INDICATORS of the Potential Effects of Climate Change on Public Health: Michigan Results, 2011

A Pilot of the Suite of Indicators Proposed by the Climate Change Working Group of the Council of State and Territorial Epidemiologists

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Executive Summary

A work group of environmental epidemiologists in the Council of State and Territorial Epidemiologists (CSTE) collaborated to enhance environmental health surveillance by identifying priority environmental health concerns and then developing methods and appropriate data sources for generating a "suite" of environmental public health indicators. A major environmental health concern is the potential adverse human health impacts of climate change. Therefore, the CSTE formed the Climate Change Working Group (CCWG) to develop and disseminate a suite of climate change indicators.

After an extensive review of the scientific literature, the CCWG drafted twenty-four climate change indicators organized into five groups: environmental indicators, health outcome indicators, mitigation indicators, adaptation indicators, and policy indicators. To improve the quality and utility of the draft Indicators and to familiarize states with their calculation, the CSTE and the CCWG invited state health departments to pilot-test their calculation and provide feedback to the CCWG. The Michigan Department of Community Health's Climate and Health Adaptation Program (MICHAP) staff participated in the pilot and generated the draft indicators. This report describes the twenty-three climate change indicators calculated for Michigan, as well as comments on their potential utility, limitations, and suggestions for improvement. Michigan data on these 23 indicators provide the foundation for the on-going assessment of the impacts of a changing climate on health and health-related programs and policies. They provide valuable baselines to track future impacts of climate change in the state, and, in some cases, suggest changes related to climate change that have already taken place. Further, they provide important information to guide the development of public health adaptation strategies and demonstrate the successful application of the CCWG methodology for generating climate change indicators with Michigan data.

A state's capacity to generate climate change indicators depends on several factors, including: personnel resources and knowledge; data availability within their state; previous experience in measuring vulnerability to climate variability and change; and length of time spent working on climate change mitigation and planning within their state. MICHAP is building on the work in this report to generate further information to inform ongoing surveillance and health adaptation planning, and will continue its collaboration with its Federal, state and local partners to validate and improve these metrics for tracking impacts of climate change on health.

I. Introduction

According to the Intergovernmental Panel on Climate Change (IPCC), changes in temperature, precipitation, and other weather variables due to climate change "are likely to affect the health status of millions of people" (IPCC, 2007). In response to concerns about climate change, the Michigan Department of Community Health (MDCH) received funding in 2009 from the Association of State and Territorial Health Officials (ASTHO) to conduct a public health needs assessment on climate change knowledge and capacity gaps, create a strategic plan for addressing these gaps, provide training to public health practitioners, and raise awareness about potential health effects from climate change. The plan, the Michigan Climate and Health Adaptation Plan (MICHAP) was implemented the following year through funding to MDCH from the Centers for Disease Control and Prevention (CDC) Climate-Ready States & Cities Initiative.

An essential component of MICHAP is to initiate surveillance of changes in climatic conditions and health effects from these changes. A climate change surveillance system is essential to quantify past and current impacts of climate change on human health, predict future impacts, develop and guide public health adaptation strategies, and evaluate the effectiveness of these strategies (English, et al., 2009). Environmental public health indicators (EPHIs) of human health vulnerability to climate change (Ebi, Mills, Smith, & Grambsch, 2006), preparedness for climate change, and public health impact of climate change (Frumkin, Hess, Luber, Malilay, & McGeehin, 2008; Patz, Engelberg, & Last, 2000) are important components of a surveillance system.

EPHIs are descriptive summary measures, written to be easy to understand and straightforward to calculate from existing environmental health data sources. If multiple states calculate these indicators over multiple years, they can be compared among states over time. They can improve environmental health practice by improving the accessibility, availability, and distribution of information for decision-making; facilitating appropriate allocation of resources by public health practitioners; assisting in the development of early warning systems, such as heat event warnings and watches; tracking program goals and objectives; and building core surveillance capacity in state and local agencies (CDC, 2003; Malecki, Resnick, & Burke, 2008). The best environmental health indicators are those that reliably predict the relationship between human health and the environment, are routinely collected, and have well-accepted definitions and data collection standards (CDC, 2003).

A workgroup of state environmental epidemiologists, convened by the Council of State and Territorial Epidemiologists (CSTE[1]), outlined a framework and set of 25 proposed EPHIs (CSTE, 2006) and then expanded the set to include a suite of indicators related to climate change and health (English, 2009). Michigan Climate and Health Adaptation Program (MICHAP) staff participated in the development and pilot testing of this suite of Climate Change Indicators. This report describes the twenty-three Climate Change Indicators calculated for Michigan, as well as comments on their potential utility, limitations, and suggestions for improvement.

[1]CSTE is an organization of member states and territories representing public health epidemiologists. CSTE works to establish more effective relationships among state and other health agencies. It also provides technical advice and assistance to partner organizations and to federal public health agencies such as the Centers for Disease Control and Prevention (CDC).

II. Materials and Methods

Development of the CSTE climate change indicators. Promising indicator ideas were selected by the CCWG after a systematic review of current published scientific literature to determine factors related to climate change that could be calculated in a straight-forward way and re-calculated periodically to follow temporal trends (English, et al., 2009). For each potential indicator, data sources were identified through web searches and discussions with data owners, and data source documentation was reviewed to determine data temporality, completeness, and availability. The result of this review was a list of indicators grouped into environmental indictors (e.g. greenhouse gas emissions), health outcome indicators (e.g. numbers of heat hospitalizations), mitigation indicators (e.g., energy consumption), adaptation indicators (e.g., presence of public health surveillance systems for climate change), and policy indicators (e.g., development of state climate action plans). Documentation was prepared for twenty-three Climate Change Indicators that described the measure (the measurement unit(s), significance, data sources, and data limitations) followed by a "how-to" guide with specific steps for generating the indictor metrics. Health departments in eleven states (including Michigan) and the District of Columbia pilot-tested these twenty-three indicators and provided feedback on the process and documentation. Indicator "how-to" guides were revised based on pilot results. The CSTE pilot summary report is available at: http://c.ymcdn.com/sites/www.cste.org/resource/resmgr/EnvironmentalHealth/CSTEClimateChangePilotSummar.pdf.

Michigan's Indicators. The Michigan Department of Community Health's Climate and Health Adaptation Program (MICHAP) staff participated in the CSTE pilot and generated the draft indicators, including comments on problems and ease of calculation of each indicator. Based on experience in the pilot, MICHAP dropped one indicator and revised procedures for generating metrics from several others in preparation for this report. A total of twenty-three climate change indicators were calculated for this report, including twenty-two from the CSTE pilot and one that had been proposed but not piloted. The methodology for calculating each CSTE indicator is available on the CSTE website at http://www.cste.org/?page=EHIndicatorsClimate
A brief summary of the Michigan results for each Indicator is presented in Section III of this report. Section IV discusses some key findings and limitations of the data. Section V provides detailed information for each Indicator, including the indicator definition or metric (e.g., "Annual number and rate of hospitalizations due to heat in the state of Michigan from 2001-2009"), its significance related to climate change, the data source(s) used, characteristics of the data, its limitations, followed by tables and/or figures summarizing the Michigan data for that Indicator. In some cases, MICHAP modified the CSTE indicator metric or methodology and these are noted in Section V. Additionally, some Indicators were updated with more recent data available subsequent to the pilot.

III. Results Summary

Environmental Indicators

CO_2 Equivalent Greenhouse Gas Emissions, 2000-2008. CO_2 equivalent greenhouse gas (GHG) emissions have declined in Michigan from a high in 2000 of nearly 195 million metric tons to approximately 176 million metric tons in 2008 (the most recent year presented; Figure 1).

Air Mass Stagnation Events, 1973-2008. Yearly air mass stagnation events for the State of Michigan varied from a high of 151 events in 2005 to a low of 83 events in 1985 (Figure 3), with an average of 120 air mass stagnation events per year over this time period.

Frequency and Severity of Wildfires, 2002-2010. The number of wildfires in Michigan has ranged from a low of 277 in 2002 to a high of 680 in 2005. The number of acres burned in Michigan has varied from a low of 966 in 2002 to a high of 23,344 in 2007. Average acres burned per wildfire has been increasing since 2002 (Figure 4), and, when compared with other Upper Midwest states, Michigan experienced higher average acres burned per fire in 2010 (Figure 5).

West Nile Disease Positive Test Results in Mosquito Pools and Sentinel Species, 1999-2010. Annual counts of positive test results in mosquito pools in Michigan have varied from a high of 212 in 2003 to a low of 2 in several years, with no data reported for 1999, 2000 and 2002. Positive results in sentinel species were only noted for one year, 2005. These data are highly dependent on test submission policies and rates which can vary by year. (Table 1).

Trends in Maximum Temperature, 1950-2009. Maximum monthly temperatures for July in Michigan exhibited considerable temporal and geographic variation. A weak trend of increasing maximum temperatures (Figure 6) was observed over the past 60 years.

Health Outcome Indicators

Heat Hospitalizations, 2001-2010. The number and rate of hospitalizations (per 100,000 residents) for heat-related illness and injury in Michigan did not show any consistent trend during these years (Table 3, Figure 7). On average, those hospitalized in Michigan for heat-related illness and injury were twice as likely to be male than female. An average of 44% of heat-related hospitalizations in Michigan were individuals 65 years of age or older (Table 4).

Injuries and Deaths from Extreme Weather Events, 1970-2010. Wildfire deaths and injuries were infrequently reported with just four injuries reported in 1999 and no other injuries or deaths reported from 1970-2010. Deaths from severe storms were more frequent, ranging from 0 to a high of 8 deaths in 1998. Injuries from severe storms ranged from 0 to a high of 171, also in 1998. Finally, deaths from flooding ranged from 0 to a high of 10 deaths in 1986 and injuries ranged from 0 to a high of 8 in 1980 (Table 5). The vast majority of extreme weather events resulted in no injuries or deaths.

Allergic Disease Hospitalizations, 2001-2010. The number and rate of hospitalizations for allergic diseases in Michigan has been increasing steadily each year, from 70,040 hospitalizations (700 per 100,000) in 2001 to 115,621 hospitalizations (1,164 per 100,000 population) in 2010 (Table 6, Figure 8); the vast majority (90%) were due to asthma.

Human Cases of Lyme Disease, 1999-2010. Human cases of Lyme disease have been steadily increasing in Michigan since reporting began in 1999. In 1999, only a single case of Lyme disease was reported to CDC as compared with 99 cases reported in 2009, the highest number to date; corresponding case rates ranged from 0.01 per 100,000 population in 1999 to nearly 1 per 100,000 population in 2009 (Figure 9). In 2010, the rate of human Lyme disease in the U.S. was 9 per 100,000; the rates in Michigan and three other Upper Mid-West states were similar and considerably lower at less than 1 per 100,000; however Wisconsin reported almost 50 cases per 100,000 population (Figure 10).

Human Cases of West Nile Virus Disease, 2003-2010. The number of human cases of West Nile virus (WNV) illness has varied considerably in Michigan since reporting began in 2003. The lowest total number of cases occurred in 2009, with fewer than five cases, and the highest number of cases was reported in 2006, with 47 neuroinvasive cases and 8 non-neuroinvasive cases. The rates of human cases of neuroinvasive WNV in Michigan ranged from <0.05 in 2009 to nearly 0.5 per 100,000 population in 2006. Rates for the non-neuroinvasive form ranged from 0 in several years to 0.07 per 100,000 population in 2005. (Figure 11) In 2010, the rate of human cases of neuroinvasive WNV in the U.S. was lower than the corresponding rate for Michigan (0.20 versus 0.25 per 100,000 population; Figure 12).

Mitigation Indicators

Total Energy Consumption Per Capita, 2000-2006. Total energy consumption per capita was much higher in the industrial sector than in any of the other three sectors measured in this indicator, with the highest value occurring in 2005. The commercial sector ranked second in total energy consumption per capita, with its highest consumption year also in 2005. Residential and transportation consumption ranked third and fourth, with their relative positions varying from year to year. Residential energy consumption was highest in 2003 and transportation energy consumption was highest in 2002 (Figure 13).

Renewable Energy Generation Per Capita, 2006-2008. Michigan's renewable energy generation per capita, at 0.36-0.39 thousand kilowatt-hours per person, is less than the U.S. average of 1.17-1.29 thousand kilowatt hours per person (Figure 14). Michigan has less hydroelectric power than the U. S. as a whole.

Vehicle Miles Traveled, 1995-2008. Michigan's annual vehicle miles traveled had generally been increasing and were very similar to the U.S. average throughout this period. Michigan's vehicle miles ranged from a low of 8,912 miles per capita in 1995 to a high of 10,386 miles per capita in 2007 (Figure 15).

Adaptation Indicators

Development of a State Adaptation Plan, 2011. In 2007, the Governor issued Executive Order No. 2008-42, which established the Michigan Climate Action Council (MCAC). MCAC was to develop a comprehensive climate change plan for Michigan, to include policy recommendations, an assessment of the projected impacts, and recommendations for adaptive strategies. Although the MCAC did not take action on adaption, MDCH developed the "Michigan Climate and Health Adaptation Plan (MICHAP), 2010 – 2015," with funding from CDC, joining 10 other states with adaptation plans in 2011 (Figure 16).

Number of Municipal Heat Island Mitigation Projects and Plans, 2010. Michigan is one of 27 states with heat island initiatives listed on the EPA's Community Actions Database as of 2010, with two projects listed (Figure 17).

Health Surveillance Systems Related to Climate Change, 2008-2009. According to the Climate Change Needs Assessment Survey conducted by the Association of State and Territorial Health Officials (ASTHO), MDCH responded that the State has adequate surveillance capacity in six of the nine mentioned surveillance systems related to climate change. However, Michigan's surveillance of anxiety, depression, and other mental health conditions and of air quality including air pollution were considered inadequate. The MDCH respondent did not know if Michigan conducted adequate surveillance of morbidity and mortality from extreme weather events (Table 7).

Need for Additional Public Health Workforce Staff, Training and Resources in Climate Change, 2008-2009. According to the ASTHO Climate Change Needs Assessment Survey, MDCH responded that there was not a need for additional staff training or resources to confront climate change as a public health issue; however, additional personnel and funding would help the agency address climate change as a public health issue.

Policy Indicators

Percent of Population Living in Cities Participating in the U.S. Conference of Mayors Climate Protection Agreement, 2011. The State of Michigan has 31 local governments participating in the U.S. Conference of Mayors Climate Protection Agreement. This represents 1.7% of all the local governments in Michigan, which includes counties, cities, towns, and townships. In total, 2,581,367 people, or 26.0% of the population of Michigan is covered by the Mayors Climate Protection Agreement. Nationally, 1,053 mayors from the 50 states, the District of Columbia, and Puerto Rico have signed the Agreement, which represents 2.7% of all local governments. In total, 88,463,807 citizens or 28.6% of the total U.S. population is covered by the Mayors Climate Protection Agreement (Table 8 and Figure 18).

Creation of a State Climate Change Advisory Board, 2008. Michigan is one of 28 states to have formed a state advisory board as of 2008 (the most current data on the EPA website). The remaining 22 states and the District of Columbia had not yet formed a state advisory board (Figure 19).

Completion of a Greenhouse Gas Inventory, 2009. Michigan is one of 46 states and the District of Columbia to have completed a state greenhouse gas (GHG) inventory as of 2009 (the most current data on the EPA website). The remaining 5 states had not completed a state GHG inventory as of 2009 (Figure 20). Michigan is not one of the 21 states to have a location listed which completed a local GHG inventory as of 2009 (Figure 21).

Number and Percent of Local Governments Participating in ICLEI, 2011. Throughout the U.S., more than 600 local governments are currently members of ICLEI-Local Governments for Sustainability, (www.iclei.org/) with four city and two county ICLEI members in Michigan as of 2010. These six local governments represent 0.3% of all local governments in Michigan and 3.4% of the total Michigan population (Table 9).

Development of a State Climate Change Action Plan, 2009. In 2007, the Governor issued Executive Order No. 2008-42, which established the Michigan Climate Action Council (MCAC). The MCAC completed and released a comprehensive Climate Action Plan for Michigan in 2009, which outlined policy recommendations for reducing GHG emissions statewide to 20% below 2005 levels by 2020 and 80% below 2005 levels by 2050; the Plan also recommended further analysis of potential impacts and actions needed for adaptation to potential health effects from climate change. Michigan is one of 34 states to have completed a climate change action plan as of 2009, the most recent year of available data (Figure 22).

Development of Local Climate Change Action Plans, 2009. Michigan is one of 27 states and the District of Columbia that does not have any local climate change action plans, according to the most recent data on the EPA website (2009). Twenty-three states contain local governments that have climate change action plans listed, with certain states having several local governments with completed action plans (Figure 23).

IV. Discussion

The Michigan climate change indicators pilot demonstrated the successful application of the CCWG methodology for generating climate change indicators with Michigan data. The data displayed in these 23 indicators provide the foundation for on-going assessment of the impacts of a changing climate on health and health-related programs and policies in Michigan. These indicators provide valuable baselines to track future impacts of climate change in the state, and, in some cases, suggest changes related to climate change that have already taken place. Further, they provide important information to guide the development of public health adaptation strategies.

A state's capacity to generate climate change indicators depends on several factors, including: personnel resources and knowledge; data availability within their state; previous experience in measuring vulnerability to climate variability and change; and length of time spent working on climate change mitigation and planning within their state. The quality, utility and limitations of the underlying data differ for each indicator; several merit additional mention. Small numbers of cases make some of the data, including 'injuries and deaths from extreme weather events', 'annual number and rate of heat hospitalizations', and 'human cases of West Nile virus' unstable. The relationship of vector-borne disease incidence to climatic conditions is complex, and resources for surveillance vary from year to year, making interpretation of temporal changes in these indicators difficult. Tracking changes in temperature is very important; however, temperature monitors are available in a limited number of locations in the state, thus, variations in temperature extremes in geographic areas without monitors are not captured and must be imputed. Illnesses directly attributable to heat do not track the full burden of heat on human health; enumerating excess morbidity and mortality overall during heat events would be a better measure, but there is no standardized methodology for making those calculations. Many policy, mitigation, and adaptation indicators rely on data from as early as 2008 and may not reflect efforts in state and local governments since that time. For example, the 'health surveillance systems related to climate change' and 'need for public health workforce staff, training and resources in climate change' indicators are based on an ASTHO Needs Assessment Survey conducted in 2008-2009, which preceded the development of the Michigan Climate and Health Adaptation Plan (MICHAP) and its products. Finally, ongoing work by the CDC's Climate and Health and Environmental Public Health Tracking programs as well as the CCWG continues to develop data and resources for monitoring climate change and its human health impacts, thus continuing to improve the definition and calculation of climate change indicators.

Future directions

MICHAP will continue to calculate selected indicators for Michigan periodically and share the results with the public and the public health community. As climate change indicators evolve and improve, MICHAP will modify its methodology to reflect best practices and their relevance and utility to the state's public health community.

Public health practitioners in local governments are interested in refining the spatial scale of these indicators and the CCWG is developing modifications for some of the climate change indicators to allow metrics to be generated for smaller areas. Limitations to local scale generation include small numbers and other data restrictions as well as access to expertise. For example, to estimate temperature changes on a local geographical scale one needs temperature monitoring data in the geographical area of interest and access to climate and health modeling expertise. Finer resolution of health outcome data, such as morbidity and mortality related to heat events, involves different but important issues related to small numbers and confidentiality of health data; these issues may prevent displaying data and calculating morbidity and mortality rates for geographical areas with small population sizes. MICHAP will continue work with the CCWG and the CDC programs to address these issues.

In conclusion, a suite of climate change indicators has been developed and pilot-tested, and Michigan data for these indicators have been generated to help in assessing the public health impacts of climate change in Michigan. MICHAP is building on the work in this report to generate further information to inform ongoing surveillance and health adaptation planning, and will continue its collaboration with its Federal, state and local partners to validate and improve these metrics for tracking impacts of climate change on health.

V. Detailed Explanations and Data for Each Indicator

Environmental Indicators

CO_2 Equivalent Greenhouse Gas Emissions, 2000-2008

Definition
Million metric tons of carbon dioxide (CO_2) equivalent greenhouse gas emissions in Michigan by sector from 2000-2008.

Significance
Global greenhouse gas (GHG) emissions, including CO_2, methane, and nitrogen dioxide (NO_2) contribute to global warming; all three are largely due to human activity and are projected to have profound effects on the world's ecosystem and public health if allowed to continue increasing unchecked. Trends in these emissions are necessary to track and monitor progress in reducing global warming.

Data Source
The United States Environmental Protection Agency (EPA) website http://www.epa.gov/statelocalclimate/resources/state_energyco2inv.html provides state CO_2 emission inventories from fossil fuel combustion going back to 1990. The EPA developed these state-level CO_2 estimates using (1) fuel consumption data from the United States Energy Information Administration (EIA) State Energy Data Consumption tables and (2) emission factors from the Inventory of US GHG Emissions and Sinks.

Michigan's Data Characteristics
GHG emissions have declined in Michigan from a high in 2000 of nearly 195 million metric tons of CO_2 equivalent GHG emissions to approximately 176 million metric tons in 2008 (Figure 1); more recent data (not shown) indicates continuing decline. In Michigan, the electric power sector was the largest producer of CO_2 equivalent GHG emissions followed by the transportation sector (Figure 2).

Data Limitations
Nationally, CO_2 emissions from fossil fuel combustion represented the largest source (80%) of total Global Warming Potential (GWP)–weighted emissions from all sources in 2008. GWP represents how much a given mass of a chemical contributes to global warming over a given time period, as compared with the same mass of carbon dioxide (EPA, 2011). Similarly, CO_2 emissions from fossil fuel combustion are the largest source of GHG emissions within Michigan. While emissions from other sources (e.g., industrial processes, solvents, agriculture, waste, land-use, land-use change, and forestry) are important and often significant within a state, they are not included in these estimates of GHG emissions due to a lack of data availability, higher level of uncertainty in quantification methods, and smaller contribution to total emissions. Additionally, emissions are estimates and are subject to error.

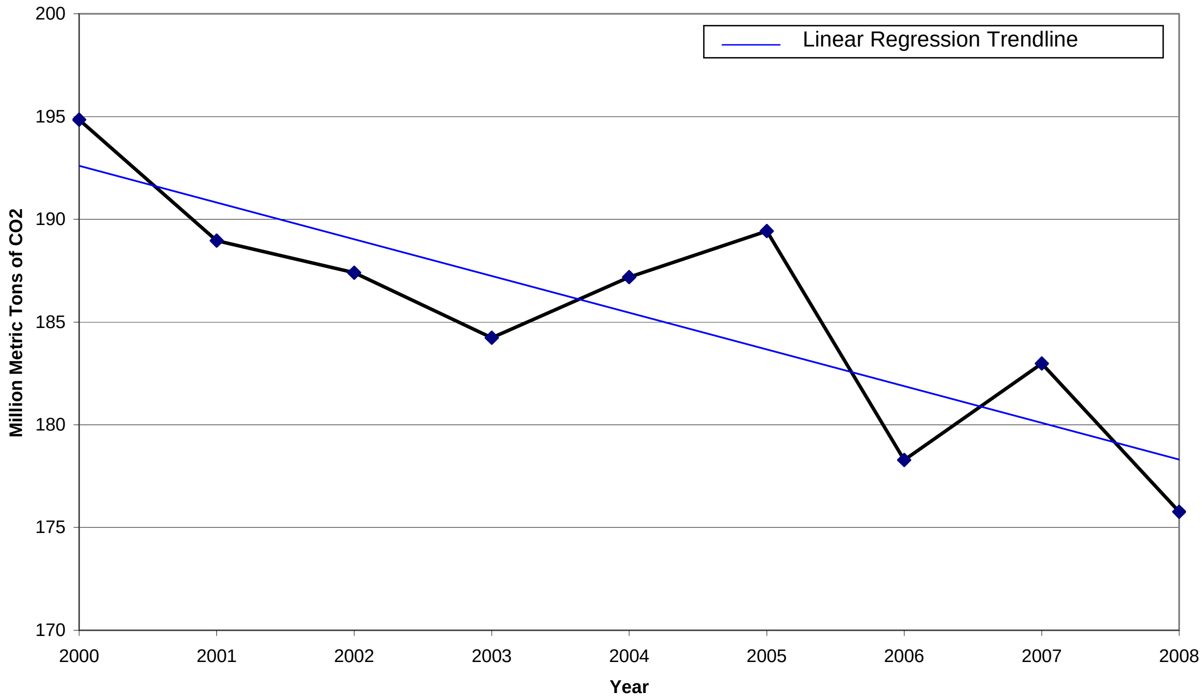

Figure 1. Million metric tons of CO_2 equivalent greenhouse gas emissions across all sectors in Michigan from 2000-2008.

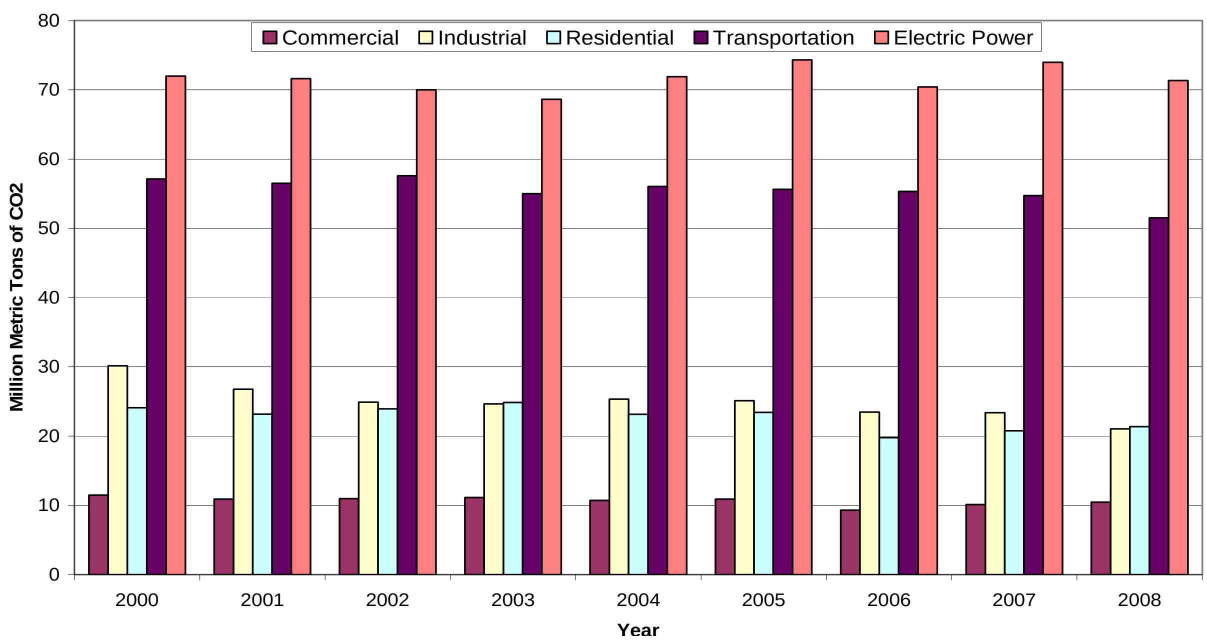

Figure 2. Million metric tons of CO_2 equivalent greenhouse gas emissions by sector in Michigan from 2000-2008.

Air Mass Stagnation Events, 1973-2008

Definitions

Annual number of air mass stagnation events in Michigan from 1973-2008. A stagnation day is defined as one with sea level geostrophic wind less than 8 meters per second (m/sec), wind less than 13 m/sec at the atmospheric height of 500-millibar pressure, and no precipitation.

Significance

Air mass stagnation events, which increase ozone production and become more frequent as weather conditions favorable to heat waves increase, are an important indicator of air quality changes associated with climate variability. While not directly related to pollutant emissions, air stagnation days can exacerbate the effects of exposure to existing air pollution.

Data Source

The National Climatic Data Center (NCDC), of the National Oceanic and Atmospheric Administration (NOAA; http://www.ncdc.noaa.gov), has Climate Impact Indicators that include an Air Mass Stagnation Index (ASI). http://www.ncdc.noaa.gov/societal-impacts/air-stagnation The CCWG obtained air mass stagnation events data for 1973-2008 from NCDC for every state; these data were used to calculate the air mass stagnation events for the state of Michigan.

Michigan's Data Characteristics

Yearly air mass stagnation events for the state of Michigan varied from a high of 151 events in 2005 to a low of 83 events in 1985 (Figure 3). A linear regression trend line shows a slight increase in events over time (statistical significance not tested; Figure 3). The average yearly total was 120 air mass stagnation events from 1973-2008.

Data Limitations

The CCWG Indicator also included average monthly air mass stagnation events, but as the Michigan monthly data were too sparse to be meaningful, regional variation was not examined.

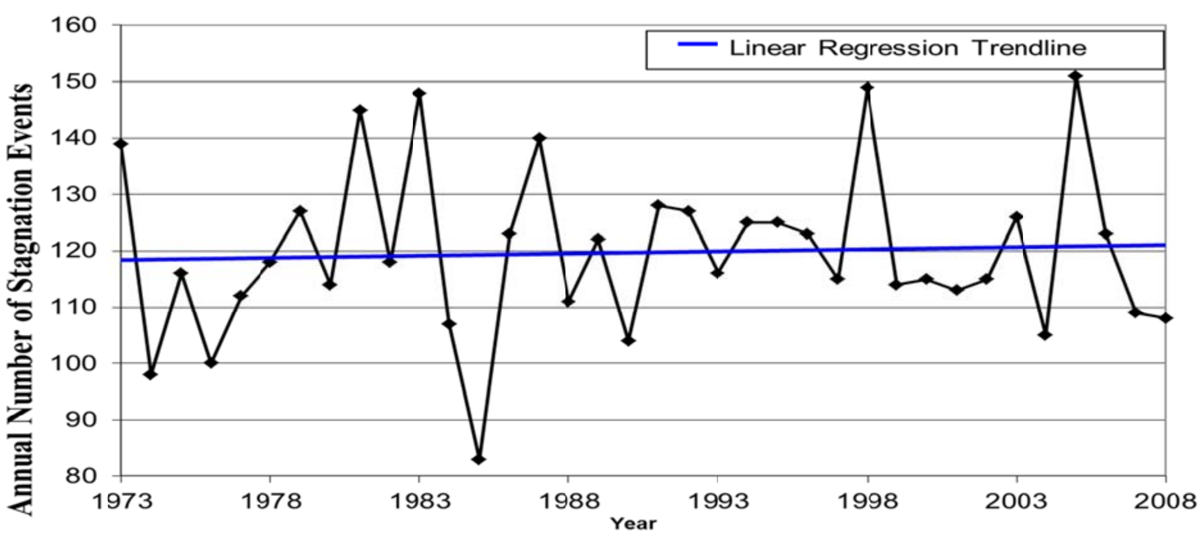

Figure 3. Annual number of Air Mass Stagnation Events in Michigan 1973-2008.

Frequency and Severity of Wildfires, 2002-2010[2]

Definitions
Annual number of fires and average acres burned per wildfire in Michigan from 2002-2010.

Significance
Warmer temperatures appear to be increasing the duration and intensity of the wildfire season in the United States. Hundreds of homes are burned annually by wildfires and damages to natural resources are sometimes extreme and irreversible. (Westerling, Hidalgo, Cayan, & Swetnam, 2006).

Data Source
Data on the number of wildfires and their severity in terms of number of acres affected per fire are collected by the National Interagency Fire Center (NIFC), at the National Interagency Coordination Center (NICC) and presented on their website (www.nifc.gov/fireInfo/fireInfo_statistics.html). Historical year-end fire statistics are compiled for each state and include data on both wildfires and prescribed (purposely set or controlled) fires.

Michigan's Data Characteristics
The number of wildfires in Michigan ranged from a low of 277 in 2002 to a high of 680 in 2005. The number of acres burned in Michigan varied from a low of 966 in 2002 to a high of 23,344 in 2007 (data not shown). Average acres burned per wildfire (calculated by dividing the number of acres burned by the number of fires) have been increasing since 2002 (statistical significance not tested; Figure 4). When compared with other Upper Midwest states, in 2010 Michigan experienced higher average acres burned per fire (Figure 5).

Data Limitations
Fires occur sporadically in Michigan, with large year-to-year variability which makes trend analysis difficult. The original indicator instructions also referenced the analysis of air monitoring data, presumably related temporally and spatially to the occurrence of the fires and the acres burned; however in Michigan, air monitoring does not occur in many areas of the state that are prone to wildfires.

[2] This indicator has been modified from the CCWG indicator, which does not include calculating average acres burned per wildfire. In addition, the URL for the site to obtain the data has been updated.

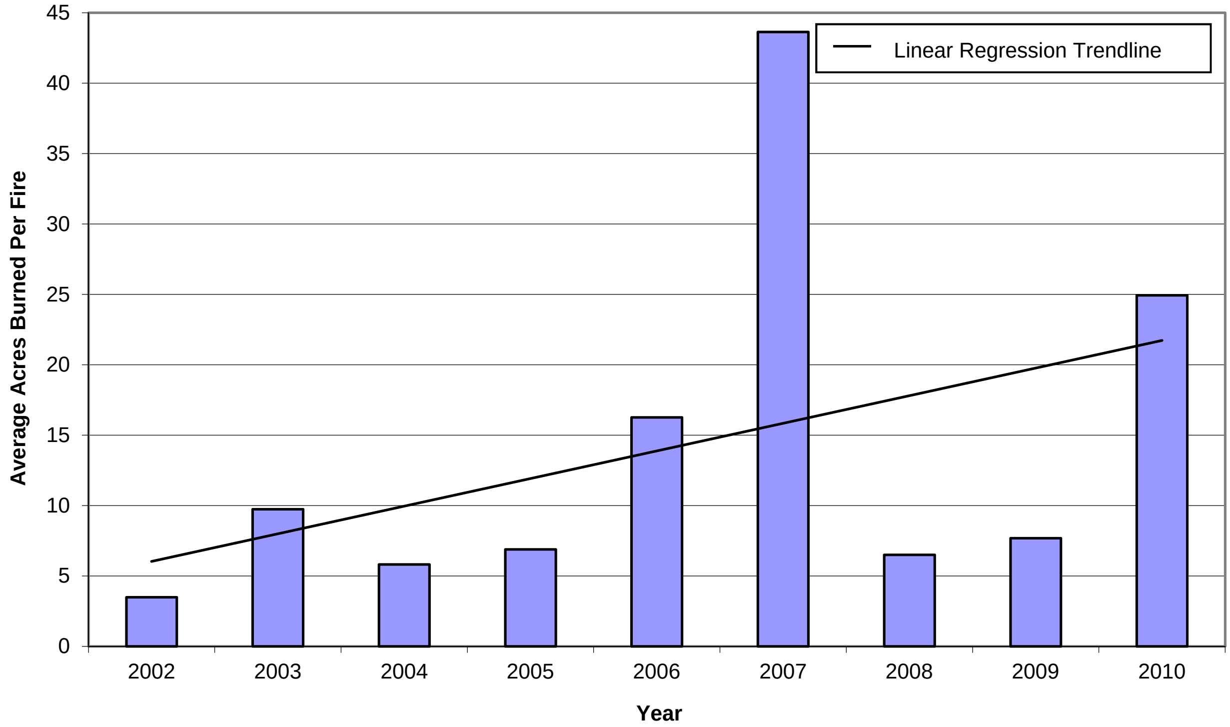

Figure 4. Average acres burned per wildfire in the state of Michigan from 2002-2010

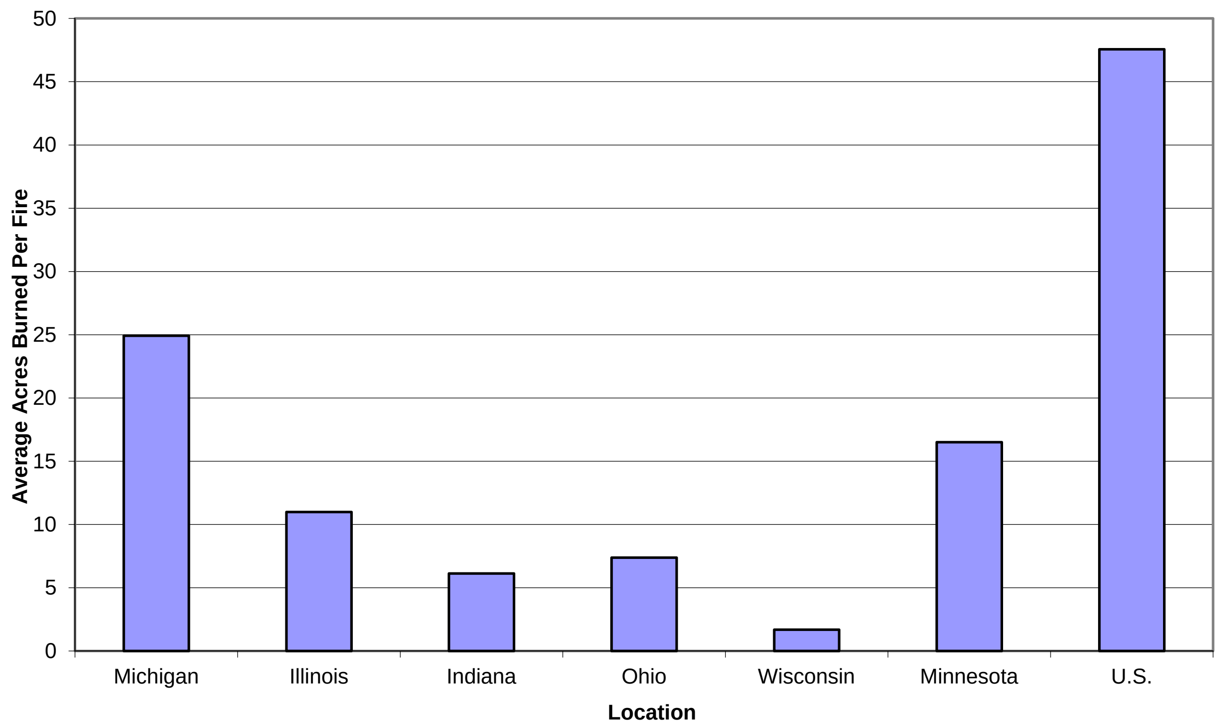

Figure 5. Comparison of the average acres burned per wildfire in the Upper Midwest and the U.S. in 2010

West Nile Disease Positive Test Results in Mosquito Pools and Sentinel Species, 1999-2010

Definitions
Number of positive West Nile virus results in mosquito pools and sentinel species per year in Michigan from 1999-2010.

Sentinel species are usually chickens; however, other bird species and horses can also serve as sentinel species.

Significance
Changes in temperature, precipitation, and humidity can greatly influence the transmission of mosquito-borne diseases, specifically relating to disease incidence and vector range. Establishing baseline data on the estimated prevalence of mosquitoes and sentinel species infected with West Nile virus in certain areas will allow for early detection of changes that may be related to climate.

Data Source
Data is collected annually by the United States Geological Survey (USGS) in conjunction with the Centers for Disease Control and Prevention (CDC) through their ArboNET/USGS Disease Maps (diseasemaps.usgs.gov/).

Mic **Figure 5.** Average acres burned per wildfire in Upper Midwest states and the U.S. in 2010
Pos
low of 2 in several years. Positive results in sentinel species were only noted for one year, 2005 (Table 1). However, these data are highly dependent on test submission rates.

Data Limitations
Variations in resources can affect a state's ability to perform testing on mosquito and sentinel species, and testing rates can fluctuate from year to year. For this reason, the absence of a positive test result does not indicate the absence of circulating virus, and temporal differences are difficult to interpret.

Table 1. Annual count of positive test results for West Nile virus in mosquitoes and sentinel species in the state of Michigan from 1999-2010.

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Mosquitos	*	*	2	*	212	70	55	152	3	2	4	2
Sentinels	0	0	0	0	0	0	8	0	0	0	0	0

* No data reported

Trends in Maximum Temperature, 1950-2009 [3]

Definitions
Maximum temperature in degrees Fahrenheit (°F) for the state of Michigan from 1950 through 2009.

Significance
It has been estimated that over the past century, the overall global surface temperature has increased by 0.7–1.4°F (NRC, 2000). Additionally, it is predicted that, in the future, climate change will increase the number of extremely hot days and decrease the number of extremely cold days (McGeehin & Mirabelli, 2001). As the U.S. becomes more urbanized and the elderly population continues to increase (Hobbs, 1996), it is likely that heat-related morbidity and mortality will become an even larger public health concern than it is today. In addition to elderly populations, infants and children under 1 year of age are considered at higher risk of mortality due to elevated ambient temperatures (Basu & Samet, 2002; CDC, 2002; Foroni, et al., 2007).

Daily temperature readings from weather monitoring stations are readily available and can be used to evaluate temporal trends in temperature. Tracking these measures may help us to better understand evolving extreme temperature changes that can occur in the future as a result of changes in climate.

Data Source
The National Climatic Data Center (NCDC), of the National Oceanic and Atmospheric Administration (NOAA), is the world's largest active archive of weather data. NCDC temperature data is collected from approximately 188 weather stations in Michigan currently; current and historical data are available online at www.ncdc.noaa.gov .

Michigan's Data Characteristics
Table 2 shows the highest recorded monthly temperatures in Michigan from 1950-2009, with no consistencies seen in either location or year recorded. Maximum monthly temperatures for July exhibited considerable year-to-year variation. A weak trend (statistical significance not tested) of increasing maximum July temperatures was observed over the past 60 years (Figure 6).

Data Limitations
This measure provides a general indication of the overall trend in maximum monthly temperatures. It may be affected by location of monitors and availability of temperature data. Temperature monitors are available in some, but not all, locations in the state. Monitors are usually placed in population centers or near airports; thus, it is difficult to capture variations in temperature extremes in geographic areas without monitors. Additionally, even though some small airports are next to less densely populated cities and have temperature monitors, there are far more temperature monitors in larger cities. This may present a bias in the maximum temperature data.

[3] The CSTE indicator, which included directions for calculating maximum and minimum temperatures calculated daily, weekly, monthly and seasonally; and diurnal range, was modified: Only the maximum temperatures in Michigan were calculated for the years 1950-2009.

Even when temperature monitoring is conducted in a geographical area, temperature data can be incomplete due to equipment failure or affected by variation among monitors, collection methods and collection dates. The data contain a small number of data flags, indicating when values were manually validated, estimated, or edited; these flags were ignored for this analysis. Analyzed sites were limited to those with at least 600 months (50 years) of data since 1950.

Table 2. Highest recorded monthly temperatures by year and location in Michigan: 1950-2009

Month	Temperature (°F)	Location	Year recorded
January	72	Ann Arbor	1950
February	72	Battle Creek	2000
March	84	Benton Harbor	2007
April	94	Baraga	1980
May	100	Marquette	1969
June	106	Monroe	1988
July	105	Saginaw	1987
August	104	Greenville	1955
September	104	Wayne	1954
October	94	Canton	2007
November	84	Wayne	1950
December	72	Dowagiac	2001

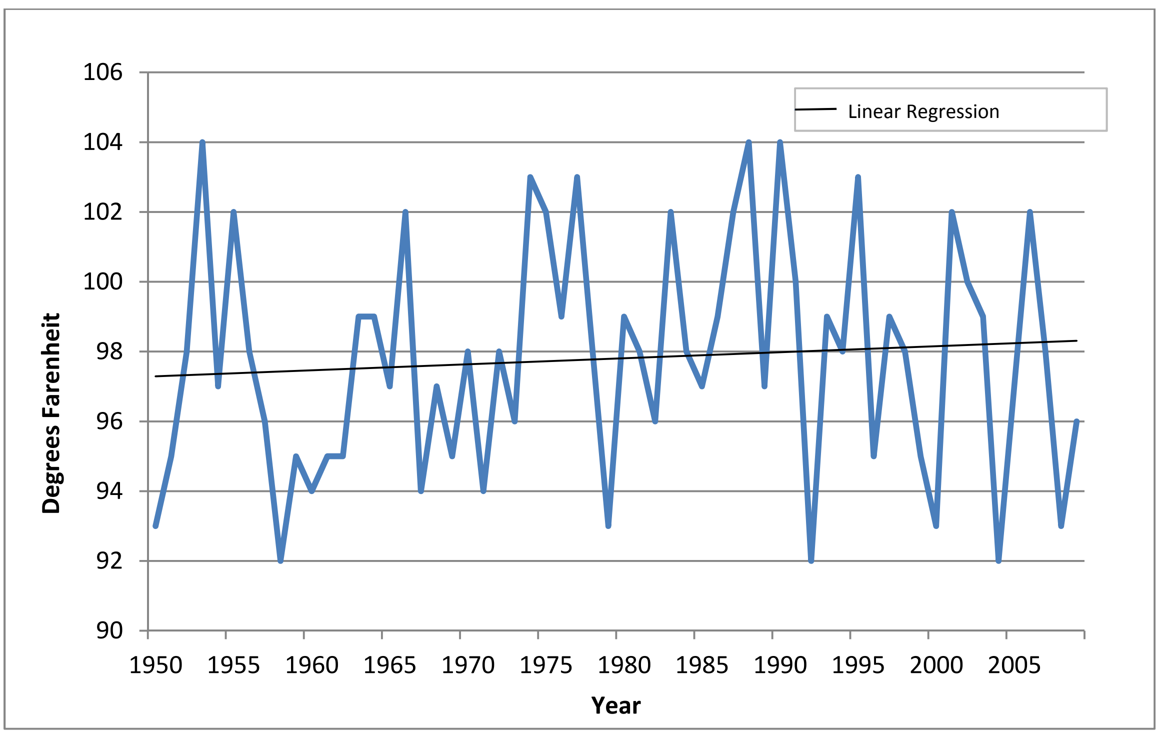

Figure 6: Maximum temperature in the month of July by year, 1950-2009.

Health Outcome Indicators

Heat Hospitalizations, 2001-2010[4]

Definitions
Annual number and rate of hospitalizations due to heat in Michigan residents from 2001-2010.

Significance
Over the past century, the overall global surface temperature has increased by 0.7–1.4°F (NRC, 2000). The Intergovernmental Panel on Climate Change (IPCC) projects with "virtual certainty" that climate change will cause more frequent, more intense, and longer heat waves. The IPCC also notes with "medium confidence" that the number of heat wave deaths will increase (medium confidence arose because of uncertainty regarding physiologic and societal adaptation) (Confalonieri, et al., 2007).

Physiological mechanisms maintain the body core temperature in a narrow optimum range around 37 degrees C (98.6 degrees F). When core body temperature rises, the physiological response is to sweat and circulate blood closer to skin's surface to assist in cooling. Adequate hydration is critical in avoiding heat-related illness. If heat exposure exceeds the physiological capacity to cool, then a range of heat-related symptoms and conditions can develop, including heat stress, heat cramps, and heat stroke.

Tracking rates of hospitalizations due to heat is a useful indicator of heat burden on human health.

Data Source
The Agency for Healthcare Research and Quality (AHRQ) Healthcare Cost and Utilization Project (HCUP) is a family of databases on patient care encounters developed through a federal-state-healthcare industry partnership and maintained by AHRQ. HCUPnet (http://hcupnet.ahrq.gov/) is a free, on-line query system based on data from HCUP. It provides access to health statistics and information on hospital inpatient utilization, including the State Inpatient Databases (SID). SID contains inpatient discharge abstracts from about 90 percent of all Michigan community hospital discharges.

ICD-9-CM codes were used in an all-listed diagnosis query of Michigan SID to obtain case data. The codes used for heat hospitalization included: the effects of heat 992.0-992.9 (heat stroke, cramps, exhaustion, etc.), and E900.0 (event caused by excessive heat due to weather conditions). Population estimates for calculating rates per 100,000 population were obtained

[4] This indicator was modified significantly from the CCWG indicator. (1) The CCWG indicator included emergency department (ED) visits as well as inpatient hospitalizations, but Michigan does not compile state-wide ED data. (2) The number of heat hospitalizations in Michigan was obtained by accessing the state's inpatient data base through HCUP, rather than directly accessing the same data from the Michigan Health and Hospitals Association. This was done because of simplicity in data extraction. Doing so precludes the possibility of analyzing cases by month of discharge as HCUP only provides data for a calendar year; however it's likely that most heat hospitalizations occur in the summer months. (3) The number of heat-related deaths averages 5 per year in Michigan, too few to analyze further.

from the U.S. Census Bureau (at the time the data was at www.census.gov/popest/eval-estimates/eval-est2010.html; current link is http://www.census.gov/popest/).

Michigan's Data Characteristics

The number and rate of hospitalizations include both primary and secondary diagnoses of heat-related illness and injury. The number and rate of hospitalization (per 100,000 residents) for heat-related illness and injury in Michigan did not show any consistent trend during the years 2001-2010 (Table 3, Figure 7). On average, those hospitalized in Michigan for heat-related illness and injury were twice as likely to be male than female (Table 4). An average of 44% (935/2,134) of the heat-related hospitalizations for these years were among those 65 years of age or older.

Data Limitations

Heat illness is under-reported as a primary diagnosis in hospitalizations, because few hospitalizations are recorded as 'heat-related,' even during extreme heat events. For instance, heart failure or respiratory conditions may be listed as the primary cause, with heat illness as a contributing factor, even when the heat exposure is the primary cause of the illness exacerbation.

Table 3. Number and rate of heat-related hospitalizations for Michigan for the years 2001-2010.

Year	Hospitalizations	Rate (per 100,000)
2001	269	2.69
2002	254	2.53
2003	135	1.34
2004	96	0.95
2005	254	2.52
2006	338	3.35
2007	241	2.4
2008	157	1.57
2009	90	0.9
2010	300	3.02

Table 4. Number of heat-related hospitalizations for Michigan for the years 2001-2010, by age group and gender.

Age Groups	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
<1	*	*	*	*	*	*	*	*	*	*
1 to 17	23	*	*	*	*	11	*	*	*	11
18 to 44	41	62	33	30	67	45	62	44	16	57
45 to 64	68	69	43	27	62	118	67	46	32	88
65 to 84	93	87	36	21	88	124	83	42	34	110
85+	42	25	13	*	28	40	20	15	*	34
Gender										
male	159	161	89	66	174	219	176	126	54	193
female	110	93	46	30	80	119	65	31	36	107
Total	269	254	135	96	254	338	241	157	90	300

* Signifies less than 10 cases in that category

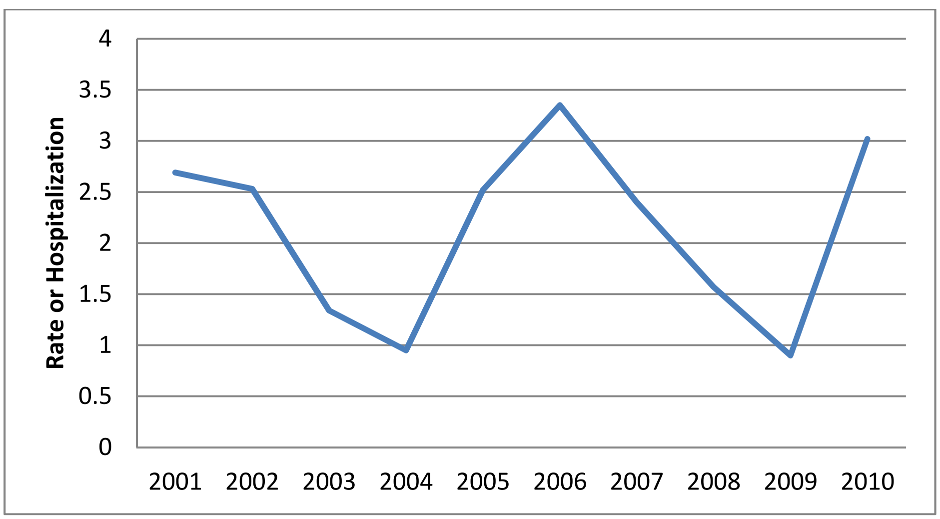

Figure 7 Rate of heat hospitalization (per 100,000 residents) in Michigan from 2001-2010.

Injuries and Deaths from Extreme Weather Events, 1970-2010[5]

Definitions

Number of injuries and deaths from wildfires, flooding, and storms in the state of Michigan from 1970-2010.

Significance

Increases in heavy precipitation, earlier regional snowmelt, and temperature variability raise risks of flooding and related community displacement and injuries (CCSP, 2008; French, Ing, Von Allmen, & Wood, 1983). Floods are the most frequent natural disaster in the U.S. and, before Hurricane Katrina, accounted for 40% of all natural disaster damage and injury (Greenough, et al., 2001). Warmer temperatures appear to be increasing the duration and intensity of the wildfire season in the United States, with hundreds of homes burned annually.

Data Source

The Spatial Hazard Events and Losses Database for the US (SHELDUS™; webra.cas.sc.edu/hvri/products/sheldus.aspx), from the Hazards and Vulnerability Research Institute (HVRI), includes every loss-causing and deadly event between 1960 and 1979 and from 1995 to the present. At the time of this analysis, the events in the SHELDUS database that occurred between 1980 and 1995 were restricted to those which caused at least one fatality or more than $50,000 in property or crop damage. The searchable database provides injury and death counts by specific event types including wildfires, flooding and storms, by county and state.

Michigan's Data Characteristics

Wildfire deaths and injuries were infrequently reported with just four injuries reported in 1999 and no other injuries or deaths reported from 1970-2010. Deaths from severe storms were more frequent, ranging from 0 to a high of 8 deaths in 1998 (Table 5). Injuries from severe storms ranged from 0 to a high of 171, also in 1998. Finally, deaths from flooding ranged from 0 to a high of 10 deaths in 1986 and injuries ranged from 0 to a high of 8 in 1980 (Table 5). It should be noted that the vast majority of events in SHELDUS do not result in an injury or death, averaging only 2.7 injuries and deaths per 100 events in the last decade (data not shown).

Data Limitations

Extreme weather events resulting in injury or death are rare in SHELDUS, making this indicator difficult to interpret. Other health conditions related to post-event trauma, such as exacerbation of pre-existing chronic conditions from population displacement, mental health issues, and occurrences of infectious disease are not recorded by SHELDUS. A the time of this analysis, the database included every event causing injury and/or death from 1960 through 1979 and from 1995 onward, but between 1980 and 1995, it only contained events that caused at least one fatality or more than $50,000 in property or crop damages. Currently SHELDUS is revising the information for this time period to be consistent with the rest of the database.

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[5] The CSTE indicator included a rate calculation, but because the Michigan numbers were so small, rates were not presented.

Table 5. Deaths and injuries from wildfires, severe storms, and flooding in Michigan 1970-2010

Year	Deaths from Wildfires	Injuries from Wildfires	Deaths from Severe Storms	Injuries from Severe Storms	Deaths from Flooding	Injuries from Flooding
1970	0	0	1	10	0	0
1971	0	0	2	40	0	0
1972	0	0	4	25	0	0
1973	0	0	3	21	3	0
1974	0	0	0	10	0	0
1975	0	0	3	62	1	4
1976	0	0	1	24	0	0
1977	0	0	0	6	0	0
1978	0	0	1	15	0	2
1979	0	0	3	41	0	0
1980	0	0	1	36	0	8
1981	0	0	1	3	1	5
1982	0	0	0	0	0	0
1983	0	0	1	11	0	0
1984	0	0	1	3	0	0
1985	0	0	0	5	0	0
1986	0	0	1	0	10	3
1987	0	0	7	1	2	1
1988	0	0	6	8	0	0
1989	0	0	1	8	0	0
1990	0	0	1	4	4	0
1991	0	0	4	3	0	0
1992	0	0	1	2	0	0
1993	0	0	0	3	0	0
1994	0	0	1	0	0	0
1995	0	0	4	6	0	0
1996	0	0	0	1	2	1
1997	0	0	5	10	0	6
1998	0	0	8	171	0	0
1999	0	4	1	2	0	0
2000	0	0	2	9	0	0
2001	0	0	0	9	3	0
2002	0	0	0	7	0	0
2003	0	0	0	7	0	0
2004	0	0	3	11	0	0
2005	0	0	0	0	0	0
2006	0	0	0	2	0	0
2007	0	0	0	2	0	0
2008	0	0	2	4	4	0
2009	0	0	1	0	0	0
2010	0	0	0	3	0	0

*Between 1980-1995, only events causing at least one death or more than $50,000 in damages were counted.

Allergic Disease Hospitalizations, 2001-2010[6]

Definition
Annual number and rate per 100,000 of hospitalizations for allergic diseases in Michigan residents from 2001-2010.

Significance
Climate change is expected to have an impact on the occurrence of extreme temperature days and weather patterns, which can affect allergic disease. Higher temperatures in heat waves accelerate chemical reactions that produce ozone and lead to increased aeroallergen production (e.g. pollen). Increased ozone and aeroallergen production are likely to influence human exposure, sensitization, and exacerbation of allergy-related illness. (D'Amato, Liccardi, D'Amato, & Cazzola, 2001). Asthma, also affected by both air pollution and aeroallergens, is the predominant chronic disease of childhood. It affects approximately 4.8 million US residents, and is the chief cause of school absenteeism and child hospitalization. Furthermore, 15-20% of children worldwide suffer from atopic dermatitis, and this figure is increasing (O'Connell, 2004).

Data Source
The Agency for Healthcare Research and Quality (AHRQ) Healthcare Cost and Utilization Project (HCUP) is a family of databases on patient care encounters developed through a federal-state-healthcare industry partnership and maintained by AHRQ. HCUPnet (http://hcupnet.ahrq.gov/) is a free, on-line query system based on data from HCUP. It provides access to health statistics and information on hospital inpatient utilization, including the State Inpatient Databases (SID). SID contains inpatient discharge abstracts from about 90 percent of all Michigan community hospital discharges.

ICD-9-CM codes were used in an all-listed diagnosis query of Michigan SID to obtain cases. The codes used for allergic diseases primarily associated with aeroallergens include: allergic rhinitis (477), asthma (493), atopic dermatitis (691.8), contact dermatitis and other eczema unspecified causes (692.9), noninfectious dermatoses of the eyelid (373.3), acute atopic conjunctivitis (372.05), and allergic conjunctivitis (372.14). Population estimates for calculating rates per 100,000 population were obtained from the U.S. Census Bureau (at the time the data was at www.census.gov/popest/eval-estimates/eval-est2010.html; current link is http://www.census.gov/popest/).

Michigan's Data Characteristics
The number and rate of hospitalizations for allergic disease in Michigan has been increasing steadily each year from 70,040 hospitalizations (700 per 100,000 population) in 2001 to 115,621 hospitalizations (1,164 per 100,000 population) in 2010 (Table 6, Figure 8). Ninety percent of these hospitalizations are due to asthma.

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[6] Two modifications to the CSTE Indicator were made: (1) Allergic disease hospitalization counts for Michigan were obtained by accessing the state's inpatient data base through HCUP, rather than directly accessing the same data from the Michigan Health and Hospitals Association. This was done because of simplicity in data extraction. (2) Numbers/rates of Emergency Department visits were not calculated because statewide ED visit data are not available in Michigan.

Data Limitations

Including secondary diagnoses in the counts may capture chronic allergic diseases rather than new diagnoses or exacerbations of diseases related to changes in current environmental conditions. Further, other factors besides increased exposure to aeroallergens (e.g. changes in diagnosis, treatment, and access to care) may explain some of the observed temporal trends.

Table 6. Number and rate (per 100,000 residents) of allergy-related hospital admissions in Michigan from 2001-2010.

Year	Hospitalizations	Population	Rate (per 100,000)
2001	70,040	10,005,334	700.03
2002	76,589	10,039,223	762.90
2003	84,970	10,072,219	843.61
2004	90,104	10,091,511	892.87
2005	98,430	10,092,426	975.29
2006	101,146	10,082,414	1003.19
2007	101,644	10,051,145	1011.27
2008	109,262	9,999,456	1092.68
2009	114,155	9,955,260	1146.68
2010	115,621	9,931,235	1164.22

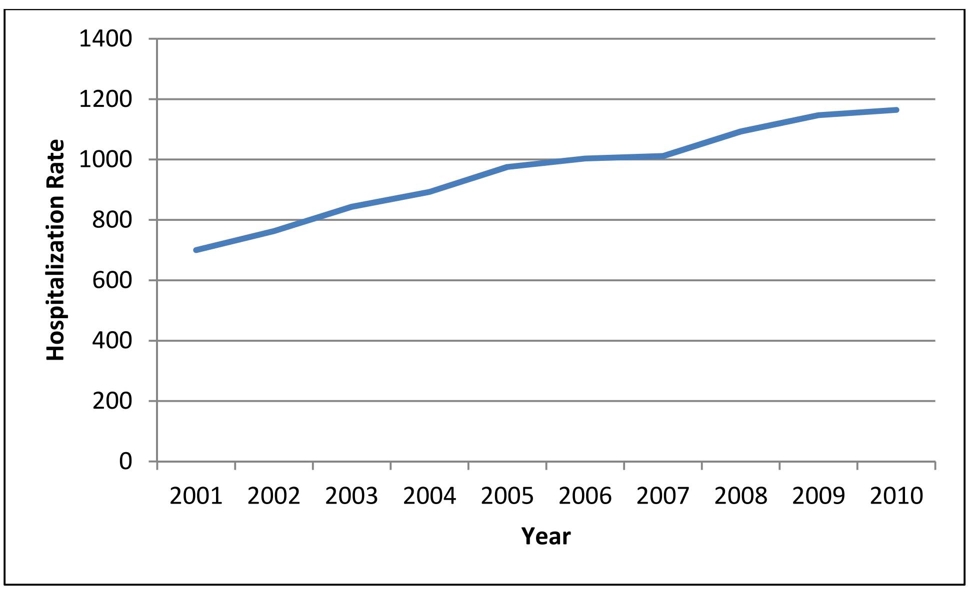

Figure 8. Rate of allergy-related hospitalizations (per 100,000 residents) in Michigan by year from 2001-20010.

Human Cases of Lyme Disease, 1999-2010

Definition
Number and rate per 100,000 population of human cases of Lyme disease in Michigan residents from 1999-2010.

Significance
Changes in temperature, precipitation, and humidity may influence the transmission of Lyme disease, including disease incidence and the range and behavior of the tick vector and its animal hosts (deer and rodents). Establishing baseline data on the location and count of Lyme disease cases will allow for early detection of changes that may be related to climate.

Data Source
The CDC maintains the Wonder Morbidity and Mortality Weekly Report website which includes data on human cases of Lyme disease from 1999-present. CDC Wonder contains cases of selected national notifiable diseases from the National Notifiable Diseases Surveillance System (NNDSS). NNDSS data are reported by the 50 states, New York City, the District of Columbia, and the U.S. territories and are collated and published weekly as numbered tables printed in the back of the *Morbidity and Mortality Weekly Report* (*MMWR*). The weekly tables and annual summaries of data on nationally notifiable diseases from all states are searchable on-line at http://wonder.cdc.gov/mmwr/mmwrmorb.asp. Population estimates for calculating rates per 100,000 population were obtained from the U.S. Census Bureau (at the time the data was at www.census.gov/popest/eval-estimates/eval-est2010.html; current link is http://www.census.gov/popest/).

Michigan's Data Characteristics
Human cases of Lyme disease have been steadily increasing in Michigan since reporting began in 1999. In 1999, only a single case of Lyme disease was reported to CDC as compared with 99 cases reported in 2009, the highest number to date. The rate of human cases of Lyme disease in Michigan ranged from 0.01 in 1999 to nearly 1.00 per 100,000 in 2009 (Figure 9). The rate of human cases in the U.S. in 2010 was 9.00 per 100,000 population. In 2010, Lyme disease rates among the Upper Mid-West states were similar at around 1 per 100,00, except Wisconsin which had almost 50 cases per 100,000 population (Figure 10).

Data Limitations
Annual counts in Michigan may be too small to produce stable rate calculations. In addition, these data do not provide information on where cases are located within the state, which can vary greatly based on differences in geography and environmental conditions. Other factors influencing trends of Lyme disease incidence in Michigan include changes in diagnosis, and gradual migration of the tick vector from the Northeast and mid-Atlantic states where Lyme disease has been endemic for many years.

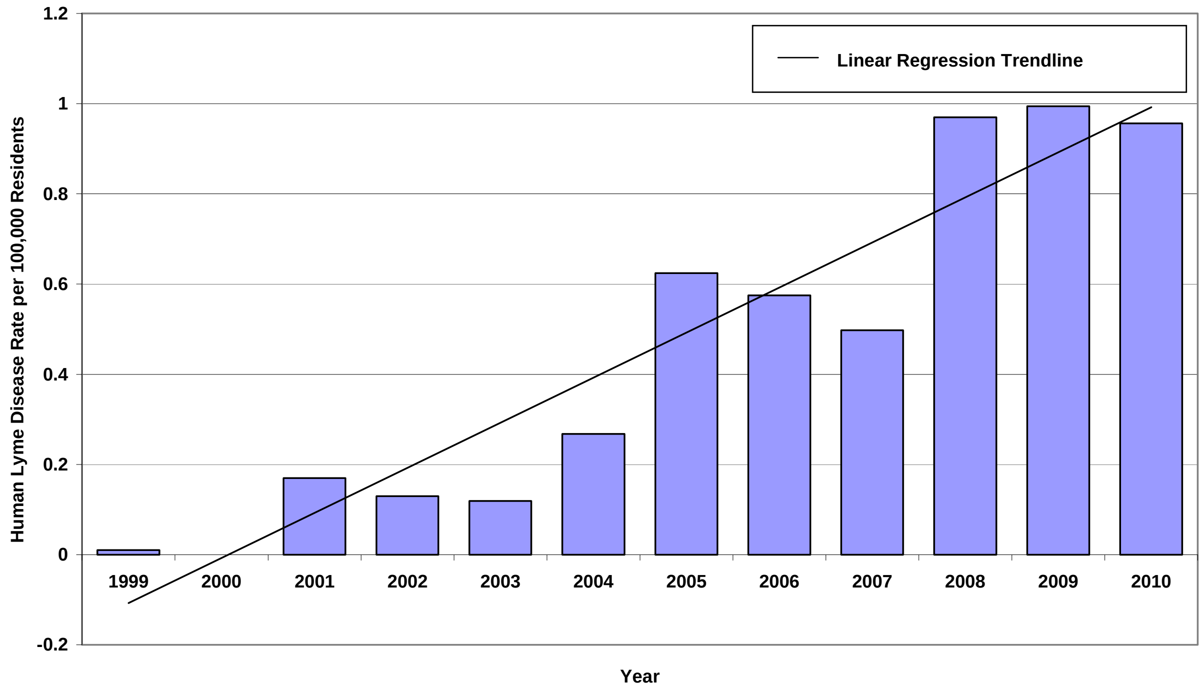

Figure 9. Human Lyme Disease case rate per 100,000 population in the state of Michigan from 1999-2010.

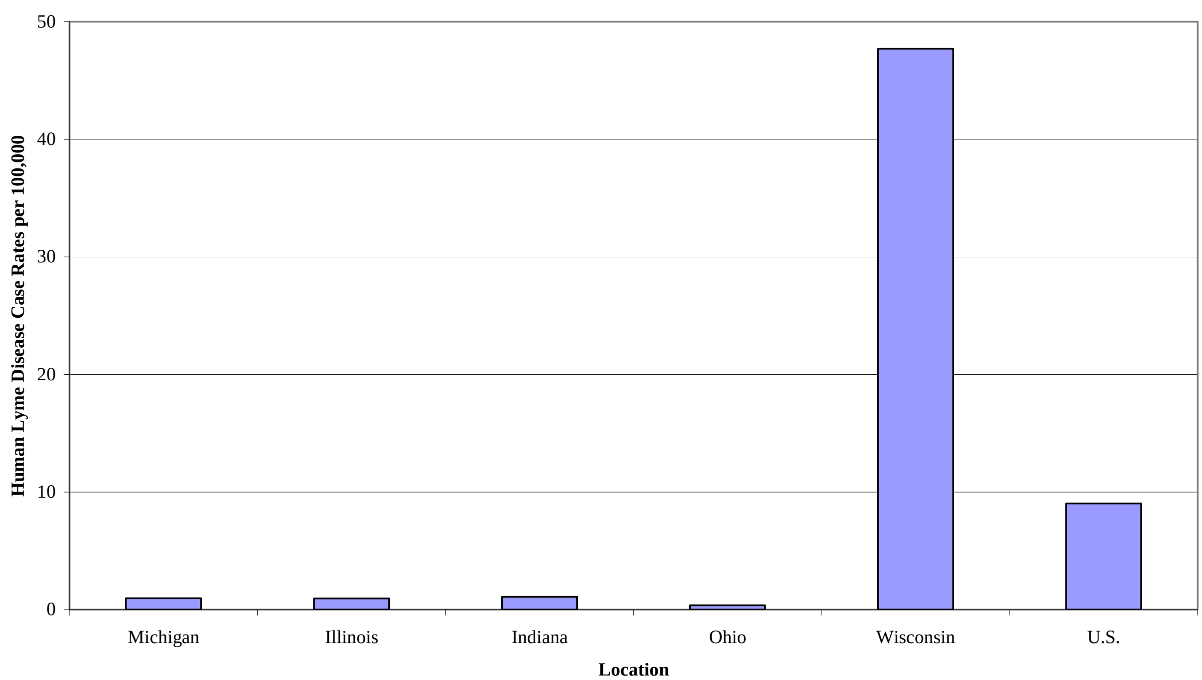

Figure 10. Comparison of human Lyme disease case rates per 100,000 in the Upper Mid-West and the United States, 2010.

Human Cases of West Nile Virus, 2003-2010

Definition
Number and rate per 100,000 population of human cases of West Nile virus diseasein Michigan residents, from 2003-2010.

Significance
Changes in temperature, precipitation, and humidity may affect the transmission of mosquito-borne disease, specifically relating to disease incidence and the range and behavior of the mosquito vector and its bird reservoir. Establishing baseline data on the location and count of West Nile virus (WNV) cases will allow for early detection of changes that may be related to climate.

Data Source
The CDC maintains the Wonder Morbidity and Mortality Weekly Report website, which includes data on human cases of WNV from 2003 to the present. CDC Wonder contains cases of selected national notifiable diseases from the National Notifiable Diseases Surveillance System (NNDSS). NNDSS data, reported by the 50 states, New York City, the District of Columbia, and the U.S. territories, are collated and published weekly as numbered tables printed in the back of the *Morbidity and Mortality Weekly Report* (*MMWR*). The weekly tables and annual summaries of data on nationally notifiable diseases from all states are searchable on-line at http://wonder.cdc.gov/mmwr/mmwrmorb.asp. Population estimates for calculating rates per 100,000 population were obtained from the U.S. Census Bureau (at the time the data was at www.census.gov/popest/eval-estimates/eval-est2010.html ; current link is http://www.census.gov/popest/).

Michigan's Data Characteristics
The number of human cases of WNV illness has varied in Michigan since reporting began in 2003. The lowest total number of cases occurred in 2009, with fewer than five cases. In contrast, the highest number of cases was reported in 2006, with 47 neuroinvasive cases and 8 non-neuroinvasive cases. Rates of human cases of neuroinvasive WNV illness in Michigan ranged from <0.05 in 2009 to nearly 0.50 per 100,000 population in 2006. Rates for the non-neuroinvasive form ranged from 0.00 in several years to 0.07 per 100,000 population in 2005 (Figure 11). In 2010, the rate of human cases of neuroinvasive WNV illness in the U.S. was lower than the corresponding rate for Michigan (0.20 versus 0.25 per 100,000 population). The Michigan rate of non-neuroinvasive cases was based on less than five cases; therefore, this rate was statistically unstable, not shown, and not compared with the corresponding U.S. rate (Figure 12).

Data Limitations
Several yearly WNV case counts for Michigan were too small to produce stable rate calculations and therefore are not shown in this report. These data do not provide information on where cases are located within a state, which can vary greatly based on differences in geography and environmental conditions. Data in NNDSS is provisional and may differ from final case counts reported at the WNV website www.cdc.gov/ncidod/dvbid/westnile. Observed temporal trends may be due to many factors including those unrelated to changing weather. Temporal trends in the disease in Michigan are similar to trends in the rest of the United States following the

beginning of the outbreak in 1999 when the first WNV cases in the Western Hemisphere were identified in New York and New Jersey; the wave of the epidemic gradually crossed the country over the subsequent years with increasing numbers of cases reported until 2007 when the number of cases reported nationwide began decreasing.

The high proportion of neuroinvasive cases reflects surveillance reporting bias in that serious cases are more likely to be reported than mild ones. Serosurveys indicate that <1% of all WNV infections result in neuroinvasive disease. Non-neuroinvasive cases were not notifiable prior to 2005 (see www.cdc.gov/ncidod/dvbid/westnile).

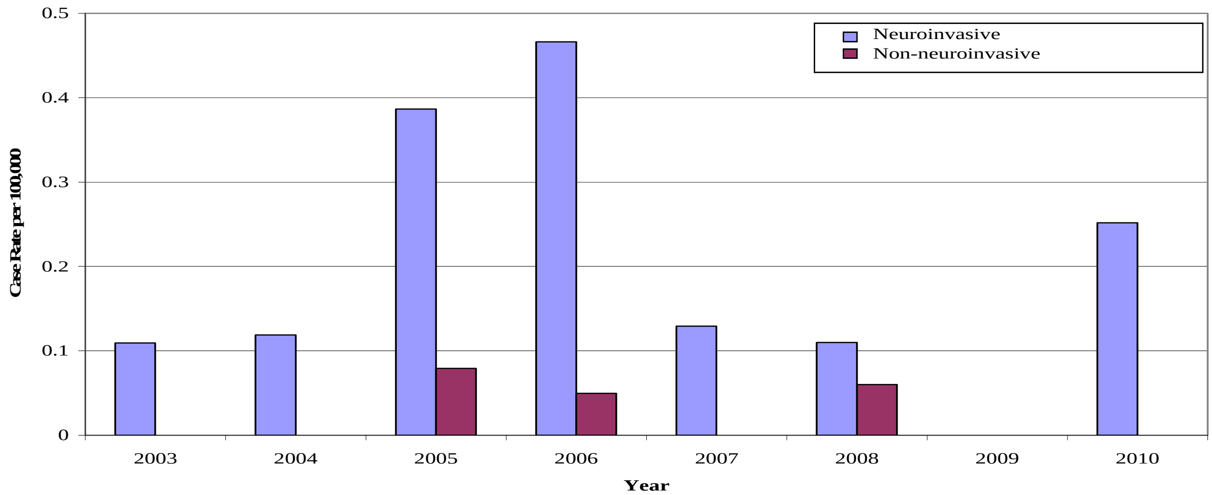

Figure 11. Human case rates of West Nile virus illness (neuroinvasive and non-neuroinvasive) per 100,000 population in the state of Michigan from 2003-2010. For the years 2003 and 2004, cases were not categorized by neuroinvasive and non-neuroinvasive forms and all are therefore listed under neuroinvasive. Rates for 2009 neuroinvasive and 2010 non-neuroinvasive illness were based on less than five cases and not shown. Zero cases of non-neuroinvasive illness occurred in 2007 and 2009.

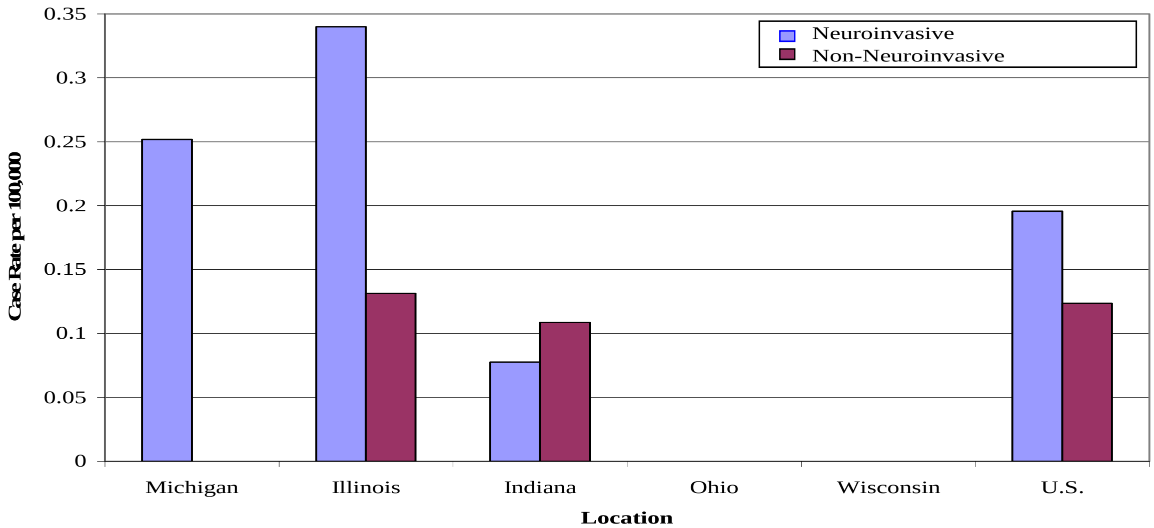

Figure 12. Comparison of 2010 human case rates per 100,000 population for West Nile virus (neuroinvasive and non-neuroinvasive) illness: U.S. and Upper Midwest Region. Rates for Michigan non-neuroinvasive, Ohio neuroinvasive and non-neuroinvasive, and Wisconsin non-neuroinvasive illness were based on less than five cases and not shown. Zero cases of neuroinvasive illness occurred in Wisconsin.

Mitigation Indicators

Total Energy Consumption Per Capita, 2000-2006

Definition
Energy consumption by sector (Residential, Transportation, Commercial, and Industrial), measured in trillion British Thermal Units (BTUs) per capita for the state of Michigan from 2000-2006.

Significance
Energy consumption patterns over time, when adjusted for state population changes and employment changes, may be an indicator of the impact of climate change mitigation and policy measures on energy efficiency. Energy efficiency measures reduce the demand for energy generated from fossil fuel sources and are targeted to specific sectors of the economy: residential, commercial, industrial, and transportation. Residential and transportation measures, which target a broad cross-section of the population, are calculated per capita to measure increased density. Commercial and industrial energy consumptions are calculated in relation to total employment.

Data Source
The U.S. Department of Energy maintains the Energy Information Administration's (EIA's) State Energy Data System (SEDS), which includes energy consumption estimates by state and by sector of the economy. SEDS exists to provide energy production, consumption, price, and expenditure estimates by state to members of Congress, federal and state agencies, and the general public, and to provide the historical data necessary for EIA's energy models that help predict future energy use. The SEDS searchable database is www.eia.doe.gov/emeu/states/_seds.html. Population estimates for calculating rates per 100,000 population were obtained from the U.S. Census Bureau (at the time the data was at www.census.gov/popest/eval-estimates/eval-est2010.html; current link is http://www.census.gov/popest/).Employment estimates for calculating rates per 100,000 employees for commercial and industrial sectors were obtained from the U.S. Census Bureau Statistics of U.S. Business (http://www.census.gov/econ/susb/).

Michigan's Data Characteristics
Total energy consumption per capita was much higher in the industrial sector than in any of the other three sectors, with the highest value during this time period occurring in 2005. The commercial sector ranked second in total energy consumption per capita, with its highest consumption year also occurring in 2005. Residential and transportation consumption ranked third and fourth, with their relative positions varying from year to year. Residential energy consumption was highest in 2003 and transportation energy consumption was the highest in 2002 (Figure 13). More recent data through 2010 is available at the SEDS website.

Data Limitations
Statewide data does not differentiate between urban, suburban, extra urban, and rural population clusters. In addition, energy consumption may not be a true indicator of energy efficiency. For example, energy efficiency could improve with a concurrent increase in overall energy

consumption; close inspection of the various factors in energy consumption is important to determine true population trends in energy consumption.

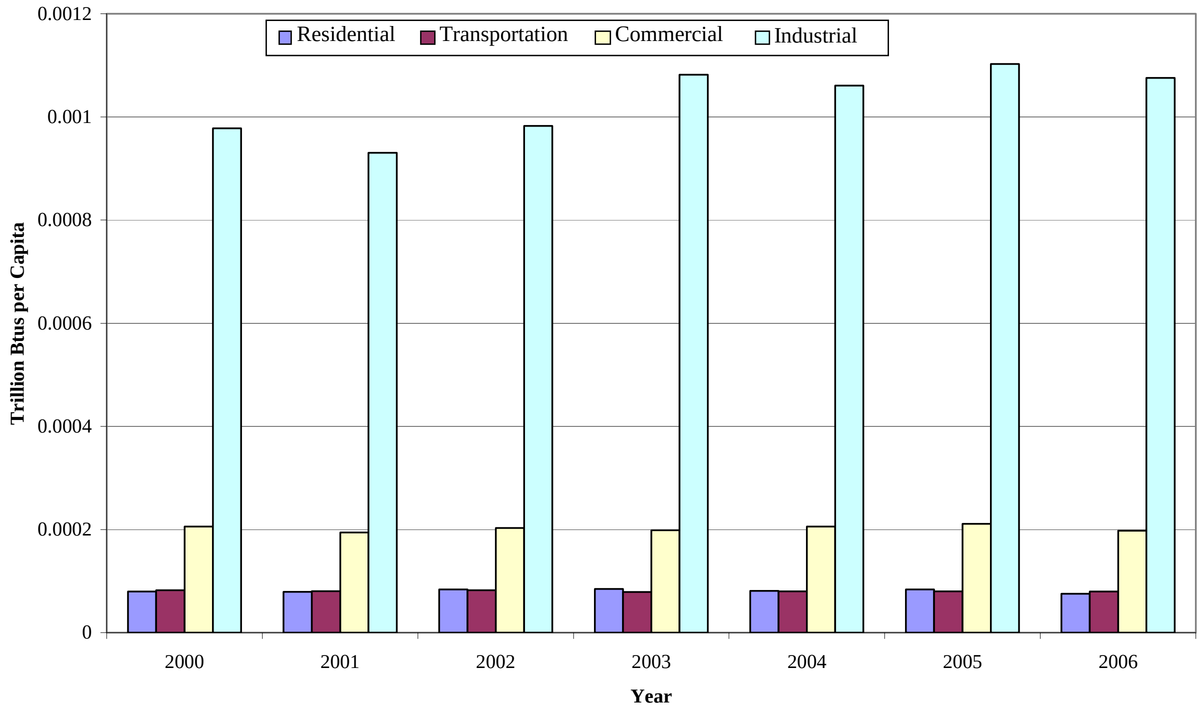

Figure 13. Total energy consumption in the state of Michigan by sector (Residential, Transportation, Commercial and Industrial) measured in trillion BTUs per capita from 2000-2006.

Renewable Energy Generation Per Capita, 2006-2008

Definition

Thousand kilowatt-hours of renewable energy generation per person in Michigan from 2006 - 2008.

Significance

Renewable energy sources were used to generate about 13% of total electricity generated in the U.S. in 2011 (EPA, 2011). As the percentage of energy generated from alternative fuel sources increases, it is likely that air quality will also improve. Renewable energy generation offsets demand for energy generated from fossil fuel sources. Renewable energy policies encourage development of both centralized renewable energy sources, such as hydroelectric and wind, and distributed sources, such as solar thermal and photovoltaic installations on individual homes and businesses.

Data Source

The Energy Information Administration (EIA), of the U.S. Department of Energy, produces the Renewable Energy Annual report (http://www.eia.gov/renewable/annual/). The renewable energy sources included in the report include biomass (wood, wood waste, municipal solid waste, landfill gas, ethanol, biodiesel, and other biomass), geothermal, wind, solar (solar thermal and photovoltaic), and conventional hydropower. Hydroelectric pumped storage facilities are excluded, because they usually use non-renewable energy sources for their operation. Since the EIA collects data only on terrestrial (land-based) solar energy systems, satellite and some military applications are also excluded. Population estimates for calculating rates per 100,000 population were obtained from the U.S. Census Bureau (at the time the data was at www.census.gov/popest/eval-estimates/eval-est2010.html; current link is http://www.census.gov/popest/).

Michigan's Data Characteristics

Michigan's renewable energy generation per capita, at 0.36-0.39 thousand kilowatt-hours per person from 2006-2008, was less than the U.S. average of 1.17-1.29 thousand kilowatt hours per person, mostly due to less use of hydroelectric power in the state (3% vs. 66% nationally) (Figure 14). In 2010, nearly 4% of Michigan's electricity was generated using renewable energy sources, about the same as in 2006 (data not shown; see http://www.eia.gov/renewable/state/Michigan/).

Data Limitations

This methodology does not incorporate energy efficiency or percentage of total energy use. For example, this indicator would not reflect the benefits to air quality if a state's population increases energy efficiency substantially while renewable energy generation remains constant. In addition, this measure does not consider state differences in factors that impact energy use and needs, such as weather and temperature information, nor does it take into account availability of natural resources needed for certain renewable energy sources, such as wind and water.

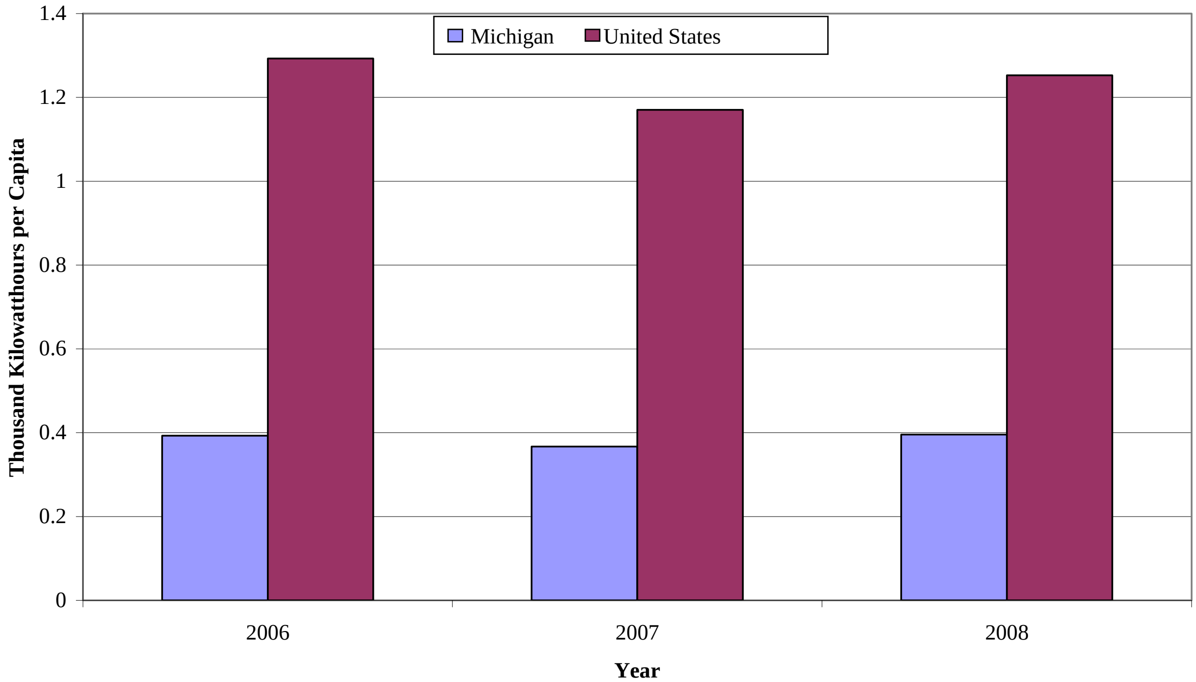

Figure 14. Thousand kilowatt-hours of total renewable energy generation per capita in the state of Michigan and the U.S. for the years 2006-2008.

Vehicle Miles Traveled Per Capita, 1995-2008

Definition
The number of vehicle miles traveled per capita in Michigan for the years 1995-2008.

Significance
Vehicle miles traveled can be an indicator of urban sprawl, air pollution, and a sedentary lifestyle. According to the U.S. EPA, transportation accounts for 29% of U.S. GHG emissions and is the fastest growing source of emissions (http://www.epa.gov/otaq/climate/index.htm). A reduction in vehicle miles traveled per capita can indicate increased population density; increased access to alternative forms of transportation, such as public transit, cycling, and walking; and climate change policies focused on improving air quality and promoting active living.

Data Source
The U.S. Department of Transportation's Federal Highway Administration publishes a yearly Highway Statistics Report, which brings together selected statistical tabulations relating to highway transportation in twelve major areas. The vast majority of highway data are submitted by the individual states. Each state is analyzed for consistency against its own past years of data and against other state and federal data sets www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.cfm .

Michigan's Data Characteristics
Michigan's annual vehicle miles traveled had generally been increasing from 1995-2008 and were similar to the U.S. average throughout this period. Michigan's vehicle miles ranged from a low of 8,912 miles per capita in 1995 to a high of 10,386 miles per capita in 2007 (Figure 15).

Data Limitations
By focusing only on vehicle miles traveled, this indicator does not reflect the use of other forms of transportation or the growing use of telecommuting as a mitigation measure. Other factors, such as a recession, can result in reductions of per capita vehicle miles, as was seen in Michigan in 2009 and later years (data not shown).

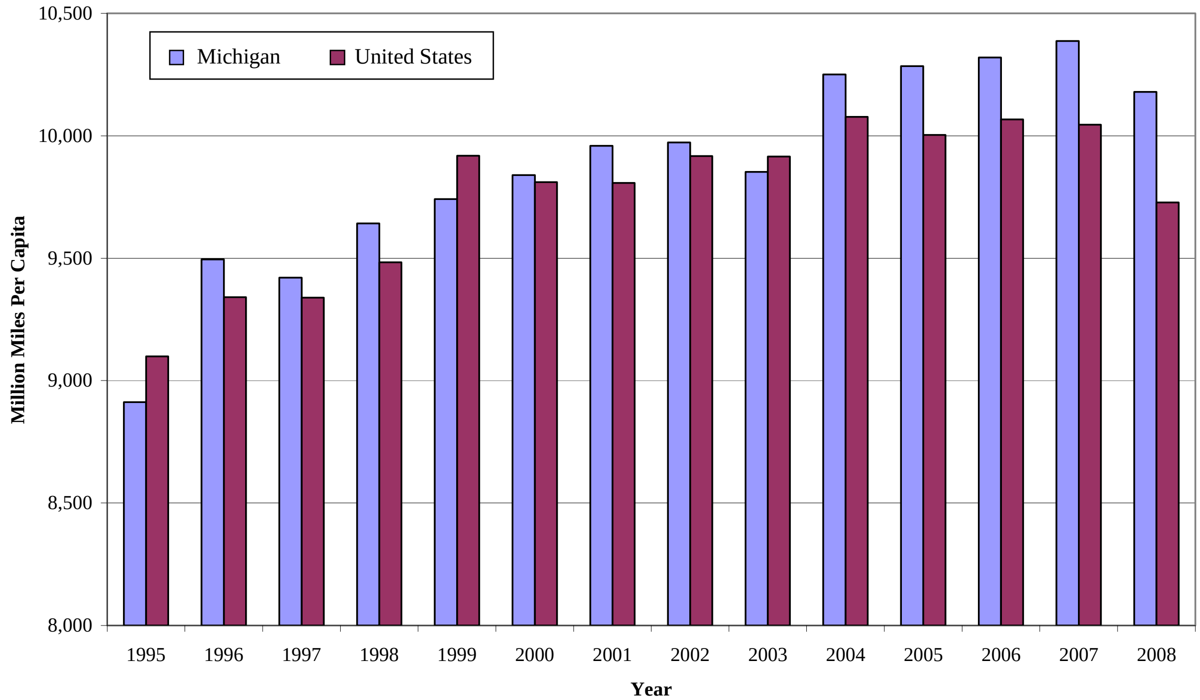

Figure 15. The number of vehicle miles traveled per capita in the state of Michigan and the United States for the years 1995-2008.

Adaptation Indicators

Development of a State Adaptation Plan, 2011

Definition
The development of a climate change adaptation plan by the state of Michigan.

Significance
Substantially reducing GHG emissions is essential to diminish the worst impacts of climate change. However, mitigation alone is not enough. Even with emission reductions, some warming will still occur. Adaptation planning at the local, state, and national levels can limit the damage caused by climate change; adaptation planning can also limit the long-term costs of responding to climate-related impacts that are expected to grow in number and intensity in the decades to come.

Data Source
The Pew Center on Global Climate Change identifies which states have developed or recommended developing adaptation plans (http://www.c2es.org/us-states-regions/policy-maps/adaptation).

Michigan's Data Characteristics
In 2007, the Governor issued Executive Order No. 2008-42, which established the Michigan Climate Action Council (MCAC). The MCAC was instructed to complete a comprehensive Climate Action Plan for Michigan, to include policy recommendations, an assessment of the projected impacts, and recommendations for adaptive strategies. The Climate Action Plan was released in March 2009, outlining policy recommendations for reducing GHG emissions. It included a recommendation to analyze potential impacts and actions needed for adaptation. Although the MCAC did not take action on the adaptation recommendation, MDCH did take action and developed the "Michigan Climate and Health Adaptation Plan, 2010 – 2015" with funding from CDC, joining ten other states with adaptation plans in 2011. (Figure 16).

Data Limitations
The Pew Center on Global Climate change does provide some links to the state adaptation plans, but generally does not provide details other than a general overview of the relevant mandate. In addition, information does not appear to be uniformly updated regularly, thus adaptation plans may have been completed by more states than Michigan, but not yet posted on this website.

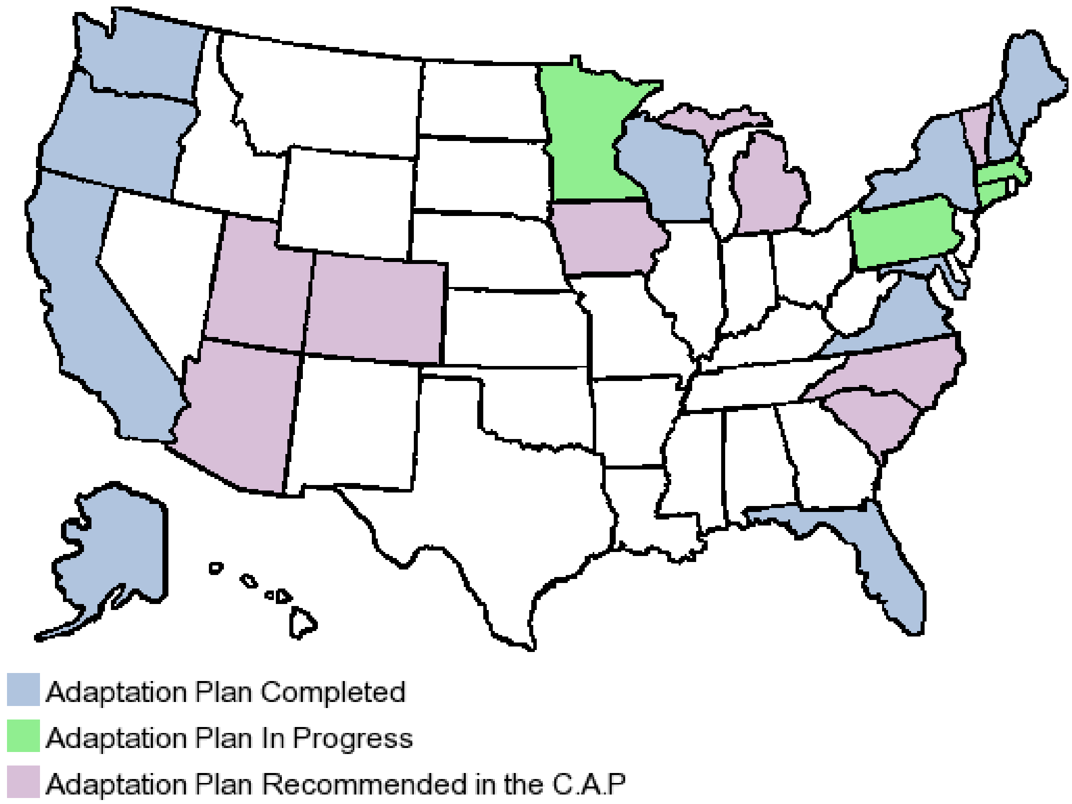

Figure 16. Map of the United States with 15 states that have completed a State Adaptation plan highlighted in blue (AK, CA, CT, FL, MA, MD, ME, NH, NY, OR, PA, VA,VT, WA,WI); 4 that have an Adaptation Plan in progress highlighted in green (DE, MN, NY, RI); and 7 that have an Adaptation plan recommended in their Climate Action Plan (CAP) highlighted in purple (AZ, CO, IA, MI, NC, SC,UT). Source: Pew Center on Global Climate Change: http://www.pewclimate.org/what_s_being_done/in_the_states/adaptation_map.cfm.

Number of Municipal Heat Island Mitigation Projects and Plans, 2010

Definition

The number and name of municipal heat island effect projects and programs in Michigan as of 2010.

Significance

The municipal (or urban) heat island effect is the tendency for urban areas and other areas with a high percentage of impervious surfaces to absorb and re-radiate solar heat. The urban heat island effect can exacerbate extreme heat events by magnifying warm temperatures, particularly in areas with low levels of vegetation. In some cases, community "hot spots" during extreme heat events have also been correlated with socio-economically disadvantaged areas, compounding a natural hazard by exposing the most vulnerable populations to the highest temperatures. The land use configurations associated with the urban heat island effect can also coincide with increased air pollution due to high traffic volume, increased pollen counts due to increased temperatures, and changes to other meteorological variables. It can also correspond to areas vulnerable to flooding, because impervious surfaces do not absorb storm water runoff.

The number of urban heat island mitigation projects and plans is an indicator of how fully an urban area is addressing the need to become more resilient in the face of increasing frequency and severity of extreme heat events and impaired air quality related to global climate change.

Data Source

The U.S. Environmental Protection Agency (EPA) maintains the Heat Island Effect website www.epa.gov/heatislands . This website includes the EPA's Urban Heat Island Community Actions Database, which provides information on more than 75 local and statewide initiatives to reduce heat islands and achieve related benefits. Each entry in the database includes a description of the activity, its status, and a link to a project website (if available).

Michigan's Data Characteristics

Michigan is one of 27 states with heat island initiatives listed on the EPA's Community Actions Database (Figure 17). Two major projects have been completed. (1) As part of the Cool Pavement initiative, in 2004 Detroit Metro Airport used 720,000 square feet of slag cement in an airport terminal expansion project. This approach increased the life expectancy of the paved surfaces as well as allowed the use of highly reflective materials in the cement, which cut down on the urban heat island effect by reflecting solar energy back into space. (2) The Ford Motor Company River Rouge plant installed a plant green roof and porous pavement in 2003, both of which mitigate the urban heat island effect and provide many environmental benefits. As a result, the company achieved a Leadership in Energy and Environmental Design (LEED) gold certification for the facility.

Data Limitations

EPA's website appears to rely on self-reports and is not kept up to date. Certain urban heat island mitigation plans may be more extensive and more fully implemented than others; however, at the time of this publication, a complete national database does not exist. Without a complete national database, it is difficult to make comparisons and learn from other plans.

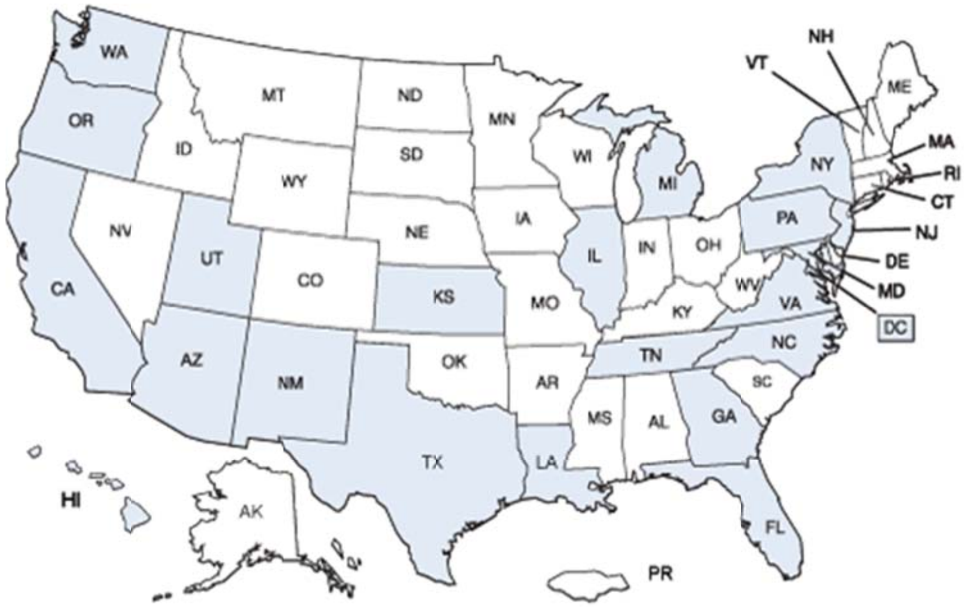

Figure 17. The EPA's Urban Heat Island Community Actions map for the United States. States highlighted in blue have initiatives at the state and/or local level to reduce heat islands. From the U.S. Environmental Protection Agency's Heat Island Effect website: http://www.epa.gov/heatislands/

Health Surveillance Systems Related to Climate Change, 2008-2009

Definition

The number of health surveillance systems related to climate change reported to be present in Michigan as of 2008-2009.

Significance

A number of health surveillance systems already exist at the local, state, and federal levels that are relevant to the health effects of climate change. These systems provide a valuable, evidence-based tool to help public health prioritize adaptation and mitigation policies to ensure that interventions benefit the most vulnerable populations. However, currently the majority of health surveillance systems related to climate change have not been identified as connected to both a specific health concern and to the larger topic of global climate change. Coordinating climate-change related surveillance efforts across disciplines should spark research into potential climate related correlations across relevant surveillance trends.

Data Source

The Association of State and Territorial Health Officials (ASTHO) conducted the Climate Change Needs Assessment Survey in 2008-2009. This assessment surveyed state and territorial health agencies regarding then-current activities and programs designed to address the public health consequences of climate change. Forty-three public health agencies completed the survey. Administered electronically, the 32 question needs assessment focused on the climate change practices, perceptions, and resource needs of state and territorial health agencies at that point in time. The survey included a section on the current level of surveillance in the state for the following nine health measures related to climate change: water-borne disease morbidity and mortality; food-borne disease morbidity and mortality; quality of air, including air pollution; anxiety, depression or other mental health conditions; extreme weather events morbidity and mortality; health effects from ozone/particulate matter; asthma/respiratory illness morbidity and mortality; heat/cold morbidity and mortality; and vector-borne diseases (Lyme disease, West Nile Virus, etc.). An ASTHO Survey PowerPoint presentation summarizing the survey results for all responding states is available at: www.astho.org/Programs/Environmental-Health/Natural-Environment/Powerpoint--SHO-survey/ ASTHO keeps state-specific responses confidential, thus each state can only compare their own responses to those of the entire group.

Michigan's Data Characteristics

The MDCH respondent reported that the state of Michigan had adequate surveillance capacity in six of the nine mentioned surveillance systems. The MDCH respondent did not know if surveillance of extreme weather events morbidity and mortality was adequate, and noted that surveillance of anxiety, depression, or other mental health conditions and of quality of air, including air pollution, in Michigan was inadequate (Table 7).

Data Limitations

Because individual states' responses to each question in the ASTHO survey are not available publically, it is not possible to compare Michigan's responses to those from states with similar demographics and geography. Further, the MDCH respondent may not have been familiar with all of the possible data sources or surveillance capacity for climate change in Michigan. Also, this information has not been updated and would not reflect activities funded by the CDC's Climate Ready States and Cities Initiative.

Table 7. Reported adequacy of surveillance capacity for nine health outcome areas in Michigan and the other 42 states and territories participating in the 2008-2009 ASTHO Climate Change Needs Assessment Survey.

Health Outcome Area	Michigan – adequate surveillance capacity?	Number (percent) of 42 other states & territories w/ adequate surveillance capacity
Water-borne disease morbidity and mortality	yes	31 (73.8%)
Food-borne disease morbidity and mortality	yes	34 (81.0%)
Quality of air, including air pollution	**no**	20 (47.6%)
Anxiety, depression or other mental health conditions	**no**	11 (26.2%)
Extreme weather events morbidity and mortality	**unknown**	18 (42.9%)
Health effects from ozone/particulate matter	yes	10 (23.8%)
Asthma/Respiratory illness morbidity and mortality	yes	25 (59.5%)
Heat/cold morbidity and mortality	yes	20 (47.6%)
Vector-borne diseases (Lyme disease, West Nile virus, etc.)	yes	32 (76.2%)

Need for Public Health Workforce Staff, Training and Resources in Climate Change, 2008-2009

Definition

The reported need for more public health workforce staff, training and resources in climate change in Michigan, as of 2008-2009.

Significance

The level of public health engagement on climate change will largely be determined by how fully its workforce integrates climate-related priorities into their work. In particular, education on the science behind climate change and its connection to core public health services will be an essential component of a successful public health response to this issue. Tracking the number of public health professionals trained in climate change indicates the level of awareness about the links between health and climate change across the public health sector.

Data Source

The Association of State and Territorial Health Officials (ASTHO) conducted the Climate Change Needs Assessment Survey in 2008-2009. This assessment surveyed state and territorial health agencies regarding current activities and programs designed to address the public health consequences of climate change. Forty-three states and territories completed the survey. Administered electronically, the 32 question needs assessment focused on the current climate change practices, perceptions, and resource needs of state and territorial health agencies. A series of questions asked about workforce dedicated to addressing potential health effects from climate changes. An ASTHO Survey PowerPoint presentation summarizing the results for all responding states: www.astho.org/Programs/Environmental-Health/Natural-Environment/Powerpoint--SHO-survey/.

Michigan's Data Characteristics

The MDCH response noted that there was not a need for additional staff training or resources to deal with climate change as a public health issue; however, the respondent indicated that additional staff and funding would be helpful.

Data Limitations

The indicator, as currently written, does not provide actual numbers of public health workers trained in climate change. This indicator also does not specify any level of training or specific core concepts, such as climate change science, and as such is of limited utility. It is also somewhat dated and would not be a useful indication of current needs and activities.

Policy Indicators

Percent of Population Living in Cities Participating in the U.S. Conference of Mayors Climate Protection Agreement, 2011

Definition
The number of local governments that have signed the Mayors Climate Protection Agreement, the percentage of local governments that have signed the agreement, and the percent of the population in Michigan that is covered by the agreement, as of 2011.

Significance
Local governments that have signed on to the Mayors Climate Protection Agreement have identified climate change as a problem with global origins and local ramifications. An indicator tracking the number and percent of jurisdictions and the percent of overall population participating in the program helps measure a state's overall performance on climate change policies in comparison with other states.

Under the Agreement, participating cities commit to take the following three actions:

1. Strive to meet or exceed the Kyoto Protocol targets in their own communities, through actions ranging from anti-sprawl land-use policies to urban forest restoration projects to public information campaigns.
2. Urge their state governments and the federal government to enact policies and programs to meet or exceed the GHG emission reduction target suggested for the United States in the Kyoto Protocol – 7% reduction from 1990 levels by 2012.
3. Urge the U.S. Congress to pass the bipartisan GHG reduction legislation, which would establish a national emissions trading system.

Data Source
The U.S. Conference of Mayors Climate Protection Center maintains a website with a list of all mayors who have signed the Mayors Climate Protection Agreement. The website also maintains maps and other information regarding the Climate Protection Agreement (www.usmayors.org/climateprotection/list.asp). Population estimates for calculating rates per 100,000 population were obtained from the U.S. Census Bureau (at the time the data was at www.census.gov/popest/eval-estimates/eval-est2010.html; current link is http://www.census.gov/popest/).

Michigan's Data Characteristics
The state of Michigan had 31 local governments participating in the U.S. Conference of Mayors Climate Protection Agreement as of 2011. This represents 1.7% of all the local governments in the State of Michigan, which includes counties, cities, towns, and townships. In total, 2,581,367 people, or 26.0% of the population of the state of Michigan was covered by the Mayors Climate Protection Agreement (Table 8). As of 2011, 1053 mayors from the 50 states, the District of Columbia, and Puerto Rico had signed the Agreement, which represents 2.7% of all the local governments. In total, 88,463,807 citizens or 28.6% of the total population of U.S. was covered by the Mayors Climate Protection Agreement (Table 8 and Figure 18).

Data Limitations
Cities listed on the Mayors Climate Protection Center website may not match exactly to cities listed on the U.S. census website for obtaining population denominator data. In addition, signatory governments are not required to pursue climate protection programs. It is therefore difficult to know whether a state with a large percentage of participating jurisdictions and/or total population has been more active on climate change initiatives than non-participating jurisdictions. Finally, an unknown number of local governments may have climate change policies or activities without signing onto the Mayor's Agreement.

Table 8 Comparison of participation in 2011 between Michigan and the United States in the Mayors' Climate Protection Agreement.

	Michigan	United States
Number of Local Governments Participating in the Mayors Climate Protection Agreement	31	1053
Percent of Local Governments Participating in the Mayors Climate Protection Agreement	1.7%	2.7%
Percent Population of Local Governments Participating in the Mayors Climate Protection Agreement	26.0%	28.6%

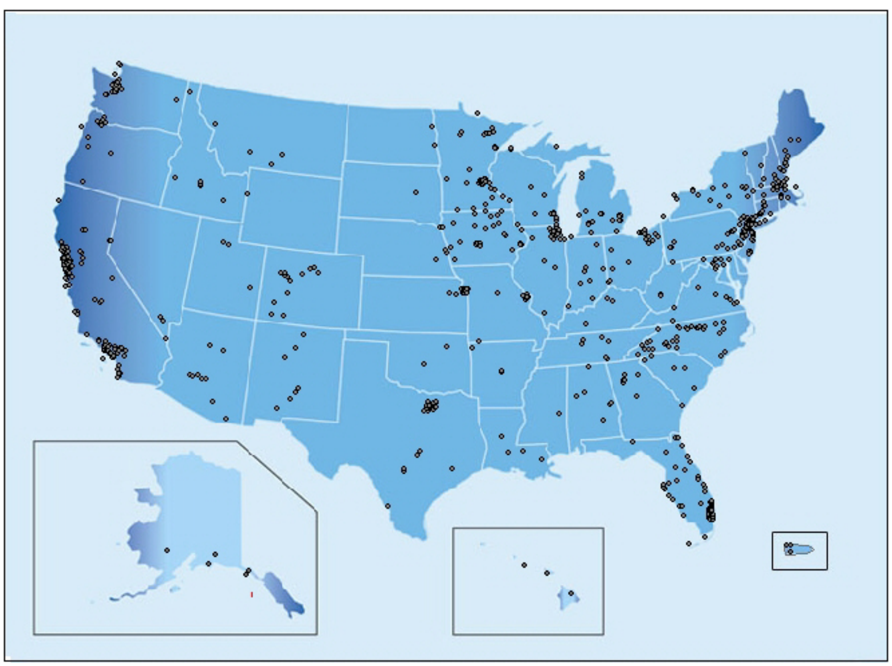

Figure 18. Map of local governments with mayors participating in the Mayors Climate Protection Agreement as of 2011. Map source: Mayors Climate Protection Website, http://www.usmayors.org/climateprotection/ClimateChange.asp

Creation of a State Climate Change Advisory Board, 2008

Definition
The creation of a state climate change advisory board in Michigan as of 2008.

Significance
A climate change advisory board is normally charged with evaluating the sources of GHG emissions and the likely impacts of climate change in a state. The resulting report frames priorities for future policy actions, including priorities related to public health. Whether or not a state has created a climate change advisory board is a strong indicator of whether or not that state has identified public policy priorities for climate change mitigation and adaptation.

Data Source
The U.S. Environmental Protection Agency (EPA), State and Local Climate Energy Program (www.epa.gov/statelocalclimate/) tracks state and regional climate policies, including the formation of state advisory boards. A state advisory board is typically established by the governor and given the task of formulating recommendations on how the state should address climate change. The board's work can include developing an emissions inventory; projecting future emissions based on expected population, economic growth, and other factors; analyzing mitigation and adaptation options; and recommending specific greenhouse gas emission reduction targets.

A state advisory board typically includes state planners, policy analysts, natural resource specialists, and representatives from both environmental interest groups and the private sector. Their expertise often represents a range of disciplines (e.g., engineering, science, economics, and policy analysis) and sectors (e.g., energy, transportation, agriculture, and forestry).

Michigan's Data Characteristics
The state of Michigan is one of 28 states to have formed a state advisory board as of 2008 (the most current data available on the EPA website) – the Michigan Climate Action Council, or MCAC. The remaining 22 states and the District of Columbia had not yet formed a state advisory board (Figure 19).

Data Limitations
This indicator does not include the next level of detail: namely, whether or not public health is included as part of the state advisory board's considerations either with regards to GHG sources and emissions or their likely effects. In addition, the data is provided on the EPA website in a text list. It does not compare advisory boards in terms of topics, which complicates comparisons across states. Finally, it only notes the creation of a state advisory board, and doesn't indicate whether the Board was active at any time in the past or present.

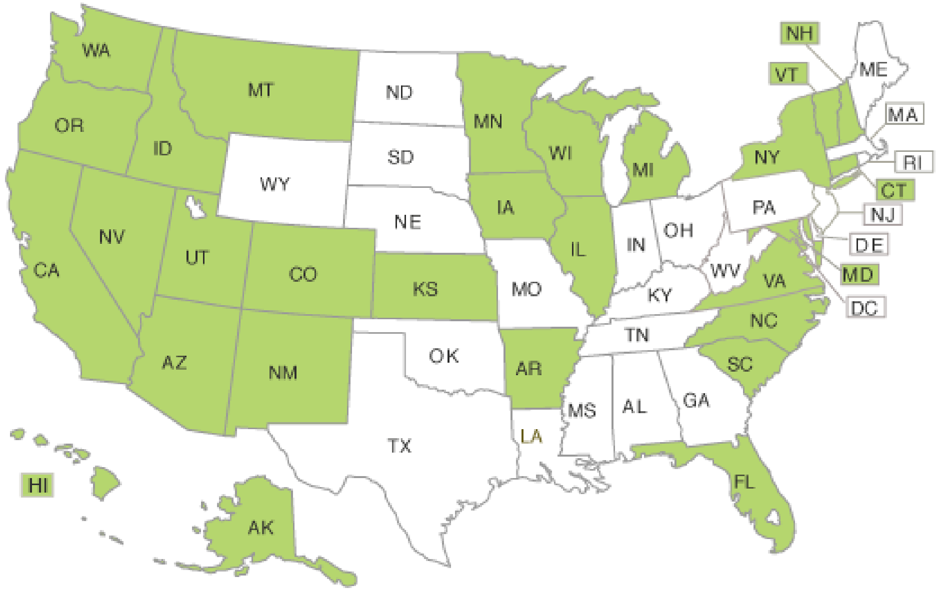

Figure 19. States (shaded in green) which had formed a state climate change advisory board, as of 2008. Map source: EPA http://www.epa.gov/statelocalclimate/state/tracking/state-planning-and-incentive-structures.html#a08

Completion of a State Greenhouse Gas (GHG) Inventory, 2009

Definition
The completion of a state GHG inventory for Michigan as of 2009.

Significance
A GHG inventory evaluates the amount of GHG emitted to and removed from the atmosphere over a specific period. It provides a baseline of a state or locality's emission levels as well as an indication of their sources, whether anthropogenic or natural. Tracking the trends of GHG inventories in a state provides a strong indication of how effective its mitigation policies have been at reducing GHG emissions. Dividing GHG emissions into sectors (residential, transportation, commercial, and industrial) can help policymakers prioritize policies to target specific sectors and sources within sectors.

Data Source
The U.S. Environmental Protection Agency, State and Local Climate Energy Program tracks state and regional climate policies and programs, including the completion of state and local (city, town, township, or county) GHG inventories (www.epa.gov/statelocalclimate).

Michigan's Data Characteristics
Michigan is one of 46 states and the District of Columbia to have completed a state GHG inventory as of 2009 (the most current data available on the EPA website; Figure 20). Michigan is not one of the 21 states to have completed a local GHG inventory as of 2009 (Figure 21).

Data Limitations
The state GHG inventory indicator is only collected at the state level and does not involve compilation and summation of data from smaller geographical areas (city, town, township, or county). State-level data derived from local inventories would allow comparisons of local GHG inventories. Also, data at this website may not be complete or up-to-date, especially for local GHG activities.

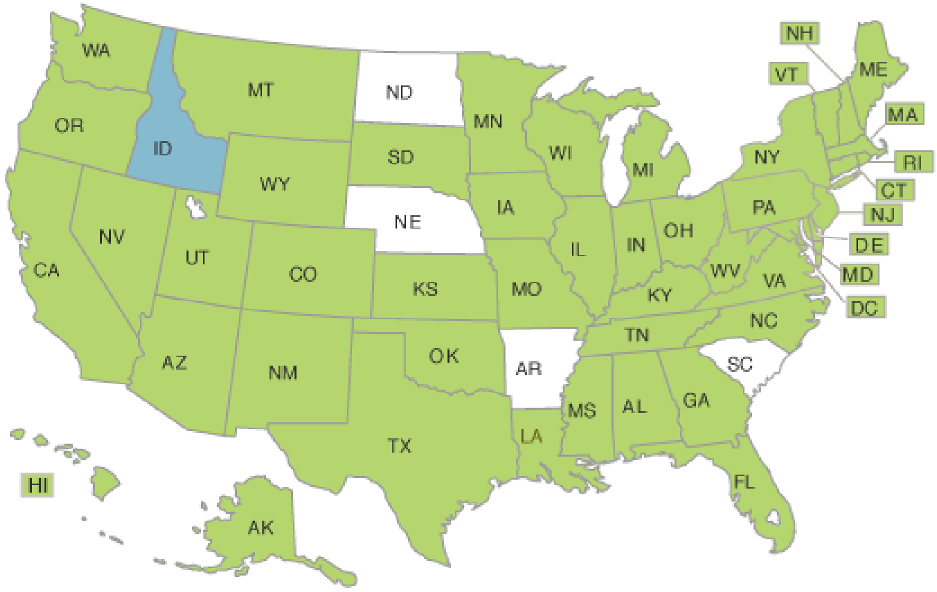

Figure 20. Map of the United States displaying the 46 states (in green) which had completed a state greenhouse gas inventory as of 2009; the one state in blue (ID) which was in process, and the remaining 4 states in white (AR, ND, NE, SC) which had not completed a greenhouse gas inventory. Map source: EPA http://www.epa.gov/statelocalclimate/state/tracking/state-planning-and-incentive-structures.html#a08

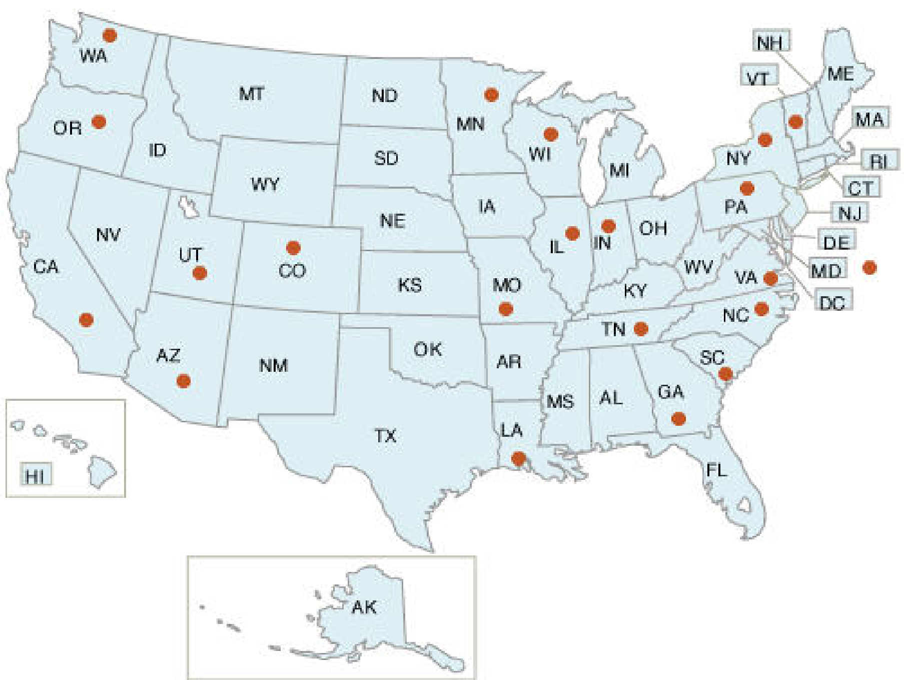

Figure 21. Map of the United States displaying 21 locations (red dots) that had completed a local greenhouse gas inventory as of 2009. Map source EPA: http://www.epa.gov/statelocalclimate/local/local-examples/index.html

Number and Percent of Local Governments Participating in ICLEI, 2011

Definition
The number and percent of local governments participating in ICLEI-Local Governments for Sustainability (ICLEI), and the percent of the population in Michigan that is living in a participating local government as of 2011.

Significance
ICLEI is an international association of local governments, whose mission is to further sustainable development at the local level. While climate change is one of ICLEI's programmatic focuses, its scope also includes related topics such as biodiversity, mobility, procurement, built environment, local economies, and water. Local governments who are members of ICLEI are leaders in sustainable development. An indicator tracking the percent of jurisdictions and the percent of overall population participating in the program can help measure a state's overall performance on sustainability in comparison with other states.

Data Source
ICLEI maintains a website with listings of its local government members (www.iclei.org/index.php?id+1387&region=NA). Population estimates for calculating rates per 100,000 population were obtained from the U.S. Census Bureau (at the time the data was at www.census.gov/popest/eval-estimates/eval-est2010.html; current link is http://www.census.gov/popest/).

Michigan's Data Characteristics
Throughout the US, more than 600 local governments are members of ICLEI as of 2011, with four city and two county ICLEI members in Michigan. These six local governments represent 0.3% of all local governments in Michigan and 3.4% of the total Michigan population.

Data Limitations
Member governments are not required to pursue ICLEI programs. It is therefore difficult to know whether a state with high levels of participation among local governments has been more active on sustainability initiatives than states with lower levels of participation. Also, smaller or less affluent communities may have climate change or sustainability activities but choose not to join ICLEI due to the high cost of membership.

Development of a State Climate Change Action Plan, 2009

Definition
The development of a climate change action plan by the state of Michigan as of 2009.

Significance
A climate change action plan is a comprehensive document that outlines a state's response to climate change, tailored to the state's specific circumstances. It typically includes:
- A detailed emission inventory;
- Baseline and projected emissions;
- A discussion of the potential impacts of climate change on the state's resources;
- Opportunities for emission reductions;
- Emission reduction goals; and
- An implementation plan.

Plans usually identify and recommend policy options based on criteria such as emission reduction potential, cost–effectiveness, and political feasibility. A climate change action plan forms the framework for policies and programs aimed at mitigation and adaptation. Early action plans often focused exclusively on mitigation interventions such as increasing energy efficiency and renewable energy sources. However, recent action plans, particularly at the state level, have started to incorporate public health as both a research and a policy item. Whether or not a state has created a climate change action plan is a strong indicator of whether or not that state has identified public policy priorities for climate change mitigation and adaptation.

Data Source
The U.S. Environmental Protection Agency (EPA) maintains a listing on its website of all the states that have completed a climate change action plan (www.epa.gov/statelocalclimate/).

Michigan's Data Characteristics
In 2007, the Governor issued Executive Order No. 2008-42, which established the Michigan Climate Action Council (MCAC). The Council was instructed to complete a comprehensive Climate Action Plan for Michigan, to include policy recommendations, an assessment of the projected impacts, and recommendations for adaptive strategies. The Climate Action Plan was released in March 2009, outlining policy recommendations for reducing GHG emissions statewide to 20% below 2005 levels by 2020 and 80% below 2005 levels by 2050, as well as a recommendation to further analyze potential impacts and action needed for adaptation to potential health effects from climate change. The Executive Order and Plan are available at: https://www.michigan.gov/deq/0,4561,7-135-50990-213752--,00.html .

Michigan is one of 34 states to have completed a climate change action plan as of 2009, the most recent year available. An additional 4 states were in the process of completing a climate change action plan, and 12 states and the District of Columbia did not have an action plan as of 2009 (Figure 22).

Data Limitations
This indicator does not include information regarding whether or not public health is a priority or if it is included in the climate change action plan. In addition, the way in which the data is presented does not allow comparison of attributes of the various climate change action plans across states. Also, there is no way to determine if any of the plans have been or are being implemented.

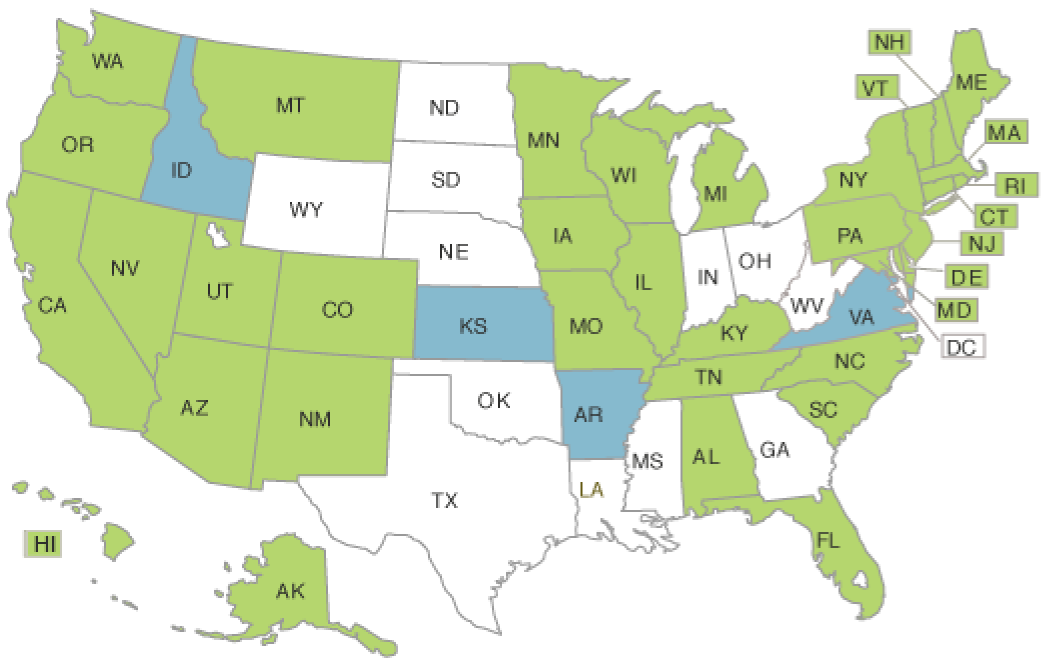

Figure 22. Climate change action plans in the United States as of 2009. 34 states in green have completed an action plan; four in blue (AR, ID, KS, VA) were in the process of forming an action plan; and the remaining 13 in white had no climate change action plan as of 2009. Source: EPA State and Local Climate and Energy Program
http://www.epa.gov/statelocalclimate/state/tracking/state-planning-and-incentive-structures.html#a01

Development of Local Climate Change Action Plans[7], 2009

Definition
The development of climate change action plans by local governments, including cities, towns, townships, and counties in Michigan as of 2009.

Significance
A climate change action plan is a comprehensive document that outlines a local government's response to climate change, tailored to the locality's specific circumstances. Plans typically include:

- A detailed emission inventory;
- Baseline and projected emissions;
- A discussion of the potential impacts of climate change on the local government's resources;
- Opportunities for emission reductions;
- Emission reduction goals; and
- An implementation plan.

Climate change action plans usually identify and recommend policy options based on criteria such as emission reduction potential, cost–effectiveness, and political feasibility. A climate change action plan forms the framework for policies and programs aimed at GHG mitigation and adaptation to health effects from climate change. Early action plans often focused exclusively on mitigation interventions such as increasing energy efficiency and renewable energy sources. However, recent action plans, particularly at the state level, have started to incorporate public health as both a research and a policy item. Whether or not a local government has created a climate change advisory action plan is a strong indicator of whether or not that jurisdiction has identified public policy priorities for climate change mitigation and adaptation.

Data Source
The U.S. Environmental Protection Agency (EPA) Local Climate and Energy Program maintains a listing on its website of local governments that have completed a climate change action plan (www.epa.gov/statelocalclimate/).

Michigan's Data Characteristics
Michigan is one of 27 states and the District of Columbia that have no local climate change action plans listed, according to the most recently available data on the EPA website (2009). Twenty-three states contain local governments that had local climate change action plans, with several states having multiple governments listed with completed action plans (Figure 23).

Data Limitations
This indicator does not include information regarding whether or not public health is a priority or if it is included in the climate change action plan. In addition, the way in which the data is presented does not allow comparison of attributes of the various local climate change action

[7] This indicator was developed by the CCWG but it was not part of the multi-state indicator pilot.

plans across each state. Also, information at this website may not be complete and not up-to-date.

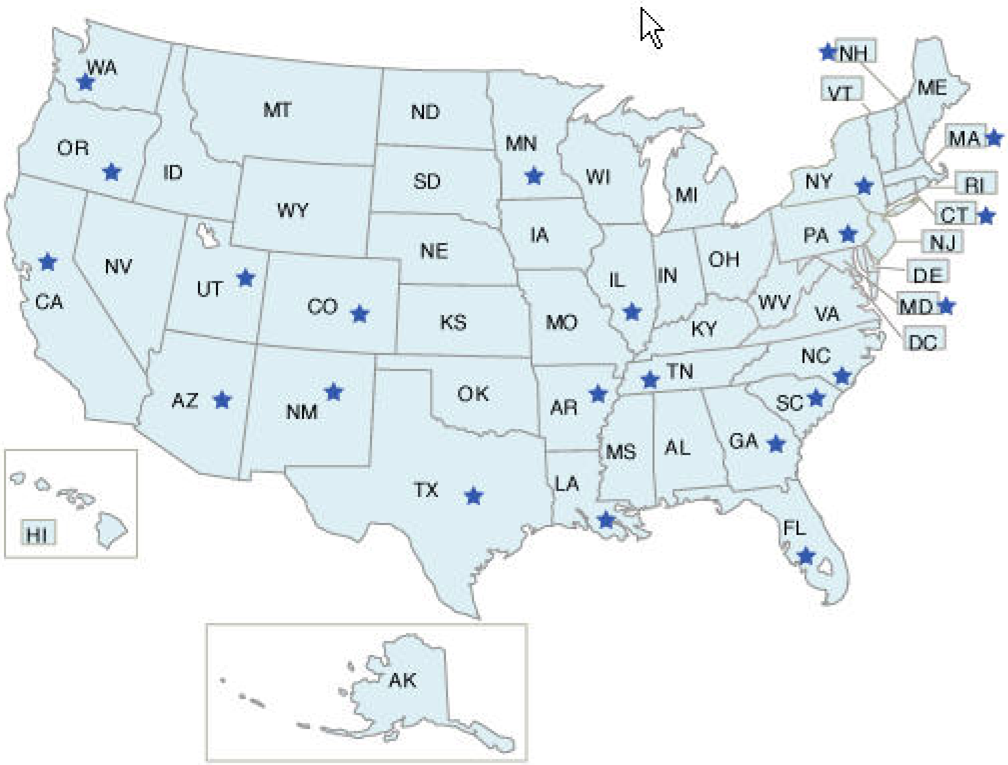

Figure 23. Map of local climate change action plans in the United States. Blue stars represent local governments with completed climate change action plans as of 2009. Source: EPA State and Local Climate and Energy Program: http://www.epa.gov/statelocalclimate/local/local-examples/index.html

VI. References

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