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WRI REPORT

CHARTING THE MIDWEST

An Inventory and Analysis of Greenhouse Gas Emissions in America's Heartland

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The Authors

FOREWORD

Confronted with global climate change—a challenge of enormous scope and complexity—and a failure of national leadership in addressing the challenge, leaders in state government have taken it upon themselves to act in the best interest of their citizens. Seventeen states are moving to cap emissions, and twenty-five more have developed programs to increase the use of renewable energy. The states that are leading in these efforts have rapidly discovered the importance of having comprehensive information on the nature and sources of GHG emissions and the complexities of the economic and technical forces that drive emissions growth.

Charting the Midwest provides an in-depth study of GHG emissions for the states of the U.S. Midwest—one of the most economically diverse regions of the country—at a critical early stage. Because there is no single path for the Midwest to follow toward realizing a low-carbon future, a rigorous up-front assessment of emission sources, trends, and drivers is essential. With this information, Illinois, Indiana, Iowa, Michigan, Missouri, Minnesota, Ohio, and Wisconsin now have an important tool necessary to design state and regional priorities appropriate to their circumstances.

We present, for the first time, GHG emission profiles that allow comparison of the various classes of GHGs across all sectors of the economy at both a state and a regional level. Our goal is to provide analysis that helps the Midwest states to address the climate change crisis in their individual and collective actions. Additionally, with this transparent accounting of GHG emissions, the Midwest states join others in opening their books to federal legislators in an effort to move forward a national climate change dialogue.

Charting the Midwest comes at a critical juncture. The science is in, and the G8 has explicitly elevated climate change as a global priority. And, now—for the first time—the United States Congress has promised to make climate change a national priority.

The Midwest states have an opportunity to play a climate leadership role that helps to shape the ongoing national debate, and, in doing so, to develop new technologies, create jobs, and build an economic base that is environmentally sustainable.

JONATHAN LASH
President, World Resources Institute
Washington, D.C.

EXECUTIVE SUMMARY

This report presents a quantitative overview and analysis of greenhouse gas (GHG) emissions in the Midwest region of the United States. The study is the first to examine all six Kyoto GHGs across the entire Midwest economy using consistent and comparable data. Although several Midwest states have previously compiled their own state GHG inventories, the methodologies and data sources of these analyses differ, making it challenging to directly compare emissions across states. The data utilized here uniquely provide a common methodological framework for readily comparing GHG emissions.

The underlying GHG emissions data of this report are exclusively drawn from the U.S. module of the World Resources Institute's Climate Analysis Indicators Tool (CAIT-US). Emissions are examined at the regional, sectoral, and state levels, and within each context, major emission sources, trends, and socioeconomic drivers are assessed. Also included in this report are GHG inventories for eight states in the Midwest: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin. Although the accuracy of emission estimates from any individual source can vary considerably, the uncertainties associated with the CAIT-US data set tend to be comparable with those of the Environmental Protection Agency's *U.S. Inventory of Greenhouse Gas Emissions and Sinks*, with sectoral emission estimates based on fuel consumption (e.g., electric generation, transportation) generally more certain than other sectors (e.g., agriculture, forestry). The latter, however, typically constitute a smaller percentage of total regional and state emissions.

These data and related analyses provide comprehensive and essential information for public officials, business representatives, advocates, and citizens in the Midwest and nationwide to fully understand the region's role in global climate change. As these and other stakeholders consider potential responses to this complex challenge, the following key findings from this report should provide a better understanding of GHG emissions in the Midwest, affirm the importance of the region in both national and international climate change conversations, and compel individuals throughout the Midwest and elsewhere to develop solutions that significantly reduce GHG emissions in ways that are both immediate and enduring.

KEY REGIONAL FINDINGS

The Midwest is a major emitter of GHG emissions in national and international terms. With GHG emissions of approximately 1.5 billion metric tons of carbon dioxide equivalent (CO_2e) in 2003, the eight Midwest states examined in this report account for nearly 25 percent of total U.S. emissions and 5 percent of world emissions. If the Midwest were its own country, it would be the fifth largest emitter in the world. All eight Midwest states rank in the top 25 nationally for GHG emissions, with four states—Ohio, Indiana, Illinois, and Michigan—ranking in the top 10.

Three sectors—electric generation, transportation, and industrial energy use—account for 75 percent of total Midwest GHG emissions. With average annual respective growth rates of 1.7 and 1.4 percent, the top two emitting sectors—electric generation and transportation—are also the fastest-growing sectors in the Midwest. Total emissions from these sectors are increasing slightly faster in the Midwest than they are nationally.

The growth rate of total Midwest GHG emissions is slower than the national growth rate. However, the four Midwest states that emit the least GHGs are experiencing emissions growth that outpaces the region and the nation. Between 1990 and 2003, Missouri, Minnesota, Iowa, and Wisconsin—the four states examined in this report with the lowest total emissions in 2003—experienced average annual respective emissions growth of 1.8, 1.4, 1.1, and 1.0 percent, as compared with the national rate of 0.9 percent. These trends were largely driven by population and economic growth.

The average person living in the Midwest emits 13 percent more GHGs annually than the national per capita average and nearly four times the global average. State emissions per capita vary considerably across the Midwest and reflect the overall emissions of various activities, such as driving, energy-intensive manufacturing, electric power generation, and the use of land for agriculture. Per capita emissions in two states, Indiana and Iowa,

at 44 and 37 metric tons of CO_2e per year, respectively, far exceed regional (26 metric tons), national (23 metric tons), and world (6 metric tons) averages. In Indiana, substantial coal use for electricity generation and a high concentration of energy-intensive industry are primary drivers, while in Iowa, coal use for electricity generation and agricultural production primarily explain these findings.

KEY SECTORAL FINDINGS

ELECTRIC GENERATION

At over half a billion metric tons of CO_2e, the electric generation sector is the largest emitting sector in the Midwest and has the largest emissions growth rate. Most states' emissions growth in the electric generation sector followed similar growth trends in total generation of electricity and in-state sales, as new generation met increasing demand. This was not the case in Illinois and Missouri, the two states with sectoral emissions growth that was more than double (53 and 54 percent, respectively) that of the region (25 percent) and the nation (24 percent). These states experienced a surge in generation largely in order to export power to serve demand in the eastern United States through the wholesale market. This is evidenced by a much smaller increase in in-state sales as compared to generation in these states.

Compared with the nation, the Midwest is much more dependent on coal to generate electricity. A major driver of regional emissions from electricity generation is the fact that approximately 75 percent of Midwest-generated electricity comes from fossil fuels, nearly all of which is coal. Only one Midwest state—Illinois—generates 50 percent or more of its power from resources other than coal. While states like Minnesota derive a greater percentage of their power from renewable sources such as wind as compared with the nation overall, the large presence of coal in the region's fuel mix plays a significant role in driving GHG emissions in this sector.

TRANSPORTATION

Midwest GHG emissions from transportation grew slightly faster than national emissions between 1990 and 2003, as drivers increased their individual travel mileage by an average of 19 percent. Population growth and an increase in the total miles driven per person are driving emissions growth in transportation at a rate that is similar to the nation as a whole. Minnesota's GHG emissions have grown at twice the rate of the region and the nation as a result of the state's faster-than-average population growth and a 25 percent increase in total distance traveled per person annually.

Gasoline combustion from passenger vehicles is the primary source of GHG emissions in the transportation sector. In all Midwest states, the combustion of gasoline is the primary source of transportation GHG emissions, with diesel fuel and jet fuel playing a smaller role that varies across states.

INDUSTRIAL ENERGY USE

Midwest emissions from industrial energy use declined by 11 percent, primarily due to the use of less GHG-intensive fuels and increased energy efficiency. These declines mostly took place in the later part of the study period. Between 1997 and 2003, regional industrial economic output increased by 10 percent, while energy consumption and GHG emissions declined by about 10 percent in the Midwest, indicating that sectoral efficiencies played a greater role in emission reductions than the loss of economic output. In two states—Ohio and Missouri—stagnant trends in economic output drove decreases in GHG emissions, contrary to regional and national trends.

AGRICULTURE

Nitrous oxide emissions constitute a greater share of emissions from the agriculture sector in the Midwest than methane. This is characteristic of the region's extensive crop cultivation, especially corn. Given the region's leadership in corn and other crop production and the use of nitrogen fertilizer to support that production, nitrous oxide is the dominant agricultural GHG across almost all Midwest states. The one exception is Wisconsin, where the dairy sector causes methane to be the more prominent agricultural GHG.

Though emissions in the agriculture sector declined between 1990 and 2003, this trend could change quickly, based on crop plantings, the expansion of livestock production, weather variability, and soil practices.

Agricultural emissions are strongly tied to the crop and livestock activities undertaken in that sector. For example, Iowa leads the region in both crop cultivation and livestock production and also has the most GHG emissions from agriculture.

KEY STATE FINDINGS

Midwest state GHG emissions vary in accordance with each state's unique circumstances. Table ES.1 provides a summary of total GHG emissions and emissions per capita for each state examined in this report and is illustrative of the similarities and differences across the region from an economy-wide perspective. The following key state findings provide an additional level of insight into GHG emissions in the Midwest.

Table ES.1 | **Midwest State GHG Emissions and Emissions per Capita: 2003**
CO_2, CH_4, N_2O, HFCs, PFCs, SF_6

STATE	GHG EMISSIONS ($MtCO_2e$)	STATE RANK (2003)	% OF U.S. GHGs	GHG EMISSIONS PER CAPITA ($MtCO_2e$)	STATE RANK (2003)
Ohio	299	4	4.4	26	21
Indiana	269	6	4.0	44	7
Illinois	268	7	4.0	21	30
Michigan	212	9	3.1	21	32
Missouri	163	15	2.4	28	19
Wisconsin	123	21	1.8	23	27
Minnesota	120	22	1.8	24	24
Iowa	108	23	1.6	37	11
Midwest	***1,562***	***N/A***	***23.2***	***26***	***N/A***
U.S. Total	***6,737***	***N/A***	***100.0***	***23***	***N/A***

Source: WRI, CAIT-US (2007).

Notes: Data are for 2003. Totals exclude emissions from international bunker fuels and land-use change and forestry.

ILLINOIS

Illinois' total GHG emissions grew by approximately 12 percent between 1990 and 2003, slightly slower than the nation as a whole. A substantial decline in emissions from industrial energy use and agriculture contributed to this state's slower overall growth. Illinois is unique in the Midwest in that it generates about half of its power from nuclear energy, which does not directly emit GHGs. If Illinois' fuel mix were similar to that of the region, emissions growth would be far larger than that identified here. Increased electricity exports were the primary driver of the 53 percent emissions growth in Illinois' electric generation sector.

INDIANA

Indiana leads the region in per capita GHG emissions, with nearly double the per capita emissions of the Midwest overall. This relatively high per capita emissions value is primarily due to the fact that the state generates 94 percent of its electricity from coal and is home to a significant amount of energy-intensive industry. Indiana is the only state in the Midwest where the industrial sector is the second largest emitting sector; in most other states, transportation emissions are larger. Emissions growth in Indiana lagged behind U.S. growth, but was similar to regional growth.

IOWA

Iowa has the lowest total GHG emissions of any Midwest state, yet it has the largest emitting agricultural sector in the region. This is due to the fact that the state is a national and regional leader in crop and livestock production. This characteristic helps to explain why Iowa has the second highest per capita emissions value in the region. The other driving factors are increases in emissions from industry and electricity generation; growth rates in both sectors outpaced regional growth between 1990 and 2003.

MICHIGAN

Michigan's total GHG emissions grew by less than 1 percent between 1990 and 2003—the smallest increase of any Midwest state. This trend is largely due to a 27 percent decrease in industrial emissions, which countered a 14 percent increase in transportation emissions. In addition, Michigan's total emissions declined between 2000 and 2002, at least partly due to a national recession. However, whereas total GHG emissions in most other Midwest states increased between 2002 and 2003, Michigan's did not.

MINNESOTA

At 44 percent, Minnesota led the Midwest in growth of GHG emissions from transportation between 1990 and 2003. This was largely due to population growth that exceeded the regional population growth rate, as well as to the fact that Minnesota drivers traveled 25 percent further in 2003 than in 1990 (indicative of urban sprawl). Minnesota leads the region in generating electricity from renewable resources, such as wind power.

MISSOURI

Between 1990 and 2003, Missouri experienced the largest absolute increase in total GHG emissions of any Midwest state, approximately 32 million metric tons of CO_2e. This increase was largely driven by a 22 percent growth in transportation emissions and a region-leading 54 percent increase in emissions from electricity generation. Overall emissions growth in Missouri outpaced population growth by a factor of two.

OHIO

With total GHG emissions of 299 million metric tons of CO_2e, Ohio is the largest emitting state in the Midwest and fourth largest nationally. This is principally due to the size of Ohio's population and economy, and its reliance on coal-fired electricity production. Ohio is one of two states in the Midwest where industrial emissions have declined sharply, in part due to stagnant economic output in this sector. Nevertheless, even with this decline, total emissions in Ohio increased by 5 percent between 1990 and 2003—roughly half the growth seen across the Midwest in this period. This growth was driven largely by emissions in the transportation sector, which outpaced regional and national trends.

WISCONSIN

Between 1990 and 2003, growth in Wisconsin's GHG emissions exceeded regional and national growth rates. This trend was largely driven by growth in emissions from industry, electricity generation, and commercial energy use. In this last sector, Wisconsin's emissions increased more than three times as much as they did regionally, mirroring a similar trend in natural gas consumption. Due to its extensive dairy industry, Wisconsin is the only Midwest state where methane emissions (from livestock) make up a majority of total emissions from agriculture.

1 INTRODUCTION

THE CHALLENGE OF CLIMATE CHANGE

Since the start of the Industrial Revolution around 1750 A.D., human activities such as the burning of fossil fuels, deforestation, and agriculture have directly increased the concentration of greenhouse gases (GHGs) in Earth's atmosphere.[1] Largely spurred by world population growth and economic development, present concentrations of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)—the most prevalent GHGs—are 35, 148, and 18 percent above pre-industrial levels, respectively, and continue to increase (IPCC, 2007). Indeed, concentrations of CO_2 and CH_4 now exceed the natural variability of at least the past 650,000 years (IPCC, 2007).

GHGs (including CO_2, CH_4, and N_2O) do occur naturally, trapping heat essential to maintaining Earth's habitability. However, increasing GHG concentrations are exacerbating the natural greenhouse effect, warming the planet, and causing significant changes to the global climate system. Over the past century, the global mean temperature rose by approximately 0.7°C (1.3°F), and in recent decades the observed rate of warming has accelerated (IPCC, 2007). The effects of this temperature increase on our planet's climate are already apparent: global sea level is rising, mountain glaciers and polar ice are receding, and changes in precipitation patterns are intensifying storms, as well as floods and droughts (see Levin and Pershing, 2007, and references therein).

Future climate change will most likely continue to create environmental, economic, and sociopolitical uncertainties. Under a range of GHG emission scenarios, climate models project an average global surface temperature increase of 0.2°C (0.4°F) per decade for the next two decades (IPCC, 2007). Although temperature increases will not be uniform worldwide, global warming of this magnitude will most likely amplify current environmental trends, placing the well-being of ecosystems and human populations at greater risk.[2] To avoid the most severe outcomes of climate change, future global warming must be mitigated by quick and collective actions that halt the upward trend in global GHG emissions and significantly reduce total emissions over time (e.g., van Vuuren et al., 2006), even as populations and economies continue to grow. The challenge of climate change is undeniably daunting.

However, although the problem of climate change is fundamentally global in scope, certain countries and regions bear a greater responsibility for producing GHG emissions. Consequently, their participation in GHG-reduction solutions is critical to reducing worldwide emissions and requires an aggressive shift

[1] See "Global Emissions of CO_2 from Fossil Fuels," in *Navigating the Numbers: Greenhouse Gas Data and International Climate Policy*, by Baumert et al. (2005), available at <http://cait.wri.org/figures.php?page=ntn/1-2>.

[2] For more information, see the Millennium Ecosystem Assessment <http://www.maweb.org/en/index.aspx> and EarthTrends <http://earthtrends.wri.org>.

away from "business as usual" to less GHG-intensive practices. The United States Midwest is one such region.

As home to approximately 60 million people, or 20 percent of the U.S. population (U.S. Census, 2006), the Midwest is a major consumer of electricity, gasoline, and manufactured goods. It is also a leading producer of industrial, agricultural, and forestry products. Midwest activities account for approximately 20 percent of national economic output (BEA, 2007), making the region a vital part of the U.S. economy, as well as the nation's culture and identity. These activities also result in significant GHG emissions: the Midwest is responsible for 5 percent of global GHGs—a contribution larger than all countries, except China, Russia, and India (see Chapter 2).

In addition to being a significant producer of GHG emissions, the Midwest will also likely be affected by global warming, as the region's average annual temperature is anticipated to rise by an estimated 2.8–5.6°C (5.0–10.0°F) by the end of this century (Kling et al., 2003; Easterling and Karl, 2001). According to recent studies (Kling et al., 2003; Easterling and Karl, 2001), changes to the region's environment and economy could include the following:

- **A reduction in river and lake levels.** Limited water availability would affect hydropower generation, domestic and agricultural water use, shipping, and biota of lake and river ecosystems.

- **Greater stresses on human health.** Stresses could include more intense and frequent heat waves, worsening air quality in urban areas, and the northward migration of disease vectors.

- **Changes in the geographic distribution of rainfall.** Variations in precipitation are expected to shift agricultural zones and could negatively affect boreal forest habitats and biodiversity.

To mitigate the effects of climate change, the Midwest must significantly reduce its GHG emissions. Therefore, the region needs to be placed in an appropriate context, beginning with an understanding of key emission sources, trends, and drivers. This report presents a quantitative overview of Midwest GHG emissions at the regional, sectoral, and state levels in an effort to create the necessary foundation for policymakers, businesses, and individuals to constructively address the paramount challenge of climate change.

REPORT OVERVIEW

Following this introduction, Chapter 2 provides a brief analysis of Midwest emissions and compares them to national and international emission totals. Chapter 3 examines GHG emissions at the sector level to identify the key drivers of emissions in the largest-emitting economic sectors of the Midwest: electricity generation, transportation, industrial energy use, and agriculture. This is followed by an analysis of GHG emissions and related indicators for each Midwest state in Chapter 4. The report's main conclusions are presented in Chapter 5.

This report also includes two sections of supplementary information and discussion that focus on GHG-related issues outside the purview of the main inventory analysis. These include an analysis of emissions from the Midwest land-use change and forestry (LUCF) sector and a review of available GHG emissions data and protocols at the municipal level. Finally, Appendix A provides a discussion of the GHG data used in this report, including associated uncertainties and additional caveats, and Appendix B presents a quantitative comparison of independently developed state GHG inventories and emissions data presented in this report.

Two additional points bear consideration by the reader. First, what follows in this report is an analysis of the GHG emissions landscape of the Midwest from 1990 through 2003 using the most comprehensive emissions data available that are also appropriate for a regional inventory and assessment. Although several Midwest states have previously compiled their own state GHG inventories (see Appendix B), the methodologies and data sources of these analyses differ, making it challenging to directly compare emissions across states. The data utilized here uniquely provide a common methodological framework for readily comparing GHG emissions. However, it is not the intent of this report to serve as a substitute for emission estimates that might be available from state or local agencies, where complementary or higher-resolution data sets could provide additional information.

Second, although general policy recommendations are often implicit in the analysis that follows, this report does *not* seek to prescribe any particular "climate policy" or assess the utility of policies already in place or currently being debated at the state and federal levels.

ANALYTICAL CONVENTIONS USED IN THIS REPORT

DATA SOURCES

Emissions data in this report are exclusively drawn from the Climate Analysis Indicators Tool – United States (CAIT-US) version 2.0, developed by the World Resources Institute (WRI). For more information regarding CAIT-US, its underlying data, and associated caveats, see Appendix A.

Additional indicators used in this report are obtained principally from federal government agencies and are cited throughout the report where applicable.

TREATMENT OF GREENHOUSE GASES AND EMISSIONS DATA

Unless otherwise noted, all GHG data presented in this report include emissions of the six GHGs recognized under the United Nations Framework Convention on Climate Change (UNFCCC): carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). HFCs, PFCs, and SF_6 are often collectively referred to as "F-gases."

All emission values in this report are expressed in million metric tons (tonnes) of CO_2 *equivalents* ($MtCO_2e$) using international standard 100-year *global warming potentials*[3] from the Intergovernmental Panel on Climate Change (1996). One metric ton is equal to 1.1 short tons (U.S. tons), or approximately 2,205 pounds.

GHG emissions data assessed here are for 1990 through 2003, the latest year for which a full six-gas, economy-wide inventory was available at the time of this publication. More recent and/or revised data will be released online at <http://cait.wri.org> as they become available.

REGIONAL AND ECONOMIC SECTOR DEFINITIONS

Discussions of the Midwest region refer to the following eight U.S. states: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin. This definition was mainly influenced by the participation

[3] To quantify the varying capacities of GHGs to convert solar radiation into heat energy during their atmospheric "lifetimes" (i.e., the extent to which a GHG contributes to global warming), the Intergovernmental Panel on Climate Change (IPCC) developed a global warming potential (GWP) index. CO_2, which has an atmospheric residence time (or lifetime) of decades to centuries, by definition has a GWP of 1; CH_4 has a GWP value of 21, or 21 times the global warming potential of CO_2; and N_2O has a GWP of 310, assuming 100-year time horizons (IPCC, 1996). 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. Emissions of non-CO_2 gases (i.e., CH_4, N_2O, F-gases) are commonly expressed in terms of "CO_2 equivalents," to account for their different GWPs relative to CO_2.

of these same eight states as they explored the development of a regional GHG registry and their desire for a more complete regional emissions inventory analysis.

Economic sector definitions (highlighted in **bold**, below) follow the guidance documents of the Emissions Inventory Improvement Program (see Appendix A).

Energy sectors are dominated by the production of CO_2 from the combustion of fossil fuels (coal, oil, and natural gas), although CH_4 and N_2O are also produced during fuel burning. These sectors include **electric generation;** the burning of fuels for **transportation,** including road, rail, and air; **industrial** energy use for activities such as chemical production; and the fuel used to heat **residential** and **commercial** buildings (e.g., natural gas).

NOTE: In the discussions that follow, emissions that result from the direct combustion of fossil fuels are reported for the commercial, industrial, and residential sectors. Reported total emissions for these sectors do not include emissions from electricity use, unless it is generated on site; electricity use by these sectors, and its associated emissions, are included in the electric generation sector. Hence, sectoral emission estimates that included electricity generation in these sectors would result in higher estimates than those reported here.

Emissions classified as **fugitive emissions** are considered a subset of energy use. They are byproducts of the mining and processing of fossil fuels—coal mining, oil refining, and natural gas transmission—as opposed to the combustion of fuels to produce energy. *Only emissions from coal mining are included in this study* (see Appendix A). Therefore fugitive emissions presented in this report only include CH_4 gas.

Nonenergy emissions include emissions classified under industrial processes, agriculture, and waste. Emissions from **industrial processes** arise from the production processes of raw materials, as opposed to the fuels consumed to produce them. For instance, CO_2 is regularly produced in chemical manufacturing. CO_2 is also a byproduct of the conversion of calcium carbonate into lime to make cement. Industrial processes are also the source of all F-gas emissions included in this report. **Agriculture** emissions include CH_4, which comes from manure and the digestive processes of ruminant livestock, and N_2O, which arises principally from commercial soil management and the application of nitrogen fertilizers. Emissions from **waste** (wastewater and landfill off-gassing) consist mostly of CH_4, but include some emissions of N_2O. GHG emissions of key sectors in the Midwest are the focus of Chapter 3.

Emissions data for two sectors are *excluded* from this report's principal analysis because of data uncertainties and difficulties in the assignment of emissions to individual states (see Appendix A for more information):

- Emissions from **international bunkers** — the activities that take place outside of national boundaries (e.g., emissions from ships in international waters);
- Net CO_2 emissions or sequestration estimates from **land-use change and forestry** (**LUCF**).

A brief discussion of the Midwest LUCF sector is provided as supplementary information.

2 MIDWEST GHG EMISSIONS IN A NATIONAL AND INTERNATIONAL CONTEXT

Greenhouse gas (GHG) emissions can be assessed in many different ways. Most commonly, figures of total emissions and/or emissions per capita (per person) are used to convey the magnitude of GHG production in a country, region, or state. However, these metrics alone are insufficient for policy formulation.

This chapter provides a summary of Midwest emissions and emissions growth by analyzing total regional GHG emissions, emissions disaggregated by economic sector and by gas, emission trends and their principal socioeconomic drivers, and emissions per capita. It also seeks to contextualize Midwest emissions by comparing regional GHG emissions to corresponding national and international emission indicators.

TOTAL EMISSIONS

- **The Midwest contributes approximately 25 percent of U.S. GHG emissions and 5 percent of world emissions.**
- **In 2003, Midwest GHG emissions totaled 1,562 $MtCO_2e$, representing 23 percent of the U.S. total.**
- **If the Midwest were its own country, it would be the fifth largest emitter in the world.**

The Unites States has the world's largest national economy and the third largest population (behind China and India). It is also the world's leading emitter of GHG pollution, generating 6,737 $MtCO_2e$ in 2003.[4] The eight Midwest states considered here—Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin—comprise roughly 20 percent of the U.S. population and gross domestic product (GDP), and accounted for approximately 23 percent (1,562 $MtCO_2e$) of total U.S. GHG emissions in 2003. Ohio, Indiana, Illinois, and Michigan are among the top 10 GHG-emitting states in the United States, and all eight Midwest states are among the top 25 emitters (Table 2.1).

The Midwest is also a significant GHG emitter in an international context, contributing nearly 5 percent of total world GHG emissions. Compared to other countries, the Midwest is the fifth largest emitter in the world, behind India and ahead of Japan (Table 2.2). From a North American perspective, the Midwest's GHG emissions are approximately 30 percent greater then the emissions of Canada and Mexico combined.

4. This total is from CAIT-US (2007). According to the most recent edition of the U.S. *Inventory of Greenhouse Gas Emissions and Sinks* (EPA, 2007), U.S. emissions in 2003 totaled 7,104 $MtCO_2e$, excluding emissions from international bunker fuels and carbon sequestration from land-use change and forestry. The difference in values is largely due to CAIT-US methodologies and data omissions documented in Appendix A.

Table 2.1 | **Top 25 GHG-Emitting U.S. States**

STATE	GHG EMISSIONS ($MtCO_2e$)	% OF U.S. GHGs
1. Texas	782	11.6
2. California	453	6.7
3. Pennsylvania	301	4.5
4. Ohio	**299**	**4.4**
5. Florida	271	4.0
6. Indiana	**269**	**4.0**
7. Illinois	**268**	**4.0**
8. New York	244	3.6
9. Michigan	**212**	**3.1**
10. Louisiana	209	3.1
11. Georgia	186	2.8
12. North Carolina	168	2.5
13. Alabama	164	2.4
14. Kentucky	164	2.4
15. Missouri	**163**	**2.4**
16. Virginia	143	2.1
17. Tennessee	141	2.1
18. New Jersey	137	2.0
19. West Virginia	133	2.0
20. Oklahoma	124	1.8
21. Wisconsin	**123**	**1.8**
22. Minnesota	**120**	**1.8**
23. Iowa	**108**	**1.6**
24. Colorado	107	1.6
25. Kansas	101	1.5
Midwest	***1,562***	***23.2***
Top 25	***5,389***	***80.0***
Bottom 25	***1,348***	***20.0***
U.S. Total	***6,737***	***100.0***

Source: WRI, CAIT-US (2007).

Notes: Data are for 2003. Totals exclude emissions from international bunker fuels and land-use change and forestry. "Bottom 25" includes Washington, DC.

EMISSIONS BY ECONOMIC SECTOR AND BY GAS

- **The electric generation, transportation, and industrial energy use sectors are the sources of 75 percent of the Midwest's total GHG emissions.**
- **Carbon dioxide (CO_2) constitutes nearly 90 percent of total emissions in the Midwest and the United States.**
- **Nitrous oxide (N_2O) emissions comprise a greater percentage of total GHG emissions in the Midwest than in the rest of the United States—most likely due to the region's extensive agricultural production.**

When comparing emissions across sectors, the Midwest is comparable to the United States as a whole. Energy use in various forms generates over 85 percent of GHG emissions in both contexts. Electricity

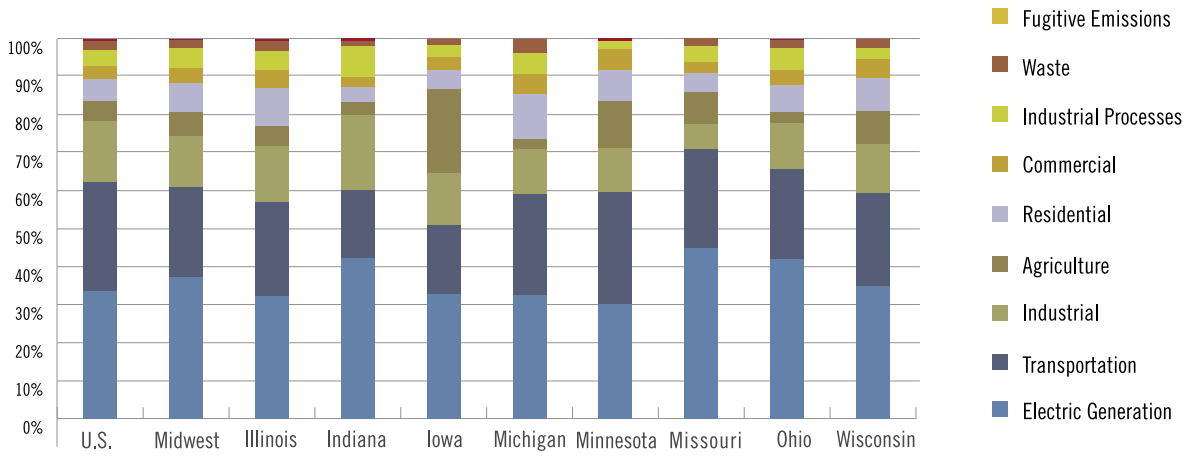
Table 2.2 | **Top 10 GHG-Emitting Countries Including the Midwest**

COUNTRY	GHG EMISSIONS ($MtCO_2e$)	% OF WORLD GHGs
1. United States	6,872	20.4
2. China	4,963	14.7
3. Russia	1,916	5.7
4. India	1,889	5.6
Midwest	**1,589**	**4.7**
5. Japan	1,352	4.0
6. Germany	1,013	3.0
7. Brazil	850	2.5
8. Canada	684	2.0
9. United Kingdom	659	2.0
10. Italy	532	1.6
Top 10	***20,730***	***61.5***
Rest of World	***12,983***	***38.5***
World Total	***33,713***	***100.0***

Sources: WRI, CAIT (2006); WRI, CAIT-US (2007).

Notes: Data are for 2000—the latest year for which an international six-gas inventory is available. Totals exclude emissions from international bunker fuels and land-use change and forestry.

Figure 2.1 | **Sectoral Shares of U.S., Midwest, and State GHG Emissions: 2003**



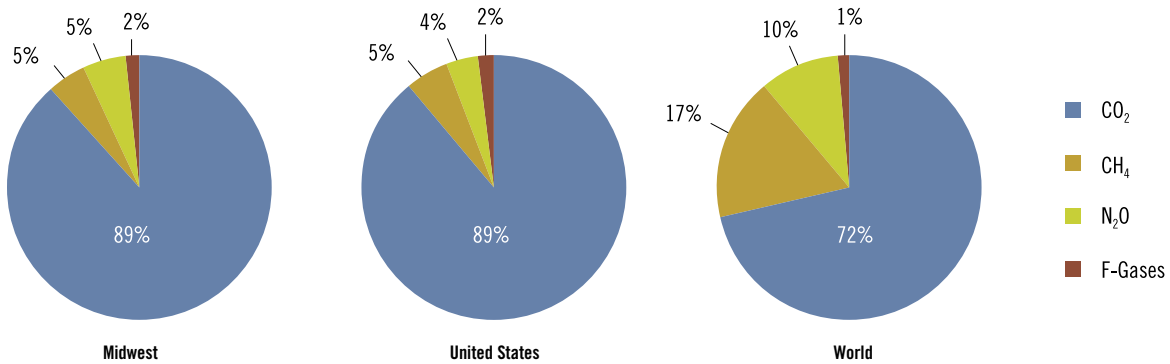
Source: WRI, CAIT-US (2007).

Note: Due to definitional differences between national and international sectors that make comparisons challenging, a "world" plot of emissions by sectoral shares is not included here.

generation alone contributes about 37 percent of Midwest emissions and 34 percent of U.S. emissions. Transportation contributes an additional 24 percent of emissions in the Midwest and 29 percent in the United States. The three largest emitting sectors in the Midwest and the nation as a whole—electric generation, transportation, and industry—are, together, responsible for approximately three-fourths of total GHG emissions (Figure 2.1). The next two largest emitting sectors in the Midwest—residential energy use and agriculture—constitute larger proportions of emissions for the Midwest than for the nation as a whole. GHG emissions from key economic sectors of the Midwest are the focus of Chapter 3, and are discussed in greater detail at the state level in Chapter 4.

The largest share of GHG emissions, by gas, for the Midwest, the United States, and the world is carbon

Figure 2.2 | **Midwest, U.S., and World GHG Emission Profiles by Gas**



Sources: WRI, CAIT (2006); WRI, CAIT-US (2007).

Notes: Midwest and U.S. data are for 2003. World data are for 2000—the latest year for which an international six-gas inventory is available. Data exclude emissions from international bunker fuels and land-use change and forestry. Totals may not add up to 100 percent due to independent rounding.

dioxide (CO_2), principally from the combustion of fossil fuels in various forms. CO_2 accounts for approximately 89 percent of total emissions in both the Midwest and the nation as a whole, but only 72 percent of emissions globally (Figure 2.2). The smaller contribution of CO_2 in the "world" emissions profile is due to the greater role agrarian-based economies play in developing countries compared to developed nations, such as the United States. Methane (CH_4) and nitrous oxide (N_2O) emissions—the principal byproducts of agricultural practices—therefore constitute a greater percentage of total emissions. Similarly, the Midwest—a relatively agriculturally intensive U.S. region—has a GHG profile with a greater total proportion of CH_4 and N_2O than the rest of the country. Additionally, N_2O emissions constitute a larger percentage of emissions in the Midwest profile than in the U.S. profile. This is likely a result of the widespread production of fertilizer-intensive crops in the Midwest, such as corn. The Midwest agriculture sector is discussed further in Chapter 3.

EMISSION TRENDS

• Total Midwest GHG emissions increased by 11 percent between 1990 and 2003, while total U.S. emissions increased by 13 percent during the same time period.

• Between 1990 and 2003, the electric generation and transportation sectors—the fastest-growing sectors in the Midwest—grew by 25 and 20 percent, respectively, comparable to national growth trends in these sectors.

• GHG emissions from industrial energy use declined by 11 percent—more than four times the national average. Total emissions from coal mining (fugitive emissions) and all nonenergy sectors (agriculture, industrial processes, and waste) also declined between 1990 and 2003.

Although a summary of recent GHG emission totals is useful, it is perhaps more important to assess changes in emissions over time. This allows for a clearer

Table 2.3 | **Midwest, U.S., and World GHG Emission Trends: 1990-2003**

STATE[a]	1990 EMISSIONS ($MtCO_2e$)	2003 EMISSIONS ($MtCO_2e$)	ABSOLUTE CHANGE ($MtCO_2e$)	AVERAGE ANNUAL % CHANGE	% CHANGE
Illinois	228	255	27	0.9	12
Indiana	222	247	25	0.8	11
Iowa	92	105	14	1.1	15
Michigan	199	200	1	< 0.1	1
Minnesota	98	117	19	1.4	20
Missouri	123	156	32	1.8	26
Ohio	269	281	12	0.3	5
Wisconsin	105	120	15	1.0	14
Midwest	***1,336***	***1,481***	***145***	***0.8***	***11***
United States	***5,720***	***6,458***	***739***	***0.9***	***13***
World[b]	***30,540***	***33,713***	***3,173***	***0.8***	***10***

Sources: WRI, CAIT (2006); WRI, CAIT-US (2007).

Notes: All totals exclude emissions from international bunker fuels and land-use change and forestry.
a. Emissions from industrial processes are excluded in state, Midwest, and U.S. totals.
b. The 2003 World total is for the year 2000—the latest year for which an international six-gas inventory is available. Calculations of absolute change, average annual percent change, and total percent change utilize 1990 and 2000 values.

Table 2.4 | **Midwest and U.S. GHG Emission Trends by Sector: 1990-2003**

	MIDWEST					U.S.
SECTOR	1990 EMISSIONS ($MtCO_2e$)	2003 EMISSIONS ($MtCO_2e$)	ABSOLUTE CHANGE ($MtCO_2e$)	AVERAGE ANNUAL % CHANGE	% CHANGE	% CHANGE
Energy Sectors	*1183*	*1346*	*163*	*1.0*	*14*	*14*
Electric Generation	465	583	118	1.7	25	24
Transportation	306	368	61	1.4	20	19
Industrial	238	211	-27	-0.9	-11	-3
Residential	109	118	9	0.6	8	12
Commercial	58	63	5	0.6	9	7
Fugitive Emissions	7	4	-3	-3.9	-40	-35
Agriculture	111	102	-9	-0.7	-8	0
Industrial Processes[a]	85	81	-4	-0.9	-5	8
Waste	42	34	-9	-1.8	-21	-9

Source: WRI, CAIT-US (2007).

Notes: Data exclude emissions from international bunker fuels and land-use change and forestry.

a. Due to data inconsistencies, Industrial Processes totals are for 1997 and 2003. Calculations of absolute change, average annual percent change, and total percent change for this sector utilize 1997 and 2003 values.

relationship to be established between emission trends and the particular influences that determine emission trajectories, also known as emission drivers (see below).

NOTE: Estimates of emissions from certain industrial process sources—most notably emissions from the production of iron and steel—are unavailable for 1990–96, creating an artificial growth in state emissions in 1997. This is problematic when comparing the absolute or percent change between 1990 and 2003 values, particularly in states where iron and steel production constitutes a significant source of emissions. Therefore, regional- and state-level emission trends discussed in this report, as well as the emission totals presented in Table 2.3, exclude emissions from industrial processes. As a result, readers will note that total GHG emission values for 2003 in Table 2.3 are lower than those presented earlier in this chapter.

From 1990 to 2003, the Midwest's GHG emissions increased by 11 percent, comparable to the 13 percent increase observed for the nation as a whole. The growth in Midwest GHG emissions was also comparable to the rise in global emissions during this period (Table 2.3).

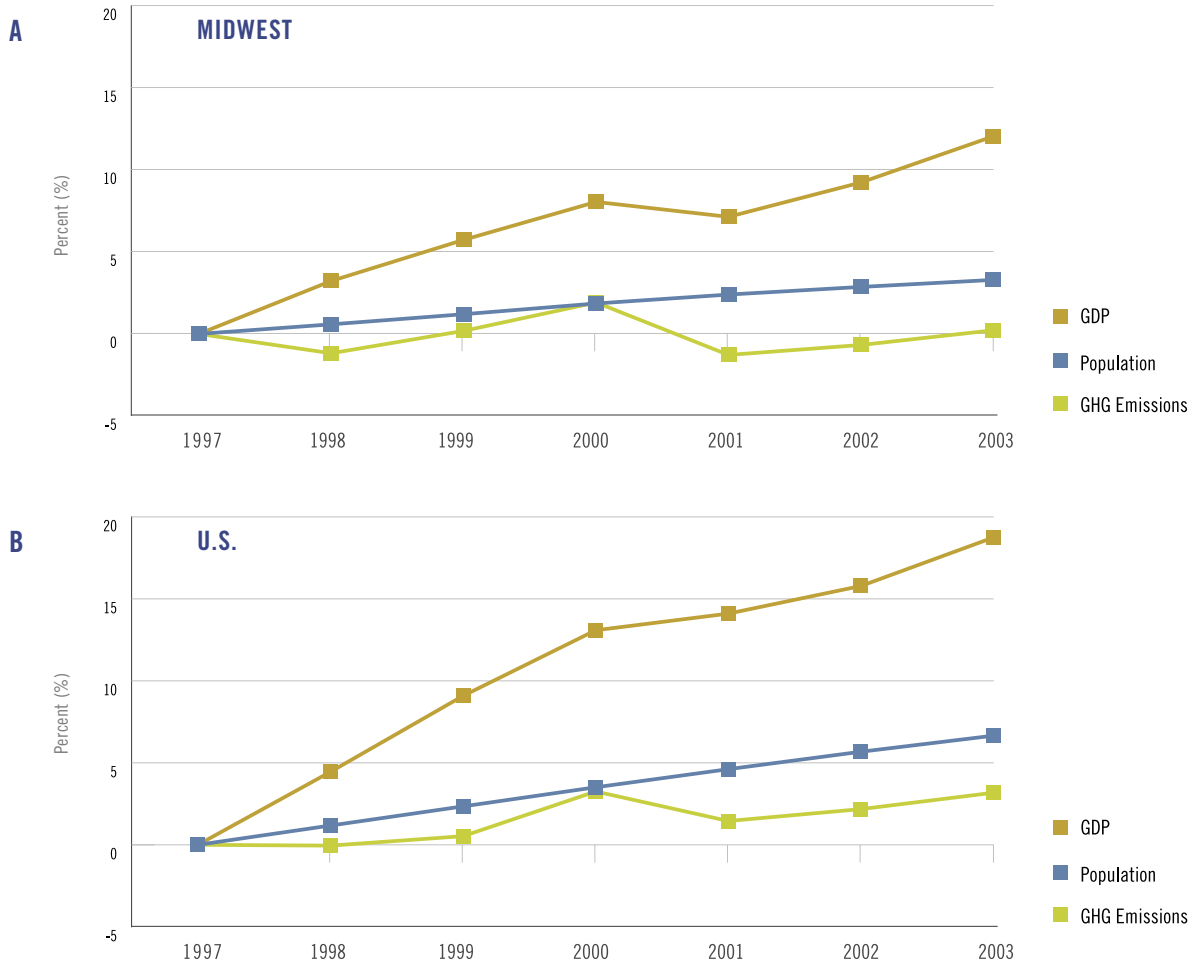
All Midwest states experienced a growth in absolute emissions between 1990 and 2003, although there was substantial variability: growth in total GHG emissions ranged from an increase of 1 percent in Michigan (<0.1 percent average annual growth) to 26 percent in Missouri (1.8 percent average annual growth). Discussions of the particular emission drivers for each state are presented in Chapter 4.

Trends in total state emissions are determined by the cumulative changes in sectoral emissions. In the Midwest, GHG emissions from all energy sectors increased by 14 percent between 1990 and 2003, equivalent to that of the nation as a whole. Emissions from the two major emitting energy sectors in the Midwest—electric generation and transportation—grew by 25 and 20 percent, respectively, between 1990 and 2003 (Table 2.4). The growth experienced in these sectors was largely responsible for the aggregate emissions growth trend in the Midwest (Table 2.3). At the national level, these sectors grew slightly less during the same time period—24 percent for electric generation and 19 percent for transportation (Table 2.4).

Between 1990 and 2003, emissions from the Midwest industrial sector decreased by four times that of the

nation as a whole, largely due to changes in the region's fuel mix, efficiency gains, and, for some states, limited economic growth (see Chapter 3). Fugitive emissions also declined during this time period, although this source of emissions is relatively small, constituting less than 1 percent of total regional emissions. Emissions from all nonenergy sectors of the Midwest—agriculture, industrial processes, and waste—also declined, primarily as a result of improved sector efficiencies. U.S. totals contrast, somewhat, showing essentially no change in agriculture emissions, an increase in emissions from industrial processes, and a less rapid decline in emissions from the waste sector between 1990 and 2003 (Table 2.4).

Figure 2.3 | **Percent Change in Midwest and U.S. GDP, Population, and GHG Emissions: 1997-2003**



Sources: WRI, CAIT-US (2007); U.S. Census (2006); BEA (2007).

Note: Percentage changes for each year are relative to 1997 totals.

EMISSION DRIVERS

• Midwest GHG emissions growth has largely been driven by increases in regional population and economic output.

• Midwest emissions from the electric generation and transportation sectors increased more than national emissions from these sectors, despite the fact that the growth of the Midwest's population and economy was slower than the national average.

• Per capita emissions in the Midwest are approximately 26 metric tons of CO_2e—13 percent higher than the U.S. average and more than 400 percent of the world average.

Total emissions and emission trends at the state, regional, and national levels are largely determined by macro-level socioeconomic factors, including population dynamics and economic output, as well as the aggregate actions of individuals.

SOCIOECONOMIC FACTORS

In general, U.S. states and regions with relatively large populations and economies tend to produce the most GHGs on an absolute basis. As evidence, 20 of the top 25 GHG-emitting states are also among the top 25 states in terms of population and state gross domestic product (GDP). Seven of the eight states in the Midwest are included in this group (U.S. Census, 2006; BEA, 2007). Iowa is currently a top 25 GHG emitter, but ranks 30th and 29th in population and state GDP, respectively.

However, the relationship between these socioeconomic drivers and emissions is nuanced, and exogenous factors can introduce additional complexities. If we look at trends in state population growth and economic output and compare them to trends in total GHG emissions, it is clear that there is not a direct correlation. Figure 2.3 shows that the population and GDP of both the Midwest and the nation have increased steadily since 1997[5], although the Midwest's growth was slower than that of the nation. Total GHG emissions also increased, although noticeable declines in emissions occurred in 1998 and 2001 in both the Midwest and the nation. The 1998 decline, which was more prominent in the Midwest, was largely attributable to an unusually warm winter and, hence, a reduction in overall residential and commercial use of fuel for heating. The decline in 2001, which was due to a mild, national economic recession, is also captured in the GDP plots in Figure 2.3.

An analysis of macroeconomic emission drivers can also be particularly informative when driver trends do not produce the expected trends in emissions. For example, as noted in the previous Emission Trends section, Midwest emissions from the electric generation and transportation sectors increased more than national emissions from these sectors. However, this growth was clearly not solely determined by regional growth in population and economic output, which increased more slowly than the national average (Figure 2.3).

Additional factors, such as economy type (e.g., industrial, agricultural) and a sector's or a state's fuel mix, can also play a significant role in determining emission totals and trends. A comprehensive examination of the principal drivers of GHG emissions in the Midwest most likely requires multi-indicator comparisons, which are beyond the scope of this study's analysis. Nevertheless, to the extent possible, trends in the macroeconomic drivers noted above and their relationship to emissions are assessed throughout this report.

INDIVIDUAL ACTIONS

Societal decisionmaking also plays a key role in determining the amount and type of GHG emissions over time. For example, F-gas emissions from the industrial processes sector have increased nationally since 1990, largely because of the rapid expansion of substitutes for banned ozone-depleting substances (EPA, 2007).

[5] Due to a change in definitions, there is a discontinuity in GDP by state data between 1996 and 1997. The U.S. Bureau of Economic Analysis warns against producing time series and calculating trends across this interval. Therefore, we have only analyzed data from 1997 to 2003. For more information, please see <http://www.bea.gov/regional/gsp/>.

Table 2.5 | **Midwest, U.S., and World GHG Emissions per Capita**

STATE	PER CAPITA EMISSIONS (Metric tons CO_2e per person)
Illinois	21
Indiana	44
Iowa	37
Michigan	21
Minnesota	24
Missouri	28
Ohio	26
Wisconsin	23
Midwest	***26***
United States	***23***
World	***6***

Source: WRI, CAIT-US (2007).

Notes: Midwest and U.S. data are for 2003. World data are for 2000—the latest year for which an international six-gas inventory is available. Data exclude emissions from international bunker fuels and land-use change and forestry.

Meanwhile, waste emissions have declined in both the Midwest and the nation since 1990, as recovery and flaring of methane from landfills have become more prevalent.

In addition to regulated or voluntary industry practices, the activities of our everyday lives are critical to determining the magnitude of GHG emissions and, hence, global warming. Whether driven by the financial "bottom line" or personal preference, how much electricity we use, what type of car or how often we drive, and our consumption of goods (copy paper, plastic bags, computers, cell phones, food, furniture, etc.) are some of the most tangible drivers of GHG emissions. As consumers of natural resources, our habits and actions directly and indirectly produce GHG emissions, and, in aggregate, send signals to industries and policymakers alike about how resources, including the climate system, are valued. Although changes in the actions of individuals cannot substitute for effective policy, they ultimately address the source of global warming and will become more acute as Midwest, U.S., and world populations continue to grow.

Therefore, it is instructive to calculate emissions per capita as part of a comprehensive GHG emission analysis. This metric is particularly useful for placing a country, region, or state into context, since an area may have relatively few total emissions due to a smaller population, but may still be carbon intensive on a per person basis. Conversely, an area may have a relatively high absolute emissions total resulting from a large population, but that population may be less carbon intensive overall.

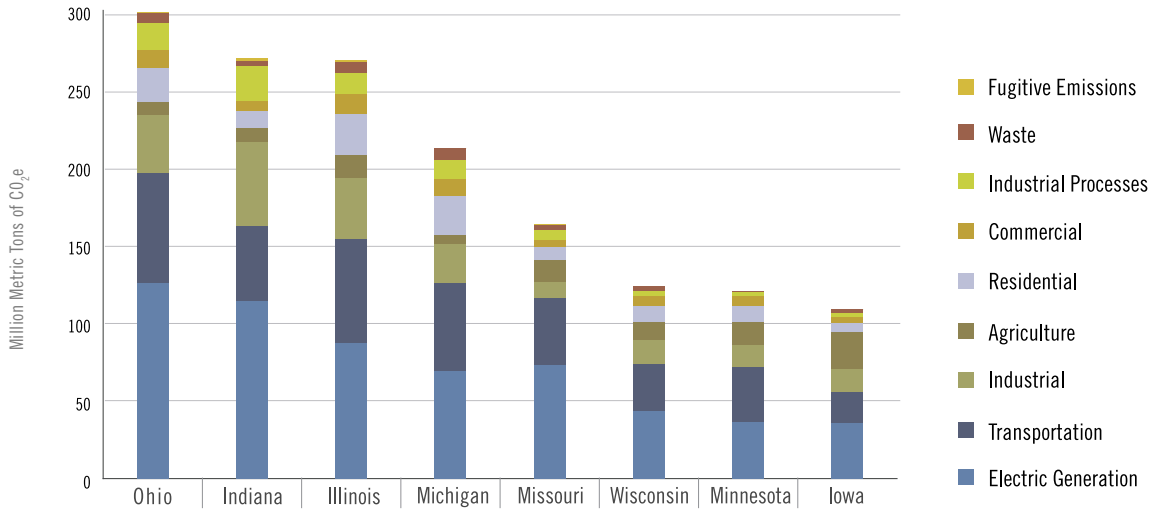
As a region, the Midwest's emissions per capita are approximately 13 percent greater than the U.S. average. The Midwest, like the rest of the nation, has a per capita emissions value that is approximately four times that of the world average, which is around 6 metric tons of CO_2e per person (Table 2.5). Emissions per capita figures for individual states are discussed in Chapter 4.

3 GHG EMISSIONS OF SELECT MIDWEST ECONOMIC SECTORS

To better understand greenhouse gas (GHG) emissions in the Midwest, it is useful to take a closer look at important economic sectors. Analyzing emissions and trends from a sectoral perspective helps to identify the areas of the economy that are the largest contributors to the buildup of GHGs in the atmosphere, and assessing the underlying causes of sectoral emissions is particularly relevant for policy discussions.

Given the variety among state sectoral emission profiles (Figure 3.1), it is clear that a regional sectoral analysis may not be applicable to each Midwest state. However, in general, three energy sectors—electric generation, transportation, and industry—as well as agriculture are large emitters in all Midwest states. Collectively, these four sectors accounted for 81 percent of Midwest GHG emissions in 2003. Therefore, they are examined in more detail in this chapter.

Figure 3.1 | **Total GHG Emissions of Midwest States by Economic Sector: 2003**



Source: WRI, CAIT-US (2007).

Table 3.1 | **GHG Emissions from Electricity Generation, State Rank, and Trends: 1990–2003**

STATE	1990 EMISSIONS ($MtCO_2e$)	2003 EMISSIONS ($MtCO_2e$)	2003 U.S. RANK	1990-2003 EMISSION TRENDS		
				ABSOLUTE CHANGE ($MtCO_2e$)	AVERAGE ANNUAL % CHANGE	% CHANGE
Ohio	109	126	2	17	1.1	16
Indiana	95	114	5	19	1.4	20
Illinois	57	87	6	30	3.3	53
Missouri	47	73	11	26	3.4	54
Michigan	68	69	12	2	0.2	2
Wisconsin	33	43	19	10	2.0	29
Minnesota	30	36	25	7	1.5	22
Iowa	27	36	26	9	2.2	33
Midwest	***465***	***583***	***N/A***	***118***	***1.7***	***25***
United States	***1815***	***2257***	***N/A***	***442***	***1.7***	***24***

Source: WRI, CAIT-US (2007).

ELECTRIC GENERATION

• At over half a billion metric tons region-wide, the electric power sector is the largest GHG-emitting sector in the Midwest.

• Three Midwest states—Ohio, Indiana, and Illinois—rank among the top 10 states nationally in terms of GHG emissions from electricity generation.

• All Midwest states except Illinois generate more than 50 percent of their electricity from coal, the most GHG-intensive fossil fuel.

• The Midwest as a whole generates approximately 76 percent of its electricity from fossil fuels, 5 percent more than the nation as a whole.

• Coal combustion is the source of 96 percent of Midwest GHG emissions from electric generation.

• Region-wide, growth in GHG emissions from electric generation is similar to increases in total electricity generation and demand.

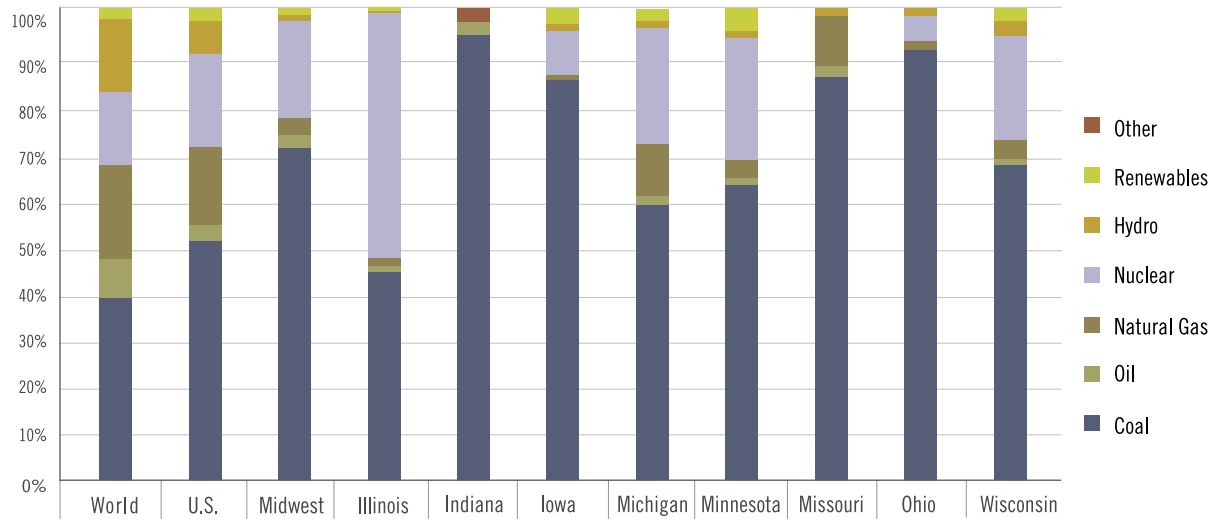
• Between 1990 and 2003, growth in GHG emissions from electricity generation was fastest in Illinois and Missouri; in both states, this growth was largely due to increases in the generation of electricity for export, not to meet in-state demand.

Electricity generation in the Midwest accounts for approximately 37 percent of the region's total GHG emissions. In 2003, Midwest GHG emissions from electricity generation totaled 25 percent of the national total, or 580 $MtCO_2e$; for comparison, this value is greater than the total GHG emissions of most countries, including France and Italy, which have population sizes comparable to the Midwest (WRI, CAIT, 2006). Ohio and Indiana each accounts for more than 5 percent of national electric generation emissions, and rank second and fifth, respectively, in total national sectoral emissions (Table 3.1). With the exception of Iowa, all Midwest states rank among the top 25 states, nationally, in terms of GHG emissions from electricity generation.

Emissions from electricity generation in the Midwest grew by 25 percent between 1990 and 2003, slightly faster than the 24 percent growth experienced nationally. During the same period, growth in GHG emissions in four Midwest states (Illinois, Iowa, Missouri, and Wisconsin) exceeded national growth by 5–30 percent (Table 3.1).

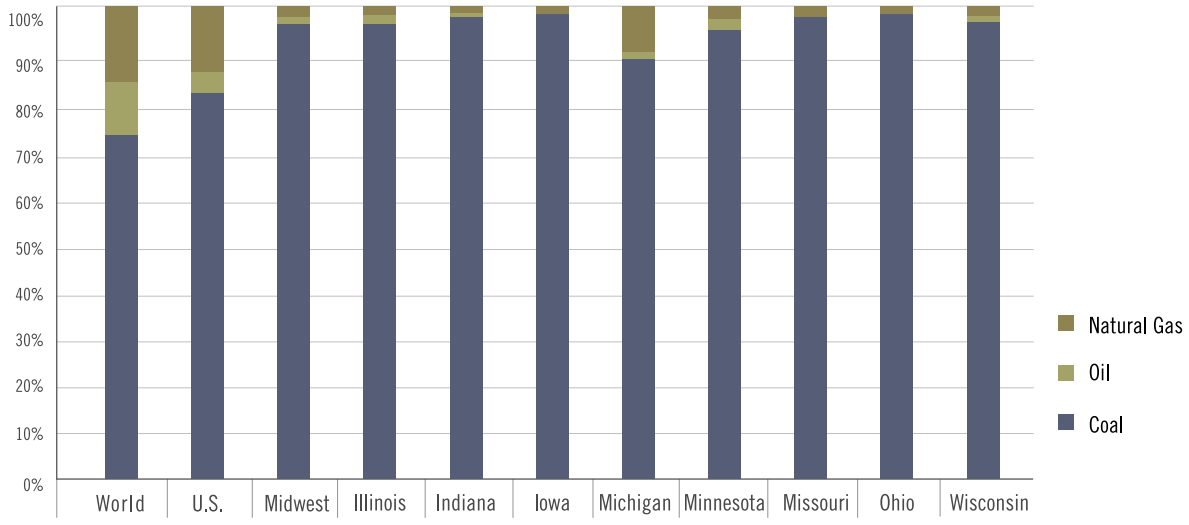
To a large extent, the emissions from electricity generation are determined by the fuel mix. Figure 3.2 compares state electricity fuel mixes to those of the region, the nation, and the world; Figure 3.3 presents GHG emissions from electricity generation by fuel for the same areas. The figures show that the Midwest as

Figure 3.2 | **World, U.S., Midwest, and State Fuel Mix in the Electric Generation Sector: 2003**



Sources: WRI, CAIT-US (2007); EIA (2007); IEA (2006).

Figure 3.3 | **World, U.S., Midwest, and State Electric Generation GHG Emissions Share by Fuel: 2003**



Sources: WRI, CAIT-US (2007); IEA (2006).

Table 3.2 | **Percentage Change in Midwest and U.S. GHG Emissions, Generation, and Retail Sales in the Electric Generation Sector: 1990-2003**

STATE	GHG EMISSIONS	ELECTRICITY GENERATION	ELECTRICITY SALES
Illinois	53	46	22
Indiana	19	23	36
Iowa	33	40	40
Michigan	2	11	32
Minnesota	22	28	34
Missouri	54	47	38
Ohio	16	15	7
Wisconsin	29	26	37
Midwest	***25***	***28***	***26***
United States	***24***	***28***	***29***

Sources: WRI, CAIT-US (2007); EIA (2007).

a whole generates 20 percent more electricity from coal—the most carbon-intensive fossil fuel source—than the national average and 32 percent more than the world average. At the state level, over 90 percent of the electricity generated in Indiana and Ohio is coal-based, while in three other states, at least 70 percent of electricity is derived from coal. In fact, Illinois is the only Midwest state that does not rely on coal to generate a majority of its electric power.

Instead, Illinois generates about 50 percent of its electricity using nuclear power (also see Illinois State Spotlight)—another important component of the Midwest's electricity generation fuel mix (Figure 3.2). Though nuclear power does have environmental impacts (including GHG emissions) from fuel mining and processing as well as waste disposal, it does not directly emit GHGs when generating electricity. All Midwest states except Indiana use nuclear power to generate some portion of their electricity, though in Iowa, Missouri, and Ohio nuclear power accounts for less than 10 percent of total generation.

Other power sources constitute smaller percentages of Midwest electric generation. Natural gas, the least carbon-intensive fossil fuel, is not used in any large amount in the Midwest states, with the exception of Michigan, where it accounts for 8 percent of generation. Similar to the nation as a whole, oil accounts for less than 2 percent of electricity generation in all Midwest states (and less than 1 percent in the region as a whole). Hydropower generation is comparably small; only in Wisconsin is the contribution from hydropower greater than 3 percent. Renewable energy, primarily from wind power, accounts for only 1 percent of Midwest electricity generation. Minnesota exceeds the region and the nation in this regard, with 5 percent of its electricity generation derived from renewable energy sources.

The Midwest's collective reliance on coal and, to a much lesser extent, nuclear generation, and its limited use of renewable power sets the region apart from the rest of the nation. Fully 96 percent of the Midwest's electric power GHG emissions are from coal combustion, while natural gas accounts for only 3 percent (Figure 3.3). Michigan, due to its relatively abundant utilization of natural gas (Figure 3.2), is the only Midwest state with less than 95 percent of its electric power GHG emissions coming from coal combustion.

Another principal driver of the observed growth in electric generation sector emissions is the increase in electricity generation in Midwest states to meet demand, locally or elsewhere (i.e., across state lines). At present, the Midwest generates approximately 20 percent of the nation's electricity, with all Midwest states experiencing at least a 10 percent growth in electricity generation between 1990 and 2003 (EIA, 2007).

Within the region, nearly 64 percent of electricity consumption takes place in residential buildings (33 percent) or commercial buildings (31 percent), with the remainder consumed by the industrial sector and less than one percent used for transportation (EIA, 2007). Growing electricity consumption in these sectors has partly led to an overall growth in sectoral GHG emissions.

However, electricity generation in some states is not necessarily increasing to meet the needs of in-state consumers. Notably, between 1990 and 2003, electricity generation in Illinois and Missouri grew by more than 45 percent; consequently, these two states also had the largest growth in GHG emissions. This growth was fueled largely by demand from customers in the eastern United States, who purchased electricity through the newly developed wholesale market. This is evidenced by the fact that these two states'

Table 3.3 | **GHG Emissions from Transportation, State Rank, and Trends: 1990–2003**

STATE	1990 EMISSIONS ($MtCO_2e$)	2003 EMISSIONS ($MtCO_2e$)	2003 U.S. RANK	1990-2003 EMISSION TRENDS		
				ABSOLUTE CHANGE ($MtCO_2e$)	AVERAGE ANNUAL % CHANGE	% CHANGE
Ohio	58	70	6	13	1.5	22
Illinois	56	66	7	10	1.3	18
Michigan	49	56	10	7	1.0	14
Indiana	42	48	14	6	1.0	14
Missouri	35	42	16	8	1.5	22
Minnesota	25	35	19	11	2.8	43
Wisconsin	25	30	25	5	1.3	19
Iowa	17	20	32	3	1.2	17
Midwest	***306***	***368***	***N/A***	***62***	***1.4***	***20***
United States	***1,630***	***1,941***	***N/A***	***311***	***1.4***	***19***

Source: WRI, CAIT-US (2007).

electricity demand (measured by in-state retail sales) increased far less than their generation; thus, the additional electricity was generated to serve out-of-state demand (Table 3.2).

TRANSPORTATION

• Midwest GHG emissions from transportation grew slightly faster than national emissions for this sector between 1990 and 2003, as more miles were driven per person in the region.

• Three states—Ohio, Illinois, and Michigan—rank in the top 10 nationally for GHG emissions from transportation.

• While most states tracked or lagged behind national emission growth trends between 1990 and 2003, Minnesota's emissions from transportation grew twice as fast as Midwest and national emissions from transportation.

• Emissions from gasoline combustion in passenger vehicles make up the majority of Midwest emissions from transportation.

• Drivers in the Midwest traveled 19 percent more miles on average in 2003 than they did in 1990, increasing GHG emissions from transportation.

• The Midwest is home to three of the top 10 busiest airports in the country: Chicago O'Hare, Minneapolis-St. Paul, and Detroit Metro Wayne County. These airports, along with Greater Cincinnati and Chicago Midway, experienced large increases in passenger traffic between 1994 and 2004.

Transportation is the second largest GHG-emitting sector in the Midwest, accounting for 24 percent of total regional emissions. All Midwest states except Iowa rank in the top 25 nationally, with regard to transportation emissions, and Ohio, Illinois, and Michigan rank in the top 10 (Table 3.3).

Transportation emissions in the Midwest increased by 20 percent between 1990 and 2003, 1 percent greater than national emissions over the same period. However, growth varied across states (Table 3.3). Five states—Illinois, Iowa, Missouri, Ohio, and Wisconsin—experienced transportation sector emissions growth that was similar (within two to three percentage points) to that experienced regionally and nationally. Indiana and Michigan experienced emissions growth that was approximately 5-6 percentage points less than the Midwest and the nation as a whole. Conversely, at 43 percent, Minnesota's transportation emissions grew more than twice as much as regional and U.S. emissions during this period (on a percentage basis).

Transportation emission trends are largely determined by trends in passenger vehicle use. Two key indicators of vehicle use—vehicle miles traveled (VMT) and VMT per capita—are presented in Table 3.4 for the Midwest

and United States. Between 1990 and 2003, VMT per capita increased by similar amounts in the Midwest and nationally, while total VMT increased by 6 percent more nationally than in the Midwest. The latter trend is most likely due to faster population growth in states outside of the Midwest.

Table 3.4 | **Midwest and U.S. Vehicle Miles Traveled, Vehicle Miles Traveled per Capita, and Trends**

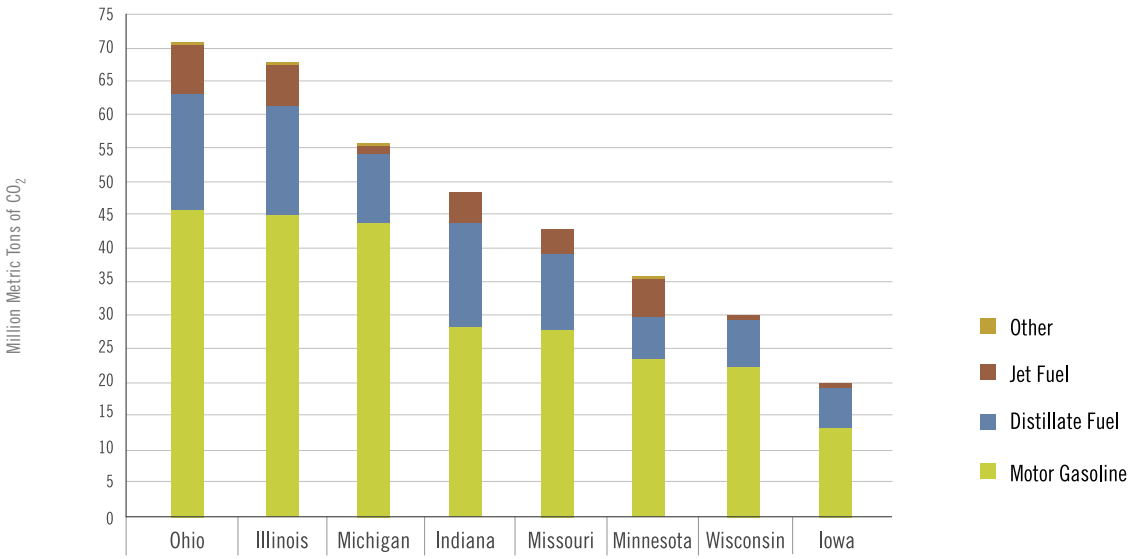
STATE	VEHICLE MILES TRAVELED (Billions)		VEHICLE MILES TRAVELED PER CAPITA	
	2003	% CHANGE, 1990-2003	2003	% CHANGE, 1990-2003
Ohio	109	19	9,566	14
Illinois	107	28	8,511	17
Michigan	101	24	10,071	15
Indiana	73	35	11,833	22
Missouri	68	34	12,079	22
Wisconsin	60	35	11,028	22
Minnesota	55	42	11,090	25
Iowa	31	35	10,610	28
Midwest	***603***	***29***	***10,218***	***19***
United States	***2,891***	***35***	***10,140***	***18***

Source: Bureau of Transportation Statistics (2007).

In Minnesota, where transportation emissions growth was largest between 1990 and 2003, VMT increased more than in any other Midwest state, and VMT per capita increased more than in all other Midwest states except for Iowa during this time period. Transportation emissions in Minnesota are driven both by increases in population (approximately 15 percent between 1990 and 2003, equivalent to the national average, but greater than all other Midwest states), and by a 25 percent increase in the VMT per person per year, as compared with 1990 (U.S. Census, 2006; Bureau of Transportation Statistics, 2007).

Reliable and comparable state-level emissions data by mode of transport are largely unavailable. However, emission estimates derived from fuel consumption are provided in Figure 3.4. These data contain greater detail on emissions from the consumption of petroleum products in the Midwest in 2003. Figure 3.4 clearly shows that gasoline combustion from passenger vehicles is the primary source of petroleum-based emissions, followed by distillate fuel (diesel) used in trucking, public transportation, farm equipment, and off-road vehicles. Jet fuel is the third largest source, with other fuels, such as residual fuel oil, aviation gasoline, and liquid petroleum gas, making up a small fraction of emissions.

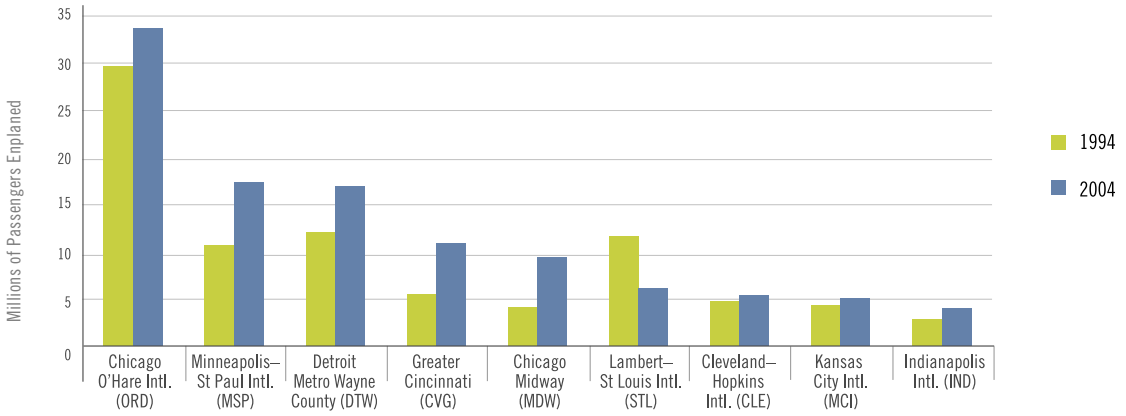
Figure 3.4 | **Estimated Midwest CO_2 Emissions from Petroleum Consumption by Fuel: 2003**



Source: EIA (2007).

Note: Consumption of jet fuel is based on sales and may not accurately assign emissions to each state. For example, a large volume of jet fuel used at Chicago airports is purchased in Indiana.

Figure 3.5 | **Passengers Enplaned on Large U.S. Carriers at Major Midwest Airports: 1994 and 2004**



Source: Bureau of Transportation Statistics (2005).

VMT and VMT per capita trends best explain growth in emissions from gasoline use, as this is the principal fuel used in passenger vehicles. However, in the two states with the lowest growth in transportation emissions—Indiana and Michigan—VMT and VMT per capita trends differ; therefore, an examination of fuel use is also critical.

Indiana experienced larger growth in VMT and VMT per capita than the nation as a whole, while Michigan experienced slower-than-average growth. Yet both states experienced similar growth in total transportation GHG emissions. The increase in VMT in Indiana had a lesser influence on overall emissions than in Michigan, because emissions from gasoline make up approximately 60 percent of the total. Conversely, slower increases in VMT and VMT per capita in Michigan had a larger influence on total emissions because gasoline accounts for over 80 percent of total emissions in this state.

Though emissions from jet fuel comprise the smallest contribution of total emissions in transportation, trends in this subsector can help explain overall emissions growth in the region. Given that the majority of air travel is interstate, it is difficult to accurately assign emissions from this activity to individual states. However, the Midwest is a national center of air travel, with several major hubs throughout the region. Therefore, it is important to consider this activity when examining transportation emissions. The volume of air passengers (in number of passengers enplaned—that is, passengers boarding commercial flights) at major Midwest airports is used here as an indicator of air travel activity. Air travel, via large U.S. carriers, saw a significant surge across the Midwest between 1994 and 2004, the years for which comprehensive data are available. This growth was in line with a similar increase across the nation. Three of the top 10 busiest airports in the country are in the Midwest: Chicago O'Hare, Minneapolis-St. Paul, and Detroit Metro Wayne County rank nationally at 2, 8, and 9, respectively (Bureau of Transportation Statistics, 2005).

All major Midwest airports experienced an increase in traffic between 1994 and 2004, with the exception of St. Louis International (Figure 3.5). Some airports in the region, namely Greater Cincinnati and Chicago Midway, doubled their traffic during this period, while St. Louis's traffic dropped by a similar proportion. Minneapolis-St. Paul saw the largest absolute increase in activity, with an additional 6.8 million passenger enplanements. Overall, if this surge in air travel continues, the Midwest will likely see a commensurate increase in total emissions from jet fuel combustion.

SECTOR HIGHLIGHT: ETHANOL

The Midwest has long been a significant producer and consumer of biofuels, with ethanol from corn being the most prevalent. Ethanol can displace gasoline use and, on average, results in 19 percent less GHG emissions as compared to gasoline, when the entire lifecycle of each fuel is considered (Farrell et al., 2006). The fact that ethanol can be produced from local feed stocks, as opposed to being imported from abroad, makes the fuel attractive from an energy security standpoint as well. Indeed, given that the Midwest is the nation's leading corn-producing region stimulating ethanol production and use is in these states' economic interest.

Despite these advantages, corn ethanol can have negative impacts on the environment, especially with regard to water quality and GHGs (principally nitrous oxide) from nitrogen fertilizer application for corn cultivation. It is important to note that these effects, while principally local, may be largely determined by trends in national markets. Other biofuels, such as biodiesel and ethanol produced from cellulose, offer other renewable options that may provide greater GHG reductions while also reducing other environmental impacts.

Table 3.5 | **Midwest and U.S. Ethanol Consumption, State Rank, Trends, and Share of Total Gasoline Blend**

STATE	2003 ETHANOL CONSUMPTION (Thousands of gallons)	2003 U.S. RANK	% CHANGE, 1990-2003	ETHANOL AS A PERCENT OF TOTAL GASOLINE AND ETHANOL BLENDS CONSUMPTION, 2003
Illinois	395,852	2	188	7
Minnesota	282,927	3	1,068	9
Ohio	188,873	4	78	3
Michigan	155,664	5	208	3
Indiana	134,820	6	113	4
Wisconsin	110,902	7	1,248	4
Iowa	107,318	8	189	6
Missouri	90,735	9	242	3
Midwest	***1,467,090***	***N/A***	***223***	***5***
United States	***2,826,012***	***N/A***	***278***	***2***

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

Nearly 52 percent of the nation's ethanol. The eight states of the Midwest rank 2–9 in total U.S. ethanol consumption; California is the nation's leading ethanol consumer. Ethanol consumption surged between 1990 and 2003, with Wisconsin and Minnesota experiencing growth rates of 1,248 and 1,068 percent, respectively (Table 3.5). These increases are nearly five times greater than those experienced in the region and the nation as a whole. Regionally, consumption in the Midwest increased by 223 percent, but this growth was still less than the 278 percent national growth. Increased ethanol consumption is likely due to several factors, including state and federal mandates for gasoline blends, state and federal incentives for biofuel production, and distribution and increases in the global price of oil.

Though the Midwest experienced less growth in ethanol consumption as compared to the nation, ethanol accounts for nearly 5 percent of total consumption of motor gasoline blends. Indeed, no Midwest state's gasoline blend contains less than 3 percent ethanol, while ethanol makes up only 2 percent of total U.S. gasoline blend consumption. Minnesota leads the region, with ethanol comprising more than 9 percent of its total gasoline blend consumption.

INDUSTRIAL ENERGY USE

- **With a decrease of 11 percent, the industrial sector is the only major energy-use sector where emissions declined in the Midwest between 1990 and 2003.**
- **Four states—Indiana, Illinois, Ohio, and Michigan—rank in the top 10 nationally when considering emissions from the industrial sector.**
- **The Midwest industrial sector relies much more on GHG-intensive fuels than the nation as a whole. As a result, 64 percent of Midwest industrial emissions come from petroleum and coal combustion, compared to 51 percent nationally.**
- **The decline in Midwest industrial emissions is largely due to an increase in process and energy efficiency and fuel switching to less GHG-intensive fuels. Region-wide, both GHG emissions and energy consumption decreased, while economic output increased.**
- **Ohio and Missouri are the only Midwest states that did not experience an increase in economic output from manufacturing while industrial GHG emissions and energy use declined.**

Industrial energy use is the third largest GHG-emitting sector in the Midwest, accounting for 14 percent of total regional emissions. All Midwest states except Minnesota and Missouri rank in the top 25, nationally, with regard to industrial emissions, and Indiana, Illinois, Ohio, and Michigan rank in the top 10 (Table 3.6).

The Midwest is endowed with a well-established and diverse industrial sector, including automobile manufacturing, petroleum refining, pulp and paper production, and diversified manufacturing. This analysis focuses only on emissions that result from the combustion of fossil fuels in the industrial sector. Emissions from industrial processes (e.g., CO_2 from chemical processes in cement production or fugitive emissions of F-gases) are omitted from this analysis because of the heterogeneity of source activities and their relatively small contribution to total emissions (2 percent of total Midwest GHG emissions).

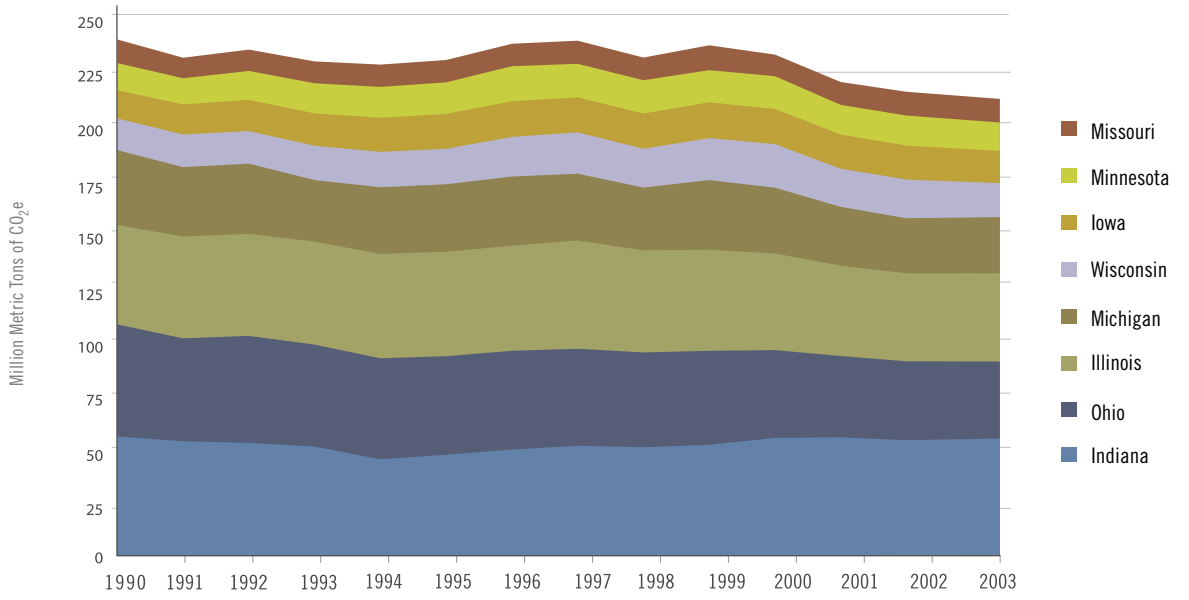
With the exception of fugitive emissions from fossil fuel production, the industrial sector is the only energy sector where Midwest emissions declined between 1990 and 2003. The 11 percent decline in total emissions was four times that experienced nationally during this period. The greatest industrial sector emission declines—more than 10 times greater

Table 3.6 | **GHG Emissions from Industrial Energy Use, State Rank, and Trends: 1990–2003**

STATE	1990 EMISSIONS ($MtCO_2e$)	2003 EMISSIONS ($MtCO_2e$)	2003 U.S. RANK	1990-2003 EMISSION TRENDS		
				ABSOLUTE CHANGE ($MtCO_2e$)	AVERAGE ANNUAL % CHANGE	% CHANGE
Indiana	55	54	4	-1	-0.1	-2
Illinois	46	39	6	-6	-1.1	-14
Ohio	52	37	7	-15	-2.6	-29
Michigan	35	25	8	-9	-2.4	-27
Wisconsin	15	16	19	1	0.7	9
Iowa	13	15	21	2	1.0	13
Minnesota	12	14	26	1	0.8	12
Missouri	11	11	29	0	-0.2	-3
Midwest	***238***	***211***	***N/A***	***-27***	***-0.9***	***-11***
United States	***1112***	***1082***	***N/A***	***-29***	***-0.2***	***-3***

Source: WRI, CAIT–US (2007).

Figure 3.6 | **Midwest Industrial Sector GHG Emission Trends by State: 1990–2003**

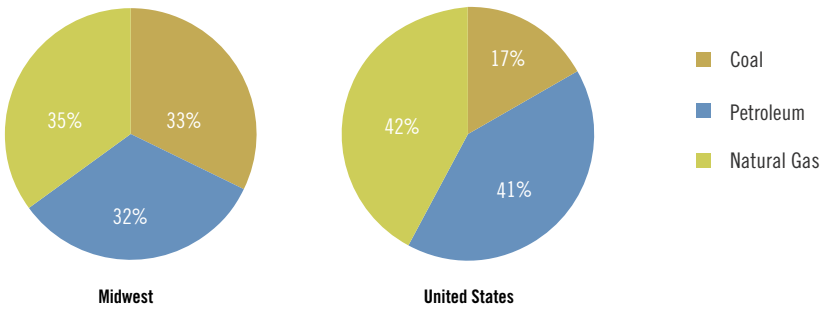


Source: WRI, CAIT–US (2007).

than the national decline—occurred in Ohio and Michigan (29 percent and 27 percent, respectively). Meanwhile, industrial emissions in Iowa, Minnesota, and Wisconsin increased during this period by 13, 12, and 9 percent, respectively, countering national and regional trends. Region-wide, emissions were relatively stable through the 1990s until 1999, when sector emissions began to decline (Figure 3.6).

Several factors can influence emission trends in this sector. First, the mix of fuels used and the degree to which that mix becomes more or less GHG intensive over time is important. The Midwest's industrial sector is more GHG intensive than the nation as a whole. The Midwest's 2003 industrial GHG emissions are split almost equally among coal, oil, and natural gas (Figure 3.7). Natural gas edges out the other two fuels, accounting for 35 percent of sector emissions. However, this percentage is lower than the U.S. total for industrial GHG emissions from natural gas (42 percent). Conversely, industrial emissions from coal contribute a smaller percentage nationally (17 percent) than in the Midwest (33 percent).

Figure 3.7 | **Midwest and U.S. Industrial Sector GHG Emissions by Fuel: 2003**



Source: WRI, CAIT-US (2007).

Table 3.7 | **Midwest and U.S. Industrial GHG Emissions, Energy Consumption, Economic Output, and Trends**

STATE	GHG EMISSIONS		NET ENERGY CONSUMPTION		STATE GDP FROM MANUFACTURING	
	2003 ($MtCO_2e$)	% CHANGE, 1997-2003	2003 (Trillion BTU)	% CHANGE, 1997-2003	2003 (Millions of current $)	% CHANGE, 1997-2003
Indiana	54	6	1,341	4	62,039	28
Illinois	40	-21	1,207	-11	66,177	2
Ohio	37	-18	1,339	-20	79,983	0
Michigan	25	-18	925	-8	78,535	15
Wisconsin	16	-16	656	-10	41,978	13
Iowa	15	-9	461	-2	21,479	16
Minnesota	14	-10	529	-16	28,591	13
Missouri	11	0	366	0	30,852	0
Midwest	***211***	***-11***	***6,824***	***-9***	***409,634***	***10***
United States	***1,082***	***-9***	***32,795***	***-7***	***1,369,234***	***7***

Sources: WRI, CAIT–US (2007); EIA (2007); BEA (2007).

Note: Trends are from 1997 to 2003, rather than from 1990 to 2003, because of inconsistent economic data for 1990–1996.

In addition to fuel mix, total energy consumption and economic output in the industrial sector are important drivers of GHG trends. For example, if energy consumption and economic output stay static or increase over time while GHG emissions decline, it is generally the result of fuel switching away from coal to less GHG-intensive fuels, such as natural gas. Conversely, if emissions and energy consumption decline while output stays steady or increases, then facilities are likely becoming more energy efficient and may also be fuel switching.

Table 3.7 presents 2003 values and trends from 1997 to 2003 for GHG emissions, energy consumption, and state gross domestic product (GDP) from manufacturing (which covers nearly all relevant industrial activities). The data reveal that emissions declined both nationally and regionally, and energy consumption also declined, though to a lesser degree. Meanwhile, economic output in this sector increased during this period, with the Midwest experiencing a larger increase than the nation as a whole. These trends indicate that both regionally and nationally a combination of fuel switching and efficiency gains occurred, and thus reduced the GHG intensity of the sector's economic output.

Five Midwest states—Illinois, Michigan, Wisconsin, Iowa, and Minnesota—all followed national and regional trends in this regard, though to varying degrees. Indiana, the state that experienced the largest increase in economic output, was the only state to experience increases in both emissions and energy consumption. Apparently, a small amount of switching toward more GHG-intensive fuels occurred in Indiana, as GHG emissions increased faster than energy consumption. Ohio and Missouri were the only states to experience no growth in economic output during this period. In Ohio, this lack of economic productivity and a much larger decrease in energy consumption were the primary causes of the 21 percent drop in GHG emissions, though fuel switching and efficiency most likely played additional roles. In Missouri, static economic output explains why energy consumption and GHG emissions remained unchanged in this time period.

AGRICULTURE

• All Midwest states rank in the top 25 nationally for GHG emissions from agriculture, with four states—Iowa, Minnesota, Illinois, and Missouri—ranking in the top 10.

• Iowa, the Midwest state with the lowest total GHG emissions, is by far the largest-emitting state with regard to the agriculture sector in the region, and ranks only behind Texas nationally.

Table 3.8 | **GHG Emissions from Agriculture, State Rank, and Trends: 1990–2003**

STATE	1990 EMISSIONS ($MtCO_2e$)	2003 EMISSIONS ($MtCO_2e$)	U.S. RANK 2003	1990-2003 EMISSION TRENDS		
				ABSOLUTE CHANGE ($MtCO_2e$)	AVERAGE ANNUAL % CHANGE	% CHANGE
Iowa	25	24	2	-1	-0.3	-4
Minnesota	15	15	6	0	-0.1	-2
Illinois	18	15	7	-3	-1.4	-17
Missouri	14	14	8	0	-0.1	-1
Wisconsin	13	11	11	-2	-1.2	-14
Indiana	11	9	14	-2	-1.3	-16
Ohio	9	8	16	-1	-0.8	-9
Michigan	6	5	23	-1	-0.9	-11
Midwest	***111***	***102***	***N/A***	***-9***	***-0.7***	***-8***
United States	***350***	***351***	***N/A***	***1***	***0.0***	***0***

Source: WRI, CAIT-US (2007).

• Reflecting the dominance of corn and other fertilizer-intensive crops, nitrous oxide is the most abundant GHG (on a CO_2-equivalent basis) in all Midwest agricultural emissions, with the exception of Wisconsin, where methane is more abundant.

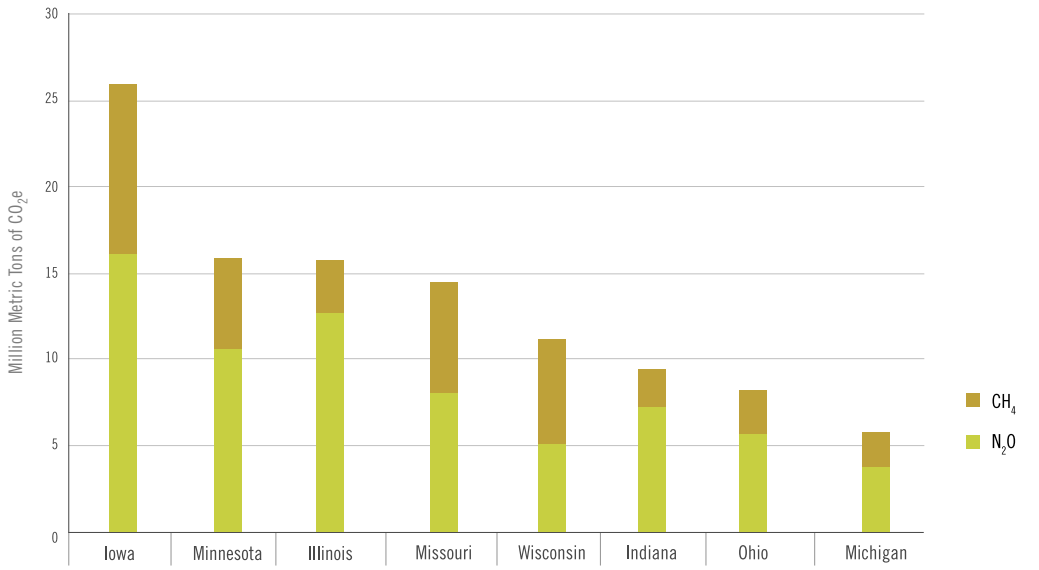
• GHG emission profiles in the agriculture sector closely mirror agricultural output, with the most productive states also being the largest emitters. In states where crops comprise a greater share of output than livestock, nitrous oxide emissions are more prevalent than methane, and vice versa.

Agriculture is the largest source of non-CO_2 GHGs in the Midwest and the nation. It is the fifth largest GHG-emitting sector in the Midwest, accounting for 7 percent of total regional emissions. All Midwest states rank in the top 25 with regard to emissions from agriculture (Table 3.8). Iowa, the Midwest state with the lowest total GHG emissions, is the top Midwest state in agricultural emissions and is the second largest U.S. emitter, behind Texas.

Emissions from this sector do not include CO_2 emissions from farm machinery and other fossil fuel combustion activities, as these are captured in the transportation and industry sectors. The agricultural sector primarily includes emissions from livestock and crop cultivation. The two GHGs in this sector are methane (CH_4) and nitrous oxide (N_2O), both gases with high global warming potentials. CH_4 emissions are primarily from enteric fermentation in livestock (a digestive process that occurs in most livestock), though some emissions do result from the anaerobic digestion of manure. N_2O is released from soils mostly via the application of nitrogen-rich fertilizers and manure. Natural factors, such as climate, weather, precipitation, and soil, can influence emissions from agriculture; as a result, annual emissions can fluctuate from year to year.

On a CO_2-equivalent basis, N_2O emissions are the most prevalent GHG in this sector in the Midwest, though this varies across states (Figure 3.8). For example, N_2O accounts for over 80 percent of agriculture GHG emissions in Illinois, but only 44 percent in Wisconsin. All Midwest states have more N_2O-intensive agricultural sector emissions, compared to the nation as a whole, with the exception of Wisconsin, primarily because the region is a world leader in corn cultivation. Corn is a resource-intensive crop, especially with regard to nitrogen-based fertilizers. Iowa, Minnesota, and Illinois, which are among the nation's primary producers of corn (USDA, 2004), are also the largest N_2O emitters in the Midwest.

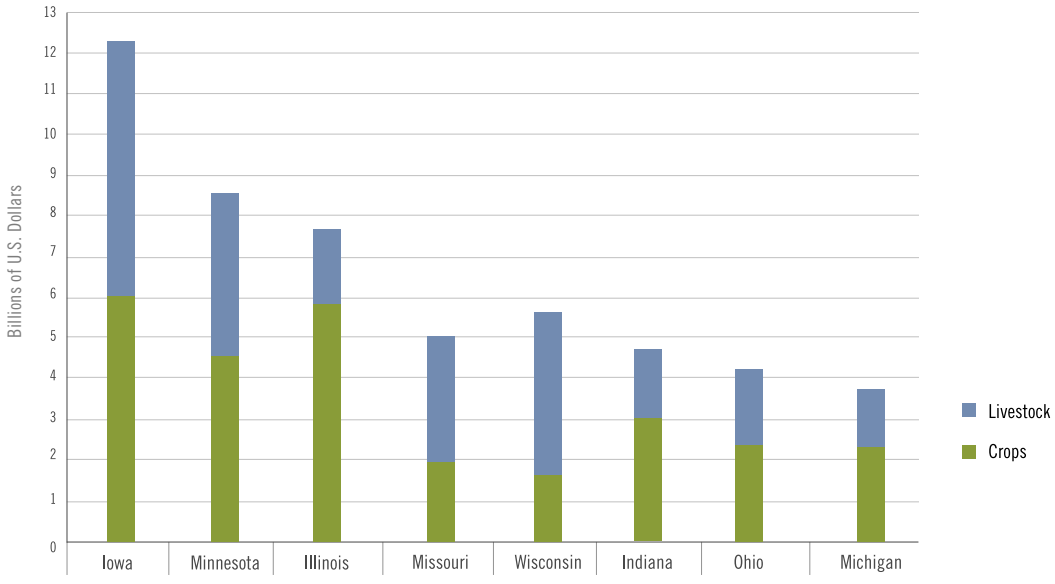
Figure 3.8 | Midwest Agricultural GHG Emissions by Gas: 2002



Source: WRI, CAIT–US (2007).

Note: 2002 data are used here for comparability with economic data presented in Figure 3.9.

Figure 3.9 | Market Value of Midwest Livestock and Crops Sold: 2002



Source: USDA (2007).

Note: 2002 data are the most recent available.

Beyond the relationship between N_2O emissions and corn cultivation, similarities among the GHG profiles of each state's agricultural sector and overall economic output from this sector are also apparent (Figures 3.8 and 3.9). With the exception of Missouri and Wisconsin, the Midwest states' regional ranks for GHG emissions and total value of farm products are the same. This exception is likely the result of two distinct factors: Wisconsin's region-leading dairy industry generates more value than Missouri's livestock industry and Missouri's crop production is far more N_2O intensive per dollar of value generated than Wisconsin's.

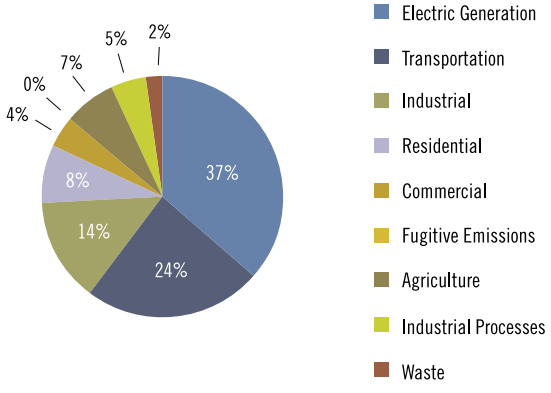
In states where crops make up a larger share of farm product value, N_2O emissions make up a majority of total emissions on a CO_2-equivalent basis. In some states, the presence of robust activity in both crop and livestock production can explain why agriculture emissions are so much higher than in other states. For example, in Iowa and Illinois, the total amount of N_2O emissions from agriculture is similar while the market value of crops sold in these states is also comparable. However, Iowa's robust livestock production generates nearly half of the total value of farm products sold in Iowa while in Illinois these products generate less than 25 percent of total product value. Iowa consequently emits a commensurate amount of CH_4 emissions from livestock production that are not present to the same degree in Illinois, making Iowa by far the leading state in the region with regard to emissions from the agriculture sector.

4 STATE GREENHOUSE GAS EMISSIONS, TRENDS, AND DRIVERS

Previous chapters of this report identify key unifying points for region- and sector-wide discussions of greenhouse gas (GHG) emissions and emission reduction policies. For reference and to facilitate comparisons to state emission profiles presented in this chapter, Figures 4.1 and 4.2 provide a summary of Midwest GHG emissions by economic sector and by gas, respectively.

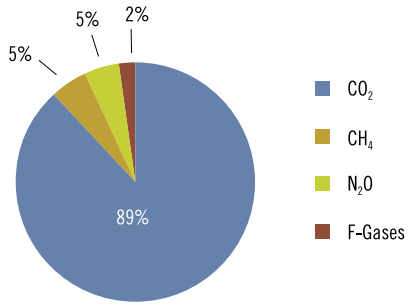
The data presented in this chapter show that while notable intraregional similarities exist, the emission profiles of individual states in the Midwest also have important differences in terms of both emission sources and emission trends that are useful for consideration by decisionmakers.

Figure 4.1 | **Midwest GHG Emissions by Economic Sector: 2003**



Source: WRI, CAIT-US (2007).

Figure 4.2 | **Midwest GHG Emissions by Gas: 2003**



Source: WRI, CAIT-US (2007).

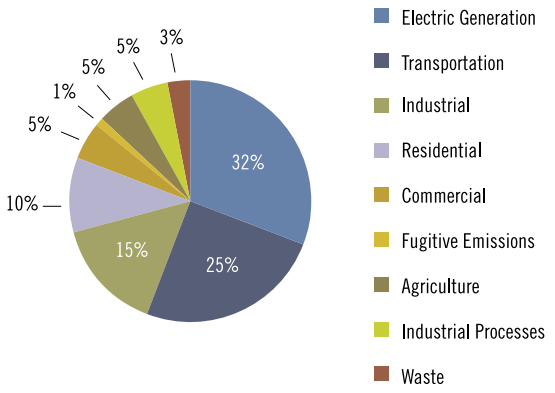
The state summaries that follow provide a general overview of emissions in each Midwest state and draw attention to the most salient aspects of state GHG emissions, their sources (i.e., largest-emitting economic sectors), emission trends, and macroeconomic emission drivers. While these summaries are informative, more comprehensive state-specific analyses will ultimately benefit from additional insights and data provided by state agencies, officials, and others.

NOTE: Economic sector and gas emission profiles presented in Chapter 4 do not include emissions from international bunker fuels or land-use change and forestry, and may not total 100 percent due to independent rounding.

ILLINOIS

- **In 2003, Illinois GHG emissions totaled 269 $MtCO_2e$, representing 17 percent of Midwest emissions and 4 percent of U.S. emissions.**
- **Illinois' top-emitting sectors include electric generation, transportation, industrial energy use, and residential energy use.**
- **GHG emissions from electric generation increased by 53 percent (30 $MtCO_2e$) between 1990 and 2003—more than twice the national average. Transportation sector emissions increased by 19 percent (10 $MtCO_2e$) during this period.**
- **More than 80 percent (approximately 12 $MtCO_2e$) of Illinois' N_2O emissions come from the agriculture sector, most likely resulting from the production of fertilizer-intensive crops, such as corn.**

Figure 4.3 | **Illinois GHG Emissions by Economic Sector: 2003**



Source: WRI, CAIT-US (2007).

Illinois is the third largest GHG emitter in the Midwest and the seventh largest emitter in the nation, in terms of absolute emissions. The state's GHG emissions account for approximately 17 percent of the Midwest's emissions and 4 percent of total U.S. emissions. Per capita emissions in Illinois are the lowest in the Midwest (with Michigan) and 9 percent less than the U.S. average. This is largely due to Illinois' reliance on nuclear power—an energy source that does not emit GHGs directly—for about half of its total electricity generation (see Illinois State Spotlight).

Approximately 72 percent of Illinois' GHG emissions are produced by the major energy sectors: electric generation (32 percent), transportation (25 percent), and industrial energy use (15 percent). Residential energy use contributes 10 percent of total state emissions (Illinois is the most populous state in the Midwest), and all other sectors contribute 5 percent or less (Figure 4.3). Illinois' gas emissions profile is comparable to that of the Midwest region as a whole. Most notably, N_2O emissions comprise a greater percentage of total emissions than CH_4 emissions, indicating the relatively important contribution of crop fertilizer and manure management in determining Illinois' emissions profile (Figure 4.4).

Between 1990 and 2003, Illinois' total GHG emissions grew by 12 percent, approximately equal to the growth in total emissions of the Midwest and the nation. Most of Illinois' emissions growth during this time period is attributable to the 53 percent increase in emission from the electric generation sector (Table 4.1). Growth in emissions from electricity generation, in turn, is partially a result of changes in Illinois' fuel mix for electricity generation. Specifically, between 1990 and 2003, Illinois increased its use of coal to generate electricity by 60 percent (EIA, 2007). Generation from nuclear power, Illinois' other primary source of

Table 4.1 | **Illinois GHG Emissions and Trends by Economic Sector: 1990-2003**

SECTOR	1990 EMISSIONS ($MtCO_2e$)	2003 EMISSIONS ($MtCO_2e$)	1990-2003 EMISSION TRENDS		
			ILLINOIS % CHANGE	MIDWEST % CHANGE	U.S. % CHANGE
Energy Sectors	*201*	*234*	*16*	*14*	*14*
Electric Generation	57	87	53	25	24
Transportation	56	66	18	20	19
Industrial	46	39	-14	-11	-3
Residential	26	27	3	8	12
Commercial	13	13	1	9	7
Fugitive Emissions	4	2	-56	-40	-35
Agriculture	18	15	-17	-8	0
Industrial Processes*	4	13	3	-5	8
Waste	9	7	-26	-21	-9
Total*	***231***	***269***	***12***	***11***	***13***

Source: WRI, CAIT-US (2007).

Notes: Totals exclude emissions from international bunker fuels and land-use change and forestry.

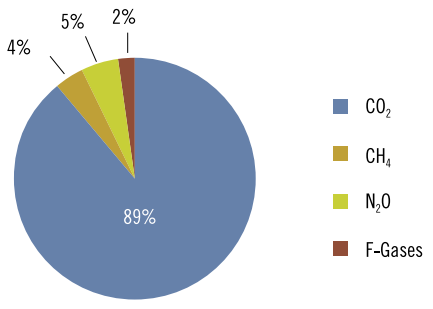
*Due to inconsistencies in industrial processes emissions data prior to 1997, the 1990 emission value for this economic sector has been replaced with the 1997 estimate. Trend calculations for industrial processes reflect the time period 1997 to 2003.

**While the 1990 total emissions value presented here includes industrial processes emissions for 1997 as noted above, calculations of total state, regional, and national emission trends do not include any industrial processes data in order to maintain consistency between 1990 and 2003.

electricity, increased by only 32 percent over the same period. As the share of total generation from coal—the most carbon-intensive fuel source—has increased, so has the share of emissions from Illinois' electric generation sector and the state's overall GHG emissions. Emissions growth in the state's electric generation sector is also due to increased electricity demand both within and outside the state, since Illinois also exports a portion of the electricity it generates (see Chapter 3, Electric Generation).

Since Illinois has the largest population and economy of any state in the Midwest, it is not surprising that recent trends in population and economic output are comparable to the region as a whole (see Figure 2.3). GHG emissions in Illinois declined early in 2000–2001 due to national economic declines. However, while state GDP rebounded between 2002 and 2003, growing by nearly 3 percent, emissions growth did not track: declines in overall population growth[6] combined with efficiency improvements in certain sectors (see Chapter 3) most likely helped to temper a similar return to emission growth rates of the late 1990s.

Figure 4.4 | **Illinois GHG Emissions by Gas: 2003**



Source: WRI, CAIT-US (2007).

[6] According to U.S. census estimates, approximately 30,000 more people were added to Illinois' population in 1998 than in 2003.

ILLINOIS STATE SPOTLIGHT: NUCLEAR GENERATION

Coal is the fuel source for more than 70 percent of the total electricity generated in the Midwest. In Illinois, however, more electricity is generated from nuclear power than coal. In fact, Illinois produces more electricity from nuclear sources than any state in the nation (Table 4.2). In 2005, the most recent year for which these data are available, Illinois generated more than 93 million megawatt hours (MWh) of electricity from nuclear sources, accounting for nearly 50 percent of its total electricity generation. Because using nuclear power to generate electricity produces no direct GHG emissions,[7] were it not for Illinois' relatively high nuclear capacity, the state's GHG emissions profile would likely be significantly more GHG intensive, since Illinois is currently the seventh largest U.S. emitter, based on absolute emissions. (For more details on the Midwest electric generation sector, see Chapter 3.)

Table 4.2 | **Top 10 Nuclear Generation States: 2005**

STATE	NUCLEAR GENERATION (Thousand MWh)	% OF STATE GENERATION FROM NUCLEAR POWER
1. Illinois	93,263	48.0
2. Pennsylvania	76,289	35.0
3. South Carolina	53,138	51.8
4. New York	42,443	28.9
5. North Carolina	39,982	30.8
6. Texas	38,232	9.6
7. California	36,155	18.1
8. Michigan	32,872	27.0
9. Alabama	31,694	23.0
10. Georgia	31,534	23.1
Midwest	***176,262***	***20.7***
Total U.S.	***781,986***	***19.3***

Source: EIA (2007).

Note: 19 states and Washington, DC, have zero nuclear generation.

[7] Though nuclear power does have environmental impacts (including GHG emissions) from fuel mining and processing as well as waste disposal, it does not directly emit GHGs when generating electricity.

INDIANA

• In 2003, Indiana GHG emissions totaled 269 $MtCO_2e$, representing 17 percent of Midwest emissions and 4 percent of U.S. emissions.

• Indiana's top-emitting sectors include electric generation, industrial energy use, transportation, and industrial processes.

• Between 1990 and 2003, approximately 90 percent (24 $MtCO_2e$) of Indiana's growth in emissions from energy sectors was attributable to an increase in emissions from electric generation and transportation.

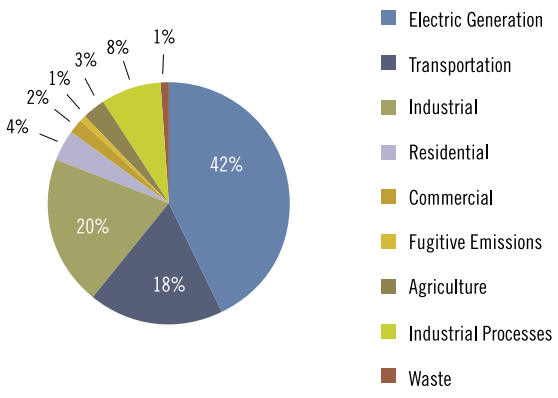
• GHG emissions from industrial energy use represent the second highest total of any sector in Indiana (behind electric generation). Between 1990 and 2003, industrial emissions decreased by 2 percent, which was one-seventh of the average decline in emissions from this sector for all other Midwest states.

Indiana is the second largest GHG emitter in the Midwest and the sixth largest emitter in the nation in terms of absolute emissions. The state's GHG emissions account for approximately 17 percent of the Midwest's emissions and 4 percent of U.S. emissions. Indiana's per capita emissions (44 metric tons of CO_2e) are the highest in the Midwest, nearly 70 percent higher than the Midwest per capita emissions average and 90 percent higher than the national average. The primary reason for Indiana's relatively high emissions per capita is the state's reliance on coal to fuel electricity production (see Indiana State Spotlight).

Approximately 80 percent of Indiana's GHG emissions are produced by the major energy sectors: electric generation (42 percent), industrial energy use (20 percent), and transportation (18 percent). Indiana is the only Midwest state where total emissions from industrial energy use are greater than those from the transportation sector. In addition, GHG emissions from industrial processes are higher than those from any other state in the Midwest, accounting for approximately 22 $MtCO_2e$, or 8 percent of total state emissions (Figure 4.5). The majority of these emissions are from the manufacturing of iron and steel as Indiana accounts for the largest share—approximately 22 percent—of the U.S. steel industry (USGS, 2003). As a result of Indiana's industrial economy and its coal-based electricity generation, CO_2 emissions comprise a greater portion of total emissions compared to other Midwest states, the region, and the nation, while CH_4 and N_2O emissions make up a smaller-than-average percentage of total emissions (Figure 4.6).

Between 1990 and 2003, Indiana's total GHG emissions grew by 11 percent, equal to that of the Midwest

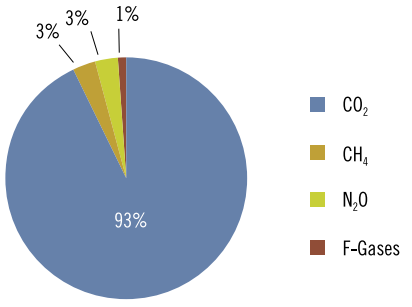
Figure 4.5 | **Indiana GHG Emissions by Economic Sector: 2003**



Source: WRI, CAIT-US (2007).

and comparable to the nation as a whole. While the percentage of emissions growth for Indiana's electric generation and transportation sectors during this period was below regional and national averages, the increase in GHG emissions in the commercial sector was nearly three times the national average (Table 4.3). Indiana's commercial sector, however, accounts for only 2 percent of state emissions. Likewise, fugitive emissions, which constitute less than 1 percent of total emissions, increased by 36 percent between 1990 and 2003, while region-wide and national data for this sector show decreases of comparable magnitude. It is also worth noting that although total industrial energy use emissions in Indiana are greater than in any other Midwest state, reductions in emissions from the industrial sector were lower than declines experienced elsewhere on a percentage basis.

Figure 4.6 | **Indiana GHG Emissions by Gas: 2003**



Source: WRI, CAIT-US (2007).

Recently, Indiana, like much of the Midwest, has experienced slowing rates of growth in population (U.S. Census, 2006). Despite this trend, state GDP has risen 16 percent since 1997, significantly above the Midwest regional average of 12 percent (BEA, 2007). Indiana and national growth in GHG emissions have generally followed the latter driver (GDP); emissions growth in Indiana between 2002 and 2003 is comparable to that experienced in the late 1990s (around 4 percent annually), prior to the recession of 2000–2001.

Table 4.3 | **Indiana GHG Emissions and Trends by Economic Sector: 1990-2003**

SECTOR	1990 EMISSIONS ($MtCO_2e$)	2003 EMISSIONS ($MtCO_2e$)	1990-2003 EMISSION TRENDS		
			INDIANA % CHANGE	MIDWEST % CHANGE	U.S. % CHANGE
Energy Sectors	*208*	*234*	*12*	*14*	*14*
Electric Generation	95	114	19	25	24
Transportation	42	48	14	20	19
Industrial	55	54	-2	-11	-3
Residential	10	11	9	8	12
Commercial	5	6	18	9	7
Fugitive Emissions	1	2	35	-40	-35
Agriculture	11	9	-16	-8	0
Industrial Processes*	3	22	-15	-5	8
Waste	3	4	17	-21	-9
Total*	***226***	***269***	***11***	***11***	***13***

Source: WRI, CAIT-US (2007).

Notes: Totals exclude emissions from international bunker fuels and land-use change and forestry.

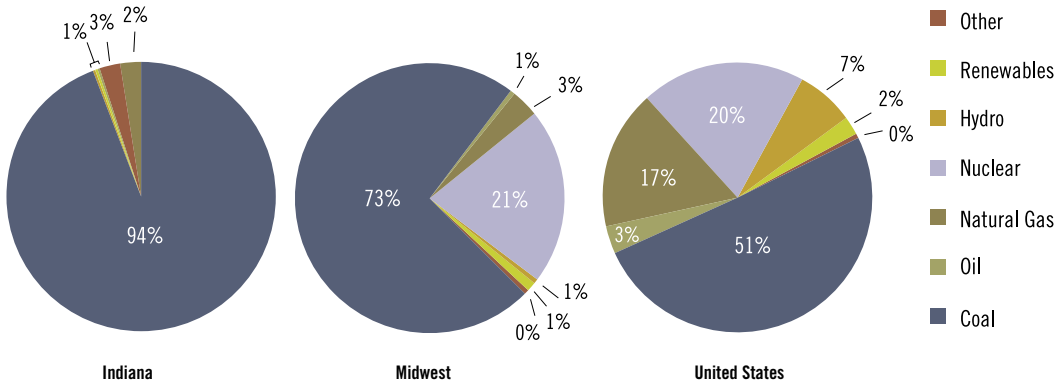
*Due to inconsistencies in industrial processes emissions data prior to 1997, the 1990 emission value for this economic sector has been replaced with the 1997 estimate. Trend calculations for industrial processes reflect the time period 1997 to 2003.

**While the 1990 total emissions value presented here includes industrial processes emissions for 1997 as noted above, calculations of total state, regional, and national emission trends do not include any industrial processes data in order to maintain consistency between 1990 and 2003.

INDIANA STATE SPOTLIGHT: ELECTRICITY PRODUCTION FROM COAL

Indiana's relatively high emissions per capita value and its GHG-intensive economy are largely attributable to the state's dependence on coal for electricity production. Nearly 95 percent of Indiana's electricity comes from coal combustion, and it is the only state in the Midwest without any nuclear generation, which produces no direct GHG emissions (Figure 4.7). For comparison, the Midwest's major sources for electricity generation, on average, include 73 percent coal and 21 percent nuclear; the national average fuel mix is 51 percent coal, 20 percent nuclear, and 17 percent natural gas. Because coal is the most GHG-intensive fossil fuel and Indiana has an electricity resource mix strongly weighted toward coal, emissions from Indiana's electric generation sector comprise an above-average proportion (42 percent) of total emissions compared to the region as a whole. In addition, CO_2 makes up a larger portion (94 percent) of Indiana's GHG emissions profile than any other state in the Midwest.

Figure 4.7 | **Indiana, Midwest, and U.S. Electricity Generation by Source: 2003**

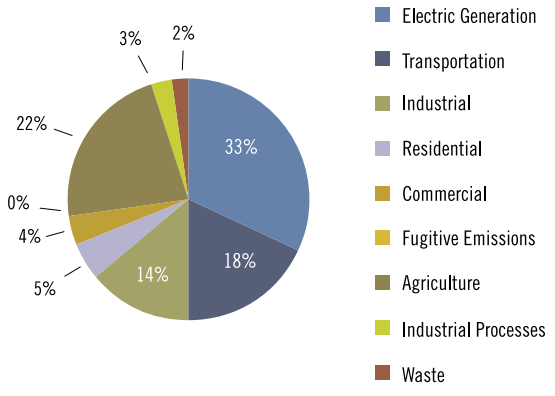


Source: EIA (2007).

IOWA

- **In 2003, Iowa GHG emissions totaled 108 $MtCO_2e$, representing 7 percent of Midwest emissions and 2 percent of U.S. emissions.**
- **Iowa's top-emitting sectors include electric generation, agriculture, transportation, and industrial energy use.**
- **Between 1990 and 2003, Iowa had one of the fastest-growing electric generation sectors in the region in terms of emissions, despite having one of the slowest-growing populations in the Midwest.**
- **GHG emissions from agriculture (CH_4 and N_2O) in Iowa account for more than 22 percent, or 24 $MtCO_2e$, of total emissions, the highest contribution from this sector of any state in the Midwest.**

Figure 4.8 | **Iowa GHG Emissions by Economic Sector: 2003**



Source: WRI, CAIT-US (2007).

Iowa is the smallest GHG emitter in the Midwest, and the 23rd largest emitter in the nation in terms of absolute emissions. The state's GHG emissions account for approximately 7 percent of the Midwest's emissions and 2 percent of U.S. emissions. Iowa's emissions profile is significantly more GHG intensive than those of the Midwest and the nation as a whole. Per capita emissions in Iowa (37 metric tons of CO_2e) are 40 percent higher than the Midwest regional per capita emissions value and nearly 60 percent higher than the national average. Iowa's high GHG per capita value is largely due to a relatively low population density and a relatively high density of emissions from agriculture (see Iowa State Spotlight).

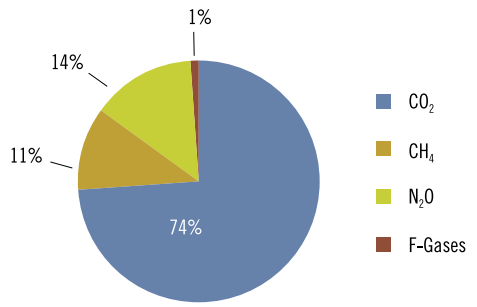
Approximately 65 percent of Iowa's GHG emissions are produced by the major energy sectors: electric generation (33 percent), transportation (18 percent), and industrial energy use (14 percent). The emissions contribution from Iowa's energy sectors is below that of the other seven states in the Midwest. Iowa's unique profile is due to a relatively large contribution from its agricultural sector, which accounts for 22 percent of total emissions (Figure 4.8). Iowa's agricultural focus is additionally borne out in the breakdown of emissions by gas. Emissions of CH_4 and N_2O—the principal emissions byproducts of agriculture—constitute one-quarter of total state emissions, which is twice the total percentage of both the Midwest and the nation as a whole (Figure 4.9). These data suggest the relative importance of both commercial crops and livestock to Iowa's economy, since CH_4 emissions are produced principally by the gastrointestinal processes of cattle and other ruminant animals, and N_2O emissions are byproducts of nitrogen-based fertilizers.

Between 1990 and 2003, Iowa's total GHG emissions grew by 15 percent, comparable to—although slightly above—Midwest and U.S. total emissions growth. Most notably, emissions growth in three energy sectors—electric generation, industrial energy use, commercial

energy use—surpassed the rate of increase for both the Midwest and the nation, although growth in the latter two sectors represents an absolute change of less than 4 $MtCO_2e$ (Table 4.4). Conversely, electric generation emissions grew by over 14 $MtCO_2e$, or 33 percent. This was one of the largest increases (on a percentage basis) observed in the Midwest during this period, despite a slower-than-average rate of growth in population and little change in Iowa's electricity generation fuel mix (WRI, CAIT-US, 2007, from EIA, 2007).

Iowa's population and state GDP steadily increased between 1997 and 2003, although not as rapidly as in the Midwest overall. Nevertheless, Iowa's total annual emissions remained approximately constant. While emissions from electricity generation grew by about 4 $MtCO_2e$ during this period, reductions in emissions from the industrial and agriculture sectors—likely due to improved efficiencies—largely offset these gains. In addition, annual variations in weather and commodity prices can be particularly important drivers of agricultural output. Since nearly one-quarter of Iowa's GHG profile is comprised of agricultural emissions, fluctuations in annual production totals are likely to impose similar variability on the total volume of emissions from agriculture. Therefore, the absence of a trend in this sector may dampen any trend in total emissions.

Figure 4.9 | **Iowa GHG Emissions by Gas: 2003**



Source: WRI, CAIT-US (2007).

Table 4.4 | **Iowa GHG Emissions and Trends by Economic Sector: 1990-2003**

SECTOR	1990 EMISSIONS ($MtCO_2e$)	2003 EMISSIONS ($MtCO_2e$)	1990-2003 EMISSION TRENDS		
			IOWA % CHANGE	MIDWEST % CHANGE	U.S. % CHANGE
Energy Sectors	*65*	*79*	*22*	*14*	*14*
Electric Generation	27	36	33	25	24
Transportation	17	20	17	20	19
Industrial	13	15	13	-11	-3
Residential	5	5	6	8	12
Commercial	3	4	20	9	7
Fugitive Emissions	0	--	--	-40	-35
Agriculture	25	24	-4	-8	0
Industrial Processes*	2	3	0	-5	8
Waste	2	2	7	-21	-9
Total*	***94***	***108***	***15***	***11***	***13***

Source: WRI, CAIT-US (2007).

Notes: Totals exclude emissions from international bunker fuels and land-use change and forestry.

*Due to inconsistencies in industrial processes emissions data prior to 1997, the 1990 emission value for this economic sector has been replaced with the 1997 estimate. Trend calculations for industrial processes reflect the time period 1997 to 2003.

**While the 1990 total emissions value presented here includes industrial processes emissions for 1997 as noted above, calculations of total state, regional, and national emission trends do not include any industrial processes data in order to maintain consistency between 1990 and 2003.

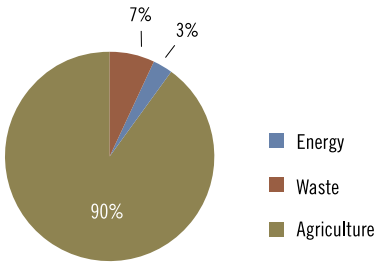
IOWA STATE SPOTLIGHT: AGRICULTURE EMISSIONS

Iowa has long been a leading producer of agricultural products, including corn, soybeans, hogs, and eggs. The agriculture industry plays a significant role in Iowa's economy, accounting for approximately 3 percent of state GDP and generating billions of dollars in revenue annually (BEA, 2007; USDA, 2007).

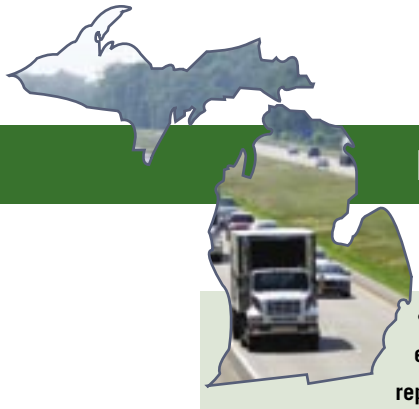
Agriculture also plays a substantial role in determining Iowa's emissions profile. Iowa's GHG emissions from the agriculture sector are higher than the agriculture emission totals of all other Midwest states (and the second highest nationally), accounting for 24 $MtCO_2e$ in 2003, or 22 percent of total state emissions. Iowa's agricultural emissions are comprised of N_2O emissions (60 percent), primarily resulting from corn cultivation, and CH_4 emissions (40 percent), largely from ruminant livestock. Agricultural emissions of these two high-global-warming-potential gases account for 90 percent of all N_2O and CH_4 emissions in the state (Figure 4.10). Iowa's total N_2O emissions from agriculture are the highest in the country, contributing approximately 14 $MtCO_2e$ in 2003.

Considering that Iowa has both the smallest population and economy in the Midwest, and nearly 90 percent of state land is used for farming (Iowa Agricultural Statistics Bulletin, 2006; WRI, CAIT-US, 2007), it is not surprising that Iowa is a relatively GHG-intensive state. For example, Iowa's agricultural emissions per capita (8 metric tons of CO_2e) is the highest in the Midwest and the fourth highest nationally (WRI, CAIT-US, 2007). (For additional information regarding the agriculture sector and agricultural emissions in the Midwest, see Chapter 3.)

Figure 4.10 | **Iowa N_2O and CH_4 Emissions by Sector: 2003**



Source: WRI, CAIT-US (2007).



MICHIGAN

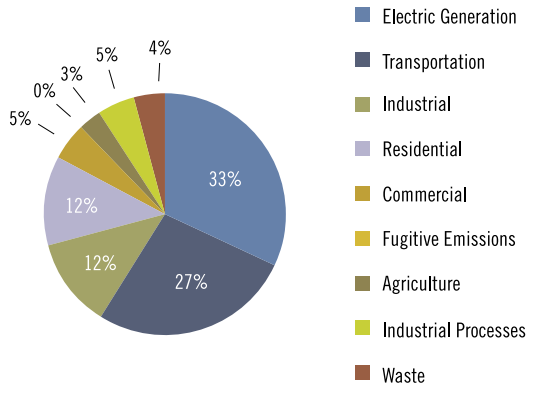
• In 2003, Michigan GHG emissions totaled 212 $MtCO_2e$, representing 14 percent of Midwest emissions and 3 percent of U.S. emissions.

• Michigan's top-emitting sectors include electric generation, transportation, industrial energy use, and residential energy use.

• Total GHG emissions in Michigan increased by 1 $MtCO_2e$ between 1990 and 2004, less than any other Midwest state. GHG growth in energy sectors was 1 percent, cumulatively, less than one-tenth the average percent increase observed for both the Midwest and the nation as a whole.

• Emissions from industrial energy use in Michigan declined by 27 percent, or approximately 9 $MtCO_2e$, between 1990 and 2003. This was more than twice the average percentage decline in this sector for all other Midwest states combined, and nine times the national average.

Figure 4.11 | **Michigan GHG Emissions by Economic Sector: 2003**



Source: WRI, CAIT-US (2007).

Michigan is the fourth largest GHG emitter in the Midwest, and the ninth largest emitter in the nation in terms of absolute emissions. The state's GHG emissions account for approximately 14 percent of the Midwest's emissions and 3 percent of U.S. emissions. Michigan's emissions profile is less GHG intensive than those of both the Midwest and the nation as a whole. Its per capita emissions (21 metric tons of CO_2e) are the lowest in the region (with Illinois)—approximately 20 percent below the Midwest regional average.

Michigan's relatively efficient GHG emissions profile is at least partly due to its electricity fuel mix, which is less reliant on carbon-intensive fuels than the rest of the region. Approximately 61 percent of Michigan's electricity is generated from coal, 25 percent from nuclear sources, and 10 percent from natural gas, compared with the region's 73 percent reliance on coal, 21 percent on nuclear power, and 3 percent on natural gas. The percentage of natural gas is relevant in this discussion, since natural gas is a less carbon-intensive fossil fuel than coal.

Approximately 71 percent of Michigan's GHG emissions are produced by the major energy sectors: electric generation (33 percent), transportation (27 percent), and industrial energy use (12 percent). At over 25 $MtCO_2e$—or 12 percent—of Michigan's emissions, residential energy use also comprises a significant portion of the state's emissions profile (Figure 4.11). This is unique to Michigan, as it is the only state in the Midwest where the residential sector is responsible for more than 10 percent of total emissions. This is likely due to a combination of Michigan's cooler climate (and, therefore, heating needs) and relatively large population (the third highest in the Midwest and eighth highest nationally). Only Illinois has a larger absolute emissions value for residential energy use. GHGs from waste also constitute an above-average percentage of total GHG emissions and account for approximately 75 percent of the state's total CH_4 emissions (Figure 4.12).

Table 4.5 | **Michigan GHG Emissions and Trends by Economic Sector: 1990-2003**

SECTOR	1990 EMISSIONS ($MtCO_2e$)	2003 EMISSIONS ($MtCO_2e$)	1990-2003 EMISSION TRENDS		
			MICHIGAN % CHANGE	MIDWEST % CHANGE	U.S. % CHANGE
Energy Sectors	*184*	*187*	*1*	*14*	*14*
Electric Generation	68	69	2	25	24
Transportation	50	56	14	20	19
Industrial	35	25	-27	-11	-3
Residential	22	25	13	8	12
Commercial	11	11	3	9	7
Fugitive Emissions	--	--	--	-40	-35
Agriculture	6	6	-11	-8	0
Industrial Processes*	3	12	-2	-5	8
Waste	9	8	-5	-21	-9
Total*	***202***	***212***	***1***	***11***	***13***

Source: WRI, CAIT-US (2007).

Notes: Totals exclude emissions from international bunker fuels and land-use change and forestry.

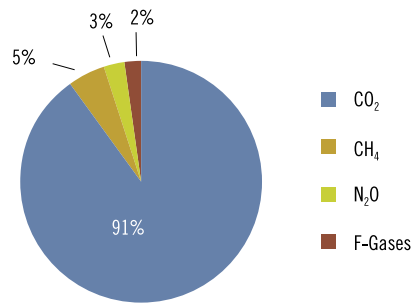
*Due to inconsistencies in industrial processes emissions data prior to 1997, the 1990 emission value for this economic sector has been replaced with the 1997 estimate. Trend calculations for industrial processes reflect the time period 1997 to 2003.

**While the 1990 total emissions value presented here includes industrial processes emissions for 1997 as noted above, calculations of total state, regional, and national emission trends do not include any industrial processes data in order to maintain consistency between 1990 and 2003.

Between 1990 and 2003, Michigan's GHG emissions grew by approximately 1 percent. This growth rate was significantly slower relative to both the region (15 percent growth) and the nation (16 percent growth) during this period, and was the slowest among all eight Midwest states. Michigan's declining emissions from industrial energy use and slow growth in emissions from the electric utility sector during this period contributed to its emissions growth rate (Table 4.5).

Between 1997 and 2003, state GDP and population increased by 9 and 3 percent, respectively. Although these values were below Midwest regional averages, they still represented positive trends in these indicators. Conversely, total GHG emissions in 2003 were 5 percent below 1997 totals, due in large part to Michigan's unique decline in total emissions from the electric generation and industrial sectors in this period (see Michigan State Spotlight).

Figure 4.12 | **Michigan GHG Emissions by Gas: 2003**



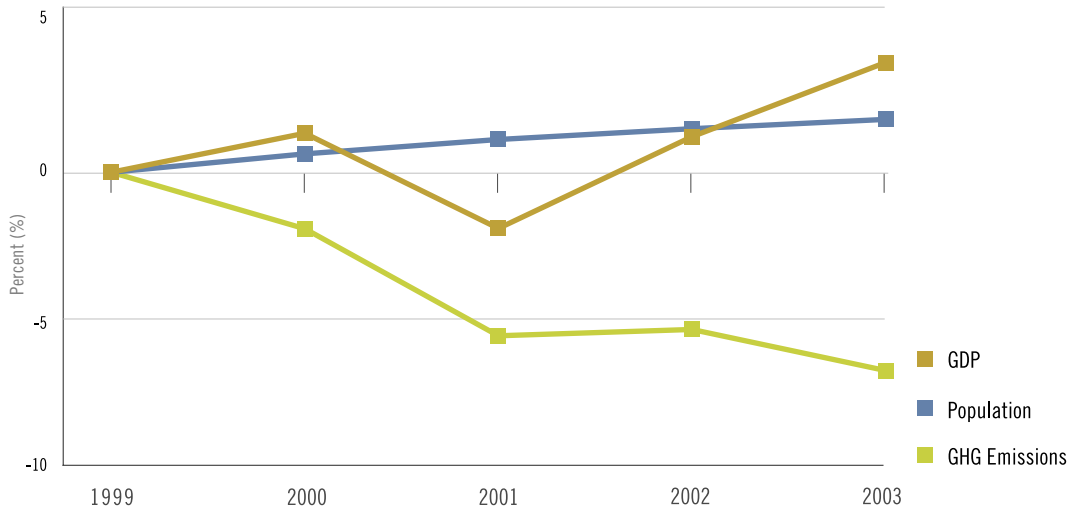
Source: WRI, CAIT-US (2007).

MICHIGAN STATE SPOTLIGHT: DECLINING TOTAL EMISSIONS

Between 1999 and 2003, Michigan's total GHG emissions decreased by approximately 6.5 percent. Although the national economic recession of 2000–2001 caused total emissions to decrease during that period in almost every Midwest state, other states within the region have since returned to a trend of increasing emissions; in contrast, Michigan has not (Figure 4.13). The long-term trend (1990–2003) analyzed in Table 4.5 includes Michigan's recent emissions decline. As a result, the magnitude of growth in emissions from electricity generation was substantially below that of both the Midwest and the nation. Similarly, emissions from industrial energy use declined by 27 percent, while only decreasing 11 percent and 3 percent regionally and nationally, respectively.

A principal driver of the trend in the electric generation sector was a change in the state's fuel mix. Between 1999 and 2003, Michigan increased its percentage of electricity from nuclear sources and decreased the percentage of electricity produced using coal (EIA, 2007). Declines in total emissions from the industrial sector can be partly explained by efficiency improvements in this sector, since Michigan's economic output from manufacturing generally increased (see Chapter 3). Additional factors include Michigan's below-average increases in population and economic growth between 1999 and 2003, relative to the national average. Economic output most likely had the greatest impact on emission trends in the energy sectors; indeed, emissions from electric generation and industrial energy use (as well as transportation) all declined during the period.

Figure 4.13 | **Percentage Change in Michigan, GDP, Population, and GHG Emissions: 1999-2003**



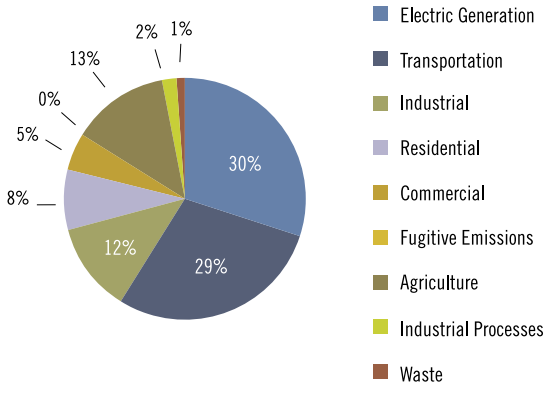
Sources: WRI, CAIT-US (2007); U.S. Census (2006); BEA (2007).

Note: Percentage changes for each year are relative to 1999 totals.

MINNESOTA

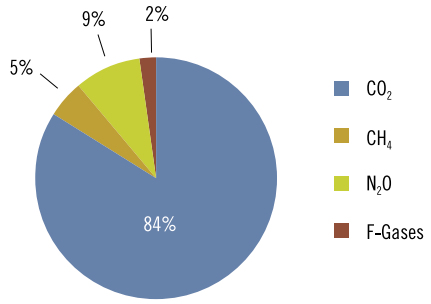
- **In 2003, Minnesota GHG emissions totaled 120 $MtCO_2e$, representing 8 percent of Midwest emissions and 2 percent of U.S. emissions.**
- **Minnesota's top-emitting sectors include electric generation, transportation, agriculture, and industrial energy use.**
- **GHG emissions from transportation increased by 43 percent between 1990 and 2003, the largest percentage increase in this sector in the Midwest. Emissions from electricity generation increased by 22 percent (approximately 7 $MtCO_2e$) over the same time period.**
- **At 4 percent, Minnesota has a higher percentage of electricity generated from renewable sources than any other Midwest state.**

Figure 4.14 | **Minnesota GHG Emissions by Economic Sector: 2003**



Source: WRI, CAIT-US (2007).

Figure 4.15 | **Minnesota GHG Emissions by Gas: 2003**



Source: WRI, CAIT-US (2007).

Minnesota is the seventh largest GHG emitter in the Midwest, and the 22nd largest in the nation in terms of absolute emissions. The state's GHG emissions represent approximately 8 percent of the Midwest's emissions and 2 percent of U.S. emissions. Minnesota's per capita emissions are about 10 percent lower than the Midwest regional average, but are comparable to the national average.

Minnesota's relatively GHG-efficient emissions profile is at least partly due to its greater-than-average reliance on zero-direct GHG-emitting sources to produce its electricity. In Minnesota, 30 percent of electricity is produced from nuclear, hydro, and renewable sources, compared to 24 percent from these sources for the Midwest as a whole. At 4 percent, a higher percentage of its electricity is generated from renewable resources (principally wind power) than any other state in the Midwest.

Approximately 71 percent of Minnesota's GHG emissions are produced by the major energy sectors: electric generation (30 percent), transportation (29 percent), and industrial energy use (12 percent). Minnesota is the only Midwest state where the GHG

Table 4.6. | **Minnesota GHG Emissions and Trends by Economic Sector: 1990-2003**

SECTOR	1990 EMISSIONS ($MtCO_2e$)	2003 EMISSIONS ($MtCO_2e$)	1990-2003 EMISSION TRENDS		
			MINNESOTA % CHANGE	MIDWEST % CHANGE	U.S. % CHANGE
Energy Sectors	*81*	*102*	*26*	*14*	*14*
Electric Generation	30	36	22	25	24
Transportation	25	35	43	20	19
Industrial	13	14	12	-11	-3
Residential	8	10	21	8	12
Commercial	6	7	13	9	7
Fugitive Emissions	--	--	--	-40	-35
Agriculture	15	15	-2	-8	0
Industrial Processes*	1	3	33	-5	8
Waste	2	1	-69	-21	-9
Total*	***99***	***120***	***20***	***11***	***13***

Source: WRI, CAIT-US (2007).

Notes: Totals exclude emissions from international bunker fuels and land-use change and forestry.

*Due to inconsistencies in industrial processes emissions data prior to 1997, the 1990 emission value for this economic sector has been replaced with the 1997 estimate. Trend calculations for industrial processes reflect the time period 1997 to 2003.

**While the 1990 total emissions value presented here includes industrial processes emissions for 1997 as noted above, calculations of total state, regional, and national emission trends do not include any industrial processes data in order to maintain consistency between 1990 and 2003.

contributions from the electric generation and transportation sectors are nearly equal (Figure 4.14). Minnesota's agriculture sector is the third largest emitting sector in the state, contributing 13 percent of total emissions, which is relatively large in a regional context. Only Iowa has a higher total value and percentage of agriculture emissions. Consequently, CH_4 and N_2O emissions constitute 14 percent of state emissions (with N_2O comprising a greater percentage of total emissions than CH_4), while CO_2 accounts for 84 percent (Figure 4.15).

Between 1990 and 2003, Minnesota's GHG emissions grew by 20 percent, nearly double the average rate of growth for the region. This growth was due primarily to increases in emissions in the electric generation and transportation sectors (Table 4.6). Combined, these sectors accounted for an additional 17 $MtCO_2e$ in 2003, compared to 1990 totals. The 43 percent growth in the state's transportation emissions during this period exceeded that of all other Midwest states (see Minnesota State Spotlight).

Increases in these sectors most likely were partly driven by above-average growth in both population and economic output. Between 1997 and 2003, Minnesota's population grew by 6 percent, while its GDP grew by 21 percent. In both instances, calculated growth was nearly double that experienced by the Midwest region as a whole.

MINNESOTA STATE SPOTLIGHT: GROWTH IN TRANSPORTATION EMISSIONS

From 1990 to 2003, GHG emissions from Minnesota's transportation sector grew by approximately 11 $MtCO_2e$. This was the second highest growth in absolute emissions from the transportation sector among Midwest states and the largest percent increase—43 percent—in the region during this period.

Several factors can dictate trends in transportation emissions. For example, increases in population typically produce increases in the number of total annual vehicle miles traveled (VMT). If, however, VMT per capita also increases, it means individuals are also driving greater distances, which could be the result of driver habits or urban sprawl, which typically creates longer distances between residential and commercial centers. The relative numbers of different types of vehicles (e.g., cars or trucks), the characteristics of vehicles (e.g., fuel economy), and the types of vehicle fuels utilized in modes of transport (e.g., gasoline, ethanol) are also critical determinants of total GHG emissions. Emission trends in the transportation sector are likely to be affected by a combination of these variables.

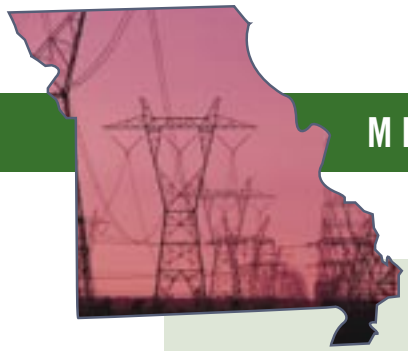
Minnesota stands out in the Midwest with respect to both transportation emissions and trends in associated emission drivers (Table 4.7). Between 1990 and 2003, Minnesota's population, total VMT, and gasoline consumption experienced a larger percentage increase than any other Midwest state. Growth in emissions, not surprisingly, was also more than twice that of other Midwest states and the U.S. average. Interestingly, however, Minnesota's population did not increase as rapidly as the U.S. average, yet total percentage increases in VMT and VMT per capita were greater than those of the nation as a whole. These data, as well as additional sources (e.g., 1000 Friends of Minnesota, 2005) suggest urban sprawl may be an important driver of Minnesota's transportation emissions. Additionally, Minnesota experienced the highest growth in transportation emissions despite the fact that it had the second highest increase in ethanol consumption between 1990 and 2003, and currently has the highest percentage of ethanol in the Midwest as part of its total transportation fuel mix (see Table 3.5). Ethanol is fuel that is generally considered to be less carbon-intensive on a lifecycle basis than gasoline. (For a discussion of transportation sector emissions in the Midwest, see Chapter 3.)

Table 4.7. | Percentage Growth in Key Transportation Sector Indicators: 1990–2003

GEOGRAPHIC AREA	ENVIRONMENT		VEHICLE USE		FUEL	
	GHG EMISSIONS FROM TRANSPORT	POPULATION	VMT	VMT PER CAPITA	GASOLINE CONSUMPTION	ETHANOL CONSUMPTION
Minnesota	43%*	15%*	42%*	23%	35%*	1,068%
Rest of Midwest	18%	9%	28%	17%	18%	175%
Total United States	***19%***	***16%***	***35%***	***16%***	***23%***	***278%***

Sources: WRI, CAIT-US (2007); U.S .Census (2006); Bureau of Transportation Statistics (2007); EIA (2007).

Note: *Indicator growth in Minnesota is largest among Midwest states.



MISSOURI

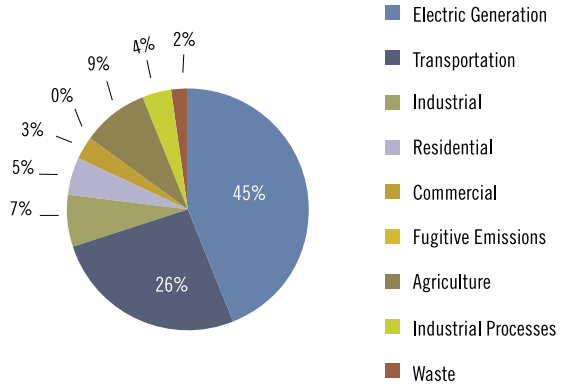
• In 2003, Missouri GHG emissions totaled 163 $MtCO_2e$, representing 10 percent of Midwest emissions and 2 percent of U.S. emissions.

• Missouri's top-emitting sectors include electric generation, transportation, agriculture, and industrial energy use.

• Between 1990 and 2003, Missouri's GHG emissions increased by 32 $MtCO_2e$, or 26 percent—the largest absolute and percentage growth of any Midwest state. Emissions growth outpaced state population growth by more than a factor of two.

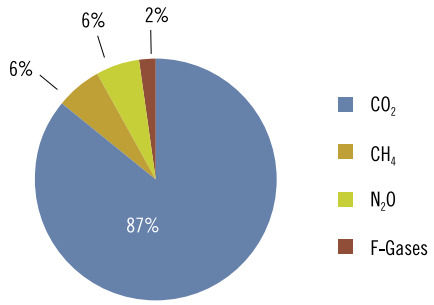
• Between 1990 and 2003, emissions from electricity generation increased by 54 percent (or 26 $MtCO_2e$)—more than twice the regional and national average values—and transportation emissions increased by 22 percent (or 8 $MtCO_2e$). These two sectors accounted for nearly all emissions growth in the state between 1990 and 2003.

Figure 4.16 | **Missouri GHG Emissions by Economic Sector: 2003**



Source: WRI, CAIT-US (2007).

Figure 4.17 | **Missouri GHG Emissions by Gas: 2003**



Source: WRI, CAIT-US (2007).

Missouri is the fifth largest GHG emitter in the Midwest, and the 15th largest in the nation in terms of absolute emissions. The state's GHG emissions account for approximately 10 percent of the Midwest's emissions and 2 percent of U.S. emissions. State per capita emissions are about 7 percent higher than the regional average and 20 percent higher than the national average. Similar to other Midwest states, Missouri's above-average GHG intensity is partly a result of its relatively high dependence on coal for electricity. In 2003, 85 percent of its electricity production was coal-based.

Approximately 77 percent of Missouri's GHG emissions were produced by the major energy sectors: electric generation (45 percent), transportation (26 percent), and industrial energy use (7 percent). Missouri's share of total emissions from electricity generation is higher than that of any other Midwest state (Figure 4.16). Again, this was due to its relatively large share (85 percent) of electricity generation from coal, compared to the average share for the Midwest

Table 4.8 | **Missouri GHG Emissions and Trends by Economic Sector: 1990–2003**

SECTOR	1990 EMISSIONS ($MtCO_2e$)	2003 EMISSIONS ($MtCO_2e$)	1990–2003 EMISSION TRENDS		
			MISSOURI% CHANGE	MIDWEST % CHANGE	U.S. % CHANGE
Energy Sectors	*105*	*138*	*32*	*14*	*14*
Electric Generation	47	73	54	25	24
Transportation	35	42	22	20	19
Industrial	11	11	-3	-11	-3
Residential	8	8	5	8	12
Commercial	4	5	3	9	7
Fugitive Emissions	0	0	-80	-40	-35
Agriculture	14	14	-1	-8	0
Industrial Processes*	4	7	10	-5	8
Waste	4	3	-23	-21	-9
Total*	***127***	***163***	***26***	***11***	***13***

Source: WRI, CAIT-US (2007).

Notes: Totals exclude emissions from international bunker fuels and land-use change and forestry.

*Due to inconsistencies in industrial processes emissions data prior to 1997, the 1990 emission value for this economic sector has been replaced with the 1997 estimate. Trend calculations for industrial processes reflect the period 1997–2003.

**While the 1990 total emission value presented here includes industrial processes emissions for 1997, as noted above, calculations of total state, regional, and national emission trends do not include any industrial processes data in order to maintain consistency between 1990 and 2003.

(73 percent). Missouri's agricultural sector produces 75 percent of total state CH_4 and N_2O emissions. In total, these gases account for approximately 12 percent of state emissions (Figure 4.17).

Between 1990 and 2003, Missouri's GHG emissions grew by 32 $MtCO_2e$, or 26 percent—the highest overall increase among Midwest states (see Missouri State Spotlight). The major contributor to this trend—emissions from electricity generation—grew by 54 percent (Table 4.8). It is worth noting that almost one-quarter of the absolute growth in electric generation emissions occurred between 2002 and 2003, despite slowing rates of population growth. Emissions growth in this sector is likely partly due to an increasing dependence on coal as a fuel source for electricity generation—coal's share increased from 82 to 85 percent between 1990 and 2003—as well as the state's 47 percent increase in total electricity generation (in MWh) during this period, the largest of any Midwest state (EIA, 2007).

Missouri is one of the two states in the Midwest (with Iowa) where GHG emissions growth between 1990 and 2003 outpaced state population growth by more than a factor of two. As a result, per capita GHG emissions in Missouri increased by 15 percent—the highest increase in the Midwest and the sixth highest nationally.

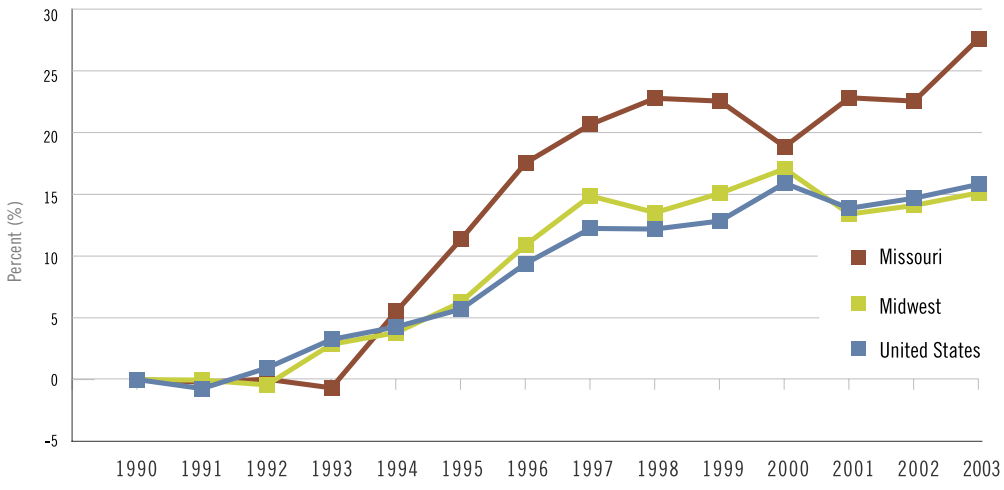
MISSOURI STATE SPOTLIGHT: HIGH EMISSIONS GROWTH RATE

In terms of GHG emissions, Missouri is the fastest-growing state in the Midwest. Between 1990 and 2003, Missouri's GHG emissions grew from 123 to 155 $MtCO_2e$ (excluding emissions from industrial processes)—a 26 percent overall increase and almost a 2 percent average annual increase. During this period, state emissions rose at a significantly higher rate than overall regional emissions (11 percent) and U.S. emissions (13 percent) (Figure 4.18).

More than 90 percent of Missouri's absolute GHG emissions growth during this period came from its two largest emitting sectors:

- Electric generation emissions grew by nearly 26 $MtCO_2e$, or 54 percent—more than double the Midwest's average growth rate in electricity emissions.
- Transportation emissions increased by about 8 $MtCO_2e$, or 22 percent—slightly faster than the Midwest's average growth rate of 20 percent.

Figure 4.18 | **Missouri GHG Emission Trends: 1990-2003**



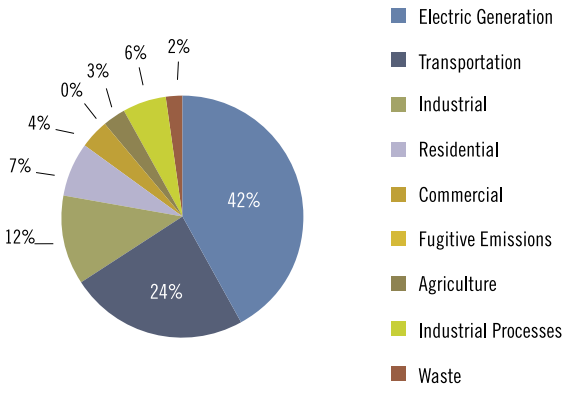
Source: WRI, CAIT-US (2007).

Note: Percentage changes for each year are relative to 1990 totals.

OHIO

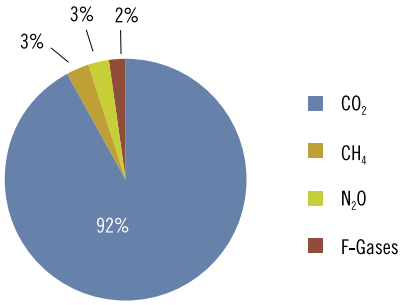
- **In 2003, Ohio GHG emissions totaled 299 $MtCO_2e$, representing 19 percent of Midwest emissions and 4 percent of U.S. emissions.**
- **Ohio's top-emitting sectors include electric generation, transportation, industrial energy use, and residential energy use.**
- **Between 1990 and 2003, industrial energy use emissions in the state declined by 15 $MtCO_2e$, or 29 percent, which was more than twice the Midwest regional average. GHG emissions from transportation increased by 13 $MtCO_2e$—the largest increase, in terms of absolute emissions, among Midwest states.**
- **Approximately 92 percent of Ohio's electricity is generated from coal. As a result, 42 percent of total emissions are produced by the electric generation sector—5 percent more than the Midwest average.**

Figure 4.19 | **Ohio GHG Emissions by Economic Sector: 2003**



Source: WRI, CAIT-US (2007).

Figure 4.20 | **Ohio GHG Emissions by Gas: 2003**



Source: WRI, CAIT-US (2007).

Ohio is the largest GHG emitter in the Midwest, and the fourth largest in the nation in terms of absolute emissions. The state's GHG emissions account for approximately 19 percent of the Midwest's emissions and 4 percent of U.S. emissions. Per capita emissions in Ohio are approximately equal to the Midwest regional per capita emissions rate of 26 metric tons of CO_2e.

Approximately 78 percent of Ohio's GHG emissions are produced by the major energy sectors: electric generation (42 percent), transportation (24 percent), and industrial energy use (12 percent). At just over 70 $MtCO_2e$, Ohio's transportation sector is the largest in the Midwest (Figure 4.19). Total emissions from transport in Ohio during 2003 were comparable to Utah's *total state* emissions. Ohio's electric generation sector also produces the most GHG emissions (126

Table 4.9 | **Ohio GHG Emissions and Trends by Economic Sector: 1990-2003**

SECTOR	1990 EMISSIONS ($MtCO_2e$)	2003 EMISSIONS ($MtCO_2e$)	1990-2003 EMISSION TRENDS		
			OHIO % CHANGE	MIDWEST % CHANGE	U.S. % CHANGE
Energy Sectors	*251*	*267*	*6*	*14*	*14*
Electric Generation	109	126	16	25	24
Transportation	58	71	22	20	19
Industrial	52	37	-29	-11	-3
Residential	21	22	5	8	12
Commercial	11	11	7	9	7
Fugitive Emissions	2	1	-48	-40	-35
Agriculture	9	8	-10	-8	0
Industrial Processes*	3	18	-14	-5	8
Waste	9	6	-31	-21	-9
Total*	***272***	***299***	***5***	***11***	***13***

Source: WRI, CAIT-US (2007).

Note: Totals exclude emissions from international bunker fuels and land-use change and forestry.

*Due to inconsistencies in industrial processes emissions data prior to 1997, the 1990 emission value for this economic sector has been replaced with the 1997 estimate. Trend calculations for industrial processes reflect the time period 1997 to 2003.

**While the 1990 total emissions value presented here includes industrial processes emissions for 1997 as noted above, calculations of total state, regional, and national emission trends do not include any industrial processes data in order to maintain consistency between 1990 and 2003.

$MtCO_2e$) among state electric utility sectors of the Midwest. This is partly due to Ohio's relatively large population and economy, and also to its use of coal as a fuel for about 92 percent of its electricity production. Consequently, CO_2 emissions comprise a larger portion of Ohio's GHG profile than the Midwest's overall profile (Figure 4.20).

Between 1990 and 2003, Ohio's GHG emissions grew by 5 percent—approximately half of the growth experienced by the Midwest and the nation. This slow growth trend was largely a result of slower-than-average growth in emissions from the electric generation sector, and a nearly 30 percent decline in emissions from industrial energy use (Table 4.9 and Ohio State Spotlight).

Since at least 1997, Ohio's GHG emissions appear to be largely driven by fluctuations in state GDP (data not shown). Most notably, both emissions and GDP declined between 2000 and 2001 (relative to 1997 levels), during a mild national recession. Previously, Ohio's total emissions had peaked in 2000 at 306 $MtCO_2e$. In 2001, they were 290 $MtCO_2e$ (WRI, CAIT-US, 2007). In more recent years, as the economy has recovered, pre-recession growth in GHG emissions has returned. Total state GHG emissions grew by 1–2 percent between 2001 and 2003.

OHIO STATE SPOTLIGHT: DECLINING EMISSIONS FROM INDUSTRIAL ENERGY USE

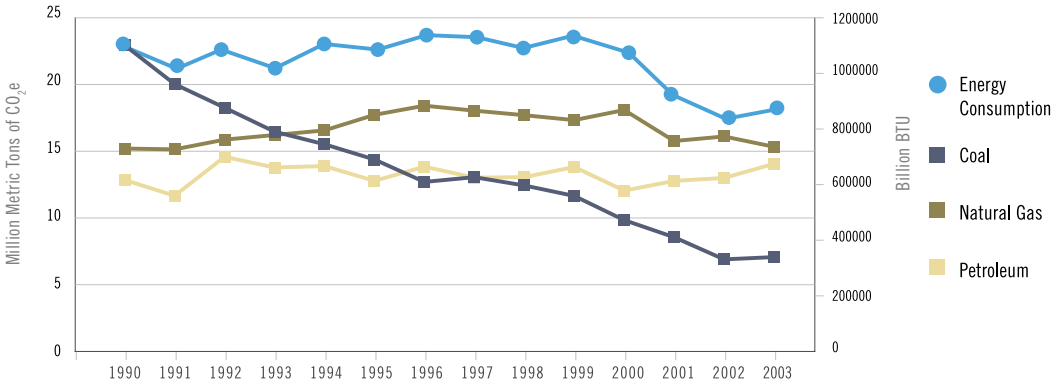
The industrial sector is the third largest GHG-emitting sector in the nation, the Midwest, and Ohio. Between 1990 and 2003, GHG emissions from energy use in Ohio's industrial sector declined by nearly 15 $MtCO_2e$, or 29 percent, the largest decrease in this sector of any Midwest state. This trend was primarily due to a reduction in coal consumption; the total amount of coal used by Ohio's industrial sector as an energy fuel source declined by nearly 70 percent between 1990 and 2003 (EIA, 2007).

Interestingly, total industrial energy consumption did not experience similar declines (or any significant declines) until 2000 (Figure 4.21). For most years throughout the 1990s, annual declines in coal were compensated for by increases in the consumption of natural gas, petroleum, and to a lesser extent, wood fuels (EIA, 2007). So despite approximately constant energy demand in this sector, GHG emissions were reduced by switching to less carbon-intensive fuels.

Between 2000 and 2002, coal use continued to decline, while petroleum use increased (EIA, 2007). The nationwide economic recession during these years appears to have been a driving factor in limiting the growth of both energy consumption and GHG emissions. Ohio was particularly hard hit in the Midwest region, experiencing essentially no growth in state GDP during this period (BEA, 2007). Consequently, both total industrial energy consumption and emissions declined. Additional drivers of this trend could also include increased efficiencies and decreases in manufacturing activities (see Chapter 3).

Notably, between 2002 and 2003, the latest year for which data are currently available, Ohio's industrial sector consumption of both coal and petroleum fuels increased and its consumption of natural gas decreased. Correspondingly, there was an increase in industrial energy use emissions, albeit less than 1 MtCO2e. More recent energy and emissions data will be required to validate whether this trend is indeed a new sectoral trajectory.

Figure 4.21 | **Ohio Industrial Sector Energy Consumption and GHG Emissions from Fossil Fuels: 1990–2003**



Sources: WRI, CAIT-US (2007); EIA (2007).

WISCONSIN

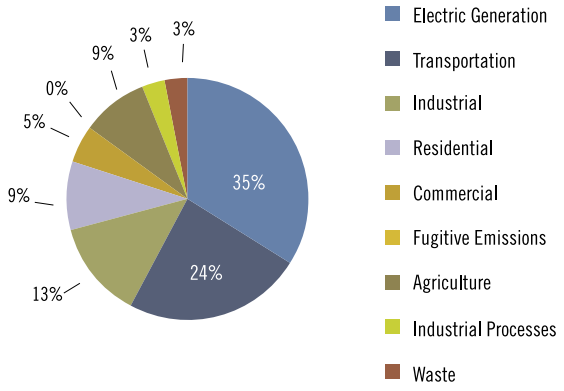
• In 2003, Wisconsin GHG emissions totaled 123 $MtCO_2e$, representing 8 percent of Midwest emissions and 2 percent of U.S. emissions.

• Wisconsin's top-emitting sectors include electric generation, transportation, industrial energy use, and agriculture.

• GHG emissions from electric generation increased by 29 percent between 1990 and 2003, representing the fastest growth among economic sectors in Wisconsin; this value was greater than both the Midwest and national averages.

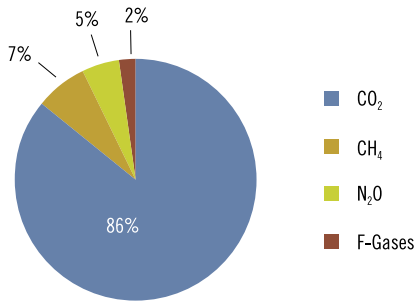
• GHG emissions from energy use in Wisconsin's commercial sector increased by 25 percent between 1990 and 2003, approximately 3 times the Midwest average. Emissions from industrial energy use increased by 37 percent between 1990 and 2000, but declined by 21 percent between 2000 and 2003.

Figure 4.22 | **Wisconsin GHG Emissions by Economic Sector: 2003**



Source: WRI, CAIT-US (2007).

Figure 4.23 | **Wisconsin GHG Emissions by Gas: 2003**



Source: WRI, CAIT-US (2007).

Wisconsin is the sixth largest GHG emitter in the Midwest, and the 21st largest in the nation in terms of absolute emissions. The state's GHG emissions account for approximately 8 percent of the Midwest's emissions and 2 percent of U.S. emissions. Wisconsin's emissions profile is less GHG intensive than the broader Midwest's profile: state per capita emissions are about 12 percent lower than the Midwest regional per capita emissions average.

Approximately 72 percent of Wisconsin's GHG emissions are produced by the major energy sectors: electric generation (35 percent), transportation (24 percent), and industrial energy use (13 percent). At about 11 $MtCO_2e$, or 9 percent each, emissions from agriculture and residential energy use also constitute considerable portions of total GHG emissions (Figure 4.22). All other GHG-emitting sectors in Wisconsin account for 5 percent or less of total emissions. As with all other Midwest states where agriculture emissions contribute more than 8 percent of total emissions (i.e., Iowa, Minnesota, and Missouri), Wisconsin's agricultural emissions account for more than 70 percent of all CH_4 and N_2O emissions from the state. However, Wisconsin is the only state in the Midwest

Table 4.10 | **Wisconsin GHG Emissions and Trends by Economic Sector: 1990–2003**

SECTOR	1990 EMISSIONS ($MtCO_2e$)	2003 EMISSIONS ($MtCO_2e$)	1990–2003 EMISSION TRENDS		
			WISCONSIN% CHANGE	MIDWEST % CHANGE	U.S. % CHANGE
Energy Sectors	*87*	*106*	*21*	*14*	*14*
Electric Generation	33	43	29	25	24
Transportation	25	30	19	20	19
Industrial	15	16	9	-11	-3
Residential	9	11	11	8	12
Commercial	5	6	25	9	7
Fugitive Emissions	--	--	--	-40	-35
Agriculture	13	11	-14	-8	0
Industrial Processes*	1	3	37	-5	8
Waste	5	3	-34	-21	-9
Total*	***106***	***123***	***14***	***11***	***13***

Source: WRI, CAIT-US (2007).

Note: Totals exclude emissions from international bunker fuels and land-use change and forestry.

*Due to inconsistencies in industrial processes emissions data prior to 1997, the 1990 emission value for this economic sector has been replaced with the 1997 estimate. Trend calculations for industrial processes reflect the period 1997–2003.

**While the 1990 total emission value presented here includes industrial processes emissions for 1997, as noted above, calculations of total state, regional, and national emission trends do not include any industrial processes data in order to maintain consistency between 1990 and 2003.

where CH_4 emissions from agriculture exceed N_2O emissions from agriculture, which is likely a result of the state's dairy industry (see Wisconsin State Spotlight). Consequently, total CH_4 emissions for the state comprise a larger percentage than N_2O emissions (Figure 4.23).

Between 1990 and 2003, Wisconsin's GHG emissions grew by 14 percent, which was approximately equal to the Midwest regional and U.S. rates of growth, although slightly higher. The emissions increase in the commercial energy use sector (25 percent) was approximately three times larger than the average growth in this sector regionally, and four times larger than the sector's growth nationwide (Table 4.10). GHG emissions from commercial energy use in Wisconsin accounted for approximately 6 $MtCO_2e$ in 2003.

Between 1990 and 2000, emissions from industrial energy use grew by 37 percent from approximately 15 $MtCO_2e$ to 20 $MtCO_2e$—the highest percentage increase during this period of any Midwest state. Since 2000, however, emissions from the industrial sector have declined, in step with the rest of the region, which was likely due to gains in energy efficiency and fuel switching (see Chapter 3). It is notable, however, that Wisconsin's economic output from manufacturing did not decline, but instead increased by 13 percent between 1997 and 2003 (BEA, 2007). Though total state GDP increased by approximately 15 percent between 1997 and 2003, on average, emissions remained fairly constant at about 125 $MtCO_2e$.

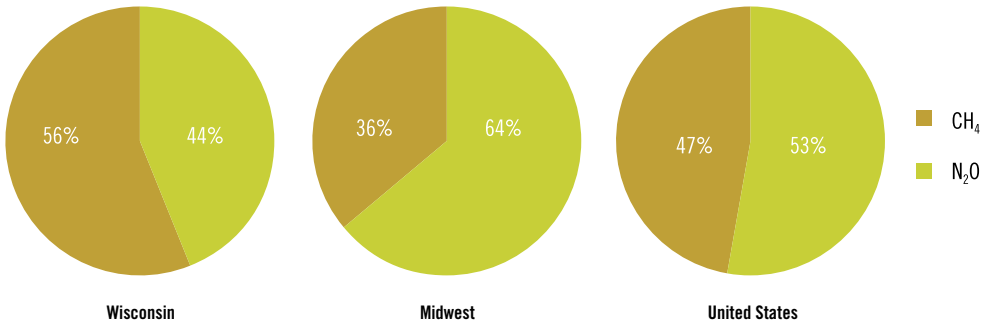
WISCONSIN STATE SPOTLIGHT: METHANE EMISSIONS FROM LIVESTOCK

All animals produce methane gas (CH_4) as a byproduct of digestion (a process known as enteric fermentation). However, animals such as cows, sheep, and goats have a special stomach, called a rumen, which allows them to break down coarse plants and grains. As a result, these so-called ruminant livestock end up producing (and emitting) more CH_4 than other animals. CH_4 is also produced as manure from these animals decomposes. Since CH_4 has a global warming potential that is 21 times that of CO_2 (IPCC, 1996), livestock can consequently represent an important source of GHG emissions.

According to the latest data available, Wisconsin has more than 1.2 million head of dairy cattle, a total greater than any other U.S. state except California, in addition to approximately 3.4 million head of nondairy cattle and calves. Wisconsin's dairy industry is a key component of the state's economy, generating upwards of three billion dollars in revenue annually from milk and other dairy products (USDA, 2007).

As a result, Wisconsin is also the only Midwest state where total CH_4 emissions constitute a larger percentage of agricultural emissions than N_2O emissions (Figure 4.24). A more detailed analysis of state GHG data reveals that emissions from enteric fermentation correlate well with the total number of heads of cattle: both indicators have generally declined since 1990 (WRI, CAIT-US, 2007; USDA, 2007). Conversely, emissions from manure management in Wisconsin have increased in recent years, after the state experienced declines in emissions from this subsector between 1990 and 1997.

Figure 4.24 | **Wisconsin, Midwest, and U.S. Agriculture Emissions by Gas: 2003**



Source: WRI, CAIT-US (2007).

5 DISCUSSION AND CONCLUSIONS

Using recent, comparable greenhouse gas (GHG) emissions data, this report reviews the U.S. Midwest's contribution to global warming and climate change by analyzing key GHG sources, trends, and macroeconomic drivers. By providing this information at the regional, sectoral, and state levels in an accessible format, the findings of this report (see below) can supply state and federal policymakers and stakeholders with the relevant context needed for developing robust, effective, and balanced climate change solutions that are best suited for the Midwest.

With significant coal reserves, a diverse industrial sector, and millions of acres of forests and farmland, the Midwest should be constructively engaged in state, regional, and federal dialogues regarding energy generation, forest management, and the future of biofuels, among many other issues. Although this report does not attempt to outline or assess what should be done to mitigate climate change in the Midwest, it should contribute to a further understanding of the issue and the Midwest's role in addressing it. Equipped with the information contained in this report, policymakers in the region will have a common language and data to support state and regional policy conversations now underway and chart a course for appropriate action to reduce the production of human-caused GHGs and mitigate global climate change.

FINDINGS

From industry to agriculture, power generation to forestry, the activities of the Midwest make the region a vital part of the national economy and an important guardian of our natural resources. What is also clear from this investigation is that the Midwest is a significant emitter of GHGs, accounting for nearly 25 percent of national emissions and 5 percent of emissions worldwide. However, GHG emissions and historic trends can vary considerably between sectors and between Midwest states. The key findings from this analysis should elucidate Midwest GHG emissions and help public officials, business representatives, and other stakeholders in the Midwest and across the country contemplate comprehensive state, regional, and national responses to address climate change. Following are key regional and sectoral findings.

KEY REGIONAL FINDINGS

The Midwest is a major emitter of GHG emissions in national and international terms. With GHG emissions of approximately 1.5 billion metric tons of carbon dioxide equivalent (CO_2e) in 2003, the Midwest accounts for nearly one-quarter of total U.S. emissions. If the Midwest were its own country, it would be the fifth largest emitter in the world.

Three sectors—electric generation, transportation, and industrial energy use—account for 75 percent of total Midwest GHG emissions. The top two emitting sectors—electric generation and transportation—are also the fastest-growing sectors in the Midwest.

Total Midwest emissions grew by 11 percent between 1990 and 2003, which is less than the nation as a whole (13 percent). However, the four Midwest states that emit the least amount of GHGs—Missouri, Minnesota, Iowa, and Wisconsin—are experiencing emissions growth that outpaces the regional and national averages, largely driven by population and economic growth.

The average person living in the Midwest emits 13 percent more GHGs than the national average and nearly four times the global average. Per capita emissions in the region are 26 metric tons of CO_2e per year. The national and world per capita averages are 23 metric tons of CO_2e and 6 metric tons of CO_2e per year, respectively.

KEY SECTORAL FINDINGS

ELECTRIC GENERATION

At over half a billion metric tons of CO_2e, the electric generation sector is the largest emitting sector in the Midwest and the sector with the largest emissions growth. Regional emissions growth in electric generation emissions was 25 percent between 1990 and 2003, which was comparable to the nation as a whole (24 percent). Most states' emissions growth in the electric generation sector followed similar growth trends in total generation of electricity and in-state sales as new generation met increasing demand.

Compared to the nation overall, the Midwest is much more dependent on coal to generate electricity. A major driver of regional emissions from electricity generation is the fact that approximately 75 percent of Midwest-generated electricity comes from fossil fuels, nearly all of which is coal.

TRANSPORTATION

Midwest GHG emissions from transportation grew slightly faster than national emissions between 1990 and 2003, as drivers increased their individual travel mileage by an average of 19 percent during this period. Population growth and an increase in the total miles driven per person are driving the growth in the Midwest's transportation emissions at a rate that is similar to the nation as a whole.

Gasoline combustion from passenger vehicles is the primary source of GHG emissions in the transportation sector. In all Midwest states, the combustion of gasoline is the primary source of transportation GHG emissions, with diesel fuel playing a smaller role that varies across states.

INDUSTRIAL ENERGY USE

Midwest emissions from industrial energy use declined by 11 percent, primarily due to the use of less GHG-intensive fuels and increased energy efficiency. Between 1997 and 2003, regional industrial economic output increased by 10 percent, while regional energy consumption and GHG emissions declined by about 10 percent, indicating that sectoral efficiencies played a greater role in emission reductions than the loss of economic output.

AGRICULTURE

Nitrous oxide emissions constitute a greater share of emissions from the agriculture sector in the Midwest than methane. This is characteristic of extensive crop cultivation, especially of corn in the region. Given the region's leadership in corn and other crop production and the use of nitrogen fertilizer to support that production, nitrous oxide is the dominant agricultural GHG across almost all Midwest states.

Though emissions in the agriculture sector declined between 1990 and 2003, this trend could change quickly based on crop plantings, the expansion of livestock production, weather variability, and soil practices. Agricultural emissions are strongly tied to the region's crop and livestock activities.

SUGGESTED AREAS FOR ADDITIONAL RESEARCH AND ACTION

The analysis undertaken in this report provides a new level of detail and comparison of GHG emissions in the Midwest, but it is by no means exhaustive. Additional areas of research and action may be useful to further the understanding of GHG emissions in the region and their implications.

Enhance and support current and new efforts at the state level to develop annual GHG emissions inventories using comparable and uniform methodologies. Much like emission inventories used in international frameworks, states should pursue the annual development of comprehensive, six-gas (CO_2 and non-CO_2 GHGs), economy-wide emissions data to enable policymakers and stakeholders to make the best decisions possible. Leading states on this front should share resources and collaborate with their counterparts in other states to identify gaps in available data, collect and review existing data, and develop best practices and methodologies.

Conduct a consistent and systematic study of GHG emission projections out to a reasonable point in the future. As part of their inventory exercises, some states have conducted GHG projections out to 2020. The U.S. Energy Information Administration (EIA) provides annual emissions projections out to 2030, but they do not apply to individual states (only regions) and they only project CO_2 emissions from energy use. Annually updated projections using similar methodologies at the state level will give policymakers and stakeholders a better grasp of what to anticipate as they contemplate future actions.

Engage policymakers and stakeholders through public processes that assess options for addressing climate change. Data and information about GHG emissions are only valuable when they are fully understood and applied. Several states in the region have public processes underway that are both increasing the overall understanding of the problem of climate change and examining potential solutions. States and other actors should engage all stakeholders through additional processes where they are not already in motion. In addition, similar regional processes should be pursued to discuss and explore issues of collective interest and potential solutions.

SUPPLEMENTARY INFORMATION

THE MIDWEST LAND-USE CHANGE AND FORESTRY SECTOR

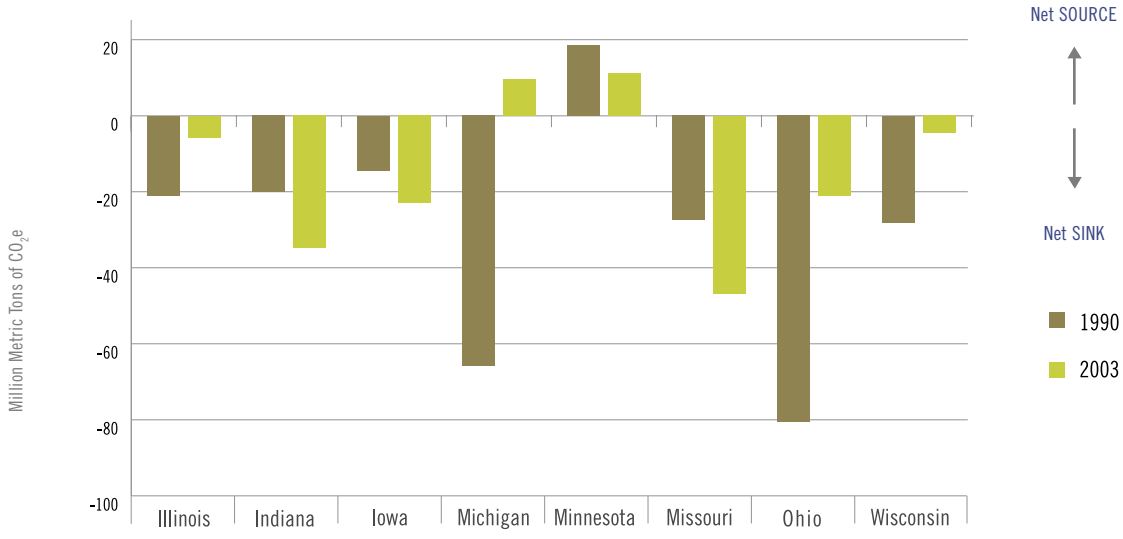
Land and plants have a natural ability to store or emit quantities of carbon dioxide (CO_2). Therefore, changes in land cover contribute to greenhouse gas (GHG) fluxes (IPCC, 2000). The land-use change and forestry (LUCF) sector is comprised of changes in GHG levels due to afforestation, deforestation, reforestation, forest management, and similar activities. Carbon is released into the atmosphere as forests are cleared or burned, and is sequestered through forest growth. Therefore, net emissions from this sector may constitute a *source* of GHGs, if released carbon exceeds sequestered carbon, or a *sink* of GHGs, if sequestered carbon exceeds released carbon.

The emission or sequestration potential of forests, cropland, grasslands, and wetlands is influenced by decisions that owners make regarding the management of their land (IPCC, 2000). Decisionmakers may include individual, local, state, and/or federal stakeholders. Although it is certain that land-use decisions impact GHG trends, the effects of these decisions can be difficult to quantify. Currently, state-level data on net emissions from the LUCF sector contain significant uncertainties.

The State Inventory Tool module that is used to compute LUCF emission estimates for U.S. states for inclusion in the CAIT-US tool (see Appendix A) includes estimates of forest carbon flux, carbon from liming of agricultural soils, carbon storage from urban trees, nitrous oxide from settlement soils, and carbon storage in landfilled yard trimmings and food scraps (EIIP, 2004). Emissions from forest fires are not included in the CAIT-US LUCF dataset. The underlying activity data for this sector, however, are difficult to tabulate and assess, creating substantial ambiguities and uncertainties regarding both absolute emission values and emission trends in this sector. Mindful of the inherent fallibility of these data, a brief analysis of the LULUCF sector for the Midwest follows.

In 2003, the U.S. LUCF sector sequestered an estimated 812 $MtCO_2e$ (EPA, 2007). The same year, the

Figure S.1 | **Net GHG Emissions/Sequestration from Land-Use Change and Forestry in Midwest States: 1990 and 2003**



Source: WRI, CAIT-US (2007).

Midwest cumulatively sequestered approximately 115 $MtCO_2e$, or about 14 percent of the national total (using estimates from WRI, CAIT-US, 2007). Although the Midwest's LUCF practices contribute to a net sink of CO_2 emissions, the region has experienced a significant (>50 percent) decrease in total sequestration in this sector since 1990, when nearly 240 $MtCO_2e$ were sequestered.

According to 1990 estimates, Michigan and Ohio accounted for more than half of the CO_2 sequestration region-wide, and all states except Minnesota received a net reduction in total CO_2 emissions from LUCF. The more than 50 percent loss in the Midwest's LUCF sequestration capacity between 1990 and 2003 was largely due to the reductions in CO_2 sequestration in Michigan and Ohio. Illinois and Wisconsin also saw overall declines in total CO_2 sequestered by LUCF activities (Figure S.1). In fact, as of 2003, Michigan's LUCF sector constituted a net source of CO_2 emissions, on the order of 10 $MtCO_2e$ annually. In 2003, Indiana, Missouri, and Iowa were the only Midwest states that increased the magnitude of their LUCF sink since 1990, with respective increases in CO_2 sequestration of 73, 71, and 59 percent. Minnesota's LUCF sector is a net source of carbon, but the amount of CO_2 emissions decreased from 19 $MtCO_2e$ in 1990 to 11 $MtCO_2e$ in 2003. For the Midwest, some primary drivers of the reduction in CO_2 sequestration from LUCF include increased sprawl and urban build-up, which releases carbon from forest stocks and soil, and prevents large forest tracts from regrowing, and increased consumption and production of paper and paper products.

CITY GHG EMISSIONS

As major economic and population centers, cities in the Midwest are also, but not exclusively, centers for significant GHG emissions. These traits often spur questions about the extent of a given city's GHG emissions, and what these data mean in a state and national context.

Given their relatively small geographic area and the large volume of goods, services, and people flowing in and out of city boundaries, accounting for GHG emissions in cities is decidedly complicated. How does a city account for emissions from commuters who live far outside the city limits but spend plenty of time working in city office buildings? What about emissions from electricity generation where power plants could be dozens of miles away but the electricity is consumed inside municipal boundaries?

City-level GHG inventory methodologies are evolving, but one protocol developed by the International Council of Local Environmental Initiatives (ICLEI) has been used by cities all over the world through the organization's Cities for Climate Protection Program.[8] The ICLEI protocol provides consistent methodologies to estimate emissions from all major emitting sectors in a city. Several cities in the Midwest participate, though few have up-to-date GHG emissions data that are publicly available. (See Tables S.1 and S.2 for illustrative city-level GHG data.) Many cities are currently updating their inventories or are creating them for the first time.

Table S.1. | **Midwest Cities Participating in ICLEI's Cities for Climate Protection Program (as of March 2007)**

MUNICIPALITY	STATE
Des Moines	IA
Carol Stream	IL
Chicago	IL
Fort Wayne	IN
Muncie	IN
Ann Arbor	MI
Delta County	MI
Grand Rapids	MI
Hennepin County	MN
Minneapolis	MN
Northfield	MN
Ramsey County	MN
Saint Paul	MN
Kansas City	MO
Toledo	OH
Dane County	WI
Madison	WI
Milwaukee	WI

Source: International Council of Local Environmental Initiatives (2007).

Table S.2. | **Total GHG Emissions from Selected Midwest Cities and Years**

CITY	TOTAL GHGs ($MtCO_2e$)	REPORTING YEAR
Ann Arbor, MI	2.4	2002
Madison, WI	5.0	1996
Minneapolis, MN	14.0	1988

Sources: City of Ann Arbor (2003); City of Madison (2002); City of Minneapolis (2005).

In addition to economy-wide inventory methodologies, a few cities specifically account for municipal emissions from government buildings and activities. Chicago, for example, does this through the Chicago Climate Exchange (CCX), a voluntary, market-based GHG reduction program. These data do not account for emissions across the entire economy, only those emitted at government facilities due to the direct combustion of fossil fuels. According to the city's 2003 CCX report, Chicago emitted 343,655 metric tons of CO_2 from the direct combustion of fossil fuels. This is a reduction of 9 percent from its 1998-2001 average baseline.

Currently, the Chicago-based Center for Neighborhood Technology (CNT) is developing a Web-based inventory tool for city-level GHG accounting based on ICLEI's protocol.[9] Through this process, CNT plans to conduct an economy-wide inventory of the City of Chicago. At the time of this writing, the release of the inventory is planned for autumn, 2007.

[8] For more information on ICLEI and the Cities for Climate Protection Program, see <http://www.iclei.org/>.

[9] For more information, see <http://www.cnt.org>.

APPENDIX A:

GHG DATA AND CAVEATS

THE CLIMATE ANALYSIS INDICATORS TOOL

The Climate Analysis Indicators Tool (CAIT) is an interactive greenhouse gas (GHG) inventory and analysis tool developed by the World Resources Institute (WRI). The CAIT-US module includes comparable GHG inventories for all 50 U.S. states plus the District of Columbia, as well as other climate-related data. All data are available free of charge, online at <http://cait.wri.org>.

The GHG emissions data presented in this report are exclusively sourced from CAIT-US version 2.0 (2007), which includes emissions data from 1990 through 2003. WRI incorporates more recent GHG data on the CAIT Web site as they become available. Consequently, many of the report's findings could lend themselves to future modifications as more recent data are compiled. CAIT-US is updated approximately annually.

CAIT-US includes economy-wide emissions of the six major greenhouse gases from most major sources and sinks (see discussions below). Table A.1 shows which gases are included in each sector. The economic sectors included in CAIT-US are the same as those sectors covered in guidance documents of the Intergovernmental Panel on Climate Change (IPCC), such as the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 1997), and the *U.S. Inventory of Greenhouse Gas Emissions and Sinks* (EPA, 2007), although they are not directly comparable with those prescribed by international reporting frameworks.

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

SECTOR	CO_2	CH_4	N_2O	F-GASES
Energy Sectors				
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 (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, because it is unclear whether to attribute them to the country of origin or the destination country. 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. Therefore, this category may constitute a net *source* of GHGs if released carbon exceeds sequestered carbon or a net *sink* if sequestered carbon exceeds released carbon. There are substantial data and methodological uncertainties regarding the calculation of carbon emissions or sequestration from LUCF at the state level, making it difficult to identify trends in this sector with any reliability or to make assurances that emissions are greater or less than zero.

DATA SOURCES AND METHODOLOGIES

CAIT-US indicators are derived from the State Inventory Tool (SIT) of the U.S. Environmental Protection Agency's (EPA's) Emissions Inventory Improvement Program (EIIP). The EIIP provides guidance and methodologies to states that are developing their own emission inventories. To facilitate state GHG inventory initiatives, the EIIP has developed a set of Excel-based modules—the SIT—to accompany its latest technical reports. The SIT includes "default" state activity data from a variety of sources, mostly federal agencies, for each U.S. state and the District of Columbia (Table A.2). A state may supplement or replace the default (EPA-supplied) data if it has its own sources that it considers more reliable. For more information regarding EPA state inventory guidance, please see <http://www.epa.gov/climatechange/emissions/state_guidance.html>.

CAIT-US uses a simple process to produce its inventories: it selects the default data for each state, uses each source module to compute emissions using the tool-supplied emission factors (also included as "defaults" in the source modules), and extracts the results. The same process is used for each state and the District of Columbia. In CAIT-US, national emission totals for the United States are a simple sum of total emissions for each state and the District of Columbia. For the sake of comparability, the source data for CAIT-US do not incorporate any state-supplied activity data; in all instances, WRI utilizes only the default data embedded in the SIT.

Table A.2. | **Partial Source List for "Default" Activity Data of EPA's State Inventory Tool by Sector**

SECTOR	SOURCE
Electric Generation, Residential, Commercial, Industrial & Transportation	Energy Information Administration (EIA) Federal Highway Administration (FHA)
Fugitive Emissions	U.S. Environmental Protection Agency (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. Environmental Protection Agency (EPA)

DATA LIMITATIONS

Opting to use the SIT and *only* EPA-supplied default activity data and emission factors to produce the CAIT-US data set provides a well-established, homogeneous methodology for compiling GHG data for each U.S. state and the District of Columbia and facilitates comparisons across states and sectors. However, in some cases this procedure produces emission estimates that have significant uncertainties due to the underlying activity data and methodologies. The compilation of CAIT-US data also excludes several emission sources. Both of these factors may cause the emission values presented in this report to differ from totals reported elsewhere, such as independent state inventories (see Appendix B).

DATA UNCERTAINTIES

In brief, uncertainties in reported GHG emission values result from the underlying activity data, emission factors, and methodologies. The following discussion, although not exhaustive, provides examples of the uncertainties that arise in the CAIT-US data due to its reliance on the EPA-supplied activity data, emissions factors, and calculation methodologies for state GHG emissions of the SIT.

Activity data and emission factors. The SIT makes use of EPA-supplied activity data and emission factors to calculate total sectoral emissions. Activity data include data sets such as total fossil fuel combustion, number of vehicles, number of cattle, and total population. Largely supplied from federal agencies (see Table A.2), these data become less precise at the state level and additionally contain their own inherent uncertainties. Although usually reliable, emission factors (e.g., the

carbon content of fossil fuels) utilized by the SIT, in some instances, can introduce additional uncertainties. For example, the appropriate emission factor for coal depends on which coal type (e.g., bituminous, sub-bituminous) is used. This can vary significantly between and within states or even between individual power plants. To calculate emissions from coal-fired electricity generation, the SIT draws on coefficients from the Energy Information Administration (EIA), but since the SIT uses only one emission factor for coal per state per year, emission totals are likely to be inexact.

Methodologies. The calculation protocols for emissions from individual sectors or subsectors can also introduce uncertainties into CAIT-US emissions data. Some examples include the following:

- In the calculation of emissions from municipal landfills, the SIT methodology assumes the waste composition of all landfills is the same; in reality, the composition of landfills is likely to vary across locations (EIIP, 2004).
- To calculate emissions from agricultural soils, the SIT uses a Tier 1 methodology (IPCC, 1997) with emission factors. This contrasts with the modeling approach employed by EPA to calculate national emissions from agricultural soils, which may be more accurate at the federal level.
- Estimates of animal stock populations are based on a single date (January 1), rather than accounting for stock fluctuations throughout the year.

For perspective, according to the *U.S. Inventory of Greenhouse Gas Emissions and Sinks*, quantitative estimates of uncertainty for different GHG sources at the national level can vary significantly: for example, -2 and 5 percent (low and high uncertainty estimate bounds) for CO_2 from fossil fuel combustion; -5 and 12 percent for CH_4 emissions from coal mining; and -39 and 32 percent for CH_4 emissions from landfills (EPA, 2007). State-level emission estimates in CAIT-US are likely to have even greater uncertainty for reasons explained above. However, in general, sources which are the largest emitters of GHGs tend to have the least amount of uncertainty associated with them, which reduces the overall uncertainty associated with estimates of a state's total emissions. A more comprehensive explanation of uncertainties for all emission sources that arise at any level is available in both the EIIP documentation that accompanies the SIT and the *U.S. Inventory of Greenhouse Gas Emissions and Sinks* (EPA, 2007).

DATA OMISSIONS

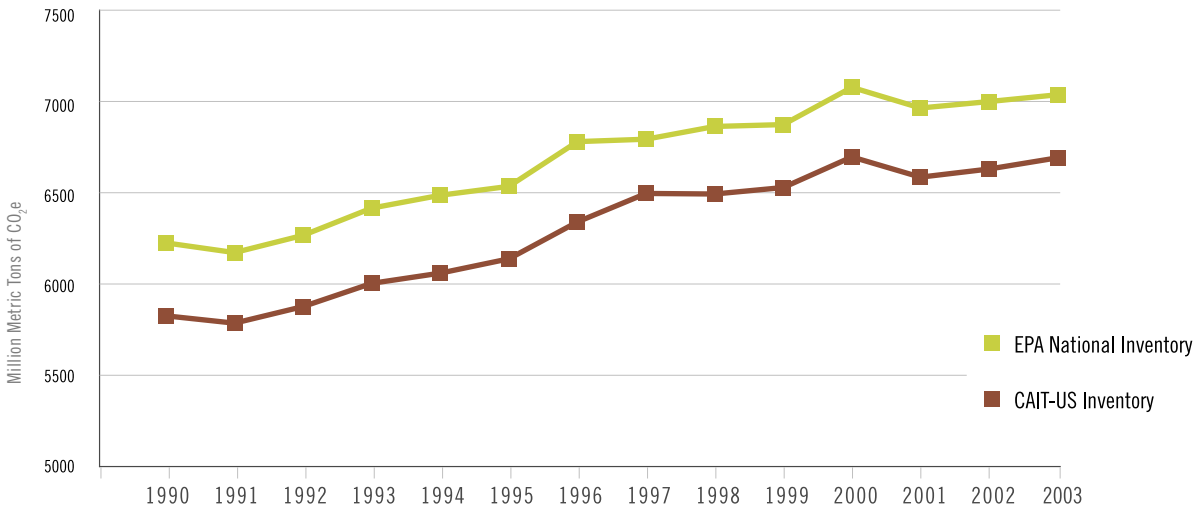
GHG emission sources included in the SIT generally follow the *U.S. Inventory of Greenhouse Gas Emissions and Sinks* (EPA, 2007). However, to ensure optimal comparability between state inventory data within CAIT-US, sectors (SIT modules) in which default activity data are largely absent have been purposely excluded when calculating state emission 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 because of a lack of production data. These industries represent 3 percent of national GHG emissions.
- *Industrial Processes*. This sector produces 2 percent of total U.S. GHG emissions. Emissions from the manufacture of nitric acid, adipic acid, ammonia and urea, HFCF-22, and magnesium are generally not included because of a lack of data.

In addition, default estimates of emissions from limestone and dolomite use are unavailable for 1990–93, and estimates of emissions from iron and steel production—a large percentage of total industrial processes emissions in several Midwest states—are 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 through 2003 (as opposed to other sectoral trends in this report, which include the years 1990–2003).

- *Waste*. Methane emissions from industrial wastewater (fruits and vegetables, meat and poultry, and pulp and paper) are not included because of a lack of data.

Figure A.1 | **Total U.S. GHG Emissions: 1990-2003**



Sources: WRI, CAIT-US (2007); EPA (2007).

Note: Totals exclude emissions from international bunker fuels and land-use change and forestry.

In addition to the overarching data omissions described above, certain sectors or subsectors within some states have missing or unreported data (i.e., no default value is provided in the SIT). The cumulative effect of purposely excluding the data noted above and/or calculating state emission values while missing data points for particular sectors or years results in an *underestimate* of total national emissions (Figure A.1). An underestimation of total emissions for any given state inventory is also likely, although this cannot be quantified for any particular state. Nevertheless, because this underestimate may be on the order of several $MtCO_2e$, it would alter the absolute emissions, per capita emissions, and trends analysis reported here.

SUMMARY

The emission estimates produced by the SIT, included in CAIT-US, and utilized in this report are, admittedly, imperfect. While using EPA-supplied default estimates and applying uniform calculation methodologies ensures comparability among states, this approach can compromise some of the nuances of state-specific data. Other inventories may incorporate levels of detail that are missing in this analysis. Therefore, states are encouraged to seek out additional data resources, if available, to supplement the analysis provided here.

Although general trends and emission values presented in this report are likely good approximations of emission totals, it is critical that the reader bear in mind that for some sectors and/or years, deviations from "true" emission values can occur. However, data sources and inventory calculation methodologies are regularly being updated and improved. As such, subsequent releases of CAIT-US should build upon the inventory tools already in existence, providing greater quantitative accuracy for all included years for both sectors and states.

APPENDIX B:

STATE INVENTORY COMPARISONS

Six of the eight Midwest states—Illinois, Iowa, Michigan, Minnesota, Missouri, and Wisconsin—previously completed an inventory of state greenhouse gas (GHG) emissions. Since GHG inventories, including those presented in this report, are never void of uncertainties and limitations, it is instructive to quantitatively analyze and compare these independently produced inventories with those derived from the Climate Analysis Indicators Tool – United States (CAIT-US; see Appendix A).

In general, CAIT-US estimates of total state GHG emissions agree with those of individual state inventories. Differences in total reported emissions (excluding land-use change and forestry and international bunkers data) between CAIT-US and all inventories for the year assessed are less than 7 percent (Table S.1). The state inventories for Illinois, Iowa, Michigan, Missouri, and Wisconsin largely utilize the guidance of the Emissions Inventory Improvement Program (EIIP) and the data and calculation methodologies of the State Inventory Tool (SIT—the same tool used to produce the emissions data of CAIT-US), while Minnesota's inventory relies extensively on data generated by in-state agencies. All inventories generally follow the guidance and methodologies of the EPA's national inventory—the *U.S. Inventory of Greenhouse Gas Emissions and Sinks*—and the Intergovernmental Panel on Climate Change (IPCC).

Table B.1. | **Comparisons of State and CAIT-US Inventories**

STATE	GHG INVENTORY YEAR OF COMPARISON	STATE INVENTORY TOTAL GHG EMISSIONS ($MtCO_2e$)	CAIT-US TOTAL GHG EMISSIONS ($MtCO_2e$)	PERCENT DIFFERENCE	STATE INVENTORY SOURCE DOCUMENT (Publication Year)
Illinois	2000	260.4	272.5	4.6	Illinois Inventory of Greenhouse Gas Emissions: 2000 (2004)
Iowa	2000	106.5	110.9	4.1	Year 2000 Iowa Greenhouse Gas Emissions Inventory (2005)
Michigan	2002	229.3	214.7	-6.4	Michigan Greenhouse Gas Inventory: 1990 and 2002 (2005)
Minnesota	2000	124.8	117.7	-5.7	Minnesota Climate Change Action Plan: A Framework for Climate Change Action (2003)
Missouri	1990	130.3	127.4	-2.2	Greenhouse Gas Emission Trends and Projections for Missouri: 1990-2015 (1999)
Wisconsin	2000	129.6	128.2	-1.1	Wisconsin's Greenhouse Gas Emissions: Trends from 1990 to 2000 (2004)

Notes: The Illinois State Inventory excludes all F-gases. The Missouri State Inventory excludes HFCs and SF_6. The Iowa State Inventory excludes HFCs. Inventory totals for all states were converted into $MtCO_2e$ from their published units in the original source document. Data exclude emissions from international bunker fuels and land-use change and forestry.

Disparities in the estimates of total emissions from the state inventories and CAIT-US are likely a result of one or more of the following: data availability, methodologies, and data values, which could include the activity data or emission factors used to calculate GHG emissions in a particular sector. Differences in any of these elements can result in disagreements among emission calculations. For states that have utilized the SIT in their inventory analysis, different iterations of the tool (i.e., 2007 for CAIT-US or an earlier version for state inventories), or the preferred input data for emission calculations (i.e., default data for CAIT-US or state-supplied estimates), can also result in different emission values. In general, the CAIT-US totals would be expected to underestimate state inventory emission totals (as is the case with four states), since the emission estimates of certain sectors and subsectors are excluded in the compilation of the CAIT-US data (see Appendix A).

To provide further specifics on both magnitudes and types of differences between individual state inventories and CAIT-US data, the following brief synopses quantitatively outline *some* of the sectoral inconsistencies between state inventories and the state emission estimates from the CAIT-US tool that contribute to the percentage differences calculated in Table S.1. The examples that follow are illustrative, *not* comprehensive. A thorough examination of *why* the observed differences occur (i.e., methodological inconsistencies) is beyond the scope of this study.

• **ILLINOIS:** Illinois' state inventory does not include emissions from iron and steel production in its estimate of emissions from industrial processes. However, these data are included in CAIT-US for the year 2000. Therefore, Illinois emissions from this sector are 5.9 $MtCO_2e$ (72 percent) lower than the CAIT-US value.

• **IOWA:** Emissions from agriculture are estimated to be approximately 5 $MtCO_2e$ higher (20 percent) in CAIT-US, most likely due to updates to the SIT since this inventory was produced.

• **MICHIGAN:** Estimates of emissions from energy use are approximately 8 $MtCO_2e$ (4 percent) lower in CAIT-US than in the state inventory. Michigan's state inventory includes emissions from natural gas and oil systems, while these data are excluded in CAIT-US (see Appendix A).

• **MINNESOTA:** Emissions from waste are approximately 3 $MtCO_2e$ lower in CAIT-US than in the state inventory. CAIT-US estimates include emissions from municipal solid waste (principally CH_4 from landfills) and emissions from municipal wastewater only (see Appendix A). The Minnesota inventory incorporates emissions from mixed municipal solid waste, industrial solid waste, demolition and construction waste, yard waste, medical waste, hazardous waste, and human waste.

• **MISSOURI:** CAIT-US data report a value for emissions from the industrial processes sector that is 4.5 $MtCO_2e$ below that of the state inventory. Since the year of comparison is 1990, CAIT-US does not include data for emissions from limestone use and nitric acid production (data are unavailable in the SIT). These estimates are included in the Missouri inventory.

• **WISCONSIN:** The estimate for emissions from the agriculture sector in 2000 is 3.2 $MtCO_2e$ (29 percent) lower in the CAIT-US tool than in the state inventory. Since similar methodologies exist for both analyses, revisions to the SIT since 2000 or the inclusion of state agency data in the Wisconsin inventory (e.g., fertilizer use data) for the agriculture sector are the most likely reasons for the discrepancy.

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GLOSSARY AND ABBREVIATIONS

CAIT-US Climate Analysis Indicators Tool-United States. See Appendix A.

CCX Chicago Climate Exchange. See http://www.chicagoclimatex.com.

CH_4 Methane. A colorless, flammable, odorless hydrocarbon that is an important greenhouse gas. All CH_4 data in this report are converted and displayed in CO_2 equivalent units, using the global warming potentials (GWPs) in IPCC (1996). CH_4 has a GWP of 21 times that of CO_2 over a 100-year horizon (IPCC, 1996). See GWP.

CNT Center for Neighborhood Technology. See http://www.cnt.org.

CO_2 Carbon dioxide. A naturally occurring gas that is also a byproduct of burning fossil fuels and biomass, other industrial processes, and land-use changes. CO_2 is the principal anthropogenic greenhouse gas affecting the Earth's temperature.

CO_2e Carbon dioxide equivalent. The amount of CO_2 by weight emitted into the atmosphere that would produce the same estimated radiative forcing as a given weight of another GHG. Carbon dioxide equivalents are computed by multiplying the weight of the gas being measured (for example, methane) by its estimated global warming potential (see GWP). One unit of carbon is equivalent to 3.664 units of CO_2.

EIA Energy Information Administration. An independent statistical agency of the U.S. Department of Energy. See http://www.eia.doe.gov.

EIIP Emissions Inventory Improvement Program. A jointly sponsored effort of the State and Territorial Air Pollution Program Administrators/Association of Local Air Pollution Control Officials (STAPPA/ALAPCO) and the U.S. Environmental Protection Agency. See http://www.epa.gov/ttn/chief/eiip/.

EPA U.S. Environmental Protection Agency. See http://www.epa.gov/.

GDP Gross domestic product. The total value of goods and services produced by labor and property located in a given country.

GHG Greenhouse gas. Any gas that absorbs and re-emits infrared radiation into the atmosphere. The main GHGs include water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

GHG INTENSITY The ratio of GHG emissions to activity or output. At the national level, this indicator is frequently shown as GHG emissions per unit of gross domestic product (see GDP). This measure is identical to CO_2 intensity, except that non-CO_2 gases may be included here.

GREENHOUSE EFFECT The effect produced as greenhouse gases allow incoming solar radiation to pass through the Earth's atmosphere, but prevent most of the outgoing longwave infrared radiation from the surface and lower atmosphere from escaping into outer space. This envelope of heat-trapping gases keeps the Earth about 30°C (54°F) warmer than if these gases did not exist.

GWP Global warming potential. An index that allows for comparison of the various greenhouse gases. It is the radiative forcing that results from the addition of 1 kilogram (2.2 pounds) of a gas to the atmosphere, compared to an equal mass of carbon dioxide. The data in this report and in CAIT use the GWP estimates in the IPCC Second Assessment Report (IPCC, 1996). Over 100 years, methane has a GWP of 21 and nitrous oxide has a GWP of 310.

HFCs Hydrofluorocarbons. A group of human-made chemicals composed of one or two carbon atoms and varying numbers of hydrogen and fluorine atoms. All HFC data in this report are converted and displayed in CO_2-equivalent units, using global warming potentials in the IPCC Second Assessment Report (1996). Most HFCs have 100-year global warming potentials in the thousands (IPCC, 1996) (see GWP).

ICLEI International Council of Local Environmental Initiatives. See http://www.iclei.org/.

IPCC Intergovernmental Panel on Climate Change. An organization established in 1988 by the World Meteorological Organization and the United Nations Environment Programme. It conducts rigorous surveys of the worldwide technical and scientific literature and publishes assessment reports widely recognized as the most credible existing sources on climate change.

LUCF Land-use change and forestry. This term corresponds to IPCC Source/Sink Category 5, and covers emissions and removals from forest and land-use change activities, including but not limited to (1) emissions and removals of CO_2 from decreases or increases in biomass stocks due to forest management, logging, fuelwood collection, etc.; (2) conversion of existing forests and natural grasslands to other land uses; (3) removal of CO_2 from the abandonment of formerly managed lands (e.g., croplands and pastures); and (4) emissions and removals of CO_2 in soil associated with land-use change and management.

$MtCO_2e$ Million metric tons of carbon dioxide equivalent. This measure can aggregate different greenhouse gases into a single measure, using global warming potentials (see GWP). One unit of carbon is equivalent to 3.664 units of carbon dioxide.

MWH Megawatt-hours. One thousand kilowatt-hours or 1 million watt-hours. A watt-hour is an electrical energy unit of measure equal to one watt of power supplied to, or taken from, an electric circuit steadily for one hour.

N_2O Nitrous oxide. A GHG emitted through soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production, and biomass burning. All N_2O data in this report are converted and displayed in CO_2-equivalent units, using the global warming potentials in the IPCC Second Assessment Report (1996). It has a GWP of 310 times that of CO_2 over a 100-year horizon (IPCC, 1996) (see GWP).

NON-CO_2 GASES Refers to the greenhouse gases methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

PFCs Perfluorocarbons. A group of human-made chemicals composed of carbon and fluorine (CF_4 and C_2F_6). PFCs have no commercial uses and are emitted as a byproduct of aluminum smelting and semiconductor manufacturing. These chemicals are potent greenhouse gases. All PFC data in this report are converted and displayed in CO_2-equivalent units, using the global warming potentials in the IPCC Second Assessment Report (1996) (see GWP).

SF_6 Sulfur hexafluoride. A potent greenhouse gas used primarily in heavy industry to insulate high-voltage equipment and to assist in the manufacturing of cable cooling systems. All SF_6 data in this report are converted and displayed in CO_2-equivalent units, using global warming potentials in the IPCC Second Assessment Report (1996). SF_6 has a GWP of 23,900 times that of CO_2 over a 100-year horizon (IPCC, 1996) (see GWP).

SIT State Inventory Tool. The U.S. Environmental Protection Agency's Excel-based companion tool to the Emissions Inventory Improvement Program guidance documentation on state greenhouse gas inventories. See Appendix A.

UNFCCC United Nations Framework Convention on Climate Change. A treaty signed at the 1992 Earth Summit in Rio de Janeiro to which nearly all countries of the world are signatories. See http://unfccc.int.

VMT Vehicle miles traveled. The total mileage traveled by all vehicles for a specified area and time period.

WRI World Resources Institute. See http://www.wri.org.

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