

Climate Resilience Strategy Paper

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Climate Change and the Chicago Region: Moving Toward a Resilience Framework

Scientific consensus indicates that our climate is changing at a global scale. In northeastern Illinois, these changes include more frequent and severe weather, extreme heat, and drought. The impacts of climate change have significant implications for the built environment, economies, ecosystems, and people in this region. Flooding has led to major road, rail, and utility outages, sewer overflows, mold, damaged property, disruptions to freight traffic, and financial losses for local businesses. Heat waves have caused illnesses, hospitalizations, and deaths in vulnerable communities, and drought has had significant adverse impacts on the region's agricultural sector and natural areas.

This strategy paper provides recommendations to build climate resilience through land use planning, infrastructure planning, natural resource management, economic development, and capacity building. The policy directions presented here will inform how ON TO 2050, the new regional plan, can help northeastern Illinois be more resilient by 2050 by adapting to and mitigating climate impacts.

Climate resilience was not directly addressed in GO TO 2040, the predecessor to ON TO 2050, and is therefore a new topic of exploration for the agency. To inform this exploration, CMAP convened a Resource Group about once a month over the course of nine months. Co-chaired by the Chicago Community Trust, the group included 15 stakeholders with a wide range of backgrounds, including transportation, stormwater management, land use, energy, public health, environmental justice, emergency response and hazard mitigation, urban design, landscape architecture, and planning. Through activities, discussions, and site visits, the group developed a shared mission and vision of regional climate resilience, generated policy ideas, and provided feedback on deliverables. Through a grant from the Chicago Community Trust, Foresight Design Initiative facilitated visioning sessions and provided significant guidance in designing meeting activities and objectives. The Resource Group lays a strong foundation for the future collaboration needed to implement the variety of resilience strategies in this paper.

Climate Change in Northeastern Illinois

Climate change is the long-term change to the atmospheric system. Weather refers to short-term conditions of sunshine, precipitation, temperature, and humidity, all of which vary daily and seasonally. When averaged over decades, weather patterns allow us to understand climate and how it is changing. Northeastern Illinois has already experienced, and is projected to see even greater, changes in temperature and precipitation from climate change. In recent years, weather events in the region have included record-breaking flooding, heat, and drought.¹ The region

¹ Chicago Metropolitan Agency for Planning, 2013, *The Primary Impacts of Climate Change in the Chicago Region*, <http://www.cmap.illinois.gov/documents/10180/14193/Appendix+A+-+Primary+Impacts+of+Climate+Change+in+the+Chicago+Region.pdf/2a85b021-f3bd-4b98-81d1-f64890adc5a7>.

broke the record for most consecutive days above 100 degrees during the Midwestern drought in 2012,² followed by a presidentially declared flood disaster in 2013.³ While seasonal vacillations are not always predictable, models can project overall trends in the region's climate.

This strategy paper draws upon a variety of sources for climate data. The Intergovernmental Panel on Climate Change (IPCC) is the primary international body tasked with assessing climate science. The IPCC periodically publishes comprehensive assessments of climate change that include both historical data and projected changes. The most recent Fifth Assessment Report was published in 2014. The IPCC models climate projections based on scenarios of high- and low-emissions futures. National and regional climate models are based upon the IPCC models. Every four years, the United States Global Change Research Program is required to conduct a National Climate Assessment⁴ that updates data about climate science and impacts across the country. The changes in climate described below come from historical data and downscaled regional, state, and local projections of future conditions that the Midwest Regional Climate Center and Illinois State Climatologist have derived from the latest 2014 National Climate Assessment. Because downscaled models vary in methodology and geography, and no one definitive model exists, data are presented at various scales. While there are variations within the region, the general climate trends for northeastern Illinois largely mirror those across the state.

Temperature

Average temperatures are getting hotter. The rate of warming has been pronounced in recent years: the Midwest has warmed by 2 degrees Fahrenheit since 2000, faster than any other decade since 1900.⁵ [Figure 1.] Although these increases may seem minor, even a few degrees of average temperature change greatly increases the risks and severity of extreme weather, heat, and drought. By the end of the century, temperatures in Illinois are expected to increase by as much as seven to 12 degrees Fahrenheit.⁶ [Figures 2-4.]

Warming is not occurring consistently. Historically, the Chicago region has only had three days over 95 degrees Fahrenheit each year. By mid-century, the region is expected to have at least 10 to 15 days over 95 degrees Fahrenheit annually.⁷ Weather advisories focus on daytime highs,

² U.S. Department of Agriculture, 2013, "U.S. Drought 2012: Farm and Food Impacts,"

<http://www.ers.usda.gov/topics/in-the-news/us-drought-2012-farm-and-food-impacts.aspx>.

³ Federal Emergency Management Agency, "Illinois Severe Storms, Straight-Line Winds and Flooding (DR-4116)," <http://www.fema.gov/disaster/4116>

⁴ National Climate Assessment 2014, <http://nca2014.globalchange.gov/>.

⁵ Great Lakes Integrated Sciences and Assessments, "Synthesis of the Third National Climate Assessment for the Great Lakes Region"

⁶ Illinois State Climatologist, <file://cmap.local/shared/AdminGroups/PlanDevelopment/Strategy%20development/Climate%20resilience/2.%20Background%20Resources/Climate%20science/Future%20Temp%20Scenarios/Future%20Climate%20Change%20Scenarios%20for%20Illinois,%20Illinois%20State%20Climatologist%20Office,%20Illinois%20State%20Water%20.html>

⁷ NCA

but most heat-related deaths occur due to persistent nighttime heat.⁸ In fact, the region's nights are also warming at a faster pace than its days. While the region has historically had 13.5 of nights above 70 degrees Fahrenheit per year, it may expect 30 to 40 nights with such conditions in the future. The region's hot temperatures are often accompanied by high humidity (as measured by heat index), making warmer temperatures feel more oppressive. A heat index over 110 degrees Fahrenheit (indicated in red in Figure 5) has been rare for most of the 20th century, but has significantly increased in recent years. [Figure 5.]

Winters are also warming. Climate models project a decrease in freezing temperatures by mid-century. One study of the Chicago region estimates a 50 to 90 percent decline in days below 0°F by the end of the 21st century.⁹ As a result of warmer winters, ice coverage has diminished in the Great Lakes by 63 percent since the 1970s.¹⁰ These winter temperature patterns may also lead to more freeze-thaw events (the cycle of moving from below to above freezing conditions). Freeze-thaw cycles lead to wear-and-tear on the built environment, causing more rapid deterioration of roadways and other infrastructure.

Precipitation

The Chicago region is experiencing heavier precipitation. Because air can hold four percent more water vapor with each degree of temperature increase, a warming climate also means more precipitation.¹¹ In the Midwest, the amount of precipitation falling in very heavy precipitation (defined as the heaviest one percent of all daily events) increased by 37 percent between 1958 and 2012.¹² The percentage increase is higher than natural variations in precipitation levels, and is second only to the Northeast. [Figure 6.] Some models estimate that 24-hour¹³ and seven-day rainfalls¹⁴ in the Midwest will double by the end of this century.

Both annual precipitation and intensity of weather events (the amount of rainfall from a single precipitation event) have also been on the rise. [Figures 7-8.] Between 1979 and 2009, the region experienced 40 percent more precipitation than the prior 30-year time period.¹⁵ Storm events are also getting bigger: up to 40 percent of total annual precipitation in recent years came from the

⁸ <http://www.c2es.org/publications/extreme-weather-and-climate-change>

⁹ Varvus, S. and Van Dorn, J. 2010. Projected future temperature and precipitation extremes in Chicago. *Journal of Great Lakes Research*, Supplement 2, Vol. 36, 22-32.

¹⁰ Wang, J., X. Bai, H. Hu, A. Clites, M. Colton, and B. Lofgren, 2012: Temporal and spatial variability of Great Lakes ice cover, 1973-2010. *Journal of Climate*, 25, 1318-1329, doi:10.1175/2011JCLI4066.1. Also see the 2014 National Climate Assessment: <http://nca2014.globalchange.gov/report/our-changing-climate/melting-ice>.

¹¹ Illinois Department of Natural Resources, 2015, Urban Flooding Awareness Act, available at: https://www.dnr.illinois.gov/WaterResources/Documents/Final_UFAA_Report.pdf.

¹² National Climate Assessment, 2014, "Heavy Downpours Increasing," available at: <http://nca2014.globalchange.gov/report/our-changing-climate/heavy-downpours-increasing>.

¹³ Rainfall accumulation within 24 hours.

¹⁴ Rainfall accumulation within seven days.

¹⁵ Illinois Department of Natural Resources, 2015, Urban Flooding Awareness Act, available at: https://www.dnr.illinois.gov/WaterResources/Documents/Final_UFAA_Report.pdf.

top 10 rainiest days.¹⁶ Historical analysis of heavy precipitation events in Chicago indicate that the once-rare 24-hour, 100-year storm, which has historically occurred once in every 100 years on average, has been met or exceeded three times in Chicago since the 1980s.¹⁷ (For reference, under current rainfall data from Bulletin 70, a 100-year storm in northeastern Illinois results in 7.58 inches of rainfall.¹⁸) Under a continued high emissions scenario, annual precipitation and heavy precipitation are both projected to increase [Figure 9].

Changes in climate have also brought drought. Although droughts have been less frequent compared to the first half of the 20th century, recent decades show wider swings between droughts and heavy precipitation [Figure 10]. Despite the total increases in precipitation levels, the Midwest is also poised to experience more consecutive dry days.¹⁹ Taken together, the region's rainfall and drought projections mean that the region faces higher risks of flash floods due to heavier rains per storm and drier ground conditions between weather events that impede infiltration.

Warmer winter temperatures will also retain more humidity in the atmosphere, resulting in more winter precipitation falling in the form of rain rather than snow.²⁰ While snowfall may decrease, climate models predict that the snow storms that do occur will be more intense, with more snowfall accumulation per event and denser, heavier snow.²¹

Climate Impacts on CMAP Priority Areas

The temperature and precipitation changes described above are important because of potential impacts on the region's built environment, natural resources, economies, communities, and people. The following section discusses climate impacts on CMAP's priority areas. This overview highlights the vulnerabilities of the region's assets and residents to climate change. Vulnerability is defined by the Intergovernmental Panel on Climate Change (IPCC) as a factor of three variables: the degree to which something or someone (1) is *exposed* to climate change, (2) is *sensitive* to those impacts, and (3) has the *adaptive capacity* (ability to adjust) to moderate potential impacts.²² In more concrete terms, soil type, hydrology, impervious coverage, and

¹⁶ Illinois Department of Natural Resources, 2015, Urban Flooding Awareness Act, available at:

https://www.dnr.illinois.gov/WaterResources/Documents/Final_UFAA_Report.pdf.

¹⁷ CMAP, Climate Adaptation Guidebook for Municipalities in the Chicago Region, Appendix A: Primary Impacts of Climate Change in the Chicago Region, <http://www.cmap.illinois.gov/documents/10180/14193/Appendix+A+-+Primary+Impacts+of+Climate+Change+in+the+Chicago+Region.pdf/2a85b021-f3bd-4b98-81d1-f64890adc5a7>.

¹⁸ Huff, F. A., and J. R. Angel, 1989. Rainfall Distributions and Hydroclimatic Characteristics of Heavy Rainstorms in Illinois (Bulletin 70), Illinois State Water Survey, <http://www.isws.illinois.edu/atmos/statecli/PDF/b70-all.pdf>.

¹⁹ 2014 National Climate Assessment, <http://www.globalchange.gov/browse/multimedia/when-it-rains-it-pours>.

²⁰ Jaffe, M. and Woloszyn, M. 2014. An Initial Assessment of Winter Climate Change Adaptation Measures for the City of Chicago. *Sea Grant Law and Policy Journal*, Vol. 6, No. 2, p. 5-25.

²¹ Jaffe, M. and Woloszyn, M. 2014. An Initial Assessment of Winter Climate Change Adaptation Measures for the City of Chicago. *Sea Grant Law and Policy Journal*, Vol. 6, No. 2, p. 5-25.

²² Intergovernmental Panel on Climate Change, 2007, Synthesis Report, available at:

https://www.ipcc.ch/publications_and_data/ar4/syr/en/mains5-2.html.

other physical attributes increase a community's exposure to flooding and heat. Even when two communities face similar levels of exposure to climate change, they may experience different levels of impacts. Characteristics of sensitivity such as age, income, and household composition mean that some people are more susceptible to those impacts. Lastly, socioeconomic factors, such as social cohesion and access to resources, influence a community's ability to mitigate or prepare for climate change.

This section is not a comprehensive climate vulnerability assessment, which typically provides much more detailed analyses for specific assets. However, this summary of physical, natural, and social vulnerabilities to climate change allows regional partners to identify areas where resilience actions are needed.

Transportation

According to the region's most recent greenhouse gas (GHG) emissions inventory, the transportation sector accounts for nearly a quarter of the region's emissions.²³ GO TO 2040 promotes investments in low-carbon transportation alternatives that reduce emissions, including transit, bicycling, and walking, to reduce emissions. Continued investments in low-carbon transportation options are needed to mitigate climate change.

The impacts of climate change on transportation infrastructure are also increasingly significant. Higher temperatures are causing more pavements to buckle and rut, and heavier rains are expected to increase scouring and deterioration of bridges.²⁴ The 2012 drought and heat led to such severe railway buckling that a train was derailed in Glenview.²⁵ Transportation infrastructure design standards will need to be recalibrated to withstand new thresholds of heat, freeze-thaw cycles, and buckling from changing temperature and precipitation patterns. Moreover, road and rail networks have experienced outages during extreme weather events, disrupting freight routes and employee commutes. The costs of simply maintaining and modernizing the region's infrastructure is high: the Metropolitan Planning Council (MPC) estimates that it will take \$43 billion to improve all of the roads, rails, and bridges in Illinois that are in poor condition.²⁶ The investments needed to make systems more resilient may be even greater.

²³ Chicago 2010 Regional Greenhouse Gas Emissions Inventory, http://www.cmap.illinois.gov/documents/10180/27573/Chicago_2010_Regional_Greenhouse_Gas_Emissions_Invento ry_05-22-12.pdf/adf2a647-246e-48e0-aead-2766fa3281e8.

²⁴ Chicago Metropolitan Agency for Planning, 2013, Climate Adaptation Guidebook for Municipalities in the Chicago Region, <http://www.cmap.illinois.gov/documents/10180/14193/FY13-0119+Climate+Adaptation+toolkit+lowres.pdf/98b5e57c-453f-4111-bc02-6e2cdea0dabc>.

²⁵ Village of Glenview, Union Pacific Road/Shermer Road Updates, <http://glenview.il.us/Pages/Union-Pacific-RailroadShermer-Road.aspx>.

²⁶ Metropolitan Planning Council, 2016, Illinois' Transportation Crisis, http://www.metroplanning.org/uploads/cms/documents/mpc_transportation_crisis_fact_sheet_2016_04_01.pdf.

Land Use

Land use and development patterns, which shape a community's built and natural environments, directly affect a community's emissions. For instance, compact developments and mixed use communities encourage walking and bicycling, reducing transportation emissions. Land use patterns also influence a community's exposure to climate impacts. Many built out communities have large areas of impervious coverage. When it rains, stormwater flows across rooftops, roadways, and other surfaces that do not allow for percolation, carrying many pollutants with it. Impervious surfaces also retain heat and intensify the urban heat island effect. Hotter surface temperatures can cause heat-related illnesses, deaths, respiratory issues, energy demand spikes through increased use of air conditioning, and ozone and thermal pollution. When ambient air temperature is the same across the region, areas with higher imperviousness experience hotter land surface temperatures that contribute to urban heat island effect. A regional analysis of land surface temperature demonstrates the correlation between impervious coverage and urban heat island effect. Lands with high- and medium-intensity developments, defined as having greater than 50 percent impervious surfaces, are five to six degrees hotter than the regional average (see Table 1). [Figure 11] Although there is a clear correlation between imperviousness and urban heat island effect, there are many strategies to mitigate heat while encouraging development. Urban forestry and other site-scale green infrastructure practices can be integrated into street and site design. Parkways and rights-of-way are appropriate places for adding street trees, the most effective vegetative cover for reducing urban heat island effect.

Table 1: Temperature by Land Cover Class in the Chicago Region

Land Cover Class ²⁷	Acreage	Percent	Average land surface temperature (LST) (°F)	Difference from regional LST (°F)
Developed, High Intensity	139,196.7	5.4%	86.5	6.6
Developed, Medium Intensity	302,821.9	11.7%	85.0	5.1
Developed, Low Intensity	611,845.9	23.7%	82.4	2.5
Planted/Cultivated	881,436.9	34.1%	81.7	1.7
Barren	11,342.4	0.4%	81.5	1.6
Herbaceous/Shrublands	60,863.0	2.6%	80.3	0.3
Wetlands	76,196.7	3.0%	78.6	-1.3
Forest	187,242.0	7.3%	78.3	-1.7
Water	55,330.0	2.1%	78.0	-1.9
Total Acreage / Avg LST	2,583,865.7	100.0%	79.9	0.0

Source: CMAP analysis of 2011 National Land Cover Dataset and Landsat 8

Agriculture

One benefit of warmer winters is longer growing seasons. Illinois may expect some long-term economic increases from this shift, but agricultural resources still remain susceptible to drought and flooding. Although total annual precipitation is expected to increase, these increases will

²⁷ For definitions of each land cover class, see the NLCD Legend here: http://www.mrlc.gov/nlcd06_leg.php.

occur mostly during the winter and spring seasons. Midwestern summers are expected to be drier and the average number of days in the region without precipitation is likely to increase. Irrigation for agriculture is projected to see the largest relative increase in water demands compared to any other water use.²⁸ Drought has already had significant recent agricultural impacts. The 2012 drought was responsible for over \$3 billion of crop losses from heat and hot winds in Illinois, which saw the highest amount of crop losses in the country that year [Figure 12].²⁹

Natural Resources

Climate changes alter where species can thrive. Plant hardiness zones identify the regions that plants and ecosystems are able to thrive within based on temperatures, precipitation levels, and climates. Climate impacts have already led to incremental changes to plant hardiness zones in the last 10 years, and more drastic changes are expected by mid-century [Figure 13]. When plant hardiness zones change, species that were once able to thrive in those areas may no longer be able to survive as the climate changes. These projections should inform how natural resource and land managers can cultivate resilient ecosystems that can thrive with changes in climate. The climate risks to natural resources are also exacerbated by developments that fragment and degrade existing ecosystems.

Increased temperatures are expected to exacerbate the presence of invasive species that are non-native to the region, including Asian longhorn beetle, and other diseases that have affected the region's urban forestry. More severe storms and flooding are likely to increase non-point source pollution of the region's aquatic ecosystems and wetlands. At the same time, an increase in projected summertime droughts will lead to ecosystem stress and habitat loss. Ecological changes will also affect migratory and reproductive cycles of the region's native aquatic, avian, and terrestrial wildlife, not to mention introduce new invasive species and diseases to the region.

These impacts have significant financial implications. The Chicago Regional Trees Initiative (CRTI) estimates that one to three million trees have been removed in the Chicago region due to emerald ash borer.³⁰ The cumulative costs of tree removal, inoculation, and reforestation are significant, and most communities have not yet replaced all of their lost trees. Figure 14 shows the number of trees at risk to various invasive insects or diseases, as well as the compensatory value of replacing those trees if lost.

²⁸ Water 2050,

<http://www.cmap.illinois.gov/documents/10180/14452/NE+IL+Regional+Water+Supply+Demand+Plan.pdf/26911cec-866e-4253-8d99-ef39c5653757>

²⁹ Natural Resources Defense Council, "Record-Breaking \$17.3 billion in Crop Losses Last Year; Significant Portion Potentially Avoidable," August 27, 2013, available at <http://www.nrdc.org/media/2013/130827.asp>. See also: <http://farmdocdaily.illinois.edu/2013/03/drought-crop-insurance-loss-2012.html>.

³⁰ <http://www.chicagotribune.com/suburbs/evanston/ct-emerald-ash-borer-met-20141225-story.html>.

Water Resources

Flooding is one of the region's primary climate change impacts. As an inland region, northeastern Illinois does not experience storm surges or sea level rise, but instead faces chronic events that cumulatively affect health and safety, housing, infrastructure, economic competitiveness, and ecosystems. For instance, typical spring storms have led to major road, rail, and utility outages, mold in basements, severe erosion, sewer overflows, and closures of local businesses.

From 1969 to 2009, flooding accounted for 41 percent of disaster losses in Illinois.³¹ Intense and severe weather events are only expected to increase with climate change. Claims filed through the National Flood Insurance Program (NFIP) in Illinois have increased sharply in the last 15 years, largely driven by three significant storm events in 2008, 2010, and 2013.³² Flooding also has water quality implications. Runoff from flooding will also lead to more non-point source pollution of waterbodies. The 2014 National Climate Assessment projects a 120 percent increase in combined sewer overflow discharges into Lake Michigan from all of its bordering states by the end of the century.³³

Flooding is exacerbated by many factors. First, urbanization has increased the prevalence of flooding. In particular, the region has seen an increase of urban flooding, which occurs irrespective of the floodplain.³⁴ Flooding in urban areas has resulted in \$1.975 billion of documented damages in the CMAP region³⁵ from 2007-2014 alone, accounting for 85.2 percent of payouts in the entire state.³⁶ [Figure 15] These figures, which are based on flood insurance claims, are likely an underestimate of the costs and prevalence of urban flooding. Second, stormwater and sewer infrastructure is often not built to accommodate heavy precipitation events. The current standards that most communities use to design stormwater and sewer systems are outdated and underestimate the occurrence of extreme rainfall that can overwhelm stormwater systems and cause flooding in homes, businesses, and roads.³⁷ Many regulations and programs like NFIP are only equipped to address floodplain-based flooding. The magnitude of urban flooding has encouraged many organizations, including CMAP, to explore green infrastructure and land use practices that can support compact communities while managing the impacts of urban flooding.

³¹ http://hvri.geog.sc.edu/SHELDUS/sheldus80_img/charts/loss/JPG/Illinois.jpg

³² Urban Flooding Awareness Act, 2015

³³ NCA3, 2014

³⁴ Urban Flooding is defined in the Urban Flooding Awareness Act as flooding that "(1) includes situations in which stormwater enters buildings through windows, doors, or other openings, (2) water backup through sewer pipes, showers, toilets, sinks, and floor drains, (3) seepage through walls and floors, and (4) the accumulation of water on property or public rights-of-way."

³⁵ The UFAA report only provides for six of the CMAP region's seven counties. These numbers are based off of National Flood Insurance Program and private insurance claims.

³⁶ For more detail about the costs and prevalence of urban flooding, see Appendix D of the Urban Flooding Awareness Act Report, https://www.dnr.illinois.gov/WaterResources/Documents/Final_UFAA_Appendices.pdf.

³⁷ *Climate Adaptation Guidebook for Municipalities in the Chicago Region, Appendix A*, Chicago Metropolitan Agency for Planning, p.17, 2013

Regional Economy

Climate change will have some positive effects on the regional economy. Warmer winters and decreased ice coverage in the Great Lakes will lead to longer shipping seasons. At the same time, climate-related weather disasters are costly. The NCA estimates that from 1980-2012, Illinois experienced about two- to three-dozen climate-related disasters that cost over \$1 billion each. [Figure 16.] Extreme weather and long-term climate changes can have significant impacts on the regional economy, especially on the region's freight and manufacturing sectors. Each year, a quarter to a third of all rail freight in the country passes through metropolitan Chicago and half of all intermodal shipments originate or terminate here.³⁸ Disruptions to supply chains—whether locally or in other places around the world—affect industry productivity in the Chicago region. Moreover, flooding and transportation or electricity outages can affect local business operations and employee commutes.

CMAP's past economic and freight policies have not directly considered the impacts of climate change on economic growth, but research shows that these impacts can be quite costly. The Federal Reserve Bank of Chicago estimates that the transportation and utility outages and other impacts of extreme weather conditions contributed to Chicago's slow rate of growth, including declines in sales and manufacturing production.³⁹

Climate-Vulnerable Populations

From public health impacts to property values, there are many human impacts of climate change in the region. Widespread and chronic flooding has damaged homes—sometimes irreparably—causing evacuations, health impacts from mold, emotional distress, and significant costs. A Center for Neighborhood Technology survey in Cook County found that a majority of respondents reported increased stress (84 percent), lost hours of work to clean up (74 percent), and lost valuables (63 percent) as a result of flooding.⁴⁰

Heat waves, too, have led to heat-related illnesses and mortality. The Chicago region experienced a historic heat wave in 1995 that led to 700 heat-related deaths, followed by another heat wave in 1999, which caused over 100 heat-related deaths. The impacts of the 1995 heat wave have resulted in major reforms to Chicago's emergency response programs: the city formed a Commission on Extreme Weather Conditions, developed a comprehensive Extreme Weather Operations Plan, and established better coordination among emergency responders call centers, and traffic management.^{41,42} Emergency management improvements have reduced

³⁸ Sources vary. OECD, <http://alliancerd.org/wp-content/uploads/2014/02/OECD-Territorial-Review-Chicago-Synopsis-2012.pdf>

³⁹ <http://www.federalreserve.gov/monetarypolicy/beigebook/beigebook201403.htm>

⁴⁰ Center for Neighborhood Technology, 2014,

http://www.cnt.org/sites/default/files/publications/CNT_PrevalenceAndCostOfUrbanFlooding2014.pdf.

⁴¹ CMAP, 2013, Climate Adaptation Guidebook for Municipalities in the Chicago Region,

<http://www.cmap.illinois.gov/documents/10180/14136/FY13-0119%20Climate%20Adaptation%20toolkit.pdf/fa5e3867-8278-4867-841a-aad4e090847a>.

heat-related deaths, but vulnerability to extreme heat will increase as heat waves become more frequent due to climate change. One study of heat mortality risk projects that a five-degree Fahrenheit increase of average daily temperatures would result in an additional 2,000 heat-related deaths compared to 2005 levels.⁴³ This estimated future heat-related mortality rate is three times the rate of the country in 2012.

A variety of socioeconomic factors make certain communities especially vulnerable to climate change. Sometimes, vulnerabilities are based on individual circumstances. For instance, elderly residents, people with chronic diseases, and people without access to air conditioning are particularly susceptible to heat waves.⁴⁴ Some socioeconomic vulnerabilities are spatially correlated with the hottest areas. Residents living in the region's top 10 percent hottest Census tracts based on average land surface temperature tend to be disproportionately people of color, have limited English language proficiency, have a family income below the poverty line, and have no health insurance coverage (see Table 2). While age is a significant factor of vulnerability to heat, there is no geographic correlation between heat and the elderly. Studies have found significantly lower urban tree canopy coverage in low-income communities and communities of color.⁴⁵ Potential reasons for this trend may relate to systemic factors, such as long-term disinvestment or lack of access to planning resources, which may result in less trees and vegetative cover.

⁴² Miller Ruben, Bonnie and Gorner, Jeremy, July 15, 2014, "Fatal heat wave 20 years ago changed Chicago's emergency response," <http://www.chicagotribune.com/news/ct-chicago-heat-wave-20-years-later-met-20150715-story.html>.

⁴³ Bobb JF, Peng RD, Bell ML, Dominici F. 2014. Heat-related mortality and adaptation to heat in the United States. *Environ Health Perspect* 122:811–816; <http://dx.doi.org/10.1289/ehp.1307392>

⁴⁴ Center for Disease Control, Climate Change and Extreme Heat Events, <http://www.cdc.gov/climateandhealth/pubs/ClimateChangeandExtremeHeatEvents.pdf>.

⁴⁵ See, for instance: Schwarz, K., Fragkias, M., Boone, C., Zhou, W., McHale, M., Grove, J., O'Neil-Dunne, J., McFadden, J., Buckley, G, Childers, D., Ogden, L., Pincetl, S., Pataki, D., Whitmer, A., Cadenasso, M., "Trees Grow on Money: Urban Tree Canopy Cover and Environmental Justice," *PLOS One*, April 1, 2015, <http://dx.doi.org/10.1371/journal.pone.0122051>.

Table 2. Heat Vulnerability

Socioeconomic Characteristic ⁴⁶	Regional Population		Top 10 Percent Hottest Census Tracts Based on Land Surface Temperature	
	Count	Percent	Count	Percent
Total Population	8,459,768	100%	511,171	100%
Elderly Population (over 65 years)	1,013,640	12.0%	45,368	9.2%
People of Color⁴⁷	4,030,135	47.6%	381,249	73.7%
Limited English Proficiency⁴⁸	1,029,670	12.2%	144,993	27.2%
Family Income below Poverty Level⁴⁹	1,160,842	13.7%	101,134	19.7%
No Health Insurance Coverage	1,146,328	13.6%	125,787	23.0%

Source: 2010-14 American Community Survey, 2010 U.S. Census, and CMAP analysis derived from Landsat 8.

The Climate Resilience Landscape

This climate resilience strategy paper builds upon CMAP’s past efforts to address climate change in planning. Initial work emphasized the impacts of land use and transportation investments on greenhouse gas mitigation. Regional partners across many sectors have been active in addressing resilience, but this section focuses on the driving policies, programs, and tools that enable CMAP to address climate resilience.

Climate Change Work at CMAP

The recommendations of GO TO 2040 are accompanied by specific regional indicators and targets that relate to greenhouse gas emissions (GHG) reduction. Relevant indicators include GHG emissions, acres of conservation open space, trail greenway mileage, and transit capacity and access. GO TO 2040 calls for a reduction of GHG emissions to 101 metric tons of carbon dioxide equivalent (MMTCO_{2e}) by 2040. This represents about a 10 percent increase of GHG emissions compared to 1990 levels, but a decrease from business as usual. While the plan does not include a standalone topic or chapter specifically focusing on climate change, GHG emissions reduction targets are included in the Energy section of the plan. More broadly,

⁴⁶ 2009-2013 American Community Survey.

⁴⁷ Includes Latino/Hispanic.

⁴⁸ Includes populations over 5 years old that speak English “less than very well.”

⁴⁹ Determined for all people except institutionalized people, people in military group quarters, people in college dormitories, and unrelated individuals under 15 years old. Poverty thresholds vary depending on family size and composition, but not by geography. The people included in this measure are below the appropriate threshold for their family context.

climate mitigation benefits are emphasized throughout the plan as co-benefits of land use, environmental, housing, and transportation recommendations.

Emissions Inventories

In order to initially assess emissions and ultimately track GO TO 2040 implementation progress on climate mitigation, CMAP has supported two regional greenhouse gas emissions inventories. The first was an [inventory of 2005 GHG emissions](#) conducted in 2008 in partnership with the Center for Neighborhood Technology. The second was an [inventory of 2010 GHG emissions](#) completed in 2012 in partnership with the City of Chicago and ICF International.

Transportation Programming

As the agency's largest program, transportation planning and programming provides the most direct avenue for CMAP to address climate change. CMAP directly administers the [Congestion Mitigation and Air Quality](#) (CMAQ) Program, which funds surface transportation projects that improve air quality and reduce emissions, and the [Transportation Alternatives Program](#) (TAP), which provides funding to support pedestrian and bicycle infrastructure.

Local Technical Assistance Program

CMAP's Local Technical Assistance (LTA) program has shaped local responses to climate change primarily through sustainability planning. CMAP has provided LTA assistance to counties and municipalities to develop various [sustainability plans](#). These plans have covered a range of environmental issues, including climate mitigation, open space preservation, watershed planning, and transit-supportive planning. Based upon these experiences, CMAP has also developed a [Sustainability Planning White Paper](#) and [Indicators Guide](#) (2015) to assist communities that wish to undertake their own sustainability plans and identify appropriate indicators to measure progress.

To respond to growing local community interest in adapting to climate change, CMAP developed a [Climate Adaptation Guidebook for Municipalities in the Chicago Region](#) in 2012. The guidebook walks through the process of adaptation planning, provides an overview of climate trends and projections in the Chicago region, and highlights zoning and other regulatory strategies to design and build more adaptable municipal infrastructure in the face of a changing climate.

Stormwater Analysis

CMAP is developing a methodology for stormwater analysis to inform land use strategies that address urban flooding. The analysis uses a variety of data, including topography, soil type, known flooded properties, historic stream locations, and land cover, to identify flowpaths of stormwater runoff. Supported by the MacArthur Foundation and Cook County, this approach is being integrated into projects through CMAP's LTA program.

Energy Impact Illinois

CMAP's implementation of climate mitigation strategies was also supported through Energy Impact Illinois, a partnership of CMAP, CNT Energy, City of Chicago, ComEd, Nicor, and others to enact energy efficiency improvements across the region. Supported through a 2010 Energy Efficiency Block Grant from the Department of Energy, this program contributed to retrofits of over 8,000 units with at least 15 percent savings per retrofit, and led to the creation of over 2,000 jobs in the region. While the program covered both residential and commercial retrofits, the bulk of the improvements were in single-family homes.

Regional Resilience Coordination

CMAP has been collaborating with governments, non-profit partners, private sector leaders, and philanthropic organizations to build long-term resilience across the region. The Calumet Stormwater Collaborative, facilitated by the Metropolitan Planning Council, has been an effective sub-regional forum to improve stormwater planning in south suburban Cook County. The [HUD National Disaster Resilience Competition](#), for which the City of Chicago, Cook County, DuPage County, and the State of Illinois were eligible, catalyzed cooperative regional efforts directly around resilience. CMAP's role as a convener of the partnership has directly informed the agency's approach to the topic of climate resilience.

External Policies Driving Climate Resilience

A few key national and international climate change policies have impacts for climate resilience in northeastern Illinois. In 2013, the Obama Administration released a Climate Action Plan to outline a national climate strategy, with recommendations for carbon reduction, adaptation, and international leadership to foster global climate action. This launched several federal resources and programs for climate resilience:

- [National Climate Resilience Toolkit](#) provides guidance on how to conduct local climate resilience planning.
 - Frameworks to assess transportation vulnerability to climate change from the [Federal Highway Administration](#) and [Federal Transit Administration](#), which have led to local transportation asset management studies from IDOT and [CTA](#) that examine road, bridge, and rail vulnerabilities to climate change and disaster.
- [2014 National Climate Assessment](#), which provides updated data for modeling and scenario planning, including regional downscaled models that inform our understanding of historical trends and project climate impacts in the future.

At the UN climate negotiations in December 2015, 187 countries adopted the universal and legally binding [Paris Agreement](#) that calls for key outcomes that support climate action. The United States pledged to reduce its emissions by 26 to 28 percent relative to 2005 levels by 2025, and by 80 percent by 2050.⁵⁰

⁵⁰ In comparison, GO TO 2040's GHG targets called for a reduction in the rate of GHG emissions to 10 percent *above* 2005 baseline levels.

The federal government has established several initiatives to achieve these targets. First is the [Clean Power Plan](#), the first federal regulation that limits carbon pollution. The Plan calls for a 32 percent reduction of emissions from power plants based on 2005 levels by 2030. Under the Clean Power Plan, each state has a customized carbon reduction goal and decides how best to meet that target. Illinois's state plan, currently under development, requires a 30 percent reduction of carbon pollution from its power plants by 2030.⁵¹ In addition, fuel efficiency standards and investments in renewable energy and energy efficiency will further reduce emissions. These national actions provide resources and policy directions for state, regional, and local governments. ON TO 2050 can contribute to national efforts by developing robust policies to build resilience in the Chicago region.

Regional Climate Resilience Framework

Guiding Principles of a Resilient Region

Strategies to build regional climate resilience must address a range of issues, from standards for the built environment to practices for natural resource management to open channels of communication. Through a series of visioning activities, the Climate Resilience Resource Group developed three overarching principles. These principles provide a framework for the region to develop resilience strategies: (1) responsive and robust infrastructure, (2) participatory and integrated processes, and (3) equitable reduction of vulnerability. Together, these guiding principles acknowledge the interconnected physical, ecological, and social systems that make up the region.

Responsive and robust infrastructure

To be more resilient, infrastructure should be more responsive to a wider range of climatic conditions. Infrastructure includes buildings, electricity grids, transportation networks, sewer pipes, and green infrastructure. In a resilient region, infrastructure is designed, operated, maintained, and retrofitted to withstand climate impacts for its designed life using the latest climate data.

Resilient infrastructure may also look different. Traditional infrastructure often contains highly centralized systems such as power plants, wastewater treatment facilities, and transportation control centers—all of which are still vital components of our region's infrastructure. From smart grids to green stormwater infrastructure, many types of infrastructure are moving toward networked systems that connect distributed and centralized components. Distributed infrastructure can take many forms, but all share certain benefits compared to their traditional, centralized counterparts: they are made up of several networked components that take up smaller footprints and allow more flexibility in siting and design. For instance, compared to

⁵¹ See more resources on Illinois requirements from EPA at <http://www3.epa.gov/airquality/cpptoolbox/illinois.pdf> and Natural Resources Defense Council at <https://www.nrdc.org/sites/default/files/PPP-Illinois-Compliance-IB.pdf>.

wastewater treatment facilities, green stormwater infrastructure can be scaled for small curb bump-outs and backyards. Just as green stormwater infrastructure can supplement, but not fully replace, sewer pipes, both distributed and centralized forms of infrastructure are necessary. Distributed infrastructure can build redundancies at multiple scales by providing multiple ways for a system to function and reducing sole reliance on a central facility.

Participatory and integrated processes

Resilience planning addresses both physical characteristics of the region and how information is communicated and decisions are made. Infrastructure management and operations have undergone technological advances, but gaps in cross-jurisdictional coordination that leverages these technologies remain. For example, platforms such as 911 calls and routing applications provide real-time information on car accidents, but most transportation agencies are not directly notified of these incidents and are therefore slow to respond. Cooperation across entities with varied boundaries, authorities, and inconsistent methods of data collection can be challenging. To address these issues, regional stakeholders must foster a better culture of collaboration to implement resilience strategies.

Regional partners can improve how they communicate by reducing siloes across jurisdictions and sectors. First, better standardization of data collection and more effective mechanisms for sharing information among peer agencies can improve the ability of stakeholders to communicate. Partners can also expand what they communicate by relying upon multiple forms of information, from technical to experiential, to guide decision making. For instance, hydrologic modeling paired with resident-generated data of flooding impacts can provide decision-makers with a more holistic understanding of the contributing factors to flooding. Furthermore, processes that cultivate expertise from all sectors from the outset ensure widespread ownership of the outcomes that is critical to implementation. In addition, a more inclusive approach to data collection increases the capacity of vulnerable residents to participate in analysis and decision making.

Equitable reduction of vulnerability

Climate impacts do not affect all communities in the region equally. A community's geographic location, physical and socioeconomic characteristics, and capacity can significantly influence its degree of vulnerability to climate change. At the broadest level, our region should emphasize strategies that reduce impacts of climate change, particularly in communities that are least equipped to respond to climate change. At a community scale, resilient municipalities should ensure the provision of critical services in all conditions. Capacity building and physical planning practices should strengthen social cohesion among residents, particularly vulnerable populations, to create the community networks necessary to withstand and recover from climate impacts.

Regional Climate Resilience Strategies

The three guiding principles above set the foundation for the policies needed to build resilience to climate change in northeastern Illinois. The strategies fall under six main themes:

- Planning for Climate Change
- Promoting Climate-Resilient Infrastructure
- Building Resilient Transportation Networks
- Addressing Climate Change through Natural Resource Management
- Building Resilience in the Energy Sector
- Fostering Economic Resilience
- Building Capacity for Resilience Planning

The strategies presented below recommend actions that CMAP should take to improve resilience and identify specific agency programs or projects that can implement the recommendations. CMAP functions broadly include transportation programming, the Local Technical Assistance Program, guidebooks, policy research, and ongoing or upcoming work to develop ON TO 2050. Strategies that should be led primarily by other regional partners with limited involvement from CMAP are described in Appendix B.

Planning for Climate Change

CMAP should pursue integrated land use and infrastructure planning that accounts for current and future climatic conditions. The land use and infrastructure decisions made today have significant implications for the region's future mobility, natural systems, and patterns of development. A built environment that is designed to withstand and respond to expected and unforeseen climatic conditions can improve the livability of our communities. ON TO 2050 can provide underlying regional data and policy direction needed to inform local planning efforts, as well as guidance for regional and local partners for taking actions that build resilience to climate change.

Achieve greater livability through resilience planning

As defined in GO TO 2040, livable communities are healthy, safe, and walkable. They provide a variety of transportation choices, recreational spaces, access to jobs and education, cultural offerings, and opportunities to participate in public processes. As climate change affects the region, communities must build resilience to continue to foster livability. Resilient and livable communities should mitigate greenhouse gas emissions that contribute to climate change and prepare for the increasing impacts of climate change.

Infill development, improved pedestrian and bicycle infrastructure, increased investments in public transit, and more efficient consumption of energy all contribute to climate mitigation, not to mention reduced congestion. ON TO 2050 should re-emphasize GO TO 2040's recommendations for climate mitigation as part of a regional resilience policy. Resilient and livable communities should anticipate negative impacts of climate change and enact strategies to thrive in the face of changing conditions. Through investments in resilient infrastructure and

planning, residents of resilient communities will have strong social networks; access to multiple transportation alternatives; and reduced vulnerabilities to heat-related illnesses. The strategy recommendations detailed in subsequent sections will help communities become more resilient and livable by 2050.

Integrate resilience policies into existing planning processes

Climate resilience planning is an emerging topic for many communities in the region. Building a resilient region entails a wide range of strategies for physical, social, and ecological systems. While some communities may choose to develop standalone climate action or resilience plans, there are many opportunities to integrate climate resilience considerations into other planning efforts.

Local governments conduct many types of planning processes, such as comprehensive plans, sub-area plans, capital improvement plans (CIPs), watershed plans, hazard mitigation plans, and issue-based plans such as sustainability, transportation, or economic development plans. Given the range of planning efforts that may govern a single community, it is important to align local plans so that they reinforce consistent resilience policies across scales and topic areas. Different units of government are responsible for different kinds of planning. Municipalities typically oversee comprehensive plans, sub-area plans, and CIPs while counties conduct stormwater, watershed, and hazard mitigation plans. Park districts and forest preserve districts also often have separate planning processes that oversee parks, open spaces, and natural resource management.

All too often, these planning processes are uncoordinated. At the broadest level, county hazard mitigation plans provide information about climate and other risks facing a community. Hazard mitigation plans, which provide significant climate risk data but are not typically reviewed for comprehensive plans, are a helpful starting point to align local plans with county policies. Local planning projects conducted through CMAP's Local Technical Assistance (LTA) program, as well as by government and consultants, should emphasize the vertical and horizontal alignment of climate recommendations within local plans at community and county levels.

Each of these planning processes should also consider how climate change affects the plan's priorities. For example, future land use plans that consider current and projected precipitation patterns can promote community growth in low flood risk areas or recommend design strategies for developments that are susceptible to flooding. CIPs can guide short-term capital investment priorities that support stronger and smarter infrastructure. Economic development plans can examine the financial impacts of climate-related disruptions on local economies, recommend resilient supply chain practices, and encourage growth in green industries. Standalone resilience plans are also an option for communities that are interested in pursuing more detailed analysis and strategies on resilience. These plans typically address the threats of climate, but some also touch upon economic resilience or other external factors. [Resilient New Orleans](#) and [A Stronger, More Resilient New York](#) are two such examples of recent resilience plans. The City of Chicago has also received a grant from the Rockefeller Foundation's 100 Resilient

Cities initiative to hire a new Chief Resilience Officer and develop its own resilience plan.⁵² The LTA program should serve as a primary mechanism to develop an approach for integrating climate change into local planning.

Update development regulations to prepare for a changing climate

To conduct climate-informed land use planning, municipalities and counties can update building codes, floodplain and stormwater regulations, zoning ordinances, subdivision standards, and other regulations pertaining to physical developments so that buildings, landscaping, and site planning take climatic conditions into consideration. For instance, updated ordinances can promote appropriate structural design standards and landscaping practices that increase the resilience of the built environment in flood-prone areas. Counties control stormwater ordinances that set standards for stormwater management in new developments. These strategies can also further climate mitigation goals by promoting energy efficiency and compact development. CMAP can be a regional leader in climate-ready regulations by incorporating climate considerations in LTA projects that relate to regulations, such as stormwater assessments and zoning and subdivision updates. CMAP and other planning entities should identify best practices and new strategies to meet resilience goals while continuing to encourage reinvestment.

Promoting Climate-Resilient Infrastructure

From road and rail buckling to bridge scouring to flooding, the region's infrastructure has experienced significant damages from extreme heat, heavy precipitation, and increasing freeze-thaw cycles. To be more resilient, infrastructure should be designed to accommodate a wider range of climate conditions. This can be achieved not only by updating design standards for infrastructure construction, but also by building multiple scales of redundancies in the face of shocks and stresses. The overarching strategies in this section apply to a range of infrastructure types, including water, stormwater, sewer, transportation, energy, and green infrastructure. Strategies specific to the last three systems—transportation, energy, and green infrastructure—are also discussed in more detail in later sections.

Update infrastructure design standards

Most of the region's roads and stormwater systems were designed using climate data that no longer matches the hotter and wetter conditions that the region has seen. To improve long-term performance, infrastructure should be built or retrofitted based on the climate conditions for its designed lifespan.

Design standards are meant to improve the lifespan and usability of infrastructure. The [Urban Flooding Awareness Act Report](#), conducted by the Illinois Department of Natural Resources (IDNR) in 2015, highlights the regulatory lag between climate science and infrastructure design policies. Bulletin 70, the most widely accepted rainfall data used to determine infrastructure

⁵² For more information on the Rockefeller 100 Resilient Cities program, please see <http://www.100resilientcities.org/cities/entry/chicago>.

design standards, relies upon data that is over 30 years out of date. IDNR calls for an update to Bulletin 70 that incorporates current rainfall gauge data and a regular update process every 10-15 years. ON TO 2050 should support this recommendation. State and local infrastructure agencies should conduct comprehensive reviews of design manuals (such as IDOT's Bureau of Local Roads and Streets Manual) to ensure that the underlying data used in their design standards are in line with best available information and that other aspects of physical design allow for resilience best practices. CMAP does not have a direct role in implementing this strategy, but considers it an important step for local planning.

Encourage infrastructure that provides multiple benefits

Infrastructure has also typically been designed to serve single-purpose functions: stormwater pipes are designed to convey runoff and the electrical grid is designed for delivering power. Infrastructure can build resilience by supporting multiple benefits and planning objectives. Complete and green streets are a great example of roadway design that can integrate green infrastructure, urban forestry, pedestrian and bicycle safety, and placemaking. Multi-purpose infrastructure planning results from integrated planning processes that enable collaboration across departments and sectors. Complete streets implementation, for instance, requires coordination between transportation agencies, stormwater engineers, and planners, civic groups promoting active transportation, and neighboring businesses. Multi-purpose infrastructure also makes economic sense as a more efficient use of capital investments when accounting for the full range of benefits.⁵³

Various design guidelines are beginning to encourage projects that provide multiple benefits. For instance, the Chicago Department of Transportation's [Sustainable Urban Infrastructure policies and guidelines](#) codify lessons learned from the city's pilot projects into a single resource that actively promotes green infrastructure in public rights-of-way to build resilience. In addition to physical design guidelines, partners can introduce more integrated processes that foster multi-purpose investments. Regularly scheduled coordination meetings, for instance, can allow departments to collaborate on capital projects.

While CMAP does not directly control infrastructure design, CMAP can prioritize infrastructure that provides co-benefits in performance-based programming. As part of ON TO 2050, CMAP and local governments can work to identify existing barriers to multi-benefit capital projects and update the appropriate standards and processes to enable infrastructure that can provide co-benefits such as stormwater management or heat island reduction.

Protect critical assets

Centralized facilities, such as energy generation and distribution facilities, hospitals, water and wastewater treatment plants, telecommunication facilities, and transportation control centers, are vital components of our region's infrastructure. Facility operators can conduct and implement climate vulnerability assessments for critical regional and community facilities to

⁵³ Chicago Department of Transportation, 2013, Sustainable Urban Infrastructure: Policies and Guidelines, Vol. 1, <http://www.cityofchicago.org/content/dam/city/depts/cdot/Sustainable%20Transportation/SUIGv1.pdf>.

improve physical and operational preparedness for climate impacts. When available, partners should look to guidelines from regulators, such as FEMA or the Department of Homeland Security, for standards of critical facilities protection.

Partners that directly control assets are the main implementers of this strategy, but CMAP can also facilitate coordination of critical asset protection through regional groups. CMAP can promote this strategy through its membership in the Calumet Stormwater Collaborative, which works to reduce the negative impacts of flooding in southern Cook County. CMAP's current participation on a Steering Committee for IDOT's transportation vulnerability assessment is one example of how the CMAP can support infrastructure agencies in carrying out this work. At the community level, CMAP can help municipalities identify important local assets and make recommendations in LTA plans that take context-specific needs and climate impacts into account.

Building Resilient Transportation Networks

Well-functioning, integrated, and low-emissions transportation systems are a critical part of a resilient region. GO TO 2040 policies for compact development and active transportation help reduce vehicle-miles traveled (VMT) and greenhouse gas emissions from the transportation sector. GO TO 2040 also calls for investments that will transform the region's transportation system into a modern, world class network. The ON TO 2050 plan offers an opportunity to reiterate some of these goals through a climate resilience lens, while also adding new policies that reduce the vulnerability of transportation networks to climate change.

Strengthen transportation infrastructure to withstand climate changes

Transportation modernization efforts should promote infrastructure that is built for the climate of its designed lifespan. As noted earlier, the region's transportation infrastructure has already experienced many negative impacts from climate change, which is only expected to worsen in the future. This toll will continue to reduce the capacity and performance of transportation systems.⁵⁴

CMAP should incorporate climate-resilient investments in its capital project evaluation and transportation programming. CMAP already considers the impacts of greenhouse gas impacts of capital projects. CMAP will explore additional climate resilience criteria, such as additional design requirements for projects in flood-prone areas. Strategy development around transit modernization will address issues of climate resilience for transit systems. Similar considerations can be applied to other areas of transportation asset management at all scales. Local transportation agencies and public works departments can also address this policy through capital improvement planning and routine transportation maintenance. The Regional Transit Authority (RTA) is also undertaking a study to assess flooding impacts on Pace bus routes. At the state level, the Illinois Department of Transportation (IDOT) is currently conducting a climate vulnerability assessment of its statewide transportation assets, which may

⁵⁴ 2014 National Climate Assessment: <http://nca2014.globalchange.gov/report/sectors/transportation>.

serve as a good starting point to pinpoint the types of investments to make the Chicago region more resilient to climate impacts. These and other transportation agencies should periodically conduct such studies as climate data is updated. CMAP's strategy paper on asset management provides a more direct avenue to address issues of infrastructure investments and maintenance.

Ensure multiple transportation options

The physical condition of transportation infrastructure is not the only aspect of a resilient system. Residents that have access to a diversity of transportation options are less vulnerable to external factors, such as road closures, as well as individual factors, such as car breakdowns or lack of car ownership. When roads or transit lines are disrupted, multimodal transportation options ensure continued mobility access. Alternative routing around affected roadway segments can direct drivers to other streets, as well as other modes of transportation. While our region boasts many transportation options, the routes and schedules of transportation networks can be better coordinated. Moreover, the levels of service can be increased in transit-supportive communities.

GO TO 2040 lays a strong policy foundation for a multimodal transportation system that serves transit riders, bicyclists, pedestrians, and drivers. ON TO 2050 should support more multimodal transit services as a strategy to increase redundancies in the transportation system. Land use planning that encourages transit-supportive densities can provide the demand necessary for multimodal hubs. Safe pedestrian and bicycling infrastructure can increase redundancies for short-distance trips. These strategies are also important for climate mitigation, as they offer low-carbon alternatives that reduce automobile use.

Communities should prioritize redundancies in places that are likely to be most affected by climate disruptions. This may mean increasing transportation options to major employment centers or increasing ad hoc services to emergency shelters or cooling centers in events of flooding or extreme heat. Lastly, communities should also ensure that their most vulnerable residents have access to multiple transportation options. Divvy, the region's bike sharing program, provides an example of improving mobility in vulnerable communities through network expansions and affordability programs. Divvy is not only increasing the number of bike stations in low-income communities, but has also initiated a Divvy for Everyone (D4E) program that offers discounted annual memberships for low-income households.⁵⁵

Coordination across transportation agencies is necessary to build multimodal redundancies. For instance, disruptions in Metra services can be alleviated by Pace or CTA bus services. The Regional Transit Authority, which oversees planning and funding for all of the region's transit agencies, should continue to provide leadership for coordinated multimodal planning. CMAP can support these efforts through its transportation programming function, as well as transportation recommendations in LTA projects.

⁵⁵ <https://www.divvybikes.com/d4e>

Adopt smarter transportation infrastructure management technologies and practices

A resilient transportation network maintains service continuity through disruptions. Transportation agencies are exploring how smart infrastructure technologies for traffic management can improve resilience. Currently, transportation control centers have limited ability to monitor conditions in the field when flooding, accidents, or other disruptions occur. Improved communications systems can allow for information to be relayed to and from control centers, field devices, and operators.

For instance, real-time monitoring and communications can smoothly reroute traffic in times of emergencies, congestion, special events, signal outages, or road closures. Some efficiencies can be gained by coordinating management practices. For instance, the Lake County Division of Transportation worked with the county's emergency call centers to establish automatic notifications of traffic incidents. Before this system, the Division of Transportation was often unaware of incidents that affected traffic or damages to their equipment during crashes. Now, the Division has been able to more efficiently respond to incidents. Although this seems simple, Lake County is the only county in the Chicago region with this integrated practice to date.⁵⁶

Other management practices can be improved through new technologies. Technologies such as sensors on roads and traffic signals can also enable adaptive signal control for efficient routing. These practices enable decision-makers to direct commuters toward alternative routes or transportation modes. One example of this strategy in practice is a partnership between the Commonwealth of Kentucky and Waze, a real-time community-based traffic and navigation app that uses user-generated data on accidents, flooded roads, construction, and other traffic disruptions to route drivers. Through a newly established Waze Connected Citizens program, the Kentucky Transportation Cabinet provides the app with data from road sensors and planned capital projects and Waze provides the Transportation Cabinet with incident reports.⁵⁷ With up-to-date crowd-sourced information, the Transportation Cabinet is able to more efficiently respond to issues on the road. This partnership enables two-way data sharing that ultimately improves the resilience of the transportation network.

CMAAP can use transportation network analyses to refine its understanding of the impact of extreme weather on transportation behavior. In addition to identifying roads that are most vulnerable to flooding, such analyses can also identify potential alternative routes, highlight road segments that warrant flood-proofing, determine the impact of road outages on commuting patterns, and increase the overall resilience of the street network. Further research on infrastructure management will be explored in separate strategy development efforts on highway operations, transit modernization, and technological advances in transportation.

⁵⁶ CMAP 2013, Briefing: Public Safety Answering Point (PSAP) to Transportation Operator Data Integration, http://www.cmap.illinois.gov/documents/10180/211812/RTOC_PSAP_Integration_Outreach.pdf/4642be34-f5b6-446e-a187-77878f921b4f.

⁵⁷ <http://migration.kentucky.gov/Newsroom/kytc/2015-01-07+WAZE+Connected.htm>

Addressing Climate Change through Natural Resource Management

Heat, flooding, and drought have significant implications for the region's natural resources. The prairies, savannahs, wetlands, forests, and lake and riverine systems in northeastern Illinois house a diversity of native flora and fauna. These natural resources have a range of functions in protecting the region from climate change, including stormwater management and the mitigation of greenhouse gas emissions, but must also be actively managed and protected as the climate changes.

Increase biodiverse ecosystems

Communities can increase resilience by encouraging more biodiverse ecosystems, which mitigate climate change through carbon sequestration. Vegetation and soils store carbon, thereby reducing greenhouse gases. A CMAP-supported Chicago Wilderness study found that a large tree can remove over 1,000 pounds of CO₂ per year. In total, the region's green infrastructure contributes to an estimated \$11.5 million of carbon sequestration services each year. GO TO 2040 calls for a target of conserving 400,000 acres of open space by 2040. This goal should remain a key strategy to address climate change in ON TO 2050. The green infrastructure strategy paper, also produced by CMAP as part of ON TO 2050 development, provides a more in-depth discussion of conservation policies in the next plan.

Both terrestrial and aquatic ecosystems should also be managed to prepare for a changing climate. Biodiverse ecosystems can better withstand invasive species and diseases and endure the impacts of extreme flooding and drought. Many of the region's native species are naturally flood- and drought-tolerant. Although many native ecosystems have been replaced by developments or non-native landscaping, communities and stewardship groups are increasingly promoting native landscaping that can cultivate healthy ecosystems for a range of weather conditions.

At the local level, CMAP can increase biodiversity by promoting landscaping ordinances and conservation design practices that support native species. The City of Chicago [Urban Tree Planting List](#) provides a good example of how a municipality can provide recommendations on tree species that are most suited for various contexts, including hardiness, biodiversity, salt tolerance, and climate change readiness.⁵⁸ CMAP should also continue to work with regional partners on research, analysis, and cross-jurisdictional implementation of resilient natural resource strategies. As a member of Chicago Wilderness, for instance, CMAP can work with partners to protect priority species from climate change and improve native habitats across the region. The Chicago Regional Trees Initiative (CRTI), of which CMAP is a partner, also provides collaborative opportunities to increase the health and diversity of the region's urban forest. CRTI's Regional Tree Census can help CMAP and other local partners identify biodiversity priorities and its collaborations with the tree industry can set forestry management standards.

⁵⁸ City of Chicago Urban Tree Planting List, http://www.cityofchicago.org/content/dam/city/depts/streets/supp_info/Forestry/Forestry%202013/Chicago_Urban_Tree_Planting_list_2012.pdf.

Support adaptive management of water resources

The Great Lakes comprise 84 percent of North America's surface freshwater supply and 21 percent of the global surface freshwater supply and serve not only as a vital source of drinking water, but also an important habitat for aquatic species. With many parts of the country and world facing significant water shortages, the Great Lakes are one of northeastern Illinois' most invaluable natural assets. Currently, 77 percent of the population in the Chicago region relies on Lake Michigan for its drinking water.⁵⁹

Changes in temperature and precipitation levels affect both the water levels and quality of waterbodies in the region. Projections do not indicate significant changes to Lake Michigan water levels,⁶⁰ but several other changes are anticipated. Water quality will be a significant issue for Lake Michigan and the region's rivers and streams. Higher temperatures and increased runoff from greater precipitation are leading to more algal blooms and combined sewer overflow events that impair water quality.⁶¹ With decreasing ice coverage on the Great Lakes, shorelines are more vulnerable to erosion and habitat degradation.⁶²

In addition to impacts on surface water, climate change and development will also affect water withdrawal rates from the groundwater supply. Water demand from all sectors is expected to increase by up to 12 percent under a high-emissions scenario.⁶³ Alongside increases in overall precipitation levels, the projected increases of drought periods also highlight the need for balancing water uses in a range of precipitation scenarios that may vary seasonally.

As recommended in Water 2050, the Chicago region should account for the uncertain impacts of climate change on water resources by practicing adaptive management. Adaptive management supports more iterative processes that allow decision-makers to address the range of flood-to-drought conditions the region is expected to see in the future.⁶⁴ Through the continued monitoring, evaluation, and learning associated with adaptive management, decision-makers can adjust their actions with increasingly better data and understanding.⁶⁵ This strategy uses recommendations from GO TO 2040 and Water 2050, the regional plan for guiding water

⁵⁹ CMAP, 2010, Water 2050, <http://www.cmap.illinois.gov/documents/10180/14452/NE+IL+Regional+Water+Supply+Demand+Plan.pdf/26911cec-866e-4253-8d99-ef39c5653757>.

⁶⁰ CMAP, 2013, Primary Impacts of Climate Change in the Chicago Region, <http://www.cmap.illinois.gov/documents/10180/14193/Appendix+A+-+Primary+Impacts+of+Climate+Change+in+the+Chicago+Region.pdf/2a85b021-f3bd-4b98-81d1-f64890adc5a7>.

⁶¹ National Climate Assessment: Midwest, 2014, <http://nca2014.globalchange.gov/report/regions/midwest>.

⁶² National Climate Assessment: Midwest, 2014, <http://nca2014.globalchange.gov/report/regions/midwest>.

⁶³ CMAP, 2010, Water 2050, <http://www.cmap.illinois.gov/documents/10180/14452/NE+IL+Regional+Water+Supply+Demand+Plan.pdf/26911cec-866e-4253-8d99-ef39c5653757>.

⁶⁴ CMAP, 2010, Water 2050, <http://www.cmap.illinois.gov/documents/10180/14452/NE+IL+Regional+Water+Supply+Demand+Plan.pdf/26911cec-866e-4253-8d99-ef39c5653757>.

supply and demand. The policies to improve water efficiency and reduce water consumption provided in GO TO 2040 remain important to building resilience in the water sector. CMAP is still in the process of determining how the agency should address water in ON TO 2050 and should build these climate change considerations into the final water policy framework.

Build climate resilience through green infrastructure

In addition to maintaining the health of the region's rich natural assets, the next plan should encourage green infrastructure as a first line of defense against climate impacts. At regional, community, and site scales, green infrastructure can reduce the impacts of flooding and urban heat island effect. The strategy directions presented here build upon the green infrastructure framework presented in a separate strategy paper, but focus on the benefits of green infrastructure for climate resilience.

Green infrastructure builds ecological redundancies at multiple scales. At the regional scale, interconnected natural areas make up the region's green infrastructure network. Site-scale green infrastructure practices use vegetation, soils, and natural processes to provide or mimic natural ecological functions, such as bioswales that capture stormwater. Like transportation redundancies for climate resilience, green infrastructure at all scales ensures a diverse array of ecological functions for specific sites, communities, and the entire region. Green infrastructure also provides a level of redundancy for gray stormwater infrastructure when storm sewers are overwhelmed by runoff. Green infrastructure can also play a significant role in reducing urban heat island effect. As CMAP's analysis of land surface temperature shows (see Table 1 and Figure 12), highly developed lands are 6.6 degrees Fahrenheit hotter and forested lands are 1.9 degrees Fahrenheit cooler than the average regional temperature. Increasing the tree canopy through urban forestry initiatives is an effective strategy for reducing urban heat island effect and mitigating the negative impacts of development.

GO TO 2040 supports the integration of green infrastructure into land use and site planning for stormwater management. ON TO 2050 can build upon those practices to encourage the use of green infrastructure for a wider range of climate resilience benefits, including carbon sequestration, reduction of urban heat island effect, and continued water quality improvements and flood control. Currently, CMAP is developing a robust methodology for identifying areas that are more susceptible to flooding. This initiative will help communities target green infrastructure and other land use-based solutions for critical areas. CMAP can apply this analysis to zoning and planning in future LTA projects to improve the effectiveness of stormwater recommendations in local plans. A forthcoming stormwater strategy will provide an opportunity translate these practices into regional stormwater policies.

Prepare agriculture resources for climate change

The region produces many agricultural crops. Warmer average temperatures have been lengthening growing seasons, enabling greater agricultural productivity. At the same time, increased frequency of freeze-thaw cycles also lead to crop losses and greater survival rates of invasive pests that are detrimental to crop yields—particularly for fruit crops.

ON TO 2050 is expected to support existing agricultural policies laid out in GO TO 2040, and can use climate resilience as a lens to address existing agricultural recommendations. GO TO 2040 calls for promotion of urban agriculture and increased access to fresh, nutritious, and affordable foods. Both of these strategies increase food security in the event of extreme events, as well as lead to a greater diversity of crops that can be less susceptible to climate impacts. Together, these strategies can be combined with specific climate preparedness techniques that increase agricultural resilience to climate change. For instance, the use of cover crops and no-till farming can increase soil health and reduce heat island impacts from crop lands. In addition, irrigation that is based on weather patterns rather than fixed schedules can reduce water usage.⁶⁶ CMAP has a limited role in implementing these practices, but can work with local stakeholders to access resources on resilient agricultural practices.

Building Resilience in the Energy Sector

Energy generation and consumption is inextricably tied to climate change. Energy from fossil fuels is a primary driver of climate change, and increased need for cooling due to higher average and peak temperatures will raise the burden on the region's electricity grid. ON TO 2050 should reiterate the energy recommendations of GO TO 2040 regarding energy efficiency and renewable energy generation. This year, a separate CMAP effort will more fully explore potential regional energy policies for ON TO 2050. The energy strategy should build upon the resilience framework presented in the climate resilience strategy paper. Among other issues, the energy strategy should consider the following:

- **Increase renewable energy generation.** Solar, wind, and other types of renewable energy produce less emissions than traditional fossil fuel-based sources. Given the Clean Power Plan's requirements to reduce statewide carbon emissions, communities are likely to increase reliance on renewable energy. As recommended in GO TO 2040, local governments can update zoning codes to permit rooftop renewable energy generation as well as standalone renewable energy systems.
- **Strengthen energy infrastructure for a changing climate.** As many residents have experienced firsthand, inclement weather is one of the most common causes of power outages in the region. Energy utilities and local governments have been improving storm hardening efforts to protect energy infrastructure from the impacts of extreme weather. In new developments, utilities are typically buried underground, but overhead utilities in older communities remain vulnerable to climate impacts. The strategy paper can explore how the energy utilities, local governments, and private companies can design and maintain energy infrastructure to better withstand extreme weather.

⁶⁶ Natural Resources Defense Council, *Soil Matters Issue Paper*, August 2013, available at: <http://www.nrdc.org/water/soil-matters/files/soil-matters-ip.pdf>.

- **Support decentralized energy generation and distribution.** Energy infrastructure decentralization can also build resilience to climate change by increasing redundancies in electricity generation and distribution. Decentralized energy infrastructure can take many forms. Rooftop solar and wind can provide power for homes and commercial facilities to reduce the burden on the grid during peak times. Microgrids are localized power grids that can connect to the main grid or function independently. District energy systems use steam and hot or chilled water to heat buildings and are commonly used in downtown areas or large campuses. Cogeneration, or combined heat and power (CHP), is a form of distributed energy that produces both heat and electricity from a single fuel source (including both renewables and fossil fuels). These alternatives can improve energy efficiency, reduce greenhouse gas emissions, and build resilience by diversifying the energy supply. All of these systems can be especially useful to increase the resilience of important facilities, such as hospitals, industrial facilities, or downtown districts. The energy strategy paper can provide regulatory, financial, and other recommendations to encourage more widespread distributed energy infrastructure.

Fostering Economic Resilience

Climate impacts affect the vitality of our regional economy. A resilient economy can withstand climate-related weather disruptions and other types of crises, shocks, and changes. CMAP can help to build economic resilience that reduces vulnerability to climate change by addressing vulnerabilities of the region's communities and industry clusters.

Reduce community vulnerability to climate change

Economic and climate resilience are closely related. Many of the communities that are hardest hit by climate impacts have also faced significant disinvestment. It is more cost-effective to invest in climate preparedness than to pay for damages from climate impacts. A study by the Multihazard Mitigation Council estimates that each dollar spent on advanced planning to reduce the impact of disasters saves four dollars of recovery expenses.⁶⁷ As research from the Center for Neighborhood Technology on chronic flooding shows, the continual diversion of resources to respond to climate impacts is eroding the economic bases of many communities in the region.⁶⁸ It is essential to ensure that those in greatest need can meaningfully participate in resilience planning and build community resilience to climate impacts. CMAP is currently developing a strategy to address inclusive growth, which will define strategies to help include more of the region's residents in the economy. The inclusive growth strategy development will include an analysis of the distribution of the region's most vulnerable residents and provide recommendations for improving access to economic opportunity for those residents. As a next step, CMAP should conduct a more targeted analysis to better understand the effects of climate

⁶⁷ Multihazard Mitigation Council, 2005, *Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities*, available at:

https://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/MMC/hms_vol1.pdf.

⁶⁸ Center for Neighborhood Technology, 2014, *The Prevalence and cost of Urban Flooding*,

http://www.cnt.org/sites/default/files/publications/CNT_PrevalenceAndCostOfUrbanFlooding2014.pdf.

change on the vulnerable communities identified through the inclusive growth work. By integrating the climate resilience and inclusive growth analyses, CMAP can develop strategies that can simultaneously build resilience for the region's most environmentally and economically vulnerable residents.

Increase the resilience of freight networks

Resilient mobility strategies should address the movement of both people and goods through the region. Northeastern Illinois is home to the country's largest rail hub and depends on a well-functioning freight system to support the national and regional economy. Severe weather events can disrupt supply chains and shipping routes which can lead to significant economic implications that extend beyond the Chicago region. In 1999, a major blizzard shut down Chicago region's rail lines, disrupting goods movement nationwide and passenger rail services for months.⁶⁹ The national impacts of this winter storm highlighted the need for improved collaboration among railroads and government agencies to reduce vulnerabilities in the freight system. The partnership of freight railroads, passenger railroads, and federal, state, and local transportation agencies resulted in the Chicago Region Environmental and Transportation Efficiency (CREATE) program. Today, CREATE is recognized as an effective public-private initiative for addressing shared day-to-day and long-term issues, such as congestion, infrastructure management, and investments in the rail system.

The intersection of freight and climate change is an emerging national topic,⁷⁰ but has not been explored in great detail at the regional level. As CMAP continues policy analysis on freight as a priority economic cluster, the agency should explore the potential implications of climate change on the regional freight network and strategies that can improve the resilience of the freight system to climate change. Efforts like the CREATE program could provide inter-agency platforms for developing coordinated actions that build resilience.

Build resilience for the region's economic clusters

Climate change will affect the many industries that make up the region's diverse economy. CMAP has conducted significant research on economic clusters, or the areas of economic specialization, in the region. From small, local businesses to multinational companies, many economic leaders in northeastern Illinois are already taking steps to build resilience. As the regional business leaders forum on "Defining Resilience for Economic Advantage" highlighted, companies are addressing resilience in a multitude of ways. These strategies include reducing the vulnerability of supply-chain operations to extreme weather; investing in manufacturing of resilience-building products such as mold-resistant materials; incorporating site-specific resilient design practices on business properties; and instituting more flexible human resources practices to accommodate weather-related disruptions for employees. ON TO 2050 can help to better understand climate change impacts on the regional economy and engage the region's

⁶⁹ For more information, see: http://www.nytimes.com/2012/05/08/us/chicago-train-congestion-slows-whole-country.html?_r=0

⁷⁰ See, for instance, this US DOT report on the Potential Impacts of Climate Change on Freight Transportation: <http://climate.dot.gov/documents/workshop1002/caldwell.pdf>.

private sector actors on strategies to build resilience. To build upon CMAP's extensive prior policy analysis on regional economic clusters, CMAP is planning to conduct further research on economic resilience. This research will build upon the resilience framework provided through the climate resilience effort to explore various frameworks for economic resilience.

Building Capacity for Resilience Planning

Adaptive capacity—or the ability to respond to changing circumstances—is a key component of building resilience to climate change. Regional partners can reduce vulnerabilities to climate change by ensuring that processes and operations are flexible and can respond to changing conditions. CMAP can better prepare regional partners to implement resilience strategies by building community capacity and providing opportunities for collaboration and resource-sharing.

Build community capacity

Many recommendations of the climate resilience strategy are targeted at local government partners. Local governments can play a significant role in addressing climate change. Regional, national, and global initiatives such as C40, Urban Sustainability Directors Network, ICLEI—Local Governments for Sustainability, Prairie State Network, Greenest Region Compact, and the Calumet Stormwater Collaborative provide networks for local governments to exchange best practices to address climate change and other environmental issues.

Many communities that are experiencing significant climate impacts, however, lack the capacity and resources to sufficiently address climate impacts. Capacity constraints can lead to systemic barriers in addressing a variety of planning issues, from reinvestment to climate change. In a resilient region, communities throughout northeastern Illinois should have equal opportunities to access to resources to conduct climate resilience planning. This entails having data and information about climate change, conducting climate resilience planning, and accessing financial resources to implement resilience initiatives.

CMAP's Climate Adaptation Guidebook for Municipalities in the Chicago Region, published in 2013, provides a basic overview of climate changes and strategies for public works infrastructure. CMAP also partnered with the Midwestern Regional Climate Center and Illinois State Climatologist Office to host a Resilient Chicago workshop that featured presentations from a variety of experts on the ecological, infrastructure, and public health impacts of climate change. CMAP can add to these resources by providing direct trainings on climate resilience planning through the LTA program. CMAP is also exploring strategies to build community capacity through upcoming strategy development. While the scope of that effort will cover community capacity broadly, the recommendations for strengthening community capacity can be able to be applied to resilience planning.

Provide climate data to build climate literacy and facilitate informed decisions

Regional stakeholders, from local elected officials to business leaders, need access to up-to-date data on climate science to make informed decisions. The Illinois Climatologist Office, Illinois State Water Survey, and Midwestern Regional Climate Center, among other entities, are charged with providing high-quality historical and projected climate data and monitoring climate changes. Many stakeholders, however, do not know about these resources or may not understand how data on precipitation or temperature changes can be applied to decision-making.

CMAP, in partnership with these and other institutions, can play a role in translating climate science to policymaking and planning. This strategy paper has resulted in new regional data about land surface temperature and social vulnerabilities to climate change. CMAP should continue to analyze climate impacts, such as regional stormwater flows. These data can be summarized through a forthcoming environmental snapshot that summarizes environmental conditions in the region and hosted on CMAP's [Data Sharing Hub](#). CMAP can also develop a consistent analytical approach for integrating climate vulnerability analyses into existing conditions research for comprehensive, capital improvement, and other plans completed through the LTA program. CMAP has already begun initial work on an automated climate vulnerability assessment tool that allows planners to evaluate the roadways, land uses, and populations in a community that are most affected by climate impacts. Ultimately, these actions build greater awareness about climate change and provide targeted guidance on how to make data-driven decisions.

Explore a platform for coordinating regional resilience initiatives

Many resilience strategies require coordinated sub-area, regional, or statewide action. Private, public, and non-profit partners across a variety of sectors have limited opportunities or incentives for cooperation. A regional partnership may be an effective way to ensure coordination of the many resilience-building policies, advocacy efforts, research needs, and best practice sharing needed to implement the ultimate recommendations of ON TO 2050. Whether this takes the form of a collective, a coalition, or a network, this platform can open channels for dialogue, knowledge exchange, and relationship building across regional stakeholders. The Climate Resilience Resource Group, convened as an ad hoc group to provide feedback on the development of the strategy paper, has been an effective outlet for cross-sector engagement. The Resource Group should identify whether a continued platform would be helpful for long-term resilience building, and if so, the objectives and structure of such a group.

Next Steps

The policy framework presented in this document sets the direction for climate resilience in ON TO 2050. Because climate resilience relates to many aspects of planning, from transportation and land use to community and economic development, this framework presents many resilience considerations for other planning topics in ON TO 2050 as well. CMAP expects these recommendations to inform future strategy papers, snapshots, technical assistance projects, policy updates, research products, and data sharing. The recommendations of ON TO 2050 are expected to synthesize these climate resilience strategies into a comprehensive vision for the region.

CMAP cannot achieve climate resilience goals alone. Regional partners are critical to the implementation of climate resilience practices. This document also includes recommendations aimed at partners in local and state governments, non-profits, philanthropy, and the private sector. Further discussions on the most effective way to continue regional collaboration will be essential to build regional resilience.

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Appendix A

The table below summarizes the climate resilience strategies by theme.

Table 3. Summary of Climate Resilience Strategies

Theme	Strategy
Planning for Climate Change	Achieve greater livability through resilience planning
	Integrate resilience policies into existing planning processes
	Update development regulations to prepare for a changing climate
Promoting Climate-Resilient Infrastructure	Update infrastructure design standards
	Encourage infrastructure that provides multiple benefits
	Protect critical assets
Building Resilient Transportation Networks	Strengthen transportation infrastructure to withstand climate changes
	Ensure multiple transportation options
	Adopt smarter transportation infrastructure management technologies and practices
Addressing Climate Change through Natural Resource Management	Increase biodiverse ecosystems
	Support adaptive management of water resources
	Build climate resilience through green infrastructure
	Prepare agricultural resources for climate change
Building Resilience in the Energy Sector	Increase renewable energy generation
	Strengthen energy infrastructure for a changing climate
	Support decentralized energy generation and distribution
Fostering Economic Resilience	Reduce community vulnerability to climate change
	Increase the resilience of freight networks
	Build resilience for the region's economic clusters
Building Capacity for Resilience Planning	Build community capacity
	Provide data to build climate literacy and facilitate informed decisions
	Explore a platform for coordinating regional resilience initiatives

Appendix B

Strong partnerships are critical for the implementation of ON TO 2050. Many of the ideas generated through the Climate Resilience Resource Group are best led by regional partners, from local governments to non-profit advocates to funders. The following table identifies strategies that should be primarily led by partner organizations. These actions complement the strategies most relevant for CMAP (strategies also directed at CMAP are italicized).

Table 4. Partner-Led Climate Resilience Strategies

Strategies		Lead implementers
Planning for Climate Change	<i>Achieve greater livability through resilience planning</i> <i>Integrate resilience policies into existing planning processes</i> <i>Update development regulations to prepare for a changing climate</i> Local governments have an especially vital role in planning for resilience. Policies, programs, and development regulations can be put in place to ensure that all planning processes work toward resilience goals.	Municipal and county governments, housing organizations
	Implement resilient building designs. Private developers and architects should design buildings and landscaping to reduce flooding impacts, increase energy efficiency, ensure compact development, and follow other principles of resilient design.	
Promoting Climate Resilient Infrastructure (includes buildings, transportation networks, energy infrastructure, stormwater and sewer pipes, and green infrastructure)	<i>Update infrastructure design standards</i> <i>Encourage infrastructure that provides multiple benefits</i> <i>Protect critical assets</i> With appropriate standards and funding in place, infrastructure agencies at local, county, and state levels should take the lead in making resilient infrastructure projects a reality. This includes updating outmoded design standards to be more resilient and incorporate multiple benefits. New development, redevelopment, and routine infrastructure maintenance projects provide opportunities to implement more resilient systems.	IDOT, RTA, CTA, Metra, Pace, Tollway, IDNR, county departments of transportation and stormwater, utilities, civic organizations, local, state, and federal governments
	Provide accessible funding for resilient infrastructure. Many traditional funding sources are not equipped to support collaborative processes to build multi-purpose infrastructure. Common funding barriers include unclear or onerous application requirements for new forms of infrastructure; inability to work across jurisdictions; difficulty aligning multiple funding sources for projects in the same place; and restrictive funding that prohibits interagency collaboration. These challenges inhibit innovative and efficient infrastructure planning. For instance, applications for the State Revolving Fund are still geared toward gray wastewater systems, making it confusing to apply for green infrastructure projects even though they are now eligible for funding. Sometimes simple updates, such as establishing clear checklists or enabling joint applications for multijurisdictional projects, can make it significantly easier to fund resilient infrastructure projects. Funding entities should also explore ways to align funding across agencies to streamline capital project construction and support more resilient infrastructure projects.	

Building Resilient Transportation Networks	<p><i>Strengthen transportation infrastructure to withstand climate changes</i></p> <p><i>Ensure multiple transportation options</i></p> <p><i>Adopt smarter transportation infrastructure management</i></p> <p>While CMAP can influence transportation policy and funding through CMAQ and TAP, transportation agencies have a primary role to play in managing assets and providing multiple options to increase redundancies.</p>	<p>IDOT, RTA, Metra, Pace, Tollway, CTA, county and municipal departments of transportation</p>
Addressing Climate Change through Natural Resource Management	<p><i>Increase biodiverse ecosystems</i></p> <p><i>Support adaptive management of water resources</i></p> <p><i>Build climate resilience through green infrastructure</i></p> <p><i>Prepare agricultural resources for climate change</i></p> <p>Resiliently managing the wide range of natural resources in the region requires collaboration across many issue areas including water supply, water quality, natural resource management, and agriculture. Attention should be given to managing both aquatic and terrestrial ecosystems and natural resources.</p>	<p>Forest preserve districts, land banks, land owners, natural resource managers, MWRD, ComEd, farmers, IEPA, IDNR, environmental non-profits, local governments, Illinois State Water Survey</p>
	<p>Develop smarter green infrastructure technologies. Emerging research is exploring the use of real-time data collection in monitoring green infrastructure performance for heat and flood control. On-site sensors can be installed in or near site-scale green infrastructure to monitor temperature, air quality, or rates of stormwater capture. For example, sensors installed alongside green stormwater infrastructure can allow operators to determine when and where parts of the system are overwhelmed so they may adjust the flow of stormwater into the system accordingly. GO TO 2040 identifies uncertainties around green stormwater infrastructure performance as a major barrier to implementation. The collection of performance data can also allow operators to evaluate the effectiveness and improve the design of green stormwater infrastructure. Research institutions, such as UI Labs, Argonne National Laboratory, and universities, can serve as key implementers of this strategy. Additional research and development opportunities exist for other forms of infrastructure as well.</p>	<p>Research institutions, philanthropic organizations, architecture and engineering firms</p>
Building Resilience in the Energy Sector	<p><i>Increase renewable energy generation</i></p> <p><i>Strengthen energy infrastructure for a changing climate</i></p> <p><i>Support decentralized energy generation and distribution</i></p> <p>The resilient energy strategies in this strategy paper should be primarily implemented by energy utilities. Already, ComEd has taken many strides to modernize the electricity grid by moving to a smart grid system. Smart grids automatically detect issues and reroute electricity to reduce power outages. Smart grid systems are not just useful for emergency situations; they have also improved day-to-day efficiencies in meter reading and billing. These improvements have enabled the electricity grid to be more responsive to unforeseen problems and more efficient in reducing peak electricity demand, thereby mitigating greenhouse gas emissions. The utility's roll-out of smart meters—a component of the smart grid—across the region should be complete for CMAP's seven-county region by 2018. Utilities and municipalities can work together to remove regulatory barriers and lower costs of clean energy generation and distribution, from</p>	<p>ComEd, Peoples Gas, Nicor, other energy utilities, municipalities, Citizens Utility Board, non-profit organizations, philanthropic organizations, private sector</p>

small-scale rooftop solar panels to district energy systems.

Fostering Economic Resilience	<p><i>Reduce community vulnerability to climate change</i></p> <p><i>Increase the resilience of freight networks</i></p> <p><i>Build resilience for the region's economic clusters</i></p> <p>The region's private sector can be a driver of economic resilience. Many businesses see climate change as a risk management issue and have taken strides to reduce weather-related disruptions on their supply chains. Businesses can also take advantage of emerging economic opportunities that come with building resilience, such as manufacturing more durable construction materials or developing smart city technologies.</p>	Private sector, municipalities, counties, non-profit organizations, chambers of commerce, community development corporations, World Business Chicago, freight operators
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Building Capacity for Resilience Planning	<p>Improve cross-jurisdictional coordination. Departments and sectors too often operate in siloes, speaking different languages, pursuing unaligned goals, and working on different timelines. Coordination is currently difficult because entities often have different data management practices, procedures, or authorities than their counterparts in other parts of the region. Resilience strategies require that organizations who may not traditionally work together coordinate share information, financial and staff resources, align timelines, and build a culture of collaboration. The types of coordination to strengthen should include partnerships between departments within counties or municipalities, units of local government; state and local governments; public, private, and non-profit sectors; and disciplinary sectors such as public health, planning, and emergency management. Strategies to improve cross-jurisdictional coordination may range from straightforward practices, such as establishing regular coordination meetings, to more long-term activities, such as establishing regional data collection standards and sharing protocols.</p>	Municipal, county and state governments, private sector, non-profits, disciplinary sectors
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	<p>Build relationships between the public and private sectors. Cross-sector relationships are also important for building resilience. Private companies are increasingly providing innovative services, such as transportation and infrastructure management. Public-private partnerships provide significant opportunities for better best practice- and data-sharing. The partnership between Waze and the Commonwealth of Kentucky, referenced in the strategy paper, is one example of an effective public-private partnership to improve resilience in the transportation sector.</p>	Public agencies, private companies that use infrastructure technologies
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	<p>Increase social cohesion. Community-based organizations should take a leading role in reducing social isolation and vulnerability to climate change. Community centers, service providers, faith-based organizations, and other community leaders can educate the public about individual actions they can take to build resilience against climate impacts, such as flood-proofing homes, checking in on elderly neighbors, and securing sufficient flood insurance coverage. Community-based organizations can also connect people to broader opportunities that build community resilience, such as planning processes, advocacy, and other forms of civic engagement. Particular emphasis should be paid to those who are most vulnerable to climate change. Social service providers and other groups that work directly with vulnerable populations. These types of capacity building</p>	Community-based organizations
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activities can better prepare residents for addressing climate impacts and ensure resilience building at the most local levels.

<p>Improve early warning alert systems. Several early warning practices, such as advisory notices for flash floods and alerts for transit delays, already exist. Improvements, however, can increase the level of detail of alerts and ensure communications to more people. For instance, to reach a wider audience, DuPage County is partnering with Walgreens stores to broadcast extreme weather warnings on the retailer’s ubiquitous LED signs. Other potential opportunities include meteorologist warnings on local news and communicating alerts through common transportation routing apps, such as Google Maps, to direct people toward mass transit options or away from affected areas. Centralized and easy-to-understand dashboard systems may also be helpful ways to provide real-time information and guidance to the public.</p>	National Weather Service, local governments, and other community partners
<p>Increase education and awareness about climate resilience. According to a 2015 national survey, 37 percent of Americans believe climate change is a serious and pressing issue, representing an 8 percentage point increase from 2010.⁷¹ These shifts in public opinion can be strong driving forces for change. Many partners point to the importance of public perception and education on climate change actions as a key factor for building regional resilience. Residents can contribute to resilience implementation by retrofitting backyards with green infrastructure, choosing low-carbon transportation options, reducing personal energy consumption, and participating in resilience planning processes. However, many residents may be unfamiliar with green infrastructure practices or have limited understanding about climate impacts in the region. Education campaigns can build public awareness about climate change and provide recommendations for building resilience at an individual scale. In turn, a more informed public can champion resilience strategies at community, regional, and national levels.</p>	Civic and non-profit organizations, schools, higher education, Illinois-Indiana Sea Grant extension programs

⁷¹ Chicago Council on Global Affairs, November 30, 2015, “Slight Rise in U.S. Public Concerns about Climate,” available at: https://www.thechicagocouncil.org/publication/slight-rise-us-public-concerns-about-climate-0?utm_source=Informz&utm_medium=Email&utm_campaign=Council