Chapter 2
Inventory and Projections of GHG Emissions

Introduction

This chapter summarizes Michigan's greenhouse gas (GHG) emissions and sinks (carbon storage) from 1990 to 2025. The Center for Climate Strategies (CCS) prepared a draft of Michigan's GHG emissions inventory and reference case projections for the Michigan Department of Environmental Quality (MDEQ). The draft inventory and reference case projections, completed in January 2008, provided the MDEQ with an initial, comprehensive understanding of current and possible future GHG emissions. The draft report was provided to the Michigan Climate Action Council (MCAC) and its Technical Work Groups (TWGs) to assist them in understanding past, current, and possible future GHG emissions in Michigan, and thereby inform the policy recommendation development process. The MCAC and TWGs have reviewed, discussed, and evaluated the draft inventory and methodologies, as well as alternative data and approaches for improving the draft GHG inventory and forecast. The inventory and forecast have since been revised to address the comments provided by the MCAC. The information in this chapter reflects the information presented in the final *Michigan Greenhouse Gas Inventory and Reference Case Projections* report (hereafter referred to as the Inventory and Projections report).[1]

Historical GHG emission estimates (1990 through 2005)[2] were developed using a set of generally accepted principles and guidelines for state GHG emission inventories, relying to the extent possible on Michigan-specific data and inputs. The reference case projections (2006-2025) are based on a compilation of various existing projections of electricity generation, fuel use, and other GHG-emitting activities, along with a set of simple, transparent assumptions described in the final Inventory and Projections report.

The Inventory and Projections report covers the six types of gases included in the U.S. GHG inventory: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of these GHGs are presented using a common metric, CO_2 equivalence (CO_2e), which indicates the relative contribution of each gas, per unit mass, to global average radiative forcing on a global warming potential-weighted basis.[3]

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[1] Center for Climate Strategies. *Final Michigan Greenhouse Gas Inventory and Reference Case Projections: 1990–2025*. Prepared for the Michigan Climate Action Council. November 2008.

[2] The last year of available historical data for each sector varies between 2000 and 2005. The University of Michigan also prepared an inventory and forecast of GHG emissions in conjunction with the MDEQ in 2005.

[3] Changes in the atmospheric concentrations of GHGs can alter the balance of energy transfers between the atmosphere, space, land, and the oceans. A gauge of these changes is called radiative forcing, which is a simple measure of changes in the energy available to the Earth–atmosphere system. Holding everything else constant, increases in GHG concentrations in the atmosphere will produce positive radiative forcing (i.e., a net increase in the absorption of energy by the Earth). See: Boucher, O., et al. "Radiative Forcing of Climate Change." Chapter 6 in *Climate Change 2001: The Scientific Basis*. Contribution of Working Group 1 of the Intergovernmental Panel on

It is important to note that the emission estimates reflect the GHG emissions associated with the electricity sources used to meet Michigan's demands, corresponding to a consumption-based approach to emissions accounting. Another way to look at electricity emissions is to consider the GHG emissions produced by electricity generation facilities in the state, a production-based method. The study covers both methods of accounting for emissions, but for consistency, all total results are reported as consumption-based.

Michigan GHG Emissions: Sources and Trends

Table 2-1 provides a summary of GHG emissions estimated for Michigan by sector for 1990, 2000, 2005, 2010, 2020, and 2025. As shown in this table, Michigan is estimated to be a net source of GHG emissions (positive, or gross, emissions). Michigan's forests serve as sinks of GHG emissions (removal of emissions, or negative emissions). Michigan's net emissions subtract the equivalent GHG reduction from emission sinks from the gross GHG emission totals. The following sections discuss GHG emission sources and sinks, trends, projections, and uncertainties.

Historical Emissions

Overview

In 2005, on a gross emissions consumption basis (i.e., excluding carbon sinks), Michigan accounted for approximately 248 million metric tons (MMt) of CO_2e emissions, an amount equal to 3.5% of total U.S. gross GHG emissions. On a net emissions basis (i.e., including carbon sinks), Michigan residents accounted for approximately 235 $MMtCO_2e$ of emissions in 2005, an amount equal to 3.8% of total U.S. net GHG emissions.[4] Michigan's GHG emissions are rising slower than those of the nation as a whole. From 1990 to 2005, Michigan's gross GHG emissions increased by 12%, while national gross emissions rose by 16%.[5]

On a per-capita basis, Michigan residents emitted about 24 metric tons (t) of gross CO_2e in 2005, similar to the national average of about 24 tCO_2e. Figure 2-1 illustrates the state's emissions per capita and per unit of economic output. Both Michigan and national per-capita emissions remained nearly constant from 1990 to 2005. This consistency in per-capita emission rates in Michigan results from growth in emissions from the electricity supply and transportation sectors, and decline in emissions from the industrial fuel use and industrial processes sectors. In both Michigan and the nation as a whole, economic growth exceeded emissions growth throughout

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Climate Change, Cambridge University Press, Cambridge, United Kingdom. Available at: http://www.grida.no/climate/ipcc_tar/wg1/212.htm.

[4] The national emissions used for these comparisons are based on 2005 emissions from U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006*, April 15, 2008, EPA430-R-08-005. Available at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

[5] During this period, population grew by 10% in Michigan and by 19% nationally. However, Michigan's economy grew at the same rate as the nation on a per-capita basis (up 32%).

the 1990 – 2005 period. From 1990 to 2005, emissions per unit of gross product dropped by 26% nationally, and by 23% in Michigan.[6]

Table 2-1. Michigan GHG emissions, historical and reference case projection, by sector*

Sector	1990	2000	2005	2010	2020	2025
	MMtCO$_2$e					
Energy (Consumption Based)	**192.5**	**218.6**	**214.7**	**220.2**	**238.7**	**248.5**
Electricity Use (Consumption)	**70.3**	**86.9**	**90.0**	**91.0**	**103.9**	**111.1**
Electricity Production (in-state)	64.0	68.1	71.4	72.3	85.3	92.6
Coal	*62.8*	*64.9*	*67.7*	*67.6*	*78.8*	*85.3*
Natural Gas	*0.46*	*1.77*	*2.38*	*3.67*	*5.40*	*6.06*
Oil	*0.66*	*0.99*	*0.71*	*0.48*	*0.48*	*0.57*
MSW/Landfill Gas	*0.12*	*0.38*	*0.34*	*0.39*	*0.44*	*0.46*
Biomass	*0.010*	*0.031*	*0.030*	*0.025*	*0.027*	*0.029*
Other Wastes	*0.009*	*0.029*	*0.16*	*0.19*	*0.21*	*0.22*
Imported/Exported Electricity	6.22	18.8	18.7	18.7	18.6	18.5
Residential/Commercial/Industrial (RCI) Fuel Use	**67.5**	**66.1**	**59.9**	**60.5**	**62.1**	**62.4**
Coal	*11.7*	*9.34*	*7.32*	*6.12*	*5.67*	*5.56*
Natural Gas	*42.8*	*43.7*	*40.4*	*42.6*	*44.4*	*44.8*
Petroleum	*12.8*	*12.9*	*12.0*	*11.6*	*11.9*	*11.8*
Wood (CH_4 and N_2O)	*0.28*	*0.17*	*0.19*	*0.20*	*0.20*	*0.20*
Transportation	**49.7**	**59.4**	**58.2**	**61.4**	**64.0**	**65.3**
On-road Gasoline	*37.4*	*43.7*	*43.3*	*45.5*	*46.2*	*46.4*
On-road Diesel	*5.21*	*8.90*	*10.2*	*11.3*	*12.9*	*13.7*
Rail, Natural Gas, LPG, Other	*1.10*	*1.16*	*0.90*	*0.93*	*0.95*	*0.95*
Marine Vessels	*1.87*	*2.61*	*2.25*	*2.18*	*2.52*	*2.70*
Jet Fuel and Aviation Gasoline	*4.15*	*3.00*	*1.52*	*1.45*	*1.50*	*1.51*
Fossil Fuel Industry	**4.94**	**6.13**	**6.64**	**7.25**	**8.70**	**9.66**
Natural Gas Industry	4.69	6.03	6.55	7.19	8.67	9.64
Oil Industry	0.25	0.10	0.086	0.061	0.032	0.024
Industrial Processes	**15.3**	**18.1**	**18.4**	**18.9**	**23.3**	**26.4**
Cement Manufacture (CO_2)	2.27	2.26	2.13	2.12	2.10	2.09
Lime Manufacture (CO_2)	0.43	0.48	0.41	0.41	0.41	0.41
Limestone and Dolomite Use (CO_2)	0.24	0.25	0.31	0.31	0.31	0.31
Soda Ash (CO_2)	0.10	0.094	0.088	0.084	0.076	0.072
Iron & Steel (CO_2)	11.2	11.0	10.2	8.47	8.12	7.95
Taconite Production (CO_2)	0.037	0.28	0.25	0.20	0.14	0.11
Magnesium Production (SF_6)	0.18	0.45	0.45	0.70	1.16	1.50
ODS Substitutes (HFC, PFC)	0.012	2.84	4.16	6.18	10.6	13.6
Electric Power T&D (SF_6)	0.82	0.47	0.40	0.37	0.34	0.33
Semiconductor Manufacturing (HFC, PFC, and SF_6)	0.001	0.004	0.004	0.004	0.003	0.003
Waste Management	**4.67**	**5.30**	**6.28**	**6.98**	**8.70**	**9.74**
Waste Combustion	0.33	1.14	1.20	1.26	1.38	1.45
Landfills	3.16	2.86	3.75	4.34	5.82	6.73

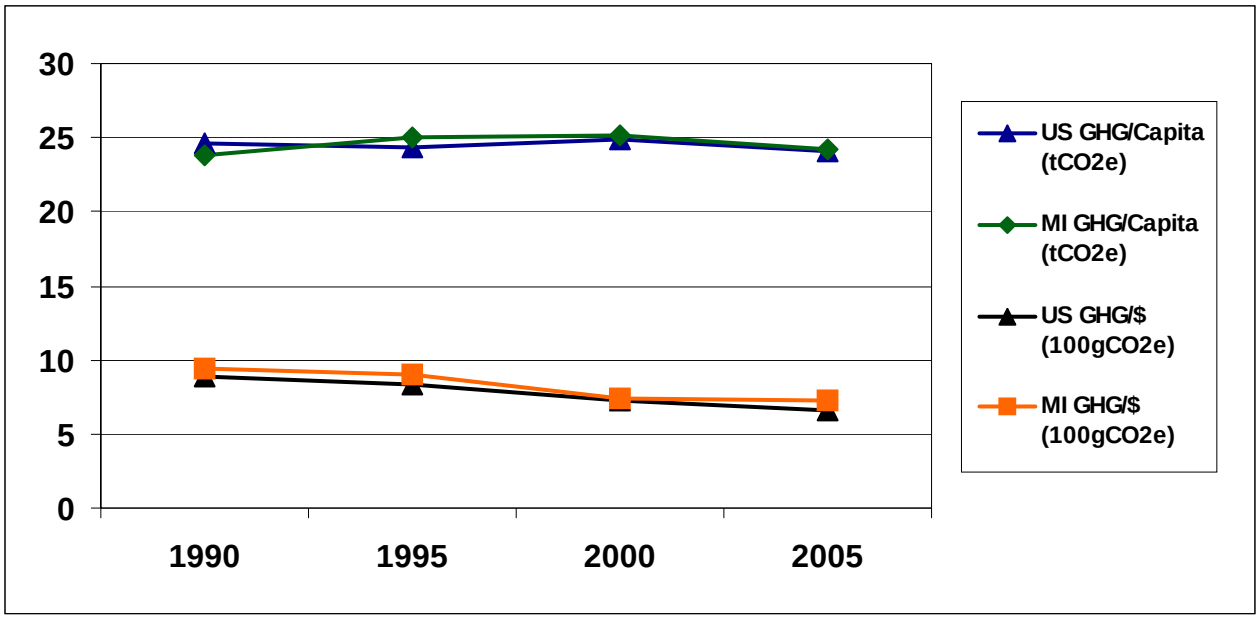
[6] Based on real gross domestic product (millions of chained 2000 dollars) that excludes the effects of inflation. U.S. Department of Commerce, Bureau of Economic Analysis. "Gross Domestic Product by State." Available at: http://www.bea.gov/regional/gsp/.

Wastewater Management	1.17	1.30	1.33	1.38	1.50	1.56
Agriculture	**8.33**	**7.99**	**8.07**	**7.71**	**7.25**	**7.03**
Enteric Fermentation	1.53	1.36	1.40	1.38	1.33	1.31
Manure Management	0.92	0.97	1.09	1.07	1.01	0.99
Agricultural Soils	3.71	3.49	3.42	3.09	2.73	2.55
Agricultural Burning	0.022	0.026	0.029	0.030	0.034	0.036
Agricultural Soils (cultivation practices)	2.14	2.14	2.14	2.14	2.14	2.14
Sector	**1990**	**2000**	**2005**	**2010**	**2020**	**2025**
	MMtCO$_2$e					
Forest Wildfires and Prescribed Burning	**0.020**	**0.020**	**0.020**	**0.020**	**0.020**	**0.020**
Gross Emissions (Consumption Basis)	**220.7**	**250.0**	**247.5**	**253.8**	**278.0**	**291.6**
Increase relative to 1990		*13%*	*12%*	*15%*	*26%*	*32%*
Emissions Sinks	**–37.9**	**–12.5**	**–12.7**	**–12.7**	**–12.7**	**–12.7**
Forestry and Land Use	**–37.9**	**–12.5**	**–12.7**	**–12.7**	**–12.7**	**–12.7**
Forested Landscape	–27.8	–8.77	–8.77	–8.77	–8.77	–8.77
Urban Forestry and Land Use	–10.1	–3.69	–3.91	–3.91	–3.91	–3.91
Net Emissions (Consumption Basis) (including forestry and land use sinks)	**182.9**	**237.5**	**234.8**	**241.1**	**265.3**	**278.9**

MMtCO$_2$e = million metric tons of carbon dioxide equivalent; CH_4 = methane; N_2O = nitrous oxide; MSW = municipal solid waste; LPG = liquefied petroleum gas; ODS = ozone-depleting substance; HFC = hydrofluorocarbon; PFC = perfluorocarbon; SF_6 = sulfur hexafluoride; T&D = transmission and distribution.

* Totals may not equal exact sum of subtotals shown in this table due to independent rounding.

Figure 2-1. Michigan and U.S. gross GHG emissions, per-capita and per-unit gross product



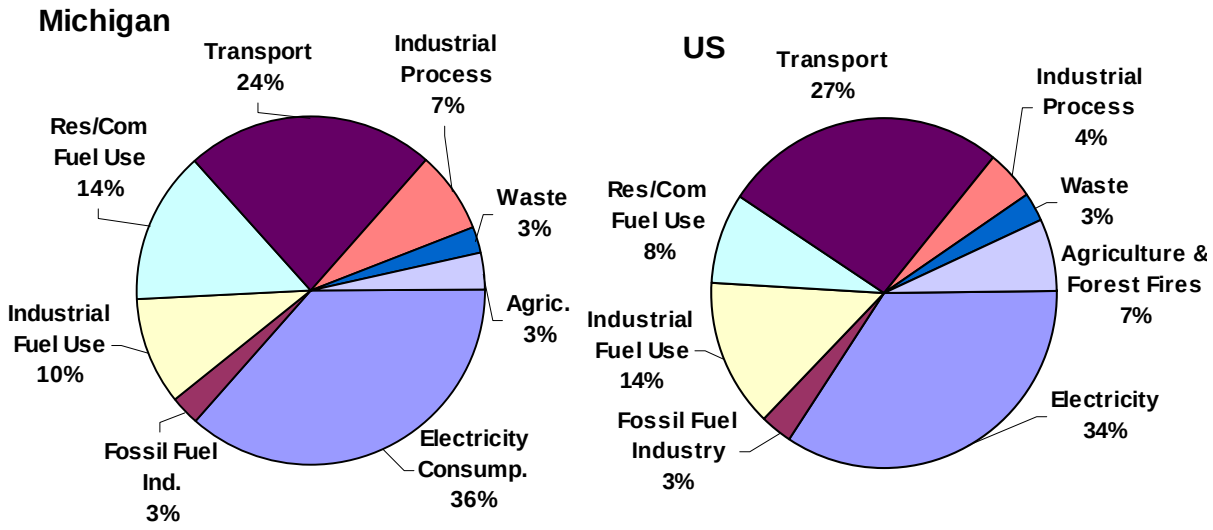
GHG = greenhouse gas; tCO$_2$e = metric tons of carbon dioxide equivalent; g = grams.

The principal sources of Michigan's GHG emissions in 2005 are electricity consumption, residential, commercial, and industrial (RCI) fuel use, and transportation, accounting for 36%, 24%, and 24% of Michigan's gross GHG emissions, respectively, as shown in Figure 2-2. The

next largest contributor is the industrial processes sector, accounting for 7% of gross GHG emissions in 2005; these emissions are rising due to the increasing use of HFCs and PFCs as substitutes for ozone-depleting chlorofluorocarbons.[7] Other industrial process emissions include CO_2 released by cement and lime manufacturing; CO_2 released during soda ash, limestone, and dolomite use; CO_2 released during taconite production and iron and steel production; SF_6 released during magnesium production and from transformers used in electricity transmission and distribution systems; and HFCs, PFCs, and SF_6 released during semiconductor manufacturing.

Figure 2-2 also shows that the agricultural and forest wildfire sectors together accounted for 3% of the gross GHG emissions in Michigan in 2005. These CH_4 and N_2O emissions primarily come from agricultural soils, enteric fermentation, manure management, and agricultural soil cultivation practices. Also, landfills and wastewater management facilities produce CH_4 and N_2O emissions that accounted for 3% of total gross GHG emissions in Michigan in 2005. Similarly, emissions associated with the production, processing, transmission, and distribution of fossil fuels accounted for 3% of the gross GHG emissions in 2005.

Figure 2-2. Gross GHG emissions by sector, 2005: Michigan and U.S.



Notes: Res/Com = Residential and commercial fuel use sectors. Emissions for the residential, commercial, and industrial fuel use sectors are associated with the direct use of fuels (natural gas, petroleum, coal, and wood) to provide space heating, water heating, process heating, cooking, and other energy end-uses. The commercial sector accounts for emissions associated with the direct use of fuels by, for example, hospitals, schools, government buildings (local, county, and state) and other commercial establishments. The industrial processes sector accounts for emissions associated with manufacturing and excludes emissions included in the industrial fuel use sector. The transportation sector accounts for emissions associated with fuel consumption by all on-road and non-highway vehicles. Non-highway vehicles include jet aircraft, gasoline-fueled piston aircraft, railway locomotives, boats, and ships. Emissions from non-highway agricultural and construction equipment are included in the industrial sector. Electricity = Electricity generation sector emissions on a consumption basis, including emissions associated with electricity imported from outside of Michigan and excluding emissions associated with electricity exported from Michigan to other states.

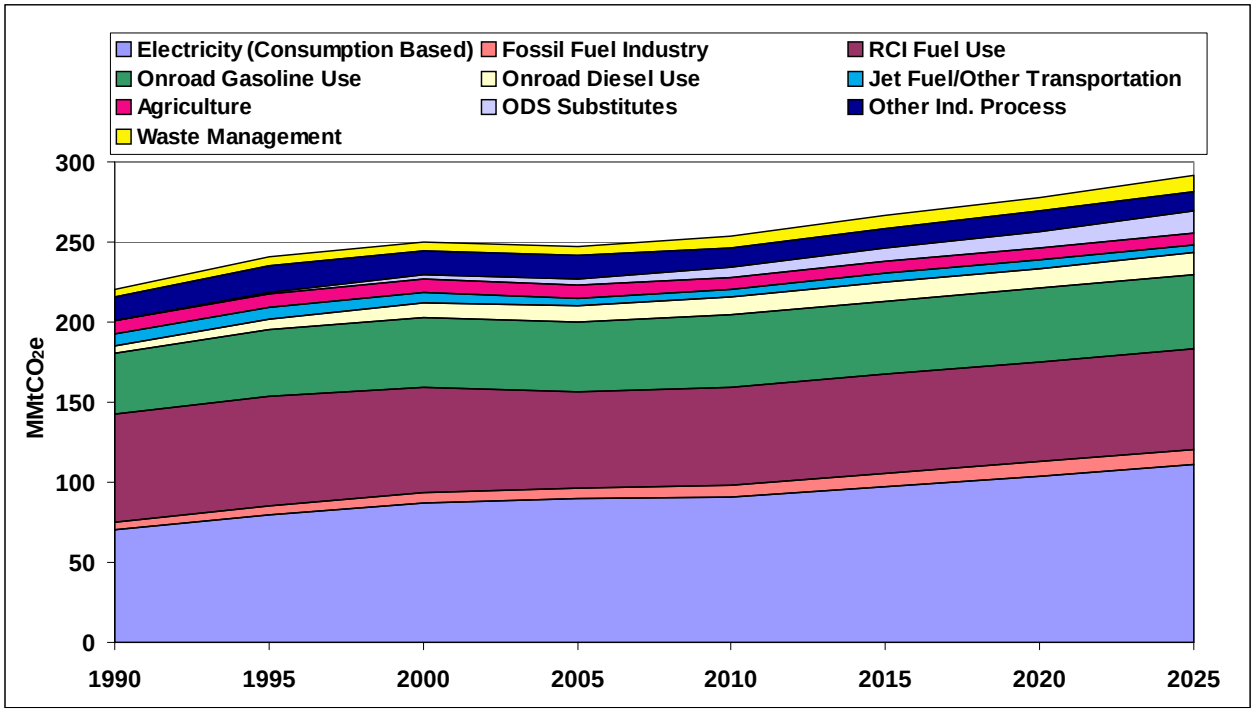
[7] Chlorofluorocarbons are also potent GHGs; however, they are not included in GHG estimates because of concerns related to implementation of the Montreal Protocol on Substances That Affect the Ozone Layer. See Appendix I in the Final Inventory and Projections report for Michigan (http://www.miclimatechange.us/stakeholder.cfm).

Forestry emissions refer to the net CO_2 flux[8] from forested lands in Michigan, which account for about 53% of the state's land area.[9] Michigan's forests are estimated to be net sinks of CO_2 emissions in the state, reducing net GHG emissions by 13 $MMtCO_2e$ in 2005.

Reference Case Projections

Relying on a variety of sources for projections, as noted in the Inventory and Projections report, a simple reference case projection of GHG emissions through 2025 was developed. As illustrated in Figure 2-3 and shown numerically in Table 2-1, under the reference case projections, Michigan's gross GHG emissions continue to grow steadily, climbing to about 292 $MMtCO_2e$ by 2025, or 32% above 1990 levels. This equates to a 0.8% annual rate of growth from 1990 to 2025. Relative to 2005, the share of emissions associated with electricity consumption and industrial processes both increase slightly to 38% and 9%, respectively, by 2025. The share of emissions from the transportation, RCI fuel use, and agriculture sectors all decrease slightly to 22%, 21%, and 2%, respectively. The emissions from the fossil fuel industries and the waste sector remain the same in 2025 as their shares in 2005.

Figure 2-3. Michigan gross GHG emissions by sector, 1990–2025: historical and projected



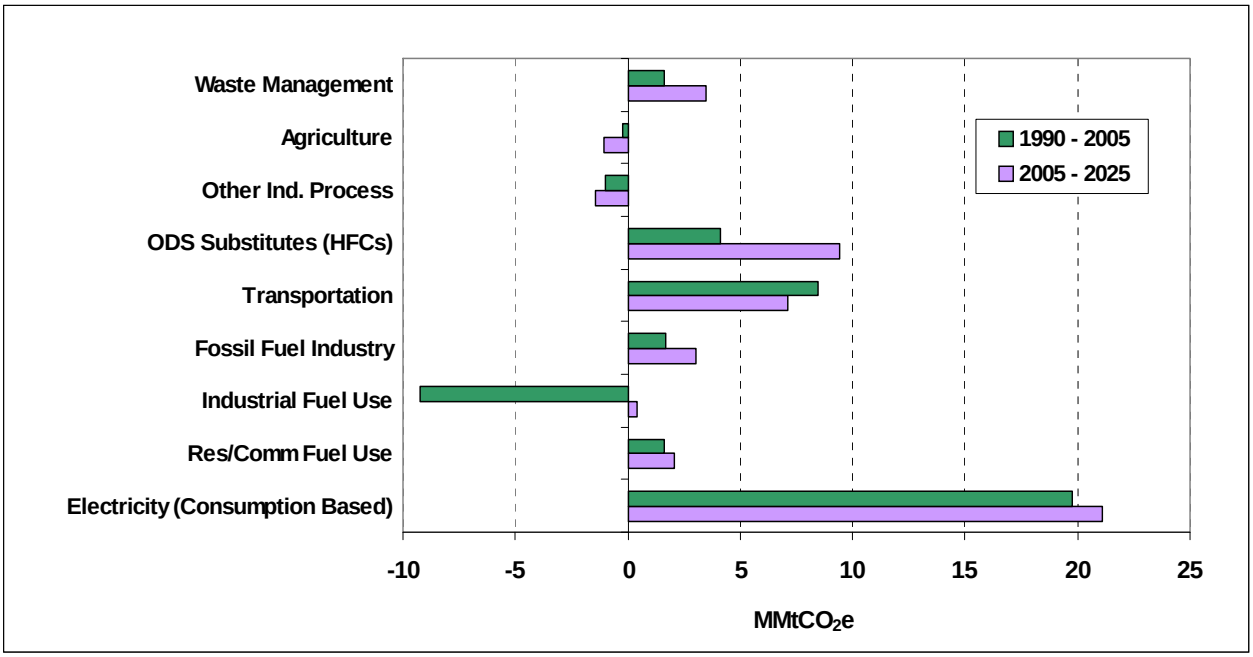
[8] "Flux" refers to both emissions of CO_2 to the atmosphere and removal (sinks) of CO_2 from the atmosphere.

[9] Total forested acreage in Michigan is 19.3 million acres. For acreage by forest type, see: Richard A. Birdsey and George M. Lewis. "Carbon in United States Forests and Wood Products, 1987–1997: State-by-State Estimates." Michigan Estimate for 1987–1997. Available from the U.S. Department of Agriculture, Forest Service, Northern Global Change Research Program, at: http://www.fs.fed.us/ne/global/pubs/books/epa/states/MI.htm. The total land area in Michigan is 36 million acres (http://www.50states.com/michigan.htm).

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; RCI = direct fuel use in residential, commercial, and industrial sectors; ODS = ozone-depleting substance; Ind. = industrial.

Emissions associated with electricity consumption are projected to be the largest contributor to future GHG emissions growth, followed by emissions from ozone-depleting substance substitutes (HFCs), and then emissions associated with the transportation sector, as shown in Figure 2-4. Other sources of emissions growth include the fossil fuel industry, the RCI fuel use sector, and the waste management sector. Table 2-2 summarizes the growth rates that drive the growth in the Michigan reference case projections, as well as the sources of these data.

Figure 2-4. Sector contributions to gross emissions growth in Michigan, 1990–2025: reference case projections



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; ODS = ozone-depleting substance; HFCs = hydrofluorocarbons; Res/Comm = direct fuel use in the residential and commercial sectors.

Table 2-2. Key annual growth rates for Michigan, historical and projected

Annual Growth Rate	1990–2005	2005–2025	Sources
Population	0.63%	0.24%	Michigan population statistics for 1990 and 2000, compiled by Michigan Information Center from US Census Bureau, are available at http://www.michigan.gov/documents/PopByCty_26001_7.pdf. Population data for 2000 to 2004 are available from Michigan Department of History, Arts, and Libraries at http://www.michigan.gov/hal/0,1607,7-160-17451_28388_28392-106981--,00.html. Michigan projections (2005–2030) available from Michigan Department of History, Arts, and Libraries at http://www.michigan.gov/hal/0,1607,7-160-17451_28388_28392-116118--,00.html.
Electricity Sales			For 1990–2005, annual growth rate in total electricity sales for all sectors combined in Michigan calculated from EIA State Electricity Profiles (Table 8) http://www.eia.doe.gov/cneaf/electricity/st_profiles/michigan.html and sales by Michigan generators calculated by subtracting T&D losses from net generations collected from EIA Annual Electric Utility Data - 906/920 database. For 2005–2025, annual growth rates are based on data that Michigan utilities provided for
Total Sales[a]	1.97%	0.99%	
Michigan Sales[b]	1.05%	1.27%	

			gross electricity sales for 2006–2025 (see Appendix II, Table 15, page 101 of *Michigan's 21st Century Electric Energy Plan*).
Vehicle Miles Traveled	1.6%	0.37%	Based on historical VMT and projected VMT growth rates provided by Michigan Department of Transportation and the Southeast Michigan Council of Governments.

[a] Represents annual growth in total sales of electricity by generators in Michigan to RCI sectors located within and outside of Michigan.

[b] Represents annual growth in total sales of electricity by generators in Michigan to RCI sectors located within Michigan.

EIA = Energy Information Administration; SIT = State (GHG) Inventory Tool; T&D = transmission and distribution; VMT = vehicle miles traveled.

A Closer Look at the Three Major Sources: Electricity Supply, RCI Fuel Use, and Transportation

As shown in Figure 2-2, electricity use in 2005 accounted for 36% of Michigan's gross GHG emissions (about 90 $MMtCO_2e$), which was higher than the national average share of emissions from electricity consumption (32%).[10] On a per-capita basis, Michigan's GHG emissions from electricity consumption are higher than the national average (in 2005, 8.8 tCO_2e per capita in Michigan, versus 8.1 tCO_2e per capita nationally). Electricity generation in Michigan is dominated by steam units, which are primarily powered by coal and nuclear fuel.

In 2005, emissions associated with Michigan's electricity consumption (90 $MMtCO_2e$) were about 19 $MMtCO_2e$ higher than those associated with electricity production (71 $MMtCO_2e$). The higher level for consumption-based emissions reflects GHG emissions associated with net imports of electricity from other states to meet electricity demand.[11] Projections of electricity sales for 2005–2025 indicate that Michigan will remain a net importer of electricity. Emissions from electricity imports are projected to be constant (19 $MMtCO_2e$/yr) during the 2006–2025 period. The reference case projection indicates that production-based emissions (associated with electricity generated in-state) will increase by about 21 $MMtCO_2e$, and consumption-based emissions (associated with electricity consumed in-state) will also increase by about 21 $MMtCO_2e$ from 2005 to 2025.

While estimates are provided for emissions from both electricity production and consumption, unless otherwise indicated, tables, figures, and totals in this report reflect electricity consumption emissions. The consumption-based approach can better reflect the emissions (and emission reductions) associated with activities occurring in the state, particularly with respect to electricity use (and efficiency improvements), and is particularly useful for decision making. Under this approach, emissions associated with electricity exported to other states would need to be covered in those states' inventories in order to avoid double counting or exclusions.

[10] For the United States as a whole, there is relatively little difference between the emissions from electricity use and emissions from electricity production, as the US imports only about 1% of its electricity, and exports even less.

[11] Estimating the emissions associated with electricity use requires an understanding of the electricity sources (both in-state and out-of-state) used by utilities to meet consumer demand. The current estimate reflects some very simple assumptions, as described in Appendix A of the Inventory and Projections report.

Activities in the RCI[12] sectors produce GHG emissions when fuels are combusted to provide space heating, process heating, and other applications. From 1990 to 2005, emissions from RCI decreased at an annual rate of 0.8%, largely due to the decrease in industrial fuel use. In 2005, combustion of oil, natural gas, coal, and wood in the RCI sectors contributed about 24% (about 60 $MMtCO_2e$) of Michigan's gross GHG emissions, slightly higher than the RCI sector contribution for the nation (22%).

In 2005, the residential sector's share of total RCI emissions from direct fuel use was 39% (23.6 $MMtCO_2e$), the commercial sector accounted for 18% (11 $MMtCO_2e$), and the industrial sector's share of total RCI emissions from direct fuel use was 42% (25 $MMtCO_2e$). Overall, emissions for the RCI sectors (excluding those associated with electricity consumption) are expected to increase by 4.1% between 2005 and 2025. Emissions from the commercial sector are projected to increase more rapidly than the residential or industrial sectors, with an 18% increase from 2005 to 2025. In contrast, emissions from the residential and industrial sectors are expected to increase by only 0.5% and 1.6%, respectively, during the same period.

Like electricity emissions, GHG emissions from transportation fuel use rose steadily from 1990 to 2005, at an average annual growth rate of 1.1%. In 2005, gasoline-powered on-road vehicles accounted for about 74% of transportation GHG emissions; on-road diesel vehicles for 18%; marine vessels for 4%; aviation fuels, rail and other sources (natural gas- and liquefied petroleum gas-fueled vehicles used in transport applications) for the remaining 4%. As a result of Michigan's population and economic growth and an increase in total vehicle miles traveled, emissions from on-road gasoline use grew at a rate of 0.98% annually between 1990 and 2005. Meanwhile, emissions from on-road diesel use rose by 4.6% per year from 1990 to 2005, suggesting an even more rapid growth in freight movement within or across the state. Emissions from on-road gasoline vehicles in 2025 are projected to increase by 0.35% annually from 2005 levels, and emissions from on-road diesel vehicles are projected to increase by 1.5% annually from 2005 to 2025, with total transportation emissions expected to reach 65 $MMtCO_2e$ by 2025.

MCAC Revisions

The following identifies the revisions that the MCAC made to the inventory and reference case projections, thus explaining the differences between the final Inventory and Projections report and the initial assessment completed in January 2008:

All Sectors: The initial assessment included GHG emission projections to 2020. This was revised to extend the GHG projections to 2025 for all sectors.

Electric Supply:

- Production-based (in-state) and consumption-based generation and emissions:
  - Excluded electricity that Donald Cook nuclear plant exports to other states.
  - Replaced this nuclear generation with electricity imports from outside the state.

[12] The industrial sector includes emissions associated with agricultural energy use and fuel used by the fossil fuel production industry.

- Emissions from pumped storage:
  - Set emissions to zero to avoid double counting of emissions (pumps are operated by electricity purchased from grid),

- Landfill gas (LFG)/municipal solid waste (MSW) and biomass emissions:
  - Added emissions for 1990–2000 (data for non-utilities inadvertently not included in the draft inventory and forecast).
  - For 1990–2000, only the aggregated non-utility generation (generation from independent power producers) can be obtained from the Energy Information Administration (EIA) Web site (EIA Electric Power Annual 2006). To get the disaggregated generation of LFG, MSW, and biomass for 1990–2000 from the aggregated Other Renewable Generation number in Electric Power Annual (this number excludes hydro electricity), we applied the proportions by fuel and by plant type in 2001 to the aggregated renewable numbers of 1990–2000.

- Transmission & distribution (T&D) line losses of Michigan:
  - The T&D line losses used in the draft analysis were revised based on the data provided by the Michigan Public Service Commission. The T&D loss rate of Consumers Energy/METC, Detroit Edison/ITC, and Upper Peninsula were collected. The weighted-average T&D loss rate of Michigan was computed based on the 2007 peak load on the system in each of the three regions

- Forecast for biomass net generation:
  - The forecast of biomass in the draft inventory and forecast used EIA regional projections, which show big increases in biomass generation in the forecast years. The EIA regional projections could be influenced by the existing renewable portfolio standard (RPS) in other states of the region. The electricity generation from biomass has been flat over the past 10 years or so in Michigan, about 1% of the total generation of the state. Biomass generation would be unlikely to significantly increase in Michigan in the forecast years unless there are strong policy regulations, such as an RPS. Therefore, in this report, for the business-as-usual condition in the forecast years, we assumed the same generation capacity from biomass as the existing capacity indicates (an average level of 2001–2005).

Transportation: MCAC approved the use of a new set of vehicle miles traveled (VMT) growth rates (for 2005–2010, 2010–2015, 2015–2020, and 2020–2025), provided by the Michigan Department of Transportation; this replaces the previous VMT growth rates used in the draft inventory and forecast.

Industrial Process: The MCAC revised iron and steel emissions by replacing the default State Inventory Tool (SIT) steel production data with crude steel production data provided by MDEQ for 1990–2005.

Fossil Fuel Industry: The MCAC added new estimates of the CO_2, CH_4, and N_2O emissions from the combustion of natural gas by internal combustion engines used to operate pipeline compressor stations. These emissions were not included in the initial assessment. These pipeline

natural gas fuel use emissions were estimated using SIT emission factors and Michigan 1990–2005 natural gas data from EIA.

Agriculture: Projections for livestock populations were revised based on feedback from the Agriculture, Forestry, and Waste TWG. Projections for beef cattle, swine, sheep, goats, and horses were estimated based on logarithmic forecasts of the historical 1990–2005 populations. Poultry populations were held at 2005 levels based on input from the poultry industry.[13]

Waste Sector: In the initial assessment, CH_4 captured for flaring and use in landfill gas to energy (LFGTE) plants were estimated with SIT defaults. The revised estimates are based on waste emplacement data for controlled landfills and date of emission capture equipment installation. Information on controlled landfills was obtained from MDEQ and a database of LFGTE projects compiled by the U.S. Environmental Protection Agency (EPA).

Open burning of MSW at residential sites was not estimated in the initial assessment. The revised report includes these emissions, which were obtained from EPA's 2002 National Emissions Inventory for estimates of the quantity of waste burned at residential sites in Michigan.[14]

Forestry: CO_2 flux estimates for 1994–2005 were revised to be based on the average calculated flux during this period using the Carbon Calculation Tool. This was done to minimize the influence of estimates in individual years and shifts between U.S. Forest Service Forest Inventory and Analysis (FIA) measurements.

Key Uncertainties

Some data gaps exist in this inventory, particularly in the reference case projections. Key tasks for future refinement of this inventory and forecast include review and revision of key drivers, such as the transportation, electricity demand, and RCI fuel use growth rates that will be major determinants of Michigan's future GHG emissions (see Table 2-2 and Figure 2-4). These growth rates are driven by uncertain economic, demographic, and land-use trends (including growth patterns and transportation system impacts), all of which deserve closer review and discussion.

[13] C. Vollmer-Sanders, MI Farm Bureau, communicated to R. Anderson, CCS, via telephone, May 2008.

[14] EPA, ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/nonpoint/2002nei_final_nonpoint_documentation0206version.pdf.