Climate Risks and Resilience in Cumberland County: Synthesis Report

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Summary

Climate hazards have long posed risks to people, communities, infrastructure, natural systems, and economies in Cumberland County, as they have throughout the world. Now the risks are changing and growing as the Earth's climate warms and changes in other ways in response to emissions of greenhouse gas pollutants that are accumulating in the atmosphere. The risks to our present wellbeing and the wellbeing of our children and future generations are substantial but can be reduced significantly. Success will require strong and urgent actions by public and private sector actors working locally, nationally, and internationally.

Needed actions include sharply reducing emissions of greenhouse gases, capturing carbon dioxide and removing it from the atmosphere, adapting to changes in the climate, and building resilience to climate hazards. Progress is being made across the United States and globally. But action needs to be scaled up and accelerated if climate risks are to be managed successfully. Locally, Cumberland County, Carlisle Borough, and Dickinson College have each adopted climate action plans that focus on reducing emissions of greenhouse gases. Largely unaddressed by the current plans are the challenges of adapting to climate change and building resilience. *Building Climate Resilience at Dickinson and in Central Pennsylvania*, a joint initiative of the County, Carlisle, and Dickinson, is intended to address this gap. Launched in 2023, the initiative is working to assess climate related risks in the region, identify and evaluate strategies for building climate resilience, and catalyze planning and action for a more resilient present and future.

Building climate resilience is a holistic approach to adaptation that focuses on increasing capacities of people, organizations, and communities to prepare for, limit, withstand, manage, and recover from the impacts of climate hazards and transform to thrive in an uncertain future. Resilience building gives emphasis to strategies that are inclusive and prioritize benefitting those who are highly vulnerable, disadvantaged, and marginalized.

This report synthesizes findings from the first phase of the initiative during which climate risks and resilience were assessed. It draws from peer-reviewed literature, national and international scientific reports, research of Dickinson College students, and other sources to assess changing climate risks in Cumberland County. The risks include threats to human health and wellbeing, infrastructure, utility services, ecosystems, ecosystem services, the economy, livelihoods, and cost of living. The report also presents examples of strategies for building resilience to climate hazards in Cumberland County. Selected strategies will be examined and evaluated in the next phase of the initiative. Previous reports from the initiative *Building Climate Resilience at Dickinson and in Central Pennsylvania* can be found online at https://www.dickinson.edu/info/20052/sustainability/4371/climate_resilience/2.

Changing Climate Hazards

Resilience strategies are needed because the climate is changing in ways that are amplifying climate hazards. For the past 70 years, global average surface temperatures increased, with each passing decade recording higher average temperatures than preceding decades. The speed of warming since 1970 has been greater than in any other 50-year period over the last two-thousand years. The ten years from 2015 through 2024 set records as the 10 warmest years since instrumental recordkeeping began in 1850 and 2024 was the warmest year on record. The rising temperatures have been accompanied by increasing frequencies, severities, and impacts of many types of extreme weather, exposing people and valued resources to greater climate-related hazards. Observed changes in extreme weather include hotter, more frequent, and longer heat waves, more frequent and more intense heavy rain events, and hurricanes in the North Atlantic that intensify more rapidly, reach high levels of intensity more frequently, and generate heavier rainfall.

Looking to the future, as atmospheric concentrations of greenhouse gases continue to increase, Cumberland County's climate is virtually certain to get hotter on average and is very likely to experience more frequent and hotter extreme heat events, become wetter on average, and have more frequent and more severe heavy rain events with each passing decade. Also possible, but projected with less confidence, are increases in flood risks in our

region, storms with greater windspeeds and rain volumes, more frequent and severe droughts, and more severe compound events such as the simultaneous occurrence of long duration heat waves, droughts, and hazardous air quality conditions.

The Risks

Human health and wellbeing are affected by climate in a variety of ways, many of which are expected to be made worse by climate change. Extreme heat events, which are very likely to become more frequent and severe in Cumberland County, already cause tens-of-thousands of people to be treated and hospitalized for acute heat-related illnesses each year, exacerbate chronic cardiovascular, pulmonary, renal, neurologic, and psychiatric diseases for even more people, and kill more people in the U.S. than floods, hurricanes, and tornados combined. Extreme heat and other forms of severe weather can cause surges in demands for physical and mental healthcare that can overwhelm emergency rooms while simultaneously disrupting the ability of healthcare facilities to provide services. Poor air quality that currently causes 60,000 to 260,000 premature deaths each year in the U.S. may be worsened by climate change, a serious concern for our region which was recently identified as one of the ten most polluted regions in the nation. Climate change can increase incidences of infectious diseases such as Lyme disease, a tick-borne disease that afflicts an estimated 100,000 people in Pennsylvania every year. Additionally, food security can be decreased by impacts of climate change on food production, prices, processing, storage, and distribution, while housing affordability can be impacted by climate change reducing housing supply and increasing costs of cooling, maintaining, repairing, and constructing housing.

As the climate becomes warmer, wetter, more variable, and more extreme, existing infrastructure will become increasingly mismatched between the climate conditions for which it was designed and the conditions to which it will be exposed. This will reduce the performance and useful lifetimes of nearly all types of infrastructure, increase repair and maintenance costs, and increase risks of failures and disruptions of services that can endanger people, their property, and their livelihoods. At risk are homes, buildings, hospitals, roads, railways, bridges, transportation depots, natural gas pipelines, and infrastructure for drinking water, wastewater, stormwater, telecommunications, electric power generation, transmission, and distribution. Infrastructure located in and even outside of floodplains will be threatened by more frequent and more severe damages from river, flash, and stormwater floods. The reliability of electric power and telecommunications are likely to decrease as storms become stronger, the health of trees near power lines and telecommunication cables degrades, and peak power demands rise during more frequent and more severe heat waves.

County residents benefit tremendously from extensive, diverse, and high-quality streams, wetlands, forests, and other ecosystems. But these valued resources are at risk from changes in climate that are adding to existing pressures on ecosystems from land development, fragmentation of wildlife habitats, pollution, overuse, and invasive species, pests and pathogens. Impacts of climate change interacting with other pressures include changes in the health, resilience, and productivity of ecosystems, the populations, geographical ranges, reproductive success, survival, and diversity of plant and animal species that inhabit the county, and the abilities of ecosystems to provide clean air, clean water, flood protection, wildlife habitat, recreation opportunities, and healthy soils and pollination for farms and food production. Ecosystems that are particularly vulnerable are those that are currently stressed and in poor condition. Of special concern are eastern brook trout, a culturally and recreationally important fish species that is highly sensitive to climate and environmental changes and is at high risk.

All the effects of changing climate hazards detailed in the report will impact the economy of Cumberland County, the livelihoods of people living and working in the county, the cost of living, and local governments' revenues and expenses. Some of the economic impacts will be beneficial, but many will be harmful. National studies estimate that the harms are likely to dominate the benefits, causing net losses of economic wellbeing for most Americans that will grow as the climate continues to warm. The economic harms are expected to be most burdensome for low-income households and others who are highly vulnerable and who lack resources to be resilient. These national patterns are likely to be replicated in Cumberland County.

The pathways by which climate change can impact the county's economy and the economic wellbeing of its residents are multiple. For example, impacts on human health will impact worker productivity, labor supply, healthcare costs, insurance premiums, insurance payouts, and workers' out-of-pocket health expenses. Changes in worker health and worker productivity will impact costs, prices, incomes, and profits in all economic sectors. The farm sector and economies of rural communities are particularly vulnerable. Impacts on the productivity of farm workers, farmland, and livestock will impact operating costs of farms, crop yields, farmers' incomes, food supplies, food prices, and food security. Spillover effects will impact economic opportunities in rural communities where farming is an important local source of income and spending power. More frequent and possibly longer interruptions in electric power and telecommunications services due to severe weather would negatively impact many businesses. As would increases in maintenance, repair, and replacement costs for infrastructure that is degraded prematurely or damaged by severe weather. As impacts ripple through the economy, local governments' tax revenues, spending, and borrowing costs will be impacted, placing pressures on their finances.

Who is Vulnerable?

Climate change will not impact all people and all communities equally, even when they are exposed to the same climate hazards. People and communities with limited financial and other resources can struggle with accessing affordable quality healthcare, childcare, food, housing, energy, transportation, and other basic needs. Consequently, they can have less capacity to cope with, respond to, and recover from the impacts of climate hazards, making them less resilient to and more vulnerable to climate change. The elderly, children, people with chronic health conditions, people with disabilities, and people with limited English language skills often face challenges in responding to climate hazards and can be more vulnerable than others. Also, some can be vulnerable because of where they live, the type of home they live in, or working in outdoor occupations or sectors that are sensitive to climate.

Applying the Social Vulnerability Index, a tool developed by the Centers for Disease Control for measuring the vulnerability of places to natural hazards, census tracts in Cumberland County are mapped with respect to the proportions of households with social, economic, and other characteristics associated with vulnerability to natural hazards. Of the 49 census tracts in the county, 18 are ranked as being among the 25% least socially vulnerable locations in Pennsylvania. These include Dickinson, Monroe, and parts of North Middleton and South Middleton townships in the center of the county and, in the eastern part of the county, Lemoyne and parts of Mechanicsburg, Camp Hill, Hampden, East Pennsboro, and Lower Allen. Seven census tracts are ranked as being among the 25% most socially vulnerable locations in Pennsylvania. These include Shippensburg Township and Borough, Enola, central areas of Carlisle, and parts of East Pennsboro.

Strengths and Weaknesses

Cumberland County has many strengths that help make our communities and residents resilient to climate and other stresses. The county's economy is a diverse one that generates significant financial resources and provides strong employment opportunities, a median income that is the 6th highest among Pennsylvania's 67 counties, an unemployment rate that is the 8th lowest in the state, a percentage of households with incomes below the federal poverty line that is the 4th lowest in the state, and a tax base sufficient to support quality schools, public infrastructure, and public services. We have a strong healthcare system that includes the Sadler Health Center, a federally qualified health center that serves people who are uninsured, underinsured, or insured through Medicaid and the Children's Health Insurance Program. We have extensive and varied infrastructure that includes mostly reliable interstate and state highways, roads, bridges, public drinking water, wastewater, and stormwater systems, and electric power and telecommunications systems. We have abundant water for farming, drinking, and commercial uses and streams, forests, and other natural systems that support wildlife and provide exceptional recreation opportunities.

Importantly, the county has numerous community organizations, faith groups, environmental organizations, businesses, educational institutions, and public agencies that provide for community needs and that have histories and relationships of working together on community problems. County resources are supplemented by state and federal resources to assist people in need through programs such as the Supplemental Nutrition Assistance Program (SNAP), the Women, Infants, and Children (WIC) program, housing choice vouchers, and the Low-Income Energy Assistance Program (LIHEAP). Businesses, organizations, and agencies in the county can access state and federal grants for economic development that help build community resilience through Community Development Block Grants, the Inflation Reduction Act, the Infrastructure Investment and Jobs Act, and other programs. Farmers and landowners can get technical assistance for adapting land management practices to the changing climate from the County Conservation District, the US Department of Agriculture's Natural Resources Conservation Service, Penn State Extension, and other sources.

We also have weaknesses that detract from our resilience. While the majority of county residents earn family supporting incomes and are able to meet their needs, nearly 8% of people in the county have incomes below the poverty line and too few resources to cope with impacts from climate hazards. Others who are working and have incomes above the poverty line can still struggle to meet basic needs, making them vulnerable to climate change. Twenty-four percent of households in the county are housing cost burdened, with housing costs that exceed 30% of their incomes. Over 26,000 people in Cumberland County, including nearly 7,000 children, were food insecure in 2022. Many struggle to pay for electric and other utilities and over 5% of the population is still not covered by private or public health insurance. Additional weaknesses include a housing stock and infrastructure that are aging and in poor condition, significant numbers of residences and other infrastructure located in floodplains, heavy use of roadways by trucking and warehousing activities, very limited public transit services, air quality that is among the worst in the nation, 786 miles of streams (30%) that are degraded and fail to meet water quality standards, and land development that converts forests and farms to other uses and place pressures on the Kittatinny Ridge, an important migration corridor for birds and other wildlife. Finally, continuation of many of the federal programs noted above that provide funds and assistance to the county is uncertain in the current environment of deep cuts to federal programs and the federal workforce.

Resilience Strategies

Taking actions and investing resources in building climate resilience in Cumberland County are important for limiting our risks to climate change. Resilience strategies that are appropriately selected, designed well, and implemented effectively can simultaneously advance climate resilience and community goals for economic development, healthcare, health outcomes, affordable housing, equity, clean air and water, and other community priorities.

The report identifies numerous resilience strategies for consideration in the next phase of the initiative, including:

- Integrate climate resilience and mitigation into the county's economic development strategy and county and municipal comprehensive plans, hazard mitigation plans, ordinances, and plans for continuity of operations.
- Maintain and enhance programs that support low-income households to access affordable healthcare, childcare, food, housing, energy, transportation, education, and job training.
- Promote heat action plans for healthcare facilities, schools, employers, and others to protect people from heat stroke and other illnesses in extreme heat events.
- Improve air quality by supporting public transit, active transportation, electric vehicles, and other means.
- Promote development that is compact, limits sprawl and encourages mixed uses of land.
- Discourage building new infrastructure in floodplains and encourage use of floodproofing measures.
- Invest in creating an electric grid that is cleaner, more reliable, smarter, and more efficient.
- Protect, preserve, and restore valued ecosystems in the county.
- Maintain and improve programs that provide technical assistance and funding to farmers and forest landowners for climate resilient agriculture and forestry.

1. Introduction

Climate hazards have long posed risks to people, communities, infrastructure, natural systems, and economies in Cumberland County, as they have throughout the world. Now the risks are changing and growing as the Earth's climate warms and changes in other ways in response to emissions of greenhouse gas pollutants that are accumulating in the atmosphere. Strategies for managing climate-related risks that were effective in the past will be increasingly ill-suited and insufficient for the changing and growing climate hazards. The risks to our present wellbeing and the wellbeing of our children and future generations are substantial but can be reduced significantly. Success will require strong and urgent actions by public and private sector actors working locally, nationally, and internationally.

Actions to reduce climate-related risks can take a variety of forms. One is to mitigate climate change by halting the growing accumulation greenhouse gas pollutants in the atmosphere. This is achieved by sharply reducing emissions of greenhouse gases, capturing them at their sources, and removing them from the atmosphere. Capturing and removing the gases in the form of carbon also requires storing the carbon securely for centuries to millennia.

Another form of action is to adapt to the changing climate to avoid or limit the resulting harms and take advantage of new opportunities. Building climate resilience is a holistic approach to adaptation that focuses on increasing capacities to prepare for, limit, withstand, manage, and recover from the impacts of climate hazards and transform to thrive in an uncertain future. Equitable climate action pursues all these approaches in ways that are inclusive and prioritize the wellbeing of those who are highly vulnerable, disadvantaged, and marginalized.

Equitable mitigation, adaptation, and resilience building are all needed, and progress is being made across the United States and globally. But action needs to be scaled up and accelerated if climate risks are to be managed successfully. Locally, Cumberland County, Carlisle Borough, and Dickinson College have each adopted climate action plans that focus primarily on reducing emissions of greenhouse gases. Largely unaddressed by the current plans are the challenges of adapting to climate change and building resilience. The initiative *Building Climate Resilience at Dickinson and in Central Pennsylvania* is intended to address this gap.

Building Climate Resilience at Dickinson and in Central Pennsylvania is a joint initiative of Dickinson College, Carlisle Borough, and Cumberland County that was launched in spring 2023. The purposes of the initiative are to assess and improve understanding of climate-related risks and vulnerabilities in our region, examine strengths and weaknesses that contribute to or undermine our resilience to climate risks, identify and evaluate strategies for building resilience, and catalyze planning and action for a more resilient present and future. The initiative is part of a wider effort involving colleges and universities across the nation that is being coordinated by Second Nature.

This report synthesizes findings from the first phase of the initiative during which climate risks and resilience were assessed. It draws from peer-reviewed literature, national and international scientific reports, research of Dickinson College students, and other sources to assess changing climate hazards in Cumberland County and the risks they pose in our region. The risks include threats to human health and wellbeing, infrastructure, utility services, ecosystems, ecosystem services, the economy, livelihoods, and cost of living. The report also presents examples of strategies for building resilience to climate hazards in Cumberland County.

The purpose of the synthesis is to set the stage and provide a foundation of knowledge for the next phase of the initiative in which resilience strategies will be examined and evaluated. The intended audience includes all who have a stake in responding to climate change – county residents, workers, farmers, students, members of community organizations, business owners, landowners, and public officials.

2. Changing Climate Hazards

The global climate warmed during the 20th and early 21st centuries and continues to warm. For the past 70 years, each passing decade has been warmer than all preceding decades. The decade 2011 – 2020 was warmer than all but one multi-century warm period over the past 125,000 years. The speed of warming has been rapid in comparison to past periods of warming, with global average surface temperature increasing faster since 1970 than in any other 50-year period over the last two-thousand years. The ten years from 2015 through 2024 are the 10 warmest years since instrumental recordkeeping began in 1850, and 2024 is the warmest year on record. These and other climate statistics give evidence that the climate is warming and that the warming is substantial and rapid. (Bardan, 2025; IPCC, 2021; NASA, 2024; and NOAA, 2024).

The rising temperatures have been accompanied by increasing frequencies, severities, and impacts of many types of extreme weather, exposing people and valued resources to greater climate-related hazards. For example, the frequencies of heat waves in major cities across the U.S., the length of heat wave seasons, and the number of heat-related illnesses and deaths from heat exposure have all increased. In 2023, more than two-thirds of Americans were subject to heat alerts, resulting in an abnormally high 119,000 emergency department visits and 2300 deaths due to heat-related illnesses. Other observed changes in climate include increases in average annual precipitation and the frequencies and intensities of heavy rain events. The intensity, frequency, and duration of hurricanes in the North Atlantic, the speed at which they intensify, and the amount of rainfall they generate have also increased. (Marvel et al, 2023; USGCRP, 2024; U.S. Department of Health and Human Services, 2024; and Vaidyanathan et al, 2024).

Collectively, the warming, increasing rainfall, and changing statistical patterns of extreme weather that have been observed globally and regionally over the past century are referred to as climate change. Unlike changes in the weather, which happen over short time periods of hours, days, weeks, seasons, and year-to-year, climate change happens over longer time scales of multiple years, decades, and longer. Numerous scientific analyses drawing on multiple types of evidence have been conducted in the U.S. and elsewhere seeking to understand the causes of the observed changes. The analyses have considered possible natural causes such as changes in the energy output of the sun, internal variability of the climate system from natural cycles, and volcanic activity that ejects aerosols high into the atmosphere. The analyses have also considered the effects of human activities such as emissions of greenhouse gases and aerosol pollutants from burning fossil fuels, industry, agriculture, and land use changes.

Careful comparisons of the spatial and temporal patterns of observed warming with the patterns of changes in the different possible causes provide overwhelming support for concluding that most of the warming observed since the middle of the 20th century has been caused by humans' emissions of greenhouse gases. This is the conclusion of the Intergovernmental Panel on Climate Change (IPCC), the U.S. Global Change Research Program (USGCRP), the U.S. National Academy of Sciences, numerous science academies of other nations, and many other scientific organizations. (IPCC, 2021; Marvel et al, 2023; and National Academy of Sciences, 2020).

Sharply reducing emissions of greenhouse gases can slow and ultimately halt human-caused climate change, but many climate hazards are very likely to continue to get worse with each passing year until net emissions reach zero. Consequently, we will need to adapt and build resilience even as we reduce emissions. Doing this successfully requires anticipating how the climate may change and taking this information into account as we plan and invest in communities, physical infrastructure, economic development, private businesses, human health, agriculture, water, energy, transportation, and environmental protection.

Complicating the challenge is uncertainty. It is not possible to know the future climate with certainty, just as we cannot know with certainty what future social, economic, and technological changes will come. To make good choices and manage risks effectively despite the uncertainties, we need to use the best available information to anticipate the range of plausible and surprising futures that we may experience and pursue robust strategies that can perform well across a range of possibilities.

Fortunately, there is a strong foundation of knowledge for characterizing the range of climate conditions that we might experience in our region. This includes evidence-based scientific knowledge about how the climate system functions and changes, empirical observations of climate and weather, analyses of the observations, and simulations from climate models. Drawing on these knowledge foundations, we can conclude that it is virtually certain that in coming years and decades the climate of southcentral Pennsylvania will become hotter on average and very likely extreme heat events will become more frequent and hotter. It is also very likely that our climate will become wetter on average and heavy rain events will become more frequent and produce larger amounts of rain. The magnitudes of the changes, and risks associated with them, are expected to grow over time until and unless global net emissions of greenhouse gases are reduced to zero. Also possible, but projected with less confidence, are increases in flood risks in our region, storms with greater windspeeds and rain volumes, more frequent and severe droughts, and more severe compound events such as the simultaneous occurrence of long duration heat waves, droughts, and hazardous air quality conditions. (Leary, 2023).

Table 1 summarizes projected changes in selected climate variables for Cumberland County for a scenario of high global emissions of greenhouse gases for three time periods: the near term, 2016 – 2035, mid-century, 2046 – 2065, and late-century, 2076 – 2095. The projections are based on simulations from 32 global climate models that are available from the U.S. Global Change Research Program (USGCRP). Low and high values of projected changes in selected climate variables from the 32 models are reported in the table to quantify the range of likely changes, keeping in mind that the ranges probably understate the scientific uncertainties and that they are based on a high emission scenario. The ranges of projected increases in temperatures, numbers of hot days, and numbers of heavy rain days are substantial and represent significant climate risks.

For other climate variables, projected changes are described qualitatively, with only the direction and not the magnitude of change noted. These are climate phenomena that are complex in their causes and behaviors and for which climate science and climate models are not yet able to provide highly reliable quantitative projections at local scales. Confidence in the projected changes for these phenomena at the scale of U.S. counties is currently low or very low in most regions. But low confidence should not be confused with low consequence or low priority for action. For example, while confidence is low in projections of increased flooding in the county, increased flooding is within the range of likely outcomes for Cumberland County and, if flooding does increase, the impacts could be severe and warrant consideration today of measures to manage flood risks that may grow in the future.

Table 1. Projected Changes in Climate Hazard Indicators in Cumberland County.

Climate Hazard Indicator	Direction of Projected Change	Confidence in Projected Change	Key Features of Changing Climate Hazards
Average Temperatures	Increase	Virtually Certain	Exposure to rising average temperatures is very high in the County and will increase throughout the century. For a high emission scenario, average temperatures in the County are projected to increase 2.0 to 3.8°F in the near-term, 4.3 to 7.2°F by mid-century, and 6.5 to 11.4°F by late century relative to the years 1971-2000. The rate of projected warming is greater than experienced in thousands of years.
Extreme Heat Events	Increase	Very High	Exposure to extreme heat events is already very high in the County and will increase throughout the century. For a high emission scenario, the average number of days that exceed 90°F is projected to increase from 7 days per year in the baseline period to 15 to 32 days per year in the near-term, 30 to 60 days per year by mid-century, and 48 to 96 days by late century. The average number of days that exceed 95°F and 100°F are also projected to increase.
Extreme Cold Events	Decrease	Very High	Exposure to extreme cold events is very high in the County, will decrease throughout the century, but will still be very high at century's end. For a high emission scenario, the average number of days per year below freezing are projected to decrease from 128 days in the baseline period to 105 to 119 in the near term, 82 to 106 by mid-century, and 59 to 89 by late century.
Average Precipitation	Increase	High	Exposure to increasing average annual precipitation is high in the County and very likely will increase throughout the century. For a high emission scenario, average annual precipitation in the County is projected to

			increase 0.2% to 13% in the near-term from a baseline of 45.2 inches, 2% to 16% by mid-century, and 4% to 22% by late century.
Heavy Rain Events	Increase	High	Exposure to extreme precipitation events is already very high in the County and very likely will increase throughout the century. For a high emission scenario, the average number of days in the County with very heavy rain, 0.8 inches or more, is projected to increase 3% to 27% in the near-term, 14% to 38% by mid-century, and 18% to 52% by late century. The number of days with extremely heavy rain, 1.4 inches or more, is also projected to increase.
Floods	Increase	Low	Exposure to floods is very high in the County. Projections of more frequent and more intense heavy rain suggest flood exposures may increase in future, but floods are complex events that have multiple contributing factors and confidence in projected changes in future flood risks is low.
Droughts	Increase	Low	Exposure to emergency drought events is low in the County but may increase. Consecutive dry days are projected to increase modestly in the County. Rising temperatures are expected to dry soils and increase the potential for more intense droughts, with drought potential increasing the more the global climate warms. However, confidence in projected changes in future drought risks is low.
Extreme Storms	Increase	Low	Exposure to risks from extreme storms is very high in the County and may increase. Greater wind speeds and greater rainfall are projected for tropical cyclones and thunderstorms, thunderstorms are projected to increase in frequency in U.S., and magnitudes of changes may increase the more the global climate warms. However, confidence in projected changes in future risks from storms is low.
Compound Events	Increase	Very Low	Some types of compound events are projected to increase at global and regional scales. Data and projections are not available for the County but there is potential for compound events to increase in frequency and severity in the County. Confidence in changes in future risks from compound events is very low.

Source: Leary, 2023. The projections are derived from simulations of 32 global climate models for the RCP8.5 scenario of high global emissions of greenhouse gases that have been downscaled to the county level and are available from the U.S. Global Change Research Program's LOCA dataset. Changes are relative to averages for the years 1971 – 2000. Reported ranges are bounded by the 10th percentile and 90th percentile projections from the 32 models. Scales for rating exposure from very low to very high and for rating confidence from very low to very high are provided in Leary (2023).

3. Social Vulnerability and Equity

Climate hazards and climate change do not impact all people and communities equally. Even people living in close geographic proximity can suffer very different impacts from hazard events. The differences correlate strongly with social, economic, health, and other characteristics of exposed individuals, households, populations, and communities that shape capacities to cope with, respond to, and recover from the impacts of hazards. People and communities with limited financial and other resources can struggle with accessing affordable quality healthcare, childcare, food, housing, energy, transportation, and other basic needs. Consequently, they can have less capacity to cope with, respond to, and recover from the impacts of climate hazards, making them less resilient to and more vulnerable to climate risks. The elderly, children, people with chronic health conditions, people with disabilities, and people with limited English language skills often face challenges in responding to climate hazards and can be more vulnerable than others. Also, some can be vulnerable because of where they live, the type of home they live in, or their occupation. Differences in these characteristics give rise to different degrees of social vulnerability to hazards. Resilience, a related concept, is sometimes considered to be the inverse of vulnerability. People with high capacities for managing and responding to risks tend to have high resilience and low vulnerability with respect to climate and other hazards. (Cutter et al, 2003; PA DEP, 2021a; USEPA, 2021; and White and Haas, 1975).

Differences in social vulnerability and resilience raise important issues of equity regarding the potential impacts of climate change. As noted in Pennsylvania's most recent climate impacts assessment and climate action plan, disproportionate impacts across populations and communities are not random and are often consequences of

discriminatory practices such as redlining, disinvestment in communities of color, and disenfranchisement of rights. For these reasons, Pennsylvania's climate action plan emphasizes environmental justice and equity concerns and favors an implementation approach designed to improve the lives of all Pennsylvanians, distribute benefits and costs of climate action equitably, and avoid unfairly burdening some communities or disproportionately favoring others.

A variety of tools for measuring social vulnerability to natural hazards have been developed by different organizations and researchers for mapping differences in vulnerability between and within communities. While the tools differ in their methods and variables used to measure social vulnerability, there is general agreement on many of the characteristics of households and groups that are associated with vulnerability. These include people with low incomes, the elderly, children, people with chronic health conditions, people with disabilities, and people living in nursing homes, high rise apartments, and mobile homes. Racial, ethnic, gender, and sexuality identities can also be indicators of vulnerability due to discrimination and bias.

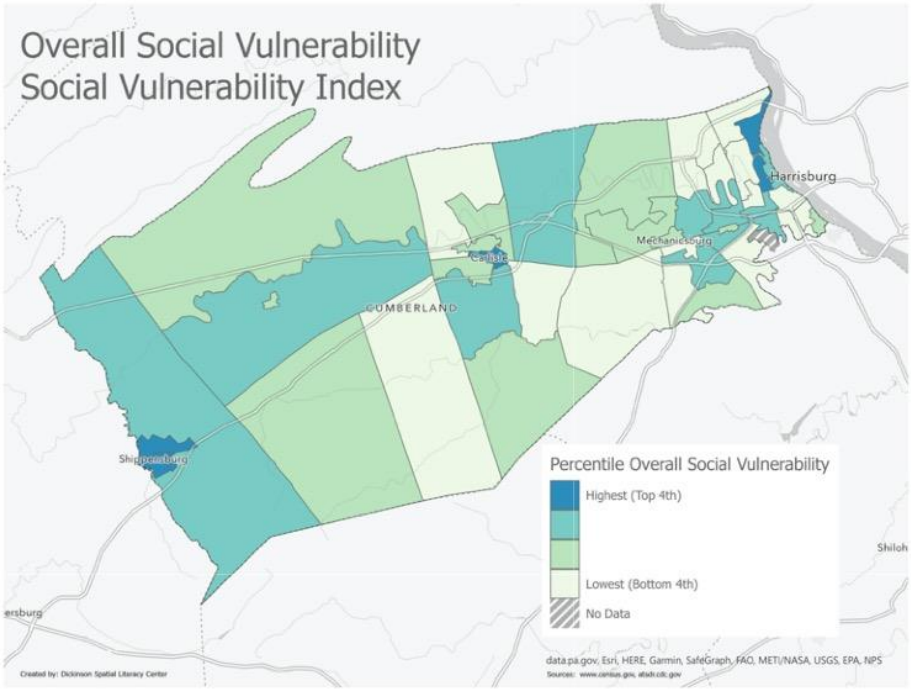
One readily available tool is the Social Vulnerability Index (SVI), developed by the Centers for Disease Control and Prevention (CDC) to help emergency managers identify and map communities that are likely to need support before, during, and after public health emergencies. These communities plausibly are also likely to be more vulnerable to climate hazards and climate change than other communities. Data from the U.S. Census and the American Community Survey for 15 variables are combined in the Social Vulnerability Index to construct measures of vulnerability by county and by census tract based in the proportions of households with characteristics associated with social vulnerability. Measures are created for overall vulnerability and for four categories of vulnerability – socioeconomic status; household composition and disability; race, ethnicity, and English language proficiency; and housing type and transportation access. (CDC, 2015).

When ranked against other counties in Pennsylvania, Cumberland County's overall SVI score is 0.11, which indicates social vulnerability in Cumberland County is lower than all but 11% of counties in the state. This reflects the low percentages of the County's population, relative to other counties in Pennsylvania, that have characteristics associated with high social vulnerability. Within the County, however, there are census tracts with significant percentages of socially vulnerable populations and these tracts rank among the most socially vulnerable tracts in the state. Values for SVI range from a low of 0.004 in census tract 116.02 in Upper Allen Township to a high of 0.91 in census tract 122.00 in central Carlisle. The SVI scores for these census tracts indicate that the western side of Upper Allen Township is among the 1% least vulnerable census tracts in Pennsylvania and that central Carlisle is among the 9% most vulnerable tracts.

The map displays overall social vulnerability by census tract in the county, as measured by the SVI. Tracts colored dark blue are among the 25% most vulnerable tracts in Pennsylvania. Tracts colored blue-green are moderately vulnerable relative to the rest of the state. Tracts colored pale-green and yellow have low and very low vulnerability respectively relative to other tracts in Pennsylvania.

Of the 49 census tracts in the county, the index ranks 18 as being among the 25% least vulnerable locations in Pennsylvania (first-quartile). These include, in the center of the county, Dickinson, Monroe, and parts of North Middleton and South Middleton townships and, in the eastern part of the county, Lemoyne and parts of Mechanicsburg, Camp Hill, Hampden, East Pennsboro, and Lower Allen. Seven census tracts are ranked as being among the 25% most vulnerable locations in Pennsylvania (fourth-quartile). These include Shippensburg Township and Borough, Enola, central areas of Carlisle, and parts of East Pennsboro. Areas with moderate overall social vulnerability (third-quartile) include Southampton, Hopewell, Newburg, North Newton, and West Pennsboro in the western part of the County, Middlesex and northern areas of South Middleton in the center of the County, and parts of Upper Allen, Lower Allen, and Hampden townships, Camp Hill, and Wormleysburg in the east of the County. Areas of the County with low overall social vulnerability (second-quartile) include Upper Mifflin, Lower Mifflin, Upper Frankford, Lower Frankford, Penn, Cooke, and South Newton townships in the west, parts of Carlisle, South Middleton, and North Middleton in the center, and Silver Spring, New Kingston, New Cumberland, Shiresmantown, and parts of Mechanicsburg and Upper Allen Township in the east.

The map should be interpreted and used with care. Measures of social vulnerability are subjective and imprecise and should not be seen as accurate predictions of where social impacts from climate change will be greatest. But the map can be useful as indicative of areas in the county where significant percentages of residents may need help coping with the effects of climate change.



Overall Social Vulnerability in Cumberland County. Map created by Gordon Cromley, Spatial Literacy Center, Dickinson College. Data source: CDC/ATSDR, Social Vulnerability Index Data and Documentation, https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html.

4. Health and Wellbeing

Climate hazards impact human health and wellbeing in southcentral Pennsylvania through multiple pathways that will be amplified by climate change. Health risks associated with climate include increasing illnesses, injuries, mental health effects, and deaths from extreme heat, diminished air and water quality, infectious disease, severe storms, and disruptions of health services from severe weather. Food security, housing, livelihoods, and incomes can also be adversely impacted. The effects of climate change on health and wellbeing are likely to fall most heavily on low and very low income households, people with chronic health conditions, marginalized People of Color, and other at risk populations that are burdened by disparities in access to healthcare, housing, food, transportation, employment opportunities, and green spaces. Many county resources provide sources of strength and resilience for managing the risks to health and wellbeing, but there are also weaknesses in the region that undermine capacities for managing the risks. Resilience building strategies can add to the strengths and address gaps where there are weaknesses. (Beardsley, 2024; Chu et al, 2023; and Semma, 2024).

4.1. Risks

4.1.1. Extreme Heat

Heat waves are deadly. They kill more people in the United States than any other climate-related hazard, accounting for more deaths on average per year than floods, hurricanes, and tornados combined. Heat exposure was the underlying or contributing cause of death for over 21,000 people in the U.S. from 1999 to 2023, with the annual number of heat related deaths increasing more than 100% from 1999 to 2023. The increase in heat-related deaths was particularly pronounced over the last 7 years, reaching a record high of 2325 deaths in 2023. Emergency room visits for heat-related illnesses numbered nearly 120,000 in 2023. While the numbers of deaths and emergency room visits attributed to heat exposure are troublingly high, experts consider them to be significant underestimates of the actual health impacts from heat exposure. (Howard et al, 2024).

Extreme heat events cause heat-related illnesses that range from mild cases of heat cramps to moderate cases of heat exhaustion to life threatening cases of heat stroke, sometimes resulting in death. Heat exposure can also exacerbate chronic diseases such as cardiovascular, pulmonary, renal, neurologic, and psychiatric diseases, often requiring emergency room visits and hospitalizations. Exacerbation of chronic diseases from heat exposure commonly outnumber acute illnesses directly attributed to heat. Elevated temperatures are also associated with poorer cognition and learning and increased aggression, anxiety, and stress disorders. (Hayden et al, 2023, and Hess et al, 2023).

For a future scenario of high emissions of greenhouse gases, the average number of hot days above 90 ^{o}F is projected to increase from 7 days per year in the period 1971-2000 to an average of 15 to 32 days per year for the period 2016-2035. By mid-century, 2046-2065, days over 90 ^{o}F are project to increase to 30 to 60 days per year on average and by late century, 2076-2095, they are projected to increase to 48 to 96 days per year. The large increases in numbers of hot days will significantly increase the frequency and severity of dangerous extreme heat events in Cumberland County. Increases in heat-related illnesses, exacerbation of chronic disease, and deaths from heat exposure are likely.

While all county residents will experience increasing risks, some populations are particularly vulnerable to heat exposure. Risks are greatest among children, adults aged 65 and over, people with chronic disease, people who are pregnant, people with disabilities, mental health, and substance abuse disorders, people who work outdoors or engage in outdoor activities, and people who lack access to cooling, live in poor quality housing, or are unhoused. Places in the county where risks can be high include developed areas that are hotter than other areas due to the urban heat island effect, as well as rural areas with limited healthcare facilities and longer travel times to emergency care. Many of these risk factors are often present for people with low-incomes and People of Color, placing these populations at higher risk from extreme heat than others. (Beardsley, 2024; Leary et al, 2024; and Semma, 2024).

Many people in Cumberland County work in construction, warehousing, agriculture, and other occupations for which exposure to heat is high and should be managed and mitigated. School children, children in day care centers, youth who participate in outdoor recreation programs, residents of nursing homes and assisted care facilities, elderly people living alone, unhoused people, and incarcerated people are populations at risk from heat exposure that will need focused attention. At Dickinson College, facilities management staff, groundskeeping staff, Public Safety officers, Dickinson Farm workers, contracted construction workers, student athletes and coaches, students and faculty members who engage in field research, and children at Dickinson's children center are groups that warrant special attention for managing heat exposure risks. Also warranting attention at a residential college are the effects of temperature on cognition, learning, aggression, anxiety, and stress disorders.

4.1.2. Air Quality

Air quality has improved dramatically in the U.S. since the mid-20th century and in more recent years because of programs that have substantially reduced emissions of many air pollutants. Yet over 100 million people live in areas where air pollution exceeds air quality standards and poor air quality continues to negatively impact health. Estimates of deaths from exposure to ground-level ozone and fine particle pollution ($PM_{2.5}$) range from 60,000 to

260,000 and more per year – which is greater than the numbers of deaths attributed to motor vehicle accidents, kidney disease, breast cancer, and prostate cancer.

Climate change will impact our air quality through multiple pathways. The net effects are complex and will vary by region. At current levels of emissions of air pollutants, modeling simulations indicate that climate change is likely to worsen air quality in many regions of the United States. Higher temperatures accelerate the photochemical reactions that produce ozone, can increase emissions of fine particulates from dry soils, vegetation, and wildfires, and increase air stagnation events, and result in greater atmospheric concentrations of pollutants. Counteracting these effects, higher humidity and rainfall can reduce concentrations of fine particles. Additionally, climate change has extended pollen seasons and increased pollen concentrations and will likely amplify these effects in the future. Projections indicate that climate change is likely to increase annual average ozone concentrations, increase pollen seasons and concentrations, increase the number of severe ozone episodes, and increase concentrations of fine particulates in the Northeastern U.S., including our county, unless emissions of pollutants are reduced below current levels. (West et al, 2023).

The annual average concentration of fine particle air pollution (PM 2.5) decreased in Cumberland County from 2005 through 2010, was largely unchanged from 2010 through 2017, and increased from 2017 through 2019. In 2019, the concentration averaged 10.8 micrograms per cubic meter in the county, which was higher than the Pennsylvania average of 9 micrograms and the national average of 8 micrograms. A comparison of fine particle air pollution across regions of the U.S. identified Central Pennsylvania as one of the ten most polluted regions in the nation for fine particle pollution, with Shippensburg, Carlisle, and west shore communities of the county emerging as hotspots for poor air quality. Central Pennsylvania differs from the other 10-worst polluted regions because the region is mostly rural while the other high-pollution regions are significantly more urbanized. Factors that contribute to poor air quality in Cumberland County are the physical geography created by South and North Mountains that can contribute to air stagnation events, high levels of pollutants from trucks and passenger vehicles traveling in and through the county, windblown dust from farms, fossil fuels combusted for industrial, commercial, and residential uses, and other sources of pollution. (Beardsley, 2024; County Health Rankings & Roadmaps, 2024; McCormick and Witherspoon, 2023; and Semma, 2024).

Worsening air quality would adversely affect the health of people living in the county, causing and aggravating a variety of health conditions of county residents that include cardiovascular disease, asthma and other respiratory diseases, adverse birth outcomes, neurological disease, and increased risk of death. The health effects of air pollution can result in losses of school days and workdays, impaired cognitive development, and reductions in worker productivity. All are at risk from poor air quality, but some are more vulnerable than others. Many of the same groups of people who are at high risk from heat exposure are also at high risk from air pollution. Extreme heat events co-occurring with hazardous air quality days can amplify the health risks.

Expected negative effects of climate change on air quality in the county may be amplified by increases in pollution from the growing logistics, trucking, and warehousing industry, rapid development in the county, and population growth. Growing wildfire risks in a warming climate, both within and beyond the county, can result in episodes of extremely hazardous air quality days. As evidenced by the Canadian wildfires in summer 2023, even distant fires can severely impact air quality in Cumberland County. (Leary et al, 2024).

The effects of climate change on air quality and health can be counteracted by increasing efforts to reduce emissions of air pollutants. Particularly noteworthy, actions that reduce emissions of greenhouse gases that cause climate change also yield major reductions in criteria air pollutants. Generating electricity with non-fossil sources of energy, shifting from gasoline and diesel-powered vehicles to electric vehicles, encouraging greater use of public transportation, walking, and cycling, improving the energy efficiency of homes and businesses, replacing conventional heating systems with modern electric heat pumps, switching to electric lawncare equipment, and other actions can make deep reductions in air pollutants such as particulates, nitrogen oxides, volatile organic compounds, carbon monoxide, and sulfur dioxide as well as the greenhouse gases carbon dioxide, nitrous oxide,

and methane. Many studies have estimated that policies that would substantially reduce greenhouse gas emissions would improve air quality in the U.S. and save many thousands of lives each year. (USEPA, 2023a).

In addition to impacting outdoor air quality, climate change can also impact indoor air quality. One pathway for this to happen is by increasing outdoor pollution and airborne allergens that infiltrate into indoor spaces. Another pathway results when heavy rains, flooding, and winds damage buildings and allow moisture and heat to enter. Heat and moisture create conditions in which mold, bacteria, dust mites, and other biological contaminants can grow. Also, buildings with inefficient, poorly performing heating, ventilation, and cooling systems can be compromised by increases in outdoor temperatures and humidity in their ability to prevent mold and other contaminants from thriving. Immediate effects of exposure to indoor air pollution include irritation of the eyes, nose, and throat, headaches, dizziness, fatigue, difficulty breathing, and asthma attacks. Longer term effects include respiratory diseases, heart disease, and cancer. (USEPA, 2024a; and USEPA, 2024b; and USEPA, 2023b).

Indoor air quality is a problem for people living and working in spaces that are poorly ventilated and climate controlled, old or poorly constructed, poorly maintained, and prone to water damage. Dickinson College has experienced several incidents in which mold has required temporary relocation of students from their residence halls, closing off access to some of the library's holdings, costly mold remediation work, and operating dehumidifiers 24-7 in academic buildings. (Semma, 2024).

4.1.3. Infectious Disease

Climate is an important determinant of the geographic distributions, abundance, and seasonality of pathogens and disease vectors and these will change as the climate changes. Whether and how risks for different infectious diseases will change as a result will depend on characteristics of disease transmission processes, risk factors of the exposed populations, behavioral responses, public health responses, and other factors. Lyme disease and other tick-borne diseases, which account for roughly 80% of all reported vector-borne diseases in the U.S., have increased steadily over the past 20 years due to a variety of reasons, one of which is climate change. Climate change is projected to continue to increase the distribution and abundance of ticks, which will increase the number of Lyme disease cases. This represents a significant risk for Pennsylvania, where an estimated 100,000 Lyme disease cases occur each year, resulting in designation of Pennsylvania as a high incidence state for Lyme by the Centers for Disease Control. (Hayden et al, 2023; PA DOH, 2024; and Pennsylvania Medical Society, 2024).

Climate change is also expanding the geographic distributions, abundances, and seasons of some species and varieties of mosquitos that transmit disease. Mosquitos that transmit West Nile Virus and Zika virus are projected to increase in range and abundances dues to climate change, which could increase infections in Pennsylvania. In Pennsylvania, the average number of days per year with weather suitable for mosquitos has lengthened by 14 days from 1980-2009 (Hayden et al, 2023, and Stevens, 2024). Cumberland County participates in a state-wide program working to prevent and treat these mosquito-borne diseases. Other mosquito-borne diseases like Dengue fever and Chikungunya virus are increasing due to climate change and other causes but local transmission in our region has not been observed. Efforts in Pennsylvania and Cumberland County focus on monitoring and measures to prevent these diseases from becoming established locally. (Cumberland County, 2024).

Higher, more variable rainfall with more heavy rain and flooding events have the potential to increase risks of waterborne diseases. These events can contaminate drinking water supplies, swimming pools, lakes, and streams with Giardia cysts, Cryptosporidium eggs, and other disease vectors. If ingested they can cause diarrhea, dehydration, abdominal cramps, vomiting, and, for immune system compromised individuals, more severe conditions. Outbreaks from public drinking water supplies are uncommon because of treatment with chlorine and chloramine, practices that should prevent any significant increases in waterborne disease from public water sources. However, people who obtain drinking water from wells or who come into contact with untreated water from swimming, fishing, boating, and other recreation activities may face increased risks. For Dickinson College, well

water at the college farm is a potential source of transmission that may warrant monitoring. (Hayden et al, 2023, and PA DOH, 2013 and 2016).

4.1.4. Physical Injuries

Increases in severe weather pose increased risks of physical injuries that can require hospitalization and result in death. Examples include drownings and bodily injuries from river and flash floods, wind-blown debris, lightning strikes, electrocution from downed powerlines, burns from wildfires, vehicle collisions due to hazardous road conditions, and falls due to slippery surfaces. Pennsylvania was second in the nation in number of fatalities from river and flash floods from 1996 to 2018 with 89 fatalities and 10th in the nation in number of injuries with 159. People living in or near floodplains are at greatest risk from river floods. The 2020 Cumberland County Hazard Mitigation Plan identified over 1300 residences in the county that are located in designated Special Hazard Flood Areas. These include residences in Carlisle, East Pennsboro, Hampden, Lower Allen, Monroe, Mount Holly Springs, New Cumberland, Shippensburg Township, Silver Spring, South Middleton, and Southampton. More than 20% of the residences in the flood zones are mobile homes that are highly vulnerable to floods and other forms of severe weather. It is important to note that the designated flood zones do not account for the likely expansion of flood plains due to climate change. Also, flash floods can happen almost anywhere in the county and are not limited to floodplains. (Cumberland County, 2020, and Pennsylvania Department of Environmental Protection, 2021).

While winters are warming and the number of days with temperatures below freezing are decreasing, hazardous winter weather is changing and will change in complex ways that may decrease some risks of physical injuries and increase others. Winter precipitation will increase, which could increase heavy snowfalls and winter downpours. Rain falling on frozen ground or snow-covered ground can produce flooding, and more rain in winter can cause more frequent slippery winter road conditions. (Climate Reality Project, 2022).

4.1.5. Mental Health

Severe weather has been shown to contribute to adverse mental health outcomes. Displacement, trauma, disruption of livelihoods, separation from social support systems, and loss of sense of place and belonging due to severe weather events impact people's mental health. In the aftermath of major hurricanes, increased use of mental health services and psychiatric medications have been documented. People who have lived through hurricanes, wildfires, extreme heat exposure, and other forms of severe weather have exhibited post-traumatic stress symptoms, depression, anxiety, aggression, violence, suicidal thoughts, and suicide. (Hayden et al, 2023).

Mental health services in the county are viewed by many as insufficient relative to the needs of county residents. The county has just one mental health provider per 420 people compared to one mental health provider per 370 people statewide. The already limited mental health services will be severely stretched by extreme events that increase demands for mental health services. The capacity of Dickinson College to support the mental wellbeing of members of its community of nearly 3000 students and employees also will be severely tested in such times. (County Health Rankings & Roadmaps, 2024, and Leary et al, 2024).

4.1.6. Healthcare Facilities and Services

Severe weather events, many of which are expected to increase in frequency and severity due to climate change, can place multiple, compounding stresses on healthcare facilities and services. Heat waves, storms, and floods can increase demand for healthcare services that can be challenging to meet. They can also pose obstacles for people to travel to healthcare facilities and obstacles for healthcare staff to report for work. Severe weather events can also damage healthcare facilities, disrupting their ability to provide services. (Beardsley, 2024).

Extreme heat events are an instructive example. Heat waves increase the volume of patients who visit emergency rooms. Patients who have suffered heat exposure can have more significant medical care needs and require longer stays in emergency departments than other patients. A surge of high-need patients can overwhelm an emergency department, as was experienced by some hospitals in the west and south in summer 2024. Compounding the problem, electricity demand can spike during a heat wave as people turn on air conditioners that draw lots of power as they struggle to cool indoor spaces and can cause electric power outages. Those who lose power will be unable to cool their homes and workplaces to safe temperatures, increasing the number of people who need healthcare for heat exposure. People with chronic health conditions who use electric powered medical equipment in their homes will not be able to care for themselves at home and many will need to go to a hospital and other healthcare facility. Heatwaves also increase the numbers of people who visit emergency rooms for mental health reasons, self-injury, violent injuries caused by others, and homicides. And some come to emergency rooms simply to find a place to be cool. (Beardsley, 2024; Patel et al, 2022; and Semma, 2024).

Healthcare facilities may also lose power in a heat wave that causes electric power demand to exceed the capacity of the electric grid to deliver power to users. While hospitals have backup generators, many nursing homes, urgent care offices, and other health facilities do not. The scenario would be made significantly worse if the heat wave is accompanied by severe storms that knock out power, knock down trees, and disrupt transportation and communications over a wide region for an extended period. (Patel et al, 2022).

4.1.7. Food Security

Climate change poses risks to food systems at local to global scales that may exacerbate problems of food insecurity. Food production is highly sensitive to changes in average climate conditions, climate variability, and the frequencies and severities of extreme events. In addition to food production, climate also impacts other parts of food supply chains, including storage, processing, distribution, retail, and consumption. Climate change can have both beneficial and harmful impacts on food systems but globally the net effects are estimated to negatively impact food security, particularly for people in the least developed countries. The effects in the U.S. and in Pennsylvania are uncertain, but it is likely that positive impacts would dominate initially in some areas but give way to negative impacts the more the climate warms and negative impacts dominating by mid-century. (Bolster et al, 2023; Gowda et al, 218; and Shortle et al, 2015).

Agriculture accounts for 48% of land use in Cumberland County and is an important source of incomes, employment, and cultural heritage, issues that are explored later in this report. Yet, despite being an agricultural county, most food consumed by people in the county is produced outside the county. Consequently, local disruptions to food production, which can negatively impact incomes and food security of farmers and others who participate in and benefit from the county's agricultural economy, generally do not impact the food security of others in the county. Local losses in food production are compensated for by interstate, intrastate, and international trade in food. But food trade can also expose county residents to price changes driven by climate and other events in other parts of the world that impact national and international food supplies. (Bolster et al, 2023).

Events beyond the county that reduce food supplies and raise food prices negatively impact food security within the county. Over 26,000 people in Cumberland County, including nearly 7,000 children and representing 10% of the population, were food insecure in 2022. Increases in food prices, housing costs, and other costs can severely burden food insecure households and decrease their ability to access nutritious food sufficient for leading healthy lives. Food and other price increases can also tip some households from a condition of being food secure to food insecure. Climate change can impact food security in other ways too. Households that experience adverse health impacts or property damage from extreme weather can lose workdays, lose jobs, and incur significant costs that take away resources that would have been available to purchase food. Households can also lose income if extreme weather disrupts their ability to travel to work or causes an employer to close temporarily or permanently. Extreme weather and power outages can close food stores, disrupt food supply chains, and impede people's abilities to access, prepare and store food. (Beardsley, 2024; Feeding America, 2024; and Leary et al, 2024).

4.1.8. Housing and Homelessness

Housing markets are strained nationally with growing shortages of affordable housing. There are 7 million fewer affordable rental homes in the U.S. than needed, with only 36 affordable rental units available for every 100 extremely low-income renters. In Cumberland County, 24% of households are burdened by housing costs that are 30% or more of household income, which strains their abilities to pay for other needs and to cope with unplanned expenses. Ten percent of households are severely housing cost burdened, spending half or more of their income on housing. (Cohen et al, 2024; County Health Rankings & Roadmaps, 2024; and FEMA, 2024).

Climate change is expected to exacerbate housing cost burdens and shortages of affordable housing by reducing housing supply by damaging housing units and increasing costs for cooling, maintaining, repairing, refurnishing, rehabilitating, and constructing housing. Increases in cooling, maintenance, and other costs will be burdensome for extremely low-income and low-income renters in low quality housing that has poor ventilation, insulation, and building envelopes, inadequate and inefficient heating and cooling systems, is lacking in tree canopy, and is located in urban heat island areas. Higher housing costs force households to make tradeoffs that can lead to adverse health outcomes, food insecurity, energy insecurity, housing precarity, and homelessness – conditions that are tightly interconnected. (Bezgrebelna et al, 2021; Chu et al, 2023; and Cohen et al, 2024).

Over 14 million homes were impacted in the U.S. by climate-related hazards in 2021 and the largest hazard events caused nearly $57 billion in damages. In 2022, 3.4 million people had to evacuate their homes due to a disaster, 40% of whom returned home within a week, 12% were out of their homes for more than 6 months, and 16% never returned home. Impacts such as these are likely to grow as climate change amplifies extreme weather events, and the limited affordable housing stock is at particular risk. Climate change is anticipated to increase the costs and disruptions of peoples' lives from climate-related hazards by increasing the frequency and severity of many types of severe weather. (Bezgrebelna, 2021, and Cohen et al, 2024).

Homeless populations are particularly vulnerable to climate hazards. They are highly exposed to the elements, lack access to air conditioning, healthcare, transportation, and sanitary facilities, often have chronic disease or mental health conditions, are often food insecure, and lack financial resources to cope with disruptive events. When natural disasters occur, it is often the case that disaster planning overlooks homeless populations. (Bezgrebelna, 2021).

4.2. Strengths and Weaknesses

People and communities are resilient to climate hazards that can impact human health when they have the resources and capacities to manage, cope with, adapt to, and recover from climate events. This includes family supporting incomes and access to quality and affordable healthcare, housing, food, energy, transportation, education, clean air, clean water, and greenspaces. These needs are met for most county residents by Cumberland County's economy, healthcare system, network of community and educational organizations, and public agencies. They are sources of strength that support health and wellbeing and add to climate resilience in the county.

The diverse economy of the county, which includes important employers that are not highly susceptible to cyclical swings, provides strong employment opportunities, incomes, and tax base that generate mostly stable and robust financial resources within the county. Median household income in Cumberland County was nearly $83,000 in 2022, which was the 6th highest among Pennsylvania's 67 counties. The unemployment rate was 3.7% in 2022, the 8th lowest in the state, and the population with incomes below the poverty line was 7.7% in 2022, which was the 4th lowest in the state (FEMA, 2024). The Cumberland Area Economic Development Corporation (CAEDC) offers a variety of services to support existing businesses and attract new businesses to the county and the wider Cumberland Valley region. Strong public schools and higher education institutions are catalysts of economic development that support residents in developing knowledge and skills for employment and for engagement in civic

activities that add to community resilience. The Cumberland County Library System, Employment Skills Training Center, PA Career Link, and other organizations are resources that assist people in finding employment, developing work skills, and connecting them to important services.

Cumberland County has a strong healthcare system with a history of collaboration among healthcare providers and community organizations that provide a variety of human and social services. There are three hospitals located in the county, Carlisle Regional Medical Center in Carlisle, Penn State Health Holy Spirit Medical Center in Camp Hill, and UPMC West Shore in Mechanicsburg, that offer a wide range of quality healthcare services. UPMC, Wellspan, Geisinger, and independent providers operate other healthcare facilities in the county. Sadler Health Center, a federally qualified health center, plays a critical role by providing primary, dental, and behavioral health care services to patients who are uninsured, underinsured, or insured through Medicaid or the Children's Health Insurance Program (CHIP). Ambulance and emergency medical services are provided by Cumberland Goodwill EMS, New Cumberland Fire Department EMS, Hampden Township EMS, Silver Spring Ambulance & Rescue, Shippensburg Area EMS, and others. Partnership for Better Health, the United Way of Carlisle and Cumberland County, the county's Emergency Operations Center, the Clean Air Board of Central Pennsylvania, and other organizations also play important roles in supporting community health.

Despite these strengths, several weaknesses undermine health and wellbeing of county residents. Many in the county have incomes at, below or near the poverty level who struggle to afford and access health care, food, housing, energy, transportation, and other basic needs. These conditions can make them vulnerable to climate-related hazards. Rural areas in the west of the county are underserved by healthcare facilities, resulting in longer travel distances and travel times to access healthcare and for emergency services to reach residents. Mental health services in Cumberland County are significantly less than other parts of Pennsylvania. People in the more developed areas of the county experience greater heat in extreme heat events due to the urban heat island effect. These same areas also have higher air pollution, which can interact with heat in dangerous ways. A significant portion of the housing stock is poorly maintained, of low quality, and vulnerable to severe weather, including mobile homes and residences located in floodplains. There is a high correspondence in the county between many of these risk factors with People of Color, people who are employed but income and asset limited, unemployed people, and people who are homeless. (County Health Rankings & Roadmaps, 2024, and Leary et al, 2024).

A number of programs are important for adding to the resilience of potentially vulnerable people and households. The Affordable Care Act (ACA) substantially expanded the number of people with health insurance through the ACA's health insurance marketplace, mandating affordable health insurance for people with preexisting conditions, and expanding Medicaid. Critically needed resources to combat food insecurity are provided by federally supported programs such as the Supplemental Nutrition Assistance Program (SNAP), nutrition program for Women, Infants, and Children (WIC), and the free and reduced-price school lunch program. Project SHARE of Carlisle, the Salvation Army, and food pantries operated by New Hope Ministries and others fill needs that are not met by federal and state programs, while the Cumberland County Food System Alliance brings organizations together to coordinate efforts for creating a local sustainable food system. Low-income people struggling to meet their housing needs are aided by the Cumberland County Housing and Redevelopment Authority, which administers the federally funded Housing Choice Voucher Program and offers other housing-related services. Transitional housing, temporary housing, and short-term emergency shelter is offered in the county by Community Cares, Safe Harbor, Samaritan Fellowship, and other organizations. These and other anti-poverty programs are countering weaknesses that undermine community resilience in the county.

4.3. Resilience Strategies

Examples of resilience strategies for health and wellbeing are presented in Tables 2 through 5 along with indicators that could be used to measure progress and primary actors for planning and implementing strategies. Some are cross-cutting strategies that can address multiple climatic and other stresses to health and wellbeing and other

strategies are targeted to specific areas of risk and resilience. Many of the strategies would produce multiple benefits and would further existing goals for the health and wellbeing of county residents.

Table 2. Examples of Health and Wellbeing Resilience Strategies: Cross-Cutting.

Strategy	Indicators of progress	Primary Actors
Sustain and enhance programs for low-income, vulnerable, and disadvantaged residents that advance healthcare access, food security, housing security, energy security, education, skills training, childcare, and increase the participation of eligible county residents in the programs.	Number of program participants. % of eligible people who participate in programs. Decrease in % population without health insurance. Decrease in % population below poverty level. Decrease in % population who are food insecure. Decrease in % population who are housing cost burdened. Improved health outcomes.	Public agencies, community organizations, community leaders
Educate the public and at-risk populations to raise awareness and understanding of climate-related risks to health and wellbeing and adaptive actions.	Number of participants in education programs. Diversity of participants. Levels of engagement. Evaluations from participants.	Public agencies, public schools, colleges and universities, community organizations
Develop and promote a robust early warning and communication system to inform all community members about forecasts of extreme heat, severe weather, floods, hazardous air quality, and other hazards and about adaptive actions that can be taken to prevent or limit the risks.	Number of people who subscribe to communication system. Diversity of subscribers. Evaluations from subscribers.	County Emergency Operations Center, public agencies, community organizations
Develop a mapping tool to identify places of priority for climate-resilience action by overlaying locations of floodplains, air quality hotspots, urban heat island hotspots, impervious surfaces, tree canopy, greenspaces, housing, healthcare, other infrastructure, community organizations, and demographic indicators of social vulnerability and resilience.	Use of the mapping tool. Evaluations from users.	County Planning Department, colleges and universities
Connect community organizations, public agencies, and private businesses to collaborate in improving health and wellbeing of county residents by building trust and relationships, developing consensus on priorities, and coordinating efforts for greater social impact.	Number of collaborating organizations. Impacts of collaborations.	Community organizations, public agencies, private businesses, colleges
Build social capital through community organizations that engage community members in advocacy, decision making, and action to serve community members' needs.	Number of members of community organizations. Number of participants in programs of community organizations. Diversity of members and participants.	Community organizations
Provide leadership training to assist people in vulnerable communities to develop skills for advocating and mobilizing resources to address community needs.	Number of participants. Diversity of participants. Evaluations from participants.	Community organizations

Table 3. Examples of Health and Wellbeing Resilience Strategies: Health.

Strategy	Indicators of progress	Primary Actors
Increase healthcare facilities and services, including mental healthcare, in rural and other underserved areas of the county.	Number of new healthcare facilities in underserved areas. Number of medical practitioners per capita in underserved areas. Number of mental healthcare providers per capita in underserved areas.	Healthcare providers, public agencies

Incorporate extreme heat events into county and municipal hazard mitigation plans.	Extreme heat events are included as a hazard in updated hazard mitigation plans. Mitigation actions for extreme heat are included in the plans.	County Planning Department, boroughs and townships that have hazard mitigation plans
Promote development and implementation of heat action plans by healthcare facilities, public agencies, educational institutions, and employers.	Number of organizations that adopt plans.	Healthcare facilities, public agencies, public schools, colleges, businesses
Increase the number of cooling shelters and add to green spaces, tree canopy, and shade structures to ameliorate urban heat islands, prioritizing underserved and vulnerable communities.	Number of cooling shelters countywide and in prioritized census tracts. % of population within 10-minute walk of a cooling shelter and/or greenspace. % tree coverage in prioritized census tracts.	Public agencies, community organizations, churches, businesses, educational institutions, developers
Improve air quality by supporting public transit and active transportation (walking, cycling), clean electricity, electric vehicles, heat pumps for cooling, and electric lawncare equipment.	Annual average concentration of PM2.5 pollution. Number and % of commuters using public transit or active transportation. Number of electric vehicles registered in the county. Number of heat pumps purchased in county.	Public agencies, businesses, colleges
Promote proactive management of indoor air quality through monitoring, maintenance, replacement of mechanical systems, and rehabilitation of spaces/buildings where problems are chronic.	Number of organizations that adopt indoor air quality improvement programs.	Organizations that own and manage buildings

Table 4. Examples of Health and Wellbeing Resilience Strategies: Food Security.

Strategy	Indicators of progress	Primary Actors
Develop and implement a comprehensive plan to advance food security in the county.	Plan adopted. Number and % of adults and children who are food insecure.	Cumberland County Food System Alliance, public agencies, food pantries, other community organizations
Increase participation of eligible beneficiaries in SNAP and WIC programs.	Number of participants. % of eligible beneficiaries who participate.	Public agencies, food pantries, other community organizations
Sustain and expand programs to educate families, youth, and others about purchasing, preparing, and eating affordable, healthy foods.	Number of participants. Diversity of participants. Evaluations of participants.	Public agencies, community organizations, healthcare providers
Sustain and increase support for programs that provide technical assistance and funding for farmers to apply climate-resilient practices for growing and marketing nutritious foods while protecting soils and water quality.	Funding for programs. Number of program participants. Diversity of participants. Evaluations from participants.	Public agencies, conservation organizations, farm sector organizations

Table 5. Examples of Health and Wellbeing Resilience Strategies: Housing.

Strategy	Indicators of progress	Primary Actors
Provide municipalities guidance and technical assistance for reviewing and revising zoning ordinances to encourage	Number of municipalities that receive guidance and assistance.	County Planning Department, municipal governments

development of affordable housing that is energy efficient and climate resilient.	Numbers of units of affordable, energy efficient, & climate resilient housing developed. % of population that is housing cost burdened.	
Seek and allocate more resources for CCHRA's Landlord Incentive Program to increase opportunities for renters with Housing Choice Vouchers.	Funding allocated to program. Number of participating landlords. Number of renters with vouchers who benefit from program.	Cumberland County Housing & Redevelopment Authority, landlords
Seek resources to relaunch CCHRA's Home Rehabilitation Program, focusing on assisting low and very low-income homeowners with weatherization, energy efficiency, indoor air quality, and climate resilience.	Home Rehabilitation Program is relaunched. Funding for the program. Number of program participants. Outcomes monitored and documented.	Cumberland County Housing & Redevelopment Authority
Connect renters and homeowners with sources of state and federal funding and technical assistance for making investments in home weatherization, energy efficiency, indoor air quality, and climate resilience.	Number of renters and homeowners who succeed in getting funding. Amount of funding received.	County Planning Department, municipalities, community organizations
Assess public housing and identify cost-effective opportunities to improve weatherization, energy efficiency, indoor air quality, and climate resilience.	Numbers and percentages of public housing improved.	Cumberland County Housing & Redevelopment Authority
Encourage owners of residential properties in current and projected Special Flood Hazard Areas to take voluntary actions to mitigate flood risks and/or relocate through ordinances, incentives and financial assistance.	Number of property owners who choose to mitigate flood risks.	County Planning Department, municipalities, property owners
Raise awareness of homeowners about growing flood risks and encourage voluntary purchase of flood insurance by those who are not required to buy national flood insurance.	Number of homeowners who purchase voluntary flood insurance.	County Planning Department, municipalities, property owners

5. Infrastructure and Utility Services

Infrastructure that is designed for the historical climate of an area is vulnerable to the changing climatic conditions that we are experiencing. As time passes and the climate becomes even warmer, wetter, more variable, and more extreme, the mismatch will grow between the conditions for which existing infrastructure is designed and the conditions to which it will be exposed. This will reduce the performance and lifetimes of infrastructure, increase repair and maintenance costs, and increase risks of failures and disruptions of services that can endanger people, their property, and their livelihoods. Older, deteriorating infrastructure that is not well maintained and is reaching the end of intended useful lifetimes is particularly at risk – a problem that is common across the United States and across Pennsylvania. The Pennsylvania State Council of the American Society of Civil Engineers issued a grade of C- in its 2022 infrastructure report card, indicating that infrastructure in the state is mediocre, requires attention, is deficient in functionality, and is vulnerable to stresses. (Chu et al, 2023; Madzelan et al, 2022; and Maxwell et al, 2018).

Infrastructure in Cumberland County is likely in a similar state and is consequently at significant risk from the changing climate. Higher average temperatures and rainfall and more frequent and extreme severe weather will interact with and compound other challenges that act on the county's infrastructure. The challenges include growth in population, land development, trucking and warehousing, electric vehicle adoption, data intensive technologies like artificial intelligence, and other trends that are placing growing demands on aging infrastructure. (Polk, 2024, and Valdez, 2024).

Going forward, adapting and retrofitting existing infrastructure and designing and constructing new infrastructure that meets the changing conditions can increase our resilience to climate and other pressures. These forward-looking actions can also produce a variety of co-benefits. Substantial benefits can be achieved by integrating strategies for adapting and creating infrastructure that is climate resilient and low-carbon and provides equitable access to infrastructure services. The benefits can include more reliable electric power, telecommunications, transportation, and drinking water services, lower risks of flood damages, more effective stormwater management, improved water quality, air quality, and human health, healthier ecosystems, protection of vulnerable people, redress of historical inequities, and lower emissions of climate changing greenhouse gas pollutants. (Chu et al, 2023; Maxwell et al, 2018).

5.1. Risks

5.1.1. Floodplains and Floods

Three types of floods pose hazards to people and infrastructure in Cumberland County – river floods, flash floods, and urban or stormwater floods, all of which are likely to be amplified by climate change. River floods occur when rain falls in a large volume for an extended period across large parts of a river basin and causes a river or major stream to overtop its banks and overflow onto neighboring land. River floods can inundate large land areas lying within the river's floodplain for multiple days. Flash floods occur when an extreme amount of rain falls in a short period in a localized area, creating runoff across the land surface that can move with high velocity and carry dangerous debris. Stormwater floods are a form of flash flood that occurs when runoff exceeds the capacity of an urban stormwater drainage system to move water away from developed areas, causing flooding of streets and properties. Flash floods and stormwater floods typically impact smaller areas and are shorter in duration than river floods. They can happen nearly anywhere, not just in floodplains. (Susquehanna Flood Forecast and Warning System, n.d.).

Flooding causes greater infrastructure damage in Pennsylvania than any other weather hazard. It is rated as the highest-risk natural hazard in the state and is identified as a high risk in Cumberland County's hazard mitigation plan. Flood risks, which are already significant, are being amplified by climate change nationally, in Pennsylvania, and in Cumberland County. Expected increases in average rainfall and more frequent heavy rain events with heavier rain volumes increase the likely occurrence of river, flash, and stormwater floods in the county. The rapid pace of development in the county, unless carefully managed, will further magnify the risks. Development can reduce infiltration of rainfall into the ground by reducing the areas of forests and agricultural lands, reducing tree canopies and vegetative groundcover, increasing the area of impervious surfaces, and placing barriers in floodways. These changes can add substantially to the volume and speed of water runoff from storms, adding to flood risks. (Cumberland County, 2020; Georgakakos et al, 2014; PA DEP, 2021; and Wehner et al, 2017).

Cumberland County's 2020 hazard mitigation plan identifies Special Flood Hazard Areas that are located within 100-year floodplains. These are areas which, based on historical flood observations and elevation contours, are estimated to be at risk of flooding once or more in every 100 years. They include properties at the confluence of the Yellow Breeches Creek and the Susquehanna River in New Cumberland, along the Conodoguinet Creek in Hogestown, and other areas of the county. Over 1500 properties are located within the designated flood hazard areas, representing 1.4% of properties in the county. The majority, 85%, are residential properties, of which more than 20% are mobile homes that are particularly vulnerable to flood damages. In addition to housing, infrastructure located in flood hazard areas and at risk from flooding include public buildings, commercial buildings, roads, railways, bridges, electricity and telecommunications infrastructure, pipelines for drinking water, wastewater, stormwater, and natural gas, parks, landscaping, and hazardous waste sites. (Cumberland County, 2020).

Boroughs and townships whose jurisdictions include areas within the flood hazard areas are required by the Pennsylvania Flood Plain Management Act to participate in the National Flood Insurance Program and to have codes or ordinances that meet flood management standards of the Federal Emergency Management Agency (FEMA). The

FEMA standards require that new construction and substantial improvements to existing structures in 100-year flood zones be elevated or flood-proofed to or above elevations of 100-year flood events. Owners of existing buildings are exempt from these requirements but can qualify for lower cost flood insurance should they choose to take actions that reduce flood risks to their properties. (PA DCED, 2021).

It is important to recognize that flood risks are not limited to infrastructure located in 100-year flood plains as other areas are also exposed to flash floods and to floods that are larger than historical 100-year flood events. Further, currently designated flood hazard zones do not account for expansions of flood plains that are likely from climate change and from development-driven changes in land use. A study conducted for FEMA estimates that 100-year river floodplains would increase 45% in area nationally by 2100, with about 70% of the increase attributed to climate change and 30% attributed to development-driven land use changes. The study also estimates that the average insured loss per flood insurance policy would increase 50% to 90% and that average policy premiums would increase 40% to 70% by 2100 in 2013 dollars. The implication is that the flood zone maps currently being used by the county for hazard mitigation planning likely understate future flood risks in the county. (AECOM, 2013, and FEMA, 2023).

5.1.2. Stormwater

Pennsylvania's stormwater infrastructure received a grade of D from the Pennsylvania State Council of the American Society of Civil Engineers. Aging stormwater systems in the state generally perform adequately for lower-intensity events but are often overwhelmed by more intense, frequent, and longer duration storms. In Cumberland County, stormwater runoff and floods cause multiple negative impacts. The impacts include carrying nutrients and other pollutants into surface and ground water where they harm water quality, eroding soils, destabilizing streambanks, building foundations, roads, bridge abutments, pipelines, and other infrastructure, and creating and exacerbating sink holes. Stormwater floods also create hazardous conditions by inundating roadways, sidewalks, and properties with unwanted water.

Because stormwater runoff from urban areas is a major source of water pollution, municipalities that are designated as urban are required by the Clean Water Act to obtain a National Pollution Discharge Elimination System (NPDES) permit. This includes all 17 municipalities in the county from Carlisle and east to the Susquehanna River, except for Mount Holly Springs. All the urban municipalities have storm sewer systems that are separate from wastewater systems that are referred to as Municipal Separate Storm Sewer Systems (MS4). The NPDES permit program requires the municipalities to have MS4 management plans and to enact best management practices (BMPs) for reducing the pollutant loads their storm water systems deliver to surface and ground waters. Rural jurisdictions in the county are not required to obtain NPDES permits or to have MS4 management plans, but they are subject to the County Wide Action Plan for clean water, which includes best management practices for rural communities. (Clean Water Cumberland, 2022; Cumberland County, 2020; Polk, 2024; and Potts, 2022).

The greater and flashier rainfall that is expected from climate change will amplify stormwater runoff problems and present significant challenges for stormwater management in both urban and rural areas of the county. Harm to water quality and aquatic ecosystems, soil erosion, and destabilization and damage to infrastructure are likely to increase unless compensating changes in stormwater management are made. (Shortle et al, 2015).

Gray and green infrastructure are used as stormwater management solutions in the county. Gray infrastructure refers to human-engineered structures, often made with concrete, that divert or retain water to prevent or reduce flooding in developed areas. Green infrastructure refers to natural and designed systems consisting of trees, vegetation, and contoured earthen landscapes that reduce flooding of developed areas by retaining water in natural areas and increasing infiltration into the ground. Examples of green infrastructure that help manage stormwater include urban trees, parks and other green spaces, bioretention basins, bioswales, rain gardens, and green roofs. Stormwater systems often integrate both gray and green infrastructure. (Ray, 2024).

Stormwater flooding is a chronic problem in Carlisle and parts of Dickinson College's campus. Carlisle's stormwater system includes 28 miles of stormwater pipes, some of which are 100 or more years old and in poor condition. In 2018, the Borough adopted a stormwater utility fee payable by property owners that is calculated based on the impervious area of properties. The collected fees are used to pay for replacing stormwater pipes, which are being replaced at a rate of 1.5 to 2.0 miles per year, and for other stormwater infrastructure and water quality improvements. Also, redevelopment of brownfield sites in Carlisle have incorporated features to improve stormwater management. A notable example is Carlisle's stormwater park on Fairground Avenue, which integrates gray and green infrastructure and was funded with grants from the U.S. and Pennsylvania departments of transportation, the USEPA, and other sources. (Polk, 2024, and Ray, 2024).

Carlisle's stormwater utility fee creates an incentive for property owners to implement measures to better manage stormwater runoff from their properties. Property owners earn credits against the fee by taking action to manage stormwater and reduce impacts on the Borough's stormwater system. Dickinson College has received credits for bioretention systems that were installed along West Louther and Cherry Streets, which substantially reduced stormwater flooding in those locations. Another Dickinson project is a water retention and diversion system integrated into the college's High Street Residence Hall, a LEED Platinum certified building. The system captures rain from the building's roof and directs the runoff to an underground cistern where it can be stored and then slowly released when flooding abates after a major rainstorm. The site also includes rain gardens along High Street that facilitate infiltration of rainfall into the ground. (Carlisle Borough, 2024; Polk, 2024; and Ray, 2024).

5.1.3. Water Quantity and Quality

Climate change is likely to make water supplies more abundant on average but also more variable and less reliable, creating challenges for managing water supplies and demands in drier than average years. It is also likely to harm water quality, necessitating adaptive responses to protect public health and ecosystems. A particular concern is the potential increase in pollution loads flowing to the Chesapeake Bay, which would trigger reductions in the allowed pollutant loads to surface waters throughout the Susquehanna basin.

Water is plentiful in Cumberland County in most years, with sufficient water to supply water withdrawals for residential, commercial, and industrial water uses while supporting rainfed agriculture, healthy forests, freshwater ecosystems, recreation, and other water uses. Water withdrawals as a percentage of available supply are typically well below the 40% threshold that is an indicator of water supply stress. But there have also been periods of severe drought that have required constraints on water use, excessively wet periods that have damaged crops, flood events that have taken lives and damaged property, and degraded water quality that has impacted people, wildlife, and ecosystems. (Zarchansky, 1986).

Cumberland County has experienced periods of drought that have ranged in severity from declared drought watches to drought emergencies. Drought impacts have fallen most heavily on agriculture, which is largely rainfed in the county. The impacts on agriculture cause cascading impacts on local economies and livelihoods in rural areas of the county. Drought impacts have also been significant for people dependent on shallow, on-lot ground water wells. To mitigate some of the impacts, drought watches and warnings have been declared by the Pennsylvania Emergency Management Agency (PEMA) when precipitation, streamflow, groundwater levels, and soil moisture are low relative to historical averages. During declared drought watches, water suppliers and users are asked to take voluntary measures to reduce water use 5% to 10%. During declared drought warnings, reductions of 10% to 15% are requested. While the measures are voluntary, curtailing water use entails some sacrifices and hardship. In more severe droughts, drought emergencies have been declared and emergency management regulations put into effect that have included prohibiting certain non-essential water uses and other restrictions that imposed significant sacrifices while seeking to mitigate the worst consequences of water shortage.

The effects of climate change on droughts are difficult to predict, but several factors indicate the potential for droughts to become more frequent, longer, and drier as the climate warms. Despite expected increases in average

rainfall, higher temperatures will increase evaporation of water from streams, lakes, and soils and greater transpiration from vegetation. Also, climate models indicate a tendency for fewer rain days and longer periods of consecutive dry days. The combined effects of greater evapotranspiration and more dry days can dry agricultural and other soils, stress vegetation, reduce stream flows and lake levels, and dry wetlands despite higher average rainfall. Over time, as warming increases, the potential for more frequent and more severe drought appears likely to grow, suggesting that it would be prudent to plan and prepare for more drought events in the future. (PA DEP, 2021).

Water quality impacts from climate change are likely to be a more substantial risk in Cumberland County than the impacts on water quantity. Impaired water quality harms human health, aquatic ecosystems, fish, and recreational uses of water. Currently, approximately 30% of Cumberland County's 786 miles of streams are degraded and do not meet water quality standards due to nitrogen, phosphorous, and sediment pollution. Agriculture is the source of an estimated 63% of nitrogen pollution entering county waterways, stormwater runoff from developed urban areas contributes 17%, discharges of treated wastewater contribute 10%, natural processes 8%, and septic systems 2%. These pollutant loadings are likely to increase as runoff increases with rising average rainfall and increases in the frequency and severity of heavy rain events. Impacts of the greater pollutant loads on water quality will be amplified by the effects of higher air temperatures, which raise water temperatures, increase metabolic processes that consume nutrients, and decrease dissolved oxygen in surface waters. (Georgakakos et al, 2014, and PA DEP, 2021).

Degraded water quality in the county would also negatively impact water quality in the Chesapeake Bay, likely resulting in more stringent actions in the county to protect the Bay. Cumberland County and other jurisdictions in the Chesapeake watershed are required by the Chesapeake Bay Program to implement watershed management plans to reduce nitrogen, phosphorous, and sediment loads entering their surface waters. But current pollution reduction targets required by the Program are estimated to be insufficient to meet water quality standards for the Bay in the future. Analyses of the effects of increasing rainfall, rainfall intensity, and temperatures project declining water quality in the Bay that would push the Bay into non-attainment status. Acting on this information, in 2020 the Chesapeake Bay Program adjusted the 2025 pollutant reduction targets for each of the river basins in the watershed, which get translated into revisions of maximum allowed pollution loads, watershed implementation plans, and management practices that are required of municipalities and landowners. It is important to note that the adjustments to date only address climate change as projected to the year 2025. Beyond 2025, as the climate continues to become warmer and wetter, further adjustments in pollutant reduction targets are likely to require stronger actions in Cumberland County and elsewhere in the Bay's watershed. (Shenk et al, 2021).

Drinking water infrastructure in Pennsylvania received a grade of D from the Pennsylvania State Council of the American Society of Civil Engineers for being old, in poor shape, and at strong risk of failure. Water mains are increasing in average age as repairs and replacement lag substantially behind what is required to maintain pipes at their recommended service life. Their poor condition makes them susceptible to damage from floods, erosion, and scouring, stresses that will increase as the climate changes and potentially increase the frequency of disruptions to drinking water service in the county.

Drinking water contamination is known to be influenced by climatic factors and will likely be a growing risk due to climate change. Extreme rain events are statistically linked to increased levels of pathogens in treated drinking water and nearly 70% of water-related disease outbreaks in the United States have been preceded by extreme rain. Climate change is expected to bring heavier rains and more frequent floods that would carry more pathogens, more nutrients that promote the growth of pathogens, and more chemical and mineral pollutants into waterways and water supply systems, increasing risks of human exposure. Primary sources of contamination are human and animal waste and nutrients running off from agricultural lands and fertilized lawns and fields. Septic fields, which are common in rural parts of Cumberland County, can become water saturated and backup to be locally important sources of contamination. (Trtanj et al, 2016).

While waterborne disease outbreaks from drinking water supplies could become more common as a result of climate change, the risks can be readily mitigated for public drinking water supplies by improving monitoring and treatment, though these measures can increase costs for supplying safe drinking water. In contrast, rising risks of waterborne illness from private wells, septic fields, and from recreational exposures and consumption of fish and shellfish cannot be addressed as easily. Managing these risks will require improved land management practices on farms and other lands to limit pathogens and nutrient pollution loads from reaching surface waters. (Trtanj et al, 2016).

Heavy rain events have contaminated drinking water supplies and disrupted drinking water services in the county. For example, runoff from a heavy rain event in November 2023 contaminated public drinking water supplies in Mechanicsburg, causing water supplies to be curtailed and a water conservation order issued. In August 2024, flooding from Tropical Storm Debby caused a water main to break in Cumberland County that cut off water service to three of four acute care facilities in the county as well as other water users. The County Board of Commissioners declared a disaster emergency while Pennsylvania American Water issued a boil water advisory to tens of thousands of customers and provided bottled water to affected customers. (Pennsylvania American Water, 2023; Polk, 2024; and Vigna, 2024). These events demonstrate the vulnerability of the county's water supply to climatic events.

5.1.4. Buildings

Buildings, as already noted, will be at increasing risk of damage from river, flash, and stormwater floods. They are, and increasingly will be, subject to other growing pressures as well. Increasing heat, wind, rainfall, and humidity can all compromise building performance, increase operating and maintenance costs, decrease useful lifetimes, and decrease occupants' comfort and productivity. Heat can cause buildings to age more quickly, wear out roofing materials faster, dry out wood in attic spaces, increase cooling costs, and increase wear on cooling and ventilation systems. In buildings with poor building enclosures that allow significant air infiltration, mechanical systems will struggle during extreme heat events to keep indoor temperatures and humidity within comfortable ranges and can become dangerously hot for occupants. As cooling costs rise, heating costs will decline with the warming climate, though the balance will likely be an increase in overall energy costs. Rising cooling costs can be burdensome, particularly for low-income households, some of whom may limit their use of air conditioning and potentially increase their risk of heat-related illnesses. (Allura, 2024; Cohen et al, 2024; and JL Architects, 2022).

More rain and heavier rain increase the risk of water damage to buildings. Water can enter penetrations in roofs made for exhaust vents, plumbing vents, skylights, and chimneys when seals are dried out and eroded, which happens eventually for all sealing methods. Building foundations are at risk of water entering below grade when soils become saturated from long and heavy rains. In extreme cases, building foundations can shift. High winds can drive rain under roof shingles, vertical siding, window frames, doors, and roofs to damage interior spaces. Very high winds can also damage building roofs and other parts of buildings. (Allura, 2024, and JL Architects, 2022).

A warmer, wetter, more humid climate can worsen indoor air quality by promoting growth of mold and bacteria. Mechanical systems need to work harder when it is hot and humid to maintain indoor temperatures and humidity at levels that limit mold and bacteria growth. This is a particular problem in older buildings, buildings with significant penetrations to their building enclosures, and buildings with inefficient heating, ventilation, and cooling systems. Higher outdoor temperatures can also increase the penetration of water vapor through building materials and into building interiors. Rain and storm events that cause water to enter buildings can also promote mold and bacteria growth if building systems are not able to maintain or return interior spaces to appropriate temperature and humidity levels. Health effects of poor indoor air quality are discussed earlier in this report. (Chu et al, 2023, and USEPA, 2024b).

A 2015 housing inventory found that 33% of housing in Cumberland County was built prior to 1960, with much of the older housing concentrated in Carlisle, Mechanicsburg, and New Cumberland. While the percentage is lower than other nearby counties, the inventory suggests a significant portion of housing in the county is relatively old and

may require more frequent and complex maintenance. These older houses are potentially more vulnerable to climate change than newer housing.

Dickinson College has buildings that range in age from over 200 years to a few years, with a total area of nearly 2 million square feet. Many of the buildings have undergone major renovations, though a number of buildings are in need of significant maintenance as evidenced by tens of millions of dollars in deferred maintenance needs. These buildings are likely vulnerable to adverse impacts from the changing climate. (Valdez Bautista, 2024).

Seven of Dickinson's buildings have earned certification for Leadership in Energy and Environmental Design (LEED), one of which received the highest rating of Platinum and six of which received Gold. Three of the buildings were new construction and four were major renovations of existing buildings. While climate resilience has not been a specific focus of the LEED certification process up until LEED v5, which is being released in 2025, many of the energy efficiency and environmental design elements promoted by LEED contribute to making buildings climate resilient as well as low-carbon in comparison to conventional buildings. The most recent LEED building is Dickinson's High Street Residence Hall, completed in 2018. Since 2018, however, Dickinson made major renovations to four buildings and did not pursue LEED certification for any of the four. Although LEED certification was not sought, the renovations did include some sustainability elements and undoubtedly the buildings were made more climate resilient through the renovation process. But Dickinson's decisions to not participate in LEED certification when making major renovations represents a step back by the college from its previous commitment to build sustainable infrastructure.

Several of Dickinson's buildings have struggled with maintaining indoor air quality and have had significant mold problems. These have resulted in students being relocated from their residence halls for multiple days, closing off a section of the library and temporarily removing affected materials from circulation, significant mold remediation expenses, and running multiple dehumidifiers for extensive periods in academic buildings and residence halls. Deficiencies in building enclosures and mechanical systems, as well as hot and humid conditions, are contributing factors to the mold problems. The Dickinson buildings that have experienced problems with mold are likely to have greater problems in a hotter and wetter future unless mechanical systems and enclosures are upgraded. (Semma, 2024, and Valdez Bautista, 2024).

5.1.5. Energy and Telecommunications

Energy and telecommunications infrastructure and services are vulnerable to and impacted by extreme weather. Damage from extreme weather can disrupt the generation, transmission, and distribution of electric power, which in turn disrupt deliveries of safe drinking water, natural gas, and fuels, transportation systems, communication systems, internet service, emergency response services, and operations of hospitals, food stores, food refrigeration, gas stations, financial systems, schools, childcare centers, retail stores, cooling and heating systems, and more. Disruptions to these and other services from extreme weather are projected to increase in frequency and duration as a result of climate change. (Maxwell, 2018; Polk, 2024; Zamuda et al, 2018; and Zamuda et al, 2023).

Efforts to adapt existing energy and telecommunications infrastructure and invest in new infrastructure to enhance climate resilience will be complicated by rapidly changing demands, technologies, market conditions, incentives, and policies. Population and economic development are growing in Cumberland County, increasing demands for energy and telecommunications services as well as other services, placing increasing pressure on the infrastructure that supports them. Electricity demand, which experienced little growth in the U.S. in recent decades, is growing more rapidly and is likely to accelerate in response to a number of trends. There is an energy transition underway that is shifting energy use away from fossil fuels and toward electricity for transportation, space heating, industrial processes, and other uses. Applications of artificial intelligence and other data-intensive activities are growing rapidly, as is the demand for electricity to power the data centers that serve them. Also, warmer temperatures are increasing average and peak energy demands for cooling.

The resulting growth in electricity demand from these trends will increase challenges for designing and operating a low or zero carbon electric grid that will be capable of supplying power reliably, including during extreme heat events. Significant efforts will be needed to permit and connect new zero carbon generation sources to the grid, add power storage technologies to manage the intermittency of renewable power, and integrate smart information technologies throughout the energy system to smooth peaks in demands and match power demands with supplies.

Extreme weather is the principal cause of electric power outages in the United States, which have been increasing in frequency. Major power outages that impacted 50,000 or more customers in the U.S. increased over 60% in 2011 – 2021 compared to 2000 – 2010. Above ground powerlines are at risk from high winds and falling trees and tree limbs, while below ground powerlines are at risk from flooding and land subsidence, which can also impact transmission towers, transformers, and substations. Nationally, climate change could increase annual expenditures on infrastructure for electricity transmission and distribution by up to 25% by the end of the century and costs for power interruptions could increase by $5 billion to $8 billion per year. (Zamuda, 2023).

In Pennsylvania, the reliability and resilience of electricity distribution companies declined in recent years, with the number and duration of power interruption events increasing since 2015. The most common cause of power interruptions in Pennsylvania are trees and tree limbs falling during storms. Factors contributing to the more frequent power interruptions include more frequent storms, trees weakened and killed by the Emerald Ash Borer and other pests, and insufficient management of vegetation overhanging and adjacent to transmission and distribution lines. Pennsylvania Power and Light (PPL), the largest electricity distributor serving Cumberland County, meets benchmark requirements of the Pennsylvania Public Utility Commission (PUC) for the number of power interruptions. However, PPL's reliability declined recently. Power interruptions increased in 2023, a year in which a record 45 storm events occurred in PPL's service area. There were 1.1 million customer interruptions and 214.4 million customer minutes interrupted across PPL's service area. An estimated 70% of the interrupted minutes was caused by trees and 14% by equipment failures. The PA PUC voiced concern in its report that possible reductions or insufficient increases in vegetation management expenditures may be responsible for increases in power outages in PPL's service area. (PA PUC, 2023).

In the future, increases in the frequency of storms and higher wind speeds could increase the frequency of power outages from storms in the county. Adding to the risks are the effects of climate change on the health of trees. As the climate changes, the climate in Cumberland County will become increasingly ill-suited for some tree species that are currently in the county. The warmer and wetter climate is also likely to increase the numbers and seasonal activities of a variety of pests and pathogens that impact trees. Damages to the health of trees in the county would increase the potential for trees and tree limbs to fall on power lines during storms and necessitate increases in electric distribution companies' expenditures on vegetation management.

Extreme heat impacts electric power in multiple ways. Higher air temperatures reduce the efficiency of power generation, transmission, and distribution, which raises the costs of power delivered to customers. Higher air temperatures also increase water temperatures. Most power plants rely on water for cooling, which becomes less efficient as water temperatures rise and can cause power plants to shut down to comply with temperature regulations. Estimated effects of higher water temperatures on electric power output in the U.S. range from decreases of 7% to 13% by 2050. (Zamuda et al, 2023).

Another impact of higher temperatures are increases in electric power demand for air conditioning, which will increase on average in warmer summers and spike during extreme heat events, increasing customers electricity costs. Spikes in demand during extreme heat events can exceed the capacity of the electric grid to deliver power and result in blackouts and brownouts, which amplify the risks of heat-related illnesses and deaths. Increases in peak demand loads in a warming climate with more severe extreme heat events will necessitate more investment by electric utilities to increase peak load generation capacity and in technologies and programs to manage and reduce peak loads. Estimates of the added costs due to climate change range up to $30 billion per year by mid-century in the U.S., with residential and commercial customers spending 4% to 18% more per year on electricity.

Estimates for Cumberland County don't exist, but it is likely that climate change will increase electricity costs in the county. (Zamuda et al, 2018, and Zamuda et al, 2023).

Natural gas distribution can also be affected by weather and climate change. Heavy rains, floods and land movement have caused damage to natural gas pipelines in Pennsylvania and elsewhere. Events that damage pipelines could become more frequent with climate change, potentially causing leaks and even explosions. Pennsylvania's Pipeline and Hazardous Materials Safety Administration (PHMSA) sends advisory statements to pipeline construction companies about the dangers of building in flood-prone areas or areas that are susceptible to earth-movement and landslides, while the Pennsylvania Public Utility Commission is responsible for regulation and safety of pipelines. There are two gas pipelines that run through Cumberland County, Mariner East II and Mariner East 2X, where karst geology adds to risks of land movement and subsidence. (Marroni, 2018, and Phillips, 2019).

Telecommunications, which encompass telephone and cellular networks, data centers, data and video transmission, the internet, and other services, are reliant on electric power. Consequently, they are vulnerable to the same climate hazards that can interrupt electric power supply and impact energy infrastructure and costs. When electric power is interrupted by severe weather, telecommunications in affected service areas will also be interrupted. Telecommunications infrastructure itself can also be impacted by severe weather, as Dickinson College and other affected internet customers learned when downed trees damaged fiber optic lines of an internet service provider on two occasions in the past year.

Heat is also a threat to telecommunications. Telecommunications infrastructure is designed to perform within specific climate and environmental conditions. When those conditions are exceeded, the quality, continuity, and cost of telecommunication services can be impaired, severely impacting customers.

Data centers house large numbers of computers that generate significant heat. Cooling and airflow systems are required to keep temperatures in a range that allows the computers to perform efficiently and prevent overheating and damage. But heat wave events push the abilities of data centers' cooling systems, which can cause equipment to overheat and fail, resulting in service outages. When this happens, users of telecommunication services are at risk of losing mission-critical services necessary for their continued operations. Even leaders in the telecommunications industry with state-of-the-art facilities have experienced severe service disruptions from extreme heat events that exceeded the cooling capacities of their data centers and caused them to go off-line for significant periods. As heat waves become more frequent and severe, telecommunications companies and users will face increased costs for cooling systems with greater capacities, backup power generation systems, energy storage systems, and redundant facilities. Users may also consider contracting with multiple providers of telecommunication services as insurance against service outages. (Adams et al, 2014, and TelecomReview, 2024)

Continuity of Dickinson College's operations are highly dependent on energy and telecommunications. Academic instruction uses information technology extensively and electric power is necessary for accessing and using the college's online learning management system, library resources, and other information sources, using digital technologies in classrooms, operating lab equipment, and lighting, cooling, heating, and ventilating classrooms. As a residential college, power is needed to provide students with safe, healthy, and comfortable housing and dining, health, recreational, and other services. Loss of power or IT services, even for short periods, severely disrupt Dickinson's ability to provide these services, adversely impacting our students and employees. Frequent or long duration interruptions of power or IT services could negatively impact the college's ability to keep our students and faculty safe, operate the college efficiently and cost effectively, and attract and retain students. Dickinson also needs to consider and plan for events that impact the college and also the capacity of the wider community to provide emergency services, hospital care, shelter, transportation, and other services.

5.1.6. Transportation

The performance of the transportation sector and transportation infrastructure are projected to be undermined in the United States by climate change. Impacts from increases in heavy precipitation, flooding, storms, and heat threaten the performance of the entire system, with significant implications for the movement of people and goods. Heavy rains and flood waters can create hazardous road conditions, wash out and damage roads and railways, compromise the structural integrity of bridges by washing sediments away from their foundations, and cause landslides in transportation corridors. Winds from storms can block roads by felling trees and downing powerlines. High temperatures place stresses on concrete roads and bridges, expand, weaken, and bend rail tracks, reduce the ability of airplanes to generate lift, and compromise the health and productivity of construction and transportation workers. Consequences of these effects include faster deterioration of transportation infrastructure, greater maintenance costs, more frequent repairs and replacement, greater stress and damage to road vehicles, more frequent and longer travel delays, and increases in accident rates. Combined, they result in a less safe, less efficient, and more costly transportation system. (Jacobs et al, 2018; Liban et al, 2023; and Polk, 2024).

The Extreme Weather Vulnerability Study of Pennsylvania's transportation systems identified weather-related hazards that are of most concern to design and maintenance personnel in district offices of the Pennsylvania Department of Transportation (PennDOT). Snow and ice were identified as the greatest concern, with flooding and intense rain also identified as major concerns. Flooding and intense rain can also impact transportation by causing landslides, mudslides, slope failures, and saturated soils compromising the structural integrity of roads, bridges, and tunnels. Downed trees and utility lines from storms are another concern that was identified. Heat was noted as causing some impacts, but staff of most districts did not consider heat to be a major issue at the time of the study. A challenge for improving the performance of Pennsylvania's transportation systems with respect to flooding and other weather hazards is securing additional funding for planning, maintaining, and designing systems for greater resilience to the changing climate. (PennDOT, 2017).

Logistics, trucking, and warehousing have grown substantially in Cumberland County and are expected to continue to grow in the future. These activities make heavy use of transportation infrastructure in the region and add to the pressures on roads and bridges. These pressures will interact with the stresses from climate change to amplify vulnerabilities of transportation in the county. (Polk, 2024).

Active transportation modes such as walking and cycling are also affected by weather and climate change. Higher average temperatures can extend the seasons when residents choose to walk and bike, but more heavy rain events, heat waves, and severe weather can result in more days when roads, trails, and sidewalks are less safe for walking and biking. The net effects on active transportation are uncertain. Pedestrian and biking infrastructure likely will be negatively impacted by climate change and require more maintenance and repairs, much like other forms of transportation infrastructure.

Dickinson College will be impacted by the effects of climate change on transportation systems. Employees' commutes could become longer and less safe, particularly affecting essential workers who must report for work no matter the weather. Students traveling to campus from within state, out of state, and internationally may experience more travel delays from events that impact road, rail, and air transportation. Long delays for students trying to leave campus at the end of terms could require providing housing and food services for stranded students, while delays for students coming to campus at the start of terms could require adjustments to academic schedules. During academic terms, students and employees may be inconvenienced more often by events that make walking and biking on campus and in Carlisle less comfortable or less safe. Disruptions to transportation can also impact supply chains for delivery of food, fuel and other supplies to campus.

5.2. Strengths and Weaknesses

Cumberland County has extensive and varied infrastructure that provides for the needs of county residents and businesses. A significant portion of the infrastructure is vulnerable to severe weather and climate change because it is old, in need of significant maintenance, and is at or near the end of useful lifetimes. Newer infrastructure operates more efficiently and reliably but typically is not designed for changing climate conditions. As the climate

continues to change, much of the infrastructure in the county is likely to operate less efficiently, become more costly to maintain, and be at greater risk of failure. Increasingly, there will be need for planning, designing, and investing in new infrastructure that can perform strongly across a range of future climate conditions that may be experienced in the county.

Flooding is a significant and potentially growing risk in Cumberland County. The county recently updated its maps of flood plains and designation of flood hazard zones, enabling improved identification of at-risk properties. Over 1500 residential properties and other infrastructure were identified as being located in designated flood hazard zones. County jurisdictions with properties in designated flood zones participate in the National Flood Insurance Program and implement codes and ordinances to manage and mitigate flood risks that can help support climate resilience. But the regulations do not prevent new development in flood zones, making it likely that more infrastructure will be built in places with significant flood risk. The regulations also do not apply to existing infrastructure, so adoption of flood proofing measures for existing structures is likely to be very limited. Maps that are used to identify areas at risk from 100-year flood events and to designate flood hazard zones do not account for the likely expansion of flood plains as heavy rain events become more frequent with climate change. Also, flood risks are present and growing beyond the designated flood zones, and residents and property owners in these areas are often unaware of the risks, not highly knowledgeable about flood proofing measures, and not insured against floods.

Stormwater flooding is a chronic problem in many areas of the county. All urban municipalities in the county have Municipal Separate Storm Sewer System (MS4) Programs for managing stormwater runoff, as required by state and federal regulations. Rural municipalities are not covered by MS4 programs but have requirements for managing stormwater runoff under the County Wide Action Plan for clean water. These programs are sources of strength in the county that contribute to climate resilience by helping to limit pollutants being carried by stormwater into county surface waters and groundwater.

Much of the grey stormwater infrastructure is old and needing replacement. Carlisle and other jurisdictions are proactively replacing stormwater pipes and implementing new green and grey infrastructure projects to improve stormwater management. Replacing, maintaining, and investing in new stormwater infrastructure can be costly for local governments. Some local governments in the county, including Carlisle Borough and Silver Spring, Hampden, and North Middleton Townships, fund the improvements through stormwater utility fees. In the case of Carlisle, there is also a credit system designed to give property owners an incentive to manage stormwater runoff from their properties.

As noted previously, water is plentiful in Cumberland County in most years and water stress has been a problem only during periods of drought. However, drought frequency and severity may increase in the warming climate, which could increase the frequency of water stress for public water supplies that would trigger water conservation measures during periods of declared water watches, warnings, and emergencies. Droughts can also have significant impacts on agriculture, which is mostly not irrigated in the county, streams, trout fisheries, and recreational water uses. The county comprehensive plan notes that the county lacks a plan for protecting public water supplies, despite a requirement under the Pennsylvania Municipalities Planning Code that the county have a plan. This deficiency is a weakness and source of vulnerability for the county.

Potential impacts of climate change on water quality likely is a greater vulnerability for the county than impacts on water quantity. The greatest water quality risks are to aquatic ecosystems, fishing and other recreational uses of our streams and lakes, and groundwater. More frequent heavy rain events may increase the frequency of contamination of public drinking water, but risks to public drinking water and public health likely can be mitigated effectively by existing water treatment systems, though the cost of treatment could increase if the quality of source water is degraded. Private groundwater wells are at greater risk of contamination from heavy rain events, with karst geology and nearby septic systems adding to the risk and compounded by limited resources of many well owners for protecting or replacing their wells.

Clean Water Cumberland is a coalition that helps coordinate efforts to protect water quality across jurisdictions through the Countywide Action Plan and the Clean Water Grant Program. Technical assistance is available from the Cumberland County Conservation District, Penn State Extension, and other groups. Additional sources of strength and resilience for protecting water quality are the Conodoguinet Creek Watershed Association, the Yellow Breeches Watershed Association, the LeTort Regional Authority, the Central Pennsylvania Conservancy, Capital RC&D, South Mountain Partnership, Cumberland Conservation Collaborative, and Cumberland Valley Trout Unlimited.

The percentage of housing stock that is older than 50 years is less in Cumberland County than in neighboring counties, suggesting that housing stock in Cumberland County may be more resilient to climate change than housing stocks of other counties. Yet, a substantial portion of housing in the county, roughly one-third, is 50+ years old. The older housing stock is concentrated in Carlisle, Mechanicsburg, and New Cumberland and is likely occupied by lower-income households. Data on the ages of other types of buildings in the county are not readily available, but it is likely that a significant portion is also old and in need of significant maintenance. Older buildings for which mechanical systems have not been updated recently or which have not maintained and improved their building enclosures have higher operating and maintenance costs, are often not resilient to climate hazards, and are likely to become even less resilient as the climate continues to change. Housing cost burdened households will struggle to manage the growing costs for cooling, maintenance, and home improvements. Institutions with significant deferred maintenance needs, like Dickinson College, will face significant challenges in retrofitting buildings to perform in the future climate.

Statewide, Pennsylvania has an electricity generation buffer of 30% relative to current demands and the PJM Interconnection helps to assure demands are met within its service area by coordinating wholesale electricity distribution. Natural gas supplies are also abundant and have displaced coal as the largest energy source used for power generation in the regional electric grid. Renewable energy sources provide a small but growing share of electricity generation and other energy uses, with substantial potential for future growth. These shifts have reduced greenhouse gas emissions per kWh of electricity generated and per unit of final energy consumed in the county while also helping to limit emissions of other air pollutants.

The Public Utility Commission identified PPL as one of three electricity distribution companies that consistently achieve reliability benchmarks for numbers of electric power interruptions, noting that PPL and the other two companies with strong reliability performance had made more capital investments through their Long-Term Infrastructure Investment Plans than other companies. But the PUC also reports that PPL's reliability decreased recently as the number of service interruptions and the duration of interruptions to customers both increased. The PUC identified insufficient vegetation management by PPL as a possible contributing factor. As climate change increases the potential for severe storms and harms the health of trees in the region, the need for robust vegetation management by utilities will increase. In the case of natural gas, pipeline distribution of gas will be at growing risk from heavy rains, floods, and land movements that will be compounded by the county's karst geology. Strong monitoring and maintenance programs will be needed to prevent damages to pipelines that could disrupt gas distribution and pose dangers to people and property.

Energy costs have been increasing, burdening lower income households and others and detracting from their resilience. As noted earlier, climate change may increase energy costs and add to the burden. This can be particularly problematic during extreme heat events for households that may have but cannot afford to run air conditioners. Pennsylvania's Low Income Home Energy Assistance Program (LIHEAP) and other assistance programs help low-income people to pay their energy utilities, helping to bolster their resilience to financial pressures.

Cumberland County is served by an extensive network of interstates, highways, roads, and bridges that enable mostly efficient travel within the county for those with motor vehicles, as well as connections to nearby major metropolitan centers. Western, rural parts of the county are not as well served as the more developed eastern half of the county. Public transit and regional rail infrastructure are less extensive and fall short of the needs of county residents and workers. Many communities in the county are walkable and bikeable, enabling many residents to use active transportation for recreation, commuting, and other purposes. But infrastructure for walking and biking often

is limited and there are routes with significant safety concerns. Deficiencies in public transit and infrastructure for active transportation contribute to the high dependence of county residents on motor vehicles. The situation is improving with more attention being given to active transportation and traffic safety in planning activities of the Harrisburg Area Transportation Study (HATS) Regional Authority, Cumberland County, and municipalities in the county.

Many roads and bridges are old, in poor condition, require costly maintenance, and have low resilience to climate hazards and climate change. Heavy truck traffic on interstates and state highways from the logistics industry that has a major presence in the county causes substantial wear and tear on infrastructure that increase maintenance costs and shorten the useable lifetime. Large volumes of truck and passenger vehicle traffic through the Cumberland Valley are major sources of air pollution that have made central Pennsylvania one of the worst areas for air quality in the nation.

People and organizations that are sources of strength for increasing the resilience of transportation infrastructure include the Cumberland County Planning Department, municipal officials working to improve active transportation opportunities and traffic safety, HATS, Cumberland Valley Rail Trail, LifeCycle at New Life Community Church, Recycle Bicycle in Harrisburg, and The Handlebar at Dickinson College.

5.3. Resilience Strategies

Examples of resilience strategies for infrastructure are presented in Tables 6 through 11 along with indicators that could be used to measure progress and primary actors for planning and implementing strategies. Some are cross-cutting strategies that can address climate-related challenges to different types of infrastructure and others are targeted to risks to specific forms of infrastructure. If the strategies are pursued collectively in a coordinated fashion, they can lay the foundations for communities that are climate resilient, economically resilient, low carbon, health promoting, and equitable.

Table 6. Examples of Infrastructure Resilience Strategies: Cross-Cutting.

Strategy	Indicators of progress	Primary Actors
Encourage development and investment in infrastructure that is compact, limits sprawl, and promotes mixed uses, active transportation, public transit, clean and reliable energy, energy efficiency, green spaces, clean air, clean water, safe drinking water, improved stormwater management, reduced flood risks, and mitigation of urban heat islands.	Improved air quality. Increase in % of commuters using public transit and active transportation. Increase in % of vehicles that are electric. Decrease in per capita energy use and energy costs. Increase in reliability of electric power. Decrease in impervious surface area. Decrease in flood damages.	County Planning Department, municipalities, HATS, utilities, businesses
Review and update county and municipal comprehensive plans and hazard mitigation plans to anticipate and incorporate the effects of potential increases in climate hazards on the safety, reliability, performance, maintenance costs, and useful lifetimes of infrastructure.	Number of jurisdictions that update plans.	County Planning Department, municipalities
Develop a mapping tool to identify places of priority for climate-resilience action by overlaying locations of floodplains, air quality hotspots, urban heat island hotspots, impervious surfaces, tree canopy, greenspaces, housing, healthcare, other infrastructure, community organizations, and demographic indicators of social vulnerability and resilience.	Use of the mapping tool. Evaluations from users.	County Planning Department, colleges and universities

Encourage organizations to create or update continuity plans for continued operations during interruptions of electric power, telecommunications, water, transportation, and supplies of important equipment and materials for extensive periods as a result of severe weather.	Continuity plans stress-tested for interruptions of critical services for 2+ weeks.	All organizations
Educate the public, homeowners, developers, and infrastructure owners about risks to infrastructure from changing climate hazards and about actions to mitigate risks and build resilience.	Number of participants in education programs. Diversity of participants. Levels of engagement. Evaluations from participants.	Public agencies, public schools, colleges and universities, community organizations

Table 7. Examples of Infrastructure Resilience Strategies: Floodplains.

Strategy	Indicators of progress	Primary Actors
Assess and map the potential for flood risks to increase within and expand beyond the current Special Flood Hazard Areas.	Periodic updates of flood hazard maps. Updated maps included in the County Hazard Mitigation Plan	Cumberland County Planning Department, PEMA, FEMA
Initiate a program to regularly assess risks, implement flood proofing measures, and consider relocation of publicly owned infrastructure that is located in current and projected future Special Flood Hazard Areas.	Inventory of at-risk infrastructure and characterizations of their risks. Number of facilities for which flood proofing measures are implemented.	County and municipal governments
Adopt plans, policies, regulations, and/or incentives to discourage the construction of new infrastructure in current and projected future Special Flood Hazard Areas.	Inventory of newly constructed infrastructure in and near flood hazard areas.	County and municipal governments
Raise awareness of private owners of existing infrastructure in current and projected future Special Flood Hazard Areas about growing flood risks and encourage them to take voluntary actions to mitigate flood risks and/or relocate through ordinances, incentives and financial assistance.	Number of infrastructure owners who choose to mitigate flood risks. Number of infrastructure owners who choose to relocate.	County Planning Department, municipalities, property owners
Raise awareness of property owners who are not required to purchase national flood insurance about growing flood risks and encourage voluntary purchase of flood insurance through incentives and financial assistance.	Number of property owners who purchase voluntary flood insurance.	County Planning Department, municipalities, property owners
Develop and promote a robust early warning and communication system to inform community members about forecasts of extreme heat, severe weather, floods, hazardous air quality, and other hazards and about adaptive actions that can be taken to prevent or limit the risks.	Number of people who subscribe. Diversity of subscribers. Evaluations from subscribers.	County Planning Department, County Emergency Operations Center, municipalities, PEMA

Table 8. Examples of Infrastructure Resilience Strategies: Water Quantity, Water Quality, and Stormwater Management.

Strategy	Indicators of progress	Primary Actors
Conduct a county water supply study to identify the location, quantity, and consumption rates of public water sources, develop a plan to protect water sources that takes into account potential future changes in precipitation averages, extremes, and drought frequency and severity, and incorporate the water supply plan into the county comprehensive plan.	County water supply study completed. Water supply plan adopted as part of the county comprehensive plan.	County Planning Commission and Planning Department, municipalities
Review and update processes for planning for, monitoring, and responding to drought watches, warnings, and emergencies to anticipate and incorporate potential increases in drought frequency and severity.	Processes updated.	PEMA, PA DEP, County Planning Commission and Planning Department, municipalities, public water suppliers
Develop and implement standards for private groundwater wells and septic systems.	Number of contaminated groundwater wells.	PA legislature, County Planning Commission

		and Planning Department, and municipalities
Review and update best management practices (BMPs) for protecting water quality, taking into account potential future changes in precipitation averages and frequencies and severities of heavy rain and drought and targeting places that can have the greatest impact on water quality.	BMPs updated. BMPs targeted to priority locations.	County Planning Commission, Planning Department, and Conservation District, Clean Water Cumberland, and municipalities
Update county and municipal stormwater management plans to anticipate and incorporate potential increases in heavy rain events and the effects of future development that reduces green space and increases impervious surface area.	Number of jurisdictions that update plans.	County Planning Department, County Conservation District, Clean Water Cumberland, and municipalities
Improve programs to regularly inspect, maintain, and replace stormwater infrastructure and assess needs for increased capacity for larger storm events.	Percentage of miles of stormwater pipelines updated.	Municipalities
Adopt storm water fees to fund stormwater infrastructure improvements in municipalities that do not yet have a fee; include credits to create incentives for property owners to manage stormwater.	Number of municipalities with fees. Revenue generated by fees. Credits awarded for stormwater management.	Municipalities
Provide technical assistance to municipalities for design, implementation, and maintenance of green infrastructure solutions for stormwater management.	Number of municipalities assisted. Number of green infrastructure projects implemented.	County Planning Department, County Conservation District, Clean Water Cumberland, Penn State Extension

Table 9. Examples of Infrastructure Resilience Strategies: Buildings.

Strategy	Indicators of progress	Primary Actors
Initiate a program to regularly assess, maintain, and improve the performance of publicly owned buildings with respect to climate resilience, energy efficiency, and indoor air quality.	Age, condition, and deferred maintenance needs of publicly owned buildings. Energy use per square foot of publicly owned buildings. Measures of indoor air quality.	Public agencies
Review and update building codes to incorporate standards for climate resilience in a warmer, wetter, more variable, and more extreme climate.	Building codes updated.	County Planning Department, municipalities
Provide technical assistance to building owners for retrofitting existing buildings to be more climate resilient, energy efficient, and healthy.	Number of retrofitted buildings.	County Planning Department, municipalities, building professional associations, building owners
Connect renters and homeowners with sources of state and federal funding and technical assistance for making investments in home weatherization, energy efficiency, indoor air quality, and climate resilience.	Number of renters and homeowners who succeed in getting funding. Amount of funding received.	County Planning Department, municipalities, community organizations

Table 10. Examples of Infrastructure Resilience Strategies: Energy and Telecommunications.

Strategy	Indicators of progress	Primary Actors
Invest in creating an electric grid that is cleaner, more reliable, and more efficient, anticipating and planning for the effects of climate change, higher peak demands in extreme heat events, and growing electricity demands.	Carbon emissions per kWh. Air quality. Frequency and duration of electric power interruptions.	Electricity distribution and generation companies, PJM Interconnector, PA DEP,

	Cost per kWh.	PA PUC, Federal Energy Regulatory Commission
Improve reliability performance of electric power distribution with greater investment in vegetation management, energy distribution automation, and maintenance, hardening, and modernization of the electric grid, anticipating and planning for more frequent severe weather and declining tree health.	Frequency and duration of electric power interruptions.	Electricity distribution companies, PA PUC
Regular inspection, maintenance, repair and replacement of natural gas pipelines, anticipating and planning for more heavy rain, flood, and land movement events that can damage pipelines.	Number of leaks and safety issues.	Natural gas distribution companies, PA DEP, Pipeline and Hazardous Materials Safety Administration
Increase energy efficiency, conserve energy, and shift to electricity for most energy end uses.	Energy use per person, per square foot, and per $ value output. GHG and air pollution emissions.	All energy users
Invest in battery systems and backup generators at critical facilities and other facilities to provide electric power during service outages.	Number and nature of critical facilities without backup battery systems and generators.	Owners and operators of critical facilities, owners and operators of other facilities
Enhance assistance to low-income households to pay for energy expenses through LIHEAP and other programs and increase participation of eligible households.	Number of households receiving assistance. Amount of assistance provided per household. % of eligible households that receive assistance.	Cumberland County Assistance Office for LIHEAP, municipalities
Expand access to broadband internet service for underserved communities and populations.		PA PUC, internet service providers, municipalities
Assess reliability of broadband internet service, the effects of severe weather on reliability, and existing regulations of broadband internet access and reliability.		PA PUC, internet service providers, municipalities
Contract with multiple internet service providers to limit risk from service interruptions.	Frequency and duration of internet service disruptions.	Internet users

Table 11. Examples of Infrastructure Resilience Strategies: Transportation.

Strategy	**Indicators of progress**	**Primary Actors**
Improve programs to regularly inspect, maintain, and replace transportation infrastructure, anticipating and planning for increased stresses from severe weather.	Age and condition of transportation infrastructure.	PennDOT, municipalities
Increase infrastructure that supports walking, biking, and use of public transit.	Miles of new bike lanes, protected bike lanes, and bike trails. Capacity of bike parking facilities. Miles of new transit routes. Frequency of buses. Increase in % of commuters using public transit and active transportation.	County Planning Department, municipalities, HATS, PennDOT, businesses
Increase awareness and enhance use of Commute PA for ride sharing.	Number of rides shared. % of commuters using Commute PA services.	County Planning Department, municipalities, employers

6. Ecosystems and Ecosystem Services

Cumberland County's ecosystems, natural areas, and wildlife are sources of tremendous value for county residents. The values include the intrinsic worth of living beings and systems, the scenic beauty of the natural world, and essential services of ecological systems that benefit people. The services include, for example, provision of clean air and clean water that support human health, production of food, fiber, and timber, protection from floods, management of stormwater, habitat for wildlife, and places and opportunities for recreation. A 2015 study estimated the value of ecosystem services in Cumberland County that are amenable to being monetized to range between $370 million and $1.4 billion *each year*, not adjusted for inflation (Kittatinny Ridge Conservation Landscape, 2015). The estimate represents a lower bound of the value of the county's ecosystems as it omits many values that cannot be monetized.

The importance of the environment and natural resources for Pennsylvanians and Cumberland County residents are reflected in the Pennsylvania State Constitution as well as surveys of county residents and Cumberland County's comprehensive plan. Section 27, Article 1 of the state constitution states that the people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and esthetic values of the environment. In a recent survey of county residents, natural features and recreational amenities were frequently named by respondents as among the places in Cumberland County that are most significant to them. The county's 2024 comprehensive plan, consistent with previous plans, states that the county is a trustee for the long-term protection of natural resources and that their protection "must be the first policy priority for Cumberland County's future growth." (Cumberland County, 2024).

But these valued resources are at risk. Climate change is rapidly transforming ecosystems in Cumberland County, across the nation, and globally, placing at risk critically important and highly valued natural resources. Impacts include changes in the health, resilience, and productivity of ecosystems, the populations, geographical ranges, reproductive success, survival, and diversity of plant and animal species, and the abilities of ecosystems to provide clean air, clean water, flood protection, recreation, and other services. These impacts have already been observed and documented, and they are projected to grow increasingly damaging as the climate continues to warm. (Lipton et al, 2018; McElwee et al, 2023; and Parmesan et al, 2022).

Species and systems that are particularly vulnerable can be identified and this information can be used to protect them more effectively. While scientific understanding is incomplete and evolving, we can anticipate that species and systems that are already under stress due to the effects of land development, habitat fragmentation, pollution, overuse, and invasive species are less resilient and among the most vulnerable to climate change. Also vulnerable are those that have limited abilities to migrate or adapt in other ways in response to the changing climate. Geographic boundaries of areas with suitable climates for many species and systems are shifting northward and to higher elevations as the climate warms, which likely will cause some to disappear from Pennsylvania. (Lipton et al, 2018, and McElwee et al, 2023).

Traditional strategies for protecting and conserving natural places and resources are becoming less effective due to climate change. Efforts are underway nationally and in Pennsylvania to adapt resource management strategies to help ecosystems and species adapt and build their resilience to the interacting effects of climate change and other stressors. (Lipton et al, 2018; McElwee et al, 2023; and PA DCNR, 2018). Resource managers in Cumberland County can learn from these experiences to better protect the county's natural resources.

6.1. Risks

6.1.1. Streams, Lakes, Wetlands, and Riparian Zones

Streams, lakes, wetlands, riparian zones and the organisms that inhabit them are highly sensitive to changes in temperature and hydrologic variables and consequently are vulnerable to climate change. Rising temperatures, increasing frequency and intensity of heavy rain events, and increasing frequency and severity

of drought conditions negatively impact water environments in multiple ways. As the climate continues to warm and change, negative impacts are expected to increase with each passing year. The growing stresses from climate change will interact and combine with other pressures on freshwater ecosystems to produce greater harms. These other pressures include, for example, pollutant loads from farms, urban areas, lawns, and wastewater treatment plants; development, road building, and conversion of forests and farms that amplify and accelerate stormwater runoff, modify stream channels, and eliminate riparian shade trees; the spread of invasive species that compete with native species; and heavy recreational and other uses. Protecting freshwater ecosystems will require managing and adapting to all these pressures. (Beach, 2024; Dupigny-Giroux et al, 2018; PA DEP, 2021; and Shortle et al, 2015).

The warming climate raises water temperatures, which degrades water quality by reducing the capacity of water to hold dissolved oxygen and accelerating decomposition and respiration processes that consume oxygen in aquatic environments. The resulting low oxygen levels stress aquatic organisms, impair their ability to grow and reproduce, and can cause their death. Extreme heat waves can cause mass mortality in fish. Additionally, higher water temperatures can cause harmful algal blooms that expose aquatic organisms to toxins that kill fish and shellfish and cause illness in birds, mammals, and humans that feed on them. (Georgakakos et al, 2014; Lall et al, 2018; PA DEP, 2021; and Parmesan et al, 2022).

More frequent and more intense heavy rain events will increase stormwater runoff and increase the amount of nitrogen, phosphorous, and sediment pollution that is washed into streams and wetlands from farms, urban areas, lawns, and construction sites. They will also result in more extreme peak flow events with high water volumes and turbulence that erode and destabilize stream banks, modify stream channels, scour stream bottoms, inundate floodplains, and increase sedimentation in streams. All of these impacts will harm the survival and health of fish, particularly trout, and macroinvertebrates such as insect larva, mussels, clams, crayfish, scuds, and worms that are critical to food chains in aquatic systems. (Shortle et al, 2015).

Wetlands are disrupted and harmed by heavy rain events, more frequent and severe periods of drought, increased evaporation and transpiration, extreme heat events, and increased pollutant loads. Particularly vulnerable to these changes are wetlands that are dependent on surface waters, some of which are at risk of disappearing because of climate change. Lakes are negatively impacted by increased variability in lake levels, increased inflows of pollutants, and higher water temperatures. Riparian areas are sensitive to changes in hydrology and moisture availability and are threatened by scouring and erosion in heavy rain events, invasive species that climate change may promote, and loss of eastern hemlock trees due to climate change. (PA DCNR 2018; Shortle et al, 2015; and Washington Department of Fish and Wildlife, n.d.).

More broadly, freshwater ecosystems that are in compromised conditions due to pollution and other pressures can be highly vulnerable to climate change while those that are in good condition tend to be more resilient. (Dupigny-Giroux et al, 2018; PA DEP, 2021; and Shortle et al, 2015). While many surface waters in Cumberland County are in good to excellent condition, an estimated 30% of stream miles in the County are impaired and do not meet water quality standards. These already impaired waters in the county are at risk of significant negative effects due to climate change. (Cumberland County, 2019).

Impacts in the county will be felt beyond the county. As described in section 4.1.3 above, and section 6.1.2 below, higher pollutant loads in the county and other places in the Chesapeake Bay watershed will result in greater pollutant loads flowing into the Bay. The higher pollutant loads, combined with the negative impacts of higher temperatures, will decrease water quality in the Bay. In order to protect water quality in the Bay and comply with agreed targets, more stringent pollution reduction requirements might be required in Pennsylvania and Cumberland County.

6.1.2. Forests

Forests across the U.S. are stressed by disturbances from outbreaks of insects and disease-causing pathogens, invasive species, wildfires, extreme weather, air pollution, heavy recreation use, and pressures to convert forest lands to other uses. Climate change acts as an additional stress on forests, both directly and indirectly. Direct impacts include the effects of changes in temperature and water availability on the health, growth, reproductive success, and mortality of trees and other forest species, their resilience for withstanding disturbances, and geographic shifts in areas with climates suitable for different species. Climate change also impacts forests indirectly by altering the frequency, severity, and scale of disturbances, seasonal timing and possible mismatches between life-cycle events and when foods and nutrients are available, migrations of species, and competition among species. The interacting direct and indirect stresses will impact the species composition, structure, and function of forests and threaten the ecosystem services they provide. Examples of affected services include provision of clean air and water, timber, wood pulp, wildlife habitat, recreation, flood protection, and carbon storage. The impacts can last for years, to decades, to centuries and longer. (Beach, 2023; Domke et al, 2023; Vose et al, 2018).

Warming and drought are important drivers of tree mortality in the U.S. and globally. Higher temperatures and drought conditions increase water evaporation from trees and soils, reduce water availability, and place physiological stresses on trees that cause defoliation, reduced growth, and tree mortality. As the climate warms further, these impacts are likely to increase and the geographic distributions of tree species are likely to shift northward. Climate change will also drive changes in forest disturbances, some of which may increase in frequency and severity and others of which may decrease. For example, tree mortality from bark beetles increased substantially in the western U.S. due in part to climate change and is likely to increase in the future. In contrast, an increasingly warmer and drier climate in the Southwest is expected to decrease white pine blister rust. (Domke et al, 2023, and Vose et al, 2018).

Climate change is also amplifying wildfire risks. The amount of forest land burned by wildfire in the U.S., the intensity and severity of wildfires, and costs for suppressing wildfires have increased substantially. While severe wildfires have mostly occurred in the West, as we learned from the Canadian wildfires in the summer of 2023, wildfires several hundred miles away can severely degrade air quality in central Pennsylvania. The causes of increased wildfire risk are multiple and include the effects of climate change in creating weather conditions that produce extreme wildfire behavior. Other causes include forest management practices, land uses, and the availability and flammability of fuel. Climate change is expected to increase wildfire severity in the future. (Domke et al, 2023).

Forests are the largest land cover type in Cumberland County, accounting for an estimated 38% of the land area. In comparison, cropland accounts for 23%, settlements 20%, and grasslands 18%. Forests in the county include Michaux State Forest, Pine Grove Furnace State Park, Kings Gap Environmental Center, Mount Holly Marsh Preserve, and private forest lands on South Mountain and Tuscarora State Forest, state game lands, and extensive private forest lands on Blue Mountain. A study of changes in landcover types in the county from 2001 to 2016 estimated that an average of 3625 acres of forest was lost each year, mostly from conversions of forest areas to settlement uses. During the same period, an average of 1669 acres of forest were gained, mostly from conversions of grasslands to forest. The net change was a loss of 1.4% of county forests on average each year. The study also produced estimates of forest area disturbed by insects, 4.3% per year, and disturbed by harvests, 0.8% per year. (Shippensburg University, 2021).

Disturbances that cause damage to Pennsylvania forests are indicative of disturbances that are important in Cumberland County. The insects and diseases that have caused the most damage in Pennsylvania's forests include the emerald ash borer, spongy moth, hemlock woolly adelgid, beech bark disease, and oak wilt (PA DCNR, 2024). Of these, several are influenced by climate change. The hemlock woolly adelgid is a non-native invasive insect that has caused significant damage to Pennsylvania's state tree, the eastern hemlock. Its spread throughout the state was facilitated by climate change, and climate change is expected to increase the

damage they cause (USEPA, 2024c). The spongy moth, previously called the gypsy moth, severely defoliated forests in North America beginning with its introduction in 1869 until a fungal pathogen began to suppress the moths in 1989. A new study, however, finds that hotter and drier conditions projected for the future will sharply reduce infection rates of moths with the pathogen, potentially enabling the spongy moth to increase the damage it causes (Liu et al, 2025). Risks to beech trees from beech bark disease may also increase due to mild winters increasing the survival of beech scale (Stephanson and Coe, 2017).

Fire has not been a major disturbance historically in Pennsylvania forests but has the potential to become more frequent and severe from climate change. Already there is evidence of the fire season extending in Pennsylvania with fires occurring year-round. Increasing fire frequency and severity in Pennsylvania pose risks of damages to trails, roads, and structures in forests and parks, park visitors being stranded and harmed, and harm to people and infrastructure located outside but near state forests. Resources and costs for managing and protecting forests and for emergency response are likely to increase. (PA DCNR, 2018).

6.1.3. Species, Wildlife, and Biodiversity

Climate change has already caused large-scale shifts in many parts of the world in the ranges and abundance of plant and animal species, increased pressures from invasive species, and changed the timing of seasonal events such as leafing out, flowering, reproduction, migration, and hibernation. These changes can alter the species composition, structure, and functioning of ecosystems in ways that degrade systems and the services they provide, decrease populations, exterminate species locally and globally, and decrease biodiversity. Extreme weather events such as heat waves have caused population losses and mass mortality in species of plants, invertebrates, amphibians, reptiles, birds, fish, and mammals. Many ecosystems face high or very high risk of biodiversity loss within the next 20 years due to projected warming and increased frequency, severity, and duration of extreme events. The risks are expected to escalate over the century as the climate continues to warm. (Domke et al, 2023; IPCC, 2022; Parmesan et al, 2022).

Plant and animal species survive and reproduce in places with climates, environmental conditions, and food sources conducive to their needs. As the climate warms and changes, the geographic boundaries of places with suitable climates shift across the landscape, causing species to migrate to occupy new ranges if they are able. Species vary in their tolerances for climatic and environmental conditions in which they can survive and reproduce and in their abilities to adapt and disperse to track shifts in climate. Those with greater tolerances and abilities to adapt and disperse are advantaged by climate change, being able to migrate faster and have greater success in becoming established in newly suitable habitats. But the rate and magnitude of climate change may exceed the abilities and tolerances of even the most adaptable species. Additionally, successful migrations and range shifts can be obstructed by urban development, farms, roads, and dams that fragment habitats and limit connections that facilitate animal and plant migrations across landscapes. (Lipton et al, 2018).

A consequence of differences in species tolerances and abilities to disperse and adapt are changes in the species compositions of ecological communities. Changes in species composition can fundamentally and sometimes abruptly change the functions and health of ecological systems by changing food webs and interspecies competition and symbiosis. Some species will experience expansions in population and geographic range, some will experience contractions, and some will go extinct locally and even globally. Looking at studies across the world, the IPCC recently concluded that large numbers of species will be at high to very high risk of extinction due to climate change. (IPCC, 2022, and Lipton et al, 2018).

Invasive species are a major driver of biodiversity loss and their spread will be strongly influenced by climate change. But the effects are complex, will vary for different invasive species and places, and are difficult to predict. Many invasives, though not all, have greater tolerances and abilities to disperse and adapt than many native species. Their spread is being aided by climate change, raising the risks of substantial disruptions and

damages to ecosystems. The kudzu vine is an example of a damaging invasive species that is spreading northward and into Pennsylvania, facilitated by climate change. While some invasives won't be favored by climate change, the widespread disruptions to natural habitats from climate change will tend to create openings for invasives to exploit, enabling increased spread. (Lipton et al, 2018, and McElwee et al, 2023).

Climate change is shifting the timing of seasonal life-cycle events of plants and animals that can negatively impact ecosystems. Plant and animal behaviors are adapted to cycles of when food, nutrients, moisture, and shelter are available and shifts in the timing of events such as leafing out, ice melt, flowering, reproduction, migration, and hibernation can result in mismatches between resource needs and availability. Mismatches can reduce breeding success and survival. Migratory birds and other migratory species can be particularly vulnerable if primary food sources are not available when they arrive at feeding grounds during migrations. (Lipton et al, 2018).

In North America, including Pennsylvania, the ranges of many species have moved northward and to higher elevations as the climate warmed, trends that are projected to continue. Populations of rare, threatened, and endangered species in Pennsylvania are at risk from climate change. Species at the southern end of their range in Pennsylvania, such as the marten and Canada lynx, are likely to decline and some may be extirpated from the state. Some species of shrubs and trees that were only found in states south of Pennsylvania in the past have now been found in Cumberland County. Problems with invasive species have been exacerbated and are sources of stress for trees such as eastern hemlock, chokecherry, yellow birch, quaking aspen, bigtooth aspen, and American beech. (Beach, 2024; PA DCNR, 2018; and Shortle et al, 2015).

Cold-water communities that support trout fisheries in Pennsylvania are highly sensitive and vulnerable to climate change. Trout and important food sources for trout such as mayflies, stoneflies, and caddisflies have low tolerances for high temperatures and low levels of dissolved oxygen. High runoff in extreme rain events can reduce water quality and negatively impact trout by delivering higher loads of nutrients, sediments, and other pollutants into streams. Larger peak stream flows that are expected with climate change negatively impact habitat for trout and aquatic insects by scouring stream banks and increasing sedimentation. Threats to brook and rainbow trout from parasitic gill lice, which have been found in Pennsylvania waters, may increase as climate change raises water temperatures. These multiple stresses are likely to be exacerbated by climate change and decrease the survival and reproductive success of trout. (Shortle et al, 2015, and Vigil et al, 2016).

Of special concern are eastern brook trout, wild populations of which are supported in Cumberland County by Big Spring, Yellow Breeches, and Mountain Creek. The Pennsylvania Fish and Boat Commission's strategic management plan for trout notes that all species of wild trout will be affected by climate change but that eastern brook trout are likely to be the most impacted because they are especially vulnerable to increased water temperature, siltation, and habitat degradation. To address climate change and other risks to eastern brook trout, the Fish and Boat Commission works with the Eastern Brook Trout Joint Venture, a collaboration that includes Trout Unlimited, the U.S. Fish and Wildlife Service, the U.S. Geologic Survey, the U.S. Forest Service and many other organizations. (Detar et al, 2020).

The Kittatinny Ridge, a 185-mile Appalachian ridge that forms the northern boundary of Cumberland County, supports diverse species and is a globally important corridor for bird migrations. It has been identified as one of the most highly resilient landscapes in the nation. Because of its diverse and connected habitats and microclimates, the Ridge is expected to be an important resource for enabling wildlife to migrate and find refuge from the changing climate. (McCarthy, 2024, and The Nature Conservancy, n.d.)

6.2. Strengths and Weaknesses

Cumberland County residents benefit from extensive, diverse, and high-quality protected forests, wetlands, and streams that provide habitats for wildlife, safeguard biodiversity, protect against floods, provide clean water and clean air, and support recreation opportunities. The county has many strengths that aid in protecting these valuable resources from climate change and contribute to climate resilience. Pennsylvania's constitution is a foundational source of strength, stating that the people have a right to clean air, pure water, and the preservation of the natural, scenic, historic and esthetic values of the environment. A variety of state and local plans incorporate goals and give emphasis to protecting Cumberland County's environment. For example, the county's newly adopted comprehensive plan states as the first goal safeguarding the irreplaceable natural resources that are essential for healthy living and economic prosperity and identifies numerous actions to achieve this goal. The comprehensive plan includes explicit reference to climate change and the need to mitigate and adapt to climate change. Additionally, the County Wide Action Plan of the Clean Water Cumberland Coalition and the Municipal Separate Storm Sewer Systems (MS4) Program provide protections for water quality and aquatic ecosystems in the county and the Chesapeake Bay. The 2017 forest management plan for Mount Holly Marsh Preserve sets goals for enhancing wildlife habitat, restoring native plant species, controlling invasive species, and protecting water quality in riparian and wetland areas. Floodplain management, zoning ordinances, and comprehensive plans of local jurisdictions in the county also provide protections.

Private landowners play an important role in protecting the county's natural areas, some of whom participate in the Pennsylvania Forest Stewards program and learn forest ecology principles and management practices that protect environmental functions of forested lands. Numerous community organizations educate members of the public about the importance of the county's ecological resources and engage volunteers in work and advocacy to protect these resources. They include the Appalachian Trail Conservancy, Audubon Society, Big Spring Watershed Association, Capital RC&D, Central Pennsylvania Conservancy, Conodoguinet Creek Watershed Association, Cumberland Conservation Collaborative, Cumberland Valley Trout Unlimited, LeTort Regional Authority, South Mountain Partnership, The Nature Conservancy – Pennsylvania chapter, and Yellow Breeches Watershed Association. Local and state public agencies are also important partners working to protect the county's environment. At the county level are the Cumberland County Planning Department, Conservation District, and Farmland Preservation program. At the state level are the Pennsylvania Department of Conservation and Natural Resources, Department of Environmental Protection, Game Commission, Fish and Boat Commission, and Michaux State Forest District Office. Penn State Extension, Dickinson College, Shippensburg University, and Messiah University are sources of information and technical assistance.

A number of weaknesses can impede efforts to protect the environment in the county from climate change and detract from climate resilience. While many of the county's surface waters are of high quality, and despite significant efforts to implement best management practices to reduce runoff of nutrients and sediments from agricultural and urban lands, an estimated 30% of stream miles are degraded and do not meet water quality standards, making them vulnerable to climate change. The Kittatinny Ridge, a critically important migration corridor for wildlife, is under pressure from commercial and residential development and only 20% of the Ridge is in protected status. Routes for wildlife to traverse Cumberland Valley from South Mountain, the terminus of the Blue Ridge mountains to the Kittatinny Ridge are impeded by agricultural development.

Memberships of many community organizations that work on environmental issues tend to be dominated by older county residents and have limited participation of People of Color and younger residents. This diminishes their ability to be inclusive of diverse voices and be effective in advocating for the environment. Many of the organizations also struggle to secure funding from grant programs and other sources. Federal, state, and county funding for environmental projects are also less than needs in the county.

6.3. Resilience Strategies

Ecosystems that have high biodiversity, are in good health, and are not strongly impacted by development, fragmentation, pollution, invasive plants, insect pests, heavy use, and other pressures are more resilient to climate change than systems that lack these characteristics. Consequently, one of the most effective strategies to build the resilience of ecosystems is to protect, preserve, and restore them. However, current ecosystem management approaches are increasingly ill-suited and less effective as the climate changes. Approaches will need to be adapted, and new strategies deployed. (McElwee et al, 2023).

Several publications examine adaptation and resilience building strategies for ecosystem management and are useful sources to inform action. They include the *Pennsylvania Climate Action Plan 2021* (PA DEP, 2021), DCNR's *Climate Change Adaptation and Mitigation Plan* (PA DCNR, 2018), the *Strategic Plan for Management of Trout Fisheries in Pennsylvania, 2020-2024* (Detra et al, 2020), and *the National Fish, Wildlife & Plants Climate Adaptation Strategy* (National Fish, Wildlife, and Plants Climate Adaptation Network, 2021).

Examples of resilience strategies for ecosystem management are presented in Tables 12 through 15 along with indicators that could be used to measure progress and primary actors for planning and implementing strategies. Some are cross-cutting strategies that can address climatic and other stresses to a broad range of ecosystem types and other strategies are targeted to specific types of systems.

Table 12. Examples of Ecosystem Resilience Strategies: Cross-Cutting.

Strategy	Indicators of progress	Primary Actors
Increase funding for conservation, restoration, preservation, and pollution reduction programs that improve the health and reduce stresses on forests, grasslands, streams, lakes, wetlands, riparian areas, and wildlife.	Funding levels of programs. Acres and stream miles conserved and protected.	State and federal funding programs, County Planning Department and county agencies, and private foundations.
Prioritize programs and projects that connect diverse habitats and facilitate migration of plants and wildlife.	Connective corridors created and protected.	Federal agencies, DCNR, County Planning Department, land conservancy organizations.
Connect county, state, and federal agencies and private organizations to share information, develop plans, coordinate efforts, and collaborate on joint projects to protect, restore, and enhance natural systems in the county.	Number of collaborating organizations. Impacts of collaborations.	County Planning Department, other county agencies, state and federal agencies, conservation organizations, educational institutions, and others.
Identify and prioritize for protection species and ecosystems that are most vulnerable to climate change.	Priorities established and protection plans created.	DCNR, DEP, Game Commission, and Fish and Boat Commission.
Establish a network and systems to monitor and assess ecosystem health, stresses on ecosystems, and effectiveness of conservation programs.	Network and systems established. Data and assessments completed and shared.	DCNR, DEP, County Planning Department.
Provide professional development for natural resource managers to gain skills for effectively managing and conserving systems in a changing climate.	Programs created and implemented. Number of participants. Assessment of outcomes.	Federal agencies, DCNR, DEP, Game Commission, Fish and Boat Commission, and higher education institutions.

Table 13. Examples of Ecosystem Resilience Strategies: Freshwater Systems

Strategy	Indicators of progress	Primary Actors
Review and update best management practices (BMPs) for protecting water quality, taking into account potential future changes in precipitation averages and frequencies and severities of heavy rain and drought and targeting places that can have the greatest impact on water quality.	BMPs updated.	County Planning Commission, Planning Department, and Conservation District, Clean Water Cumberland, and municipalities
Prioritize areas with high nutrient and sediment loads and impaired water quality for implementation of best management practices.	BMPs implemented in priority locations. Reduced nutrient and sediment loads. Reduced stream miles with impaired water quality.	County Planning Commission, Planning Department, and Conservation District, Clean Water Cumberland, and municipalities.
Protect, restore, and enhance riparian areas and floodplains.	Stream miles of riparian buffers. Area of protected floodplains. Reduced stream miles with impaired water quality.	County Conservation District, DCNR, conservancy organizations, municipalities, and landowners.
Assure and support compliance with requirements for erosion and sediment control and management of manure, nutrients, and barnyard runoff.	Compliance records. Technical assistance provided to landowners.	County Conservation District, USDA Natural Resource Conservation Service, conservancy organizations, municipalities, and landowners.

Table 14. Examples of Ecosystem Resilience Strategies: Forests

Strategy	Indicators of progress	Primary Actors
Manage public forests to facilitate adaptation to the changing climate by managing for diversity of species and habitats and favoring native tree species and genotypes that have wide moisture and temperature tolerances and are suited to expected future conditions.	Measures of forest health and diversity.	DCNR, County Planning Department, and municipalities.
Support forest landowners to manage their lands for the changing climate training, technical assistance, and funding through the PA Forest Stewards and other programs.	Number of Forest Stewards. Technical assistance and funds provided to landowners. Acres of forests managed with sound conservation practices.	DCNR, US Forest Service, Penn State Extension, County Planning Department, municipalities, and conservancy organizations.
Increase resources for monitoring and managing forest health, insect infestations, pathogens, and invasive species.	Funding levels. Data on infestations, invasives, and associated damages.	PA legislature, US Forest Service, DCNR, County Planning Department, municipalities, and conservancy organizations.
Monitor and assess changing wildfire risks and potential needs for expanded planning, education, training, and resources for predicting, preventing, and responding to wildfires.	Data collected, shared, and evaluated on trends in drought conditions, wildfire incidences, and predictions from wildfire models.	DCNR, DEP, PEMA, County Planning Department, Emergency Operations Center, municipalities, and land conservancy organizations.

Table 15. Examples of Ecosystem Resilience Strategies: Wildlife and Biodiversity

Strategy	Indicators of progress	Primary Actors
Sustain the Kittatinny Ridge as a connective corridor for wildlife and plant migration by increasing land areas along the Ridge that are protected through conservation easements.	Percentage of land area that is protected. Connectivity of protected tracts.	DCNR, Game Commission, The Nature Conservancy, other land conservancy organizations, County Planning Department, municipalities, and landowners.
Create safe passageways of forested and other natural habitats for wildlife and plants to migrate across Cumberland Valley from South Mountain to the Kittatinny Ridge.	Miles, area, diversity, and connectivity of protected forested and other lands suitable for migration.	DCNR, PA Department of Agriculture, South Mountain Partnership, The Nature Conservancy, other land conservancy organizations, County Planning Department, municipalities, and landowners.
Increase efforts to protect trout fisheries in Cumberland County, with an emphasis on streams that support wild eastern brook trout, by restoring and enhancing stream channels, removing barriers that limit fish migration, stabilizing stream banks, restoring and planting riparian buffers, removing and controlling invasive plants, and reducing pollutant loads.	Miles of improved streams and riparian buffers. Stream miles that support wild trout populations. Populations and health of wild trout.	Fish and Boat Commission, DCNR, Eastern Brook Trout Joint Venture, watershed associations, County Planning Department, municipalities, and landowners.
Promote land management practices that increase habitat for pollinators, birds, and other wildlife such as agroforestry, converting turf lawns to woods and meadows, and planting pollinator-friendly annuals, perennials, shrubs, and trees.	Land area using management practices that support wildlife. Populations and health of pollinators, birds, and other wildlife.	Penn State Extension, DCNR, PA Department of Agriculture, land conservancy organizations, County Planning Department, municipalities, and landowners.

7. Economy, Livelihoods, and Cost of Living

All the effects of changing climate hazards described in previous sections of this report will impact the economy of Cumberland County, the livelihoods of people living and working in the county, the cost of living, and local governments' revenues and expenses. Some of the impacts will be beneficial, but many will be harmful. National studies estimate that the harms are likely to dominate the benefits, causing net losses of economic wellbeing for most Americans. The economic harms are expected to be most burdensome for low-income households, the elderly, people with chronic health issues and disabilities, children, people of color, and people who earn their livelihoods working outdoors or in sectors that are highly vulnerable to climate hazards and change. The greater and more rapid are the changes in climate, the greater will be the losses in economic wellbeing. (Hsiang et al, 2023, and Weinstock, 2022).

The magnitude of the economic impacts is incompletely studied and dependent on uncertain changes in greenhouse gas emissions, climate, capital investments, technologies, labor supply, regulatory environments, market conditions, and other factors. Reviews of existing studies indicate that the effects of climate change on U.S. economic activity are likely to slow the annual rate of growth in Gross Domestic Product (GDP) and may decrease

business investment, which would reduce gains in future incomes from economic progress. By the year 2100, estimates of lost GDP range from roughly 1% to 14% per capita, which will be unequally distributed across the population. The estimated GDP losses omit many likely impacts of climate change on the economy, both positive and negative, and likely understate the range of plausible GDP losses. Additionally, GDP is a highly imperfect measure of wellbeing that omits the value of nonmarket goods and services that contribute to wellbeing, many of which will be adversely impacted by climate change. (Hsiang et al, 2023, and Weinstock, 2022).

7.1. Risks

The pathways by which climate change can impact the economy and economic wellbeing are multiple. For example, impacts on human health will impact worker productivity, labor supply, healthcare costs, insurance premiums, insurance payouts, and workers' out-of-pocket health expenses. Changes in worker health and worker productivity will impact costs, prices, incomes, and profits in all economic sectors. The farm sector and rural communities and economies are particularly vulnerable. Impacts on the productivity of farm workers, farmland, and livestock will impact operating costs of farms, crop yields, farmers' incomes, food supplies, food prices, and food security. Spillover effects impact economic opportunities in rural communities where farming is an important source of income and spending power. More frequent and possibly longer interruptions in electric power and telecommunications services due to severe weather would negatively impact many businesses. As would increases in maintenance, repair, and replacement costs for infrastructure that is degraded prematurely or damaged by severe weather. As impacts ripple through the economy, local governments' tax revenues, spending, and borrowing costs will be impacted and place pressures on their finances. These and other risks to economic activity and economic wellbeing in Cumberland County are examined below.

7.1.1. Worker Health, Safety, and Productivity

As reported in Section 3 of this report, extreme heat kills more people in the U.S. than any other climate-related hazard and causes heat-related illnesses ranging from mild conditions such as heat cramps to more severe and life threatening conditions such as heat stroke. In 2023, extreme heat events resulted in nearly 120,000 emergency room visits. Heat also decreases worker productivity, labor supply, and output, which raise costs and reduce revenues and profits of businesses. It can also lead to lower incomes for workers and increased out of pocket costs for medical care. Analyses of multiple studies of the effects of heat on productivity find that productivity decreases for temperatures greater than roughly 68 ^{o}F and that the average loss is 1% for one degree of warming above 77^{o}F. At higher temperatures, the percentage loss per degree of additional warming increases. Extreme heat events that last multiple days and even weeks can result in substantial reductions in output. The worker productivity impacts of higher temperatures and more extreme heat events can have large consequences for economic wellbeing. (Heal and Parker, 2016; Hsiang et al, 2023; and Weinstock, 2022).

Impacts of heat on worker productivity affect most economic sectors but is particularly pronounced for sectors in which employees work outdoors or in spaces with little or no temperature control, including agriculture, landscaping, construction, manufacturing, and warehouse loading docks. A range of actions could be taken to protect worker health and safety from extreme heat, some of which may also reduce productivity or result in added costs for employers. Workers could protect their health by wearing lighter clothing, keeping hydrated, seeking shade, taking more breaks, slowing the pace of work, ending the workday earlier, or taking days off. But workers often have limited agency to take these actions on their own. Employers could protect their workers by allowing and facilitating health-protecting actions and by implementing workplace changes such as improving ventilation and temperature control, providing shade, and providing easily accessible drinking water. (Moes, 2024, and Parker and Heal, 2016).

7.1.2. Agriculture, Rural Communities, and Food Security

Agribusiness is one of six industry clusters targeted for future development in Cumberland County's economic development strategy. The strength of farming in the county is cited in the plan as a foundation for expanding agribusiness, coupled with an existing base of food manufacturing, packaging, and distribution operations (CAEDC, 2015). However, pressures on agriculture from climate change may threaten the viability of expanding agribusiness in the county.

Agriculture is a prominent feature of Cumberland County's heritage and landscape and an important sector of the county's economy. In 2022, the most recent year of the United States Department of Agriculture's (USDA) Census of Agriculture, the county's 1186 farms occupied roughly 146,000 acres, a decrease of 14% from 2017. The area in farms represents 42% of the total land area of the county, 83% of which is cropland, 5% is pasture, 7% is woodland, and 5% is allocated to other uses. The market value of agricultural products sold by county farms in 2022 was $300 million, up 37% from 2017. After subtracting expenses, county farms yielded a net farm income of just over $100 million. Sales of livestock, poultry, and animal products accounted for 73% of total farm sales and crops accounted for 27%. Average sales per farm were $253,000 but 41 percent of farms had sales of less than $10,000 and accounted for under 1% of total farm sales. (USDA, 2022).

Agriculture in Cumberland County, like agriculture everywhere, is adapted to the historical local climate and is vulnerable to changes. Climate change will change the crops and crop varieties that can be grown in the county, the yields that can be attained, the frequencies and severities of crop losses, the farm practices that will be effective, the costs of operations, and the net incomes that can be realized. Climate change will impact the health and productivity of farmworkers, soils, and livestock, the length and timing of growing seasons, pressures from agricultural pests, disease, and weeds, and runoff of pollutants from farm fields to surface waters and groundwater wells. It will also impact the lives of residents of Cumberland County's rural communities. Because of the prominence of agriculture in the county, impacts on agriculture would be felt countywide. (Moes, 2024).

Some of the impacts will be beneficial and open new opportunities, but many will be harmful. In the near term, when the magnitude of warming is less than 2°C (3.6°F) above preindustrial temperatures, beneficial effects may dominate and increase outputs of some crops and farm incomes in the region. But as warming increases beyond that level, beneficial effects are expected to diminish and negative effects amplified. By mid-century, the balance likely will tilt to be dominated by negative outcomes, nationally and in Pennsylvania. (Bolster et al, 2023; Gowda et al, 2018; Shortle et al, 2015; Walthall et al 2012).

Farmers and residents of rural communities can lessen their risks of harm by adapting to and managing the risks from the changing climate hazards. They can also play important roles in helping to mitigate climate change by reducing the use of fossil energy sources and farm inputs that produce emissions of greenhouse gas pollutants, growing energy crops, and adopting and expanding the use of farming and land management practices that take carbon out of the atmosphere, store it in soils, and regenerate soil health. Integrating actions to both mitigate and adapt to climate change can be advantageous to farmers, residents, the local economy, the land, and the environment.

Climate impact assessments conducted for Pennsylvania in 2015 and 2021 report a variety of effects on the production of crops, fruits, vegetables, and livestock. In the near term, yields of soybeans and wheat may increase slightly, benefitting from longer frost-free growing seasons, the potential for double cropping of soybeans and wheat, and higher carbon dioxide concentrations in the atmosphere that stimulate growth. In contrast, corn yields may decrease due to hotter summers and potentially drier soils. Yields of cool temperature fruits, like apples and grapes, and cool temperature vegetables, like potatoes, are likely to decline, while yields and growing seasons are likely to increase for peaches. Fluctuations in water availability in a more variable climate and increases in cloud cover may damage and blemish fruits and vegetables, which would decrease their quality and market value. Later in the century, corn yields could decline 10% to 20% in Pennsylvania. Livestock, particularly dairy cows, will be

adversely affected by higher temperatures and more frequent extreme heat events. (Jagermeyr et al, 2021; PA DEP, 2021; and Shortle et al, 2015).

Projected increases in rainfall, particularly heavy rainfall, will increase soil erosion, leach nutrients, and deplete carbon from soils, negatively impacting soil productivity, agricultural output, and water quality. More frequent heavy rain will wash away soils and nutrients from county farms and carry them to surface waters, including the LeTort Spring Run, Big Spring Creek, Conodoguinet Creek, Yellow Breeches Creek, the Susquehanna River, and, eventually, the Chesapeake Bay. Sediments rich in nitrogen and phosphorous nutrients that enter these waterways degrade them by stimulating algal blooms that deplete oxygen, block light, produce toxins, and harm aquatic life. Warmer water temperatures, driven by increases in surface air temperatures, will amplify the impacts of nutrient loads on water quality. The impacts to water quality in the county are projected to increase challenges for meeting water quality obligations under Chesapeake Bay program, possibly triggering more stringent regulation of nutrient and sediment loadings from farms and other lands in Cumberland County. (Kaufman et al, 2014).

Pressures on agriculture from pests, weeds, and diseases are likely to increase. Many insect pests, disease vectors, and parasitic nematodes will be able to extend their ranges northward as the climate warms, increase their populations, produce more generations per season, be active more months of the year, and intensify the pressures they exert during critical plant development periods. Warming and carbon dioxide fertilization may promote weed growth and extend northward the ranges of tropical and warm-season weeds. Changing pest, weed, and disease pressures will likely be met with a variety of management strategies that could include wider adoption of Integrated Pest Management but could also include greater applications of synthetic insecticides, herbicides, and fungicides. Other strategies that might be employed are more mechanical weeding, wider use of no-till and low-till practices, and adoption of crops and livestock with greater resistance and improved genetics. Some strategies can have negative effects such as greater exposure of farmworkers to harmful substances, degraded water quality, and insects becoming more resistant to insecticides. (Gowda et al, 2018; Shortle et al, 2015; Walthall et al, 2012).

Cumberland County's 1300+ farmworkers, including roughly 200 migrant workers, plus the County's 2100+ farm producers will face greater risks from heat-related illness and death as the climate changes. Farmworkers are at greater risk of heat-related illness in the current climate than other workers and are 20 times more likely to die from heat stress than the average for all U.S. civilian workers. Factors that contribute to heat risk for farmworkers include absence of shade, limited opportunities to hydrate, and minimal breaks. Low-quality housing provided to migrant and temporary farmworkers can also add to the risks, as do poverty, migrant status, language barriers, and barriers to accessing health care. By mid-century, the average number of days farmworkers are exposed to unsafe temperatures in Cumberland County is estimated to increase from 5 days per year to over 30 days per year. By late century the number of days of unsafe temperatures is estimated to increase to nearly 70 days per year. (Luginbuhl et al, 2008, and Tigchelaar et al, 2020).

Rural communities of Cumberland County are strongly dependent on the farm sector for incomes and livelihoods and consequently are highly sensitive and vulnerable to climate impacts on agricultural production and profitability. Those who earn their incomes directly from farming would suffer financial losses should climate change impact agriculture negatively. For others, declines in farm production and net farm incomes can adversely impact their incomes from non-farm sources as local spending by farm producers declines. Further effects may be felt if decreases in farm incomes are deep and sustained and if few residents earn non-farm income from outside their local community. The local tax base could shrink, necessitating decreases in public services and reduced maintenance and investments in public infrastructure. Some jobs could be lost, some local businesses could close or move, and new employers could become more difficult to attract. If these impacts are persistent, some residents, particularly young people and young families, may move away from rural communities to seek opportunities elsewhere. The remaining population would likely be older on average, be in poorer health, need more services, and be less able to volunteer in the community.

The above scenario is uncertain, but it is a possible future in rural Cumberland County. In an alternative scenario, rural areas might experience loss of farmland if farming becomes less profitable and farms are subdivided and

developed for housing. While this would bring an influx of people, resources, and economic activity, it would change the character of the communities where it happens. Yet another future could be experienced in which farmers successfully adapt to the changing climate, thrive financially, and contribute to the vitality of their rural communities. Versions of each of these scenarios might play out in different parts of the County and over different time periods. Which scenario is most likely to be realized will be shaped by the decisions that are made by farmers, rural community residents, business owners, and municipal officials.

Looking beyond Cumberland County, the impacts of climate change on agriculture will be a mix of positive and negative effects that will vary by region and over time. For warming up to 2°C (3.6°F) above average temperatures of the preindustrial period, available adaptation options have the potential to offset much of the negative effects on global food production, though many low-income countries may experience largely negative impacts. For warming beyond 2°C, adaptation is unlikely to be sufficient to compensate and negative impacts on global food production may prevail, increasing the number of people in the world at risk of hunger and malnutrition. Food security in the U.S. and in Cumberland County may also be aggravated by increasing prices for important food commodities in the U.S. due to projected impacts of climate change on output. The higher prices would benefit food producers, but consumers would be harmed and those with incomes near or below the poverty level would face increased struggles to afford sufficient nutritious food. Residents of rural communities, where poverty rates are often higher than in other communities, can be vulnerable to decreases in food security. (Bezner Kerr et al, 2022, and Bolster et al, 2023).

7.1.3. Healthcare, Housing, and Energy

Healthcare and social assistance is another industry cluster targeted for future development in the county's economic development strategy. The sector is the second largest employer in the county and has experienced significant growth in recent years to serve the county's growing population and retirement communities. The sector will be tested by the effects of climate change on the health of county residents. As described in Section 2, climate change will impact health through multiple pathways that include heat-related illnesses and deaths from more extreme heat events, impacts of impaired air quality on cardiovascular disease, asthma, and other diseases, increased incidences of diseases transmitted by ticks, mosquitos, and other vectors, and mental health effects associated with extreme weather events. (CAEDC, 2015; West et al, 2023).

Collectively the impacts on human health are likely to raise costs for medical care, insurance premiums, out of pocket health expenditures, and costs of preventive measures. The financial burdens will be particularly hard to manage for low-income households and households without health insurance. The financial operations of healthcare facilities can also be impacted. Heat waves, storms, and floods can damage healthcare facilities, interrupt power, and impede staff from getting to work. Severe weather can also result in surges of high-need patients visiting emergency rooms that can overwhelm their capacity to serve patients and raise costs. If the financial capacities of the communities served by healthcare providers is harmed, this too can financially impact the sector. (Hayden et al, 2023; Hess et al, 2023; and Howard et al, 2024).

Heat, wind, and rain damage housing structures, reduce the durability of houses, degrade indoor air quality, and increase the costs of maintaining, cooling, and operating houses. These effects will be amplified by climate change, raising costs for homeowners, renters, and landlords, which can be particularly burdensome for low-income households and people living in poorly maintained homes. Homes represent a substantial share of the wealth of many homeowners and growing risk of damages to homes from climate hazards can reduce housing values and the wealth of affected homeowners. Builders will need to modify designs, materials, and construction practices for new housing, adding to costs, so that the housing they construct will perform well in the changing climate. Severe weather damages millions of homes each year and reduces the housing stock, particularly for affordable housing, problems that will increase with climate change. Costs are also incurred when people are evacuated from their homes due to severe weather, provided temporary shelter, and relocated. In locations of high risk, such as flood plains, climate hazards decrease the value of homes. Property insurance premiums may increase, and private

insurance may become unavailable for some high-risk properties. (Allura, 2024; Chu et al, 2023; Cohen et al, 2024; JL Architects, 2022; and Weinstock, 2022).

Climate change impacts on the energy system will have economic consequences for the county. As previously described, impacts on energy infrastructure, reliability, and demands are likely to increase costs for power generators, distributors and users. Growing risks of power outages from severe weather will require increased expenditures by power distribution companies to improve management of vegetation, adopt automation technologies, and maintain, repair, and replace infrastructure. Growing electricity demand and higher peak demands will require investments to increase the capacity and reliability of electric grids. The negative effects of higher air temperatures, higher water temperatures, and extreme heat events on the capacity and efficiency of electricity generation, transmission, and distribution will also necessitate increased investment in infrastructure. Much of the higher costs are likely to be passed on to energy consumers in higher prices. In addition, consumers' winter heating needs will decrease while summer cooling needs increase, with the net effect likely to be increasing annual energy costs. Costs also will be incurred by energy users seeking to manage growing energy costs through energy conservation and efficiency measures. (PA DEP, 2021, and Zamuda et al, 2023).

7.1.4. Tourism and Recreation

Tourism, another of the six industries that are targeted for further development in the county's economic development strategy, brings many visitors to Cumberland Valley. In 2022, visitors spent nearly $900 million in the county for food, beverages, lodging, transportation, and other services, supporting over 6,000 tourism related jobs and generating $44 million in state and local taxes. Parks, forests, streams, lakes, family farms, hiking trails, water trails, bike routes, and historical sites are important county resources that attract visitors while also supporting recreational activities of county residents. Tourism is vulnerable to climate change because climate change will impact many of the natural resources that attract visitors, the recreational activities they support, and other values that residents derive from them. (CAEDC, 2024; CAEDC, 2015; Moes, 2024; and Russo, 2022).

The direct effects of warming will have positive and negative effects on recreational opportunities. Warmer average temperatures will extend the season for many outdoor recreation activities, enabling them to begin earlier in the spring and end later in the fall or winter. In contrast, more hot days and extremely hot days will tend to decrease participation in outdoor recreation. A national study found that climate change will increase participation in running, cycling, and water sports, decrease participation in hiking, hunting, and skiing, and that the overall net effect would likely be an increase in participation in outdoor recreation. (Chan and Wichman, 2022; PA DEP, 2021)

However, indirect effects of climate change on natural resources that support tourism and recreation are likely to be mostly negative. Recreational uses of forests may be reduced by negative impacts of climate change on the health of county forests. As the climate changes, some current tree species will be poorly suited to the new climate and suffer mortality, forest pests and diseases will place greater pressures on forests, new invasive species will expand into the region and some existing species will increase in abundance, and wildfire risks will increase. The longer hiking season can also be detrimental for sensitive forest ecosystems that need periods of low use to recover and be resilient to human pressures. It also puts additional pressure on infrastructure in parks and forests. Managing these impacts in state parks and forests will require more staff and increase costs. (PA DCNR, 2018, and PA DEP, 2021).

Heavier rainfalls will wash more nutrient pollutants and sediments into streams and lakes, water temperatures will rise, and water quality will decline. Lower quality water and warmer water will negatively impact the county's high quality trout fisheries, an important destination sport for tourism. More flood events will increase risks of damages to trails, roads, bridges, dams, buildings, and historical sites in our parks, result in park closures, and increase costs for managing parks. (PA DCNR, 2018, and PA DEP, 2021).

7.1.5. Business Interruptions, Supply Chains, Markets, and Prices

Cumberland County is connected to the wider region, the nation, and the world through transportation and communication systems, electric power grids, supply chains, and markets. When these systems operate smoothly, they provide access to a wider range of goods and services at lower costs, higher quality of life, and greater economic opportunity than would be possible without them. But the connections also expose county residents and businesses to risks from climatic hazards that occur in and beyond the county.

Interruptions of electric power, telecommunications, transportation, and water services from severe weather is a major cost for businesses. Weather related electric power interruptions cost U.S. businesses and other customers $25 billion to $70 billion each year. Increases in the frequency and severity of extreme weather from climate change are projected to increase the cumulative cost of power interruptions by $2 trillion to $5.6 trillion by the end of the century (Larsen et al, 2018, and Zamuda et al, 2023). Snow, ice, heavy rain, floods, high winds, hurricanes, and extreme temperatures disrupt transportation by impacting road conditions, causing accidents, and delaying the movement of goods and people. Severe weather causes over 20% of delays on roadways, losing trucking companies an estimated 33 billion vehicle hours annually and costing them $3.5 billion per year (Freight Right, 2021). Warehousing, logistics, and trucking, which are important economic activities and employers in Cumberland County, are vulnerable to changing frequencies of severe weather events. While climate change likely will decrease the frequency of snowfall and ice, it likely will increase the frequency of other types of severe weather that impact the county's transportation-related businesses.

County residents and businesses can also be impacted by disruptions to supply chains that originate beyond the county. Tropical storms, storm surges, and severe weather can shut down and damage production facilities, seaports, airports, rail and highway systems, logistics companies, warehouses, distribution centers, and fulfillment centers. The impacts can cascade through regional and national supply chains for energy, food, equipment, materials, and consumer goods. Energy supplies can be particularly vulnerable. Nearly 50% of U.S. oil refining capacity is located in the Gulf Coast region and is exposed to risks from tropical storms. Refining facilities in the Mid-Atlantic region can also be at risk from tropical storms but have been impacted less often. The forecast of a major hurricane in the Gulf can cause oil refining capacity of more than 1 million barrels per day to be taken offline temporarily in preparation for a storm (USEIA, 2024). If a storm results in significant damage to refining facilities, depots, ports, or pipelines, it can result in longer disruptions, shortages of refined petroleum products, and price increases. Storms that shutdown and damage refining and related facilities can cause significant reductions in supplies of refinery products, interruptions in their distribution, price increases, and market instabilities that could impact Pennsylvania. These risks are likely to grow as the climate warms.

As already noted, climate change can impact global food production, food prices, and food security. Studies of the potential effects of climate change on world agriculture estimate that global production of important food crops such as corn, wheat, and soybeans could decrease 5% to 35% by mid-century and that prices in global commodity markets could increase up to 30% (Bolster et al, 2023, and Gowda et al, 2018). Price increases of this magnitude would have significant negative impacts on food security in many parts of the world and would also impact producers and consumers in Cumberland County. Supply chains for other important materials and consumer goods can be disrupted by tropical storms and impact Cumberland County. For example, hurricanes Helene and Milton caused the two largest suppliers of IV fluids and dialysis solutions in the U.S. to close, resulting in national shortages that have impacted hospitals in Pennsylvania (Doerfler, 2024, and Guay, 2024).

7.1.6. Uncertainty, Risks, and Investment

Climate change creates economic uncertainties by posing risks of physical impacts on people and assets that can affect returns on investments of many types. The risks can include, for example, the potential for costly damages and loss of services of physical assets, losses of labor productivity, losses of land productivity, reduced market values of at-risk assets, greater borrowing costs, and greater insurance costs. Technological changes, policy changes,

and market transitions that are motivated by climate change adaptation and mitigation also pose uncertainties and financial risks. Uncertainty about the impacts of and responses to climate change are economic burdens that drive up the costs of decision-making, planning, and investing as people, businesses, and the public sector put resources into informing themselves about the risks, altering investment choices, and hedging their risks for different scenarios of the future. It is possible for climate risks to result in lower aggregate investment in the U.S. and lower economic growth, though there is no clear evidence yet and potential effects on investment are not well researched. (Archaya et al, 2024; Hsiang et al, 2023; Weinstock, 2022)

There is already evidence, however, in real estate, mortgage, and insurance markets in areas with high and growing risks of flooding, tropical storms, and wildfires that climate hazards have lowered values of properties, increased borrowing costs, increased insurance premiums, and caused some insurance companies to withdraw from or limit their activities in markets perceived to be high risk. Municipalities in areas perceived to have high risks from climate hazards can face lower bond prices and higher interest rates for borrowing. The prices of stocks and returns on investment portfolios can potentially be affected by climate risks. (Archaya et al, 2024, and Hsiang et al, 2023).

As climate change progresses, the financial risks may grow for individuals, financial institutions, and other institutions in the county through their investment and retirement portfolios. Portfolios with high exposure to assets located in regions with growing climate hazards, or in economic sectors that are particularly vulnerable to climate impacts, may be riskier than portfolios with lower exposures. Concern about the financial risks of climate change has motivated research on ways to stress test investment portfolios for high-impact climate change scenarios and consideration of strategies for designing portfolios to hedge against the risks.

7.2. Strengths and Weaknesses

Many of the strengths and weaknesses discussed in previous sections of the report are also relevant to the economic resilience of Cumberland County. The county's economy is diverse and tends to be less prone to cyclical swings than many other counties in Pennsylvania. The county's school systems, higher education institutions, employers, and workforce development programs support a population that is well educated and skilled. The median household income is high, the poverty rate is low, and unemployment is low relative to state averages. A diverse transportation network connects the county to multiple economic centers and supply routes for materials and consumer goods. Economic development efforts, assisted by the Cumberland Area Economic Development Corporation (CAEDC) and supported by municipalities and the county's business community, have provided economic opportunities and a good quality of life for most county residents. These and other sources of strength contribute to the economic resilience of the county.

Despite the strengths, many county residents have incomes near or below the poverty level, are food insecure, are housing cost burdened, and struggle to afford health care, energy utilities, and other goods and services that are necessary for a good quality of life. Local, state, and federal agencies, and a variety of community organizations help struggling families and individuals, but the assistance often falls short of the needs. Continued and enhanced support will be needed, particularly as climate change disproportionately impacts struggling families and individuals.

Four of the six industry clusters targeted for economic development by CAEDC's strategic plan are potentially vulnerable to climate change. These are agribusiness, tourism, transportation and warehousing, and health care and social assistance. Vulnerabilities of these sectors to climate hazards should be monitored to determine whether and how to adapt efforts to support them, while also looking for new opportunities for economic development that may emerge. The county's aging infrastructure and housing stock can be weaknesses that require greater public and private investment to maintain in the changing climate, which could adversely influence location decisions of businesses. The county's air quality, water quality, and flood risks may also adversely affect business location decisions if climate change makes them worse.

7.3. Resilience Strategies

Many of the examples of resilience strategies presented earlier in the report would also help to increase the resilience of the county's economy and residents' incomes, livelihoods, and cost of living. Selected examples from previous sections of the report, plus some additional examples of strategies for building economic resilience, are presented in Tables 12 through 16.

Table 16. Examples of Economic Resilience Strategies: Cross-Cutting.

Strategy	Indicators of progress	Primary Actors
Engage diverse stakeholders to integrate climate resilience into the county's economic development strategy and comprehensive plan. The plans should connect climate resilience with other county goals for economic development, compact development, affordable housing, active transportation, energy efficiency, preservation of farmland, green spaces, clean air, and clean water.	Engagement of diverse stakeholders. Creation of plans with goals, strategies, and measurable objectives for climate resilience that support other county goals.	Cumberland Area Economic Development Corporation, County Planning Department, County Commissioners, municipalities, community stakeholders, and businesses
Educate the public, property owners, developers, infrastructure owners, and others about climate risks and actions to mitigate risks and build resilience for infrastructure, economic sectors, incomes, and livelihoods.	Number of participants in education programs. Diversity of participants. Levels of engagement. Evaluations of programs from participants.	Public agencies, public schools, colleges and universities, community organizations
Connect property owners, businesses, municipalities, and others with sources of information, technical assistance, and funding for increasing their climate resilience.	Numbers of people and entities that seek and obtain technical assistance and funding. Amount of funding received.	County Planning Department, Cumberland Area Economic Development Corporation, County Conservation District, Penn State Extension, Natural Resources Conservation Service, and other organizations
Adopt plans, policies, regulations, and/or incentives to discourage the construction of new infrastructure in current and projected future Special Flood Hazard Areas.	Inventory of newly constructed infrastructure in and near flood hazard areas.	County and municipal governments

Table 17. Examples of Economic Resilience Strategies: Agriculture, Rural Communities, and Food Security.

Strategy	Indicators of progress	Primary Actors
Sustain and increase support for programs that provide technical assistance and funding to farmers to apply climate-resilient practices for growing and marketing nutritious foods while protecting soils and water quality.	Funding for programs. Number of program participants. Diversity of participants. Evaluations from participants.	Public agencies, conservation organizations, farm sector organizations
Develop and implement a comprehensive plan to advance food security in the county.	Plan adopted. Number and % of adults and children who are food insecure.	Cumberland County Food System Alliance, public agencies, food pantries, other community organizations
Increase healthcare facilities and services, including mental healthcare, in rural and other underserved areas of the county.	Number of new healthcare facilities in underserved areas. Number of medical practitioners per capita in underserved areas.	Healthcare providers, public agencies

	Number of mental healthcare providers per capita in underserved areas.	

Table 18. Examples of Economic Resilience Strategies: Healthcare, Housing, and Energy.

Strategy	Indicators of progress	Primary Actors
Increase healthcare facilities and services, including mental healthcare, in rural and other underserved areas of the county.	Number of new healthcare facilities in underserved areas. Number of medical practitioners per capita in underserved areas. Number of mental healthcare providers per capita in underserved areas.	Healthcare providers, public agencies
Sustain and enhance programs for low-income, vulnerable, and disadvantaged residents that advance healthcare access, food security, housing security, energy security, education, skills training, and childcare and increase the participation of eligible county residents in the programs.	Number of program participants. % of eligible people who participate in programs. Decrease in % population without health insurance. Decrease in % population below poverty level. Decrease in % population who are food insecure. Decrease in % population who are housing cost burdened. Improved health outcomes.	Municipalities, public agencies, community organizations, community leaders
Provide municipalities guidance and technical assistance for reviewing and revising zoning ordinances to encourage development of affordable housing that is energy efficient and climate resilient.	Number of municipalities that receive guidance and assistance. Numbers of units of affordable, energy efficient, & climate resilient housing developed. % of population that is housing cost burdened.	County Planning Department, municipal governments
Connect renters, homeowners, and businesses with sources of state and federal funding and technical assistance for making investments in home and building weatherization, energy efficiency, indoor air quality, and climate resilience.	Number of renters, homeowners, and business owners who take action to improve their homes/buildings. Number of renters, homeowners, and business owners who succeed in accessing funding. Amount of funding received.	County Planning Department, municipalities, community organizations, homeowners, building owners
Encourage employers to proactively adopt and implement worker health and safety programs for preventing and responding to workers' exposures to extreme heat.	Number of employers who adopt and implement programs. Number of reported heat-related illnesses and deaths.	Cumberland County Department of Health, Harrisburg office of Occupational Safety & Health Administration, health care systems in the county, employers, and unions

Table 19. Examples of Economic Resilience Strategies: Tourism and Recreation.

Strategy	Indicators of progress	Primary Actors
Work with PA DCNR and conservation organizations to monitor and develop and implement plans for protecting and managing valued forests, parks, hiking and water trails, trout fisheries, and other natural areas that may be stressed by climate change and potential increases in recreational uses.	Indicators of ecosystem health and diversity	PA DCNR, Cumberland County Planning Department, municipal parks and recreation offices, Central Pennsylvania Conservancy, Capital

		RC&D, Cumberland Conservation Collaborative, and South Mountain Partnership
Monitor and protect riparian zones, stream banks, and streams from stormwater runoff, nutrient loads, and erosion to support their ecological health and continued recreational uses.	Tree cover in riparian zones and over streams. Nutrient loads. Trout populations, survival rates, and size distribution.	Cumberland County Planning Department, County Conservation District, Clean Water Cumberland, watershed associations, Cumberland Conservation Collaborative, and South Mountain Partnership
Design and upgrade infrastructure in parks to be more resilient to floods and stormwater runoff.		PA DCNR, municipal parks and recreation offices,

Table 20. Examples of Economic Resilience Strategies: Business Interruptions, Supply Chains, Markets, and Prices.

Strategy	Indicators of progress	Primary Actors
Invest in creating an electric grid that is cleaner, more reliable, and more efficient, anticipating and planning for the effects of climate change, higher peak demands in extreme heat events, and growing electricity demands.	Carbon emissions per kWh. Air quality. Frequency and duration of electric power interruptions. Cost per kWh.	Electricity distribution and generation companies, PJM Interconnector, PA DEP, PA PUC, Federal Energy Regulatory Commission
Encourage organizations to create or update continuity plans for continued operations during interruptions of electric power, telecommunications, water, transportation, and supplies of important equipment and materials for extensive periods as a result of severe weather.	Continuity plans stress-tested for interruptions of critical services for 2+ weeks.	All organizations

Table 21. Examples of Economic Resilience Strategies: Uncertainties, Risks, and Investment.

Strategy	Indicators of progress	Primary Actors
Monitor changes in real estate values, mortgage rates, property and flood insurance premiums, insurance claims, and insurance cancelations in and near flood zones.	Data collected and made available.	PA Department of Community and Economic Development, CAEDC, PA Emergency Management Agency, Federal Emergency Management Agency
Raise awareness of property owners about growing flood risks, actions to mitigate flood risks, the National Flood Insurance Program, and private flood insurance options.	Number of property owners who choose to mitigate flood risks. Number of property owners who purchase voluntary flood insurance.	County Planning Department, municipalities, property owners
Learn about and apply stress tests to investment portfolios for climate risks.		Investment portfolio managers

About the Author

Neil Leary is the founding Director of the Center for Sustainability Education at Dickinson College where he leads efforts to integrate sustainability across Dickinson's liberal arts curriculum, coordinates co-curricular living lab programs, teaches courses on climate change, sustainable and resilient communities, and campus sustainability, and is chair of the Climate Resilience Working Group. He has participated in climate change research and assessments for 30-years. He was a leader, editor, and author of the 2001 report of the Intergovernmental Panel on Climate Change (IPCC) on climate change impacts, adaptation and vulnerability, was an editorial board member of the IPCC's 2007 and 2013 reports, and was recognized by the IPCC for his role in work that earned a Nobel Peace Prize for the IPCC in 2007. As a senior scientist and program manager from 2001 to 2008 at the Global Change System for Analysis, Research and Training (START), Neil directed international assessments of climate change vulnerability and adaptation in Africa, Asia, the Caribbean and Latin America that engaged several hundred scientists from more than 60 countries. Prior to working at START, Neil was a senior economist with the climate change division of the U.S. Environmental Protection Agency. Neil received a Ph.D. in economics from the University of Washington in 1988 and a B.A. from Macalester College in 1980.

Previous Reports from Building Climate Resilience at Dickinson and in Central Pennsylvania

2025

- Climate Risks and Resilience at Dickinson College: Strategies for Infrastructure, Utilities, and Grounds, K. Sipe, Feb 28, 2025.
- Climate Risks and Resilience at Dickinson College: Strategies for College Finances, K. Gauchan, February 28, 2025.
- Climate Risks and Resilience at Dickinson College: Strategies for Continuity of Operations, N. Donia, February 28, 2025.
- Climate Risks and Resilience at Dickinson College: Strategies for Health and Wellbeing, N. Salsich, February 28, 2025.

2024

- Climate Risks and Resilience at Dickinson College: Ecosystem Services, Green Infrastructure, and Stormwater Management, A. Ray, June 3, 2024.
- Climate Risks and Resilience at Dickinson College: Health and Wellbeing, R. Semma, June 3, 2024.
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2023

- Social Vulnerability, Resilience, and Equity, N. Leary and G. Messimer, September 15, 2023.
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