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Responding to Climate Change in New York State:

The synthesis report of the *Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State*

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All the figures and tables in this document are drawn from the ClimAID Foundation Report: *Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State*.

Responding to Climate Change in New York State

Climate change is already beginning to affect the people and resources of New York State, and these impacts are projected to grow. At the same time, the state has the potential capacity to address many climate-related risks, thereby reducing negative impacts and taking advantage of possible opportunities. ClimAID: the Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State was undertaken to provide decision-makers with cutting-edge information on the state's vulnerability to climate change and to facilitate the development of adaptation strategies informed by both local experience and scientific knowledge.

This state-level assessment of climate change impacts is specifically geared to assist in the development of adaptation strategies. It acknowledges the need to plan for and adapt to climate change impacts in a range of sectors: Water Resources, Coastal Zones, Ecosystems, Agriculture, Energy, Transportation, Telecommunications, and Public Health.

The author team for this report is composed of university and research scientists who are specialists in climate change science, impacts, and adaptation. To ensure that the information provided would be relevant to decisions made by public and private sector practitioners, stakeholders from state and local agencies, non-profit organizations, and the business community participated in the process as well.

This document provides a general synthesis of highlights from a larger technical report that includes much more detail, case studies, and references. The larger report provides useful information to decision-makers, such as state officials, city planners, water and energy managers, farmers, business owners, and others as they begin responding to climate change in New York State.

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Climate Risks for New York State

Temperatures are increasing, precipitation patterns are changing, and sea level is rising. These climatic changes are projected to occur at much faster than natural rates because of increased amounts of greenhouse gases in the atmosphere. Some types of extreme weather and climate events have already increased in frequency and intensity and these changes are projected to continue.

These climate changes are already having impacts in some aspects of society, the economy, and natural ecosystems and these impacts are expected to increase. Not all of these changes will be gradual. When certain tipping points are crossed, impacts can increase dramatically. Past climate is no longer a reliable guide to the future. This affects planning for water, energy, and all other social and economic systems.

Heat Waves

Heat waves will become more frequent and intense, increasing heat-related illness and death and posing new challenges to the energy system, air quality, and agriculture.

Summer Drought

Summer drought is projected to increase, affecting water supply, agriculture, ecosystems, and energy production.

Heavy Downpours

Heavy downpours are increasing and are projected to increase further. These can lead to flooding and related impacts on water quality, infrastructure, and agriculture.

Coastal Flooding

Coastal flooding due to sea level rise and storm surge will increasingly put lives and property at risk. Health, water quality, energy, infrastructure, and coastal ecosystems are all affected.

Interactions

Interactions between climate change and other stresses such as pollution and increasing demand for resources will create new challenges.

Wide-Ranging Impacts

Major changes to ecosystems including species range shifts, population crashes, and other sudden transformations could have wide ranging impacts, not only for natural systems but also for health, agriculture, and other sectors.

Opportunities

Climate change may create new opportunities related to a longer, warmer growing season for agriculture and the potential for abundant water resources.

Climate Issues in New York State's Regions

Each region of New York State (as defined by ClimAID) has unique attributes that will be affected by climate change. Many of the issues highlighted below are described in more detail in the sector discussions that follow.

Region 1: Western New York Great Lakes Plain

- Agricultural revenue highest in state
- Relatively low rainfall, increased summer drought risk
- High value crops could need irrigation
- Improved conditions for grapes projected

Table 1: Temperature and Precipitation Projections, Region 1

	Baseline	2050s	2080s
Temperature	48 °F	+3.0 to 5.5°	+4.5 to 8.5°
Precipitation	37 inches	0 to +10%	0 to +15%

Region 2: Catskill Mountains and Hudson River Valley

- Watershed for New York City water supply
- Spruce/fir forests disappear from mountains
- Popular apple varieties decline
- Winter recreation declines; summer opportunities increase
- Hemlock wooly adelgid destroys trees
- Native brook trout decline, replaced by bass

Table 2: Temperature and Precipitation Projections, Region 2

	Baseline	2050s	2080s
Temperature	48 °F	+3.0 to 5.0°	+4.0 to 8.0°
Precipitation	48 inches	0 to +10%	+5 to 10%

Region 3: Southern Tier

- Dairy dominates agricultural economy
- Milk production losses projected
- Susquehanna River flooding increases
- One of the first parts of the state hit by invasive insects, weeds, and other pests moving north

Table 3: Temperature and Precipitation Projections, Region 3

	Baseline	2050s	2080s
Temperature	46 °F	+3.5 to 5.5°	+4.5 to 8.5°
Precipitation	38 inches	0 to +10%	+5 to 10%

Region 4: New York City and Long Island

- Highest density population in the state
- Sea level rise and storm surge increase coastal flooding, erosion, and wetland loss
- Challenges for water supply and wastewater treatment
- Heat-related deaths increase
- Illnesses related to air quality increase
- Higher summer energy demand stresses the energy system

Table 4: Temperature and Precipitation Projections, Region 4

	Baseline	2050s	2080s
Temperature	53° F	+3.0 to 5.0°	+4.0 to 7.5°
Precipitation	47 inches	0 to +10%	+5 to 10%

Region 5: Hudson and Mohawk River Valley

- Major rivers characterize this region
- Saltwater front moves further up the Hudson River
- Potential contamination of New York City's back-up water supply
- Propagation of storm surge up the Hudson from the coast
- Popular apple varieties decline

Table 5: Temperature and Precipitation Projections, Region 5

	Baseline	2050s	2080s
Temperature	50 °F	+3.0 to 5.5°	+4.0 to 8.0°
Precipitation	38 inches	0 to +5%	+5 to 10%

Region 6: Tug Hill Plateau

- Important region for hydropower
- Lake effect snows could increase in the short term
- Snowmobiling opportunities decline
- Great Lakes water levels may decline

Table 6: Temperature and Precipitation Projections, Region 6

	Baseline	2050s	2080s
Temperature	44 °F	+3.5 to 5.5°	+4.5 to 9.0°
Precipitation	51 inches	0 to +10%	+5 to 15%

Region 7: Adirondack Mountains

- Popular tourist destination
- Loss of high-elevation plants, animals, and ecosystem types
- Winter recreation declines; summer opportunities increase
- Milk production declines, though less than other regions

Table 7: Temperature and Precipitation Projections, Region 7

	Baseline	2050s	2080s
Temperature	42 °F	+3.0 to 5.5°	+4.0 to 9.0°
Precipitation	38 inches	0 to +5%	+5 to 15%

Climate Projections

The climate-related risks discussed here will affect the state's economy and environment. Some of the most serious vulnerabilities and potential adaptation strategies are highlighted in this report.

Temperature and Precipitation

Temperatures are expected to rise across the state, by 1.5 to 3°F by the 2020s, 3 to 5.5°F by the 2050s, and 4 to 9°F by the 2080s. The lower ends of these ranges are for lower greenhouse gas emissions scenarios (in which society reduces heat-trapping gas emissions) and the higher ends for higher emissions scenarios (in which emissions continue to increase). These are not the best and worst cases, however. Sharp cuts in global emissions could result in temperature increases lower than the bottoms of these ranges, while a continuation of business-as-usual could result in increases higher than the high ends. Using a mid-range emissions scenario, A1B, yields temperature increases of about 7°F by the 2080s for most of the state. The A1B scenario is associated with relatively rapid increases in emissions for the first half of this century, followed by a gradual decrease in emissions after 2050.

The observed annual average temperature in the New York City region during the late 20th century was approximately 56°F. Using 16 global climate models and three emissions scenarios, average annual temperature projections for the end of the 21st century range from approximately 58°F to nearly 68°F, an increase of between 2 and 12°F. The central range for these models ranges from about 60°F for the lower emissions scenario to about 63°F for the higher emissions scenario.

Annual average precipitation is projected to increase by up to 5 percent by the 2020s, up to 10 percent by the 2050s and up to 15 percent by the 2080s, with the greatest increases in the northern parts of the state. This will not be distributed evenly over the course of the year. Much of this additional precipitation is likely to occur during the winter months as rain, with the possibility of slightly reduced precipitation projected for the late summer and early fall.

Continuing the observed trend, more precipitation is expected to fall in heavy downpours and less in light rains.

Table 8: Projected % Change in Seasonal Precipitation by the 2050s

ClimAID Region	Winter	Spring	Summer	Fall
1. Western New York Great Lakes Plain	+5 to 15	0 to +15	-10 to +10	-5 to +10
2. Catskill Mountains and Hudson River Valley	0 to +15	0 to +10	-5 to +10	-5 to +10
3. Southern Tier	+5 to 15	0 to +10	-5 to +5	-10 to +5
4. New York City and Long Island	0 to +15	0 to +10	-5 to +10	-5 to +10
5. Hudson and Mohawk River Valley	+5 to 15	-5 to +10	-5 to +5	-5 to +10
6. Tug Hill Plateau	+5 to 15	0 to +10	-5 to +10	-5 to +10
7. Adirondack Mountains	+5 to 15	-5 to +10	-5 to +5	-5 to +10

Higher temperatures and increased heat waves have the potential to

- increase fatigue of materials in water, energy, transportation and telecommunications infrastructure;
- affect drinking water supply;
- cause a greater frequency of summer heat stress on people, plants and animals;
- alter pest populations and habits, affecting agriculture and ecosystems;
- change the distribution of key crops such as apples, cabbage, and potatoes;
- cause reductions in dairy milk production;
- increase electricity demand for cooling;
- lead to declines in air quality that cause respiratory illness; and
- cause more heat-related deaths.

Increased frequency of heavy downpours has the potential to

- affect drinking water supply;

- heighten risk of river flooding;
- flood key rail lines, roadways and transportation hubs; and
- increase delays and hazards related to extreme weather events.

Sea Level Rise

Sea level rise projections that do not include significant melting of the polar ice sheets (which is already observed to be occurring) suggest 1 to 5 inches of rise by the 2020s, 5 to 12 inches by the 2050s and 8 to 23 inches by the 2080s. Scenarios that include rapid melting of polar ice project 4 to 10 inches of sea level rise by the 2020s, 17 to 29 inches by the 2050s and 37 to 55 inches by the 2080s.

Table 9 shows the central range of sea level rise projections, rounded to the nearest inch, based on the average of the ClimAID global climate models for a range of greenhouse gas emissions scenarios as reported by IPCC 2007 and the ClimAID rapid ice melt scenario (based on accelerated melting of the Greenland and West Antarctic Ice Sheets).

Table 9: Projected Sea Level Rise for New York State (in inches)

	2020s	2050s	2080s
GCM-based	+1 to 5	+5 to 12	+8 to 23
Rapid-ice-melt scenario	+4 to 10	+17 to 29	+37 to 55

Sea level rise and coastal flooding have the potential to

- increase risk of storm surge-related flooding along coast;
- expand areas at risk of coastal flooding;
- increase vulnerability of energy facilities located in coastal areas;
- flood transportation and communication facilities; and
- cause saltwater intrusion into some freshwater supplies near the coasts.

Adaptation can Reduce Impacts

Adaptation refers to actions taken to prepare for climate change, helping to reduce adverse impacts or take advantage of beneficial ones.

Strategies can include changes in operations, management, infrastructure, and/or policies that reduce risk and/or capitalize on potential opportunities associated with climate change. Adaptations can take place at the individual, household, community, organization, and institutional level. Adaptation can be thought of as just better planning, incorporating the most current information about climate into a variety of decisions. Adaptation should be woven into the everyday practices of organizations and agencies.

Adaptive capacity refers to the ability of a system to adjust to actual or expected climate stresses or to cope with their consequences.

New York State as a whole is generally considered to have significant resources and capacity for effective adaptation responses. However, the costs and benefits of adaptation will not be evenly distributed throughout the state. There can also be a variety of unintended consequences of adaptation options. For example, building sea walls to protect coastal property from rising sea levels can exacerbate the loss of coastal wetlands that serve to protect coastlines from storm surge damage.

Adaptations undertaken in one sector often have implications for other sectors.

For example, increased use of air conditioning is an adaptation to reduce heat-related illness and death in the health sector as well as to reduce heat stress on livestock in the agriculture sector. However, such a strategy would increase peak summer energy use, increasing demands on both energy and water resources. If increased tree planting is used to reduce urban heat, it will be important to plant low-pollen tree species because allergenic pollen is on the rise in a warmer, higher-CO₂ world. These examples point to the need for integrated thinking about adaptation strategies to avoid creating new problems. In addition, climate change and some adaptation options can worsen social and economic inequalities that are already present and create new inequalities. This raises equity issues that are discussed on the following pages.

Adaptation strategies do not directly include actions aimed at reducing the speed and amount of climate change.

Actions to reduce climate change, often called “mitigation,” involve lowering emissions of heat-trapping gases or increasing their removal from the atmosphere. Mitigation measures would reduce climate change impacts in the longer term.

There are interactions between adaptation and mitigation.

For example, improving insulation and using reflective roofing material keeps buildings cooler in summer (adaptation) as well as reducing energy use and the related heat-trapping emissions (mitigation). There can be a variety of interactions between mitigation and adaptation measures. Some measures, such as green roofs, reduce emissions by decreasing the need for air conditioning as well as lessen impacts by keeping buildings cooler and reducing stormwater flooding. On the other hand, increasing use of air conditioning to adapt to rising temperatures results in increased emissions. Thus, mitigation and adaptation measures should be considered in concert. Both are necessary elements of an effective response strategy. These two types of responses are also linked in that more effective mitigation measures would reduce the amount of climate change, and therefore affect the need for adaptation.

Our choices can make us more or less vulnerable to climate change.

For example, building in coastal zones and river flood plains and paving over large amounts of land make us more vulnerable to flooding and inundation due to sea level rise and increasing heavy downpours. In contrast, decisions made taking into account the adaptation principles described here can make us less vulnerable, that is, better able to withstand the impacts of climate change. However, even the best efforts to reduce vulnerability will not be sufficient to eliminate all damages associated with climate change in the long-term. The goal is to create a more climate-resilient New York State.

Examples of Adaptation Strategies

Reduce other stresses to help improve the adaptive capacity of any system, making it more resilient to climate change. This is true for water and energy supply systems, natural ecosystems, and other sectors.

- For ecosystems, options include reducing human transport of invasive species, controlling sprawl and other habitat destruction, and providing dispersal corridors to allow species range shifts in response to climate change.
- For water and energy systems, options include lowering demand through efficiency measures and consumer education.
- For coasts, reducing development and preserving wetlands through various policies can help.
- For human health, pollution reduction and better management of chronic disease would increase resilience.

Take advantage of normal capital repair and replacement cycles of infrastructure to build in climate change adaptations that are flexible to future conditions.

- When building long-lived infrastructure, such as power plants, tunnels, and bridges, consider projected increases in temperature and sea level, and changes in precipitation patterns.
- Designing a 1-foot floodwall with a strong enough foundation to support an added foot or two of height if needed is an example of flexible adaptation.
- When building new dairy barns, design for better ventilation and possibly the ability to add other cooling technologies.
- Incorporate climate change projections such as the increase in heavy downpours and sea level rise in capital investment decisions currently being made in storm water and wastewater systems.

Examine and revise regulatory mechanisms and land use policies such as zoning, setbacks, building codes, and incentives, taking climate change into account.

- Regulations concerning infrastructure such as those that govern bridge height and clearance, dam height and strength, materials used, dimensions of drainage culverts for roads, roof strength, and foundation depth should be reconsidered.
- Definitions of flood zones should be revisited and how they may change in the future should be considered.
- Regulations that affect adaptive capacity should be assessed. For example, stronger regulations to control invasive species can help make ecosystems more resilient, and stronger efficiency standards can make water and energy systems more resilient.
- Changes in treaties such as those governing water rights might be appropriate if the amounts and distributions of the resources change. Risk sharing mechanisms including various types of insurance and regional planning approaches should also be examined.

Improve monitoring, measurement, and data gathering and distribution to provide the information needed to adapt as climate change proceeds.

- Monitor climate change science for the latest developments.
- A central repository for information on new norms for climate, species, etc. would help to reduce uncertainty and better inform policy.
- Monitoring the effectiveness of various adaptation strategies is important.
- There is a need to better monitor hazards and events, and to archive and make this information widely available. This might include air quality monitoring, citizen watches for invasive species, and real-time data gathering on the impacts of extreme weather events (such as, crop and timber value lost, reduction in dairy production, cost of property damaged, and numbers of heat-related illnesses and deaths).

- In addition to monitoring hazards, events, and adaptation strategies, combine the tracking of these indicators to improve understanding of what impacts will result from various climate events and what adaptation strategies are effective.

Adaptation Assessment Steps

1. Identify current and future climate hazards
2. Conduct risk assessment inventory of infrastructure and assets
3. Characterize risk of climate change on infrastructure
4. Develop initial adaptation strategies
5. Link strategies to capital and rehabilitation cycles
6. Prepare Adaptation Plans
7. Implement Adaptation Plans
8. Monitor and reassess

Environmental Equity

Climate change risks, vulnerabilities, and capacities to adapt are uneven across regions, sectors, households, individuals, and social groups.

Certain groups will be disproportionately affected by the impacts of climate change.

Equity issues emerge because climate change impacts and adaptation policies can worsen existing inequalities and can also create new patterns of winners and losers.

Intergenerational equity issues arise from the fact that future generations will suffer the consequences of past and current generations' actions.

The same groups, such as the elderly, tend to be at risk for adverse impacts of climate change across multiple sectors.

There is a need for more attention to how the impacts of climate change adaptation policies affect different populations, areas, and industries. Affected communities and populations should have a voice in the adaptation policy process.

Particular Areas/Locations at Risk

- Rural areas, especially small towns, are more vulnerable to, and have less capacity to cope with, extreme events such as floods, droughts, ice storms and other climate-related stressors.
- Regions that depend on agriculture and tourism (such as fishing, skiing, and snowmobiling) may be especially in need of adaptation assistance.
- Low-income urban neighborhoods, especially those within flood zones, are less able to cope with climate impacts such as heat waves, flooding, and coastal storms.
- Coastal zones are vulnerable to sea level rise and storm surge. There are already numerous properties in coastal zones that cannot get insurance, for example.

Particular Groups at Risk

- Elderly, disabled and health-compromised individuals are more vulnerable to climate hazards, including floods and heat waves.
- Low-income groups have limited ability to meet higher energy costs, making them more vulnerable to the effects of heat waves.
- Those who lack affordable health care are more vulnerable to climate-related illnesses such as asthma.
- Those who depend on public transportation to get to work, and lack private cars for evacuating during emergencies, are vulnerable.
- Farm workers may be exposed to more chemicals if pesticide use increases in response to climate change.
- Asthma sufferers will be more vulnerable to the decline in air quality during heat waves.

Particular Firms and Industries at Risk

- Smaller businesses are less able to cope with climate-related interruptions and stresses than larger businesses.
- With often more limited capital reserves, smaller firms are less able to withstand revenue loss associated with power and communication service disruptions.
- Small businesses tend to have less capital available to make investments to promote adaptation, such as the use of snowmaking in ski areas, or adoption of new crops or techniques on small farms.

Economics

New York State's climate has already begun to change and impacts related to increasing temperatures and sea level rise are already being felt in the state, with associated costs. Future climate change has the potential to cause even more significant economic costs for New York State. Additional economic costs are likely to be several billion dollars per year by the middle of this century. However, many costs of climate change are still not known and are difficult to estimate. Climate-change related economic impacts will be experienced in all sectors, types of communities and regions across the state.

Types of Climate Impact Costs

Direct costs include costs that are incurred as the direct economic outcomes of a specific climate event or aspect of climate change. Direct costs can be measured by standard methods of national income accounting, including lost production and loss of value to consumers.

Indirect costs are costs incurred as secondary outcomes of the direct costs of a specific event or facet of climate change. Examples include jobs lost in firms that provide inputs to firms directly harmed by climate change.

Impact costs are direct costs associated with the impacts of climate change, for example the reduction in milk produced by dairy cows due to heat stress.

Adaptation costs include direct costs associated with adapting to the impacts of climate change, such as the cost of cooling dairy barns to reduce heat stress on dairy cows.

Costs of residual damage are direct costs of impacts that cannot be adapted to, for example, reductions in milk production due to heat stress that may occur if cooling capacity is exceeded.

Regions

All regions of the state will incur economic costs associated with climate change. Specific economic impacts will affect particular regions. For example, the negative impact on the state's winter recreation industry will adversely affect the Catskill and Adirondack regions.

The coastal zone, because of its relative exposure and vulnerability to storms and the concentration of residences, businesses, and infrastructure on the shore, will experience the greatest economic impact of any single region. The urbanized areas of the state with high population density will incur higher public health costs because of existing and projected urban heat island conditions.

Sectors

All sectors will incur costs associated with climate change; however, the costs will be highly uneven across and within sectors.

- All sectors are likely to experience significant economic impacts that may alter the overall structure and function of the sector.
- Water and flooding related management costs will affect almost all sectors.
- The highest direct economic costs of climate change are connected to large scale capital investment, housing, and commercial activity in the coastal zone.
- Sectors such as agriculture and telecommunications are inherently dynamic, changing annually, seasonally, and in some cases even daily. The economic consequences of climate change will be woven into the risk management and operations of the sector.

Timing

Economic costs of climate change impacts will generally increase throughout the century as the rate of climate change accelerates. Some of the largest costs will be associated with extreme events such as large scale floods and heat waves. Costs associated with average climate changes are expected to increase more slowly over time.

The timing of impacts could be more mixed for sectors that are expected to experience both potential benefits and costs. For example, in the agricultural sector, short term costs could eventually be overwhelmed by the emergence of longer term benefits, or vice versa.

Climate Change Adaptation Costs and Benefits

The implementation of adaptation strategies will bring economic benefits to the state. For each sector, a wide variety of adaptation options at varying costs are available.

- Transportation, the coastal zone, and water resources will have the most significant climate change impact costs and will require the most adaptations.
- Energy, telecommunications, and agriculture sectors have costs that could be large if there is no adaptation; but adaptation to climate could be seen as a regular part of moderate re-investment.
- The benefit-cost ratio comparing avoided impacts to costs of adaptation is highest for the public health and coastal zones sectors, moderate for the water resources, agriculture, energy, and transportation sectors, and low for the telecommunications sector.

Economic Diversity of Coastal Populations

New York City and Long Island are among the areas most at risk from climate change. Many areas along these coasts are already at risk from coastal flooding during storms, and much more land will be at risk as sea level rise accelerates. The impacts and costs of climate change and adaptation options in this heavily developed coastal zone will be large and diverse. There is a great deal of property in harm's way, including long-lived, high-value infrastructure such as roads, airports, bridges, and power plants. The population of this region is very diverse, from low-income inner-city neighborhoods (with median incomes of \$0 - \$9,769) to very high income communities (with median incomes greater than \$135,974).

Water Resources Sector

Context

New York State has an abundance of water resources, including large freshwater lakes, high-yielding groundwater aquifers and major rivers.

Water resources are managed by a diverse array of large and small agencies, governments and institutions, with little statewide coordination.

Water resources are already subject to numerous human-induced stresses, such as increasing demand for water and insufficient water supply coordination; these pressures are likely to increase over the next several decades.

Water quality is already at risk from aging wastewater treatment plants, continued combined sewage overflow events, and excess pollution from agricultural and urban areas.

Key Climate Impacts

Rising air temperatures intensify the water cycle by driving increased evaporation and precipitation. The resulting altered patterns of precipitation include more rain falling in heavy events, often with longer dry periods in between. Such changes can have a variety of effects on water resources.

Heavy downpours have increased over the past 50 years and this trend is projected to continue, causing an increase in localized flash flooding in urban areas and hilly regions. One model projects that the number of rainfall events per year that exceed one inch of rain will increase from about 4-5 events in 1961 to 6-7 events by the end of the century. Actual observations from 1960 to 2000 show this increase, although at an even steeper rate than the model predicts. (The model used for this projection was the UK Met Office Hadley Centre Climate Model Version 3, whose results are broadly consistent with those of the other 15 GCMs used by ClimAID.)

The amount of rain falling in a "100-year" storm is projected to increase, while the number of years between such storms ("return period") is projected to decrease. Thus, rainstorms will become both more severe and more frequent. One model projects that the amount of rain from a 100-year storm will increase from about 5.3 inches in 1961 to about 5.5 inches in 2061, and the return period will decrease from 100 years to about 80 years. (The model used for this projection was the UK Met Office Hadley Centre Climate Model Version 3, whose results are broadly consistent with those of the other 15 GCMs used by ClimAID.)

Flooding has the potential to increase pollutants in the water supply and inundate wastewater treatment plants and other vulnerable development within floodplains.

Less frequent summer rainfall is expected to result in additional, and possibly longer, summer dry periods, potentially impacting the ability of water supply systems to meet demands.

Reduced summer flows on large rivers and lowered groundwater tables could lead to conflicts among competing water users.

Increasing water temperatures in rivers and streams will affect aquatic health and reduce the capacity of streams to assimilate effluent from wastewater treatment plants.

Adaptation Options

Adaptation can build on water managers' existing capacity to handle large variability. Strategies can be designed to be flexible to a range of future conditions. New York's relative wealth of water resources, if properly managed, can contribute to resilience and new economic opportunities.

Operations, Management, and Infrastructure Strategies

- Relocate infrastructure such as wastewater treatment plants and high-density housing to higher elevations and outside of high risk floodplains. For infrastructure that must remain in the floodplain, elevate structures, construct berms or levees to reduce flood damage.
- Adopt stormwater infrastructure and management practices and upgrade combined sewer and stormwater systems to reduce pollution.

Larger-Scale Strategies

- Use multiple strategies to increase water use efficiency. Conserve water through leak detection programs; use of low-flow showerheads, toilets, and washing machines; and rain barrels for garden watering. Research equitable water pricing programs.
- Establish stream flow regulations that mimic natural seasonal flow patterns, including minimum flow requirements, to protect aquatic ecosystem health.
- Expand basin-level commissions to provide better oversight, address water quality issues, and take leadership on monitoring, conservation, coordination of emergency response, and new infrastructure.
- Develop more comprehensive drought management programs that include improved monitoring of water supply storage levels and that institute specific conservation measures when supplies decline below set thresholds. Update and enlarge stockpiles of emergency equipment to help small water supply systems and to assist during emergencies.

Co-Benefits

Continuing and expanding current water resource management practices, such as reducing stormwater runoff into water bodies, will benefit pollution control as well as climate adaptation. Encouraging water conservation strategies and minimum flow criteria to prepare for potential summer droughts will help to guarantee water sufficiency.

Particularly Vulnerable Groups

Smaller water systems are more vulnerable to drought and other types of water supply disruptions than larger systems, since large systems tend to be more closely managed and often have more resources for dealing with drought.

The elderly and people with disabilities tend to be more vulnerable to immediate flood hazards due to limited mobility.

Rapidly developing, higher-income exurban communities may experience water scarcity as demand increases in these areas and overwhelms local supplies.

Lower-income or non-English speaking populations may be particularly vulnerable to increasing levels of disease-causing agents in the water supply or contaminants in well water as they may be less aware of government programs and warnings and have less access to health care.

Case Study: Susquehanna River Flooding, June 2006—The Value of Preparedness

Flooding is already a major problem across New York State with damages costing an average of \$50 million each year. There are several flood management strategies that can help solve current problems while addressing possible future ones.

The June 2006 Susquehanna River flood—the largest on record since gauging began on the river in 1912—provides insights into strategies that can be used to reduce flood risks and impacts. Days of very heavy rain on top of already saturated soils from weeks of rain caused the daily discharge level of the Susquehanna River to spike from about 5000 cubic feet/second to over 70,000 cubic feet/second in late June, flooding thousands of properties. Record precipitation from June 25 to 28, totaling 3 to 11 inches, culminated in significant flooding in the basin. Twelve counties in New York and 30 in Pennsylvania were declared disaster areas. Rainfall coupled with runoff from steep hillsides contributed to river water levels rising from less than 5 feet to nearly 21 feet in nine hours. Broome County, N.Y., incurred the most damages.

In Broome County, about 3,350 properties were flooded. Fifty-eight percent of the flooded properties were residential and 10 percent were commercial. Nearly 30 percent of the shopping area, two sewage treatment plants, a public works facility, a hospital, and several hundred miles of roads were also flooded. The town of Conklin was the hardest hit, with 30 percent of its properties flooded, followed by 13 percent in Kirkwood, and 10 percent in Port Dickinson. In total, 1,020 of the properties that were flooded were not within FEMA's Special

Flood Hazard Area, including 723 residential properties. These properties were valued at more than \$46.3 million and were exempt from having federally mandated insurance.

Despite the very rapid onset of the flood and the thousands of properties that were inundated, there were only four deaths, thanks to the Susquehanna River Basin's well-developed flood-response system. The area has an excellent warning-and-response system that links NOAA-based weather forecasts to real-time USGS streamflow data and coordinates with regional and local emergency response teams. The June 2006 response included pre-flood community-wide warnings and evacuations, water pumping and sand bag efforts, and emergency evacuations and medical services during the flood. Such a system is not inexpensive to operate; a single USGS gauge can cost nearly \$20,000 per year to maintain and the system has nearly 10 such gauges. However, the value of such an early warning system is apparent when large floods do occur, and remains important for the future.

While the area has extensive levees and dams, some are outdated and the current system is not adequate to deal with potential higher-magnitude floods. Development within the floodplains behind these barriers has intensified, making communities more vulnerable and damages greater when floods occur. Strategies to help further reduce flood risk include moving out of the highest risk areas with homeowner buyouts following floods, and relocating infrastructure, such as wastewater treatment plants, out of floodplains. This strategy was used successfully in Conklin, and elsewhere. It reduces subsequent flood risk, both to lives and buildings, and monetary costs can be comparable to or less than costs to expand levees. It also expands natural flood-control processes by expanding the undeveloped areas so that floodwaters can spread out and dissipate instead of being forced downstream. In some areas, downstream flooding can also be lessened by reducing stormwater runoff through improving soil infiltration capacity, expanding vegetated surfaces, and decreasing impervious surfaces such as roads.

Coastal Zones Sector

Context

New York's coastal zones are becoming more developed, further increasing the consequences of flooding, coastal erosion, and sea level rise.

More than a half million people live within the 100-year coastal floodplain in New York State.

Coastal marshes and wetlands are highly sensitive and must maintain a delicate balance as they are affected by rapid sea level rise, wave erosion, sediment deposition and other forces. These important ecosystems provide wildlife habitat, protect coastlines against storms, and absorb pollution.

Coastal impacts propagate into inland areas, such as up the Hudson River, all the way to the Troy Dam.

Key Climate Impacts

High water levels, strong winds, and heavy precipitation resulting from strong coastal storms already cause billions of dollars in damages and disrupt transportation and power distribution systems. Sea level rise will lead to more frequent and extensive coastal flooding, particularly in low-lying areas of Long Island and New York City. Warming ocean waters raise sea level through thermal expansion and have the potential to strengthen the most powerful storms.

Barrier islands are being dramatically altered by strong coastal storms as ocean waters overwash dunes, create new inlets, and erode beaches.

Sea level rise will greatly amplify risks to coastal populations and will lead to permanent inundation of low-lying areas, more frequent flooding by storm surges, and increased beach erosion.

Loss of coastal wetlands reduces species diversity, including fish and shellfish populations.

Some marine species, such as lobsters, are moving north out of New York State, while other species, such as the blue claw crab, are increasing in the warmer waters.

Saltwater could reach farther up the Hudson River and in estuaries, contaminating water supplies. Tides and storm surges may propagate farther, increasing flood risk both near and far from the coast.

Sea level rise may become the dominant stressor acting on vulnerable salt marshes.

The impacts of climate change occur in the context of numerous other stresses, many of which are also caused by human activities. While climate change increases air and water temperatures and alters precipitation and runoff patterns, nitrogen from agricultural areas is an additional stress that harms fish and shellfish in the coastal zone. This can lead to closures of shellfish-harvesting areas, such as in the Peconic Estuary of Long Island.

Adaptation Options

Implementation of adaptation strategies in coastal zones is complicated by the complex interactions of natural and human systems and competing demands for resources.

Operations, Management, and Infrastructure Strategies

- Move sand onto beaches, although doing so can lead to habitat disruption and erosion in the area of removal, and is only a temporary solution. Add sediment from shipping channels to marshes, although this may not keep up with the rate of loss.
- Consider use of engineering-based strategies such as constructing or raising sea walls, and bio-engineered strategies including restoring or creating wetlands.
- Site new infrastructure and developments outside of future floodplains, taking into consideration the effects of sea level rise, erosion of barrier islands and coastlines, and wetland inundation.

Larger-Scale Strategies

- Buy out land or perform land swaps to encourage people to move out of flood-prone areas and allow for wetlands to shift inland. Enact rolling easements to help protect coastal wetlands by prohibiting seawall construction while still allowing some near-shore development.
- Improve building codes to promote storm-resistant structures and increase shoreline setbacks.

Co-Benefits

Protecting wetland areas has mitigation and other ecosystem service co-benefits because they provide critical functions such as capturing carbon, providing habitat for fish and other species, and serving as a buffer for storm surge.

Particularly Vulnerable Groups

Within the coastal zone, elderly and disabled residents and households without cars are particularly vulnerable to flood hazards as they have more difficulty evacuating in a timely manner.

Low-income populations living in coastal and near-coastal zones will be less able to recover from damages resulting from extreme weather events than will wealthier populations.

Racial and ethnic minorities are more vulnerable to extreme events than non-minority populations; African Americans and Latinos represent a significant portion of the people living in the New York City flood zone.

Coldwater marine species, such as lobsters, are vulnerable to increases in sea surface temperature and some are already beginning to move north out of New York State waters.

Freshwater ecosystems in estuaries are vulnerable to saltwater intrusion as sea level rises.

Case Study: Effects of Sea Level Rise on Vital Coastal Wetlands

Salt marshes are essential ecosystems in New York State that provide a number of services including protection against coastal storm damage, habitat for migratory birds, nurseries for local fisheries, and recreation opportunities for residents. Over the past several decades, the area of these essential ecosystems has declined dramatically.

While sea level rise is currently a relatively minor component among several human-induced stressors (including draining of marshes, building seawalls, and dredging navigation channels) that may be contributing to the submergence and loss of vulnerable marshes, sea level rise may become the dominant factor in future decades.

At Jamaica Bay in New York City, island salt marsh area declined by 20 to 35 percent between the mid-1920s and mid-1970s. Since the mid 1970s, despite the implementation of regulations limiting dredging and filling activity, the rate of loss has accelerated; by 2008 close to 70 percent of the mid-1920s marsh area had been lost. In a 2003 pilot project at Big Egg Marsh, sediment was sprayed to a thickness of up to 3 feet and plugs of *Spartina alterniflora*, a marsh plant, were planted. In 2006 at Elder's Point East, a large-scale, \$12 million restoration project used sand from maintenance dredging to artificially elevate the marsh. At both sites, the elevated stands of marsh plants are currently thriving. The successes of these two projects led to initiation of the 2010 restoration at Elder's Point West with plans underway for Yellow Bar Hassock.

Udalls Cove Park in Queens and Pelham Bay Park in the Bronx have also experienced significant marsh loss. At Udalls Cove Park, marsh area has declined by 38 percent since 1974 and by 33 and 45 percent at two locations in Pelham Bay Park. Monitoring stations have been established in these parks to track the changes. The data are being used in combination with projected rates of sea level rise and aerial photographs to assist park managers, scientists and public advocates in managing and thereby perhaps minimizing salt marsh loss in the coming decades.

Case Study: Sea Level Rise and Severe Coastal Storms—Vulnerability of Urban and Suburban Communities

New York's highly developed and populated coastlines are vulnerable to severe coastal storms, such as hurricanes. The urban and suburban regions of Long Beach and the communities along the mainland coastline of Great South Bay are two examples of areas at risk. Flood adaptation strategies for such areas require a holistic approach that promotes resiliency across communities.

Sea level rise in combination with a coastal storm that currently occurs about once every 100 years on average is expected to place a growing population and more property at risk from flood and storm damage. In 2020, nearly 96,000 people in the Long Beach area alone may be at risk from sea level rise under the rapid ice melt scenario; by 2080, that number may rise to more than 114,500 people. The value of property at risk in the Long Beach area under this scenario ranges from about \$6.4 billion in 2020 to about \$7.2 billion in 2080.

To help protect against the effects of sea level rise and coastal storm flooding, a number of adaptation strategies could be undertaken. In terms of financial cost, relocating agricultural and low-density residential development further away from the coast is an appropriate adaptation strategy. Engineering-based strategies, such as constructing levees and sea walls, can be appropriate for moderate- and high-density development, although they involve tradeoffs.

Each adaptation measure may create new patterns of winners and losers. For example, sea walls may protect some people within a community while others are left vulnerable to flooding. Seawalls also prevent wetlands from migrating inland, resulting in the loss of wetlands that are important nurseries for marine species and that also help protect the coastline from damage during storms. Relocating infrastructure to higher elevation areas may result in gentrification in the upland community, making low-income populations more vulnerable. Such patterns of vulnerability need to be considered when planning for adaptation to reduce climate change impacts.

Ecosystems Sector

Context

Healthy ecosystems are our life support system, providing us with essential goods and services that would be extremely expensive or impossible to replace. Ecosystems purify air and water, and provide flood control. They supply us with products like food and timber, and sequester carbon and build soils. They provide recreation, hunting, and fishing, and wild places in which to enjoy nature. Human disruption of ecosystems, through climate change and other factors such as habitat destruction and pollution, can reduce ecosystems' ability to provide us with these valuable ecosystem services.

The vast majority of New York's forests and other natural landscapes are privately owned (more than 90 percent of the state's 15.8 million acres of potential timberland), with implications for land-use planning and policies.

Urbanization and other land-use changes have fragmented large, connected habitats important for species dispersal and migration.

Increasing deer populations cause economic losses to agricultural crops and urban landscapes, and their selective feeding in natural landscapes alters plant community structure with cascading effects on other species.

Many non-climate stressors currently have negative effects on New York's ecosystems. These stressors include invasive species, air pollution, acid precipitation, and excess nitrogen and phosphorus in the state's waterways.

Key Climate Impacts

Within the next several decades New York State is likely to see widespread shifts in species composition in the state's forests and other natural landscapes, with the loss of spruce-fir forests, alpine tundra and boreal plant communities.

Climate change will favor the expansion of some invasive species into New York, such as the aggressive weed, kudzu, and the insect pest, hemlock woolly adelgid. Some habitat and food generalists (such as white-tailed deer) may also benefit.

A longer growing season and the potential fertilization effect of increasing carbon dioxide could increase the productivity of some hardwood tree species, provided growth is not limited by other factors such as drought or nutrient deficiency.

Carbon dioxide fertilization tends to preferentially increase the growth rate of fast growing species, which are often weeds and other invasive species.

Lakes, streams, inland wetlands and associated aquatic species will be highly vulnerable to changes in the timing, supply, and intensity of rainfall and snowmelt, groundwater recharge and duration of ice cover.

Increasing water temperatures will negatively affect brook trout and other native coldwater fish.

Snowpack is projected to decline sharply due to future warming. One model projects that at Wanakena, NY, in the Adirondacks, the maximum snow depth in February will decrease from about 18 inches (the average depth observed over the 1971-2000 baseline period) to 5 inches by the 2080s. (This projection used the UK Met Office Hadley Centre Model version 3 for three future time periods under one relatively high emissions scenario (A2); these projections are broadly consistent with those of other models used in ClimAID.)

Adaptation Options

When considering adaptation strategies for ecosystems, it is important to manage primarily for important ecosystem services and biodiversity rather than attempting to maintain the current mix of species.

Operations, Management, and Infrastructure Strategies

- Develop management interventions to reduce vulnerability of high-priority species and communities, and determine minimum area needed to maintain boreal or other threatened ecosystems.

Larger-Scale Strategies

- Maintain healthy ecosystems so they are more tolerant or better able to adapt to climate change by minimizing other stressors such as pollution, invasive species, and sprawl and other habitat-destroying forces.
- Facilitate natural adaptation by protecting riparian zones and migration corridors for species adjusting to climate changes.
- Institutionalize a comprehensive and coordinated monitoring effort and accessible database to track species range shifts and other indicators of habitat and ecosystem response to climate change. Identifying and prioritizing what to monitor and, in some cases, developing new indicators will be required.

Co-Benefits

Maintaining healthy ecosystems in a changing climate will allow them to continue to provide services such as provision of water resources, maintenance of biodiversity, and recreation.

Particularly Vulnerable Groups

Communities whose economies depend on skiing and snowmobiling will be negatively affected by higher temperatures and reduced snowpack.

Communities that depend on tourism associated with coldwater fisheries such as trout could be particularly vulnerable, although there could be increases in warmer water fish species that could help offset these losses.

Characteristics that make species and communities highly vulnerable to climate change include: being adapted to cold or high-elevation conditions; being near the southern boundary of their ranges; having a narrow range of temperature tolerance; having specialized habitat or food requirements; being susceptible to new competitors, invasive species, or pests; having poor dispersal ability; having low genetic diversity; and having low population levels.

Vulnerable species and ecosystems include: spruce-fir forests of the Adirondack and Catskill mountains; boreal and alpine tundra communities of the Adirondack mountains; hemlock forests; brook trout, Atlantic salmon, and other coldwater fish; snow-dependent species such as snowshoe hare, voles and other rodents, and their winter predators such as fox and bobcat; moose; bird species such as Baltimore oriole and rose-breasted grosbeak; amphibians and other wetland species.

Case Study: Cascading effects of climate change on animals, plants, and the economy

Shaded and cool hemlock forests provide unique wildlife habitat and are the single most prevalent conifer species in New York state. Suitable habitat for the eastern hemlock is expected to decline in New York as a result of increasing average summer temperatures as well as the spread of the invasive insect, the hemlock woolly adelgid. The hemlock woolly adelgid is already well established in New York and recently has spread to the central part of the state, in part due to rising winter temperatures that are allowing the insect to survive the winter. Hemlocks already are dying from infestations in New York's southern and Hudson Valley regions. Currently there is no way to prevent the spread or the effects of the insect. Extensive loss of hemlock forests will have cascading, far-reaching effects on a variety of wildlife species and their ecosystems.

New York's state fish, the brook trout, is at particular risk from hemlock loss and is already at risk from increasing temperatures. The southern extent of the habitable range for brook trout is in New York and the historical abundance of the fish is likely to be severely reduced by warming. Brook trout depend on coldwater refuges in streams and lakes to survive. Lakes that are unstratified lack coldwater refuges and are likely to lose all of their trout. These represent about 41 percent of brook trout lakes in the Adirondack Mountains, for example. Brook trout in streams and rivers will also be vulnerable as water temperatures rise along with air temperatures. Their vulnerability will be complicated by the extensive loss of hemlock forests, which shade and maintain lower water temperatures in streams.

The loss of brook trout will cause changes in New York's fishing economy and may have disproportionate effects on small, fishing-dependent communities in which millions of dollars are spent by tourists who come to fish for trout. Possible adaptation strategies for keeping streams cool enough for brook trout include maintaining or increasing vegetation that provides shade along rivers, streams, and lake shorelines, and minimizing disturbances that would impede water flows and groundwater inputs.

Even more important from an economic perspective are the broader impacts of climate change on mountain forests. The local economies of the Adirondacks, Catskills, and Finger Lakes are dominated by tourism and recreation. Two-thirds of the current tree species in mountainous areas of the Adirondacks will be outside of their sustainable climate zone and in severe decline by the end of this century if current emissions trends continue.

Hunting, fishing and wildlife viewing make significant contributions to New York State's economy. More than 4.6 million people fish, hunt, or wildlife watch in the state, spending \$3.5 billion annually on equipment, trip-related expenditures, licenses, contributions, land ownership and leasing and other items. The loss of spruce-fir forests and alpine meadows will negatively affect these experiences and their economic contributions to the state.

Winter recreation is another major component of the economic value of the state's natural ecosystems. New York has more ski areas than any other state, hosting an average of 4 million visitors each year, contributing \$1 billion to the state's economy and employing 10,000 people. New York is also part of a six-state network of snowmobile trails that totals 40,500 miles and contributes \$3 billion each year to the Northeast regional economy. Shorter, warmer winters and reduced snowpack will have significant negative impacts on winter recreation in the state and the region.

Agriculture Sector

Context

The agriculture sector in New York State encompasses more than 34,000 farms that occupy about one-quarter of the state's land area (more than 7.5 million acres) and contribute \$4.5 billion annually to the state's economy.

A large majority of New York agriculture is currently rain-fed without irrigation, but summer precipitation is currently not sufficient to fully meet crop water needs most years.

Economic pressures have led to consolidation into fewer, larger farms, particularly in the dairy industry. The costs of adapting to climate change may exacerbate this trend.

Agriculture is sensitive to the volatile and rising costs of energy, a challenge that climate change is likely to exacerbate.

Key Climate Impacts

Increased summer heat stress will negatively affect cool-season crops and livestock unless farmers take adaptive measures such as shifting to more heat-tolerant crop varieties and improving cooling capacity of livestock facilities.

Increased weed and pest pressure associated with longer growing seasons and warmer winters will be an increasingly important challenge.

Water management will be a more serious challenge for New York farmers in the future due to increased frequency of heavy rainfall events, and more frequent and intense summer water deficits by mid to late century.

The combination of precipitation, evaporative water loss from soils and plants, and runoff determine whether there is a water deficit or excess. Runoff is the fraction of precipitation that is not evaporated and exceeds the soil-holding capacity and thus passes into deep groundwater or into streams. In summertime, there is a moisture deficit as evaporative losses increase due to higher temperatures, resulting in virtually no runoff during the warmest months; the opposite occurs during the winter months, leading to a slight water excess. ClimAID projections show that both the summer water deficit and winter excess are expected to increase in a warming climate.

Opportunities to explore new crops, new varieties, and new markets will come with higher temperatures and a longer growing season.

As climate warms, the date of last frost comes ever earlier in the year. One model projects that the last frost will occur nearly 20 days earlier than it did in 2010. (This model's (HadCM3) projections are broadly consistent with those of the other models used in ClimAID.)

Adaptation Options

A changing climate presents challenges and potential opportunities for New York state farmers. Responding will necessitate both on-farm and state-level strategies.

Operations, Management, and Infrastructure Strategies

- Change planting dates, varieties or crops grown. Increase farm diversification.
- Improve cooling capacity, including the use of fans and sprinklers in dairy barns.
- Increase use of chemical and non-chemical techniques for controlling pests, pathogens, and weeds.
- Develop new crop varieties for projected New York climate and market opportunities.
- Invest in irrigation and/or drainage systems.

Larger-Scale Strategies

- Develop decision tools to assist farmers in determining the optimum timing and magnitude of investments to cope with climate change.

Co-Benefits

There are several opportunities for reducing greenhouse gas emissions with agriculture adaptation options including improved manure management, generation of on-site energy, increasing the use of soil organic matter, and using nitrogen fertilizer more efficiently.

Particularly Vulnerable Groups

Dairy milk production and the productivity and/or quality of some cool-season crops such as apples, potatoes, and cabbage will be particularly vulnerable to increases in summer heat stress. Adaptations such as improving cooling capacity of dairy barns or changing varieties or crops are straightforward but will not be cost-free or risk-free. For example, the state could lose some favorite varieties of apples, such as McIntosh and Empire, for which it currently has national recognition, and have to replace them with more heat-tolerant varieties.

Smaller farms may have less information and training and less capital to invest in adaptation strategies such as stress-tolerant plant varieties, increased chemical and water inputs, and enhanced livestock cooling. By adding to already severe competitive pressure, climate change is likely to exacerbate current trends towards consolidation into fewer, larger farms, especially in the dairy sector.

Farms specializing in cool-season crops may have challenges finding appropriate new varieties that meet both production demands and market expectations.

Without pro-active development of non-chemical approaches, increased pesticide and fertilizer use could harm sensitive environments, such as streams and rivers.

Case Study: Changes for the Grape Industry

New York's grape harvest ranked third in the nation in 2007, with the crop valued at nearly 50 million dollars. In recent years, however, challenges associated with cold injury to crops have cost the states agriculture industry millions of dollars. Increasing temperatures at the beginning of winter reduce cold hardiness and can raise the probability of midwinter damage. In late winter or early spring (after the winter-chilling requirement has been met), an earlier arrival of spring or a prolonged warm period may lead to premature budding and increased vulnerability to spring frost. These conditions are projected to occur more frequently in the later part of this century, leading to a slight increase in the potential for spring frost injury in New York's Concord grapes.

In the long term, warmer winters and a longer growing season may bring opportunities to introduce a wider range of high value, less cold-tolerant European red wine grape varieties such as Cabernet Sauvignon and Zinfandel, that currently are constrained by the state's climate.

Adaptation strategies to avoid damage from spring frost events (such as using wind machines that pull warmer air down from high above ground during temperature inversions, and changing pruning and mulching strategies) are well established. New research will be required to integrate weather forecasts into early-warning systems for extreme events such as hard freeze and spring frost events. Linking these warning systems to the susceptibility of crops to damage could help reduce losses.

Case Study: Dairy Heat Stress

Heat stress has both short- and long-term effects on the health and performance of dairy cattle depending on severity and timing of the stress. Short-term impacts include decreases in feed intake and milk production. Under heat stress cows spend less time resting and more time standing and walking. A decrease of 1 hour of resting time is associated with a decrease of 2 to 3 pounds of milk produced per cow. Severe heat stress can cause lameness and poor reproductive performance (calving), with subsequent long-term negative effects on milk production. While short-term responses can be partially reversed after a heat wave, long-term effects are less easily reversed.

By the 2080s, the magnitude of annual N.Y. milk production decline associated with heat stress is projected to increase six-fold compared to current heat stress-related declines. Economic losses associated with the projected increase in heat stress range from \$37 to \$66 per cow per year. These ClimAID estimates took into account only

short-term heat stress effects. They did not consider the potential long-term effects of severe stress on milk production, so they may underestimate losses.

Modifying feeding and providing adequate water can help ameliorate heat stress in cows, but cannot substitute for improving cooling capacity in dairy barns (for example, through improved ventilation, high airspeeds directly over the cows, and sprinkler systems). Many ventilation systems are inherently more cost-effective when deployed for larger barns. Small farms that cannot afford these kinds of adaptation measures will be most vulnerable to the impacts of warming.

Energy Sector

Context

The energy system in New York State is designed to cope with a wide range of climate variability.

Climate change is likely to exacerbate existing risks rather than create new ones.

Extreme, short-term weather events and changes in demand are particularly important to the energy industry.

The state's annual electricity load has increased by about 4.3 percent per year. New York City and Long Island account for about half of the total demand.

New York State's electricity sources vary regionally. For example, about half the fossil fuel-fired plants are in New York City and Long Island while most of the state's hydropower is in central and northern New York.

Wind power deployment is expected to increase across the state.

Natural gas is the most commonly used source of heating energy in buildings, although there are strong regional differences, which reflect the lack of gas service in many parts of the state.

Energy prices vary widely, with higher prices in eastern New York than in western parts of the state.

Table 10: New York State Electricity Generation by Fuel Type (2008)

Fuel Type	Percentage of New York State
Nuclear	29%
Oil and Gas	23%
Hydro	19%
Natural Gas	13%
Coal	13%
Methane/waste/solar/wood	2%
Wind	1%

Key Climate Impacts

Impacts of climate change on energy demand are likely to be more significant than impacts on supply. Climate change will adversely affect system operations, increase the difficulty of ensuring adequate supply during peak demand periods, and exacerbate problematic conditions, such as the urban heat island effect.

More frequent heat waves will cause an increase in the use of air conditioning, stressing power supplies and increasing peak demand loads.

Increased air and water temperatures will decrease the efficiency of power plants, as they decrease cooling capacity.

Coastal infrastructure is vulnerable to flooding as a result of sea level rise and coastal storms. The majority of New York City's power plants are located at low elevations on the coast and are thus vulnerable to sea level rise and storm surge.

Hydropower is vulnerable to projected increases in summer drought.

The availability and reliability of solar power systems are vulnerable to changes in cloud cover although this may be offset by advances in technology; wind power systems are similarly vulnerable to changes in wind speed and direction.

Biomass energy availability depends on weather conditions during the growing season, which will be affected by a changing climate.

Transformers and distribution lines for both electric and gas supply are vulnerable to extreme weather events, such as heat waves and flooding.

Higher winter temperatures are expected to decrease winter heating demand, which will primarily affect natural gas markets, while increases in cooling demand will affect electricity markets; such changes will vary regionally.

The indirect financial impacts of climate change may be greater than the direct impacts of climate change. These indirect impacts include those to investors and insurance companies as infrastructure becomes more vulnerable and those borne by consumers due to changing energy prices and the need to use more energy.

Table 11: Projected changes in peak electricity demand for heating and cooling - 2020s (compared to current peak demand). ClimAID global climate models project that average annual temperature will rise by 1.5 to 3.0°F in the 2020s compared to the 1970-1999 baseline period. An analysis of the sensitivity of energy demand to these changes shows that while heating energy use will decrease slightly, cooling energy use will increase much more.

Weather Station	Heating Season Decrease in MWp Electricity Demand in 2020s	Cooling Season Increase in MWp Electricity Demand in 2020s
Buffalo	14 - 27	55 - 111
Rochester	9 - 18	53 - 105
Syracuse	19 - 37	61 - 122
Massena	5 - 10	7 - 15
Watertown	11 - 21	29 - 57
Albany	15 - 29	63 - 126
Poughkeepsie	12 - 25	72 - 145
NY City (LGA)	40 - 80	249 - 497
Islip	27 - 58	194 - 387

Adaptation Options

Planning for climate change must balance the need to make energy systems more resilient with the cost of such investments and changes. One way to do this is to incorporate adaptation planning into the replacement cycles of system assets, which have a long but relatively fixed lifespan. As temperatures rise, it will be even more important to encourage the use of energy efficient cooling methods such as shading buildings and windows, or using highly reflective roof paints to reduce buildings' temperatures. Although demand-side management, which encourages consumers to use energy more efficiently, is already a key state policy, it could be made an even greater priority.

Operations, Management, and Infrastructure Strategies

- Use transformers and wiring that function efficiently at higher temperatures.
- Construct berms and levees to protect infrastructure from flooding; install saltwater-resistant transformers to protect against sea level rise and saltwater intrusion.
- Review and revise tree trimming practices to account for changes in vegetation due to climate change.

Larger-Scale Strategies

- Adjust reservoir release policies to ensure sufficient summer hydropower capacity.

- Improve energy efficiency in areas that are likely to have the largest increases in demand.

Co-benefits

Increasing energy efficiency can help people to adapt to higher temperatures while reducing greenhouse gas emissions in order to mitigate climate change.

Particularly Vulnerable Groups

For lower-income residents, increased energy costs associated with air conditioning may be difficult to afford.

Low-income residents living in urban areas, which are already subject to urban heat island effects, may be especially vulnerable to higher energy costs.

New energy facilities to power the increased demand for air conditioning may place burdens on communities located nearby.

Elderly, disabled, and health-compromised residents are especially vulnerable to energy outages associated with extreme climate events.

Case Study: Impacts of Extreme Heat in Cities

Sustained high temperatures contribute to increased energy usage during heat waves, primarily for cooling indoor space and industrial equipment. When high temperatures persist overnight during these extended heat events, the likelihood of outages increases. While the network design of local grids tends to isolate outages geographically, limiting the number of customers affected, prolonged heat waves can cause multiple outages across a city. The impacts of power outages can extend well beyond the energy sector, affecting health, transportation, and telecommunication.

In New York City, urban heat island effects already contribute to an increase in energy demand during hot summer periods. Worsening heat waves under climate change pose a challenge for the city's energy sector. Existing urban heat island patterns will become more intense, such that areas that are already warmer due to heat island effects will become relatively hotter during a heat wave. The effects of heat islands are especially prominent in many lower income neighborhoods, such as Fordham in the Bronx and Crown Heights in Brooklyn. These neighborhoods often have fewer trees on the street and higher building density, both of which contribute to hotter conditions.

Higher poverty areas of New York City, including Central Harlem, Washington Heights, Fordham, the South Bronx, Greenpoint, Williamsburg, Bedford-Stuyvesant, and others, have lower rates of home air conditioning than other areas, putting them at greater risk for heat-related health problems. But even households that have air conditioning in these areas may be reluctant to use it because of the high cost of energy, which represents a large portion of their household income.

To provide enough power during heat waves to meet the increase in peak demand, less efficient and more highly polluting sources of power may be used. High ozone levels due to the combination of high temperatures and air pollution are particularly harmful for the elderly and ill.

Power outages and other disruptions to supply have significant financial impacts, with costs to U.S. consumers ranging from \$119 billion to \$188 billion per year. The workforce—especially those living farther from their jobs or who are more dependent on forms of transportation that become inoperable during power outages—are likely to bear these losses. During the 2003 Northeast blackout, loss of wages was estimated to account for two-thirds of the total financial losses.

Those providing emergency services, including emergency health professionals, also may have difficulty getting to work during a power outage, thereby increasing risks to individuals in need of assistance. During the 2003 Northeast blackout, the health services sector had the second highest workforce losses as a result of business closures. Demand for emergency services during the outage increased significantly as did the rate of respiratory device failure.

To protect against severe power outages, smart grid technology can be used to help avoid them altogether by providing network operators with clearer metrics of the potential risk. Reducing demand and distributed generation (which generates electricity from many small sources) can also help lessen the risk of power outages. During heat waves and in advance of peak demand, voluntary and mandatory load-reduction programs that call for customers to reduce usage also can be employed.

Transportation Sector

Context

Context New York State is home to a 113,000-mile network of Interstate and State Highways including 16,000 bridges, a 4,600-mile rail network including the largest mass transit system in the U.S., some 500 public and private aviation facilities, more than 130 public transit operators, four port authorities, and numerous private ports. Transportation contributes about 10 percent, or \$100 billion annually, to the state's economy.

The highest concentration of transportation infrastructure is generally located in regions that are population centers and vital drivers of the global, national and state economy. Threats to these dense metropolitan transportation systems (especially New York City) would have far-reaching impacts.

Ground transportation systems (roads and rails) in coastal population centers are often placed underground in tunnels very close to or below sea level.

Since transportation is a networked system, delays and failures in one system can affect other systems.

Key Climate Impacts

Over the next few decades, heat waves and heavy precipitation events are likely to dominate the causes for moderate, more frequent transportation problems such as flooded streets and delays in mass transit.

By later this century, it is very likely that coastal flooding will be more frequent and intense due to sea level rise. The 100-year flood zones are likely to change throughout the century as sea level rises. Major adaptations are likely to be needed, not only in the coastal zones, but also in Troy and Albany as sea level rise and storm surge propagate up the tide-controlled Hudson River.

Materials used in transportation infrastructure, such as asphalt and train rails, are vulnerable to increased temperatures and frequency of extreme heat events.

Air conditioning requirements in buses, trucks, and trains, and ventilation requirements for tunnels will increase.

Low-lying transportation systems such as subways and tunnels, especially in coastal and near-coastal areas, are at particular risk of flooding as a result of sea level rise, storm surge, and heavy precipitation events.

As sea level rises, many more New York City streets will be at risk of flooding. Under current conditions, about 11 percent of city streets are at risk. With 2 feet of sea level rise, that increases to about 25 percent. With 4 feet of sea level rise, about 34 percent of NY City streets are at risk. Table 12 gives the total length in miles of NY City streets at risk of flooding under current conditions with a 100-year storm, and with 2 feet and 4 feet of sea level rise.

Table 12: Miles of New York City Streets at Risk of Flooding with Sea Level Rise

	Current 100-Year Storm	2-Foot SLR	4-Foot SLR
Flooded Street Length	917.1 mi	2181.1 mi	2919.1 mi
Dry Street Length	7714.7 mi	6450.6 mi	5712.7 mi

Transportation systems are vulnerable to ice and snowstorms, although requirements for salting and snow removal may decrease as precipitation tends to occur more often as rain than snow. Freeze/thaw cycles that disturb roadbeds may increase in some regions as winter temperatures rise.

Runways may need to be lengthened in some locations since hotter air provides less lift and hence requires higher speeds for take off. Newer, more powerful aircraft can reduce this potential impact.

The Great Lakes may see a shorter season of winter ice cover, leading to a longer shipping season. However, reduced ice cover may result in an increase in “lake effect” snow events, which cause various transportation-related problems.

New York State has the most days per year of freezing rain in the nation. This affects air and ground transportation directly and also indirectly through electric and communication outages. It is unknown how climate change will influence the frequency of freezing rain in the future.

Adaptation Options

Disaster management studies have shown that every \$1 invested in preventative measures saves \$4 in losses not incurred.

Operations, Management, and Infrastructure Strategies

- Perform engineering-based risk assessments of assets and operations and complete adaptation plans based on these assessments, including financing.
- Protect coastal transportation infrastructure with levees, sea walls and pumping facilities; elevate bridge landings, roads, railroads, airports, and collision fenders on bridge foundations; design innovative gates at subway, rail and road tunnel entrances and ventilation openings.
- Relocate critical systems to higher ground out of future flood zones.
- Lengthen airport runways and expansion joints on bridges; upgrade to energy-efficient air conditioning on trains, subways, and buses; use heat-resistant construction materials for pavements and rail tracks.

Larger-Scale Strategies

- Change standards for engineering specifications related to climate such as for heat-resistant materials and the capacity of drainage systems.
- Form alliances to set performance standards to reduce climate risks; form mutual insurance pools that spread risks.

Co-Benefits

Making improvements to public transportation systems will not only facilitate adaptation, but also enhance energy efficiency and increase ridership, thus helping to reduce greenhouse gas emissions and mitigate climate change.

Particularly Vulnerable Groups

Low-income and elderly populations, especially in urban areas, are particularly vulnerable to disruption to transportation services, limiting their ability to get to work or evacuate during emergencies and extreme weather events.

Transport interruptions take a particular toll on working women, who tend to have less spare time because of child and family care and on average earn less than men.

Workers on hourly payrolls can less afford transportation-related work loss or delays compared to more affluent, salaried employees whose pay does not depend on the number of hours worked.

Lower-income neighborhoods, whether rural, suburban, or urban, generally have already poor transportation options and little or no redundancy. Increases in extreme events will worsen their situation.

Case Study: Sea Level Rise and a 100-Year Coastal Storm—Impacts on New York City Metropolitan Area

Sea level rise in combination with coastal storm surge has the ability to severely damage transportation systems in New York—particularly those in New York City and the surrounding metropolitan region since much of the systems are located at low elevations, and some in tunnels below sea level. By the end of this century, the ClimAID projections show that sea level is expected to rise by 2 to 4 feet with significant implications for the transportation sector.

Damages from a coastal storm in the New York City metropolitan area that currently occurs on average once every 100 years would be significant. At current sea level, economic losses from such a storm would amount to about \$58 billion. Losses under a 2-foot sea level rise scenario increase to \$70 billion and to \$84 billion under a

4-foot sea level rise scenario. All sectors of the transportation system would be affected, including roads, railways, subways, airports, and seaports.

The effects of such a flooding scenario would occur rapidly. A 100-year flood with a 4-foot rise in sea level (consistent with the ClimAID rapid-ice-melt scenario projections in the 2080s) would flood a large fraction of Manhattan subways, including virtually all of the tunnels crossing into the Bronx beneath the Harlem River and the tunnels under the East River. Many of the tunnels lying below flood heights (including subway, highway, and rail) would fill up with water in less than 1 hour. At the low-lying La Guardia airport, sea level rise would wipe out the effectiveness of existing levees, even for less severe storms. The outage times estimated for the various transportation systems range from 1 to 29 days, depending on the infrastructure and sea level rise scenario. More detailed engineering-based vulnerability assessments are needed to improve these preliminary estimates.

The social and economic effects of a 100-year storm would not be distributed evenly. People with limited mobility and transportation options would be affected the most, including low-income households, the disabled, and the elderly. These populations also may be less likely to access relief from centralized facilities located beyond walking distance.

To protect against the impacts of a 100-year storm, sea walls, floodgates, and pumping stations could be constructed in the short term. In the long term, transportation infrastructure could be relocated to higher elevation areas, outside of the future floodplain, and some tunnel structures could be outfitted with engineered flood protection. The sustainability of a proposed barrier system to protect the entire New York harbor has not been established and requires careful cost/benefit assessments of long-term risks and of exit strategies when prolonged sea level rise combined with coastal storm surge begins to exceed the finite design elevations of any such barrier system.

Annualized losses from the expected climate hazards for the entire metropolitan transportation systems are estimated in the hundreds of millions of dollars per year now, increasing to billions of dollars per year by mid-century. Required annual capital costs to make the transportation systems resilient to climate hazards in this coastal setting are on the order of one quarter of the expected losses that are estimated to occur if no protective adaptation measures were undertaken. Therefore preventive measures are likely to be highly cost-effective, but require engineering assessments, and must be in place before irreparable flood damage occurs. This will require capital investments.

Telecommunications Sector

Context

Telecommunications infrastructure is vital to New York State's economy and welfare; its capacity and reliability are essential to the effective functioning of emergency services as well as global commerce and the state's economy.

The sector is largely privately operated, but it has important public functions.

Because of rapidly changing telecommunications technology and deregulated, fiercely competitive markets, some operators often focus on short-term market share and profitability rather than pursuing long-term strategies to achieve reliability and redundancy.

Under current climate conditions and severe weather events, there are already serious vulnerabilities that in many instances prevent the telecommunications sector from delivering services to the public. If the sector could be made more resilient to the current climate, then the incremental threat from climate change is likely to be more manageable.

The sector is tightly coupled to the energy sector, with power outages affecting the reliability of communication services; many of its communication lines also are located on the same poles as power lines. During the December 2008 ice storm, some counties in the Capital region experienced power outages of between 10,000 and 15,000 customers, which likely had significant impacts on telecommunications services.

Modern digital technologies, including telecommunication services based on fiber optics, broadband, and the Internet, can be more vulnerable to power outages than traditional landline technology that was - or in some places still is - self-powered.

Wireless mobile phone services and landlines often share the same backbone network. In these instances, redundancy is essential to avoid simultaneous breakdowns.

Reports of service outages to federal or state regulators are not accessible to the public and are not uniformly mandatory across the different types of services.

During the 1998 ice storm, the number of emergency radio calls per day and blocked radio calls due to overload increased dramatically. In one New York state county, the normal daily background call traffic reached a maximum of less than 2,000 calls. During the days following the storm, the number of calls peaked at over 40,000 calls in one day, with over 8,000 calls blocked that same day due to overload.

Key Climate Impacts

Communication service delivery is vulnerable to hurricanes, lightning, ice, snow, and wind storms, and other extreme weather events, some of which are projected to change in frequency and/or intensity.

The delivery of telecommunication services is sensitive to power outages, such as those resulting from the increased demand associated with heat waves, which are expected to increase with climate change. The number of electric grid disruptions caused by extreme weather has increased ten-fold since 1992. The fraction of all grid disturbances caused by weather-related phenomena has more than tripled from about 20 percent in the early 1990s to about 65 percent in recent years. While there is no definite cause-and-effect relationship between climate change and grid disruptions, it does suggest that weather and climate extremes have important effects on grid disruptions. Projections of future increases in extreme events suggest increased risks for the electric grid and the telecommunications that depend on it.

Communication lines and other infrastructure are vulnerable to heavy precipitation events, flooding, and/or freezing rain.

In coastal and near-coastal areas, sea level rise in combination with coastal storm surge flooding will be a considerable threat later this century.

Adaptation Options

Changes to telecommunications infrastructure to make it more robust, resilient, and redundant will reduce future climate-related outages.

Operations, Management, and Infrastructure Strategies

- Trim trees near communication lines; place communication cables underground where technically and economically feasible.
- Provide backup power at cell towers with generators, solar-powered battery banks, and “cells on wheels” that can replace disabled towers.
- Extend the fuel storage capacity to run back-up generators for extended times.
- Relocate central communications offices out of future floodplains.
- Improve backup cell phone charging options by standardizing charging interfaces, including for car chargers, which allow any phone to be recharged by any charger.
- Assess, develop, and expand alternative communication technologies to increase redundancy and/or reliability.

Larger-Scale Strategies

- Reassess industry performance standards combined with appropriate, more uniform regulation across all types of telecommunication services. Provide better enforcement of regulations, including uniform mandatory reporting of outages.
- Develop high-speed broadband and wireless services in low population-density rural areas.
- Diversify communication media by separating cable and phone services and increasing the use of internet-based telephone services.
- Decouple telecommunications infrastructure from electric grid infrastructure to the extent possible.

Co-benefits

Increasing redundancy and reliability in the telecommunications sector will reduce outages not only from a changing climate, but also from other non-climate related risks. Improving telecommunications technology reliability will also help to reduce greenhouse gas emissions from travel.

Particularly Vulnerable Groups

Customers in rural, remote areas are more vulnerable to service disruptions than customers in urban areas, because they have fewer backup service options and often lack wireless and broadband services.

Restoration of communication services following a storm typically happens first in urban areas and then in rural areas, with smaller, remote communities likely to be restored last; this places people in rural areas at increased risk during emergencies.

Within remote, rural areas, elderly, disabled, and health-compromised populations are especially vulnerable to communication service disruptions associated with storm events due to their more limited mobility.

Lower-income populations are more likely to drop landline services; this increases their risk during emergency situations, as a result of their more limited communication options.

Case Study: Winter Storm in Central, Western and Northern New York—Vulnerability of Telecommunication Services

Severe winter storms in New York generally follow this pattern: a low-pressure system moves up the Atlantic Coast bringing warm moist air that encounters cold dry air in a high-pressure system over Canada and extends into the northern parts of New York. The northward movement of the counterclockwise-rotating storm system causes warm air to overrun the cold air mass. This typically forms three moving bands of precipitation oriented southwest to northeast; precipitation falls as snow in the northernmost band, ice in the middle band, and rain in the southernmost band.

It is uncertain how climate change will influence extreme winter storms. A hypothetical composite of historical extreme winter storms is described. While the three types of precipitation (rain, freezing rain, and snow) would

not necessarily be expected to occur concurrently in these proportions, each of these types of extreme winter precipitation is currently expected to occur on average at least once per century.

- Up to 8 inches of rain fall in the rain band in near-coastal New York over a period of 36 hours.
- Up to 4 inches of freezing rain falls in the ice band in central New York, of which between 1 and 2 inches accumulates as ice, over a period of 24 hours.
- Up to 2 feet of snow accumulates in the snow band in northern and western New York over a period of 48 hours.

A storm of this magnitude could result in widespread power and communication outages, with most people who lose electricity also losing communication services. In the Central New York ice storm area, about a half million people would be without power. It would take up to 10 days to restore power to half of these customers living in the larger cities such as Albany, Binghamton, and Schenectady, and up to five weeks to fully restore services to those living in remote, rural areas. Fewer people would be affected in the western and northern New York snow accumulation area. There services may be restored more quickly, first in cities and progressing to rural areas.

Economic damages from productivity losses alone would amount to about 900 million dollars. Costs associated with direct damages - such as spoiled food, damaged orchards, replacement of downed poles and electric and phone wires, medical costs and emergency shelter expenses - would be of a similar magnitude. In total, productivity and direct damage costs would amount to about \$2 billion. These numbers, however, likely underestimate the total costs, given that a 1998 ice storm resulted in losses of about \$5.4 billion in Canada alone.

Those most vulnerable to power and communication service disruptions are those that are unable to leave their homes (those with limited transportation options) and those who lack access to cell phones, including elderly, low-income, disabled, and rural populations.

To protect against communication and power outages, trees near power and communication lines can be trimmed, backup poles and wires can be stocked to replace those that are damaged, and readiness of emergency crews to assist with restoration can be arranged in advance of storms. Increasing the fuel supply to extend the duration of emergency backup power at mobile phone cell towers with difficult road access is especially important in areas with low landline, broadband, and internet penetration.

Public Health Sector

Context

New York State relies primarily on a county-based system for public health service delivery, resulting in a decentralized system in which core services are not provided uniformly.

Information and the capacity to integrate climate change into public health planning remains limited at the local level.

Cardiovascular disease is the leading cause of death in the state and is made worse by extreme heat and poor air quality.

Childhood asthma is an important current health challenge in many parts of New York State, especially in the five counties that comprise New York City, and is made worse by poor air quality.

New York State has experienced the emergence of several vector-borne diseases (those spread by carriers such as mosquitoes and ticks) in the past few decades.

Asthma

Asthma is climate-sensitive, as it is exacerbated by allergies and air pollution, both of which are related to climate. Childhood asthma is an important current health challenge in many parts of New York State, with many asthma events severe enough to require hospitalization. Children from lower-income families who often lack health insurance, regular doctor visits, and medications that can control attacks are more likely to have to seek hospital treatment.

The number of adults with physician-diagnosed asthma in New York State increased by about 2-3% between 1996 and 2006. This trend is expected to continue given ClimAID projections of rising temperatures and carbon dioxide because asthma is exacerbated by pollen and ground-level ozone. Pollen production increases under high atmospheric carbon dioxide levels, and ozone tends to increase with higher temperatures.

Urban Heat Island Effect

Large amounts of concrete and asphalt in cities absorb and hold heat. Tall buildings prevent heat from dissipating and reduce air flow. At the same time, there is generally little vegetation to provide shade and evaporative cooling. As a result, parts of cities can be up to 10°F warmer than the surrounding rural areas, compounding the temperature increases that people experience as a result of human-induced warming. Even suburban residential areas can be up to 3°F warmer than the nearby rural land. Park land within urban areas can be up to 6°F cooler, helping to lessen the heat island effect.

Key Climate Impacts

Demand for health services and the need for public health surveillance and monitoring will increase as climate continues to change.

Heat-related illness and death are projected to increase, while cold-related death is projected to decrease. Increases in heat-related death are projected to outweigh reductions in cold-related death. A preliminary study of all of these temperature-related deaths from 2010 to 2100 in New York County was undertaken using 5 climate models from the set of ClimAID models under lower (B1) and higher (A2) emissions scenarios. The results suggest that increases in heat-related deaths will outweigh reductions in cold-related deaths, resulting in a net increase in deaths due to climate change. The lower-emission scenario (B1) is projected to result in substantially fewer deaths by the 2080s. The chart shows the results from 5 models for the higher (A2) emissions scenario. These results are broadly consistent with the other global climate models used in ClimAID.

More intense precipitation and flooding along the coasts and rivers could lead to increased stress and mental health impacts, impaired ability to deliver public health and medical services, increased respiratory diseases such as asthma, and increased outbreaks of gastrointestinal diseases.

Cardiovascular and respiratory-related illness and death will be affected by worsening air quality, including more smog, wildfires, pollens, and molds.

Vector-borne diseases, such as those spread by mosquitoes and ticks (like West Nile virus), may expand or their distribution patterns may change.

Water supply, recreational water quality, and food production will be at increased risk due to increased temperatures and changing precipitation patterns.

Water- and food-borne diseases are likely to increase without adaptation intervention.

Adaptation Options

Enhanced capacity will be needed to integrate climate adaptation strategies into existing health programs.

Operations, Management, and Infrastructure Strategies

- Extend surveillance of climate and health indicators, including a statewide network of publicly available data monitoring airborne pollen and mold.
- Evaluate extreme heat response plans, focusing particularly on expanding access to cooling services during heat events. Build on this knowledge to develop similar systems for other climate health risks. Target strategies and messages for the most vulnerable populations.
- Plant low-pollen trees in cities to reduce heat without increasing allergenic pollen.

Larger-Scale Strategies

- Environment and health initiatives should be better integrated so that they address both human and ecosystem health and avoid the divide that often exists between them.

Co-Benefits

Adaptation strategies which maximize co-benefits, such as cleaner air, improved nutrition or increased physical activity, should be given priority. Investing in structural adaptations to reduce heat vulnerability, including tree planting, green roofs, and high-reflectivity building materials, will help to reduce energy demand and expense while reducing heat-related risks.

Steps to Developing Successful Adaptation Strategies in the Public Health Sector

- Assessment
 - Monitor health
 - Diagnose and investigate
- Policy Development
 - Inform, education, empower
 - Mobilize community partnerships
 - Develop policies
- Assurance
 - Enforce laws
 - Link to/provide care
 - Assure competent workforce
 - Evaluate

These steps form a continuous cycle of assessment and development. System management and research should be ongoing throughout the process.

Particularly Vulnerable Groups

Without intervention, existing health disparities are likely to be exacerbated by climate change.

Age, preexisting illness, neighborhood infrastructure and/or poverty put people at elevated risk.

In urban areas, the elderly, persons with impaired immune systems, children, and poor are at particular risk for heat-related illness and death.

People in northern parts of the state who are not accustomed to extreme heat are at particular risk for heat-related death.

People with asthma are particularly vulnerable to ozone and fine-particle air pollution, which could lead to increased illness and death.

Low-income individuals are more likely to go to the hospital for asthma attacks than wealthier individuals with health insurance who are under doctor supervision and have access to asthma control medications.

Children, outdoor laborers, and athletes also may be at greater risk for respiratory diseases than those who spend more time indoors and are less active.

Residents of coastal areas are vulnerable to direct impacts of storm surge flooding, mental health stressors related to evacuation, and mold and toxic exposures when they return home.

Case Study: Heat and Respiratory Problems Affect Those Most Vulnerable

Certain groups—including the elderly, low-income populations, and minorities—are more vulnerable than others to climate change-related health risks including heat-related illness and death, and decreased respiratory function.

Summer heat waves have caused increased death in cities across the United States—including in New York City. Climate change will increase the frequency and intensity of heat waves. Urban areas are especially vulnerable because of the high concentrations of susceptible populations and the influence of the urban heat island effect, which makes cities hotter than surrounding areas. Health-relevant increases in heat waves are likely to occur within 20 to 30 years, with much larger increases 50 to 100 years from now. Heat related deaths are projected to increase significantly as a result.

Home air conditioning is a critical factor for preventing heat-related illness and death. Air conditioning is especially important for elderly, very young, and health-compromised individuals, all of whom have a lower internal capacity to regulate body temperature. In New York City, about 84 percent of households had air conditioning in 2003. But, such resources are not distributed evenly across the city. Many residents living in lower income neighborhoods lack air conditioning and are thus more vulnerable to extreme heat events. Others, including low-income elderly residents—particularly those living alone—may be reluctant to use air conditioning even if they have it due to concerns about energy costs, even during periods of extreme heat. However, air conditioning is highly vulnerable to power outages, pointing to the need for longer-term strategies to reduce heat vulnerability.

The health effects of extreme heat events can be reduced through adaptation measures. Warning systems and outreach can be used in conjunction with providing more access to public places with air conditioning, such as offering longer hours at community centers for seniors and reducing fares on public transportation. Long-term, engineering-based strategies also can be undertaken, including tree planting, installing green or reflective roofing and insulation in public housing to reduce indoor air temperatures.

Respiratory illness and death also are likely to increase with climate change. Rising temperatures and increasing emissions will result in more air pollution, with summer ozone levels likely to increase significantly. Ozone can increase the risk of asthma-related hospital visits and death. Already, many New Yorkers live in areas in which ozone levels do not meet health standards.

African Americans and Hispanics are particularly vulnerable to decreased air quality because they tend to live in urban centers where they are more exposed to air pollutants. As a group, they are significantly more likely to be hospitalized and die from asthma than other population groups. Children, outdoor laborers, and athletes also may be at greater risk of air pollution exposure than those who spend more time indoors and are less active.

Another probable impact of climate change is increased levels of mold and other allergens that contribute to respiratory health problems. Dampness of households, a key variable for mold growth, is associated with

socioeconomic status, and could intensify with projected precipitation increases. Mold may contribute to the high rates of hospitalization for asthma among African Americans in cities such as New York.

Conclusions

New York State is highly diverse, with simultaneous and intersecting challenges and opportunities. Among them, climate change will affect the people, sectors and regions of the state in the coming decades. Those that are already facing significant stress will likely be most at risk from future climate change. The success of the state's response will depend on developing effective adaptation strategies by connecting climate change with ongoing proactive policy and management initiatives. Climate change will bring opportunities as well as constraints, and interactions of climate change with other stresses, such as increased resource demand, will create new challenges.

The risks associated with sea level rise and coastal flooding are among the greatest climate-related challenges faced by New York State, affecting public health and ecosystems as well as critical infrastructure across many sectors including water, energy, transportation, and communication. Heat waves and heavy downpours will also affect many people and sectors. These and other drivers of climate change impacts will have a wide variety of effects that will require a range of adaptation strategies that can help reduce these impacts in the future. Such adaptation strategies are also likely to produce benefits today, since they will help to lessen impacts of climate extremes that currently cause damages. Examples of adaptation strategies in each sector have appeared throughout this report.

There is a range of adaptation needs, many of which can be undertaken in the near-term at relatively modest cost. And there are some infrastructure investments – especially relating to transportation and coastal zones – that are likely to be needed in the long-term and that would be expensive (though less expensive than the costs incurred in the absence of such measures). This suggests the need for increased and on-going interaction between scientists and policy-makers to ensure that science better informs policy, as well as the need for increased scientific and technical capabilities to be brought to bear on adaptations that involve the developing infrastructure of New York State.

Summary of Observed Climate Changes

- Annual average temperatures in New York State have risen about 2.4°F since 1970, with winter warming exceeding 4.4°F.
- Sea level along New York's coastline has risen about one foot since 1900.
- Since 1900, there has been no discernible trend in annual average precipitation for the state as a whole.
- Intense precipitation events (heavy downpours) have increased in recent decades.

Summary of Projected Changes

- Climate models with a range of greenhouse gas emissions scenarios suggest temperature increases across New York State of between 1.5 to 3°F in the 2020s, 3 to 5.5°F in the 2050s, and 4 to 9°F in the 2080s.
- Most climate models project a small increase in annual precipitation. Variability is expected to continue to be large. Projected precipitation increases are largest in winter, mainly as rain, and small decreases may occur in late summer/early fall.
- Sea level rise projections for the coast and tidal Hudson River based on IPCC methods (which do not include increased melting of polar ice sheets), are 1-5 inches by the 2020s, 5-12 inches by the 2050s, and 8-23 inches by the 2080s.
- If the melting of the Greenland and West Antarctic Ice Sheets continues to accelerate, sea level rise would exceed projections based on IPCC methods. A rapid ice melt scenario, based on observed rates of melting and paleoclimate records, yields sea level rise of 37-55 inches by the 2080s.
- Extreme heat events are very likely to increase, and extreme cold events are very likely to decrease throughout New York State.
- Intense precipitation events (heavy downpours) are likely to increase. Short-duration warm season droughts are projected to become more common.
- Coastal flooding associated with sea level rise is very likely to increase. Areas not subject to coastal flooding now could become so in the future.

Recommendations

The ClimAID process has yielded some general recommendations for potential actions that can be taken by policy-makers, managers, and researchers. These recommendations can help make New York State more resilient to current and future climate risk by bringing cutting-edge knowledge and data to groups of empowered and collaborating decision-makers.

Recommendations Aimed at Statewide Decision-Makers

- Promote adaptation strategies that enable incremental and flexible adaptations in sectors, amongst communities, and across time.
- Identify synergies between mitigation and adaptation. Taking steps to mitigate climate change now will reduce vulnerabilities, increase resilience, and enhance opportunities across all sectors. At the same time, some potential adaptation strategies present significant mitigation opportunities while others work against mitigation.
- Improve public and private stakeholder and general public education and awareness about all aspects of climate change. This could encourage the formation of new partnerships for developing climate change adaptations, especially given limited financial and human resources, and advantage of shared knowledge.
- Analyze and address environmental justice issues related to climate change and adaptation on a regular basis.
- Consider regional, federal and international climate-related approaches when exploring climate adaptation options. This is crucial because it is clear that New York State adaptation potential (and mitigation potential as well) will be affected by national and international policies and regulations as well as state-level policies.

Management Recommendations Associated with Everyday Operations within Stakeholder Agencies and Organizations

- Integrate adaptation responses into the everyday practices of organizations and agencies, with the potential for complimentary effects or unintended consequences of adaptation strategies taken into account.
- Evaluate design and performance standards and policy regulations based on up-to-date climate projections.
- Take climate change into account within organizational planning and development efforts.
- Identify opportunities for partnerships among organizations and agencies within the state and region.
- Create standardized, statewide climate change mitigation and adaptation decision tools for decision-makers, including a central database of climate risk and adaptation information for the state that is the result of an ongoing partnership between scientists and stakeholders.

Recommendations for Science and Research

- Refine climate change scenarios for New York State on an on-going basis as new climate models and downscaled products become available.
- Conduct targeted impacts research in conjunction with local, state, and regional stakeholders.
- Implement and institutionalize an indicators and monitoring program focused on climate, impacts, and adaptation strategies.
- Improve mapping and spatial analysis to help present new impact data and adaptation strategies.
- Focus studies on specific systems that may be subject to nonlinearities or “tipping points.” Work should be encouraged to understand the potential for tipping points associated with climate change impacts on natural and social systems.
- Research climate variability, extreme events, and other stakeholder-identified variables of interest including ice storms, extreme precipitation events, and wind patterns.

- Build on economic cost and benefit work to create a better understanding of the costs of climate change and benefits of adaptations on a sector by sector basis.

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