Appendix H: Climate Change

GET THERE TOGETHER.

Kentucky's Long-Range Transportation Vision

CLIMATE

Transportation system infrastructure affects both the natural and human environments. In turn, changes in the climate and environment can impact the safety, mobility, and resiliency of transportation systems. All federally funded or federally involved transportation related activities require an environmental analysis to comply with the National Environmental Policy Act (NEPA) and applicable state and federal standards.

Climate Summary

According to KYClimate.org, "the climate of Kentucky reflects the interplay of several locational influences. Kentucky's inland location contributes to a continental influence, which acting alone, tends to produce a large seasonal temperature range between summer and winter. Meanwhile, its position north of the Gulf of Mexico contributes a tropical marine influence that moderates temperatures and yields ample precipitation. Kentucky's mid-latitude position places it in a region where weather can be highly variable. While prevailing surface winds are southerly and light, upper-level westerly winds steer frontal systems across the state. These systems bring warm, moist air from the south, followed by cooler and drier air from the north."[1]

The annual mean temperature in Kentucky is just above 56˚F, and the state annually receives on average 50" of precipitation. It is a temperate climate with polar air masses bringing temperatures well below freezing in the winter, and tropical air masses bringing extreme heat and humidity in the summer. Kentucky can also feel the effects of severe thunderstorms, wind, hail, heavy precipitation, and tornadoes, typically in the spring and summer. The state, though seldom, can also experience severe winter storms (e.g., heavy snowfall or ice events).

Climate Impacts on Transportation

Heat

Periods of excessive summer heat are likely to increase wildfires, threatening communities, and infrastructure directly and bringing about road and rail closures in affected areas. Longer periods of extreme heat may compromise pavement integrity (e.g., softening asphalt and increasing rutting from traffic), cause deformation of rail lines and derailments or, at a minimum, speed restrictions, and cause thermal expansion of bridge joints, adversely affecting bridge operation and increasing maintenance costs.

More heat extremes, however, are likely to be problematic. They could cause heat buckling of runways. Extreme heat can also affect aircraft lift; hotter air is less dense, reducing mass flowing over the wing to create lift. The problem is exacerbated at high-altitude airports. If runways are not

[1] "Kentucky Climate Center." http://kyclimate.org/narrative.html.

sufficiently long for large aircraft to build up enough speed to generate lift, aircraft weight must be reduced or some flights canceled altogether. Thus, increases in extreme heat are likely to result in payload restrictions, flight cancellations, and service disruptions at affected airports and could require some airports to extend runway lengths, if feasible.

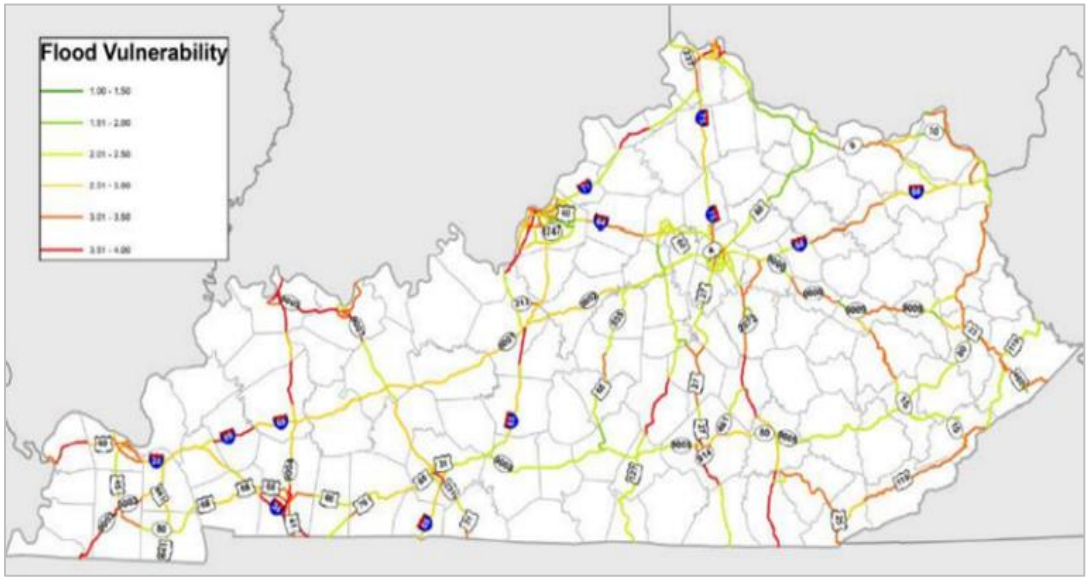
Drought

As the number of severe droughts increases this could pose challenges for river transportation. For example, Kentucky experienced severe droughts in 2005 and 2007. The 2007 drought lowered the Ohio River water levels significantly enough that portions of the river were closed to commercial navigation and shipments of goods between Kentucky and the Mississippi were delayed. The 2007 drought caused production at the Tennessee Valley Authority's (TVA's) hydroelectric plants decrease 30 percent and required the plant to use fuel-burning power plants.[2]

Environmental Hazards

The Kentucky Transportation Center (KTC) aided KYTC in identifying assets that are most vulnerable to natural hazards. In 2016, KYTC administered a federally funded natural hazard vulnerability assessment utilizing the Vulnerability Assessment Scoring Tool (VAST) for National Highway System (NHS) routes. KYTC's NHS assets, including highway segments, bridges, and culverts, were evaluated for risk against earthquakes, floods, landslides, and sinkholes using available data. Each of the 12 KYTC Districts individually contributed to the identification of the most critical extreme weather and natural hazards in their District and helped to develop mitigation strategies for the highest priority identified risks.[3]

Figure 1: Mapped VAST results for flood vulnerability of KY's NHS (KTC, 2018)



[2] "What Climate Change Means for Tennessee - US EPA." https://www.epa.gov/sites/production/files/2016-09/documents/climate-change-tn.pdf.e - US EPA
[3] "Vulnerability Assessment Scoring Tool (VAST) - Climate.gov." https://toolkit.climate.gov/tool/vulnerability-assessment-scoring-tool-vast.

Kentucky has over 90,000 miles of streams within the state making it prone to flooding during any season. The most frequent types of flooding in Kentucky are river floods and flash floods. A river flood occurs when water levels overtake riverbanks due to the accumulation of precipitation in stream channels. Flash floods occur because of a heavy amount of rainfall in a brief period resulting in rapidly increasing water levels which flow through stream channels, urban streets, or mountain valleys. Flash flooding can occur anywhere in the Commonwealth, but it is particularly an issue in eastern Kentucky, where steep topography directs water into the streams and valleys.[4]

Storms

Tornadoes are most frequent in the spring and summer, but they can take place year-round. Kentucky experiences an average of 21 tornados each year. Tornadoes are most frequent in the Ohio River Valley region but can occur statewide. Tornadoes effects on the transportation system are generally minimal and temporary. The most common damage is related to highway signage and signalization as well as debris in the roadway. In Kentucky, the number of severe hail days ranges from 4 to 7, most of which occur in the western part of the state.

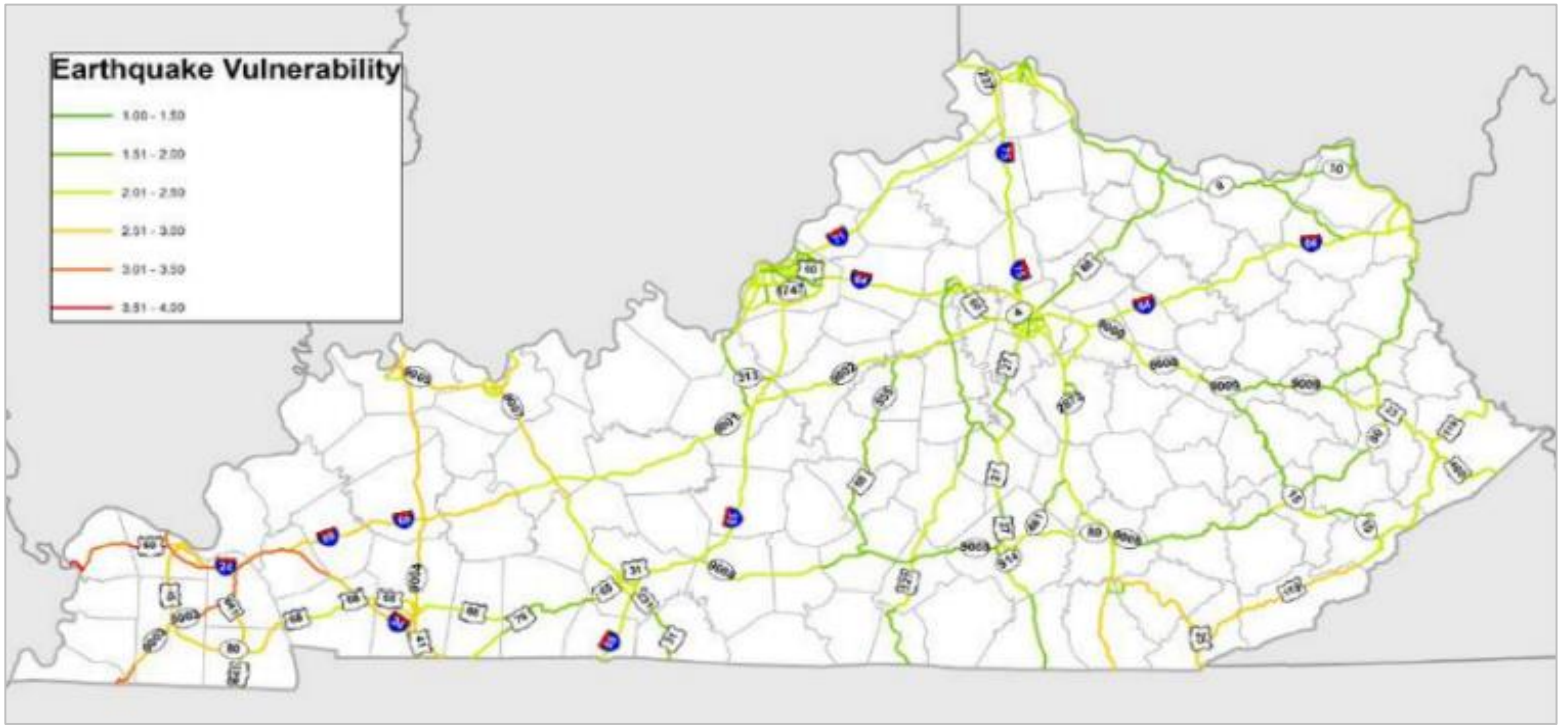
Kentucky can also be negatively impacted by significant wind events, generally as part of larger severe weather events, such as downbursts or straight-line winds from thunderstorms. Although rare, derechos have occurred in the state. A derecho is a large system of high winds causing damage over at least 240 miles and with gusts of at least 58 mph with isolated gusts of 75 mph or higher. Kentucky can also be affected by tropical storm systems on occasion. Winter storms are common in Kentucky. Eastern Kentucky has the highest annual snowfall, while the western and southern parts of the state receive smaller amounts of snowfall. Winter and ice storms can damage trees and power lines, obstructing roads and posing safety hazards on roadways as well as travel delays. Deicing salts used to treat pavements can degrade bridges and other structures.[5]

[4] "Vulnerability Assessment Scoring Tool (VAST) - Climate.gov." https://toolkit.climate.gov/tool/vulnerability-assessment-scoring-tool-vast.
[5] "DEICING SALTS, THEIR USE AND EFFECTS." https://trid.trb.org/view/39062.

Earthquake, Landslides & Karst

The western part of the state is adjacent to two seismic zones, the New Madrid seismic zone down the Mississippi River along Tennessee, Arkansas, Missouri, and Kentucky; and the Wabash Valley seismic zone of Illinois, Indiana, and Kentucky. Earthquakes can damage or destroy buildings, roads, bridges, and other humanly made structures. The expected lifecycles of assets in western Kentucky, however, suggests a low likelihood to experience a severe earthquake though the chance does exist. In Kentucky, landslides occur most frequently in the mountains and plateaus of eastern Kentucky, the Outer Bluegrass, the Knobs region, and the Ohio River Valley. Landslides can damage transportation infrastructure and need significant funding to repair. Lane closures necessitated by these events disrupts the transportation system. [6]

Figure 2: Mapped VAST results for earthquake vulnerability of KY's NHS (KTC, 2018)



[6] "Vulnerability Assessment Scoring Tool (VAST) - Climate.gov." https://toolkit.climate.gov/tool/vulnerability-assessment-scoring-tool-vast.

Figure 3: Mapped VAST results for sinkhole vulnerability of KY's NHS (KTC, 2018)

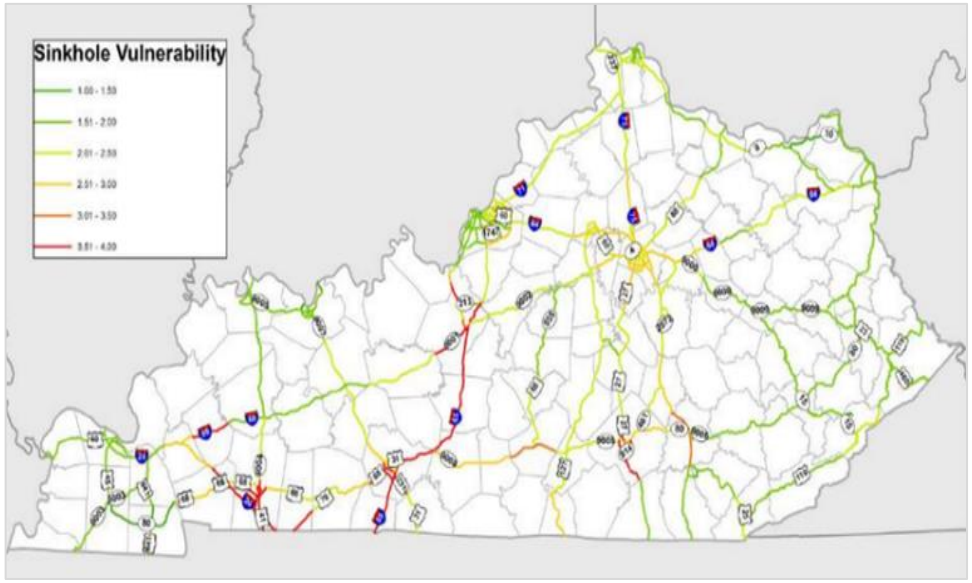
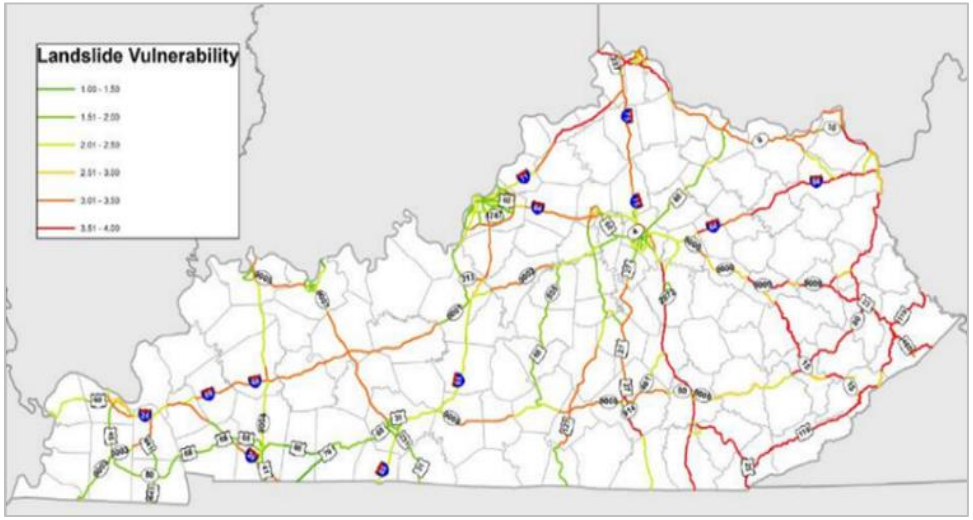


Figure 4: Mapped VAST results for landslide vulnerability of KY's NHS (KTC, 2018)



The Inner Bluegrass Region, the Western Pennyroyal region, and the Eastern Pennyroyal region have the highest karst potential in the state. It is estimated that 55 percent of the land in the state has the potential for karst development with 38 percent of the state having enough karst development to be recognized topographically, and 25 percent having well-developed karst features. Sinkholes can cause roadway surfaces, ditch lines, and bridge foundations to collapse resulting in costly repairs. In addition, karst-related flooding can temporarily close roads and cause roadway damage, or problems with drainage and rainwater runoff.

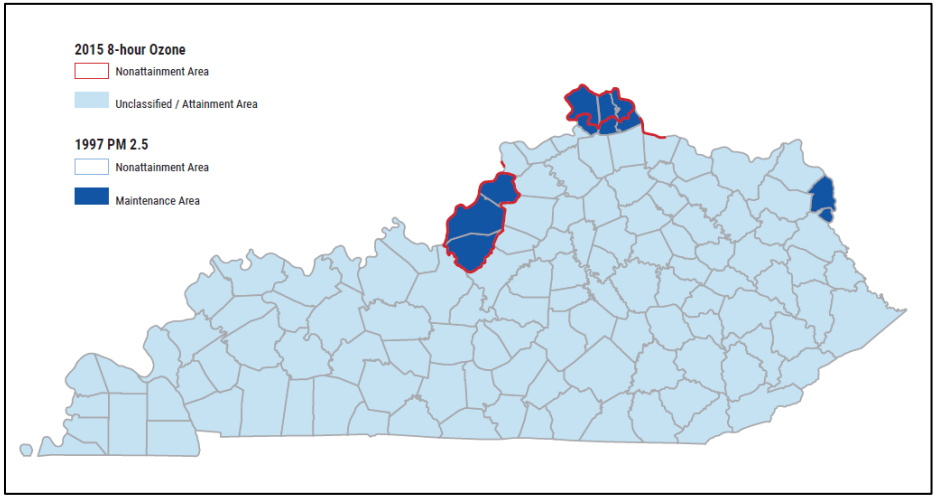
Air Quality

Although Kentucky is largely a rural state, air quality is still a major concern. KYTC's top priority is the health and safety of the Commonwealth's citizens. KYTC knows that emissions from motor vehicles that use our highways are one of the leading causes of air pollution.

Since the Clean Air Act Amendment of 1990 and subsequent policies, 41 percent of the total emissions of six principal air pollutants have decreased. Those six criteria pollutants are ground level ozone (smog), fine particulate matter (PM2.5), lead, carbon monoxide, nitrogen dioxide, and sulfur dioxide

The Environmental Protection Agency (EPA) created National Ambient Air Quality Standards (NAAQS) which are used to designate areas as attainment, nonattainment, or attainment with an approved maintenance plan. A status of attainment means that an area has never had an air quality problem. A status of non-attainment means that an area is in violation of at least one of the six principal air pollutants and must take action to correct the issue. A status of attainment with an approved maintenance plan means that it has been demonstrated to the EPA that an area which was once designated nonattainment is no longer in violation of any of the six principal air pollutants, and a plan is in place to prevent reversion into nonattainment.[7]

Figure 5 Air Quality Nonattainment and Maintenance Areas (EPA, 2021)



[7] "Nonattainment Areas for Criteria Pollutants (Green Book) | US EPA." 01 Jun. 2022, https://www.epa.gov/green-book.

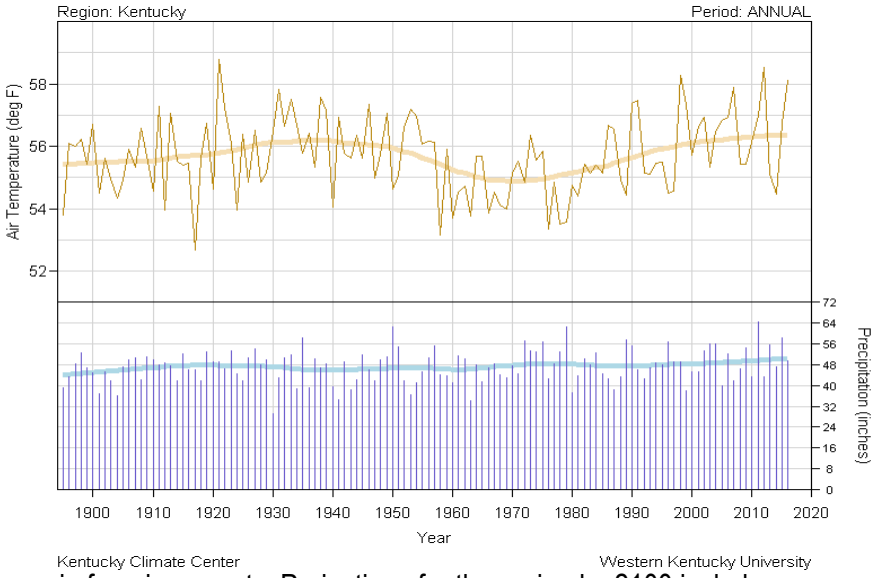
KEY TRENDS, CHALLENGES, AND OPPORTUNITIES

Trends

Kentucky's climate has been warming since the most recent cool period of the 1960s and 1970s. The average annual temperature in the Western, Central, and Bluegrass divisions now exceeds that of the prior warm period during the 1930s and 1940s. The average temperature in the Eastern division is near its earlier peak.

Average annual precipitation has been trending upward in the Western, Central, and Bluegrass divisions and is at or near its highest level since 1895. In contrast, the Eastern division has experienced a decline in average precipitation since the mid-1990s and is near the minimum reached in the late 1930s.

Figure 6: Kentucky Climate Trends: 1895 through 2016



Temperatures across the Southeast Climate Region are expected to increase during this century. Major warming consequences include significant increases in the number of hot days exceeding 95°F and decreases in freezing events. Projections for the region by 2100 include increases of 10°F for interior states of the region with a regional average increase ranging from 2°F to 6°F.

The annual number of days with extreme precipitation is expected to increase across most of the region by the mid-21st century, particularly along the southern Appalachians, as well as parts of Tennessee and Kentucky. Large cities located on or near waterways, such as the Ohio River, may be more susceptible to flooding. This may overwhelm infrastructure in cities. Currently 14 Superfund or Superfund Alternative Sites are located in the Kentucky; 12 of these sites have ongoing five-year reviews required by residual waste. The anticipated climate change attributes of heavy rains, increased temperatures, and high humidity cycles will likely facilitate this trend to continue, whereupon the population will be exposed to poorer indoor air quality.

Warmer air temperatures will result in warmer water that will hold less dissolved oxygen making instances of low oxygen levels and hypoxia more likely, foster harmful algal blooms and change the toxicity of some pollutants, and could cause an increased number of waters to be recognized as "impaired"[8] .

[8] www.kyconservation.org/climate

Challenges

In addition to the specific climate impacts on transportation listed above, climate change, in general, destabilizes the Earth's temperature equilibrium and has significant impacts on human beings and the environment.

The direct consequences of climate change include:

- rising maximum temperatures
- rising minimum temperatures
- rising sea levels
- higher ocean temperatures[9]
- an increase in heavy precipitation (heavy rain and hail)
- shrinking glaciers
- thawing permafrost

The indirect consequences of climate change include:

- an increase in hunger and water crises, especially in developing countries
- health risks through rising air temperatures and heatwaves
- economic implications of dealing with secondary damage related to climate change
- increasing spread of pests and pathogens
- loss of biodiversity due to limited adaptability and adaptability speed of flora and fauna
- ocean acidification due to increased HCO3 concentrations in the water as a consequence of increased CO_2 concentrations
- the need for adaptation in all areas (e.g., agriculture, forestry, energy, infrastructure, tourism, etc.)[10]

Opportunities

KYTC is currently working on following plans to help address climate change.

CMAQ Performance Plan

The Congestion Mitigation Air Quality (CMAQ) Performance Plan is a collaborative effort between KYTC and the MPOs and ADDs representing counties that are considered to be non-attainment or maintenance areas as determined by the Environmental Protection Agency (EPA). The KYTC CMAQ Performance reports also involves collaboration with the FHWA and other stakeholders. The plan is developed in accordance with the requirements of 23 CFR 490.107(c) and 23 USC 149(I) b and addresses the progress made toward the performance measures promulgated through

[9] https://www.myclimate.org/information/faq/faq-detail/what-are-the-effects-of-climate-change/
[10] https://www.myclimate.org/information/faq/faq-detail/what-are-the-effects-of-climate-change/

the PM3 regulation Subpart G (Measures to Assess the CMAQ Program – Traffic Congestion) and Subpart H (Measures to Assess the CMAQ Program – On-road Mobile Source Emissions).

Resiliency Improvement Plan (RIP)

The purpose of KYTC's RIP is to prioritize and direct resiliency improvements for the transportation system statewide to help prepare for, respond to and recover from weather events or natural disasters. The RIP is a required document for a portion of federal funds that could help mitigate the risk of recurring damage from these events. Eligible projects include highways, transit systems, intercity passenger rail, and port facilities as well as construction activities.

Carbon Reduction Program and the Carbon Reduction Strategy

KYTC's Carbon Reduction Program and the Carbon Reduction Strategy is a requirement of the Bipartisan Infrastructure Law (BIL). The programs goals include reducing single-occupancy vehicle trips and facilitating the use of vehicles or modes of travel that result in lower emissions. This will be collaborative process between KYTC and the MPOs. KYTC's Carbon Reduction Strategy is due to USDOT by November 15, 2023.

The following pages list opportunities for combating climate change per the Kentucky Conservation Committee (KCC).[11]

KCC Opportunities

Buildings, Cities, and Towns

- Amend state building codes to incorporate the International Energy Conservation Code.
- Expand partnerships to promote energy efficiency in buildings, including weatherizing, insulation, lighting, and programmable thermostats.
- Promote local adoption and utilization of Energy Project Assessment Districts , also known as PACE financing) in more Kentucky communities.
- Offer incentives for efficient and net-zero buildings, such as the Green Schools initiative.
- Share strategies among communities adopting "complete streets" initiatives.

Land Use: Wild Lands

While most climate protection efforts have been focused on reducing fossil-fuel use, science shows natural climate solutions—the conservation, restoration and management of forests, grasslands, and wetlands—can deliver up to 37% of the needed emission reductions.

- Protect and expand Kentucky's remaining forested areas to increase carbon sequestration, climate mitigation, and forest resilience.
- Provide tax incentives and work with landowners to increase private land preservation and improve forest health.
- Limit forest fragmentation and develop forested corridors to improve species preservation, improve wildlife habitat, and ecological function.
- Increase reforestation of abandoned and mined lands and other vacant lands.
- Update guidance on woody biomass as a fuel source, to address climate impacts and reduction targets.

[11] "Climate Action — Ky Conservation Committee." https://kyconservation.org/climate-action.

KCC Opportunities (cont.)

Land Use: Food & Agriculture

- Provide more incentives for local sustainably grown food.
- Encourage the promotion of plant-based food consumption.
- Expand programs that encourage reduction of food waste being landfilled, which generates significant methane emissions.
- Encourage properly sited and managed composting and methane recovery through anaerobic digestion programs, being mindful of environmental justice concerns in site selection.
- Increase educational resources on regenerative agriculture, farmland restoration, nutrient management, and rotational grazing to reduce pollution/build healthy soils. This includes restoring urban soils for safe use as well as enriching rural farmland.

Transportation

- Turn our major highways into a statewide network of "electric corridors" to provide fast electric vehicle (EV) chargers at least every 70 miles.
- Shift highway funding models away from gasoline and diesel fuel taxes to a new model based on vehicle weight and miles traveled, that supports improved infrastructure funding but does not penalize electric vehicle owners and supports improved public transit. Establish a task force to explore Kentucky's options.
- Electrify fleet vehicles and public transportation.
- Expand local BikeShare programs.
- Address local land use plans to coordinate transportation between the workplace and residences to minimize the need for single occupancy vehicle miles.

KCC Opportunities (cont.)

Energy Transformation

- Limit new, long-term investment into older, dirtier and/or less efficient technologies, (e.g., coal-fired plants and gas pipelines) to avoid tying up assets in unsustainable infrastructure and to make more space for renewables.
- Oppose the subsidization of coal and nuclear plants.
- Deny utilities' requests to shift all fixed costs onto meter charges, which acts as a disincentive to increased energy efficiency.
- Provide more incentives and pilot projects for distributed renewable power, including solar farms, rooftop solar, geothermal and hydro-power, as well as energy storage within the industrial sector.
- Promote expansion of Energy Project Assessment Districts and other energy efficiency incentives into the residential sector for new buildings and rehabilitation of older structures.
- Expand the adoption of Combined Heat & Power (CHP) technologies through Industrial Revenue Bonds to support implementation. Modify "Standby Rates" (charges levied by utilities when an on-site system experiences a scheduled or emergency outage) to support CHP.
- Encourage the Kentucky Energy and Environment Cabinet to conduct workshops on energy storage technology, targeting regulators, staff, and industry.
- Promote resiliency incentives for battery banks, targeting specific vulnerable facilities including schools, hospitals, and government buildings that are sensitive to power interruptions, and provide incentives for low-income facilities such as halfway houses and missions to stabilize their expenses.
- Encourage incentives for utility investment in storage to offset energy spikes.
- Increase energy security by providing residential and community access to redundant energy systems (residential solar, energy storage, etc.).

KCC Opportunities (cont.)

Water Infrastructure

- Conduct a climate analysis on watersheds, to assess their capacity for storm events.
- Create redundancy in water supplies that allow the flexibility to shift between surface and groundwater options where available.
- Have cities prepare an action plan for adding decentralized water supply and sanitation options to provide resilience and complement centralized systems. This would include cisterns and gray water recycling.
- Integrate more water conservation and green infrastructure options for stormwater management for reducing climate impacts (the ability to withstand increased rainfall, droughts) such as permeable surface materials for paved areas, rainwater collection systems, and bioswales.
- Develop citizen engagement for a "water smart" culture, to augment official data gathering to introduce water stewardship and climate change concepts. Promote systems where the local community remains involved in critical decision-making on how and where their drinking water is sourced, and their wastewater is managed.