	4,992	7,679	3,985	3,934	570	254	163	66
Natural Gas	130,622	148,806	150,410	150,849	146,902	146,752	132,519	156,814

As in the residential sector, each fuel used in commercial buildings will have different rates of GHG emissions. Figure 3 shows the GHG emissions (MMTCO2e) attributed to each fuel used in the commercial sector. The emissions from burning firewood to heat commercial buildings are accounted for in the land use change 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 3 – Commercial Sector GHG Emissions by Fuel Type (MMTCO2e)



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, the industrial process, 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 50 percent of the GHG emissions from the industrial sector.

Combustion of Fossil Fuels in the Industrial Sector

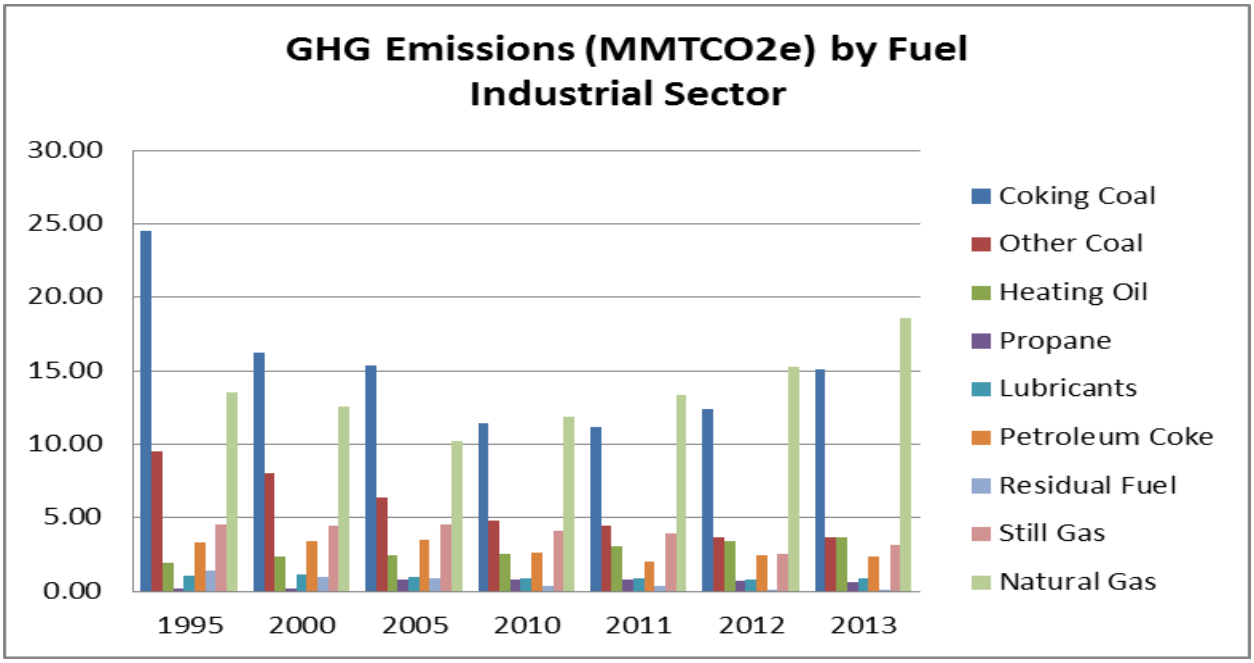
The emissions attributed to the industrial sector result from fuels used in industrial processing within the Commonwealth. These fuels, in order of decreasing use in 2013, are natural gas, coal/coke, heating oil, coal, and various other fuels. Table 4 shows the amount of each fuel used (billion Btu) in the industrial sector within the Commonwealth. Several factors will have an effect on the amount of a fuel being used, including production levels and the price/availability of a particular fuel.

Table 4 – Industrial Sector Fuel Consumption (Billion Btu)

	1990	1995	2000	2005	2010	2011	2012	2013
Coking Coal	280,218	261,897	173,020	164,228	121,445	119,431	132,211	160,754
Other Coal	101,704	101,143	85,359	67,654	51,240	47,564	38,897	38,584
Heating Oil	43,482	25,496	32,294	32,926	34,119	40,766	45,537	50,149
Propane	6,641	3,436	3,313	12,030	12,464	13,026	11,277	9,695
Lubricants	15,577	14,861	15,875	13,392	12,495	11,855	10,907	11,541
Petroleum Coke	31,513	32,927	32,961	34,433	25,763	20,099	23,758	23,189
Residual Fuel	36,050	18,158	12,538	12,039	4,272	4,376	1,287	874
Still Gas	71,842	68,368	66,807	67,662	61,778	58,929	38,293	46,680
Natural Gas	245,738	255,702	237,183	193,374	223,481	251,294	288,558	350,292

As in the residential and commercial sectors, each fuel used in the industrial sector will have different rates of GHG emissions. Figure 4 shows the GHG emissions (MMTCO2e) attributed to each fuel used in the industrial sector. The emissions related to electricity use within the industrial sector are accounted for in the electricity production sector. The emissions related to the industrial process itself are accounted for in the following section.

Figure 4 – Industrial Sector GHG Emissions by Fuel Type (MMTCO2e)



Industrial Process

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. The GHG emissions attributed to ODS substitutes are determined using a national emission total and then assigning a state value based on population. For example, in 2013 the United States experienced over 158 MMTCO2e of GHG emissions in the production and use of ODS substitutes. Pennsylvania's population in 2013 was 4.07 percent of the national population; therefore, 4.04% of 158 MMTCO2e (6.41 MMTCO2e) was assigned to Pennsylvania's inventory. Table 5 shows the GHG emissions (MMTCO2e) attributed to each of the processes included within the industrial sector.

Table 5 – Industrial Sector Process Emissions (MMTCO2e)

	1990	1995	2000	2005	2010	2011	2012	2013
Cement Manufacture	2.66	3.08	3.36	3.13	2.96	2.83	2.89	2.97
Lime Manufacture	1.13	1.07	1.19	0.85	1.72	1.79	1.68	1.65
Limestone and Dolomite Use	-	0.58	0.39	0.55	0.87	0.81	0.59	0.75
Iron & Steel Production	-	-	6.33	4.48	6.44	6.65	6.66	6.82
ODS Substitutes	0.01	1.60	3.85	4.64	5.93	6.07	6.24	6.41
Electric Power Transmission and Distribution Systems	1.07	0.85	0.55	0.43	0.28	0.27	0.22	0.20
Total	**4.88**	**7.18**	**15.67**	**14.08**	**18.20**	**18.42**	**18.29**	**18.81**

Please note that tracking of GHG emissions for Limestone and Dolomite use did not begin in the Commonwealth until 1994 and for Iron and Steel Production until 1997.

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 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 6 shows the GHG emissions (MMTCO2e) attributed to underground and surface coal mining, coal processing, and abandoned underground mines.

Table 6 – Coal Mining-Related Process Emissions (MMTCO2e)

	1990	1995	2000	2005	2010	2011	2012	2013
Underground Mining	7.98	9.91	9.57	6.64	9.39	6.69	6.89	8.56
Surface Mining	1.65	1.14	0.97	0.73	0.61	0.67	0.54	0.50
Underground Processing	0.86	0.88	1.23	1.16	1.01	1.01	0.96	0.90
Surface Processing	0.27	0.18	0.16	0.12	0.10	0.11	0.09	0.08
Abandoned Mines	0.50	1.24	0.84	0.87	0.66	0.64	0.62	0.60
Total	**11.25**	**13.35**	**12.78**	**9.52**	**11.78**	**9.11**	**9.10**	**10.63**

Natural Gas and Oil Systems

The GHG emissions associated with natural gas production, transmission, and distribution are accounted for in this section. 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. The natural gas transmission data became available in 2001 while the distribution data became available in 1997. DEP began to collect site-specific emission data from natural gas production in 2010. In order to provide consistency from previous years, this inventory continues to use default SIT emission factors for natural gas production for all years. An emission factor is also used to determine the GHG emissions based on the total oil production within the Commonwealth. Table 7 shows the GHG emissions (MMTCO2e) attributed to natural gas production, transmission, and distribution, and oil production.

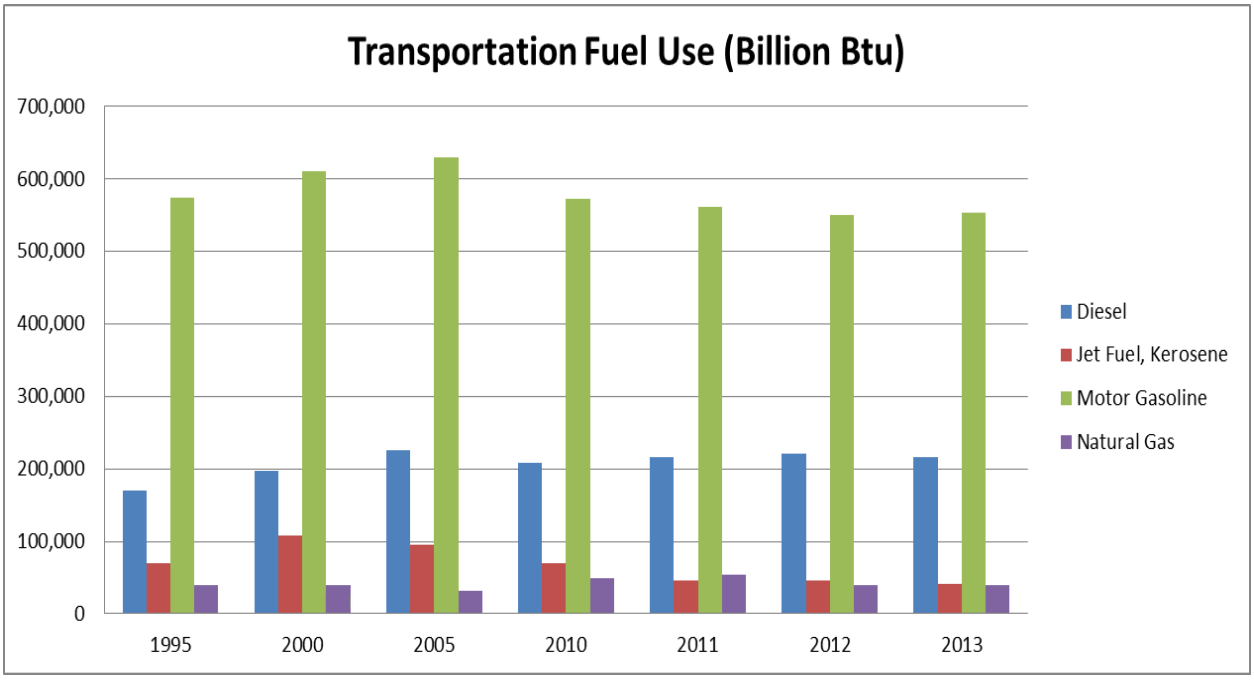
Table 7 – Natural Gas Production Process Emissions (MMTCO2e)

	1990	1995	2000	2005	2010	2011	2012	2013
Natural Gas Production	3.05	3.15	3.67	4.78	4.56	5.57	5.65	5.85
Natural Gas Transmission	-	-	-	1.92	1.97	1.89	1.94	1.95
Natural Gas Distribution	-	-	3.16	3.01	2.92	2.92	2.91	2.84
Oil Production	0.03	0.02	0.02	0.03	0.03	0.04	0.04	0.05
Total	**3.08**	**3.17**	**6.85**	**9.74**	**9.48**	**10.41**	**10.54**	**10.69**

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 2013, are gasoline, diesel, jet fuel, and natural gas. Figure 5 shows the amount of each fuel used (billion Btu) in transportation within the Commonwealth. Several factors will have an effect on 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 5 – Transportation Sector Fuel Use (Billion Btu)



As in the previous sectors, each fuel used in transportation will have different rates of GHG emissions. Table 8 shows the GHG emission (MMTCO2e) attributed to each fuel used in the transportation sector.

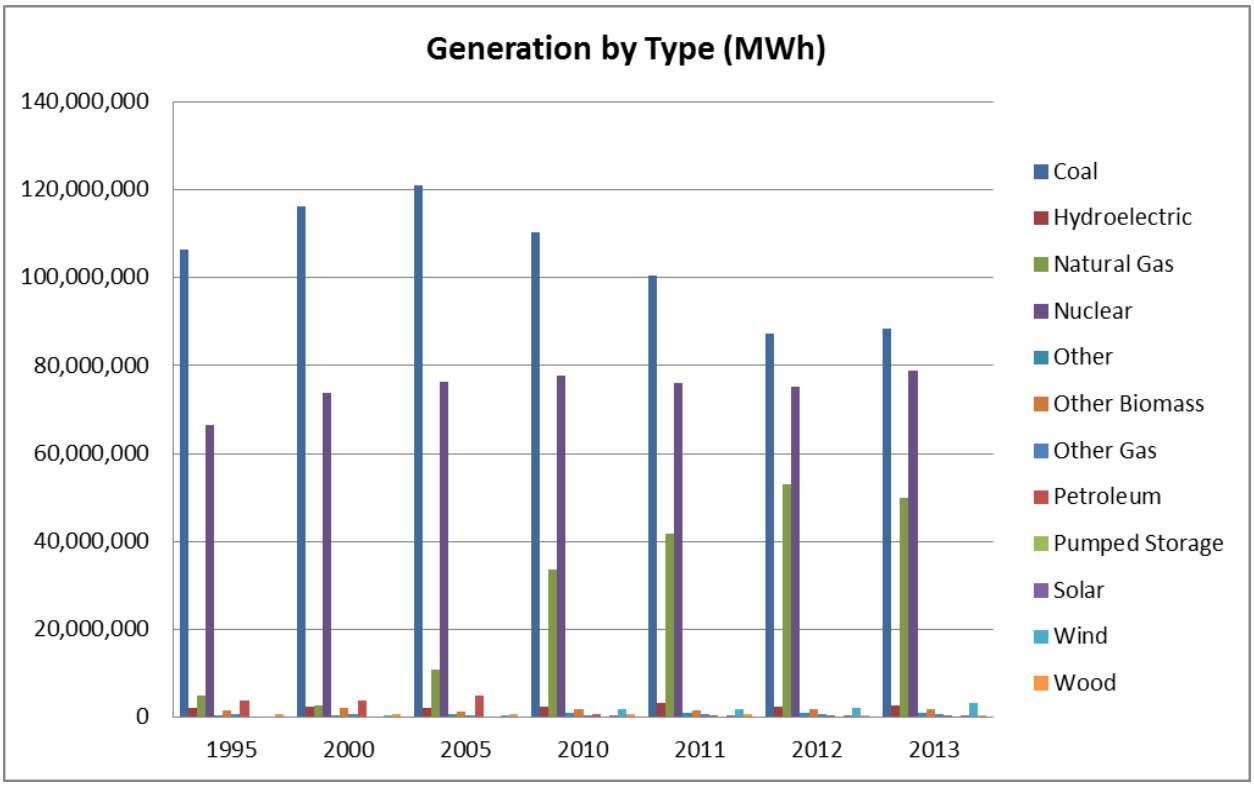
Table 8 – Transportation Sector Emissions by Fuel Consumption (MMTCO2e)

	1990	1995	2000	2005	2010	2011	2012	2013
Diesel	9.99	12.58	14.63	16.70	15.41	16.04	16.35	15.97
Jet Fuel, Kerosene	4.81	5.04	7.91	7.01	5.20	3.44	3.44	3.09
Motor Gasoline	42.33	44.11	46.25	46.60	41.77	40.81	39.94	40.06
Natural Gas	1.90	2.09	2.14	1.72	2.63	2.85	2.08	2.14
Total	**59.03**	**63.82**	**70.92**	**72.03**	**65.02**	**63.14**	**61.82**	**61.25**

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. Over one third of the statewide gross emissions in 2013 came from this 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 coal, nuclear, and natural gas. Figure 6 shows the electricity generation (MWh) in Pennsylvania by fuel.

Figure 6 – Electricity Generation by Type (MWh)



The largest changes in the production of electricity since 1990 have occurred in the use of coal and natural gas. Table 9 gives the relative percentages of each fuel used to generate electricity in Pennsylvania.

Table 9 – Electricity Generation by Fuel Type (%)

	1990	1995	2000	2005	2010	2011	2012	2013
Coal	60.74%	57.34%	57.62%	55.45%	48.04%	44.26%	39.01%	39.00%
Hydroelectric	1.63%	1.09%	1.14%	1.02%	1.02%	1.42%	1.00%	1.11%
Natural Gas	1.61%	2.66%	1.34%	4.96%	14.68%	18.39%	23.75%	22.02%
Nuclear	32.90%	35.84%	36.58%	34.98%	33.87%	33.50%	33.65%	34.71%
Other	0.00%	0.02%	0.03%	0.34%	0.37%	0.39%	0.40%	0.37%
Other Biomass	0.17%	0.89%	1.00%	0.62%	0.74%	0.73%	0.79%	0.81%
Other Gas	0.48%	0.42%	0.30%	0.25%	0.24%	0.27%	0.27%	0.29%
Petroleum	2.65%	1.97%	1.86%	2.27%	0.25%	0.19%	0.13%	0.20%
Pumped Storage	-0.50%	-0.67%	-0.20%	-0.33%	-0.31%	-0.22%	-0.20%	-0.24%
Solar	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.03%
Wind	0.00%	0.00%	0.00%	0.13%	0.81%	0.79%	0.95%	1.48%
Wood	0.31%	0.44%	0.34%	0.32%	0.29%	0.28%	0.24%	0.22%

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, natural gas, and oil. Table 10 shows the amount of each of these fuels consumed (billion Btu) in generating electricity in Pennsylvania.

Table 10 – Fuel Use for Electricity Generation (Billion Btu)

	1990	1995	2000	2005	2010	2011	2012	2013
Coal	1,054,707	1,062,368	1,210,638	1,224,911	1,119,758	1,028,374	904,245	905,843
Natural Gas	13,972	40,618	21,298	83,531	252,182	314,973	406,963	378,099
Oil	54,274	38,544	44,914	51,783	6,813	5,326	3,566	3,908

As in the previous sectors, each fuel used in electricity production has different rates of GHG emissions. Figure 7 shows the GHG emission (MMTCO2e) attributed to the three primary fuels used in the electricity production sector.

Figure 7– GHG Emissions by Fuel Type

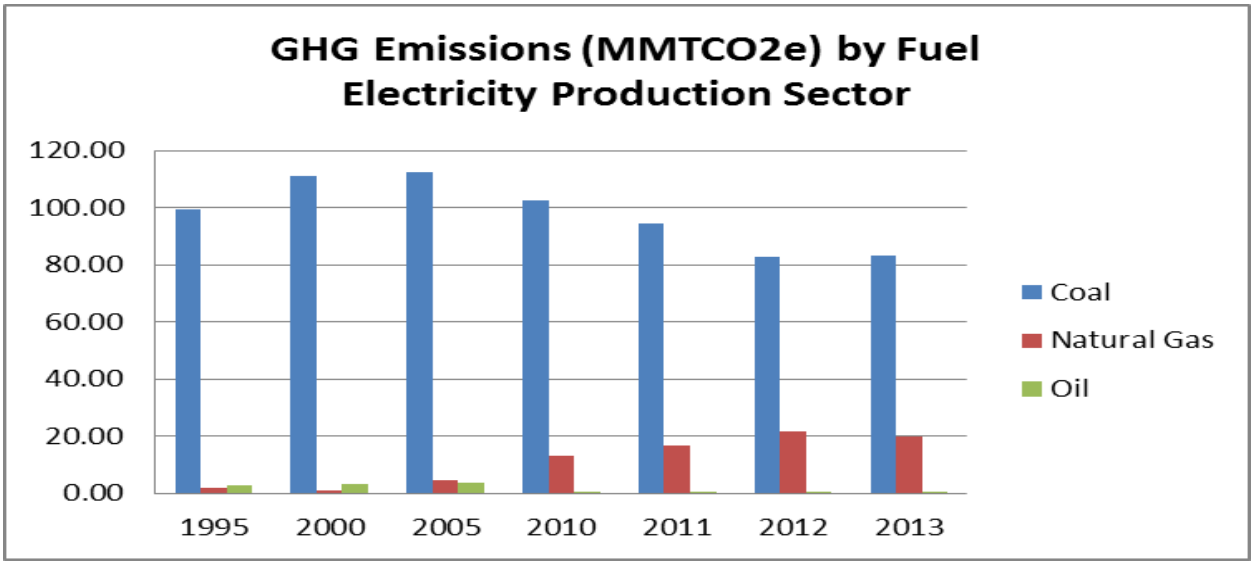


Table 11 gives the relative percentage of GHG emissions attributed to the three primary fuels used in the electricity production sector.

Table 11 – Contribution to GHG Emissions, by Fuel Type, in the Electricity Sector (%)

	1990	1995	2000	2005	2010	2011	2012	2013
Coal	95.4%	95.2%	96.1%	93.1%	88.1%	84.7%	79.2%	80.3%
Natural Gas	0.7%	2.1%	1.0%	3.7%	11.5%	15.0%	20.6%	19.4%
Oil	3.9%	2.8%	2.9%	3.2%	0.4%	0.4%	0.3%	0.3%

As noted in Tables 9 and 11, for Pennsylvania's electricity generation sector in 2013 coal produced over 80 percent of the GHG emissions while producing 39.0 percent of the electricity; natural gas produced approximately 19 percent of the GHG emissions while producing approximately 22 percent of the electricity; petroleum resources produced less than one half of one percent of the GHG emissions while producing about two tenth of one percent of all electricity generated in the Commonwealth. Nuclear fuel, which produces no GHG emissions, was responsible for generating 34.71 percent of the electricity.

As noted in previous inventory reports, Pennsylvania has historically been and is projected to remain an exporter of electricity to neighboring states. Table 12 shows the total consumption of electricity (GWh) within the residential, commercial, industrial, and transportation sectors.

Table 12 – Electricity Consumption by Sector (GWh)

	1990	1995	2000	2005	2010	2011	2012	2013
Residential	38.17	42.80	45.01	53.66	55.26	54.80	52.88	54.25
Commercial	30.20	35.54	42.99	45.78	47.37	43.54	42.92	43.15
Industrial	45.99	47.53	45.45	47.95	45.46	49.59	48.04	48.05
Transportation	0.40	0.38	0.40	0.88	0.89	0.84	0.88	0.81
Line Loss	6.41%	6.41%	6.41%	6.41%	5.82%	5.82%	9.17%	9.17%
Total	**122.62**	**134.90**	**143.02**	**158.44**	**158.18**	**157.96**	**159.33**	**161.03**

Table 13 gives the total amount of electricity (GWh) consumed in Pennsylvania and the total amount of electricity (GWh) generated. The difference between the two values is the total amount of electricity (GWh) exported from Pennsylvania.

Table 13 – Electricity Generated, Consumed and Exported (GWh)

	1990	1995	2000	2005	2010	2011	2012	2013
Electricity Consumed	122.62	134.90	143.02	158.44	158.18	157.96	159.33	161.03
Electricity Generated	175.62	185.45	201.69	218.09	229.75	227.31	223.42	226.79
Electricity Exported	53.01	50.55	58.67	59.66	71.57	69.35	64.09	65.76

Agriculture Sector

At consistently less than 8 MMTCO2e 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 14 lists the number (1,000 head) of each type of farm animal accounted for in the SIT.

Table 14 – Animal Populations Contributing to GHG Emissions (1,000 Head)

	1990	1995	2000	2005	2010	2011	2012	2013
Dairy Cows	694	639	619	566	540	543	540	535
Dairy Replacement Heifers	285	275	285	275	300	310	315	310
Beef Cows	166	171	151	154	160	167	160	155
Beef Replacement Heifers	39	42	35	40	40	40	45	55
Heifer Stockers	28	24	20	55	50	50	55	0
Steer Stockers	199	188	165	170	150	130	145	170
Feedlot Heifers	22	25	25	24	24	24	24	24
Feedlot Steer	44	47	44	44	46	46	46	46
Bulls	29	27	25	25	25	25	25	25
Sheep	134	110	90	100	100	98	89	86
Goats	10	23	37	52	54	52	50	48
Swine	920	1,000	1,030	1,100	1,110	1,120	1,140	1,080
Horses	61	83	108	115	118	119	120	121

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 15 shows the GHG emissions (MMTCO2e) attributed to each animal in the agriculture sector due to enteric fermentation.

Table 15 – GHG Emissions, by Livestock Type, from Enteric Fermentation (MMTCO2e)

	1990	1995	2000	2005	2010	2011	2012	2013
Dairy Cows	2.253	2.098	2.136	1.936	1.949	1.960	1.949	1.931
Dairy Replacement Heifers	0.492	0.452	0.471	0.440	0.495	0.511	0.519	0.511
Beef Cows	0.366	0.388	0.341	0.357	0.402	0.419	0.402	0.389
Beef Replacement Heifers	0.058	0.066	0.055	0.065	0.071	0.071	0.080	0.098
Heifer Stockers	0.035	0.033	0.030	0.082	0.080	0.080	0.088	0.000
Steer Stockers	0.270	0.264	0.240	0.245	0.233	0.202	0.225	0.264
Feedlot Heifers	0.022	0.024	0.025	0.024	0.026	0.026	0.026	0.026
Feedlot Steer	0.043	0.043	0.042	0.042	0.048	0.048	0.048	0.048
Bulls	0.065	0.063	0.058	0.060	0.065	0.065	0.065	0.065
Sheep	0.027	0.022	0.018	0.020	0.020	0.020	0.018	0.017
Goats	0.001	0.003	0.005	0.006	0.007	0.006	0.006	0.006
Swine	0.035	0.038	0.039	0.041	0.042	0.042	0.043	0.041
Horses	0.027	0.037	0.049	0.052	0.053	0.054	0.054	0.054
Total	**3.694**	**3.532**	**3.507**	**3.370**	**3.491**	**3.505**	**3.524**	**3.451**

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. Table16 shows the GHG emission (MMTCO2e) attributed to each animal in the agriculture sector due to manure management. The "other" category includes sheep, goats, and horses.

Table 16 – GHG Emissions, by Livestock Type, from Manure Management (MMTCO2e)

	1990	1995	2000	2005	2010	2011	2012	2013
Dairy Cattle	0.598	0.578	0.640	0.658	0.639	0.644	0.643	0.637
Beef Cattle	0.048	0.049	0.048	0.048	0.050	0.050	0.051	0.049
Swine	0.247	0.290	0.273	0.318	0.324	0.323	0.322	0.314
Poultry	0.229	0.236	0.211	0.227	0.210	0.210	0.209	0.220
Other	0.006	0.008	0.010	0.010	0.011	0.011	0.011	0.011
Total	**1.129**	**1.162**	**1.183**	**1.262**	**1.235**	**1.239**	**1.237**	**1.231**

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 17 below shows the estimated GHG emissions (MMTCO2e) resulting from agriculture soils management.

Table 17 – GHG Emissions from the Management of Agricultural Soils (MMTCO2e)

	1990	1995	2000	2005	2010	2011	2012	2013
Direct	2.16	2.16	2.24	2.13	2.13	2.12	2.19	2.05
Indirect	0.41	0.44	0.44	0.42	0.42	0.42	0.43	0.38
Total	**2.57**	**2.60**	**2.67**	**2.55**	**2.55**	**2.54**	**2.61**	**2.43**

Waste Management

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 would otherwise be produced in a landfill, but 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 18 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. (This calculation methodology has changed from previous years and is currently under discussion between EPA and the waste industry.) A small amount (10 percent) of the landfilled solid waste was assumed to oxidize each year and thus would not be contributing to the amount of methane emitted. Table 18 shows the GHG emissions (MMTCO2e) attributable to the potential landfill gas, the avoided methane emissions, and the avoided emissions due to solid waste oxidation.

Table 18 – GHG Emissions Associated with Landfilling Operations (MMTCO2e)

	1990	1995	2000	2005	2010	2011	2012	2013
Potential Landfill CH4	8.104	8.511	8.552	8.805	10.019	10.265	10.501	10.728
CH4 Avoided	0.000	-0.475	-2.840	-2.988	-2.210	-2.210	-2.210	-2.210
Oxidation	0.810	0.804	0.571	0.582	0.781	0.805	0.829	0.852
Total CH4 Emissions (Landfills)	**7.294**	**7.232**	**5.141**	**5.235**	**7.028**	**7.249**	**7.462**	**7.666**

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 CO2 is emitted from the combustion of these materials. This section also 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 19 shows the GHG emissions (MMTCO2e) attributable to the combustion of plastics, synthetic rubber, and synthetic fibers of the waste combustion portion of the waste management sector.

Table 19 – GHG Emissions Associated with Waste Combustion (MMTCO2e)

	1990	1995	2000	2005	2010	2011	2012	2013
CO2	0.222	0.670	1.059	1.580	2.213	2.256	2.280	2.275
N2O	0.008	0.021	0.027	0.034	0.043	0.043	0.043	0.043
CH4	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
CO2, N2O, CH4 Emissions (Waste Combustion)	**0.231**	**0.692**	**1.087**	**1.615**	**2.257**	**2.300**	**2.325**	**2.319**

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 particular (red meat, poultry, pulp and paper) types of industrial wastewater treatment. The SIT was used to calculate the municipal wastewater and industrial wastewater GHG emissions. Production data was collected for the poultry and pulp and paper industrial wastewater treatment sector and multiplied by the SIT-supplied emission factors to determine the total GHG emissions. Table 20 shows the GHG emissions (MMTCO2e) attributed to the treatment of wastewater from municipal and industrial sources in the waste management sector.

Table 20 – GHG Emissions Associated with Wastewater Treatment (MMTCO2e)

	1990	1995	2000	2005	2010	2011	2012	2013
Municipal CH4	0.953	0.964	0.984	0.989	1.018	1.020	1.022	1.023
Municipal N2O	0.311	0.322	0.338	0.334	0.354	0.355	0.357	0.358
Industrial CH4	0.030	0.034	0.336	0.338	0.344	0.342	0.348	0.346
Total Emissions Wastewater Treatment	**1.293**	**1.321**	**1.657**	**1.661**	**1.715**	**1.717**	**1.726**	**1.726**

Table 21 shows the GHG emissions (MMTCO2e) totals for the solid waste and wastewater treatment portions of the waste management sector.

Table 21 – Total GHG Emissions from the Waste Management Sector (MMTCO2e)

	1990	1995	2000	2005	2010	2011	2012	2013
Solid Waste	7.524	7.924	6.228	6.850	9.285	9.549	9.786	9.985
Wastewater	1.293	1.321	1.657	1.661	1.715	1.717	1.726	1.726
Total Waste Management	**8.817**	**9.246**	**7.885**	**8.512**	**11.000**	**11.266**	**11.513**	**11.711**

Forestry and Land Use

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 2013, over 34 $MMTCO_2$ of GHG was sequestered in the forestry and land use sector, more than the GHG emissions from the residential, commercial and agricultural sectors combined. This sector includes forested lands and soils, liming and fertilization of agricultural soils, trees located in urban settings, yard waste, and forest fires. Data from the SIT was the primary source of information for this section. Data concerning forest fires was collected and used dating back to 2002. Table 22 shows the total GHG emissions produced (positive values) and emissions sequestered (negative values) (MMTCO2e) totals for the forestry and land use sector.

Table 22 – GHG Emissions and Reductions from Forestry and Land Use

	1990	1995	2000	2005	2010	2011	2012	2013
Forest Carbon Flux	-19.82	-18.52	-18.52	-30.54	-30.31	-30.31	-30.31	-30.31
Liming of Agricultural Soils	0.18	0.15	0.12	0.02	0.21	0.11	0.12	0.07
Urea Fertilization	0.03	0.03	0.04	0.02	0.03	0.02	0.02	0.02
Urban Trees	-2.48	-2.79	-3.11	-3.42	-3.74	-3.80	-3.87	-3.93
Landfilled Yard Trimmings and Food Scraps	-1.10	-0.61	-0.45	-0.39	-0.43	-0.43	-0.42	-0.40
Forest Fires	0.00	0.00	0.00	0.02	0.09	0.08	0.10	0.15
N2O from Settlement Soils	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.03
Total	**-23.16**	**-21.72**	**-21.88**	**-34.25**	**-34.11**	**-34.29**	**-34.31**	**-34.36**

Pennsylvania currently has no stated goals in regards to GHG emission reductions. Several other states across the nation have adopted GHG reduction goals, such as a 20 percent reduction of 2000 emissions values by 2020 and 50 percent or 80 percent reductions by 2050. Without substantial changes in the industrial, transportation, and electric power sectors, and significant changes in the other sectors, these goals are not reachable for Pennsylvania.