RESEARCH Scientists from Kent State University (KSU), the University at Buffalo (UB), and the University of Michigan's Great Lakes Integrated Sciences + Assessments Center (GLISA) developed training materials for the climate ambassadors and conducted research as follows:

Historical Climatology (Appendix D) The climatology review prepared by GLISA documents the changes underway in Cleveland, including:

- *Rising average temperatures:* Annual average temperatures warmed by 2.4°F from 1956-2012, faster than the national and global rates. Average low temperatures have warmed faster than high temperatures.
- *Longer freeze-free season:* The freeze-free season (growing season), lengthened by 20 days from 1956-2012.
- *More precipitation:* Total annual precipitation increased steeply by 25.8% from 1956 through 2012, while summer precipitation remained relatively unchanged.
- *Heavier precipitation:* From the 1961-1990 period to the 1991-2010 period, the amount of precipitation falling during the heaviest 1% of precipitation events increased by 22.2%.

Of particular concern is the increase in heavy precipitation. A "very heavy" precipitation day, as defined by the National Climate Assessment, is in the top 1% of daily precipitation totals. These precipitation events are typically disruptive and can cause infrastructure damage. Cleveland has seen a 16.3% increase in heavy precipitation events. The cumulative change in the precipitation falling during these events was 22.2%. Another key finding is that the freeze-free season (growing season) lengthened by 20 days from 1956-2012. The average date of first freeze is arriving 9.4 days later and the average date of last freeze is arriving 10.6 days earlier.

Mortality Rates (Appendix F) Extreme weather threatens human life. Dr. Scott Sheridan (KSU) looked at mortality rates in the Cleveland/Cuyahoga County for the overall population and for demographic subsets of the population based on gender, age, and race. Overall mortality increases in the event of high heat days, with the most immediately observable impacts in cardiovascular-related mortality and those 75 and older, regardless of sex or race. Within these categories, there is a sharper increase in black mortality than white, and slightly higher for men than women. Looking at a 14-day period, in which the impacts are assessed in aggregate, a generally similar pattern is observed, although results are broader and more intense. The relative risk is greatest for cardiovascular and respiratory mortality. A greater risk is observed for blacks than whites, while across age and sex differences are minimal.

In cold weather, more mixed results emerge. Typically the most negative impacts are not immediately observed, but rather are observed several days to two weeks later, most notably with increases in respiratory diseases. For 14-day cumulative results, increases in mortality are observed in overall mortality. Blacks and whites, and males and females, are equally affected. Cardiovascular and respiratory mortality are greater than deaths from other causes. Those 75 and older are more affected than younger people.

Urban Heat Island and Land Cover Analysis (Appendix G) Dr. Pravin Bhiwapurkar (KSU) analyzed urban heat island effects and land cover in the four target neighborhoods of Slavic Village, Kinsman, Glenville, and Detroit Shoreway. Strategies to adapt for a changing urban climate are summarized at the following scales:

House and parcel-scale recommendations:

1. Use light colored shingles or paint roofs white to increase roof albedo values.
2. Increase insulation, especially in attics, and improve air tightness of buildings.
3. Promote natural ventilation during warm weather using operable windows.
4. Replace existing windows with energy-efficient windows.

5. Plant shade trees, shrubs, and vines on the west and southwest sides of the house; solar friendly deciduous trees to shade the east; an open understory to allow penetration of cool breezes; and evergreens to the northwest and west for protection from winter winds.
6. Shade air conditioners or place them on the north side of a building where feasible.
7. Reduce impervious surfaces.
8. Promote onsite green infrastructure strategies such as rain gardens, bioswales, water-smart gardening, and urban agriculture.

Neighborhood-scale recommendations:

1. Remove unneeded impervious surfaces, such as abandoned parking lots.
2. Maintain/expand existing tree canopy by providing funding and training for residents
3. Propose greening strategies for vacant land, like stormwater retention or urban farming, in locations where market demand for traditional real estate development is limited.

Urban-scale recommendations

1. Consolidate vacant parcels for urban forests and other green space uses, since larger green spaces offer a greater range of benefits than small, scattered-site greening efforts.
2. Concentrate greening efforts in neighborhoods where existing tree canopy is minimal; and in headwaters areas to capture stormwater runoff and improve water quality.
3. A variety of urban greening approaches should be considered. For example, large industrial properties provide opportunities for green roofs. Parking lots are suitable for green infrastructure. Transportation networks allow for increased street tree density and canopy cover. A diverse range of greening efforts improve the health of urban ecosystems and offer economic and social benefits.

Additional Research The team identified at least three additional studies that would be helpful for local climate change planning efforts. We plan to engage the university network formed through this initiative (Kent State University, University at Buffalo, University of Michigan) to pursue external funding for research that is targeted to local needs.

1. *Parcel-Level Vulnerability:* It may be possible to combine data from state and county sources, along with a survey of city residents, to map parcel-level vulnerability to climate impacts. The results would be helpful for targeting programs and outreach efforts, supporting first responders during extreme weather events, and coordinating demolition of abandoned houses. We are currently developing a proposal to the National Oceanic and Atmospheric Administration, and will also explore funding from Homeland Security, Health and Human Services, and the National Institutes of Health.
2. *Neighborhood Weather Stations:* While data gathered at the three airport weather stations begins to show how the urban heat island effect may impact Cleveland as a whole, additional weather stations in each of Cleveland's neighborhoods would provide temperature and precipitation data that could be analyzed against land cover maps to determine relationships among variables like land use, population density, and distance to Lake Erie. Potential funding sources include local foundations, the National Science Foundation, Health and Human Services, the National Oceanic and Atmospheric Administration, and the Environmental Protection Agency.
3. *Temperature in Weatherized Homes:* Investigating thermal environmental conditions in homes pre- and post-weatherization will help determine how insulation affects interior temperature and moisture levels, and reduces associated illnesses like hypertension and asthma. Potential funding sources include local foundations, University Hospitals, the Cleveland Clinic, Health and Human Services, and the National Institutes of Health.

3. CLIMATE CHANGE in CLEVELAND and the GREAT LAKES

Based on peer-reviewed scientific literature, climate projections, and assessments conducted for the U.S. Global Change Research Program (compiled in Appendix C), Cleveland can expect physical changes in temperature, precipitation, and extreme weather events, including:

- *Increased Temperatures:* From 1956 to 2012, the average annual temperature in Cleveland increased by 2.4°F. By 2070, the average annual temperature may warm by an additional 4°F. These higher temperatures will increase the number of heat-related deaths, reduce water quality in Lake Erie, strain food systems, degrade air quality, and put pressure on native plants and animals.
- *Changes in Precipitation:* From 1956 to 2012, the average annual precipitation in Cleveland increased by 25.8%. During the fall, the increase was greater at 57.4%. Heavy rain and lake effect snow are expected to increase. This may cause flooding, combined sewer overflows, a reduction in river and stream quality, and higher maintenance costs.
- *Extreme Weather Events:* Weather-related threats in Northeastern Ohio include severe storms, flooding, lake effect snow, tornadoes, temperature extremes, and erosion/landslides. A warming climate and decreasing ice cover on Lake Erie may cause an increase in the frequency and intensity of these extreme weather events, threatening human life and causing significant property damage.

These conditions may affect local sectors and systems, including:

- *Public Health:* Increased heat wave frequency and intensity, increased humidity, degraded air quality, reduced water quality, and change in vector borne disease patterns will increase public health risks.
- *Water Quality:* Climate change will exacerbate a range of risks to Lake Erie, including harmful algal blooms, an increased number of combined sewer overflows, and declining beach health.
- *Food Systems:* In the next few decades, longer growing seasons and rising carbon dioxide levels will increase yields of some crops, though those benefits will be progressively offset by extreme weather events. In the long term, climate change is expected to decrease agricultural productivity.
- *Forests and Land Cover:* The composition of forests is changing as the climate warms. Many tree species are shifting northward, with more southerly varieties replacing them. Many iconic tree species (e.g., Sugar Maple, Buckeye) will slowly be replaced by other species in the next century.
- *Energy:* Cleveland has an energy-intensive economy with per capita greenhouse gas emissions higher than the national average. The city has a lot of poor-quality housing, which increases household energy usage. Warmer temperatures will reduce building heating loads, but these gains may be offset by increased reliance on air-conditioning.
- *Transportation Systems:* Decline in ice cover will lengthen the commercial navigation season on Lake Erie. More freeze-thaw cycles, flooding, erosion, lake effect snow, and heat waves may cause significant damage to local transportation infrastructure.
- *Fish and Wildlife:* The effects of increased heat stress, flooding, drought, and late spring freezes on natural and developed ecosystems may be magnified by pest prevalence, increased competition from non-native or opportunistic native species, ecosystem disturbances, and land-use change.