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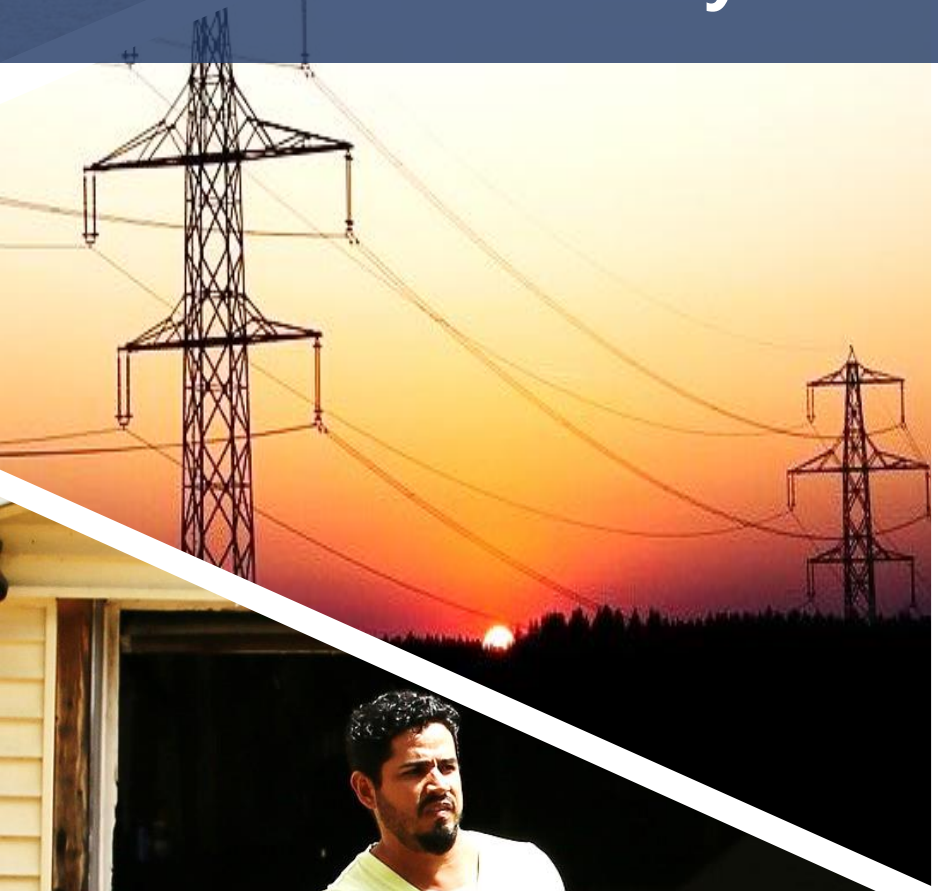
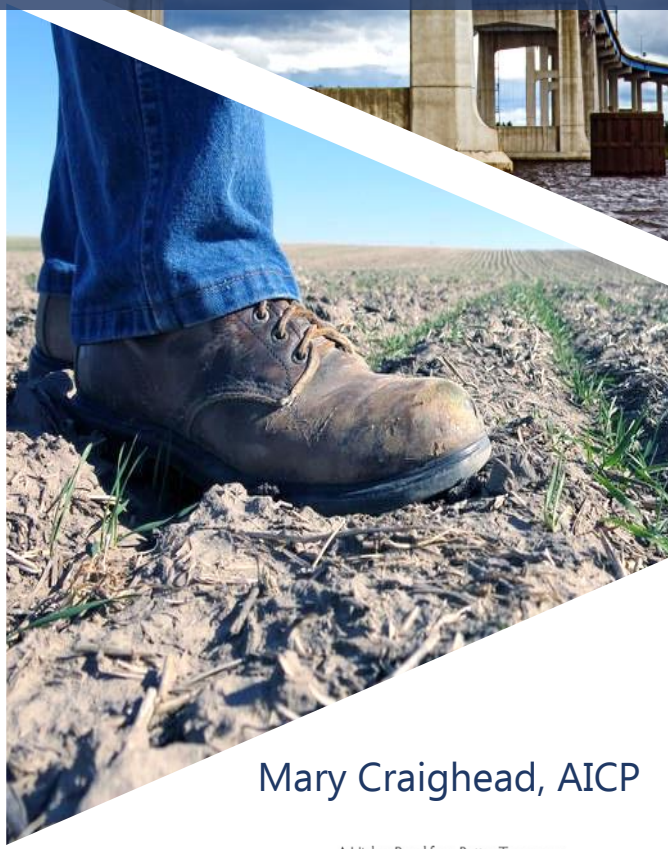
Climate Change and Its Impact on Infrastructure Systems in the Midwest





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A Higher Road for a Better Tomorrow

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EXECUTIVE SUMMARY

The lifeblood of a community is its infrastructure system. In light of Hurricanes Harvey, Irma, and Maria – which are only the most recent examples of extreme weather events to affect the nation – the Midwest Economic Policy Institute (MEPI) has examined the anticipated impact climate change will have on the Midwest.

Climate change is observable in the Midwest.

- The Midwest is home to over 61 million people and an expansive transportation network that supports $2.6 trillion in regional gross domestic product.
- The average air temperature in the Midwest increased by 4.5 degrees from 1980 to 2010.
- The percent of days with "very heavy precipitation" has increased by 27 percent in the Midwest since the late 1950s.
- The Great Lakes have experienced less ice coverage, leaving lakeshores susceptible to flooding and erosion.

Climate change-caused damage to transportation systems could result in economic losses.

- Extreme weather conditions will negatively impact the physical conditions of existing infrastructure and increase maintenance costs.
- Increased heat will reduce the life of asphalt, add stress to expansion joints for bridges and highways, cause pavements and railways to buckle, and affect aircraft performance.
- Flooding will weaken structural supports for bridges, deteriorate soil that supports infrastructure, shorten the lifespan of pavement, and increase sedimentation in waterways.
- Damage to significant freight routes or hubs, such as those in Chicago and across the Midwest, would require trade flows to shift, imposing significant economic costs.

The production and distribution of energy can be significantly impacted by climate change.

- The Midwest is a net distributor of electricity to other regions.
- Flooding, high winds, ice, snow, and storms can damage facilities and above-ground transmission lines across the Midwest.
- The Midwest is particularly susceptible to electricity outages, with four states ranking among the top 10 states that experienced the most outages between 2003 and 2012.
- Rising temperatures caused by climate change have led to increased demand for cooling and will require $6 billion in future investments to keep up with the region's needs.

Midwestern states must plan and design infrastructure to address climate change.

- Minnesota and Michigan lead the Midwest in adequately preparing their systems for the effects of climate change, evident by their adoption of Climate Action and Adaptation Plans.
- The state Departments of Transportation in Illinois, Michigan, Ohio, and Minnesota have all pursued asset management programs to address climate change and assess vulnerabilities.
- In transportation projects, climate change can and should be accounted for through the rainfall and heat standards used in the design process.
- New public infrastructure and private developments should be limited or prohibited in unsafe areas that have already experienced weather-related damage.

No one policy or action alone will halt the harmful effects of climate change. While some Midwestern states have taken actions to address negative impacts on infrastructure systems, more needs to be done. As infrastructure investments continue to be debated, climate change and its impact on these systems must also be considered.

INTRODUCTION

The lifeblood of a community is its infrastructure system. Ensuring that it successfully and efficiently operates is vital for all residents and businesses, and this is especially true during hazardous weather events. As expressed by Puentes, "Infrastructure enables trade, powers businesses, connects workers to their jobs, creates opportunities for struggling communities and protects the nation from an increasingly unpredictable natural environment" (2015).

As the nation and the world see an increase in the number and severity of extreme weather events attributable to climate change, national, state, and local governments must continue to invest in infrastructure and appropriately plan for and mitigate against future extreme weather patterns (Huber and Gulledge, 2011; EPA, 2015). In light of Hurricanes Harvey, Irma, and Maria – which are only the most recent examples of extreme events that have occurred worldwide – this report examines the impact that climate change is anticipated to have on the Midwest, specifically considering two of the most important infrastructure systems: transportation and electricity. Ultimately, adequate investments are vital to ensure that the region's infrastructure system will continue to successfully operate and adapt to both the needs of its residents and businesses, while accommodating future weather patterns.

CLIMATE CHANGE IN THE MIDWEST

The Midwest – defined in this report as Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin – is home to over 61 million people, seven of the nation's most populous cities, and an expansive transportation network that serves as the freight hub of North America (U.S. Census Bureau, 2015). Its landscapes vary from the Great Lakes and forests to extensive agricultural lands. All these features contribute to a regional gross domestic product that totals over $2.6 trillion (Pryor et al., 2014).

Figure1: Climate Change Indicators for the Midwest

Historical Air Temperature	Increase
1900 - 2010	1.5 degrees
1950 - 2010	3.0 degrees
1980 - 2010	4.5 degrees
Future Air Temperature*	**Increase**
Mid Century (2046-2065) relative to 1979-2000	4.9 degrees
End Century (2081-2100) relative to 1979-2000	8.5 degrees
Future Precipitation*	**Increase**
Spring - Mid Century (2041-2062) relative to 1979-2000	9%
Summer - Mid Century (2041-2062) relative to 1979-2000	-8%

*assuming continued global emissions growth

Source: Pryor et al., 2014

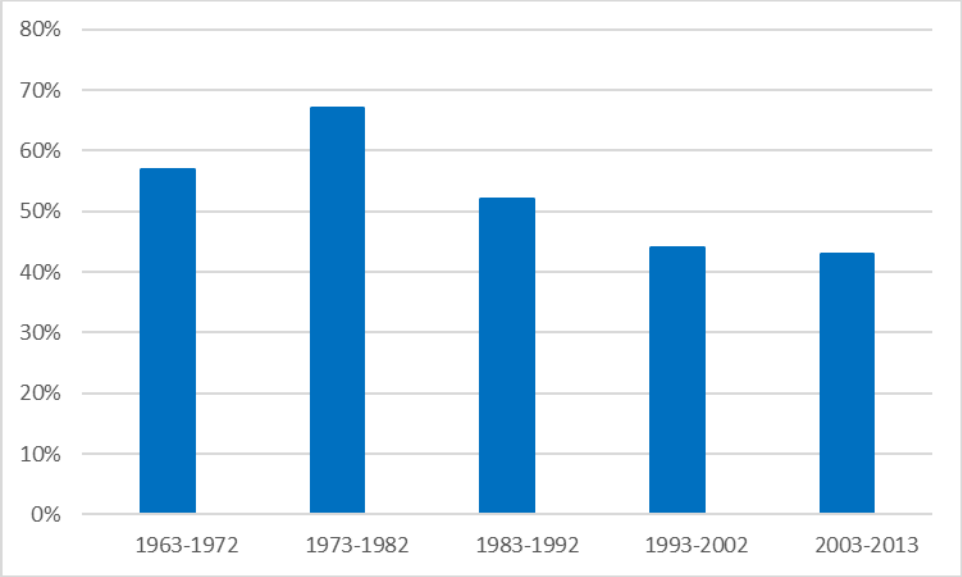
Climate change throughout the Midwest is observable in air temperatures and precipitation levels, not to mention the number of extreme weather events experienced. Figure 1 summarizes both historical and anticipated future air temperatures and future precipitation for the Midwest region. The average air temperature has noticeably increased in recent decades, with the increase between 1980 and 2010 being three times that of the average between 1900 to 2010; this indicates that temperatures have risen most sharply in recent decades due to human activity. Furthermore, if the

world continues to increase the amount of emissions emitted, the average air temperature throughout the Midwest will increase by almost 5 degrees by mid-century and 8.5 degrees by the end of the century.

Precipitation patterns are also expected to be altered, with spring precipitation increasing by 9 percent by the middle of the current century and summer precipitation decreasing by 8 percent in the same timeframe (Figure 1). The frequency and intensity of rainfalls is also anticipated to change; the percent of days with rainfalls classified as "very heavy precipitation" has already increased by 27 percent in the Midwest between 1958 and 2007 (Huber and Gulledge, 2011).

Climate change is also evident in the Great Lakes, as illustrated in Figure 2. Since 1993, the lakes have cumulatively experienced less ice coverage due to warmer temperatures. While this allows for slightly longer shipping seasons – with the season increasing by an average of 8 days between 1994 and 2011 – it also leaves the lakeshores susceptible to erosion and flooding.

Figure 2: Annual Maximum Ice Coverage in the Great Lakes



Source: Walsh et al., 2014

Evidence clearly shows that the climate is changing both in the Midwest and worldwide (Gaffney and Steffen, 2017); while this section briefly summarizes major factors already impacting the region, the influence will be far reaching, encompassing many other elements, such as wildlife, vegetation, and water and air quality. Above these troubling environmental impacts, extreme weather events also have the ability to threaten both the Midwest's residents and its economy through flooding, heat stress, drought, and varying freeze patterns (Pryor et al., 2014). Adopting adaptation and mitigation strategies to lessen future impacts is of the utmost importance, with transportation and energy infrastructure being some of the most crucial aspects.

CLIMATE CHANGE AND INFRASTRUCTURE

There are few things more important than a region's infrastructure system for residents and businesses to function and thrive. A dependable transportation system is crucial to ensure the efficient movement of food, energy, and trade, and allows workers and consumers to access jobs and markets. Additionally, energy production and distribution facilities must function reliably to ensure

electricity is adequately provided for the region. However, the physical damage to these infrastructure systems and disruption of the services as a result of climate change and increased extreme weather events has the ability to cripple the region and cause significant economic and personal losses (Schwartz et al., 2014).

Transportation

As average temperatures increase and major flooding events become more common, transportation infrastructure – including roads, bridges, public transit systems, railroads, airports, ports, and waterways – will be adversely impacted throughout the Midwest.

Most basically, extreme weather conditions will negatively impact the physical conditions of existing infrastructure that can take months and years to repair and will increase overall maintenance costs. Increased heat will reduce the life of asphalt, add stress to expansion joints for bridges and highways, cause pavements and railways to buckle, and affect aircraft performance (Schwartz et al., 2014). Flooding will weaken structural supports for bridges, promote deterioration of soil that supports roadways, tunnels, and bridges, shorten the life expectancy of pavement, and increase sedimentation in waterway channels (EPA, 2017). Lastly, more frequent freeze-thaw cycles common to the Midwest will add stress to pavements (Cambridge Systematics, Inc. and MDOT, n.d.).

In addition to these physical damages, the impact will be amplified as the consequences of these damages disrupt the transportation network and its ability to transport needed goods and people. Both initially during a weather event and after as damages are being assessed and repaired, transportation systems can become entirely unusable due to flooding, debris, or damage. Flooding can lead to homes and businesses being cut off from needed supplies and also contribute to inland waterways being unsafe. Conversely, droughts will also disrupt waterway travel, particularly impactful for freight movements on barges, if water levels are too low and vessels cannot pass (Schwartz et al., 2014).

As true with any network, disabling any one crucial link will result in a ripple effect throughout the entire system; this is truest of freight movements. Damage to significant freight routes or hubs, such as those in Chicago and across the Midwest, will cause delays and disruptions nationwide as trucks, trains, ships, and barges will no longer be able to use the most efficient route. Trade flows would be required to shift and economic costs would be significant (Schwartz et al., 2014).

Electricity

Similar to the transportation network, the production and distribution of energy can be significantly impacted by climate change and extreme weather events. As an example of one of the most vital energy systems in the country, the electricity network consists of power plants that generate power, transmission lines that carry the power, and finally substations that distribute the power to communities. All of these facilities are susceptible to damage as a result of climate change-influenced weather events (Kenward and Urooj, 2014). Energy infrastructure also includes the transportation facilities – like railroads, highways, and waterways – used to transport coal, crude oil, or other energy related commodities (Dell et al., 2014).

Flooding has the potential to impact power generating facilities and high winds, ice, snow, and electrical storms can damage transmission lines. These risks are particularly evident in the Midwest, where the majority of electricity transmission and distribution is above ground (Kenward and Urooj, 2014). As illustrated in Figure 3, the Midwest is particularly susceptible to electricity outages due to weather events, with four of the eight Midwest states ranking among the top 10 states that experienced the most outages between 2003 and 2012. Those four states comprise 67 percent of the

region's population and experienced 203 total outages. The outage rates speak to both the increase in the number of extreme weather events and the need for infrastructure protection against these events.

Figure 3: Rank of Weather Related Electricity Outages by State

State	Outages	Rank	Population	% of Midwest
Michigan	71	1	9,900,571	16%
Ohio	54	3	11,575,977	19%
Illinois	39	9	12,873,761	21%
Indiana	39	9	6,568,645	11%
Missouri	12	28	6,045,448	10%
Minnesota	10	30	5,419,171	9%
Wisconsin	6	33	5,742,117	9%
Iowa	5	34	3,093,526	5%

Source: Kenward and Urooj, 2014

Furthermore, energy production and its sources – such as coal, oil, and natural gas– are not isolated by region; a significant proportion of national energy facilities are located along the Gulf of Mexico and its vulnerability to hurricanes can impact energy production nationwide (Dell et al., 2014). Similarly, due to the nature of energy production and its transmission to various areas, infrastructure damages pose significant risks to widespread regions, as exemplified by the Midwest serving as a net distributor of electricity to other regions (Pryor et al., 2014).

Beyond production and distribution, climate change will impact overall energy use. Increased temperatures have already led to increased demand for cooling for households and businesses. The demand for heating in the Midwest has typically been five to seven times that of cooling, however longer summers and higher temperatures are expected to alter this ratio (Pryor et al., 2014). As a result, the electrical grid will face additional stress, as cooling is performed almost exclusively through electricity, whereas heating is divided between electricity, natural gas, heating oil, and other sources (Dell et al., 2014). The increased demand will require significant infrastructure investments to keep up with the region's needs; by the middle of the century, demand in the Midwest is expected to be equivalent to five large power generating plants and require over $6 billion in total investments (Pryor et al., 2014).

ADAPTATION AND MITIGATION

Existing infrastructure was constructed to handle weather events that were considered typical based on historical data. As local, state, and federal governments are facing a changing climate and an increase in the frequency and severity of extreme weather events, infrastructure needs to be planned and designed to appropriately address these changes. Without adapting to these changes and mitigating against future impacts, communities will continue to suffer both physical and economic damages (Bierbaum et al., 2014).

A large portion of national infrastructure is publicly owned, so local, state, and federal policies will have the greatest ability to both curb the emissions contributing to climate change and require new standards to help communities adapt to changing weather patterns. The federal government took a number of steps under the Obama Administration to address these challenges, including the Clean Power Plan, participation in the worldwide Paris Agreement, setting energy-efficiency standards for appliances and buildings, and establishing a Task Force on Climate Preparedness and Resilience

(Obama White House, 2017). While these measures have not been upheld in the Trump Administration, most recently exemplified by the rescindment of Obama Administration requirements for the federal government to account for climate change and sea-level change when constructing infrastructure, state and local governments have implemented their own climate change measures and should continue to do so (Friedman, 2017).

Figure 4 summarizes the statewide climate change policies by state for the Midwest, where Minnesota and Michigan lead the region in adequately preparing their infrastructure systems for the effects of climate change. Greenhouse Gas (GHG) Emission Targets refer to policies that stipulate specific emissions values states aim to achieve by a particular year; they show a state's commitment to curbing the largest contributing factor of climate change. Similarly, a Climate Action Plan identifies policies and actions – including GHG emission reductions – that can be taken to lessen the state's contribution to climate change. On the other hand, an Adaptation Plan outlines a state's vulnerabilities towards climate change and creates a plan and implementation process to address those weaknesses (C2ES, 2016).

Figure 4: State Climate Policies in the Midwest

	Illinois	Indiana	Iowa	Michigan	Minnesota	Missouri	Ohio	Wisconsin
Greenhouse Gas Emissions Targets	X			X	X			
Climate Action Plans	X		X	X	X	X		X
Adaptation Plans (completed or in progress)			X	X	X			X

C2ES, 2016; Georgetown Climate Center, 2017

While six of eight Midwestern states have adopted Climate Action Plans, only four have pursued adaptation plans and three have greenhouse gas emissions targets. Adaptation plans in particular are crucial to ensuring that future infrastructure can handle extreme weather events. As previously described, heavy precipitation and high temperatures can adversely impact both transportation and energy systems. Specifically considering transportation projects, as new developments are planned and constructed, climate change can be accounted for through the rainfall and heat standards used in the design process (FHWA, 2013). While very few state Departments of Transportation across the nation have explicitly required stricter design standards – either due to the belief in uncertainty of climate models or increased project costs – select standards have been updated in Canada (FHWA, 2013; Neumann, 2009). Ultimately, updated design standards will be complicated and require coordination between various levels of government and non-government organizations that set standards. However, governments can begin to consider the impacts and whether changes are appropriate in particular situations (FHWA, 2013).

An asset management system is a prime example of an alternate policy that accounts for climate change. An asset management system inventories existing infrastructure and potential hazards, evaluates its vulnerability, and ultimately offers potential alternatives (IDOT, EWGCOG, CMAP, 2014). It allows for the consideration of different investment and maintenance scenarios and the evaluation of life-cycle costs, leading to the appropriate prioritization and most cost-effective projects. In the Midwest, the state Departments of Transportation in Illinois, Michigan, Ohio, and Minnesota have all pursued asset management programs as a means to address climate change (IDOT, EWGCOG, CMAP, 2014; Cambridge Systematics, Inc. and MDOT, n.d.; ODOT, 2017; MnDOT, 2017).

Lastly, the most basic form of climate change adaptation is refraining from building assets in areas that have already experienced weather-related damage and are deemed unsafe. This strategy is most applicable to coastal areas and those in floodplains. Not only should public infrastructure be limited or even prohibited from being constructed in these areas, but land use regulations that forbid private development in these areas should also be considered (Neumann, 2009). While this strategy may not be applicable to the majority of the Midwest, the region's proximity to the Great Lakes – particularly Michigan with over 3,000 miles of shoreline – should be especially considered (Cambridge Systematics and MnDOT, n.d.).

CONCLUSION

Climate change has already caused, and will continue to cause for many years to come, unimaginable impacts on the nation's population, environments, and economy. No one policy or action alone will halt the harmful effects and – while the local, state, and federal governments have made great strides in recent decades – there is much more that can and should be done. In particular, action must be taken to mitigate against future impacts to transportation and electricity systems, as they serve as two of the most important infrastructure systems to both the nation's residents and economy.

The Midwest is expected to feel the effects of climate change in the form of higher temperatures, prolonged summers, increased heavy rain events, and more frequent freeze-thaw cycles. This will lead to damage, deterioration, and added stress to existing transportation and electricity facilities. Interruptions of services during extreme weather events will also contribute to widespread impacts to freight movements and electricity production, both of which will adversely impact the economy. While some Midwestern states have taken actions to address these issues, in the form of statewide adaptation plans, more needs to be done to protect these vital systems.

As it currently stands, infrastructure is grossly underfunded to meet the maintenance and growth needs of the nation. Without accounting for needed climate change adaptations, the funding gap between needs and estimated revenues between 2016 and 2025 for the nation already stands at over $2 trillion for national infrastructure systems (all transportation, water, energy, park, and school facilities) (ASCE, 2017). Ultimately, as infrastructure investments continue to be debated, climate change and its impact on these systems must also be considered.

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