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Climate Change and Its Impact on Infrastructure Systems in Indiana

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A Higher Road for a Better Tomorrow
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EXECUTIVE SUMMARY

There are few things more important to a thriving state than its infrastructure systems. This report by the Midwest Economic Policy Institute examines Indiana's transportation and electricity systems and the impact climate change will have on them in the future. Indiana has experienced an increase in the number and severity of extreme weather events attributable to climate change, in addition to rising temperatures and increased precipitation. And ultimately, the state and local governments must protect their investments by mitigating against future extreme weather patterns and their adverse effects.

Climate change is already observable in Indiana.

- Average temperatures have risen by 1 degree (F) since the 1950s.
- Indiana currently gets 38 and 46 inches of rain per year; depending on the region, this is an increase of 8% to 10% since the 1951-1980 period.
- By the middle of the century, 50 more days will reach over 90 degrees (F) each year.
- Spring rainfall will increase by 16% by the 2050s.
- Indiana has already been impacted by extreme weather events, including widespread flooding in 2008 and 2015 and severe drought in 2012.

Indiana's transportation systems are vulnerable to climate change-related damage.

- Increased heat will reduce the lifespan of pavements, add stress to joints and materials 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 roadways, tunnels, and bridges, and increase sedimentation in waterways.
- Indiana has already felt these effects, as widespread flooding in 2008 resulted in the closure of Interstate 70 near Coverdale and Interstate 80/94 in Northwest Indiana.

The production and distribution of electricity will similarly be impacted.

- Indiana has over 5,100 miles of high voltage transmission lines and over 8,000 miles of low-voltage lines that are susceptible to high winds, ice, snow, and electrical storms.
- Over 81% of electricity in Indiana is generated from coal-powered plants; flooding can impact rail lines and waterways, both of which are crucial to the transportation of coal.
- Transmission line capacity decreases as temperatures rise, reducing the available power supply; at the same time, Indiana will have higher electricity demands due to increased air conditioning use.

Indiana must mitigate against future climate changes and adapt to existing impacts on infrastructure.

- Infrastructure systems are susceptible to the long-range impacts of climate change because structures have an extended design life, some reaching up to 100 years.
- Mitigation strategies include greenhouse gas (GHG) emission regulations and climate action plans, both of which have been dismissed by Indiana leaders.
- Indiana does not currently employ any climate adaptation plans statewide, however INDOT's Transportation Asset Management program may be able to account for climate impacts if desired.
- Climate change can be accounted for in infrastructure design through updated temperature and precipitation values.
- Indiana minimally regulates development in floodplains, but local governments can recommend stricter development regulations, as Columbus, IN, did following flooding in 2008.
- While Indiana on the whole has made few efforts to mitigate against climate change, 16 mayors of Indiana cities, including Indianapolis, committed to reducing GHG emissions in their own cities.

Climate change will have widespread and unimaginable impacts on Indiana's residents, businesses, industries, and environment. Despite clear evidence that the state's climate is changing and will continue to do so in the future, Indiana has done little to mitigate against future impacts. No one policy or action alone will halt the harmful effects of climate change; however, without action, tens of millions of dollars of investment in infrastructure systems that serve as the heart of Indiana's economy are at risk.

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INTRODUCTION

There are few things more important to a thriving state than its infrastructure systems. In particular, transportation and electricity are depended on by residents and businesses on a daily basis. The transportation network allows for safe passage for businesses delivering their products to markets and consumers accessing those markets, while also guaranteeing the public's access to jobs, schools, hospitals, and countless other public services. Similarly, the vast electricity infrastructure system powers those businesses and homes and keeps them warm during the winter and cool at the height of summer. In short, Indiana can only count on a prosperous economy if its infrastructure systems are dependable and efficient.

Indiana is home to over 6.6 million people and almost 500,000 companies, all of which are supported by these infrastructure systems (USCB, 2017). It has 14 metropolitan areas in addition to substantial rural and agricultural land. Indiana's industries vary from manufacturing to healthcare and agriculture, contributing to its over $347 billion (2016$) Gross Domestic Product (BEA, 2017). However, climate change has the ability to threaten the growing state by damaging and disrupting its infrastructure systems. The effects will be felt by all residents and businesses if actions are not taken to protect these vital infrastructure systems.

This report by the Midwest Economic Policy Institute examines the state's infrastructure systems and the impact that climate change will have in the future. Similar to the Midwest on the whole, Indiana has experienced an increase in the number and severity of extreme weather events attributable to climate change, in addition to rising temperatures and increased precipitation. Ultimately, the state and local governments must protect their investments and appropriately plan for and mitigate against future extreme weather patterns and their adverse effects.

CLIMATE CHANGE IN INDIANA

Observed Precipitation and Temperature Changes

Since the beginning of the 1900s, average temperatures have risen by 1 degree (F), and with the exception of the 1930s "Dust Bowl" era, the temperatures since 2000 have been the highest than any other historical period. Winters have continued to warm with the average number of very cold nights – defined as those with a minimum temperature below 0 degrees (F) – noticeably lower since the 1990s. Additionally, annual precipitation has varied widely over the years, however the wettest five-year period in Indiana was 2007-2011 (NOAA, 2017).

Figure 1 summarizes the observed past precipitation levels and temperatures throughout four regions in Indiana: Northwest, Northeast, Central/Southeast, and Southwest. Each region is defined by the National Oceanic and Atmospheric Administration (NOAA) and typically groups 5-10 counties that have a similar climate. The regions are depicted in Figure 2. While the climate is relatively similar throughout Indiana, these four regions were chosen to capture the most populated areas and provide a broad understanding of minor climate differences throughout the state.

On average, Indiana regions currently receive between 38 and 46 inches of rain per year. This is an increase of 5% to 10% since the 1951-1980 period. Most notably, every region experienced the highest increase, over 15%, in the fall (defined as September, October, and November). The lowest increases were witnessed in the Spring in the Northeast and Northwest and the Summer in the Central and Southwest regions, with the Southwest actually experiencing a 2% decrease in precipitation in the Summer.

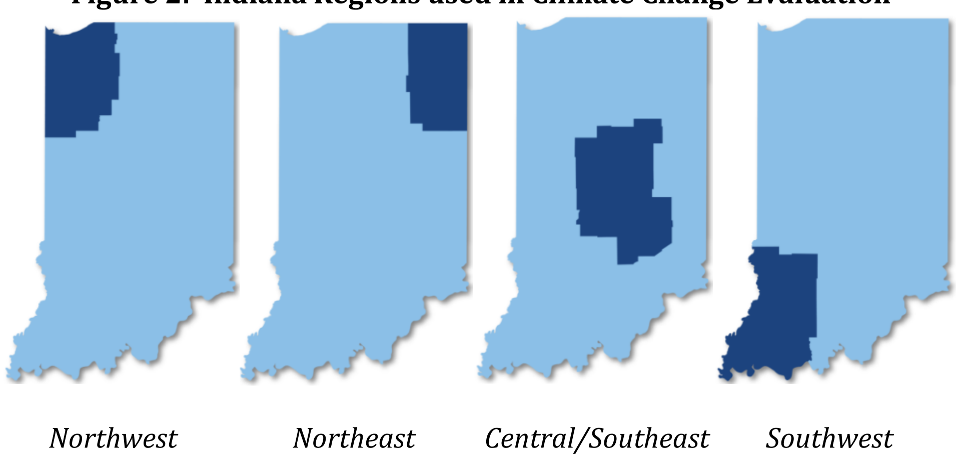
Figure 1: Observed Indiana Precipitation and Temperature Data by Region

		Precipitation		Temperature	
		Current (in)*	Observed Change**	Current (degrees F)^	Observed Change (degrees F)^^
Central / Southeast	Annual	42.29	8.19%	51.74	0.92
	Winter	7.97	6.13%	29.58	1.80
	Spring	12.16	8.86%	51.29	1.07
	Summer	12.3	1.74%	72.31	0.32
	Fall	9.85	17.82%	53.88	0.68
Northwest	Annual	38.95	5.78%	50.13	0.98
	Winter	6.43	9.35%	27.05	1.97
	Spring	10.35	0.29%	49.48	1.16
	Summer	12.47	2.30%	71.45	0.41
	Fall	9.73	15.70%	52.61	0.57
Southwest	Annual	46.52	9.69%	54.85	0.82
	Winter	9.68	7.92%	33.31	1.63
	Spring	14.08	10.95%	54.58	0.82
	Summer	11.62	-2.11%	75.02	0.38
	Fall	11.13	24.64%	56.57	0.62
Northeast	Annual	38.14	8.32%	49.85	1.01
	Winter	6.83	9.98%	27.12	1.87
	Spring	10.22	2.30%	49.02	1.19
	Summer	11.88	9.19%	71.05	0.47
	Fall	9.27	14.02%	52.25	0.61

* Total precipitation in inches for 1981-2010
** % change between the 1981-2010 period and historical 1951-1980 period
^ Average temperature for 1981-2010
^^ Difference between the 1981-2010 period and historical 1951-1980 period

Source(s): University of Michigan Cities Impact and Adaptation Tool

Figure 2: Indiana Regions used in Climate Change Evaluation



The current average annual temperature ranges between 50 and 52 degrees across these four regions. The observed change since the 1951-1980 period is approximately 1 degree higher (1.8% on average). As described above, the largest increase occurred during the winter months (December, January, and February), with just under a 2 degree increase for most regions. The second largest increase was observed in the Spring, with an average increase of around 1 degree. The summers experienced the lowest temperature increase, ranging between 0.32 degrees in the Central/Southeast region to 0.47 degrees in the Northeast.

Future Precipitation and Temperature Conditions

As summarized in Figure 3, by the middle of the century, Indiana is expected to experience over 50 more days annually that reach over 90 degrees (F). Similarly, the average coldest day of the year will be 7 degrees warmer and the average date of the last spring freeze will be 15 days earlier. Precipitation levels are likewise anticipated to increase, particularly in the winter and spring months; specifically, spring rainfall is expected to increase by 16%.

Figure 3: Future Indiana Climate Conditions

	Today	2050s
Number of 90 degree (F) days (annually)	20	74
Average coldest day of the year (degrees F)	-7	0
Average date of last Spring freeze	20-Apr	5-Apr
Percent change in Spring rainfall	-	+ 16%

Source(s): Purdue Climate Change Research Center, 2018

Taking a closer look, Figure 4 summarizes the projected temperature increases by the middle of the century (between 2041 and 2070) compared to current temperatures. Using the same four regions illustrated above, the maximum increase in annual temperatures is expected to range from 6.41 degrees in the southwest to 7.5 degrees in the Central / Southeast. The largest increases are anticipated to occur in the Summer months (June, July, and August) across all four regions, with the Central / Southeast region potentially increasing by almost 10 degrees. Overall, the Northwest and Central / Southeast regions are expected to warm slightly more than the Southwest and Northeast regions.

Figure 4: Future Projected Indiana Temperature Change* (degrees F) by Region

	Central / Southeast	Northwest	Southwest	Northeast
Annual	3.14 - 7.50	3.00 - 7.36	1.93 - 6.41	2.74 - 7.06
Winter	2.42 - 7.90	2.28 - 7.96	0.75 - 6.31	2.26 - 7.62
Spring	1.92 - 7.76	1.81 - 8.05	0.94 - 6.62	1.44 - 7.44
Summer	2.32 - 9.40	2.25 - 9.41	1.06 - 8.78	1.92 - 8.56
Fall	2.48 - 7.44	2.25 - 7.53	1.53 - 6.45	2.05 - 7.09

* Difference between projected period of 2041-2070 and current conditions 1981-2010

Source(s): University of Michigan Cities Impact and Adaptation Tool

Extreme Weather Events

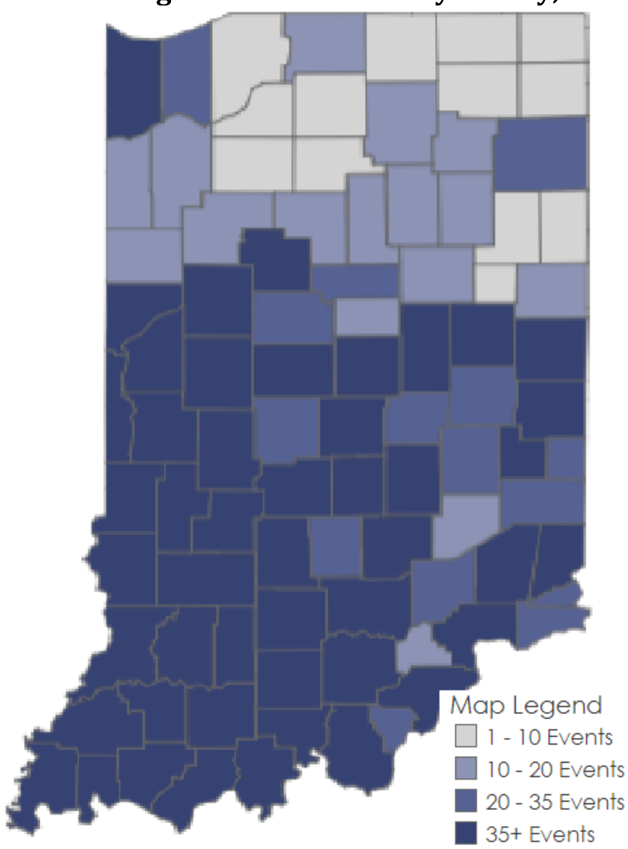
In addition to the change in temperatures and precipitation, Indiana can also expect to encounter an increased number of extreme weather events. Flooding, heat stress, drought, and varying freeze patterns are all anticipated to continue to impact Indiana, posing particular threats for infrastructure systems.

While these threats are expected to continue in the future, Indiana has already experienced them, having been impacted by severe drought and flooding events in the last decade. In 2012, rainfall in the spring and summer months of May, June, and July was 5 inches less than usual, totaling only 6.57 inches. Over 70% of the state was considered to be in extreme drought by August, causing significant damage to crops. Conversely, June 2008 brought significant flooding across most of Indiana, with many streams reaching record flood levels. Overall, 39 counties were declared disaster areas. Flooding occurred again in June and July of 2015, with Indianapolis experiencing the wettest July on record, with over 8.6 inches of rainfall above normal levels (NOAA, 2017).

These three circumstances – the oscillation between extreme drought and extreme flooding – are prime examples of the severe weather events the state can expect in the future. Overall, the frequency and intensity of flooding is expected to increase in Indiana, much as it has been observed in recent years. Furthermore, despite additional rainfall, increased temperatures will also increase the rate of evaporation, leading to decreased soil moisture, and more severe droughts (NOAA, 2017).

To further understand the magnitude of flooding, Figure 5 illustrates the number of claims filed in Indiana under the National Flood Insurance Program (NFIP) by county since 1996. It is clear that southern Indiana has experienced a significant amount of flooding over the years. Most substantial, Gibson and Knox Counties in Southwest Indiana had 176 and 135 flooding events, respectively. To illustrate some of the most populated areas, Marion County (Indianapolis) had 76 events, Vanderburgh (Evansville) had 100, and Lake County (Northwest Indiana) had 40.

Figure 5: Flooding Events in Indiana by County, 1996-2016



Source(s): FEMA, 2018

CLIMATE CHANGE AND INFRASTRUCTURE

It is obvious that Indiana's climate is changing. And while it is clear that the state will experience increased temperatures and rainfall, those factors will also lead to flooding, heat stress, drought, and varying freeze thaw patterns (Pryor et al., 2014). In particular, infrastructure systems are vulnerable to both physical damage and disruption of services as a result of climate change-related extreme weather events, leading to significant economic and personal losses.

Transportation

Indiana has a vast transportation system, including 14 interstate highways, 11,000 miles of state-maintained roadways, 117 public-use airports, three water ports, 4,000 miles of railway, and a variety of transit systems statewide, not to mention the extensive local infrastructure systems (INDOT, 2018a).

The most basic impact will occur in physical damage to roadway, bridge, and rail structures. Heat will reduce the lifespan of pavements, add stress to joints and materials for bridges and highways, cause pavements and railways to buckle, and affect aircraft performance (Schwartz et a., 2014). Varying temperatures, particularly in the winter, will increase the number of freeze-thaw cycles, impacting roadway materials and increasing maintenance costs (C2ES, 2018). Flooding will weaken structural supports for bridges, deteriorate soil that supports roadways, tunnels, and bridges, and increase sedimentation in waterways. Bridges that cross waterways will be particularly impacted, as increased flood flow patterns and water velocities will impact bridge supports (Meyer, 2006).

In addition to physical damage, the impact will be amplified as these damages impact the transportation network's ability to transport needed goods and people. Both initially during a weather event and following, as damages are being assessed and repaired, transportation systems can become entirely unusable due to flooding, debris, or damage. Flooding can lead to impassable roadways – stranding homes and businesses from needed supplies – contribute to inland waterways being unsafe, and disrupt standard travel. Conversely, droughts will leave waterways too shallow for vessels to traverse, particularly impacting freight shipments on barges. And since Indiana serves as the "Crossroads of America," carrying 724 million tons of freight annually, it also has the potential to impact the greater Midwest region and nation on the whole (INDOT, 2018b). The economy of Indiana, the Midwest, and the nation depend on a functioning transportation network, however flooding and damages that lead to closures and delays will negatively impact businesses both near and far.

Examples of disruptions and damages that have already occurred in Indiana can be found below. They represent just a small portion of extreme weather-related infrastructure disruptions that have impacted the state in recent years.

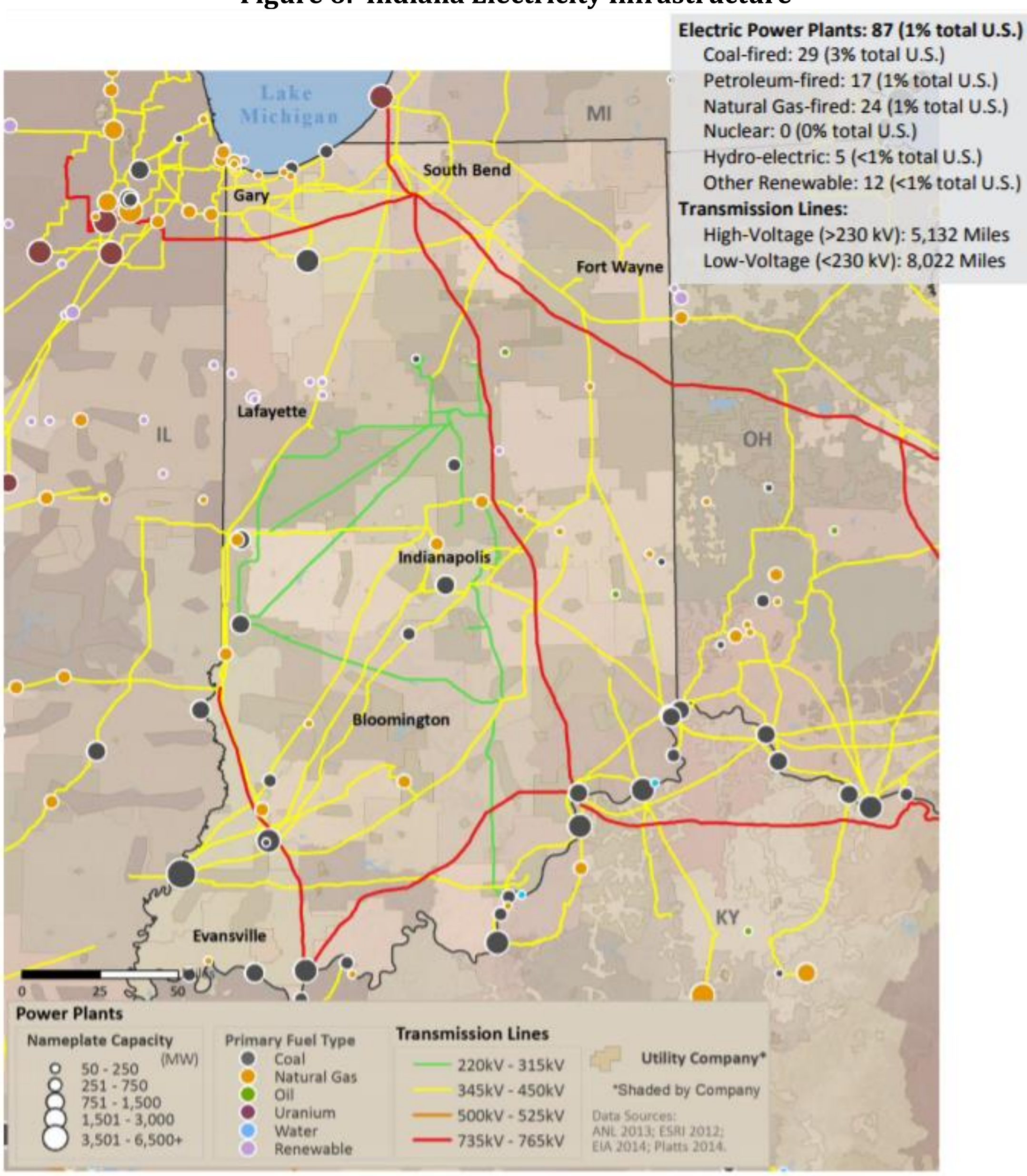
- 2008 Flood in Central and Southern Indiana: Interstate 70 near Coverdale was closed following flooding. Roadway collapse was imminent due to erosion and required immediate repairs. Significant delays were experienced as traffic was diverted to nearby local roadways (*IndyStar*, 2008). Overall, more than 40 counties were declared disaster areas and roads and bridges remained closed due to flood damage over two months following the events (IN DNR, 2008).
- 2008 Flood in Northwest Indiana: Flooding closed Interstate 80/94 in Northwest Indiana for a week, significantly impacting commerce for freight flows passing through the Chicago region (Franklin, 2012).
- 2016 Heat in Northcentral Indiana: Heat damage led to buckling of concrete on portions of Indiana 331 near Mishawaka and several roadways in South Bend. Both roadways required repairs (Blake, 2017).

- [Increased Freeze-Thaw Cycles in 2005](): Extreme temperature changes, resulting in repeated freeze-thaw cycles, led to buckling railway at several locations in Merrillville in Northwest Indiana (Laverty, 2005).

Electricity

Much like the transportation network, the production and distribution of electricity can be impacted by climate change and severe weather events. The electricity system is composed of power plants that generate power, transmission lines that carry the power, and finally substations that distribute power to communities. All of these systems remain susceptible to damage as a result of climate change-influenced weather events (Kenward and Urooj, 2014). Furthermore, the resources used to generate electricity – including coal, crude oil, or other commodities – can be further impacted during transport due to damages or delays on the transportation network (Dell et al., 2014).

Figure 6: Indiana Electricity Infrastructure



Source(s): DOE, 2016

Electricity is a primary source of energy for Indiana; the state consumes over 105 terawatt hours (TWh) and produces over 114 TWh (DOE, 2016a). The state's heavy industrial sector is a principal electricity customer, in addition to over 25% of Indiana residents relying on electricity as the main source of energy for home heating (EIA, 2017). Electricity production is supported by 29 coal-fired, 17 petroleum-fired, 24 natural gas-fired, 5 hydro-electric, and 12 renewable plants (Figure 6). The state also has over 5,100 miles of high voltage transmission lines and more than 8,000 miles of low-voltage lines (DOE, 2016a).

As illustrated in Figure 6, Indiana's electricity production facilities are widespread. The potential for damage due to climate change and extreme weather events can come in the form of flooding, high winds, ice, snow, and electrical storms. Transmission lines in particular are susceptible to these conditions, especially in Indiana where a large portion of electricity transmission and distribution is above ground (Kenward and Urooj, 2014). Between 1992 and 2009, the number of electric transmission outages caused by severe weather was 14, with 9 from thunderstorms and 4 from heat waves (DOE, 2016a). Furthermore, between 2003 and 2012, Indiana experienced 39 major electricity outages due to weather, ranking 9th in the nation and 3rd in the Midwest (Kenward and Urooj, 2014).

Over 81% of electricity generation in Indiana is from coal-powered plants, which are largely located along the border of the state on rivers (DOE, 2016a); while no evidence suggests flooding has been an issue for these plants in the past, extreme storms may impact them in the future. Flooding can also impact important rail lines and waterways by both flooding and drought; both systems are crucial to the transportation of coal (DOE, 2015).

In addition to damage, the operation of power plants and transmission of electricity is not as effective in higher temperatures. Higher air and water temperatures overall will reduce productivity of plants and can even force plants to cease operations. Transmission line capacity also decreases in high temperatures, reducing the available power supply (DOE, 2015). This is particularly worrisome to Indiana because the state is a net importer of electricity from neighboring states and Canada (Nateghi and Mukherjee, 2017).

Finally, Indiana can expect to experience higher demands for electricity due to increased temperatures and humidity. Currently, energy demand is five to seven times higher in the winter from heating demands. However, Indiana's number of cooling degree days (CDD) – defined as the number of degrees that a day's average temperature is above 65 degrees (F) – is expected to increase annually by 450 to 750 degree days. Because air conditioning uses electricity, and heating is commonly powered by coal or natural gas, warmer temperatures will put additional strain on the electricity system (DOE, 2015).

MITIGATION AND ADAPTATION IN INDIANA

Understanding that Indiana's climate is changing and has the capability to affect the state's infrastructure systems, state and local governments must take actions to mitigate against future climate changes and adapt to the already apparent impacts. Infrastructure, in particular, is susceptible to the long-range impacts of a changing climate because structures have an extended design life. While roadways and pavements typically have a design life around 20 years, the useful life of bridges can reach to 100 years (Meyer, 2006). Additionally, power plants are often designed to last 15-40 years and electricity transmission lines can last up to 75 years (Nierop, 2013). Consequently, it is in the taxpayers' best interest to ensure the climate and weather predictions are taken into account. Doing so will reduce future disaster costs, save lives, and facilitate an easier recovery following extreme weather events.

Mitigation Strategies

The broadest mitigation strategy a state can employ is the reduction of greenhouse gas (GHG) emissions, the leading contributor to climate change. Similarly, a state may adopt a Climate Action Plan that identifies policies and actions – including GHG reductions – that can be taken to lessen the state's contribution to climate change (C2ES, 2016).

The State of Indiana has not taken steps to adopt any climate change-related policies. In fact, both current Indiana Governor Holcomb and former governor, now Vice President Pence, opposed any efforts on the federal level (under the Obama Administration) to curb GHG emissions and mitigate against climate change. Most notably, Indiana, under the leadership of then Governor Pence, filed suit against federal restrictions to GHG emissions under the Clean Power Plan and current Governor Holcomb applauded President Trump's steps to roll-back these policies (Groppe, 2017). Similarly, state leaders have opposed the support of renewable energy sources, with Governor Holcomb signing a bill in 2017 that eliminates incentives for rooftop solar electricity (Deaton, 2017).

Adaptation Strategies – Planning

A climate adaptation plan, on the other hand, allows a state to prepare for climate changes that have already begun. The plan outlines vulnerabilities towards climate change and creates a plan and implementation process to address those weaknesses (C2ES, 2016). Adaptation plans are particularly important to infrastructure, as it aids in ensuring vital transportation and electricity systems can handle extreme weather events. They collect data on infrastructure systems and potential impacts allowing government agencies to closely analyze risks and balance them against costs (Johnson, et al., 2012).

The most obvious agency to handle an adaptation plan for transportation infrastructure is the Department of Transportation. INDOT has not pursued any form of an adaptation plan, but it currently employs an asset management plan, which can act as a starting point in the future. INDOT's Transportation Asset Management (TAM) program serves as a strategic process to evaluate the existing conditions of physical assets, identify maintenance needs, assess potential risks, and identify the best investment strategies for operations, maintenance, replacements, or improvements. While INDOT's TAM program is an effective tool to most efficiently use the money available to support a thriving transportation network, it does not overtly account for climate impacts in the analysis. However, the program can offer a perfect first step for Indiana to closely examine its infrastructure in the context of climate change when the state chooses to act (INDOT, 2018c).

Similarly, electricity adaptation comes in the form of planning for risks and adjusting operations. While transportation infrastructure is largely publicly owned, electricity is often privately owned. Many electricity providers have already implemented plans to adapt to existing weather patterns and anticipated future impacts. These may include equipment design standards, smart grids and infrastructure monitoring technologies, energy efficiency programs, and demand response tools. The approaches work together to ensure stronger equipment overall and minimize outages and repair times (DOE, 2016b). In Indiana, Hoosier Energy – a generation and transmission cooperative serving central and southern Indiana – has done just that. They are expanding their demand-side management practices, targeting water heaters, air conditioners, and heat pumps to reduce loads on the electricity system and improve overall efficiency (DOE, 2015).

Adaptation Strategies – Design Standards

Updated design standards for infrastructure may be one option identified within adaptation plans. Engineering design standards for roadways and bridges depend on temperatures, temperature variability, precipitation, and flood flow patterns and velocities to dictate materials, pavement thickness, foundation and structural support, slope, and drainage. Existing design standards often use historical climate and weather data, but future climate projections should be considered (Meyer, 2006). As previously mentioned, since many infrastructure assets are designed to last over the long term, the changing climate can prove to be an issue to these structures in the future. As stated by Professor Meyer, "We need to be thinking today of the potential impacts of climate change on infrastructure that will be still serving society 100 years in the future" (2006).

Updated design standards may call for thicker pavements, different material types, varied culvert location or size, higher bridge heights, or different bridge foundations (Meyer, 2006). Additionally, different infrastructure projects that remedy flooding may be considered, such as green stormwater infrastructure, including green roofs, rain gardens, permeable pavers, and porous concrete and asphalt (City of Chicago, 2014).

Similar to transportation infrastructure, electricity systems can also be designed to withstand higher temperatures, winds, and precipitation. Lines, poles, substations, and other transmission and distribution equipment can all be designed to withstand these conditions. Transmission lines may be moved underground or covered in a hydrophobic coating that protects from water and ice coating. Lines can also be strengthened with steel poles and pole treatments, and breakaway cables can be installed to avoid complete system failures in the form of cascading poles (DOE, 2016b).

Depending on the type of infrastructure, design standards are either managed by a government agency or a private entity. In the case of road and bridge projects, most are publicly owned, and those on the state maintained roadways abide by design guidelines adopted by the state. Similarly, if a project is receiving federal funding, that project must abide by federal design guidelines. Updating design standards can prove to be difficult, as existing standards have undergone extensive testing and practical experience in their development. Over 11 professional organizations are sources for design guidance, including the Federal Highway Administration (FHWA), American Society for Testing and Materials, and the American Association of State Highway and Transportation Officials (AASHTO) – and professional engineers spend years carefully considering and testing potential changes (Meyer, 2006). Despite these difficulties, evidence has clearly shown that future climate change standards should be implemented. And considering the anticipated time lapse to appropriately test and evaluate any updates, the sooner new design standards related to climate change are considered, the better.

Neither Indiana nor the federal government have adopted updated design standards with regard to climate change at this time. Conversely, some private entities – including electricity providers, railways, and pipelines – have pursued standards that account for the anticipated future climate, understanding the economic cost that will be apparent without changes (C2ES, 2018).

Adaptation Strategies – Location

The most basic form of climate adaptation is avoiding specific locations that are prone to climate-related damage, such as flooding. While the exact location of roadways is at least partially impacted by environmental studies, future climate factors – like increased precipitation and potential flooding or erosion – should also be taken into account. While, transportation planners and engineers use official flood-plain maps to determine drainage and appropriate designs for the 100- and 500-year flood levels (Meyer, 2006), these maps are often developed using historic values that underestimate precipitation levels and do not accurately capture future flooding (C2ES, 2018).

While Indiana does prohibit the construction of a place of residence in most floodways throughout the state, the construction of any other structure is allowed as long as the proper permits have been obtained. The state also allows existing residences located within the floodway that have been substantially damaged to be rebuilt, as long as they abide by state and federal regulations. The Indiana Department of Natural Resources (IN DNR), which manages flood control activities in the state, follows the same standards as the Federal Emergency Management Agency (FEMA), regulating development within the 100-year floodplain (IN DNR, 2014). Consequently, Indiana is minimally regulating the development of structures, which inherently impacts related transportation and electricity infrastructure.

As an example of increased regulations, following the widespread flooding in 2008, the City of Columbus, IN formed a Flood Regulation Study Committee to research options for the regulation of development in local floodplains. They ultimately recommended continued local regulation within the 500-year floodplain, prohibition of new development in all floodways of streams, and a ban of the development of new critical and flood-sensitive facilities in the 500-year flood plain (City of Columbus – Bartholomew County Planning Department, 2012).

Local Mitigation and Adaptation Efforts

While it is clear that the State of Indiana has made few efforts towards mitigating against climate change or offering adaptation strategies and regulations, local governments and organizations throughout the state have stepped up to do their part. Following President Trump's withdrawal from the 2015 worldwide Paris climate agreement – designed to curb worldwide emissions – the mayor of Indianapolis announced the city's commitment to carbon neutrality by the year 2050 (Dovey, 2017). Furthermore, 16 mayors of Indiana cities joined the Mayors Climate Protection Agreement, also committing to reduce GHG emissions by taking actions in their cities (Obama White House Archives, n.d.).

Additionally, the City of Michigan City was awarded over $224,000 from the U.S. Environment Protection Agency in 2015 to construct green infrastructure – including bioswales, native trees, and porous pavement – to improve water quality across the Great Lakes Basin. Within the last 5 years, the IN DNR, Indiana Lake Michigan Coastal Program, University of Michigan, and NOAA have offered plans and data related to climate change impacts on Lake Michigan. The Federal Highway Administration also offered workshops to Indiana Metropolitan Planning Organizations (MPOs) to explore tools and strategies related to climate change and infrastructure (Adaptation Clearinghouse, n.d.).

CONCLUSION

Climate change will have widespread and unimaginable impacts on Indiana's residents, businesses, industries, and environment. Despite clear evidence that the state's climate is changing and will continue to do so in the future, Indiana has done little to mitigate against future impacts. No one policy or action alone will halt the harmful effects of climate change, however actions must be made.

In particular, Indiana's transportation and electricity infrastructure systems are susceptible to damage, deterioration, and added stress due to higher temperatures, prolonged summers, increased heavy rain events, and more frequent freeze-thaw cycles. Furthermore, extreme weather events – much like the severe flooding and droughts experienced in recent years – will become more common and continue to threaten these vital infrastructure assets. Interruptions of services due to these events will also impact freight movements and electricity production and demand, both of which will adversely impact the state's economy.

As Indiana's state and local governments consider issues ranging from modernizing transportation systems to planning new housing and commercial developments, it is in the taxpayers' best interest that they also account for today's climate realities. Ultimately, without action by state leaders, tens of millions of dollars of investment in infrastructure systems that serve as the heart of Indiana's economy are at risk.

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