Wisconsin Greenhouse Gas Emissions Inventory and Projections

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Table of Contents

Overview

This report, produced by the World Resources Institute, provides a summary of greenhouse gas (GHG) emissions in the State of Wisconsin for consideration by the Wisconsin Governor's Task Force on Global Warming. Unless otherwise noted, all data used in this report come from the U.S. module of the Climate Analysis Indicators Tool (CAIT-US) from the World Resources Institute (see Appendix A). The report includes a GHG inventory for Wisconsin for the year 2003, an analysis of GHGs by gas and by sector, historical emissions data for 1990 to 2003, baseline emissions projections to 2020, and general discussion.

Greenhouse Gases and their Sources

Emissions of six major GHGs are included in this report: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and the "F-gases"—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexalfuoride (SF_6). Total emissions of these gases are attributed to nine economic sectors, highlighted in **bold** throughout the following section. The sectors and conventions described below are utilized throughout this report. For additional information regarding sector definitions and the CAIT data set, please see Appendix A.

Anthropogenic CO_2 emissions come principally from the combustion of fossil fuels (coal, oil, and natural gas) to produce energy. Activities such as **electricity generation**, road, rail, and air **transportation**, fuel consumption in the manufacturing of chemicals and other **industrial** products, and the heating of **residential** and **commercial** buildings[1] together account for the overwhelming majority—typically greater than 95 percent—of CO_2 emissions in U.S. states.

Methane (CH_4) and nitrous oxide (N_2O) are also produced during fuel burning, but both gases are more readily associated with **agriculture** practices. Methane is produced by the digestive processes of ruminant livestock and N_2O results from the working of agricultural soils and from the application of commercial nitrogen fertilizers. Methane is also a byproduct of human **waste—**landfill off-gassing and wastewater. Additional sources of methane include rice cultivation and **fugitive emissions** (a subset of energy emissions) that are produced during the mining of coal and the processing and refining of oil and natural gas. Neither of these sources, however, is relevant to Wisconsin, and therefore they do not appear in the inventory analysis that follows.

Finally, "F-gas" emissions, as well as additional CO_2 emissions, are produced mainly by **industrial processes**. This sector includes emissions from the production processes of raw materials, as opposed to the emissions from the fuels consumed to produce them. For instance, CO_2 is regularly produced in chemical manufacturing and is also a byproduct of the conversion

[1] In the discussions that follow, only emissions that result from the direct combustion of fossil fuels are reported for the commercial, industrial, and residential sectors. They do *not* include emissions from electricity use in these sectors (unless it is generated on-site); electricity use by these sectors, and its associated emissions, are included in the electric utilities sector. Hence, sectoral emissions estimates that included electricity generation in these sectors would likely result in higher estimates than those reported here.

of calcium carbonate into lime to make cement.

Emissions estimates for two sectors are *not* included in this inventory. Emissions from land use, land use change, and forestry (LULUCF) and emissions from international bunkers (activities that take place outside of national boundaries, such as emissions from ships in international waters) are excluded due to data uncertainties and difficulties in the assignment of emissions to individual states (see Appendix A). However, a presentation of current data for Wisconsin's LULUCF sector is available following the inventory section of this report.

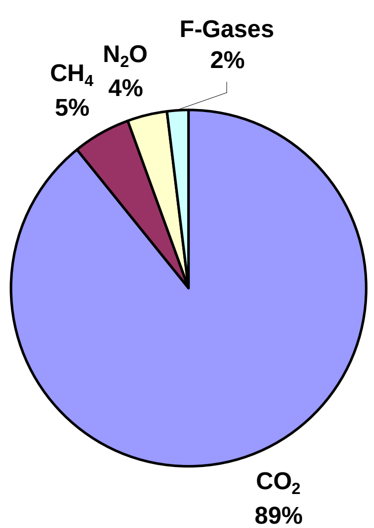
It is clear that GHGs have myriad sources; they also have different *global warming potentials* (GWPs). In order to quantify the varying capacities which GHGs have to convert solar radiation into heat energy during their atmospheric "lifetimes" (i.e., the extent to which a GHG contributes to global warming), GHGs are assigned a GWP index value. CO_2, by definition, has a GWP of 1. CH_4 has an index value of 21, or a global warming potential that is 21 times that of CO_2, and N_2O has a GWP of 310 (assuming 100-year time horizons). The HFCs and PFCs have GWPs ranging from 140 to 11,700, and the GWP for SF_6 is 23,900 (IPCC, 1996). These "high GWP" gases are emitted in much smaller quantities than other GHGs, so their impact, while still significant relative to the absolute quantity emitted, is comparatively less.

To account for the different GWP of greenhouse gases, emissions of non-CO_2 gases (i.e., CH_4, N_2O, "F-gases") are commonly expressed in terms of "*CO_2 equivalents*," or CO_2e. In this report, all data are presented in million metric tons (tonnes) of CO_2 equivalents ($MtCO_2e$). One metric ton is equal to 1.1 short tons (U.S. tons) or approximately 2,205 pounds.

Greenhouse Gas Emissions in the United States

Figure 1a and 1b present a breakdown of U.S. emissions by gas and by economic sector, respectively. These charts are based on national estimates from the CAIT-US module and may disagree with estimates in the *EPA National Inventory* (see Appendix A). According to CAIT estimates, total GHG emissions in the U.S. in 2003 were approximately 6,737 $MtCO_2e$.

A. 2003 U.S. GHG Emissions by Gas



B. 2003 U.S. GHG Emissions by Sector

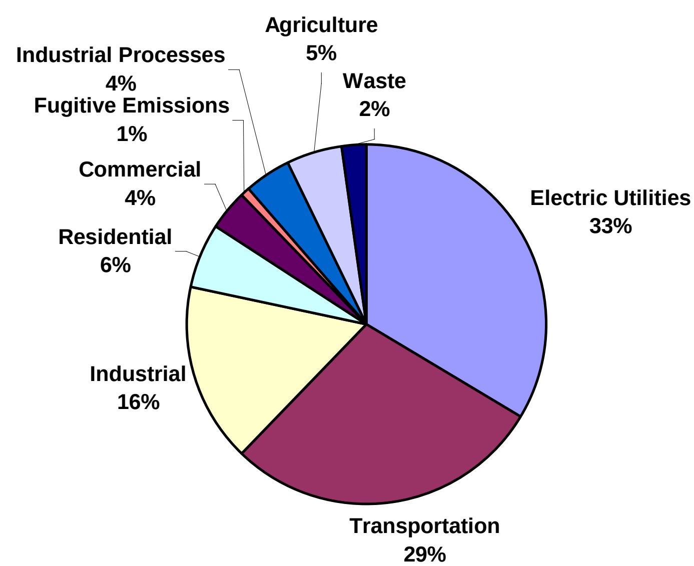


Figure 1. Source: CAIT-US, WRI (2007).

Greenhouse Gas Emissions in Wisconsin

In 2003, the most recent year for which data are available, Wisconsin produced an estimated 123 million metric tons of GHGs on a CO_2 equivalent basis ($MtCO_2e$), making it the 21st largest emitter compared to other states, slightly behind Oklahoma and ahead of Minnesota (table 1). Wisconsin generated approximately 2 percent of total U.S. emissions in 2003, relatively less than most other Midwest states (shown in bold in Table 1). Globally, Wisconsin ranks as the 42nd largest emitter in the world, just behind Romania.

Per capita emissions in Wisconsin were approximately 23 metric tons CO_2e per person in 2003. This figure is equal to the national average.

Table 2 shows a breakout of 2003 emissions by sector and gas, as further illustrated in Figure 2.

Table 1. State GHG Emissions in 2003

Rank	State	$MtCO_2e$	% of US
1	Texas	782.3	11.6%
2	California	452.9	6.7%
3	Pennsylvania	301.0	4.5%
4	**Ohio**	**298.9**	**4.4%**
5	Florida	271.3	4.0%
6	**Indiana**	**269.3**	**4.0%**
7	**Illinois**	**268.5**	**4.0%**
8	New York	243.7	3.6%
9	**Michigan**	**211.7**	**3.1%**
10	Louisiana	209.5	3.1%
20	Oklahoma	123.9	1.8%
21	**Wisconsin**	**123.1**	**1.8%**
22	**Minnesota**	**120.0**	**1.8%**
23	**Iowa**	**108.2**	**1.6%**
24	Colorado	106.7	1.6%
25	Kansas	100.7	1.5%

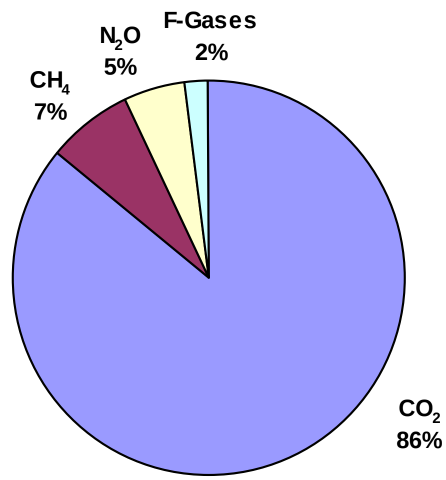
Table 2. Wisconsin 2003 Emissions by Sector and Gas ($MtCO_2e$)

Sector	Greenhouse Gas				
	CO_2	CH_4	N_2O	F-Gases	Total
Energy	*104.3*	*0.2*	*1.1*		*105.6*
Electricity Generation	42.9	< 0.1	0.2		43.1
Residential	10.5	0.1	< 0.1		10.6
Commercial	6.1	< 0.1	< 0.1		6.1
Industrial	15.8	0.1	0.1		15.9
Transport	29.1	< 0.1	0.8		29.9
Fugitive Emissions	--	--	--	--	--
Industrial Processes	1.2			2.2	3.5
Agriculture		6.1	4.8		10.9
Waste		2.8	0.3		3.1
Total	**105.5**	**9.1**	**6.3**	**2.2**	**123.1**

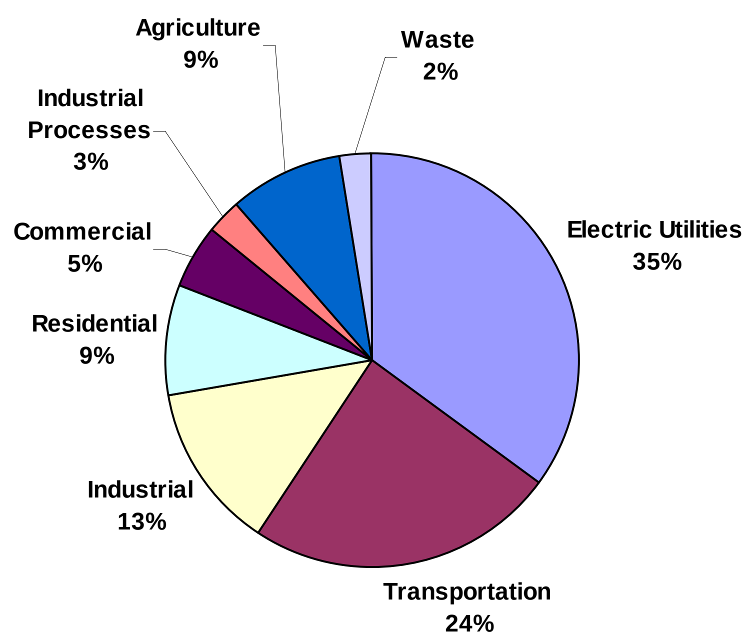
Note: Columns and rows in table 2 may not sum exactly due to rounding.

Figure 2. Wisconsin Emissions by Gas and Sector

Wisconsin Emissions by Gas (2003)	**$MtCO_2e$**	**%**
CO_2	105.5	86%
CH_4	9.1	7%
N_2O	6.3	5%
High-GWP Gases (HFCs, PFCs, SF_6)	2.2	2%
Total – All Gases	**123.1**	



Wisconsin Emissions by Sector (2003)	**$MtCO_2e$**	**%**
Energy	*105.6*	*86%*
Electricity Generation	43.1	35%
Residential	10.6	9%
Commercial	6.1	5%
Industrial	15.9	13%
Transportation	29.9	24%
Fugitive Emissions	--	--
Industrial Processes	3.5	3%
Agriculture	10.9	9%
Waste	3.1	2%
Total – All Sectors	**123.1**	



Emissions by Gas and Economic Sector[2]

In Wisconsin, as in all other states, carbon dioxide (CO_2), the principal greenhouse gas produced by energy-related activities, comprises the largest share of GHG emissions. According to 2003 estimates, Wisconsin's CO_2 emissions were approximately 106 $MtCO_2e$ or 86 percent of total emissions, about 3 percent below the national average.

Conversely, Wisconsin's shares of CH_4 and N_2O emissions represented slightly greater proportions of overall emissions compared to the U.S. as a whole. This is due to the state's relatively large agricultural sector—the principal source of CH_4 and N_2O gases—which accounted for 9 percent of Wisconsin's total emissions, nearly double the sectoral contribution percentage at the national level. Total CH_4 and N_2O emissions in 2003 were approximately 15 $MtCO_2e$ combined, comprising 12 percent of the state total. Emissions from agriculture accounted for approximately 70 percent of total CH_4 and N_2O emissions.

F-gases play a smaller role, constituting about 2 percent of Wisconsin emissions, comparable to the national average.

The largest emitting sectors in Wisconsin are electric utilities (35 percent), transportation (24 percent), industrial energy use (13 percent), and agriculture (9 percent). Together, these four sectors account for more than 80 percent of total state emissions. GHG emissions from electricity generation and transportation alone account for nearly 60 percent of state emissions. A brief summary of Wisconsin's electricity generation fuel mix is provided in box 1.

Wisconsin's sectoral emissions profile is, overall, comparable to that of the U.S. Most notably, emissions from agriculture (as noted above) constitute a higher proportion of total emissions at the state level, as do emissions from the heating of residential and commercial properties.

Box 1: Wisconsin Electricity Generation

Emissions in the electricity generation sector come from the fuels used to produce electricity, which is then distributed to other sectors: residential, commercial and industrial (see footnote 1). In 2003, in-state electricity generation was just over 60,000 megawatt hours (MWh). Approximately 70 percent of this total was produced from coal. Nuclear power accounted for 20 percent of total generation, and hydroelectric and renewable resources totaled 5 percent (figure 3). Although Wisconsin's proportion of nuclear generation is comparable to the national average for 2003, coal comprises nearly 20 percent more of Wisconsin's fuel mix than it does for the U.S. as a whole.

Wisconsin Electricity Production by Fuel, 2003

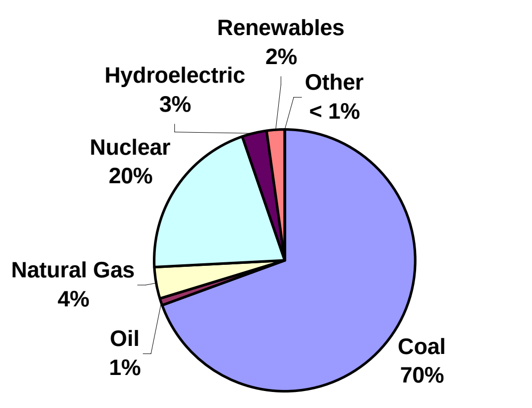


Figure 3. Source: CAIT-US, WRI (2007) from EIA.

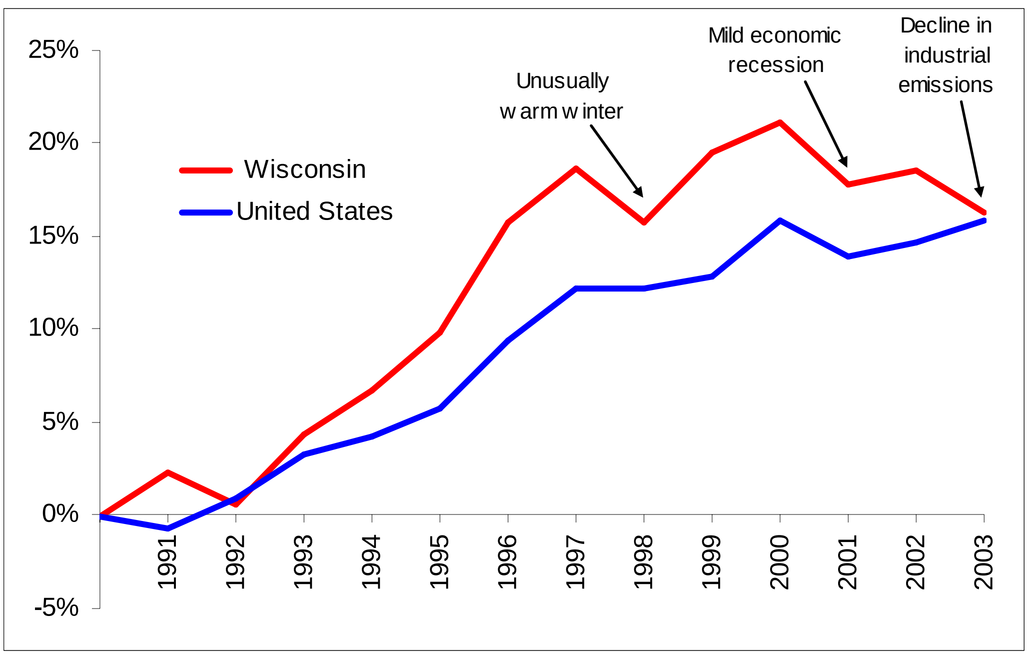
[2] For a comprehensive description of emissions sectors with specific application to the state of Wisconsin, see *Wisconsin's Greenhouse Gas Emissions: Trends from 1990 to 2000,* Wisconsin Department of Natural Resources, February 2004.

Greenhouse Gas Emissions Trends in Wisconsin

Total emissions in Wisconsin increased between 1990 and 2003, as they did in all other states. In Wisconsin's case, GHG emissions growth generally outpaced national growth through 2000 (figure 4), but annual emissions declined in 1998, 2001, and again in 2003 such that the increase from 1990 to 2003 in Wisconsin (16.3 percent) was comparable to the national increase (15.8 percent).

Among the periods of declining emissions, the decrease observed in 1998 coincided with an abnormally warm winter in Wisconsin that reduced heating demands and contributed to declines in emissions from electric generation, and energy use in the industrial, residential, and commercial sectors. The next observed decline, in 2001, was related to a nation-wide mild economic recession. Both U.S. and Wisconsin GHG emissions decreased as a result of lower economic output. A decline in Wisconsin's emissions in 2003, however, did not correspond to a national trend. Instead, it was an approximately 10 percent (2 $MtCO_2e$) reduction in emissions from Wisconsin's industrial sector that drove the decrease in 2003.

Figure 4: Change in total GHG emissions relative to 1990



Indeed, a comparison of growth trends at the sector level reveals some important differences between emissions growth in Wisconsin and the U.S. as a whole. Table 3 presents emission trends in Wisconsin and the U.S., and figure 5 presents the annual trends in Wisconsin emissions by sector between 1990 and 2003. Emissions growth in most sectors is comparable to average national growth, though Wisconsin's electricity generation, commercial, and industrial process emissions increased faster than the national rate.

Table 3. Emissions Growth in Wisconsin vs. U.S.				
Wisconsin	**1990**	**2003**	**Growth**	**Annual Rate**
Total ($MtCO_2e$)	**105.9**	**123.1**	**16.3%**	**1.2%**
Electric Generation	33.4	43.1	29.3%	2.0%
Transportation	25.1	29.9	18.9%	1.3%
Industrial	14.7	15.9	8.8%	0.7%
Residential	9.5	10.6	11.5%	0.8%
Commercial	4.9	6.1	25.3%	1.8%
Fugitive Emissions	--	--	--	--
Agriculture	12.8	10.9	-14.4%	-1.2%
Industrial Processes*	2.5	3.5	36.7%	5.3%
Waste	4.7	3.1	-34.4%	-3.2%
U.S.	**1990**	**2003**	**Growth**	**Annual Rate**
Total ($MtCO_2e$)	**5817.5**	**6737.2**	**15.8%**	**1.1%**
Electric Generation	1815.4	2257.0	24.3%	1.7%
Transportation	1630.3	1941.1	19.1%	1.4%
Industrial	1111.6	1082.5	-2.6%	-0.2%
Residential	346.9	389.1	12.2%	0.9%
Commercial	226.0	241.3	6.8%	0.5%
Fugitive Emissions	81.9	53.1	-35.2%	-3.3%
Agriculture	350.1	351.0	0.3%	0.0%
Industrial Processes*	259.3	278.8	7.5%	1.2%
Waste	157.4	143.3	-9.0%	-0.7%

Source: WRI, CAIT-US (2007).

* Emissions growth figures for industrial processes are relative to 1997 emissions values (not 1990) due to differences in data availability for industrial processes emissions for 1990-1996 and 1997-2003.

By 2003, Wisconsin's GHG emissions from electric generation had increased 29 percent compared to 1990 levels, higher than the national increase of 24 percent during this period. This difference is intriguing considering that neither Wisconsin's population nor economy—the two key macroeconomic drivers of emissions growth—increased faster than the U.S. as a whole during this time period (according to available data). However, the proportion of Wisconsin electricity generated from nuclear power—a source with no direct GHG emissions—has decreased since 1990 at the expense of fossil fuels such as natural gas. At the national level, the proportion of U.S. electricity generated from coal, a more GHG-intensive fuel source than alternatives such as natural gas, declined slightly from 53 percent in 1990 to just less than 51 percent in 2003. These counter-trends in fuel mix could at least partially explain the observed differences in magnitude between U.S. and Wisconsin electric utilities emissions trends.

The explanatory factor for Wisconsin's overall growth in emissions from electricity generation is an increase of 26 percent in total generation during this time period. Thus, while the fuel mix in this sector stayed relatively static (e.g., coal's share of total electricity generation in Wisconsin remained at approximately 70 percent from 1990 to 2003), an increase in generation resulted in a proportional increase in GHG emissions.

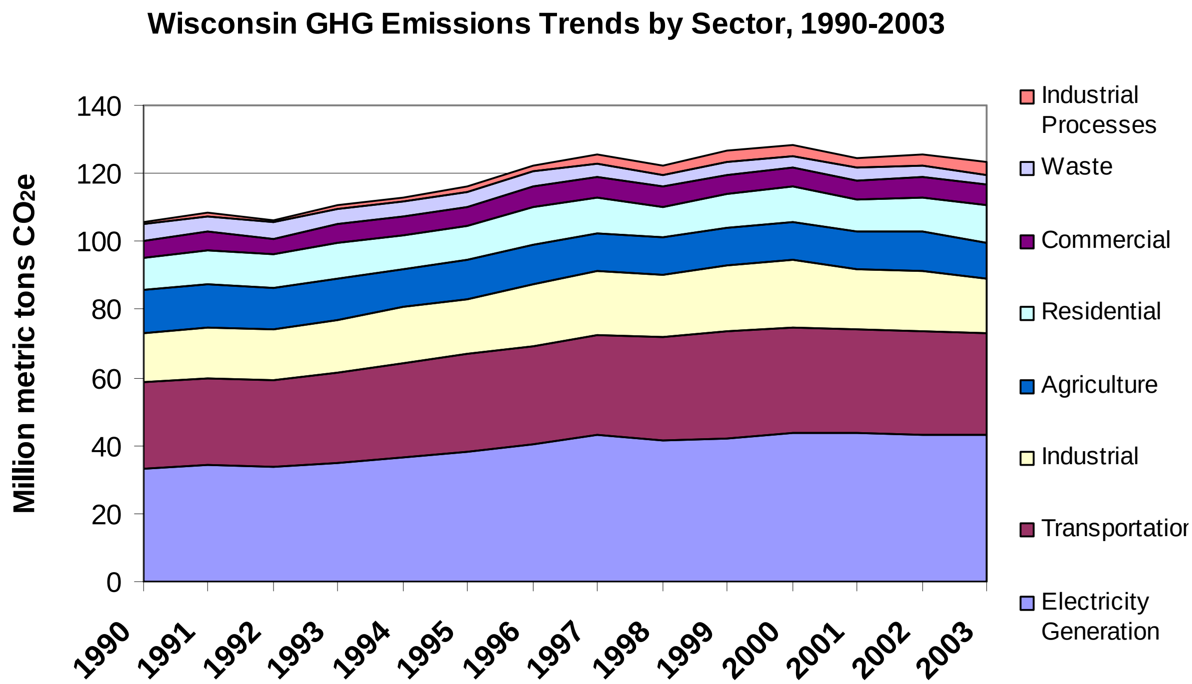


Figure 5. Source: CAIT-US, WRI (2007). **Note:** Due to differences in the availability of industrial processes emissions data prior to 1997, an artificial increase in emissions from this sector appears between 1996 and 1997.

Emissions growth in Wisconsin's transportation sector has reflected the national trend, increasing approximately 19 percent from 1990 levels. Vehicle miles traveled have steadily increased during this time, rising 35 percent since 1990, equal to the national average. This trend has resulted in higher gasoline consumption and associated GHG emissions. As of 2003, Wisconsin ranked 33rd, nationally, in terms of annual gasoline consumption per capita at 468 gallons per person. Additionally, Wisconsin ranked 7th among U.S. states in both total ethanol consumed and ethanol consumption per capita (CAIT-US, 2007 from EIA).

Industrial sector emissions in Wisconsin increased nearly nine percent from 1990 to 2003, in stark contrast to a decline nationally of more than two percent and an average decline in the Midwest region of around 11 percent. Through 2000, in fact, Wisconsin's industrial emissions had increased more than 35 percent compared to 1990. By 2003, however, industrial emissions had declined more than 20 percent from their peak in 2000. Recent data show that Wisconsin's industrial sector energy consumption has declined approximately 10 percent since 1997 (EIA, 2007). At the same time, state gross domestic product (GDP) from manufacturing has increased 13 percent (Bureau of Economic Analysis, 2007). It is likely then that sectoral gains in energy efficiency and fuel switching to less GHG-intensive fuels like natural gas and biofuels are principally responsible for declining emissions in the industrial sector.

While industrial emissions declined from 2000 levels, residential and commercial sector emissions continued to grow during this period, 4 and 7 percent respectively. Overall, since 1990, Wisconsin's residential emissions increased nearly 12 percent, comparable to the increase nationally. Emissions from Wisconsin's commercial sector, meanwhile, increased 25 percent since 1990, over three times the national percentage increase in commercial sector emissions of 7 percent. This trend mirrors a 31 percent increase in natural gas consumption experienced in this sector between 1990 and 2003, a period in which coal use remained steady at very low levels and fuel oil use declined substantially. It is unclear without additional data, however, what the main socio-economic drivers are of the increase in emissions from commercial energy use.

Though Wisconsin's agriculture sector emissions have declined 14 percent relative to 1990 (equal to approximately 1.8 $MtCO_2e$), the sector still plays an important role in the state's overall GHG inventory, responsible for approximately 9 percent of total emissions (for comparison, agriculture sector emissions for the U.S. are only 5 percent of the national total). It is also important to note that much of Wisconsin's agriculture emissions are in the form of CH_4 from animal digestive processes associated with the state's dairy industry, unlike emissions from agriculture in other Midwest states, which are dominated by N_2O from corn production and crop/soil management. Indeed, CH_4 has increased in importance in this sector between 1990 and 2003 due to the fact that approximately 1.3 $MtCO_2e$ of overall reductions in Wisconsin's agricultural emissions are attributable to declines in N_2O, principally from improvements in manure management, while the remainder (approximately 0.5 $MtCO_2e$) came from reductions in CH_4. It is important to note, however, that although Wisconsin has experienced recent declines in emissions from the agriculture sector, emissions from this sector are typically highly variable from year-to-year depending on crop planting, weather and the amount of total acreage under cultivation. This trend could easily reverse if there are significant changes in production variables.

Emissions from industrial processes and waste each constitute less than 3 percent of Wisconsin's overall GHG inventory, but changes since 1990 are reflective of broader trends. Industrial processes emissions have increased more than 36 percent since 1990, due largely to the rapid expansion of F-gas emissions as industry transitioned to substitutes for ozone-depleting substances. Waste emissions, meanwhile, declined more than 34 percent during this period, nearly four times the national decline in waste emissions from 1990 to 2003. In general, the decline in waste emissions can be attributed to more recovery and flaring of methane from landfills. Population growth in Wisconsin was slower than the national rate, which explains why the population-based estimates for GHG emissions from waste would have declined faster than the national rate (see Appendix A).

Land Use, Land Use Change, and Forestry

Emissions from the land use, land use change, and forestry (LULUCF) sector account for changes in GHG levels due to afforestation, deforestation, reforestation, forest management and similar activities. As forests are cleared or burned, carbon is released into the atmosphere. Carbon can also be sequestered through forest growth—a carbon "sink." Net emissions from this sector may constitute a source of GHGs if released carbon exceeds sequestered carbon, or a "sink," if sequestered carbon exceeds released carbon.

Included in the totals presented below are estimates of forest carbon flux (supplied by the USDA Forest Service and their Carbon Calculation Tool), carbon from liming of agricultural soils, carbon storage from urban trees, N_2O from settlement soils, and carbon storage in landfilled yard trimmings and food scraps. Emissions from forest fires are not included. The underlying nationally-derived data for this sector, however, are difficult to tabulate, assess and assign to individual states, creating *substantial ambiguities and uncertainties* regarding both absolute emissions values and emissions trends in this sector.

For example, in 2003, the United States LULUCF sector sequestered an estimated 812 $MtCO_2e$, according to the latest edition of the *The U.S. Inventory of Greenhouse Gas Emissions and Sinks* (USEPA, 2007). The latest figure incorporated into CAIT-US (v.2.0) estimates the total national sink to be 867 $MtCO_2e$, a difference of 55 $MtCO_2e$. Mindful of the inherent uncertainties in these data, a brief analysis the LULUCF sector for Wisconsin follows. More information is available in the description of WRI's CAIT tool in Appendix A.

Wisconsin's LULUCF Sector

In 2003, approximately 5 $MtCO_2e$ was sequestered by Wisconsin LULUCF. Since 1990, however, Wisconsin's net "sink" has declined by approximately 23 $MtCO_2e$ or almost 85 percent (figure 6). According to the data, this has largely been due to changes in soil organic carbon—a measure of the amount of organic matter in soils. Over this time period, soil has become a net source of CO_2. In the early 1990s, soil was still serving as a net "sink." Within the Midwest, similar trends can be observed in Illinois, Ohio, and Michigan. Nationally, however, the carbon "sink" has increased since 1990.

Some drivers of the reduction in CO_2 sequestration from LULUCF include urbanization and the intensification of agriculture, which release carbon from forest stocks and soil and prevent large forest tracts from re-growing, and the increased production of paper and paper products.

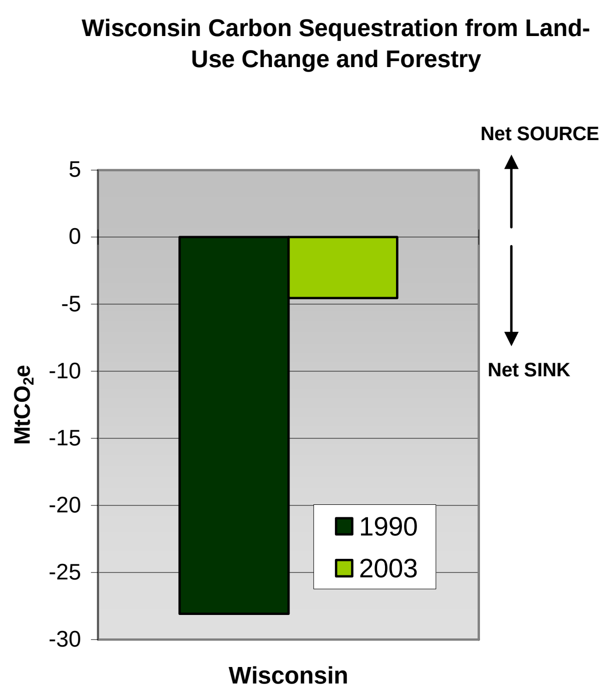


Figure 6. Source: CAIT-US, WRI (2007).

Projections of Wisconsin GHG Emissions through 2020

The previous sections of this document present and analyze historic GHG activity in Wisconsin. For a more complete understanding of state GHG emissions looking forward, it is useful to examine possible future scenarios. Although such an exercise is informative, it should be noted that emissions projections are not 100 percent certain snapshots of the future but possible outcomes of current and future activity. With this in mind, a range of possible future emissions cases were developed for this analysis. These cases are "low," "business as usual," and "high." Table 4 presents key emissions data for each case using 1990 emissions as a reference year.

Table 4. WI GHG emissions in 2020 under three projection cases and a comparison with 1990 emissions levels

Projection Case	Total GHG Emissions 2020 ($MtCO_2e$)	Total Increase from 1990 ($MtCO_2e$)	Percentage Increase from 1990
Low	133.6	27.8	26.2%
Business as Usual (BAU)	149.1	43.2	40.8%
High	170.3	64.4	60.8%

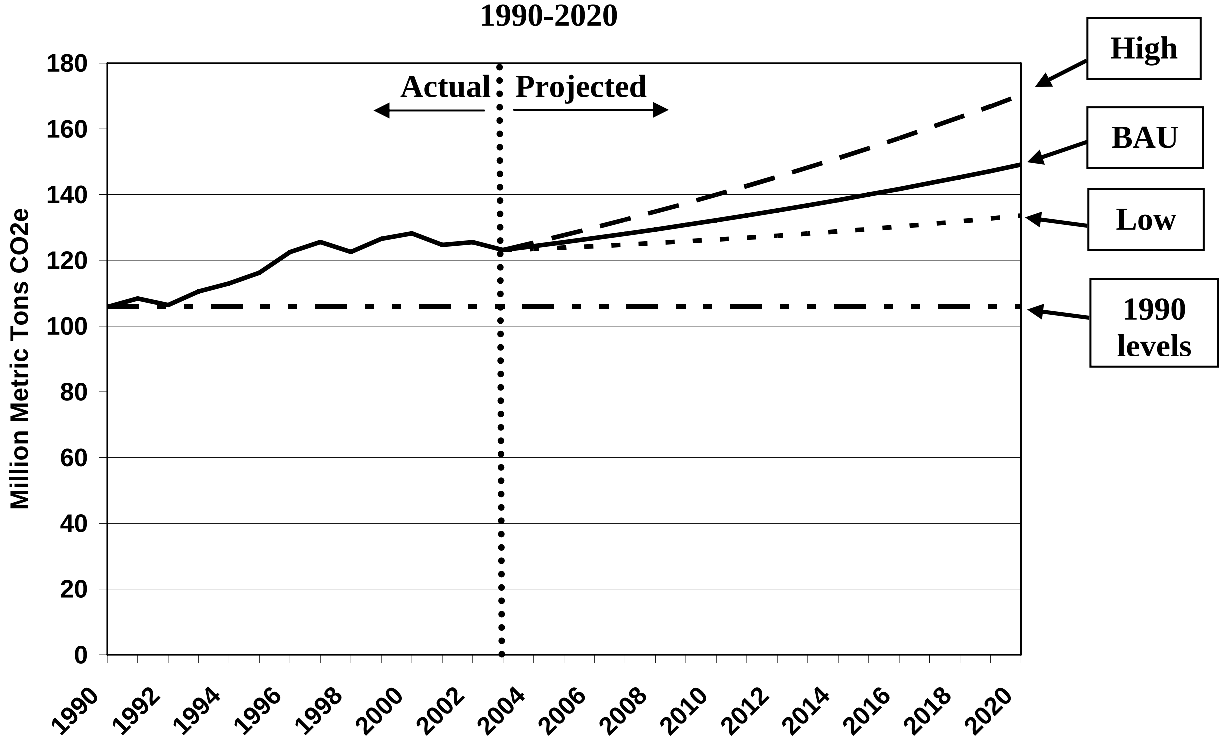
Emissions cases vary due to relative weights given to input data from historic trends and projections compiled by the Energy Information Administration for the East North Central region as presented in the Annual Energy Outlook, 2007. For a complete discussion of the methodology used to construct all emissions projection cases and related assumptions see Appendix B. Finally, figure 7 graphically presents historical emissions and the three projection cases from 1990 to 2020.

In the low case, emissions increase at an average annual rate of 0.48 percent between 2003 and 2020. Under this scenario, emissions grow to 133.6 $MtCO_2Eq$ by 2020, an increase of 26.2 percent above 1990 levels. 2020 emissions in this case are only 5.5 $MtCO_2e$ higher than their historic peak of 128.2 $MtCO_2e$ in the year 2000. This case does not include any emissions from proposed or planned power plants or other large point source emitters and instead is solely based on EIA regional projections for energy consumption and historic trends in non-energy sectors.

In the high case projection, emissions increase at an average annual rate of 1.92 percent between 2003 and 2020. Under this scenario emissions are 170.3 $MtCO_2e$ in 2020 or 60.8 percent above 1990 levels. This case assumes all proposed power plants in the state are built and run at full capacity while emissions growth in the electric generation sector increases at historical rates beyond 2012. All other sectors grow at historic rates with the exception of the agriculture and waste sectors where no growth is assumed.

Finally, under the BAU case, GHG emissions in Wisconsin between 2003 and 2020 are projected to increase at an average annual rate of 1.13 percent. By 2020, Wisconsin's emissions are projected to grow to 149.1 $MtCO_2e$, an increase of 23.6 $MtCO_2e$ over 2003 levels, or 19.0 percent. Compared to 1990 emissions, 2020 projected emissions represent an increase of 43.2 $MtCO_2e$, or 40.8 percent. This case assumes all proposed power plants that have a high level of certainty of completion are built and run at full capacity. In addition, historic rates are used for non-energy sectors while all other sector increase at rates derived from both historic trends and EIA regional projections.

Figure 7. Wisconsin Actual Emissions and Projected Emissions Cases, 1990-2020



Under the BAU case, projected emissions growth is slightly higher than the projected growth for the nation as whole of 1.05 percent. The rate of growth is also slightly lower than historic emissions growth in Wisconsin between 1990 and 2003 and is therefore seen as the most plausible scenario. Wisconsin's projected emissions are expected to be driven by a continuing increase in emissions from the generation of electric power from fossil fuels. Emissions from transportation are also expected to increase substantially.

According to the U.S. Census, Wisconsin's population in 2020 is projected to be 6,004,954, an increase of 538,025 or approximately 10 percent over the 2003 total. This results in an average annual population growth rate of 0.52 percent, slower than the U.S. projected rate of 0.80 percent for the same time period. In the projection period, BAU GHG emissions are projected to grow twice as fast as Wisconsin's population, resulting in an increase in Wisconsin per capita emissions from 22.5 metric tons per person in 2003 to 24.8 metric tons per person in 2020.

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Appendix A – GHG Data of this Report: Information, Sources, and Caveats

The Climate Analysis Indicators Tool

The Climate Analysis Indicators Tool (CAIT) is an inventory and analysis tool developed by the World Resources Institute. Among other data, the CAIT-US module includes greenhouse gas (GHG) inventories for all 50 states plus the District of Columbia for the six major greenhouse gases between 1990 and 2003. The data included in this report were released in CAIT-US version 2.0 (2007). All data are publicly accessible free of charge at http://cait.wri.org.

Years, Gases and Sectors

CAIT-US (v.2.0) covers 1990-2003. Table A-1 shows which gases are included in each sector.

Table A-1. CAIT-US Sector and Gas Coverage

Sector	CO_2	CH_4	N_2O	F-Gases
Energy				
Electricity Generation	X	X	X	
Residential	X	X	X	
Commercial	X	X	X	
Industrial	X	X	X	
Transportation	X	X	X	
Fugitive Emissions		X		
Industrial Processes	X			X
Agriculture		X	X	
Waste		X	X	

This report generally excludes two common categories of emissions from its inventory analysis (although they are included in CAIT-US):

- International Bunker Fuels. These emissions come from fuel use during international transportation; for instance, air travel or shipping to and from other countries. Attribution of these emissions is controversial; it is unclear whether to attribute them to the country of origin or the destination. This issue is even more difficult at the U.S. state level.

- Land-use Change and Forestry (LUCF). This category is comprised of changes in GHG levels due to afforestation, deforestation, reforestation, forest management and similar activities. Carbon is released into the atmosphere as forests are cleared or burned, and is sequestered through forest growth. On balance, this category may either be a source of GHGs if released carbon released exceeds sequestered carbon or a "sink" if sequestered carbon exceeds released carbon. LUCF is believed to be a significant sink at the national level but there are significant data uncertainties at the state level. The ambiguity and uncertainty of the underlying data make it difficult to identify trends in this sector with any reliability or assurances that emissions are greater or less than zero; therefore, contributions from LUCF are excluded in this inventory, but discussed briefly following the main inventory discussion.

Data Sources

CAIT-US indicators derive from the Emissions Inventory Improvement Program (EIIP) of the U.S. Environmental Protection Agency (EPA), which provides guidance and methodologies to states that are developing their own emissions inventories following the revised IPCC guidelines for emissions reporting. The EIIP has developed a set of tools—State Inventory Tools (SIT)—that accompany its latest technical reports. The Excel-based tools contain state-level proxy data that a state may use to calculate its emissions (table A-2). The state-level proxy data in the EPA inventory tools comes from a variety of sources, mostly federal agencies:

Table A-2. Proxy Sources for CAIT-US by Sector

Sector	Source
Electricity Generation, Residential, Commercial, Industrial & Transportation	Energy Information Administration (EIA) Federal Highway Administration
Fugitive Emissions	U.S. EPA
Industrial Processes	U.S. Geological Survey (USGS) *Directory of Chemical Producers* (SRI 2000)
Agriculture	U.S. Department of Agriculture (USDA) *Commercial Fertilizers Report*, Fertilizer Institute
Waste	U.S. EPA

A state may supplement or replace the "default" (EPA-supplied) data if it has its own sources that it considers more reliable.

CAIT-US uses a simple process to produce its inventories; it selects the default proxy data for each state, uses the tools to compute emissions using the tool-supplied emissions coefficients, and extracts the results. The same process is used for each state and the District of Columbia. National emissions totals for the United States, except where noted, are a simple sum of total emissions for each state and the District of Columbia. Although the inventory tools allow states to enter their own data, for the sake of comparability, CAIT-US does not incorporate state-supplied proxy data where available.

Data Limitations

State emissions inventory data generated by utilizing "default" proxy data within the SIT underlies the CAIT-US module, and, subsequently, the estimates presented in this report. Opting to utilize *only* EPA-supplied data provides a well-established, homogeneous methodology for computing sectoral emissions values for each U.S. state and the District of Columbia. As a result, comparisons across states and sectors can be readily made. However, it is important to note that this procedure also produces emissions estimates that, in some instances, may differ from those reported by individual state inventory initiatives where more appropriate or precise data may be available, as well as the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (U.S. EPA), which includes several emissions sources not featured in the EIIP tools (particularly sources of methane).

Differences between CAIT-US data (the data used in this report) and other sources of emissions inventory data for U.S. states arise primarily due to methodological and data uncertainties and data omissions.

Data Uncertainties

The SIT make use of EPA-supplied proxy data and emissions factors to calculate total sectoral emissions since, in most instances, direct measurement of greenhouse gas emissions are unavailable. The use of activity data and emissions factors to produce sectoral emissions estimates can result in state-level emissions estimates that are inaccurate to varying degrees.

Additionally, all sectors in this inventory are subject to some level of uncertainty owing to the fact that the default proxy data comes from federal agencies (i.e., source data inaccuracies are carried through and applied to the inventory tools), and the data becomes less precise at the state level.

This is especially true for non-energy sectors and fugitive emissions. For example, significant uncertainties in the industrial processes sector arise from variations in the production methods of raw materials from state to state. In addition, production data for ozone depleting substance substitutes and semiconductors are estimated from national production data based on state population and state-level shipments, respectively, which may also have underlying uncertainties. In the agriculture sector, estimates of animal stock populations are based on a single point in time (January 1), rather than accounting for stock fluctuations throughout the year.

These are just some examples of the uncertainties surrounding the EPA-supplied proxy data, calculation methodologies, and emissions factors. For a complete description of CAIT-US data uncertainties, please see the accompanying guidance documents to the EIIP tools or the State Inventory Tools themselves. The *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (U.S. EPA) also provides a detailed explanation of uncertainties for all sectors that arise at any level due to estimation methods.

Data Omissions

To ensure optimal comparability between state inventory data within the CAIT-US module, sectors in which “default” proxy data are largely absent have been purposely excluded when calculating state emissions totals. Instances where end use data are missing entirely are noted below.

- *Fugitive Emissions.* Emissions from oil and natural gas processing and refining (including transmission, distribution, and flaring) are not included due to lack of production data. These industries represent 3 percent of emissions at the national level.

- *Industrial Processes.* At the national level, emissions from this sector represent 2 percent of total emissions. Emissions from manufacture of nitric acid, adipic acid, aluminum, HFCF-22 and magnesium are not included due to lack of data.

  In addition, "default" estimates of emissions from limestone and dolomite use are unavailable for 1990-1993 and estimates of emissions from iron and steel production is unavailable until 1997. As a result, many states exhibit "step functions" in their total industrial processes data, that is, a lack of complete industrial processes emissions data prior to 1997 causes an artificial increase in these data beginning in that year. In an effort to avoid presenting misleading comparisons with other sectors, trends in the industrial processes sector are only assessed from 1997-2003 (as opposed to most trends in this report which span 1990-2003).

- *Waste.* Emissions from landfills (waste in place) and wastewater are estimates from national statistics using state-level population as a proxy for assigning emissions to individual states. Emissions from industrial wastewater methane (fruits & vegetables, meat & poultry, pulp & paper) are not included due to a lack of data.

In addition to the emissions data described above, certain sectors or sub-sectors within some states also have missing or unreported data (e.g., nitrous oxide from histosols in agriculture) and no "default" value is provided. The cumulative effect of purposely excluding the data noted above (due to issues of availability) and performing SIT calculations with missing estimates for particular states, sectors, or years, results, generally, in an *underestimate* of sectoral and total emissions for any given state inventory. This underestimate may be on the order of several million metric tons of CO_2 equivalent and would therefore alter the absolute emissions, per capita emissions, and emissions trends analysis reported here.

Summary

The emissions data produced by the State Inventory Tools, included in the CAIT-US module, and utilized in this report are, admittedly, imperfect. Applying uniform calculation methodologies to "default" proxy estimates ensures comparability between states, but as a result, the nuances of state-specific data are often compromised. Other inventory tools may incorporate levels of detail that are missing in this analysis and serve as better indicators of emissions for sectors where EPA "default" data estimates may be inappropriate to a particular state or a tool module is incomplete. Although general trends and emissions values presented in this report are likely good approximations of emissions totals, it is critical that the reader bear in mind that for some sectors and/or years, significant deviations from "true" emissions values can occur. However, it is important to note that data sources and inventory calculation methodologies are regularly being updated and improved. As such, subsequent releases of the CAIT-US module should build upon the tools already in existence, providing greater quantitative accuracy for all included years for both sectors and states.

Appendix B – Methodology and Assumptions for Projections

Projections in this report were computed separately for each sector using the following methods and assumptions, using the 2003 inventory as a baseline.

Energy Sectors

The Energy Information Administration (EIA) of the U.S. Department of Energy publishes the *Annual Energy Outlook* (AEO), a comprehensive set of forecasts for energy consumption, production, prices, and related indicators (including CO_2 emissions) for the United States. The AEO only projects CO_2 emissions at the national level. In the 2007 edition, the AEO projected that CO_2 emissions nationally would rise 24 percent over 2003 levels by 2020.

Although the AEO does project CO_2 emissions at the regional level, it does not provide projections at the state level or break projections out by economic sector. With that said, AEO regional projections do contain quite detailed annual projections of energy consumption organized by sector and then by fuel. The East North Central (ENC) region comprises Illinois, Indiana, Ohio, Michigan and Wisconsin. In this exercise, ENC regional and sectoral energy consumption growth rates for 2004 to 2020 from the AEO were adjusted to subtract energy consumption from renewable fuels. These fuels are assumed to result in no net CO_2 emissions from their combustion. For the residential, commercial, industrial, electric generation and transportation sectors, the renewables adjusted growth rates for total energy use in Wisconsin were assumed to be the same as those for the larger region. These growth rates are used in various ways depending on the emissions case, as described in detail below. For non-energy sectors other methods were used to project emissions. These methods are described immediately after the energy sector section.

Low emissions case

In the low emissions case, the growth rate for energy use is used to project CO_2 emissions growth for these five sectors: 0.14 percent annually in the residential sector, 0.70 percent in the commercial sector, -2.10 percent in the industrial sector, 1.20 percent in the electric generation sector and 0.56 percent in transportation.

It should be noted the growth of emissions in the electric generation sector may be different in Wisconsin compared to the ENC region. Between 1990 and 2003, emissions from this sector grew 24 percent nationally and 21 percent in the ENC region, but they grew 29 percent in Wisconsin. These rates suggest that there may be some range of error when using ENC projections as a proxy for emissions in the Wisconsin electricity generation sector. The BAU case attempts to capture an emission scenario in this sector that may be more representative of future trends in the state.

High emissions case

In the high case, historic annual growth rates for Wisconsin emissions were applied to 2003 for these four energy sectors: 0.84 percent annually in the residential sector, 1.75 percent in the commercial sector, 0.65 percent in the industrial sector and 1.34 percent in transportation. For the electric generation sector, an initial exercise incorporated estimated annual emissions data on expected future new and retired power plants provided by Wisconsin Department of Natural Resources and Public Service Commission. The net annual emissions of all of these plants were added to the 2003 CAIT base-year data for this sector with the assumption that net emissions from these new facilities would be fully present by 2012 (see table B-1 for data). That is to say all new plant operations and closures would be fully implemented by this year. One plant retirement was not factored in to this calculation—the Port Washington coal fired unit. A review of EIA 2005 emissions data for this sector revealed that there was no commensurate emissions drop from the retirement of this unit, meaning other facilities increase generation and thus emissions to compensate for the reduction in capacity.

From 2003 to 2012, the historic annual growth rate of 2.00 percent is applied to total emissions in this sector ultimately resulting in 2020 sectoral emissions of 72.15 $MtCO_2e$. An average annual growth rate from 2003 through 2020 of 3.07 percent was then calculated to capture the overall trend in this sector due to the calculations and assumptions described above. This growth rate was then applied uniformly as the annual emissions growth rate for this sector in the high emissions case.

Table B-1: Expected new and retired power plant units incorporated into Wisconsin high and BAU projections.

New Units	**In Service Year**	**Estimated Annual Emissions (MtCO2e)**
Port WA gas 1	2005	1,429,281
Weston 4	2008	4,006,720
Port WA gas 2	2008	1,429,281
Elm Road 1	2009	4,496,776
Elm Road 2	2010	4,496,776
Nelson Dewey 3	2012	3,033,117
Retired Units	**Out of Service Year**	**Estimated Annual Emissions (MtCO2e)**
Port WA Coal	2005	1,708,912
MGE Madison	2012	426,304
Total Net Annual Emissions in 2012 from new and retired plants		**16,756,735**

Source: Wisconsin Public Service Commission and Wisconsin Department of Natural Resources from plant permits. Note: Estimated emissions assume an 85 percent capacity factor for coal fired plants and 60 percent capacity factor for natural gas fired plants.

The focus on large generation capacity additions to Wisconsin's electric generation sector is appropriate as unlike other energy sectors, this sector often can be difficult to project solely based on regional projections and historic trends. Decisions to construct or retire one plant can have large effects on sectoral emissions. Thus this methodology attempts to capture known future changes in emissions to provide the most accurate projections. This approach does not attempt to capture any changes in electric generation sector emissions due to changes in electrical grid operations and dispatch that may occur in the future.

Business as usual case

In the business as usual case, the growth rates for the five energy sectors were calculated by averaging the low case rates and the high case rates. This results in the following annual growth rates for these five sectors: 0.49 percent annually in the residential sector, 1.23 percent in the commercial sector, -0.73 percent in the industrial sector, 2.14 percent in the electric generation sector and 0.95 percent in transportation. These rates were then applied to year 2003 emissions data. In this projection case, all new and retired power plants are accounted for but there is only a small amount of additional emissions growth in this sector beyond the anticipated emissions from these projects.

Industrial Processes

The AEO does not project emissions from industrial processes. In all projection cases contained in this document, the historical rate from 1997 through 2003 of 5.35 percent is used. While estimates of emissions from this sector are problematic at the state level, owing in part to the variety of activities involved and to data uncertainty, for this study an historic rate was considered to be more appropriate than an otherwise arbitrary rate. Given the small percentage of Wisconsin's emissions classified under industrial processes, use of the historic growth rate is reasonable.

Agriculture

Likewise, the AEO does not project emissions from agriculture. The low and BAU projections assume that emissions growth in the agriculture sector declines at the historic rate of -1.18 percent while in the high case, zero percent growth is assumed. Historical trends in this sector reflect a steady decline in N_2O emissions while CH_4 emissions stay relatively static. This trend could reverse if nitrogen intensive crops such as corn experience a surge in acres planted. Given that market forces and future dynamics in this sector are uncertain, the historic rates are viewed as appropriate if conservative, while a zero growth assumption is not unlikely.

Waste

Likewise, the AEO does not project emissions from waste, but these forecasts assume that these emissions will decline by an annual rate of 3.19 percent, consistent with historical declines from 1990-2003. Historic declines in this sector were due to slower population growth as compared with the nation as a whole. As discussed in the projections section of this document, this population trend is projected to continue. This disparity lends us to conclude that while the 3.19 percent rate of decline is in line with historic trends it is likely to be a conservative estimate. Thus the historic rate is used for both the low and BAU cases while a zero growth assumption is made for the high case.

Land Use Change and Forestry

Given the inherent uncertainty surrounding the available historical data for LUCF and the difficulty in accurately factoring in all of the relevant variables needed for a robust projection of carbon sequestration, we do not attempt to provide a projection of carbon performance in this sector.

Table B-2 presents a summary of annual growth rates used in each case by sector, table B-3 presents actual and projected total annual emissions for Wisconsin from 1990 to 2020 under the BAU case.

Table B-2: Summary of Annual Emission Growth Rates in Projection Cases by Sector			
	Projection Case		
Sector	**Low**	**BAU**	**High**
Utilities	1.20%	2.14%	3.07%
Residential	0.14%	0.49%	0.84%
Commercial	0.70%	1.23%	1.75%
Industrial	-2.10%	-0.73%	0.65%
Transport	0.56%	0.95%	1.34%
Industrial Processes	5.35%	5.35%	5.35%
Agriculture	-1.18%	-1.18%	0.00%
Waste	-3.19%	-3.19%	0.00%
Total	**0.48%**	**1.13%**	**1.92%**

Table B-3. Wisconsin Actual and Projected GHG Emissions 1990-2020			
Thousand Metric Tons CO_2e			
Actual		**Projected**	
1990	105,852	**2004**	124,301
1991	108,344	**2005**	125,513
1992	106,424	**2006**	126,766
1993	110,492	**2007**	128,059
1994	112,931	**2008**	129,394
1995	116,263	**2009**	130,771
1996	122,506	**2010**	132,193
1997	125,569	**2011**	133,659
1998	122,517	**2012**	135,171
1999	126,542	**2013**	136,731
2000	128,193	**2014**	138,339
2001	124,697	**2015**	139,996
2002	125,487	**2016**	141,705
2003	123,128	**2017**	143,466
		2018	145,282
		2019	147,152
		2020	149,080

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