



Virginia Greenhouse Gas Inventory – Baseline Virginia Department of Environmental Quality

Issued November 2021

Summary and Overview

This report summarizes results of the economy-wide greenhouse gas (GHG) inventory carried out by the Virginia Department of Environmental Quality (DEQ), and includes sector-specific analyses and methodologies.

Released from a broad range of human activities, GHGs are gases that trap heat in the atmosphere, and include carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and fluorinated gases (HFCs and SF₆). Solar radiation in the lower atmosphere acts like a greenhouse, preventing heat from escaping and contributing to global warming. To manage the risk of climate change, track progress, and identify opportunities, and as required by law, DEQ collects information on many types of pollutants, including GHGs. This information is included in the GHG inventory, which is updated every 4 years. DEQ's baseline GHG inventories use 2005 and 2010 data.

During the 2005 and 2010 reporting periods, approximately 172 million metric tons of carbon dioxide equivalent (MMTCO_{2e}) and 160 MMTCO_{2e} were emitted in the Commonwealth, respectively. CO_{2e} is the standard way of describing GHGs so that they can be compared because different gases can have different global warming potentials. For example, a ton of methane emissions will cause at least 25 times the amount of warming as a ton of CO₂, and can be described as 25 tons of CO_{2e}. Approximately 51 MMTCO_{2e} were sequestered by agriculture, soil and trees during both years, resulting in net emissions of 121 MMTCO_{2e} and 109 MMTCO_{2e}, respectively. The current inventory used the U.S. Environmental Protection Agency's (EPA) State Inventory Tool (SIT) to calculate Virginia's economy-wide emissions. Figures 1 and 2 depict emissions by source each year.

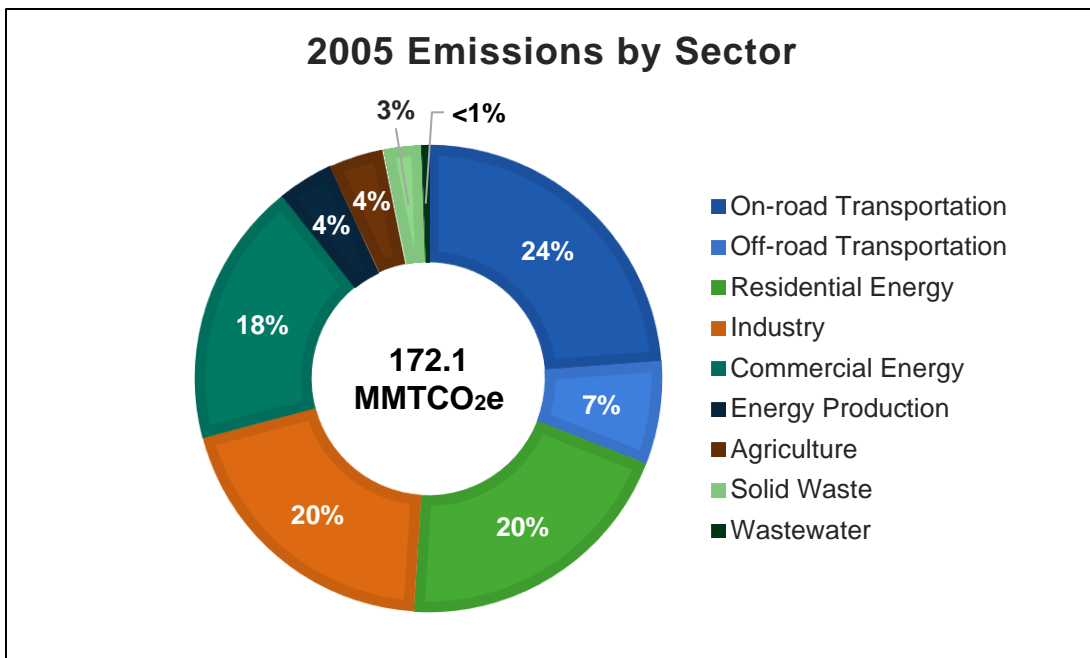


Figure 1. Sources of 2005 GHG emissions

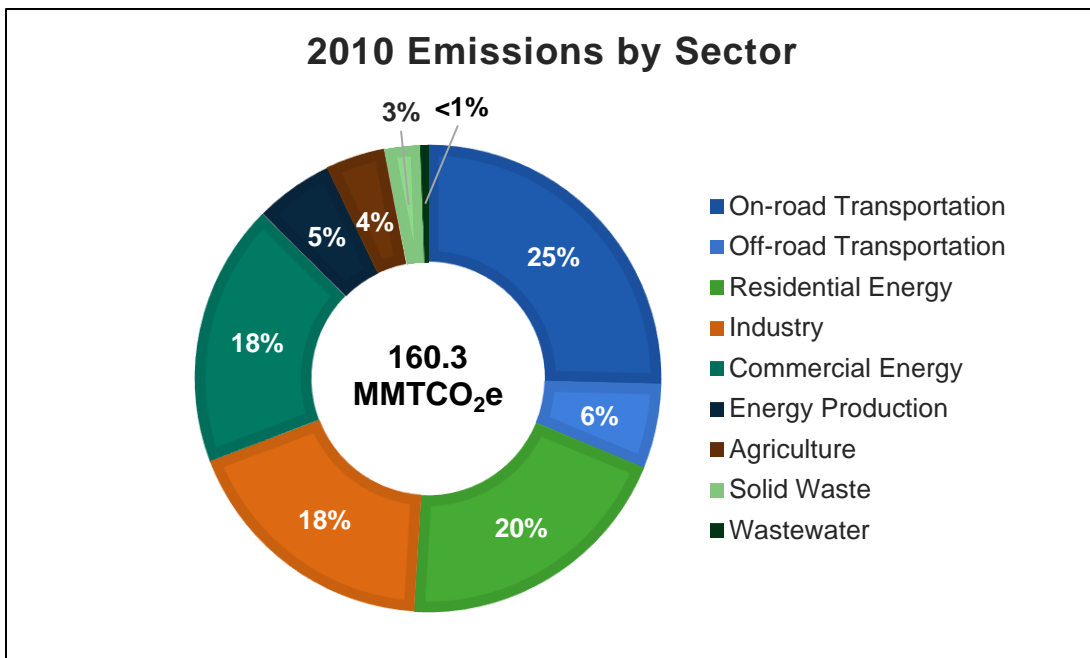


Figure 2. Sources of 2005 GHG emissions

Methodology

SIT, which was used to develop the inventory, is composed of 11 sector-specific modules:

- Agriculture
- Combustion of fossil fuels (CO₂ only)
- Coal mining
- Electricity consumption
- Industrial processes
- Land use, land use change and forestry
- Mobile combustion (transportation)
- Natural gas and oil
- Solid waste
- Stationary combustion (CH₄ and N₂O)
- Wastewater

SIT modules contain default data for individual states, which users can select or supply their own data. DEQ used default data for most sectors, but supplemented the natural gas and oil module with data from the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration.

Results produced from SIT generated ten sector source categories plus sequestration from land use, as depicted in the list above. DEQ used the detailed results from SIT to generate eight alternative sector categories to represent the results in a more easily understandable format, as depicted in Figures 1 and 2. Results by SIT category, as well as power sector emissions can be found in the appendix.

The following sections provide sector-specific details on 2005 and 2010 GHG emissions. It should be noted that most tables of results will include a breakdown of individual GHGs (CO₂, CH₄, N₂O and others) in addition to total CO₂e. Note that the results from some SIT modules only report CO₂e, not individual gases. Therefore, CO₂e values will be higher than the sum of individual gases in many of the following sections. It should also be noted that negative values represent emissions that have been avoided or sequestered.

Transportation

The transportation sector was the Commonwealth's highest emitter in 2005 and 2010. Emissions from transportation were 53.32 MMTCO₂e in 2005 and 50.01 MMTCO₂e in 2010, which comprised approximately 31 percent of total emissions in both years. In 2005, on-road and off-road mobile source emissions were 41.01 MMTCO₂e and 12.31 MMTCO₂e, respectively, which comprised about 24 percent and 7 percent of total emissions, respectively. In 2010, on-road and off-road mobile source emissions were 40.67 MMTCO₂e and 9.34 MMTCO₂e, respectively, which comprised about 25 percent and 6 percent of total emissions, respectively. Transportation emissions include CO₂, CH₄ and N₂O from on-road and off-road fuels, electricity used for light rail and vehicle lubricants. Table 1 depicts the sources of all transportation emissions by vehicle type. Table 2 depicts the sources of CO₂ emissions by fuel type. Figures 3 and 4 depicts emissions by vehicle type, grouped into on-road and off-road.

Vehicle Type	2005				2010				Percent Change
	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	Total	
Light Duty	30.0416	0.09159	1.31188	31.4451	27.0844	0.06136	0.65141	27.7971	-12%
Heavy Duty	9.44667	0.00578	0.05133	9.50379	12.7279	0.00260	0.02722	12.7577	34%
Bus	0.01196	0.00062	0.00066	0.01324	0.02754	0.00143	0.00152	0.03049	130%
Motorcycle	0.04833	0.00078	0.00094	0.05005	0.08523	0.00141	0.00172	0.08836	77%
Aviation	7.79598	0.00682	0.07111	7.87391	5.23683	0.00417	0.04788	5.28888	-33%
Boat	0.63990	0.00116	0.00479	0.64585	0.40007	0.00072	0.00300	0.40379	-37%
Rail	0.59534	0.00130	0.00497	0.60168	0.49414	0.00108	0.00413	0.49935	-17%
Tractor	0.51091	0.00195	0.00413	0.51698	0.25191	0.00098	0.00207	0.25496	-51%
Construction	1.76573	0.00249	0.01317	1.78139	2.20974	0.00311	0.01648	2.22933	25%
Utility	0.59770	0.00084	0.00447	0.60302	0.38055	0.00054	0.00285	0.38394	-36%
Other	0.28544	N/A	N/A	0.28544	0.28057	N/A	N/A	0.28057	-2%

Table 1. Transportation emissions by vehicle type (MMTCO₂e)

Fuel Type	2005	2010	Percent Change
Gasoline	31.6288	27.8831	-12%
Diesel	11.9233	15.7104	32%
Jet Fuel	7.71823	5.20440	-33%
Aviation Gasoline	0.07775	0.03243	-58%
Residual Fuel Oil	0.09111	0.03819	-58%
CNG	0.01271	0.02793	120%
LPG	0.00223	0.00162	-27%
LNG	0.00001	0.00004	300%
Electricity	0.09485	0.00000	-100%
Lubricants	0.19059	0.28057	47%

Table 2. Transportation CO₂ emissions by fuel type (MMTCO₂)

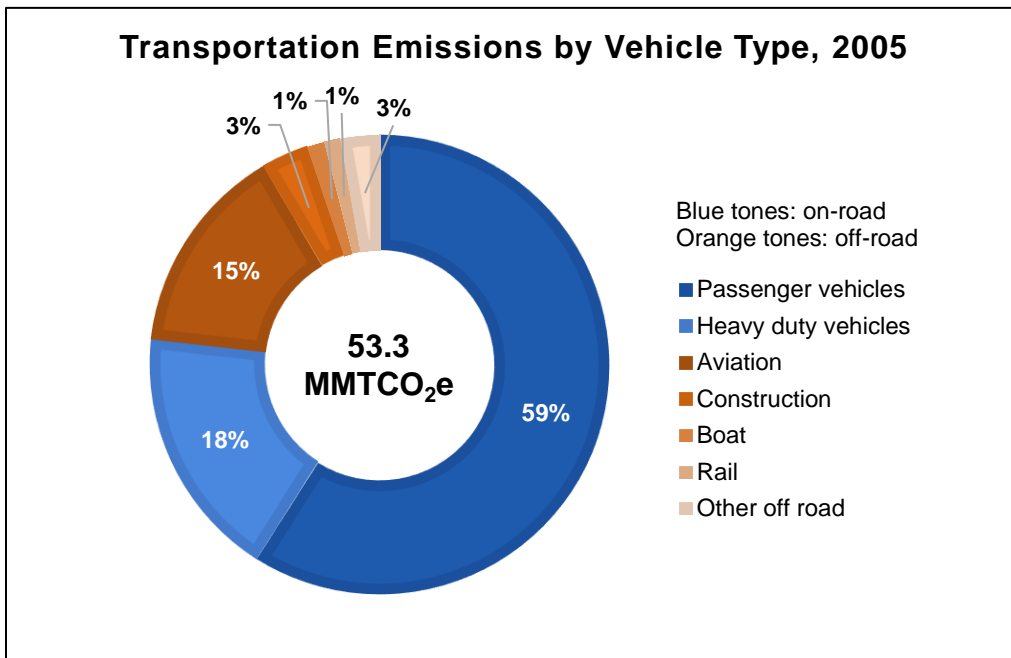


Figure 2. 2005 transportation emissions by vehicle type, grouped by on-road and off-road

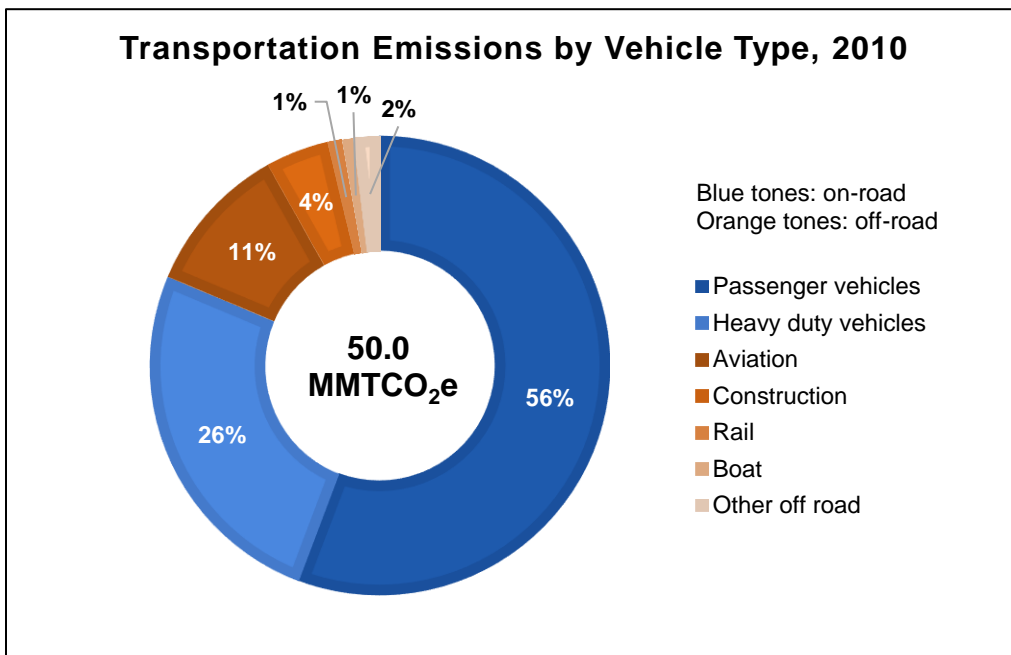


Figure 4. 2010 transportation emissions by vehicle type, grouped by on-road and off-road

Industry

Industry was the second largest source of GHGs in the Commonwealth. Emissions from industry totaled 34.22 MMTCO₂e in 2005 and 29.27 MMTCO₂e in 2010, which was approximately 20 percent and 18 percent off all emissions respectively. Sources of industrial emissions are stationary combustion of fossil fuels, electricity use and process emissions. Table 3 depicts the breakdown of industrial emissions by source. Table 4 displays the breakdown of process emissions by industry.

Source	2005					2010					Percent Change
	CO ₂	CH ₄	N ₂ O	HFCs, PFCs, NF ₃ , SF ₆	Total	CO ₂	CH ₄	N ₂ O	HFCs, PFCs, NF ₃ , SF ₆	Total	
Stationary Combustion	17.68	0.082	0.140	N/A	17.91	12.88	0.060	0.102	N/A	13.04	-27%
Electricity Use	11.23	N/A	N/A	N/A	11.23	8.620	N/A	N/A	N/A	8.620	-23%
Process Emissions	2.070	N/A	N/A	3.018	5.088	3.543	N/A	N/A	4.074	7.617	50%

Table 3. Industrial emissions by source (MMTCo₂e)

Industry	2005			2010			Percent Change
	CO ₂	HFCs, PFCs, NF ₃ , SF ₆	Total	CO ₂	HFCs, PFCs, NF ₃ , SF ₆	Total	
Cement	0.38699	N/A	0.38699	0.56264	N/A	0.56264	45%
Lime	0.00000	N/A	0.00000	0.84496	N/A	0.84496	N/A
Limestone & Dolomite	0.20817	N/A	0.20817	0.18762	N/A	0.18762	-10%
Soda Ash	0.06563	N/A	0.06563	0.05682	N/A	0.05682	-13%
Iron & Steel	1.03411	N/A	1.03411	0.81688	N/A	0.81688	-21%
Ammonia	0.37341	N/A	0.37341	1.07158	N/A	1.07158	187%
Urea	0.00198	N/A	0.00198	0.00233	N/A	0.00233	18%
ODS	N/A	2.76918	2.76918	N/A	3.86878	3.86878	40%
Semiconductor	N/A	0.00000	0.00000	N/A	0.03369	0.03369	N/A
Electric T&D	N/A	0.24828	0.24828	N/A	0.17166	0.17166	-31%

Table 4. Process emissions by industry (MMTCo₂e)

Commercial Energy

Commercial energy, the third largest source of GHG emissions, is composed of electricity use and stationary combustion of fossil fuels by commercial entities. Emissions totaled 31.59 MMTCo₂e in 2005 and 29.20 MMTCo₂e in 2010, which was approximately 18 percent of total emissions in both years. Table 5 displays detailed emissions from the commercial sector.

Source	2005				2010				Percent Change
	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	Total	
Electricity Use	25.907	N/A	N/A	25.907	24.155	N/A	N/A	24.155	-7%
Stationary Combustion	5.6449	0.0323	0.0102	5.6874	5.0033	0.0288	0.0081	5.0402	-11%

Table 5. Commercial emissions by source (MMTCo₂e)

Residential Energy

Residential energy is composed of electricity use and stationary combustion of fossil fuels by residential buildings. Residential emissions totaled 34.48 MMTCo₂e in 2005 and 31.65 MMTCo₂e in 2010, which was approximately 20 percent of total emissions in both years. Table 6 displays detailed emissions from the residential sector.

Source	2005				2010				Percent Change
	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	Total	
Electricity Use	25.902	N/A	N/A	25.902	24.358	N/A	N/A	24.358	-6%
Stationary Combustion	8.4108	0.1336	0.0290	8.5734	7.1263	0.1426	0.0281	7.2970	-15%

Table 6. Residential emissions by source (MMTCo₂e)

Energy Production

Energy production is composed of emissions from coal mining and the production, transmission and distribution of natural gas and oil. Energy production emissions totaled 6.68 MMTCO_{2e} in 2005 and 8.70 MMTCO_{2e} in 2010, which was approximately 4 percent and 5 percent of all emissions respectively. Table 7 depicts emissions by sector. Table 8 displays detailed coal mining emissions. Table 9 displays detailed natural gas and oil emissions.

Sector	2005	2010	Percent Change
Coal Mining	5.0785	6.4253	27%
Natural Gas & Oil	1.5965	2.2782	43%

Table 7. Energy production emissions by sector (MMTCO_{2e})

Mine Type	2005	2010	Percent Change
Active	4.1577	4.3341	4%
Abandoned – Vented	0.1652	0.2471	50%
Abandoned – Sealed	0.4562	1.0580	132%
Abandoned – Flooded	0.2994	0.7861	163%

Table 8. Coal mining emissions by mine type (MMTCO_{2e})

Sector	Activity	2005	2010	Percent Change
Natural Gas	Production	0.4235	0.7657	81%
	Transmission	0.0910	0.5999	559%
	Distribution	1.0815	0.9125	-16%
Oil	Production	0.0005	0.0002	-60%

Table 9. Natural gas & oil emissions by activity (MMTCO_{2e})

Agriculture

Agriculture emissions come from a variety of agricultural practices, including fertilization, livestock management and residue burning. Agriculture emissions totaled 6.42 MMTCO_{2e} in 2005 and 6.56 MMTCO_{2e} in 2010, which was approximately 4 percent of all emissions in both years. Table 10 displays agriculture emissions by source.

Source	2005				2010				Percent Change
	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	Total	
Liming	0.0257	N/A	N/A	0.0257	0.2135	N/A	N/A	0.2135	731%
Urea Fertilization	0.0153	N/A	N/A	0.0153	0.0180	N/A	N/A	0.0180	18%
Enteric Fermentation	N/A	2.8372	N/A	2.8372	N/A	2.7572	N/A	2.7572	-3%
Manure Management	N/A	0.4482	0.3065	0.7547	N/A	0.4317	0.2782	0.7099	-6%
Agricultural Residue Burning	N/A	0.0004	0.0003	0.0007	N/A	0.0003	0.0002	0.0005	-29%
Soils	N/A	N/A	2.7879	2.7879	N/A	N/A	2.8611	2.8611	3%

Table 10. Agriculture emissions by source (MMTCO_{2e})

Solid Waste

Solid waste emissions are composed of emissions associated with decomposition in landfills and emissions from waste incineration. Solid waste emissions totaled 4.56 MMTCO_{2e} in 2005 and 3.96 MMTCO_{2e} in 2010, which was approximately 3 percent of all emissions in both years. Table 11 displays emissions from landfills. Table 12 displays emissions from waste incineration.

Source	2005	2010	Percent Change
Potential CH ₄ (Waste Generation)	7.1453	7.6443	7%
Avoided CH ₄ (Flaring & Landfill Gas to Energy)	-3.1530	-4.1981	33%
Oxidation	-0.3992	-0.3446	-14%
Net Emissions	3.5931	3.1016	-14%

Table 11. Emissions from landfills (MMTCO_{2e})

Waste Type	2005				2010				Percent Change
	CO ₂	CH ₄	N ₂ O	Total	CO ₂	CH ₄	N ₂ O	Total	
Plastic	0.6499	N/A	N/A	0.6499	0.5681	N/A	N/A	0.5681	-13%
Synthetic Rubber	0.0975	N/A	N/A	0.0975	0.0877	N/A	N/A	0.0877	-10%
Synthetic Fibers	0.2423	N/A	N/A	0.2423	0.1864	N/A	N/A	0.1864	-23%
Unspecified	N/A	0.0006	0.0174	0.0180	N/A	0.0005	0.0163	0.0168	-7%

Table 12. Emissions from waste incineration by waste type (MMTCO_{2e})

Wastewater

Wastewater emissions come from processes used by municipal and industrial wastewater treatment facilities and their effluent water discharge. Wastewater emissions totaled 0.85 MMTCO_{2e} in 2005 and 0.90 MMTCO_{2e} in 2010, which was less than 1 percent of total emissions in both years. Table 13 displays wastewater emissions by facility type.

Facility Type	2005			2010			Percent Change
	CH ₄	N ₂ O	Total	CH ₄	N ₂ O	Total	
Municipal	0.6043	0.2296	0.8339	0.6425	0.2383	0.8808	6%
Industrial	0.0199	N/A	0.0199	0.0147	N/A	0.0147	-26%

Table 13. Wastewater emissions by facility type (MMTCO_{2e})

Land Use and Forestry

The land use and forestry sector accounts for sequestration of carbon by vegetation and other land uses. This sequestration of carbon offsets emissions from other sectors. Approximately 50.88 MMTCO_{2e} in 2005 and 51.14 MMTCO_{2e} were sequestered and offset by land use and forestry. Economy-wide emissions without considering land use and forestry were 171.93 MMTCO_{2e} in 2005 and 160.45 MMTCO_{2e} in 2010. When factoring in the land use and forestry sector, net economy-wide emissions were 121.05 MMTCO_{2e} in 2005 and 109.31 MMTCO_{2e} in 2010. Table 14 provides a breakdown of sources of sequestration.

Source	2005	2010	Percent Change
Forestry	-46.463	-47.043	1%
Urban Trees	-1.5578	-2.1951	41%
Landfilled Yard Trimmings & Food Scraps	-0.2630	-0.2938	12%
N ₂ O from Settlement Soils	0.0359	0.0393	9%
Agricultural Soil Carbon Flux	-2.6288	-1.6444	-37%
Net Emissions	-50.877	-51.136	1%

Table 14. Carbon sequestered from land use and forestry (MMTCO_{2e})

Appendix

This appendix contains additional details not included in the main portion of the inventory report. Figure 5 and 6 depict emissions broken down by the default SIT sectors. Power sector emissions are reported in Figure 7, Figure 8 and Table 15. Power sector emissions differ from electricity consumption emissions because consumption includes electricity imported from other states, as well as emissions associated with the end-use of the electricity, such as indirect emissions from heating. Table 16 provides details on data inputs and sources of this data.

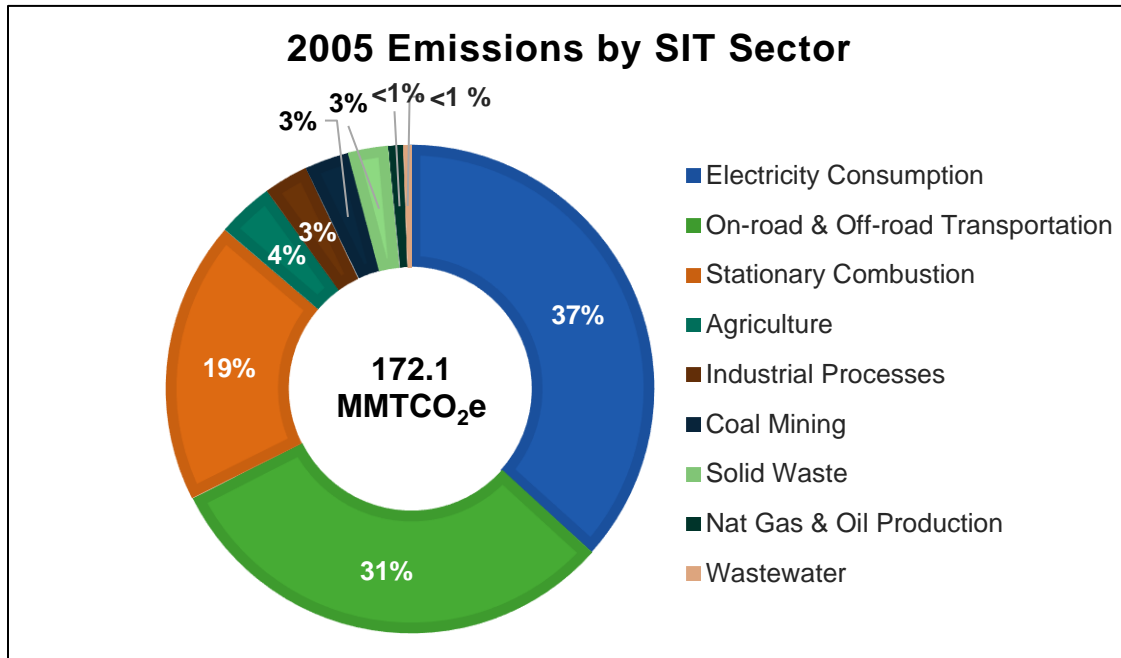


Figure 5. 2005 emissions by SIT categories

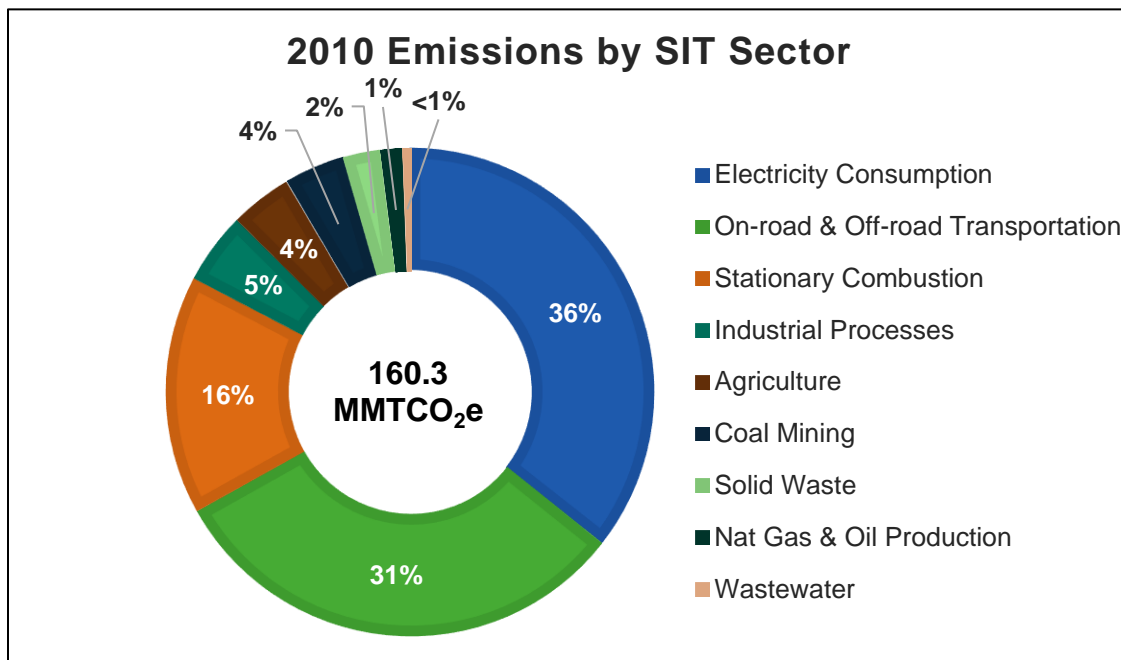


Figure 6. 2010 emissions by SIT categories

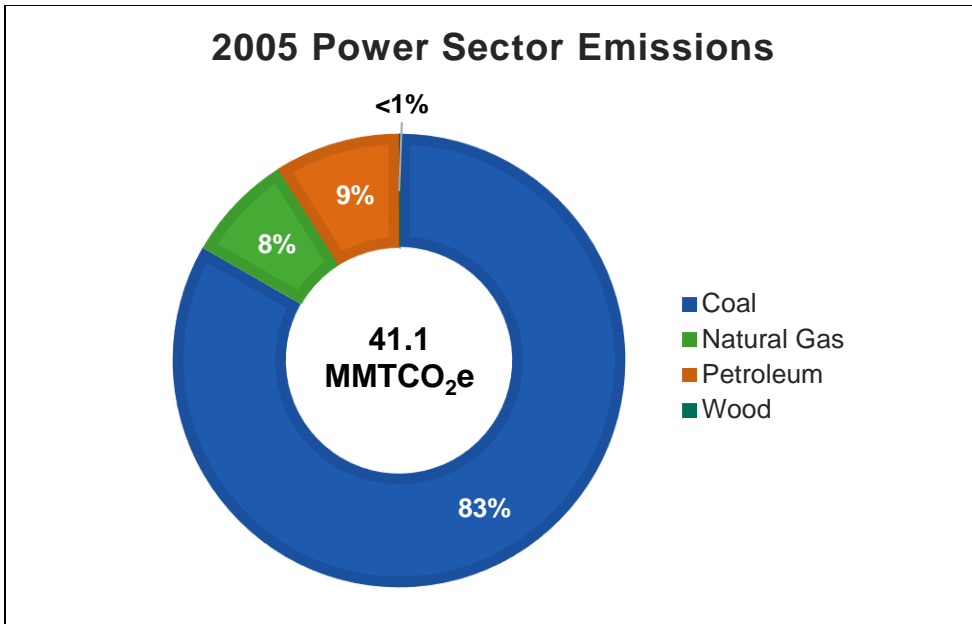


Figure 7. 2005 power sector emissions by fuel type

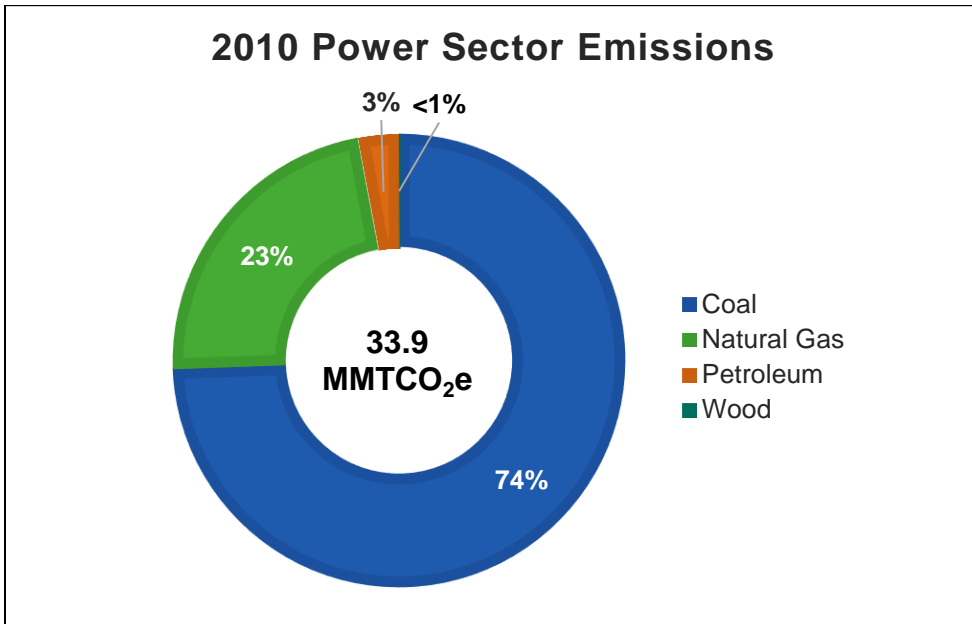


Figure 8. 2010 power sector emissions by fuel type

GHG Type	2005	2010	Percent Change
CO ₂	40.9157	33.7003	-18%
CH ₄	0.01876	0.01588	-15%
N ₂ O	0.18168	0.13490	-26%
Total CO₂e	41.1161	33.8511	-18%

Table 15. Power sector emissions by GHG (MMTCO₂e)

Inventory Data Inputs & Sources

Sector	Data Input	Default Data Sources	Supplemental Data Sources
On-road Transportation	Vehicle Miles Traveled (VMT)	Federal Highway Administration (FHWA)	None
	Annual mileage accumulation	Environmental Protection Agency (EPA)	None
	Emissions control technologies	EPA	None
	Age distribution of vehicles	EPA	None
	Emissions factors	EPA	None
Off-road Transportation	Aviation fuel consumption and activity	Energy Information Administration (EIA)	None
	Boat fuel consumption	FHWA and EPA	None
	Locomotive activity	EIA	None
	Agriculture, construction and other off-road gasoline consumption	FHWA	None
	Other off-road activity	EPA	None
	Emissions factors	EIA and Intergovernmental Panel on Climate Change (IPCC)	None
Residential, Commercial and Industrial Energy	Electricity consumption	EIA	None
	Stationary combustion	EIA	None
Industrial Processes	Iron and steel production	American Iron and Steel Institute (AISI)	None
	Cement and lime production	United States Geological Survey (USGS)	Supplemented with EPA GHG Reporting Program (GHGRP)
	Semiconductor and ozone depleting substances (ODS) substitutes national emissions	EPA	None
	Soda ash production and consumption	EPA	None
	Limestone and dolomite consumption	EPA	None
	Ammonia production and urea consumption	USGS	Supplemented with EPA GHGRP
	Electric power SF ₆ consumption	EPA	None
	Emissions factors	IPCC and EPA	None
	Agriculture	Livestock population	US Department of Agriculture (USDA)
Crop production		USDA	None
Crop area burned		EPA	None
Manure management data		EPA	None
Urea and fertilizer consumption		Association of American Plant Food Control	None

Sector	Data Input	Default Data Sources	Supplemental Data Sources
		Officials (AAPFCO) and The Fertilizer Institute	
	Liming application	USGS	None
Coal	Abandoned and underground mines	EPA	None
	Coal production	EIA	None
	Ventilation systems data	EPA	None
Solid Waste	Methane flared or recovered	EPA	None
	Solid waste quantity	EPA	None
Natural Gas and Oil	Pipeline data	US Department of Transportation (DOT)	None
	Natural gas production	EIA	None
Wastewater	Population	US Census	None
	Industrial wastewater treatment	EPA	None
Land Use and Forestry	Settlement soils data	AAPFCO and The Fertilizer Institute	None
	Landfilled yard trimmings and food scraps	EPA	None
	Forest carbon flux	US Forest Service (USFS)	None
	Urban tree coverage	USFS	None
	Agricultural soil carbon flux	EPA	None

Table 16. SIT data inputs and sources of data