Michigan's Path to a Prosperous Future: Climate Challenges and Opportunities

Paper 4c in a Five-Part Series

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CITIZENS RESEARCH COUNCIL OF MICHIGAN

About the Series

Altarum and the Citizens Research Council of Michigan have joined forces to present a realistic, data-informed vision of Michigan's future based on current trends and trajectories across multiple dimensions – economic, demographic, workforce, infrastructure, environment, and public services. The papers are available on both organizations' websites.

Research for this project was conducted in two phases. Phase I involved a landscape scan of existing resources and expert knowledge of trends and challenges. For each domain, published and grey literature were reviewed and interviews with stakeholders were conducted to answer questions such as:

- Where is Michigan now – strengths, weaknesses, major challenges?
- What data is available to characterize the current situation and to track progress? Are there existing forecasts, either descriptive or data-driven?
- How does Michigan compare to other states, especially in the Midwest?
- What path are we on currently, and where are opportunities to shift the path through policies and investment?

Phase 2, as represented in an Executive Summary and a series of five papers, built on Phase 1 to include data and context.

Altarum (altarum.org) is a nonprofit organization focused on improving the health of individuals with fewer financial resources and populations disenfranchised by the health care system.

The Citizens Research Council (crcmich.org) works to improve government in Michigan by providing factual, unbiased, independent information concerning significant issues of state and local government organization, policy, and finance.

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Report Highlights

- Climate change due to human emission of greenhouse gases is an observable phenomenon that has already impacted Michigan's climate and weather. Michigan is getting warmer, particularly in winter and spring months. Additionally, Michigan is experiencing more precipitation (rain and snow), much of this coming in increasingly powerful and destructive storms.

- Michigan, the U.S., and most advanced nations have reduced greenhouse gas emissions in recent decades, largely from substituting natural gas for coal in power generation, as well as adoption of renewable energy such as wind and solar. However, global emissions of greenhouse gases are at record high levels and are likely to increase in the coming years as developing nations grow their economies.

- Michigan has recently adopted the MI Healthy Climate Plan, which aspires to achieve statewide "carbon neutrality" by 2050 to mitigate the impacts of climate change. Unfortunately, as a global phenomenon, it is not possible for Michigan to measurably mitigate climate change through state-level emissions-reduction policies.

- As Michigan pursues the laudable goal of carbon emissions reduction, policymakers must also prepare for the inevitable impacts of continuing climate change. Approaches should emphasize climate resilience and adaptation to put Michigan in the best position to build healthy communities and achieve economic sustainability in a changing world.

Introduction

Climate change poses a threat to the wellbeing of Michiganders and all of humanity. Extreme weather and shifting climate trends threaten to disrupt long-established land-use patterns that are critical to many aspects of the modern economy. Adapting to a changing climate while transitioning the global economy away from fossil fuels will be a defining challenge of the 21st century.

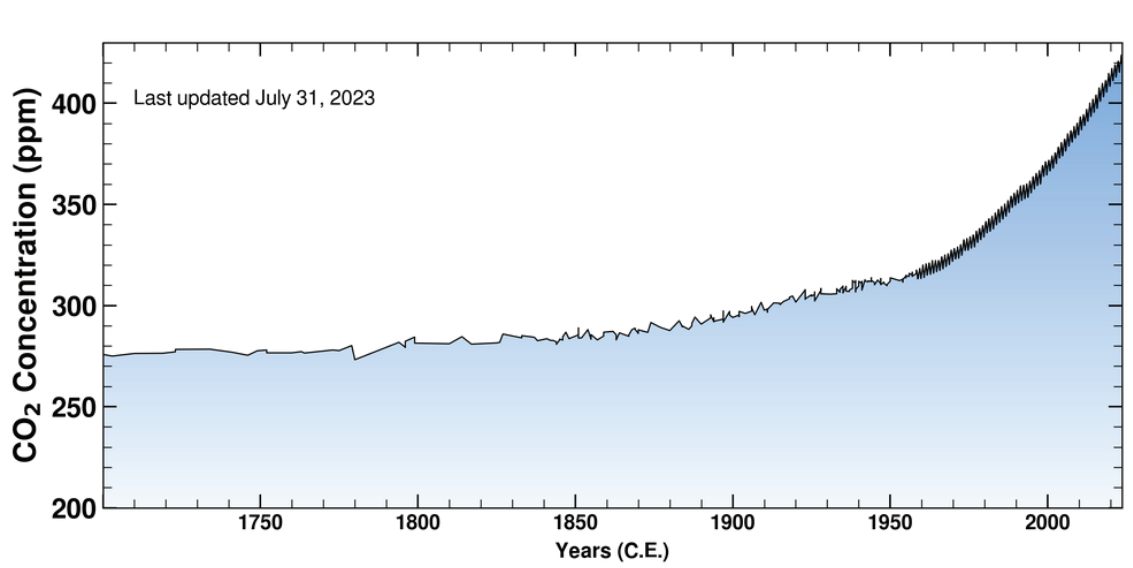
Earth's climate is changing at an unprecedented rate. The rapid change is almost certainly a result of combustion of fossil fuels and other industrial activities that increase the concentration of greenhouse gasses in Earth's atmosphere.

The term climate refers to long-term weather patterns and trends. Weather is short-term phenomena such as temperature, precipitation, wind, and storm events. Weather reflects climate, but any single weather event does not necessarily imply climate change, no matter how unusual. But when weather events show consistent trends over years and decades that deviate from long-term averages, it is safe to conclude that the climate is changing.

Earth's climate has undergone numerous and extreme changes over the planet's 4.5-billion-year history. Previous changes resulted from natural phenomena such as variations in our sun's intensity, cyclical changes in Earth's orbit, and gradual changes to Earth's atmosphere due to geological and biological activity. This time is different; human use of fossil fuels is the main driver.

Using ice core data, it is known that the concentration of carbon dioxide in Earth's atmosphere was about 270 parts per million (ppm) before the industrial revolution. Current levels, measured directly, are approximately 420 ppm (Figure 1).[1]

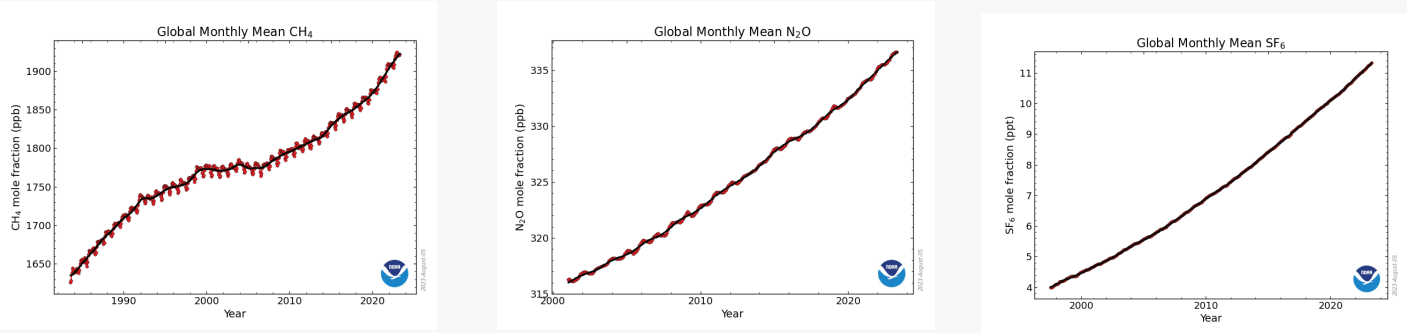
Figure 1: Carbon Dioxide Concentration, 0 C.E. to 2020 C.E.



Source: UC San Diego, Scripps Institute of Oceanography.

Earth's climate is complex and not fully understood. However, it is virtually certain that the planet is now undergoing rapid climate change due to significant changes in Earth's atmosphere caused by human activity. Most impactful to these changes are the use of fossil fuels such as coal, oil, and natural gas. Combustion of these materials produces the energy that has allowed development of the modern economy, but also emits carbon dioxide, our planet's most significant greenhouse gas (GHG). Other GHG emissions are also on the rise (Figure 2).

Figure 2: Increasing Concentrations of Methane, Nitrous Oxide, and Sulphur Hexaflouride

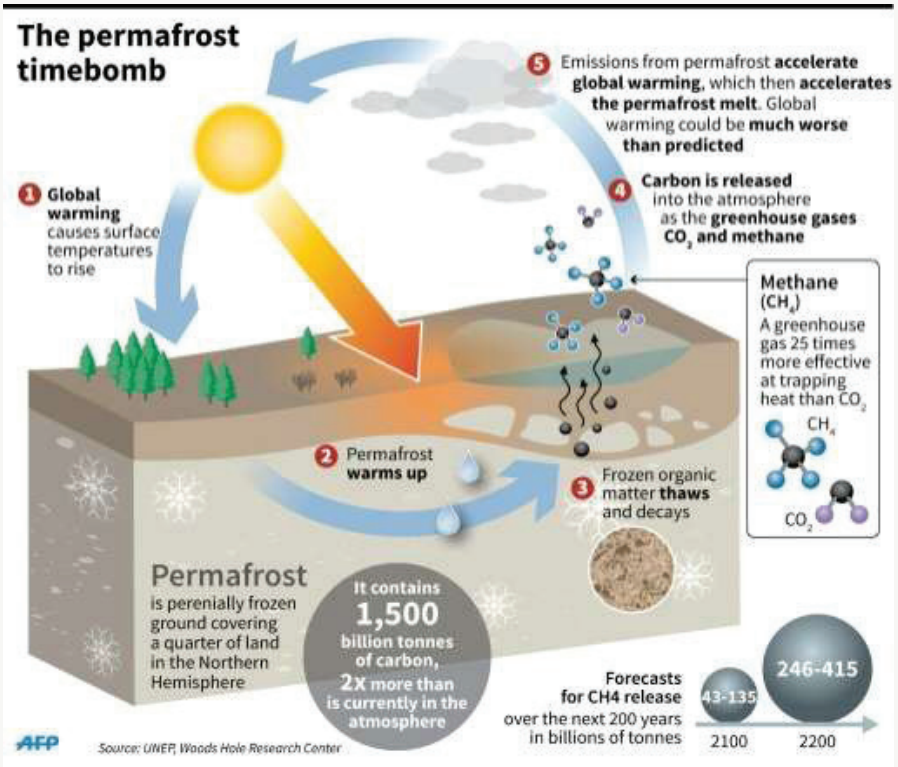


Source: NOAA Global Monitoring Laboratory, https://gml.noaa.gov/ccgg/.

Greenhouse gas (GHG) emissions make life on Earth possible by absorbing and re-emitting infrared radiation (heat). Without GHGs, the earth would experience wild temperature swings between night and day. GHG levels have been variable throughout Earth's history, but have been consistent for several thousand years, providing a relatively stable climate that aided the development of human civilization. Since the industrial revolution, human activity has rapidly increased the concentration of GHGs in the atmosphere, measurably raising the planet's overall temperature.[2]

Scientists estimate that the temperature of the Earth has increased by at least 1.5°F (0.8°C) since 1900 (Figure 3).[3] This may not seem like much, but this increase in temperature implies a significant increase in the overall amount of energy in Earth's atmosphere and oceans. This relatively rapid change is likely to catalyze an increasingly unstable climate, with more frequent extreme weather events such as heat waves, cold snaps, devastating draughts, and powerful storms.

Figure 3: Example of Climate Change Inducing Positive Feedback Loop, Permafrost Melt



Source: phys.org. Climate change: the state of emissions pledges to UN. October 16, 2015, https://phys.org/news/2015-10-climate-state-emissions-pledges.html.

Various feedback mechanisms amplify the impact of GHG emissions. For example, global warming has triggered the thawing of arctic permafrost, which releases previously sequestered carbon dioxide and methane into the atmosphere, which drives further warming. There are several such "positive feedback loops" (Figure 3).[4,a]

Additionally, the full climate impacts of GHG emissions are not immediate. The climate change being experienced now is due to the cumulative effect of decades of fossil fuel combustion. The full impact of carbon emissions released today will probably not have maximum impact until at least a decade from now.[5]

Even if GHG emissions are reduced drastically and rapidly, climate change may continue proceed nearly unabated due to natural feedback loops.

Between various feedback loops that amplify GHG emissions, and the lag time between carbon dioxide emissions and maximum warming impact, even if emissions of GHGs stopped today, the impacts on climate would continue for decades and possibly centuries.[6] In any case, this scenario only becomes relevant if humans achieve net-zero GHG emissions, and they are not on a path to doing that—locally, nationally, or globally.[7]

Ambitions to mitigate climate change to manageable levels generally assume carbon capture and sequestration technologies that are not yet proven and may have unintended consequences.[8] Even if GHG emissions are reduced drastically and rapidly, climate change is likely to become increasingly impactful in coming years.[9] As Michigan attempts to mitigate carbon dioxide output by decarbonizing the state economy, it must also adapt to changes in the climate that are already set in motion. There is fundamental uncertainty in climate forecasting, but the worst-case scenarios are disconcerting.[10] It is prudent to prepare.

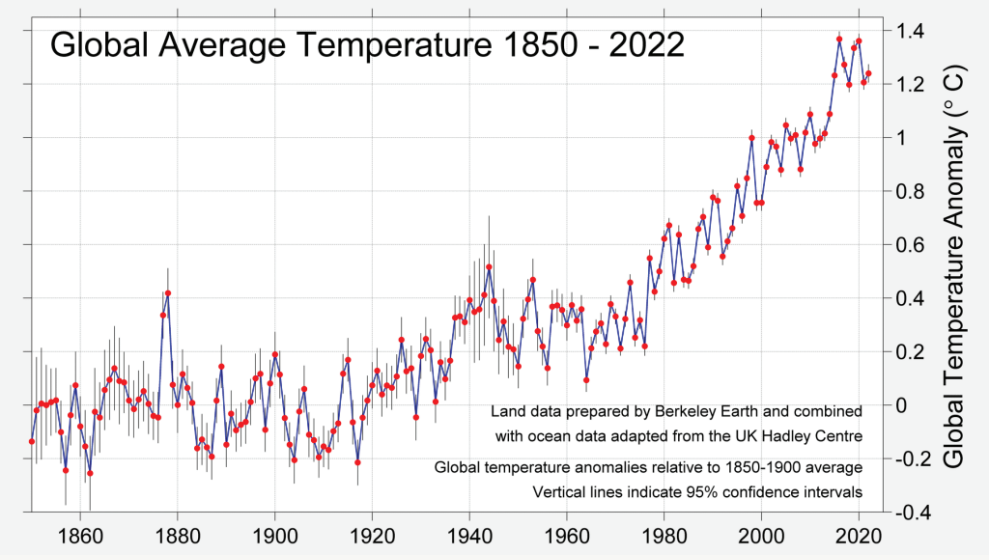
Human activity continues to add GHGs to Earth's atmosphere. While advanced economies (including Michigan and the U.S.) have reduced carbon dioxide output in recent years—primarily due to substituting natural gas for coal in power generation—the amount of carbon dioxide in Earth's atmosphere is increasing faster than ever.[11,12]

It is not within the capacity of Michigan state policy to meaningfully mitigate the climate change that Michigan experiences. It is within the capacity of state policy to prepare for such changes.

2023 is likely to be the warmest year, globally, in modern records.[13]

Earth's climate is changing, and Michigan's along with it (Figures 4 and 5). The climate will continue to change. It is not within the capacity of state policy to impact Michigan's climate. It is within the capacity of state policy to prepare for such changes.

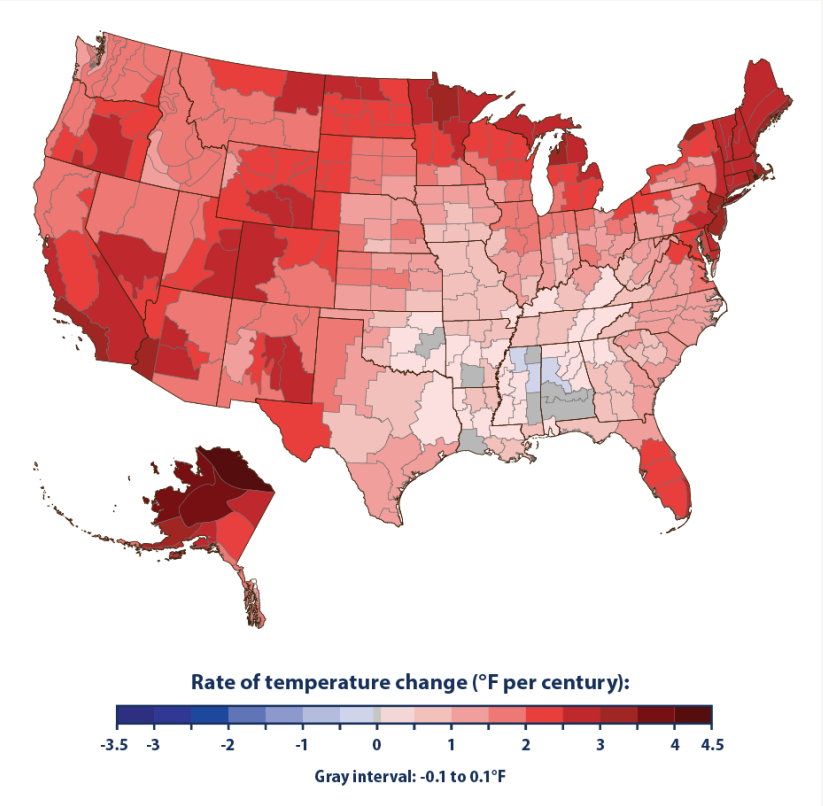
Figure 4: Average Annual Global Temperature Anomaly, 1850-2022



Source: Berkeley Earth, https://berkeleyearth.org/global-temperature-report-for-2022/.

[a] There are also negative feedback loops that increase the amount of carbon sequestration in a warmer planet, but probably not enough to counteract positive feedback. Earth's climate is an extremely complex system. Long-term modelling is difficult and all hypotheses are subject to continual review.

Figure 5: Rate of Temperature Change in the United States, 1901 to 2021



Source: US EPA, https://www.epa.gov/climate-indicators/climate-change-indicators-us-and-global-temperature.

Climate Resilience and Climate Adaptation

In recent years, there has been a linguistic shift in some circles from talking about "climate change adaptation" to "climate resilience." These concepts are related but not synonymous. There are minor variations in how these terms are used in key literature, but generally:

A key feature of climate change is climate instability and uncertainty.

Resilience is a capacity of a system to withstand or recover from disruption. Climate resilience refers to situations where that disruption is related to rapid climate change or extreme weather events.[14]

Adaptation is an action or sequence of actions. Climate change adaptation refers to actions taken, or processes put in place, to better optimize a system for a changing climate.[15]

The choice of terms used can impact how executive agencies and courts interpret legislation, regulation, and policy, so it is important to be as precise as possible.[16] This paper emphasizes climate change adaptation as a framework to discuss climate policy.

A climate-resilient community will be able to withstand the effects of climate change, but a climate-adapted community will be able to thrive.

Adaptation may include building climate resilience. However, adaptation should emphasize designing a system to work within the context of a changing climate such that the risk of climate-related disruptions is minimized, thus reducing necessary reliance on climate resilience.

A climate-resilient community will be able to withstand the effects of climate change, but a climate-adapted community will be able to thrive. An emphasis on resilience may even promote maladaptation—scenarios where systemic risks from climate change are locked-in or amplified (e.g., sea walls that enable further exposure through intensification of developments in low-lying coastal areas).

Another reason to frame the discussion around adaptation rather than resilience is that sustainable communities should be resilient to many disruptions beyond those caused by climate change. Building resilient communities should center on capacity-building and empowerment of key institutions to respond quickly and competently to any emergent challenges, including those unrelated to climate and weather (e.g., epidemics, earthquakes, terrorist threats, economic strife, etc.). [17]

Climate resilience and adaptation are related to, but distinct from, climate change mitigation. Climate change mitigation refers to efforts to reduce or prevent emission of greenhouse gases. As a global phenomenon, climate change mitigation requires cooperative global efforts. On the other hand, climate adaptation and resilience policies provide substantial benefits at the state and local level.

Current Michigan Climate Policy

It is only within the past few years that Michigan has begun to recognize the impacts of a changing climate through an official state policy. Michigan explicitly does not have a statewide climate adaptation plan. The primary statewide effort focused on climate change is the MI Healthy Climate Plan, which states, "this Plan is … not a comprehensive plan to adapt and become resilient to the effects of climate change." The central feature of this plan is for Michigan to achieve "carbon neutrality" by 2050 (with an interim goal of 52 percent reduction by 2030).[18] In other words, Michigan's climate policy is primarily a climate change mitigation plan.

Michigan does not have an official climate adaptation policy.

The Plan's goal of carbon neutrality by 2050 reflects goals set by the Intergovernmental Panel on Climate Change (IPCC) to limit global warming to 1.5°C (2.7°F). It is believed that global warming in excess of 1.5°C "would cause unavoidable increases in multiple climate hazards and present multiple risks to ecosystems and humans."[19]

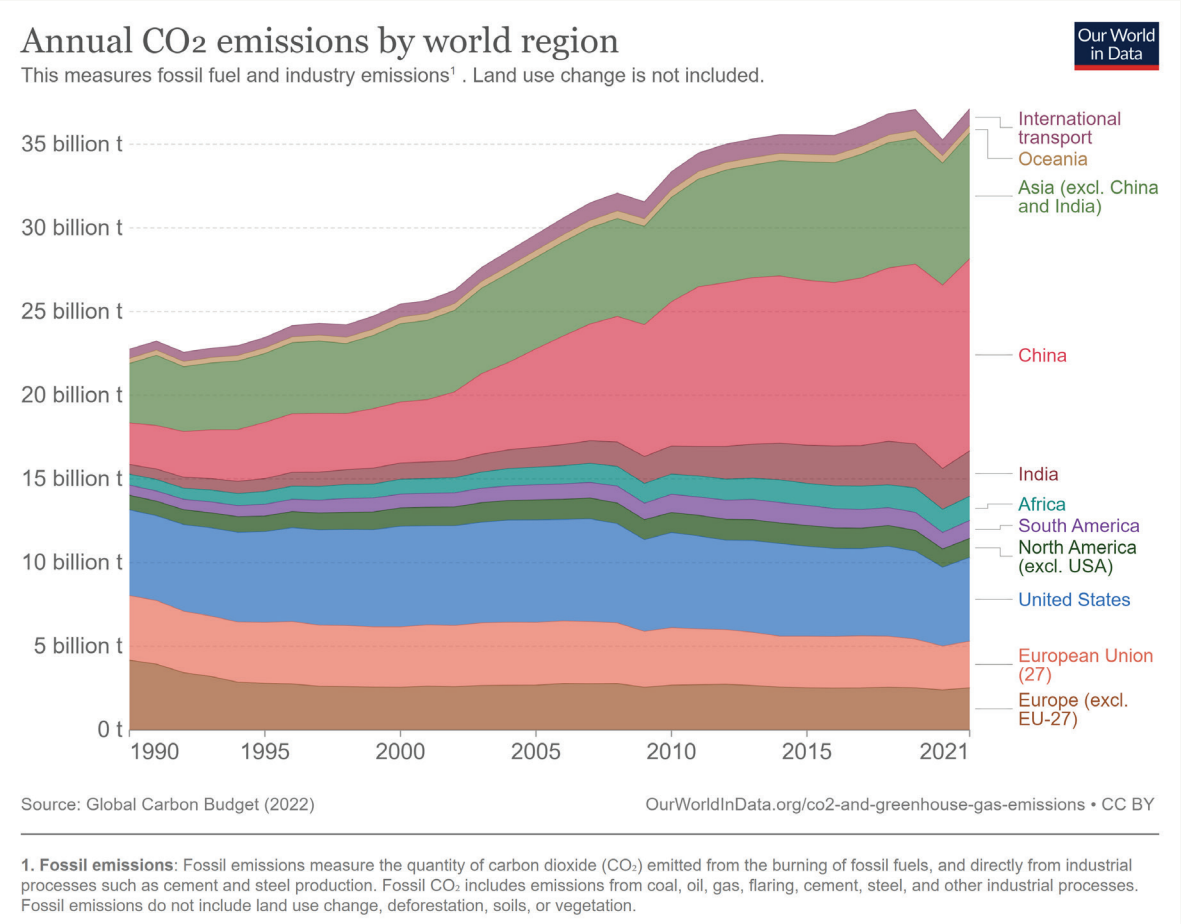
The MI Healthy Climate Plan envisions a future where "Michigan has mitigated the worst impacts of climate change."[20] However, GHGs impact the entire planet regardless of where they are emitted. While Michigan has already significantly reduced carbon emissions in recent decades,[b] global fossil carbon dioxide emissions are at record high levels and continue to increase.[21] Global carbon dioxide emissions are currently about 37 billion tons per year, and may increase for the foreseeable future as developing nations grow their economies (Figure 6). Michigan currently contributes about 135 million tons of carbon dioxide emissions,[22] less than half of a percent of the global total. It is simply not possible for state policy to meaningfully mitigate the climate change that Michigan experiences.

Even under the most ambitious emissions reduction scenario considered, IPCC estimates that "there is greater than 50 percent likelihood that global warming will reach or exceed the 1.5°C threshold before 2040.[23] Even when all current global climate mitigation policies are considered (which may not be fully implemented), Earth is on track to experience global warming of 2.1°C - 3.4°C (3.8°F – 6.1°F) by 2100.[24]

Michigan should do its part to reduce emissions and encourage others to do the same. But policy makers cannot assume that climate change will be mitigated. Without a coordinated statewide plan for climate resilience and adaptation, it is left to individual departments, organizations, policymakers, and individual citizens to develop plans outside of statewide coordination or guidance. Michigan public policies must prepare for the worst as we hope for the best.

[b] Michigan's 15 percent reduction on GHG emissions occurred almost entirely by substituting natural gas for coal in power generation. (Samantha Williams. "New Analysis: Michigan Must Supercharge Climate Action." Natural Resources Defense Council. October 3, 2022 https://www.nrdc.org/bio/samantha-williams/new-analysis-michigan-must-supercharge-climate-action.)

Figure 6: Rate of Disease Prevalence for Common Conditions, Michigan, Other Midwest States, and U.S. Average, 2020



Source: America's Health Rankings, available at https://www.americashealthrankings.org/explore/annual

How Michigan's Climate is Changing

Climate change in Michigan is not a future possibility. It is happening now and can be confirmed by observation, measurement, and statistics.

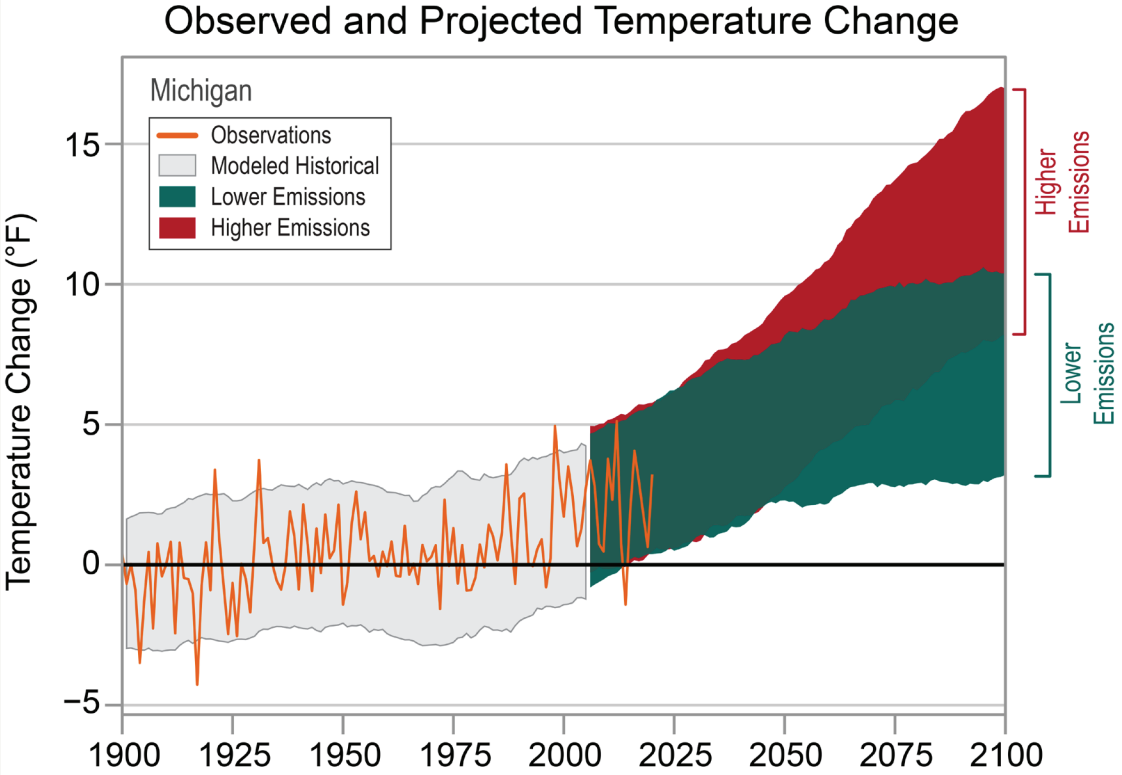
Temperature

While the average global temperature has increased by roughly 1.7°F (0.9°C) since 1900, this increase varies regionally. Average annual temperatures in Michigan have risen nearly 3°F (1.7°C) since 1900 (Figure 7).[25]

It is notable that the increase in average annual temperature is primarily a result of warmer winters. Since 1900, summer temperatures in Michigan have been relatively consistent, but winter and spring temperatures have increased. This is also true for Michigan's neighboring states.[26,c]

[c] A 2020 publication by the Michigan Department of Health and Human Services states that average summer temperatures in Michigan have increased by about 2.5°F since 1895 and the frequency of heat waves have increased in the Midwest. MDHHS cites NOAA data but appears to have performed a novel evaluation on it. As such, we are adopting the findings of the 2022 NOAA state climate summary for Michigan which states that Michigan's summers have remained relatively consistent. https://statesummaries.ncics.org/chapter/mi/

Figure 7: Observed and Projected Average Annual Temperature Changes in Michigan, 1900 to 2100



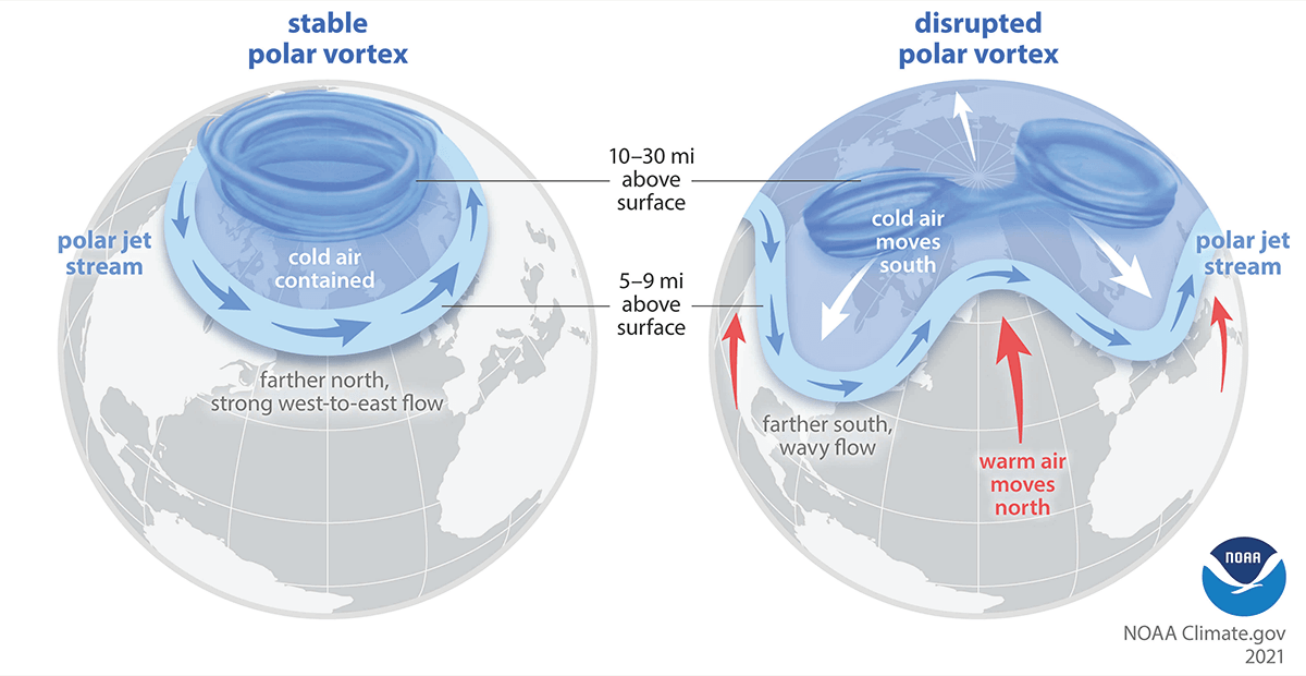
Source: R. Frankson, K.E. Kunkel, S.M. Champion, and J. Runkle. Michigan State Climate Summary 2022. NOAA Technical Report NESDIS 150-MI. NOAA/NESDIS, Silver Spring, MD. 2022, https://statesummaries.ncics.org/chapter/mi/.

While Michigan's summers have not become notably warmer under climate change thus far, this trend may not hold. Michigan should prepare for summers to eventually trend warmer, possibly with more frequent and more extreme heat waves. In 2021, the typically cool Pacific Northwest region suffered under a weeks-long "heat dome" that broke multiple records.[27] The summer of 2023 brought another record-breaking heat wave to the American Southwest, while vast areas of Canada experienced unusual heat and drought conditions that drove an unprecedented wildfire season.[28] Michigan has escaped such an extreme heat dome event thus far, but there is no reason to believe the state is immune.[d]

A key feature of climate change is climate instability and uncertainty. While Michigan winters are becoming warmer overall, climate change may increase the probability of short-term winter cold snaps. Ironically, the warming of the arctic region might result in cold arctic air intruding farther south than has been historically typical, due to weakening of the arctic jet stream ("the polar vortex").[29] Michigan and the United States generally have experienced some notable cold snaps in recent winters. Overall, it is unclear from existing data if this is an anomaly or likely to be a persistent feature of climate change (Figure 8).[30]

[d] While the Great Lakes moderate land surface temperature extremes near the coast, the impact is typically limited to a few degrees F and the moderating effect diminishes substantially more than a few miles away from the coast.

Figure 8: Climate Change May More Frequently Destabilize the Polar Vortex, Leading to Severe Winter Cold Snaps



Source: https://scijinks.gov/polar-vortex/

Precipitation

One of the most disconcerting features of climate change is the likelihood of increases in both floods and droughts in many regions, Michigan included.

Rising temperatures increase evaporation rates and lead to soil moisture loss. Thus, summer droughts, historically common in Michigan, are likely to be more intense in the future. Drought conditions could reduce crop growth and bring high wildfire potential to Michigan's forested areas.[e]

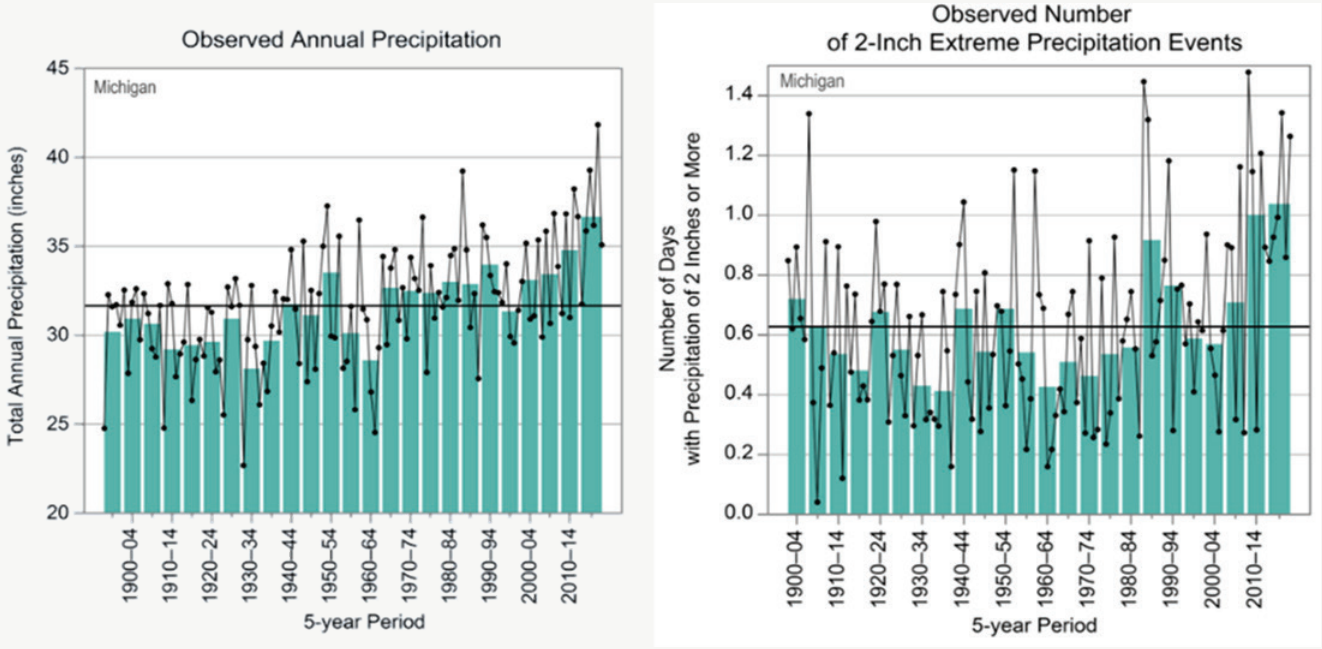
One of the most disconcerting features of climate change is the likelihood of increases in both floods and droughts.

On the other hand, warmer air has a higher capacity to hold water vapor, so precipitation events are likely to be more intense in the future. Data suggests this is already happening, with both annual precipitation and events with greater than two inches of precipitation increasing in recent decades (Figure 9).[31]

In the winter and spring of 2023, Michigan experienced significantly above-average precipitation.[32] Much of this precipitation was associated with destructive storms that brought ice and wet, heavy snow that led to widespread, long-lasting power outages, significant disruption, and economic losses.[33] Subsequently, Michigan's spring and early summer was extraordinarily dry, putting the state in drought condition and imposing hazardous wildfire risk.[34] Such weather reflects the variation in extreme weather events that are expected with advancing climate change.

[e] Additional factors such as tree blights and proliferation of invasive species that create thick deadwood thickets could further increase wildfire risk.

Figure 9: Michigan is Experiencing More Annual Precipitation and More Extreme Precipitation Events



Source: R. Frankson, K.E. Kunkel, S.M. Champion, and J. Runkle. Michigan State Climate Summary 2022. NOAA Technical Report NESDIS 150-MI. NOAA/NESDIS, Silver Spring, MD. 2022, https://statesummaries.ncics.org/chapter/mi/.

The Great Lakes

In June 2022, a Michigan Technology University (MTU) professor published research describing a novel model to predict water level changes in the Great Lakes.[35] The model predicts that under specific (relatively extreme) climate change scenarios, water levels in the Great Lakes may rise significantly—as much as 17 inches in the case of Lake Michigan-Huron.[f]

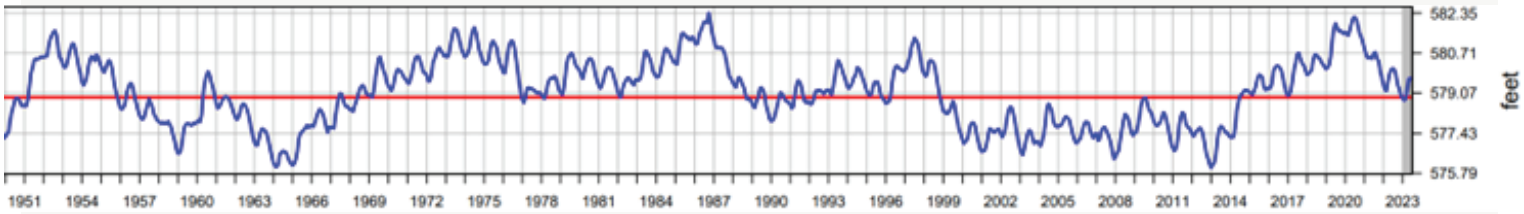
The water levels in the Great Lakes reached near-record highs in 2019 and 2020. This recent history, coupled with the MTU study, drove some fairly alarmist headlines implying that drastic water level rise in the Great Lakes is likely.[36] However, this is just one model.

Despite recent reporting that climate change will cause the water levels in the Great Lakes to rise, we don't know that. The lake levels are a result of multiple complex interactions and we don't yet know how long-term levels will trend.

While scientists are fairly certain that climate change will bring overall warmer temperatures and more precipitation to the Great Lakes basin, it is unclear how these factors will balance out and drive water level fluctuations in the Great Lakes. The recent near-record highs in Lake Michigan-Huron came only seven years after near-record lows, and returned to near the historical mean in 2022. As shown in Figure 10, there is no observed correlation between Great Lakes levels and continuing climate change.

[f]Though Lakes Michigan and Huron are traditionally considered two lakes, they are hydrologically connected and have the same water level, making them, technically, a single lake: Lake Michigan-Huron.

Figure 10: Historical water level in Lake Michigan/Huron , 1950 to 2023 (feet above sea level)



Source: US Army Corps of Engineers, https://lre-wm.usace.army.mil/ForecastData/GLBasinConditions/LTA-GLWL-Graph.pdf.

While it is unclear how climate change will impact long-term trends in Great Lakes water levels, it is clear that the temperature of the water is trending warmer. The U.S. National Oceanic and Atmospheric Administration (NOAA) has data on Great Lakes water temperature dating back to 1980, and the average water temperature has risen about 3°F in that time.[37] This increased water and air temperature tends to decrease the amount of ice cover in winter, though there is much annual variability.[38] The warmer water and decreased ice cover may lead to increases in lake-effect precipitation in much of the upper peninsula and the west coast of the lower peninsula in the autumn and winter months. It is also somewhat likely that this lake-effect precipitation will increasingly fall as rain rather than snow.[39] There remains substantial uncertainty in this data and related models.[40]

Preparing Michigan for Climate Change

Climate change will impact Michiganders in multiple ways, including public health, infrastructure (transportation, water, power), agriculture, and the environment. Public policies that mitigate and adapt to climate change reflect public policies that have broad socioeconomic benefits, independent of climate change. The main difference is that approaches must keep in mind that the weather in the future is likely to be increasingly extreme and unpredictable.

Health Policy

The Michigan Department of Health and Human Services has published a series of Climate and Health Adaptation Plans. The most recent Plan covers 2016 to 2021.[41] Health-related adaptations to climate change include the following:

- Develop responses for emergencies related to extreme weather that are protective of vulnerable populations, including heat-related illness and respiratory diseases.
- Ensure accessibility to health care services for people with chronic conditions during service disruptions.
- Address anxiety, depression or other mental health conditions, including those related to climate-induced stressors.
- Assess and respond to increased risk of waterborne and vector-borne diseases, especially Lyme disease and West Nile virus.
- Enact regulations to guide infrastructure changes that reduce ambient heat, such as reducing parking lot size, or adopting a tree canopy policy.
- Open and support cooling centers in vulnerable neighborhoods. Assure reliable transit to such centers.
- Increase air quality monitoring stations.
- Reduce traffic volume and vehicle emissions.
- Implement land use policies to limit sprawl and reduce the exposure of school and residential areas to traffic and industrial air pollutants.

Infrastructure Policy

The primary challenge on infrastructure imposed by climate change will be precipitation events of increasing volume and intensity. Destructive windstorms may also become more frequent. Infrastructure planning and design should account for these factors. Examples include:

- Electric power grid "hardening" and undergrounding of service lines to reduce disruptive storm-related power outages. Undergrounding of lines has the additional benefit of allowing urban tree canopies to more fully develop, reducing urban heat island effects.
- Underground broadband fiber lines to prevent loss of internet service related to storm events.
- Design storm sewers and stormwater management systems to accommodate severe precipitation events. Routinely maintain stormwater management infrastructure so that capacity is not diminished over time.
- Minimize impervious surfaces (i.e., pavement), particularly in urban areas.
- Utilize 'green infrastructure' (stormwater management features that include green plants and trees) to improve stormwater management and reduce heat island effects.
- Provide drinking fountains, public pools, splash pads, and interactive water fountains to provide cooling opportunities and recreational benefits.
- Routinely inspect critical dams, levees, and other flood control facilities and repair those in poor condition.

Agricultural Policy

The diversity of Michigan's agricultural industry is second only to California. In addition to the value of the produce and livestock produced, Michigan agriculture contributes to tourism and offers cultural amenities that may draw new residents. The changing climate will likely impact crop yields and pressure farmers to experiment with new varieties of crops and livestock. Public policies should support local food production, such as through research and pilot projects to develop agricultural approaches that are adapted to the changing climate.

Environmental Policy

Michigan's natural resources and environment could be a strength in attracting new residents to the state. However, as detailed in the Michigan's Path to a Prosperous Future: Environmental Challenges and Opportunities paper of this series, there are many challenges related to protecting and remediating Michigan's environment. Climate change amplifies these challenges. Protecting Michigan's natural resources with respect to climate change may include the following:

- Dedicate resources to understand, track, and respond to harmful pests, diseases, and blights that threaten native plants and animals with economic and ecosystem value.
- Dedicate resources to understand, track, and respond to invasive species that threaten to outcompete native species, reduce biodiversity, and impose other negative impacts on ecosystems.
- Implement land-use and forestry practices to reduce the likelihood of destructive wildfires during drought conditions.
- Remediate sites with soil contamination to prevent pollutants from washing into groundwater and surface waters.
- Support research and pilot programs dedicated to developing new strains of trees that are resistant to impacts of climate change, such as droughts and damaging blights.
- Manage shoreline areas to reduce erosion and contamination by nutrients, road salt, and other pollutants.

Public policies that help Michigan successfully adapt to climate change will promote the wellbeing of citizens and help support a sustainable state economy. If Michigan does this well, the state could become a future haven for 'climate migrants'—people who choose to move to regions that are less susceptible to the most extreme impacts of climate change. Successful public policies must be strategic and consider unintended consequences, otherwise, climate policies may lead to 'maladaptation' (discussed below).

Maladaptation

The latest report from the Intergovernmental Panel on Climate Change (IPCC) emphasizes the risk of governments investing in climate programs that result in maladaptation. Maladaptation is defined as, "actions that may lead to increased risk of adverse climate-related outcomes, including via increased greenhouse gas emissions, increased or shifted vulnerability to climate change, more inequitable outcomes, or diminished welfare, now or in the future."[42]

Maladaptation is typically an unintended consequence of actions to adapt to or mitigate climate change that do not fully consider systemic impacts.[43] Maladaptive responses to climate change can create lock-ins of vulnerability, exposure and risks that are difficult and expensive to change and exacerbate existing inequalities.[44,45]

Michigan's current climate policy risks maladaptation by emphasizing carbon reduction without addressing resilience and adaptation. Maladaptation can be avoided through proper systems analysis and long-term planning. A few specific areas where Michigan may be in danger of maladaptation include the following:

Maladaptation refers to unintended negative consequences of climate policy that do not consider systemic impacts and unintended consequences.

Seawalls and shoreline hardening: Building seawalls and placing boulders to harden shorelines may reduce localized impacts of shoreline erosion in the short-term, but can increase erosion in other areas due to wave energy being redirected to other parts of the shoreline. Such practices may also lock-in long-term risks by encouraging land uses that are vulnerable to extreme weather and climate change.[46]

Fire suppression of fire-adapted ecosystems: Wildfires were once part of a natural regulatory cycle of Michigan's ecosystems. The suppression of natural fires has disrupted species balance, allowing nuisance and invasive species to dominate, and reducing ecosystem resilience to climate change and ability to provide ecosystem services for climate change adaptation. This has also led to a build-up of combustible material in many of Michigan's forested areas, increasing the risk that if a wildfire does occur, it could be destructive.[47,48] Michigan does not necessarily need to reintroduce fire back into the ecosystem, but natural resource managers should be aware of the risks imposed by such ecosystem changes and take measures to mitigate the risk, such as strategic clearing and management of fire-prone invasive species.

Vehicle electrification without systemic reform: Transportation is a primary source of GHG emissions, and thus subsidizing a transition to lower-carbon electric vehicles is an obvious solution.[49] However, if unintended consequences are not considered, the transition to electric vehicles could lock-in unsustainable and vulnerable transportation system dynamics and land-use patterns.[50] As the vehicle fleet is electrified, society should also work to reduce reliance on personal vehicles.[g]

Renewable energy transition: As Michigan transitions away from coal and other fossil-fuel sources to generate electricity, it must take care to assure that changes do not come at the expense of grid reliability and increased costs to vulnerable rate payers.

[g] For example, through strategic land-use policy that is more amenable to transit and non-motorized transportation.

Summary and Discussion

Michigan's climate is changing. Overall, average temperatures are increasing. Additionally, precipitation is increasing and more often falls during powerful destructive storms.

Michigan is ahead of many U.S. states in that a critical mass of policymakers appear to recognize the disruptive potential of climate change. The MI Healthy Climate Plan demonstrates a willingness to participate in a global effort to drastically reduce carbon emissions. The MI Healthy Climate Plan describes an ambition to achieve statewide carbon neutrality by 2050. However, it does not describe a roadmap to achieve that, and it is unclear if such a goal is feasible.

Extreme weather events will exacerbate all existing challenges. Extreme precipitation events may further overwhelm stormwater infrastructure. Powerful storms may more frequently topple trees and create power outages. Vulnerable communities may be increasingly at risk from heat waves and cold snaps. Michigan's agricultural industry will face increasing uncertainty.

If Michigan acts strategically, climate change may make the state a more amenable option for people looking to relocate. There is anecdotal evidence of "climate migrants" seeking to escape extreme storms and heat waves of more southern locations,[h] but demographics do not yet show this. Some of the fastest growing cities in the U.S. would be essentially uninhabitable without ubiquitous air conditioning.[i] Meanwhile, Michigan's population growth lags most similar cold-weather states. Economic development strategists in Michigan need to stop blaming our climate for stagnant population growth, but should not expect it to become our savior.

A core weakness in Michigan's climate policy is that there is not a comprehensive statewide framework for climate adaptation. Mitigating the impacts of climate change insofar as weather trends such as temperature and precipitation is outside the capacity of state policy. Michigan's primary climate policy document—the MI Healthy Climate Plan—does not reflect such an understanding.

Public policy should recognize that Michigan cannot impact the weather or climate that the state experiences. However, we can build community resilience to challenges related to climate change and otherwise. Moreover, policy should emphasize climate adaptation strategies, investing in infrastructure and institutions that work with our changing climate.

h Kelly House. "Can climate migrants offset Michigan's population woes? Maybe, experts say." Great Lakes Now. June 13, 2023.
i Census.gov. Fastest-Growing Cities Are Still in the West and South. May 26, 2022.

Endnotes

[1] UC San Diego, Scripps Institute of Oceanography. "The Keeling Curve." https://keelingcurve.ucsd.edu/

[2] Ben Clarke et al. Extreme weather impacts of climate change: an attribution perspective. Environ. Res.: Climate 1 012001. 2022. https://iopscience.iop.org/article/10.1088/2752-5295/ac6e7d

[3] U.S. Environmental Protection Agency. Climate Change Indicators: U.S. and Global Temperature. 2022. https://www.epa.gov/climate-indicators/climate-change-indicators-us-and-global-temperature

[4] Will Steffen et al. "Trajectories of the Earth System in the Anthropocene." Proceedings of the National Academy of Sciences 115.33. 2018. pp. 8252-8259. https://www.pnas.org/doi/pdf/10.1073/pnas.1810141115

[5] Kirsten Zickfeld and Tyler Herrington. "The time lag between a carbon dioxide emission and maximum warming increases with the size of the emission." 2015 Environ. Res. Lett. 10 031001. March 2015. https://iopscience.iop.org/article/10.1088/1748-9326/10/3/031001

[6] Zeke Hausfather. Explainer: Will global warming 'stop' as soon as net-zero emissions are reached? Carbon Brief. April 29, 2021. https://www.carbonbrief.org/explainer-will-global-warming-stop-as-soon-as-net-zero-emissions-are-reached/

[7] Rahul Tongia. "Flatten-the-curve: Why total carbon emissions matter much more than 'date of zero.'" (CSEP Working Paper 14). New Delhi: Centre for Social and Economic Progress. 2021. https://csep.org/wp-content/uploads/2021/09/Flatten-the-curve_F.pdf

[8] IEA (2022), Direct Air Capture, IEA, Paris https://www.iea.org/reports/direct-air-capture

[9] IPCC AR6 Synthesis Report, p. 33-50. https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_LongerReport.pdf

[10] Nico Wunderling, Donges, J., Kurths, J., & Winkelmann, R. "Interacting tipping elements increase risk of climate domino effects under global warming." Earth System Dynamics Discussions, 12. 2021. pp. 601–619. https://esd.copernicus.org/preprints/esd-2020-18/esd-2020-18.pdf

[11] NOAA Global Monitoring Laboratory. https://gml.noaa.gov/ccgg/trends/

[12] UN Emissions Gap Report 2021. https://www.unep.org/resources/emissions-gap-report-2021

[13] World Meteorological Organization. Global temperatures set to reach new records in next five years. May 17, 2023. https://public.wmo.int/en/media/press-release/global-temperatures-set-reach-new-records-next-five-years

[14] U.S. Climate Resilience Toolkit. https://toolkit.climate.gov/

[15] Congressional Research Service. Climate Change: Defining Adaption and Resilience, with Implications for Policy. May 11, 2021. https://sgp.fas.org/crs/misc/IF11827.pdf

[16] Ibid.

[17] Meagan Muir et al. Detroit Resilience Hub Framework. 2021. See especially pp. 16-18. https://deepblue.lib.umich.edu/bitstream/handle/2027.42/172183/EcoWorks%20Detroit%20Resilience%20Hub_399.pdf?sequence=1&isAllowed=y

[18] Michigan Department of Environment, Great Lakes, and Environment (EGLE). MI Healthy Climate Plan. 2022. p. 6. https://www.michigan.gov/egle/about/organization/climate-and-energy/mi-healthy-climate-plan

[19] Intergovernmental Panel on Climate Change (IPCC). Sixth Assessment Report (AR6), Summary for Policymakers. p. 13. https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf

[20] Michigan Department of Environment, Great Lakes, and Environment (EGLE). MI Healthy Climate Plan. 2022. p. 26. https://www.michigan.gov/egle/about/organization/climate-and-energy/mi-healthy-climate-plan

[21] Friedlingstein et al. Global Carbon Budget 2022. Earth Syst. Sci. Data, 14, 4811–4900, 2022. https://essd.copernicus.org/articles/14/4811/2022/essd-14-4811-2022.pdf

[22] St. Louis Fed. Economic Data: Total Carbon Dioxide Emissions from All Sectors, All Fuels for Michigan. https://fred.stlouisfed.org/series/EMISSCO2TOTVTTTOMIA

[23] Intergovernmental Panel on Climate Change (IPCC). Sixth Assessment Report (AR6), Summary for Policymakers. p. 8. https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf

[24] IPCC AR6 Synthesis Report, p.24-25. https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_LongerReport.pdf

[25] R. Frankson, K.E. Kunkel, S.M. Champion, and J. Runkle. Michigan State Climate Summary 2022. NOAA Technical Report NESDIS 150-MI. NOAA/NESDIS, Silver Spring, MD. 2022. https://statesummaries.ncics.org/chapter/mi/

[26] Ibid.

[27] Jeff Berardelli. "Pacific Northwest bakes under once-in-a-millennium heat dome." CBS News. June 29, 2021. https://www.cbsnews.com/news/heat-wave-dome-2021-seattle-portland-weather/

[28] Matthew Cappucci, Tamia Fowlkes and Shera Avi-Yonah. "Relentless heat wave reaching maximum strength: Weather updates." The Washington Post. July 16, 2023. https://www.washingtonpost.com/weather/2023/07/16/extreme-heat-waves-temperatures-outlook-updates/

[29] Rebecca Lindsey. Understanding the Arctic polar vortex. NOAA. March 5, 2021. https://www.climate.gov/news-features/understanding-climate/understanding-arctic-polar-vortex

[30] Paul Voosen. "Landmark study casts doubt on controversial theory linking melting arctic to severe winter weather." Science. May 12, 2021. https://www.science.org/content/article/landmark-study-casts-doubt-controversial-theory-linking-melting-arctic-severe-winter

[31] R. Frankson, K.E. Kunkel, S.M. Champion, and J. Runkle. Michigan State Climate Summary 2022. NOAA Technical Report NESDIS 150-MI. NOAA/NESDIS, Silver Spring, MD. 2022. https://statesummaries.ncics.org/chapter/mi/

[32] Mark Torregrossa. "Michigan certainly isn't lacking precipitation so far this year; Some over 20 inches already." MLive. May 4, 2023. https://www.mlive.com/weather/2023/05/michigan-certainly-isnt-lacking-precipitation-so-far-this-year-some-over-20-inches-already.html

[33] Eric Paul Dennis. "Undergrounding Electrical Lines is an Option to Prevent Power Outages, but State Policy is Needed to Better Enable the Practice.' Citizens Research Council of Michigan. March 29, 2023. https://crcmich.org/dennis_digonce_underground_prevent_power_outages

[34] Sara Powers. "Michigan DNR warns of extreme fire danger, red flag warning issued for northern lower peninsula." CBS Detroit. June 6, 2023. https://www.cbsnews.com/detroit/news/michigan-dnr-warns-of-extreme-fire-danger-throughout-state/

[35] Xue, P., Ye, X., Pal, J. S., Chu, P. Y., Kayastha, M. B., and Huang, C.: Climate projections over the Great Lakes Region: using two-way coupling of a regional climate model with a 3-D lake model, Geosci. Model Dev., 15, 4425–4446, 2022. https://gmd.copernicus.org/articles/15/4425/2022/gmd-15-4425-2022.html

[36] Natasha Blakely. "Great Lakes water levels could increase on average from 7.5 to 17 inches in next few decades, study says." Bridge Michigan. June 27, 2022. https://www.bridgemi.com/michigan-environment-watch/great-lakes-water-levels-could-increase-average-75-17-inches-next-few

[37] Carol Thompson. "Great Lakes' record warmth likely to fuel lake effect snow, may disrupt fish." PHYS.org. November 8, 2021. https://phys.org/news/2021-11-great-lakes-warmth-fuel-lake.html

[38] U.S. EPA. Climate Change Indicators: Great Lakes Ice Cover. April 2021. https://www.epa.gov/climate-indicators/climate-change-indicators-great-lakes-ice-cover

[39] Alex Hill. "Mapping the Great Lakes: Snowfall in the snowbelt." Great Lakes Now. January 23, 2023. https://www.greatlakesnow.org/2023/01/mapping-great-lakes-snowfall-snowbelt/

[40] GLISA – NOAA Climate Adaptive Partnerships. Snow in the Great Lakes: Past, Present, and Future https://glisa.umich.edu/resources-tools/climate-impacts/snow-in-the-great-lakes-past-present-and-the-future/

[41] Cameron Lorraine and Aaron Ferguson. Michigan Climate and Health Adaptation Program (MICHAP), Strategic Plan Update: 2016-2021. August 31, 2016. https://www.michigan.gov/mdhhs/-/media/Project/Websites/mdhhs/Folder2/Folder16/Folder1/Folder116/MDCH_climate_change_strategicPlan_final_1-24-2011_.pdf?rev=d80f9db32c9649538a4f43668a9cecd7&hash=E476A3AF3F5447BA644817DC6666455D

[42] IPCC AR6 Technical Summary. p. 7. https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_TechnicalSummary.pdf

[43] Lisa F.Schipper. Maladaptation: When Adaptation to Climate Change Goes Very Wrong. One Earth. 2020. https://www.sciencedirect.com/science/article/pii/S2590332220304838#fig1

[44] IPCC AR6 Technical Summary. P.27. https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_TechnicalSummary.pdf

[45] IPCC AR6 Synthesis Report, p.28. https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_LongerReport.pdf

[46] Kelly House. "Michigan's coast is being armored with seawalls, making erosion worse." Bridge. July 17, 2020. https://www.bridgemi.com/michigan-environment-watch/michigans-coast-being-armored-seawalls-making-erosion-worse

[47] Michigan THIRA Hazard Analysis (draft) 2012. https://www.michigan.gov/-/media/Project/Websites/msp/EMHSD/documents/THIRA_State_of_Michigan_Draft_First_Steps.pdf?rev=2936fb5ddfc74b52a19cea687615d560

[48] Holly Fretwell and Jonathan Wood. Fix America's Forests. PERC. April 2021. https://www.perc.org/wp-content/uploads/2021/04/fix-americas-forests-restore-national-forests-tackle-wildfire-crisis.pdf

[49] Susan Rusinowski. "MI Healthy Climate Plan Lacks Equitable and Accountable Strategies for Transportation Decarbonization." Citizens Research Council of Michigan. August 17, 2022. https://crcmich.org/rusinowski_climate-transportation-equity

[50] Coner Bronsdon. "Electric Cars Won't Solve Climate Change." Planetizen. March 9, 2021. https://www.planetizen.com/blogs/112490-electric-cars-wont-solve-climate-change