Wisconsin Department of Natural Resources

Wisconsin Greenhouse Gas Emissions Inventory Report

Publication Date: August 2020

Publication Number: AM-580-2020

WISCONSIN
DEPT. OF NATURAL RESOURCES

Disclaimer

Table of Contents

Executive Summary

The Wisconsin Greenhouse Gas Emissions Inventory Report is an inventory of greenhouse gas (GHG) emissions in Wisconsin developed by the Wisconsin Department of Natural Resources (WDNR) Air Management Program for consideration by the Office of Sustainability and Clean Energy and the Governor's Task Force on Climate Change. Default data from the U.S. Environmental Protection Agency's (EPA's) State Inventory Tool (SIT) was used to develop this report. To compare GHG emissions across time, the report includes a GHG emission inventory for 2005 and 2017 as well as a description of the GHG emissions trend in Wisconsin from 1990 through 2017.

Table 1 summarizes Wisconsin emissions by economic sector. Some key findings of the inventory and analysis include:

- GHG emissions in the state decreased by approximately nine percent from 2005 to 2017.
- The electricity generation sector emitted the most GHGs in 2017 (33.1 percent of total emissions); the largest decrease in emissions from 2005 to 2017 (16.1 percent) also came from this sector.
- The residential, commercial, industrial, and transportation) sectors also showed modest emission decreases from 2005 to 2017.
- Emissions from industrial processes and agriculture increased from 2005 to 2017.
- Between 2005 and 2017, agriculture emissions increased by 2.3 $MtCO_2e$, the highest increase among all sectors.
- Carbon dioxide accounted for most of the GHG emissions in 2017, 81.3 percent.

Greenhouse Gases and their Sources

This report includes emissions of six major GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6). For the purposes of this report HFCs, PFCs and SF_6 are reported together as "F-gases."

Carbon dioxide (CO_2) emissions are primarily associated with the combustion of fossil fuels like coal, oil, and natural gas to produce energy. The majority of CO_2 emissions, both nationally and in Wisconsin, come from five energy-based economic sectors: electricity generation, residential, commercial, industrial, and transportation. While CH_4 and N_2O are also released in small amounts in fossil fuel combustion, they are mostly associated with the agriculture and waste sectors. F-gases are released almost exclusively by the industrial process sector. Because land-use, land-use change, and forestry (LULUCF) sectors can both store (sequester) and emit carbon, the inventory discusses carbon sequestration and GHG emissions for the LULUCF sector separately in the report.

The six GHGs quantified in this report are known to have very different global warming potentials (GWPs). GWP is a measure of how much energy the emissions from one ton of a gas will absorb in the atmosphere over a given period, relative to the emissions of one ton of CO_2. The larger the GWP, the more a given gas warms the planet compared to CO_2.[1] To account for the different GWP of GHGs, emissions are commonly expressed in units of 'CO_2 equivalent' or CO_2e. The use of these units allows

[1] See Appendix B for more details on the GWPs used in EPA's inventory tool.

direct comparisons between the climate change impacts of emissions of different gases. For the purposes of this report, all emissions are shown in million metric tons of CO_2e ($MtCO_2e$).

State Inventory Tool (SIT)

EPA's State Inventory Tool (SIT) is an interactive spreadsheet model developed to assist state agencies in estimating state GHG emission inventories. Its methods are consistent with those recommended in the 2006 Intergovernmental Panel on Climate Change guidelines for GHG emission inventories. The inventory tool gives users the option of using either state specific data or default data supplied from various federal agencies and other national sources (for years 1990-2017).[2] In this inventory, WDNR used EPA default data only.

In Executive Order #38, Governor Evers required Wisconsin to meet U.S. climate targets set in the 2015 Paris Agreement; that is, a 26-28 percent reduction in GHG emissions from 2005 values by 2025. Consistent with this requirement, this report provides detailed emissions estimates for 2005, as well as 2017.[3] In addition, the SIT was used to generate GHG emissions trends in Wisconsin from 1990 through 2017.

Wisconsin Emissions by Economic Sector

Table 1 shows the total Wisconsin emissions by sector for 2005 and 2017, as well as the percent change between the two years.[4] Figure 1 shows the percentage of total emissions attributed to each sector in 2005 and 2017. In 2017, Wisconsin's GHG emissions were an estimated 122.2 $MtCO_2e$, 1.8 percent of total U.S. emissions in 2017[5], an 8.7 percent decrease from the 2005 emissions total of 133.9 $MtCO_2e$ (Table 1).

---

[2] For additional details on EPA's inventory tool, methodology, and data sources see Appendix A.

[3] 2017 is the most recent year for which EPA default data are included in the SIT at the time of this report. EPA's inventory tool can facilitate emissions estimates for the years 1990-2030, however, state-level default data are only populated in the tool for 1990-2017. 2018 data will not be available in the SIT until late 2020.

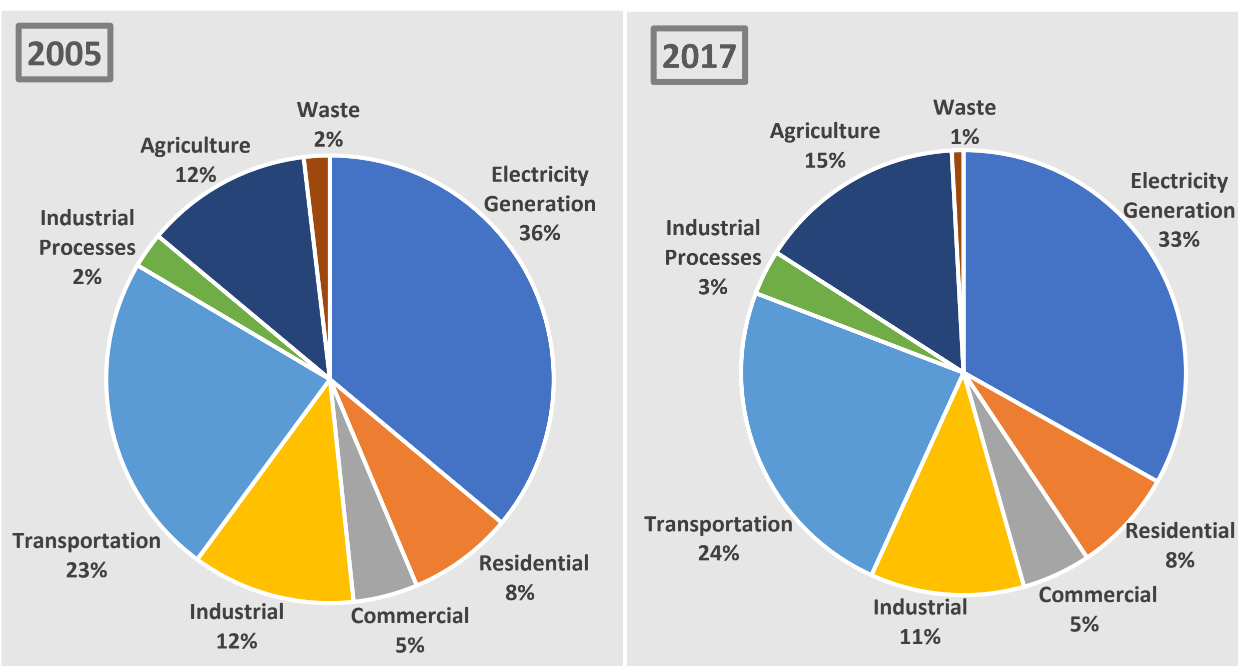
[4] Carbon sequestration in the LULUCF sector is considered in a separate section, below.

[5] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017 https://www.epa.gov/sites/production/files/2019-04/documents/us-ghg-inventory-2019-main-text.pdf

Table 1. Wisconsin Emissions by Economic Sector (MtCO2e)

	2005	**2017**	**Change**	
			Amount	**Percent**
	MtCO2e			
Energy	*111.8*	*98.8*	*-13.0*	*-11.6%*
Electricity Generation	48.3	40.5	-7.8	-16.1%
Residential	10.2	9.1	-1.1	-10.8%
Commercial	6.2	6.1	-0.1	-1.6%
Industrial	15.8	13.7	-2.1	-13.3%
Transportation	31.3	29.4	-1.9	-6.1%
Industrial Processes	3.4	4.0	+0.6	+17.6%
Agriculture	16.1	18.4	+2.3	+14.3%
Waste	2.5	1.0	-1.5	-60.0%
Total - All Sectors	**133.9**	**122.2**	**-11.6**	**-8.7%**

Figure 1. Wisconsin Emissions by Sector



The discussion below contains an overview of each sector. For additional details and a more complete discussion of EPA's inventory tool methodology see Appendix A.

Electricity Generation

Electricity generation is the largest source of GHG emissions in Wisconsin. This sector includes only direct emissions from electric generating units located within the state. Indirect emissions from electricity imports are not included in this estimate. In 2017, Wisconsin's electricity generation sector generated 33 percent of all GHG emissions in the state. Between 2005 and 2017 emissions from the electricity generation sector decreased 16.1 percent (7.8 MtCO2e) the largest decrease among sectors. In roughly the same time period, Minnesota reported 23.8 percent decrease in emissions from the electricity sector.[6] Between 2005 and 2017 Iowa's emissions from electric generation decreased by 27.7 percent.[7]

Transportation

The transportation sector is the second largest source of GHG emissions in Wisconsin, representing 24 percent of total emissions in 2017. Emissions from the transportation sector decreased approximately 1.9 $MtCO_2e$, or 6.1 percent, from 2005 through 2017. Transportation emissions include emissions from on-road gasoline and diesel vehicles, alternative fuel vehicles, and off-road vehicles. Emissions from the transportation sector will vary annually based on the age of vehicles and the vehicle miles traveled.

Residential, Commercial and Industrial

The remaining energy-based sectors (residential, commercial, and industrial) decreased their emissions by 3.3 $MtCO_2e$, or 10.2 percent, from 2005 to 2017. Emissions attributed to these economic sectors include all fossil fuel combustion not associated with electrical generation, such as space and water heating.

Agriculture

In 2017, agriculture emissions accounted for 15.1 percent of total state GHG emissions, compared to eight percent nationally.[8] Between 2005 and 2017, emissions from agricultural activities in Wisconsin increased by 2.3 $MtCO_2e$, the largest absolute increase in emissions in the Wisconsin GHG inventory. The agriculture sector includes emissions related to agricultural production. This includes methane enteric fermentation (normal microbial digestive process in livestock that produces methane) and manure, nitrous oxide from fertilizer, and carbon dioxide from agricultural soils and agricultural residue burning.

Industrial Process

Despite a 17.6 percent increase (0.6 $MtCO_2e$) in GHG emissions from 2005 to 2017, industrial process emissions were just 3.3 percent of total GHG emissions in the state in 2017. The industrial process sector is of interest because it emits all of the high GWP gases, or F-gases, and because emissions from this sector increased by the largest percentage from 2005 to 2017. Emissions from non-energy related process reactions are accounted for here, including iron and steel production, semiconductor manufacturing, limestone use, and use of refrigerants.

---

[6] https://www.pca.state.mn.us/air/greenhouse-gas-emissions-data

[7] 2005 value from 2014 Greenhouse Gas Inventory Report and 2017 value from 2017 Greenhouse Gas Inventory Report. https://www.iowadnr.gov/environmental-protection/air-quality/greenhouse-gas-emissions

[8] *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017*

Waste

The waste sector includes emissions from both solid waste and wastewater treatment. Together they contribute fewer emissions than any other sector in this analysis: only 1.9 percent of total state emissions in 2005 and 0.8 percent in 2017. Between 2005 to 2017, emissions decreased in the waste sector by 60.0 percent.

Wisconsin Emissions by Greenhouse Gas

As previously described, this inventory accounts for six different GHGs. Table 2 shows total state emissions by type of greenhouse gas for the years 2005 and 2017, as well as the percent change in emissions of each gas over that period. Figure 2 shows the percentage of total emissions attributed to the type of greenhouse gases. Figure 3 shows the sectors responsible for emissions of each greenhouse gas by percentage.

Table 2: Wisconsin Emissions by Type of Greenhouse Gas (MtCO2e)

Greenhouse gas	2005	2017	Change	
			Amount	Percent
Carbon Dioxide (CO_2)	111.5	99.4	-12.1	-10.9%
Methane (CH_4)	11.3	11.8	+0.5	+4.4%
Nitrous Oxide (N_2O)	9.0	8.2	-0.8	-8.9%
F-Gases (HFC, PFC, SF_6)	2.1	2.8	+0.7	+33.3%
Total - All Gases	**133.9**	**122.2**	**-11.7**	**-8.7%**

Carbon dioxide (CO_2) makes up the vast majority of total GHG emissions in both state and national emissions inventories. In Wisconsin, CO_2 accounted for 81.3 percent of Wisconsin's total GHG emissions in 2017. Emission reductions from CO_2 account for nearly all the GHG emission reductions achieved in Wisconsin from 2005 to 2017, decreasing by 12.1 $MtCO_2e$, or 10.9 percent.

Methane (CH_4) represents the next largest source of GHG emissions. The main sector associated with CH_4 emissions is agriculture, which experienced emissions growth during this time. Nitrous oxide (N_2O) represents a slightly smaller share of emissions than CH_4. Most of the N_2O emissions also come from the agriculture sector. Emissions of F-gases increased by 33.3 percent from 2005 through 2017. However, F-gases are a small portion of the total GHG inventory, accounting for 2.8 percent of total emissions in 2017.

Figure 2. Wisconsin Emissions by Greenhouse Gas

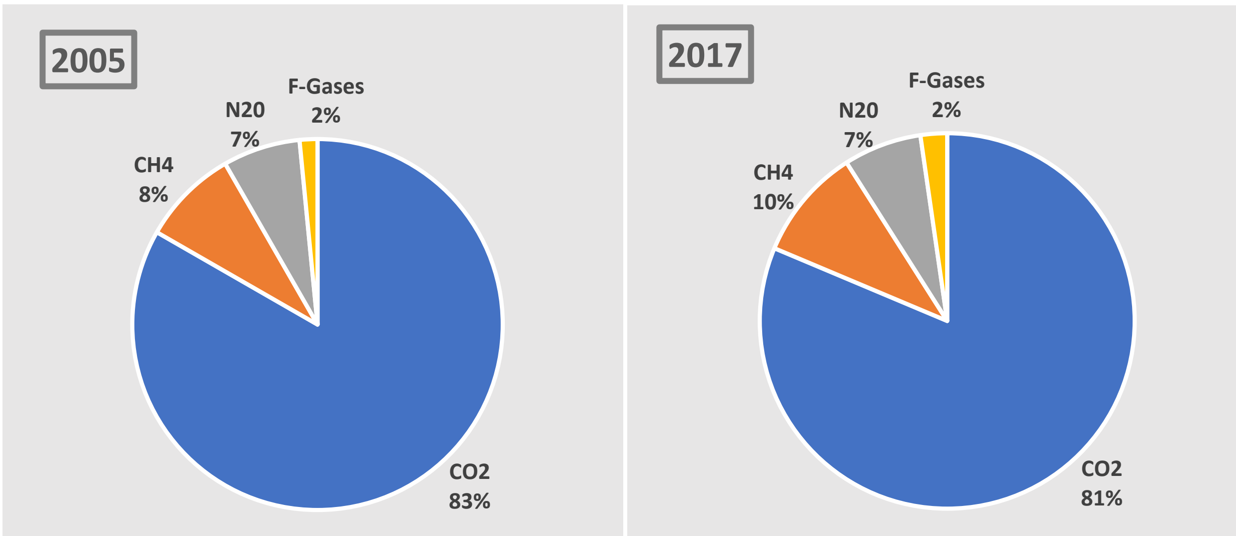
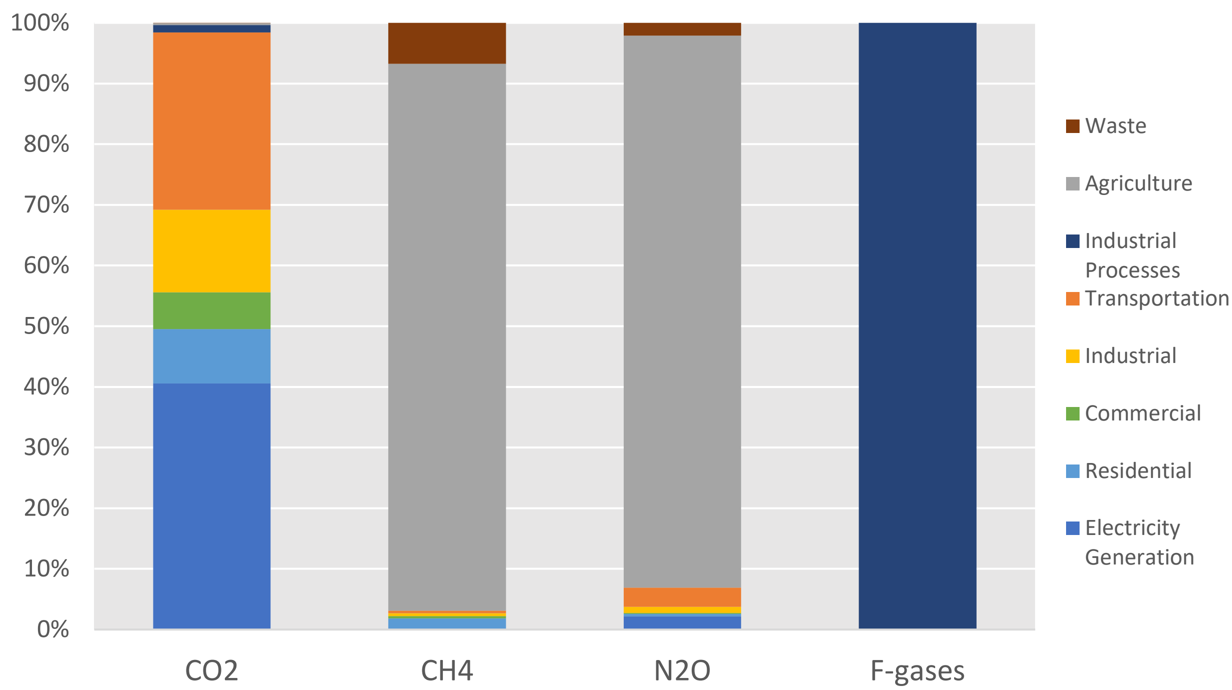


Figure 3. Wisconsin Emissions by Greenhouse Gas and Economic Sector



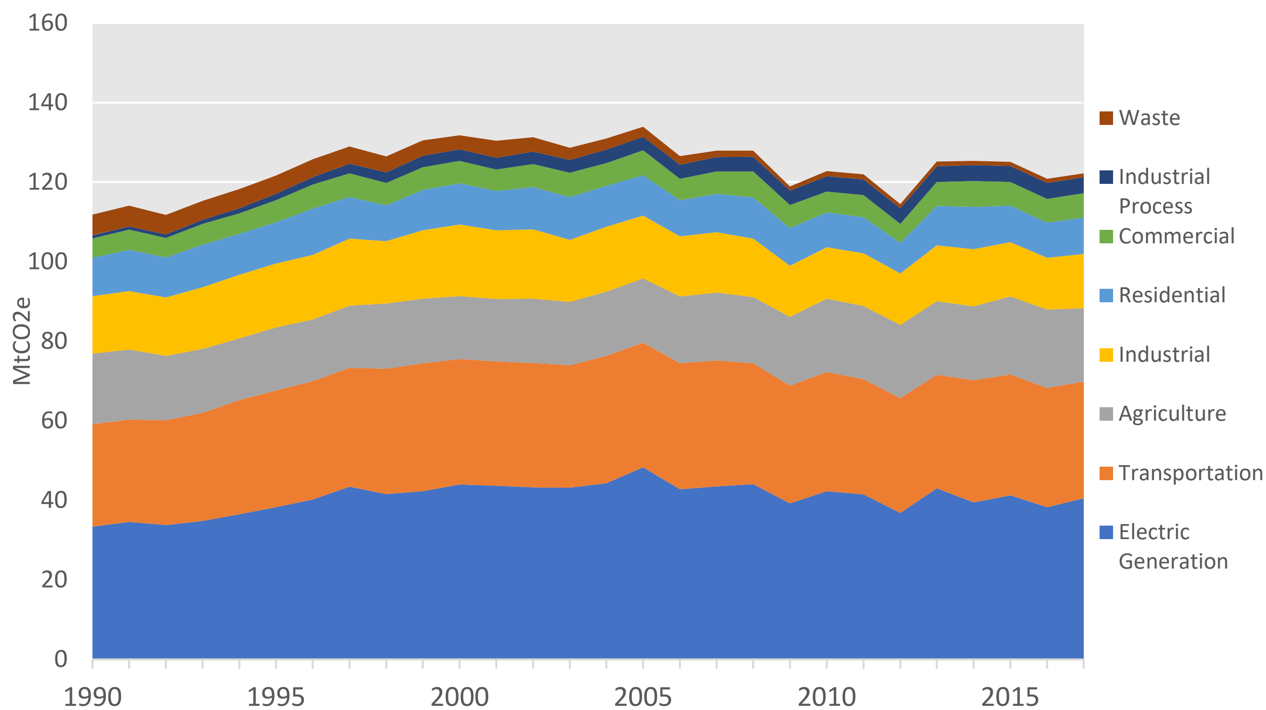
GHG Emission Trends in Wisconsin (1990-2017)

Assessing long-term trends in GHG emissions can help distinguish annual variability in emissions (due to factors like weather and economic conditions) from long-term reductions driven by technology improvements or behavioral change. Figure 4 shows emissions in $MtCO_2e$ from 1990 through 2017 by economic sector.

Between 1990 and 2005, total emissions in Wisconsin increased in all but four years. Many states, including Wisconsin, reached their GHG emissions peak in 2005. From 2006 through 2012 GHG emissions trended downward. Emissions rebounded in 2013, then decreased slightly through 2017.

Electric generation and transportation consistently contributed the most to total GHG emissions and are primarily responsible for both the increase in emissions up to 2005 and the decreases observed afterward. The agriculture sector has also consistently represented a large percentage of GHG emissions. Emissions from the two smallest sectors, waste and industrial process, appear to have changed the most over this period. In 1990, industrial process emissions accounted for only 0.7 percent of total GHG emissions. However, by 2017 emissions from this sector increased to 3.3 percent of total emissions. Waste emissions in the state decreased from about five percent of total GHG emissions in 1990 to less than one percent of total emissions in 2017.

Figure 4. Wisconsin GHG Emissions by Economic Sector 1990-2017



Land Use, Land Use Change, and Forestry

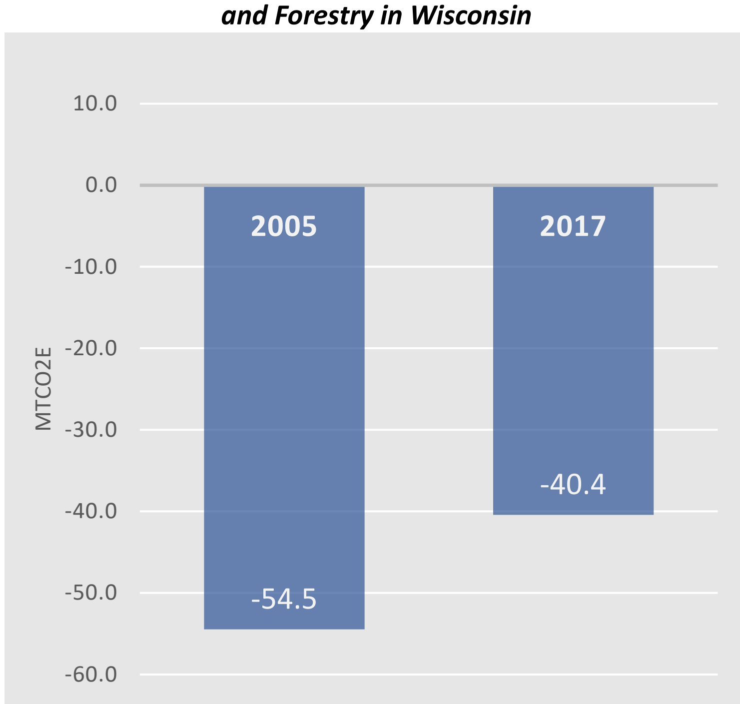
The Land Use, Land Use Change, and Forestry (LULUCF) sector is significantly different from the other economic sectors included in this report because land (soil), trees and plants both emit and store carbon. Therefore, EPA's LULUCF module estimates both direct emissions from sources and indirect impacts of storing carbon (carbon sequestration) in forests and agricultural soils. When GHG emissions exceed the sequestered GHGs, the sector is considered a 'net source' of emissions to the atmosphere. However, when the sequestered GHGs exceed the emissions, then the sector is a 'net sink.'

Land use (i.e. forestland, wetlands, croplands, grasslands, and urban development) land use change (conversion of lands between these land use types), and forestry includes the GHG impacts of both forestry and agricultural practices. This includes afforestation (planting trees where there were no trees previously), deforestation (removing forest or stands of trees), reforestation (planting trees on land that had been forested previously), forest management, and carbon stored in agricultural soils, among others.

Since at least the early 1990s, the LULUCF sector has been a 'net sink' of carbon emissions in Wisconsin. In 2005, the LULUCF sector stored approximately 54.5 $MtCO_2e$; however, that number decreased to 40.4 $MtCO_2e$ by 2017, a reduction of almost 25.9 percent (Figure 4). Many factors contribute to the change in carbon sequestration, including the conversion of cropland to urban development and the intensification of agriculture.

GHG emissions estimates for this sector have a larger level of uncertainty than estimates from other sectors due to a range of factors. Federal agencies, in collaboration with states and nonprofits, are continuing to improve the data quality and methods used in the LULUCF module.

Figure 4. Carbon Sequestration from Land-Use, Land Use Change and Forestry in Wisconsin



*Note: Values above zero on the chart above would indicate the sector was a 'source' of GHG emissions and negative values represent the sector is a 'sink' for GHG emissions.

Conclusion

This report describes Wisconsin GHG emissions over time, through both an inventory of emissions and an overview of emission trends. GHG emissions in Wisconsin peaked in 2005 at 133.9 $MtCO_2e$. Since that time, emissions have decreased by 11.7 $MtCO_2e$ to 122.2 $MtCO_2e$ in 2017. Over this same period, GHG emissions have decreased in each of the five energy-based sectors (electricity generation, residential, commercial, industrial, and transportation) and the waste sector while increasing in both the agricultural and industrial process sectors. Electricity generation, transportation, and agriculture consistently represented the largest emitting sectors. In addition, Wisconsin's LULUCF sector, largely the state's forests, are a net carbon sink in the state. However, this contribution has decreased over time due to the conversion of cropland to urban development and the intensification of agriculture. In 2005, the LULUCF sector stored approximately 54.5 $MtCO_2e$; however, that number decreased to 40.4 $MtCO_2e$ by 2017, a reduction of almost 25.9 percent.

Appendix A - State Inventory Tool Overview

State Inventory Tool

EPA's State Inventory Tool (SIT) is an inventory and analysis tool developed to assist states in compiling GHG inventories. The tool consists of 11 estimation modules and one synthesis module. The estimation modules apply a top-down approach to calculate GHG emissions from anthropogenic source sectors and use methodologies consistent with those recommended in the 2006 Intergovernmental Panel on Climate Change guidelines for greenhouse gas inventories.

Table A-1 lists the 11 modules and the pollutants covered by each module.

Table A-1. Greenhouse Gas Coverage by SIT Module

Module	Pollutant(s)
Agriculture	CO_2, CH_4, N_2O
CO_2 from Fossil Fuel	CO_2
Coal (mining)	CH_4
Electricity Consumption	CO_2
Industrial Processes	CO_2, N_2O, HFC, PFC, SF_6
Land-Use, Land-Use Change and Forestry	CO_2, N_2O
Mobile Combustion	CH_4, N_2O
Natural Gas and Oil	CH_4
Solid Waste	CO_2, CH_4, N_2O
Stationary Combustion	CH_4, N_2O
Wastewater	CH_4, N_2O

Data Sources

Each SIT module is populated with either state specific data or state-level default data that states can use to calculate emissions. The default data in the tool comes from a variety of sources, primarily from EPA and other federal agencies (see Table A-2). The SIT allows states to replace default data included in the tool with data from other state-specific sources that may be more representative of actual emissions in the state.

Each module in the tool requires hundreds of inputs. EPA provides several resources to help users identify the data sources EPA used in the tool. Some data citations are imbedded in the modules themselves and can be accessed using the notes function in the Microsoft Excel tool. Additionally, EPA provides a user guide to accompany each module, which includes details about the methodology used for each module. For the most detailed information, EPA recommends referring to the methodology section in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* report published each year.[9]

[9] The 2017 *Inventory of U.S. Greenhouse Gas Emissions and Sinks* report can be accessed here: https://www.epa.gov/sites/production/files/2019-04/documents/us-ghg-inventory-2019-main-text.pdf

Table A-2. Default Data Sources by Module

Module	Data Source(s)
Agriculture	U.S. Department of Agriculture (USDA) U.S. Geological Survey (USGS)
CO from Fossil Fuel	U.S. Energy Information Administration (EIA)
Coal (mining)	EIA, U.S. Environmental Protection Agency (EPA)
Electricity Consumption	EIA
Industrial Processes	EPA, USGS
Land-Use, Land-Use Change, and Forestry	USDA, U.S. Forest Service (USFS)
Mobile Combustion	EIA, EPA, Federal Highway Administration (FHWA)
Natural Gas and Oil	EIA
Solid Waste	EPA
Stationary Combustion	EIA, EPA
Wastewater	EPA

Methodology

For the purpose of this inventory, WDNR did not incorporate any state-supplied data. Instead, the tool was run exclusively using the SIT's default data. First, the default data for Wisconsin were selected in each module of the tool. The tool then applied that data to the EPA-supplied emission coefficients to produce results. In a post-processing exercise conducted outside of the tool, WDNR then attributed these results to eight commonly referenced economic sectors: agriculture, electricity generation, residential, commercial, industrial, transportation, industrial process, and waste.[10] Table A-3 gives a summary of how emissions produced by the SIT modules were attributed to the economic sectors. The results were quality assured to avoid both double-counting and the inadvertent omission of data.

[10] WDNR did not utilize EPA's synthesis module to compile the results as it did not align with the economic sectors selected for the report.

Table A-3. Attribution of SIT Results

Economic Sector	Description of Results
Electricity Generation Residential Commercial Industrial	Emissions for each of these energy-based sectors were calculated by adding the portion of the *CO_2 from Fossil Fuel Combustion* module attributable to each sector to the CH_4 and N_2O emissions from the *Stationary Combustion* module for each sector.
Transportation	Transportation emissions were calculated by adding the transportation results from the *CO_2 from Fossil Fuel Combustion* module and the CH_4 and N_2O emissions from the *Mobile Combustion* module.
Industrial Process	The industrial process sector corresponds directly to the *Industrial Process* module in the SIT.
Agriculture	The agriculture sector corresponds directly to the *Agriculture* module in the SIT.
Waste	Emissions in the waste sector include the CO_2, CH_4 and N_2O emissions from the *Solid Waste* module and CH_4 and N_2O emissions from the *Wastewater* module.

The LULUCF module is comprised of six sections: forest carbon flux; urban trees; N_2O from settlement soils; non-CO_2 emissions from forest fires; net carbon flux of landfilled yard trimmings and food scraps; and agricultural soil carbon flux. As discussed in the report, the LULUCF sector is unique in that it can act as either a net source or a net sink of GHG emissions. There are also significant data uncertainties associated with this sector, which makes it difficult to identify trends over time. Because of these differences, the results from this sector are provided separately in the inventory.

Data Uncertainties

The SIT modules use EPA-supplied default data and emission factors to calculate total sector emissions because direct measurements are not available for most sectors. It is important to recognize that, while using activity data and emission factors is the most accurate way to estimate state-level GHG emissions, this practice also creates significant uncertainties across sectors. In addition, default data from federal agencies can often become less precise when applied to a specific state, particularly in non-energy sectors.

The user guides for each module contain a more complete discussion of data uncertainties produced by the SIT.[11] Additional discussion of the data uncertainties that arise from the estimation methods used in the module can be found in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* report.[12]

[11] https://www.epa.gov/statelocalenergy/download-state-inventory-and-projection-tool

[12] *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017*

Data Omissions

As previously discussed in this report, WDNR relied solely on EPA default data for inventory calculations. The following two modules in EPA's inventory tool did not include default data for Wisconsin; therefore, no emissions from these sectors are represented in the inventory:

- *Coal (mining) module.* Wisconsin does not have any active or retired coal mines; therefore, no default data were included in the SIT module for the state, and no emissions from this module or sector are included in this inventory.
- *Natural Gas and Oil module.* Wisconsin contains some sources of oil and natural gas processing emissions, such as natural gas pipelines. However, no default data were included in the SIT module for the state for this module and no emissions from this module are included in this inventory.

In addition to the sector emissions described above, some sub-sectors within certain modules also have missing or unreported data (meaning no 'default' value was provided). Where sub-sector data were not available, calculations were performed without these sub-sector data and the inventory may underestimate total emissions in these areas. Some examples of sub-sector data that were not included in the inventory due to lack of default data are forest fire emissions (in the land-use module) and industrial process emissions from cement manufacturing.

Appendix B - Global Warming Potential (GWP)

The GHGs included in this inventory each have a unique GWP. GWP is a measure of how much energy the emissions from one ton of a gas will absorb in the atmosphere over a given period of time, relative to the emissions of one ton of CO_2.[13] In this report, GWP-weighted emissions are reported in million metric tons of CO_2 equivalent ($MtCO_2e$). The use of these units allows direct comparison between the climate change impacts of emissions of different gases. Table B-1 lists the GWPs used in the EPA inventory tool.

Table B-1. Global Warming Potentials (100-Year Time Horizon) Used in EPA's State Inventory Tool [14]

Greenhouse Gas	Global Warming Potential (GWP)
CO_2	1
CH_4[a]	25
N_2O	298
HFC-23	14,800
HFC-32	675
HFC-125	3,500
HFC-134a	1,430
HFC-143a	4,470
HFC-152a	124
HFC-227ea	3,220
HFC-236fa	9,810
HFC-4310mee	1,640
CF_4	7,390
C_2F_6	12,200
C_4F_{10}	8,860
C_6F_{14}	9,300
SF_6	22,800
NF_3	17,200

[a] *The GWP of the CH_4 includes the direct effects of those indirect effects due to production of tropospheric ozone and stratospheric water vapor. The indirect effect due to production of CO_2 is not included.*

[13] GWP is defined by the Intergovernmental Panel on Climate Change as the ratio of the accumulated radiative forcing within a specific time horizon caused by emitting one kilogram of the gas, relative to that of the reference gas CO_2.

[14] IPCC Fourth Assessment Report (AR4) (IPCC 2007).