Chapter 12

Conclusions and Recommendations

Contents

Climate Change and New York State

Adapting to a changing climate is challenging in New York State due to its diverse nature geographically, economically, and socially. The main drivers of climate change impacts—higher temperature, sea level rise and its potential to increase coastal flooding, and changes in precipitation—will have a wide variety of effects on the sectors and regions across the state and will engender a wide range of adaptation strategies. Climate change will bring opportunities as well as constraints, and interactions of climate change with other stresses, such as population growth, will create new challenges.

While New York State ranks 27th among the states in area (54,556 square miles, including 7,342 square miles of inland water), it is subject to a much wider range of climate impacts than its size in square miles would suggest. The north-to-south distance from the Canadian border to the tip of Staten Island is over 300 miles; from east to west (from the longitude of the eastern tip of Long Island to the longitude of the western border of New York State at Lake Erie), the distance is over 400 miles. Further diversity stems from the presence of the densely populated New York City, while much of the state is rural in character. Thus, climate hazards are likely to produce a range of impacts on the rural and urban fabric of New York State in the coming decades.

The adaptation strategies described in the ClimAID Assessment could be useful in preparing for and responding to climate risks now and 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 damage. However, given the scientific uncertainties in projecting future climate change, monitoring of climate and impacts indicators is critical so that flexible adaptation pathways for the region can be achieved over time.

This chapter summarizes the overall conclusions and recommendations of the ClimAID assessment. They focus on the five integrating themes (climate, vulnerability, adaptation, equity and environmental justice, and economics) and the eight sectors (Water Resources, Coastal Zones, Ecosystems, Agriculture, Energy, Transportation, Telecommunications, and Public Health). The conclusions and recommendations highlight sectoral, geographical, and temporal dimensions in responding to the risks posted by climate change in New York State.

Integrating Themes

This section highlights the conclusions focused on the five integrating themes.

Climate

The humid continental climate of New York State varies from warmer to cooler and from wetter to dryer regions. The weather that New York State has experienced historically provides a context for assessing climate changes that are projected for the rest of the century. The ClimAID Assessment found that much of the state is already warming and that projected climate changes in temperature and other variables could bring significant impacts.

Observed Climate Trends

Observed climate trends include the following:

- Annual temperatures have been rising throughout the state since the start of the 20th century. State-average temperatures have increased by approximately 0.6°F per decade since 1970, with winter warming exceeding 1.1°F per decade.
- Since 1900, there has been no discernable trend in annual precipitation, which is characterized by large interannual and interdecadal variability.
- Sea level along New York's coastline has risen by approximately 1 foot since 1900.
- Intense precipitation events (heavy downpours) have increased in recent decades.

As a whole, New York State has experienced a significant warming trend over the past three to four decades. Sea level along New York's coastline has increased approximately 12 inches over the past century. Given these trends and projections of future changes, past climate will likely be a less consistent predictor of future climate, and, in turn, reliance on past climate records may not suffice as benchmarks for forecasting.

Climate Projections

In regard to projections, climate change is extremely likely to bring higher temperatures to New York State, with slightly larger increases in the north of the state than along the coastal plain (See **Table 12.1** for definitions of likelihood used in the ClimAID Assessment). Heat waves are very likely to become more frequent, more intense, and longer in duration.

Total annual precipitation will more likely than not increase, likely occurring as more frequent intense rainstorms. Summer droughts could increase in frequency, intensity, and duration, especially as the century progresses. Meanwhile, there will likely be a reduction in snowpack and an increase in the length of the growing season.

Additionally, rising sea levels are extremely likely and are very likely to lead to more frequent and damaging flooding along the shores and estuaries of New York State related to coastal storm events in the future.

However, significant uncertainties exist about future climate risks due to difficulties in projecting greenhouse gas emissions and imprecise understanding of climate sensitivity to greenhouse gas forcing, among other factors.

Projected changes in mean climate

Projections of mean climate changes include the following:

- Mean temperature increase is extremely likely this century. Downscaled results from global climate models with a range of greenhouse gas emissions scenarios indicate that temperatures across New York State[1] may increase 1.5–3.0°F by the 2020s,[2] 3.0–5.5°F by the 2050s, and 4.0–9.0°F by the 2080s.

Likelihood	Probability of occurrence
Extremely likely	>95% probability of occurrence
Very likely	>90% probability of occurrence
Likely	>66% probability of occurrence
More likely than not	>50% probability of occurrence

Table 12.1 Likelihood and probability of occurrence

- While most downscaled results for New York State from global climate models project a small increase in annual precipitation, interannual and interdecadal variability are expected to continue to be large. Projected precipitation increases are largest in winter, and small decreases may occur in late summer/early fall.
- Rising sea levels are extremely likely this century. Sea level rise projections for the coast and tidal Hudson River, based on GCM-based methods, are 1–5 inches by the 2020s, 5–12 inches by the 2050s, and 8–23 inches by the 2080s.
- There is a possibility that sea level rise may exceed projections based on GCM-based methods, if the melting of the Greenland and West Antarctic Ice Sheets continues to accelerate. 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.

Changes in climate variability and extreme events

Climate variability refers to temporal fluctuations about the mean at daily, seasonal, annual, and decadal timescales. The quantitative projection methods in the ClimAID Assessment generally assume climate variability will remain unchanged as long-term average conditions shift. As a result of changing long-term averages alone, some types of extreme events are projected to become more frequent, longer, and intense (e.g., heat events), while events at the other extreme (e.g., cold events) are projected to decrease. Projected changes in extreme climate events include the following:

- Extreme heat events are very likely to increase and extreme cold events are very likely to decrease throughout New York State.
- Intense precipitation events are likely to increase. Short-duration warm season droughts will more likely than not become more common.
- Coastal flooding associated with sea level rise is very likely to increase.

In the case of brief intense rain events (for which only qualitative projections can be provided), both the mean and variability are projected to increase, based on a combination of global and regional climate model

[1] The range of temperature projections is the lowest and highest of values across the middle 67 percent of projections for all regions of New York State.

[2] The temperature and precipitation timeslices reflect a 30-year average centered around the given decade, i.e., the time period for the 2020s is from 2010–2039. For sea level rise, the timeslice represents a 10-year average.

simulations, process-based understanding, and observed trends. Both heavy precipitation events and warm-season droughts (which depend on several climate variables) are projected to become more frequent and intense during this century.

Whether extreme multi-year droughts will become more frequent and intense than at present is a question that is not fully answerable today. Historical observations of large interannual precipitation variability suggest that extreme drought at a variety of timescales will continue to be a risk for the region during the 21st century.

Vulnerability

Impacts associated with climate changes are projected to be felt in a wide range of sectors and regions. How vulnerability is manifested depends on the magnitude of the impacts (e.g., the area or number of people affected) and the intensity (e.g., the degree of damage caused). Timing is also critical: Is the impact expected to happen in the near term or in the distant future? Are rare events becoming more frequent? And are impacts reversible over the timescale of generations? Other key aspects of vulnerability include the potential for adaptation and potential thresholds or trigger points that could exacerbate the change.

Sectoral Dimensions

Climate change impacts will be directly connected with ongoing transitions within the state, such as population growth and economic development. See **Table 12.2** for key sector-related vulnerabilities. Climate change in many cases will alter the functioning of the state's key sectors by causing shifts within its physical and social systems. For example, climate change is already resulting, and will very likely continue to result, in north-to-south shifts in the state's ecoregions. Thus, there is a clear need for ecosystem management approaches that focus on preserving diversity, rather than on protection of individual species.

The impacts of climate change on water and agricultural resources present both potential challenges and opportunities for the state. New York State water managers and farmers will face increased climate variability and potential for times of water stress. Opportunities for the state could emerge vis-à-vis the development of new crops and modes of agricultural production associated with underused agricultural land and potential water supply. For example, in comparison to many other states, New York's current and projected relative wealth of water resources, if properly managed, can contribute to resilience and new economic opportunities. Opportunities to explore new varieties, new crops, and new markets may come with higher temperatures and longer growing seasons.

The energy and public health sectors also will experience shifts in climate risks. In both cases, sector managers will likely face greater climate variability and system stress from more frequent and intense extreme events such as heat waves. The shifts in climate will both exacerbate existing risks and create new risks, such as increased fatigue on equipment and outbreaks of diseases previously not widely seen.

Overall, the climate risk associated with sea level rise is a key pressing impact for the state in terms of dollars associated with both impacts and adaptation. Its impacts will cut across many sectors, from ecosystems to critical infrastructure (e.g., for water, energy, transportation, and communication) and public health. More frequent extreme events such as heat waves and heavy downpours, as well as gradual climate shifts, will increase the amount of climate risk faced by critical transportation and telecommunication infrastructure throughout the state.

Geographic Dimensions

Climate change impacts will be felt across the entire state. Coastal zone communities, populations, and ecosystems face significant risks and potential damages from sea level rise and enhanced coastal flooding. A critical task is the determination of the shift in the extent of the 1-in-100-year flood zones (those areas designated as having a 1 percent probability of flooding any given year) and associated uncertainties.

Natural resource- and agriculture-dependent communities in rural areas will face both significant challenges and potential opportunities. Riverine communities may face increased risk of flooding from extreme rainfall events. Communities dependent on small-scale water supply systems may face water supply management issues. In urban areas, poor communities—especially in flood zones and in areas lacking in vegetation—may be less able to cope with extreme rainfall events.

Temporal Dimensions

Climate change already has begun in New York State. If greenhouse gas emissions continue unabated, the rate and magnitude of climate change are expected to increase over time. Establishing an ongoing monitoring system and strengthening climate science capabilities will provide enhanced opportunities for understanding and responding to future climate change.

Climate-change-related extreme events and system-level shifts could occur at any time. The risk of extreme events associated with high temperatures and intense precipitation events will likely increase, while intense cold waves will likely decrease. Natural and human systems in the state are thus subject to a variety of gradual and rapid transitions related to climate.

Table 12.2 Sector-specific Climate Change Vulnerability

Water Resources							
Main Climate Variable	Specific Climate Variable	Probability of Specific Climate Variable	Climate Variable Notes	Impact on Resource	Likelihood of Impact	Consequence without Adaptation	Magnitude of Consequence*
Infrastructure							
Precipitation	Increase in mean precipitation	More likely than not	N/A	New maximum potential stream flow/flooding in large basins	Uncertain	Increase in the number of moderate floods	Medium
				Urbanized watersheds rapidly aggregate water and have a limited capacity to attenuate rainfall inputs	Medium	Increase in the number of flash floods	High
				Increased flooding of wastewater treatment plants	Low	Routine interruption of operations for an extended time period	High
Sea Level Rise	Sea level rise	Very likely	N/A	Flooding of coastal water infrastructure, including wastewater treatment plants	Medium	Temporary or permanent disruption of service	High
Drinking Water Supply							
Temperature	Increase in mean temperature	Very likely	Increase in mean temperatures may be greater 1) in the north than south, and 2) in winter than in summer in the north	Increased demand	Low	Increased strain on system	Low
	Increase in extreme heat events	Likely	N/A				
Temperature / Precipitation	Drought	Uncertain	Toward the end of the century, warm season droughts will more likely than not increase	Changes in groundwater depths	High	Increased possibility of well depletion	High
				Seasonal variation in reservoir inflow and aquifer recharge	High	Decreased reliability of historical levels for planning	High
				Low wells, wells in moderately productive aquifers, and small reservoirs	Medium	These areas will have to tap into larger reservoir systems, increasing overall strain on systems	High
Precipitation	Increase in mean precipitation	More likely than not	N/A	Increased turbidity of water supply reservoirs	Medium	Decreased quality of water supplies (also see water quality section)	High
Commercial and Agriculture Water Availability							
Temperature	Increase in mean temperature	Very likely	Increase in mean temperatures may be greater 1) in the north than south, and 2) in winter than in summer in the north	Increased demand for crops and livestock and for cooling commercial infrastructure systems	Low	Increased strain on system	Low
	Increase in extreme heat events	Likely	N/A				
Temperature / Precipitation	Drought	Uncertain	Towards the end of the century, warm season droughts will more likely than not increase	Greater competition for water between potable, commercial uses, and ecological needs	Medium	Lessened dependence on hydroelectricity as an energy supply	Medium
				Decrease in availability of water resources for equipment cooling	High	Facilities turn to low-consumption, "once-through" cooling where water is returned to the same water body at a higher temperature, influencing aquatic organisms	Medium
				Increased consumption due to natural gas drilling in deep shales	Low	Withdrawals will not be spread uniformly across a basin and intensive withdrawals from smaller headwater streams may lead to localized low flows	Medium
Precipitation	Increase in mean precipitation	More likely than not	N/A	Increased turbidity of water supply reservoirs	Medium	Decreased quality of water supplies (also see water quality section)	High

Water Resources (continued)

Main Climate Variable	Specific Climate Variable	Probability of Specific Climate Variable	Climate Variable Notes	Impact on Resource	Likelihood of Impact	Consequence without Adaptation	Magnitude of Consequence*
Water Quality							
Temperature	Increase in mean annual temperature	Very likely	Increase in mean temperatures may be greater 1) in the north than south, and 2) in winter than in summer in the north	Favorable corn-based ethanol production	Medium	May lead to increased agricultural land use in NYS	Medium
				Greater pathogen survivability in waters	High	Increased potential for disease in aquatic life	High
				Increased algal growth in water bodies as well as increased dissolved organic matter exported from soils and wetlands	High	Impairs recreational use and normal ecosystem function; increased organic matter may increase the concentration of disinfection by-products (DBP) in drinking water (potentially harmful chemicals that form when chlorine added to kill pathogens reacts with organic matter)	High
	Increase in water temperature of streams and rivers	Likely/ very likely	Depends on many factors besides air temperature, such as precipitation, water demand, and land cover	Warmer water holds less dissolved oxygen (DO), so warmer waters will increase strain on streams that already experience oxygen depletion	Medium	High DO levels are detrimental to aquatic organisms	Medium
Precipitation	Increase in mean annual precipitation	More likely than not	N/A	Expanded agriculture in water-rich areas	Medium	Increased nutrient (nitrogen and phosphorus) loading, which leads to degraded water quality and ecosystem health	Medium
	Increase in extreme precipitation events	More likely than not	N/A	Increased runoff and reduced infiltration of rain into natural ground cover and soils	High	Greater potential for CSOs	High

Notes: N/A = Not Applicable
CSO = Combined sewer overflow
* Factors that are considered when determining the magnitude of consequence, defined as the combined impact of the occurrence should a given hazard occur, include: effects on internal operations, capital and operating costs, public health, the economy, and the environment, as well as the number of people affected. (see Annex II to the full report, “Adaptation Guidebook”)

Coastal Zones

Main Climate Variable	Specific Climate Variable	Probability of Specific Climate Variable	Climate Variable Notes	Impact on Resource	Likelihood of Impact	Consequence without Adaptation	Magnitude of Con-sequence*
Infrastructure and Coastal Property							
Sea level rise	Permanent inundation of coastal areas	N/A	By 2050, only a small increase in the area permanently inundated is expected	Entrances to bridges, tunnels, segments of highways, wastewater treatment plants, and sewer outfall systems permanently under sea water	High	Failure of systems	High
				Coastal properties permanently under sea water	High	Abandonment of waterfront structures and residences (ground floor or potentially altogether)	Medium
				Increase in salinity of influent into wastewater pollution control plants	Medium	Corrosion of materials and equipment, failure of systems	High
	Increased frequency, intensity, and duration of storm surge and coastal flooding	Likely/very likely	Will depend both on sea level rise and on uncertain changes in tropical cyclones and nor'easters	Coastal property damage	High	Potential loss of life	High
						Economic impact	High
						Complications to evacuation routes	Medium
				Increased wear and tear on equipment not designed for salt-water exposure	Medium	Failure of systems	Medium
						More frequent delays and service interruptions on public transportation and low-lying highways	Medium
Ecosystems							
Temperature	Warmer coastal sea surface temperatures	Likely	N/A	Heightened disease, harmful algae blooms, and increased competition over resources	High	Ecosystem vulnerability	Medium
				Northward shift in range of habitat for many commercially important fish and shellfish species	High	Decline in fishing industry	High
Precipitation	Increased mean precipitation	More likely than not	N/A	Affect rates of groundwater recharge lake levels	Medium	Potential shortages of drinking water availability	High
				Increased or reduced stream flow	Medium	Affect the delivery of nutrients and pollutants to coastal waters potentially leading to poorer water quality	Medium
Sea level rise	Permanent inundation of coastal areas	N/A	By 2050, only a small increase in the area permanently inundated is expected	Permanent inundation of wetlands	High	Loss of critical wetland habitat	High
	Increased storm surge and coastal flooding	Likely/very likely	Will depend both on sea level rise and on uncertain changes in tropical cyclones and nor'easters	Increased beach erosion	High	Barrier migrations and loss of barrier islands resulting in exposure of the bay and mainland shoreline to more oceanic conditions	High
	Increased wave action	Likely	Will depend both on sea level rise and on uncertain changes in tropical cyclones and nor'easters	Erosion and reshaping of shorelines	Medium	Affect the location and extent of storm surge inundation	High

Notes: N/A = Not Applicable
* Factors that are considered when determining the magnitude of consequence, defined as the combined impact of the occurrence should a given hazard occur, include: effects on internal operations, capital and operating costs, public health, the economy, and the environment, as well as the number of people affected. (see Annex II to the full report, "Adaptation Guidebook")

Ecosystems							
Main Climate Variable	Specific Climate Variable	Probability of Specific Climate Variable	Climate Variable Notes	Impact on Resource	Likelihood of Impact	Consequence without Adaptation	Magnitude of Consequence*
Plants							
Temperature	Increase in mean annual temperature	Very likely	Increase in mean temperatures may be greater 1) in the north than south, and 2) in winter than in summer in the north	Potential increase in plant growth with large differences between species	Medium	Altered plant community structure and potential for invasives	Low
	Warmer winters	Very likely	N/A	Longer growing season	Medium	Shift in ecosystems	High
				Earlier blooming of perennials	High	Potential to throw off symbiotic relationships	High
				Potential changes in sap flow	Medium	Negative effects on maple syrup production requiring some regions to increasingly rely on more expensive technology	High
Animals and Insects							
Temperature	Increase in mean annual temperature	Very likely	Increase in mean temperatures may be greater 1) in the north than south, and 2) in winter than in summer in the north	Insects see more generations per season	Medium	Rate of invasive and pest species rises	High
	Warming waters	Likely/very likely	Depends on air temperature, precipitation, water demand, and land cover	Decline in coldwater fish species such as brook trout and other native species	High	Changes in coldwater ecosystems	High
						Decline in fishing industry for coldwater species	Medium
	Warmer winters	Very likely	N/A	Northward shift in range of many species, including undesirable pests, diseases and vectors of disease, invasives	High	Changes in ecosystems, decline of native species	High
				Increased winter survival of deer populations	High	Increasing deer inflicted damage to plants	Medium
				Increased survival of marginally over-wintering insect pests	Medium	Increased pest threat to ecosystems	Medium
				Earlier arrival of migratory birds	High	Potential to throw off symbiotic relationships	High
	Reduction in snow cover	Unknown	Earlier snowmelt is likely/ very likely	Negative effects on survival of animals and insects who depend on snow for insulation and protective habitat	High	Changes in ecosystems, decline of native species	High
				Increased winter deer feeding	High	Increased vegetation damage	Medium
Recreation							
Temperature	Reduction in snow cover	Unknown	Earlier snowmelt is likely/ very likely	Less natural snow for ski industry	High	Smaller, more southerly or lower altitude ski operations may have more difficulty keeping up with increasing demands on artificial snowmaking capacity	Medium

Notes: N/A = Not Applicable
* Factors that are considered when determining the magnitude of consequence, defined as the combined impact of the occurrence should a given hazard occur, include: effects on internal operations, capital and operating costs, public health, the economy, and the environment, as well as the number of people affected. (see Annex II to the full report, "Adaptation Guidebook")

Agriculture

Main Climate Variable	Specific Climate Variable	Probability of Specific Climate Variable	Climate Variable Notes	Impact on Resource	Likelihood of Impact	Consequence without Adaptation	Magnitude of Consequence*
Crops							
Temperature	Increase in mean temperatures	Very likely	Warming may be greater 1) in the north than south, and 2) in winter than in summer in the north	Longer growing season for certain crops	High	Potentially increased crop yield and may expand market opportunity for some crops, but also prices go down	Medium
						Weeds will grow faster and will have to be controlled for longer periods	Medium
						Increased seasonal water and nutrient requirements	Medium
				Increased weed, disease, and insect pressure	Medium	Lower native crop survival, increase in prices	High
				Increased relative risk of freeze or frost damage and/or reduced winter chill-hour accumulation required for normal spring development	High	Lower survival of perennial fruit crops	High
				Weed species more resistant to herbicides	Low	Change in species composition potentially not favoring native crops	Medium
				Northward expansion of disease range and weeds (plants that have not built immunity to new pathogens are more susceptible to disease and larger populations of pathogens survive to initially infect plants)	High	Lower crop survival	High
				Crop damage due to sudden changes, such as increased freeze damage of woody plants due to loss of winter hardiness or premature leaf-out and frost damage	Medium	Decrease in crop yield	Medium
	Warmer winters	Very likely	N/A	Lengthened growing season	Medium	Could increase productivity or quality of some woody perennials (e.g., European wine grapes)	High
				Not enough freeze days for certain crops	Medium	By mid to late century, negatively affect crops adapted to current climate (e.g., Concord grape, some apple varieties)	Medium
				More winter cover crop options; depending on variability of winter temps, can lead to increased freeze or frost damage of woody perennials	Medium	Decrease in crop yield	Medium
	Increase in extreme heat events	Likely	N/A	Stress on crops, especially if extreme events occur in clusters	Medium to High	Major crop and profit loss	Medium to High
				Heat stress effects	High	Negatively affect yield or quality of many cool-season crops that currently dominate the ag economy, such as apple, potato, cabbage, and other cold crops	High

Notes: N/A = Not Applicable
* Factors that are considered when determining the magnitude of consequence, defined as the combined impact of the occurrence should a given hazard occur, include: effects on internal operations, capital and operating costs, public health, the economy, and the environment, as well as the number of people affected. (see Annex II to the full report, "Adaptation Guidebook")

Agriculture (continued)

Main Climate Variable	Specific Climate Variable	Probability of Specific Climate Variable	Climate Variable Notes	Impact on Resource	Likelihood of Impact	Consequence without Adaptation	Magnitude of Consequence*
Crops (continued)							
Precipitation	Increase in mean precipitation	More likely than not	N/A	Increased flooding resulting in inability to access field during critical times	Medium	Direct crop damage, increased chemical contamination of waterways and harvested crops	Medium
				Increased flooding risk could delay spring planting and harvest	High	Negatively affect market prices; reduction in the high-value early season production of vegetable crops	High
				Increased soil compaction because of tractor use on wet soils	High	Increased vulnerability to future flooding and drought; increasing runoff and erosion; plants have difficulty in compacted soil because the mineral grains are pressed together leaving little space for air and water, which are essential for root growth	High
				Increased crop root disease and anoxia	High	Decrease in crop productivity and yield	High
				Wash-off of applied chemicals	Medium	Decrease in crop productivity and yield	High
	Increase in droughts	Uncertain	N/A	Decrease the duration of leaf wetness and reduce forms of pathogen attack on leaves	High	Decrease in crop productivity	High
				Increased stress on plants	High	Reduced yields and crop losses, particularly for rain-fed agriculture	Medium
				Inadequate irrigation capacity for some high value crop growers	High	Decrease in crop yield	Medium
				Dry streams or wells	Medium	Increased pumping costs from wells	Medium
	Increase in intense precipitation events	More likely than not	N/A	Stress on crops, especially if extreme events occur in clusters	Medium to High	Major crop and profit loss	Medium to High
	Changes in cloud cover and radiation	Uncertain	N/A	Cloudy periods during critical development stages impacts plant growth	High	Affect plant growth, yields, and crop water use	High
Livestock (Dairy)							
Temp-erature	Increase in extreme heat events	Likely	N/A	Increased stress to livestock	High	Decrease in milk production; reduced calving rates	Medium
Insects and Weed Pests							
Temperature	Increase mean temperatures	Very likely	Warming may be greater 1) in the north than south, and 2) in winter than in summer in the north	More generations per season; shifts in species range	High	Increased vulnerability of crops to pests	High
	Warmer winters	Very likely	N/A	Increased spring populations of marginally overwintering insects	High	Increased vulnerability of crops to pests and invasives	High
				Northward range expansion of invasive weeds			

Notes: N/A = Not Applicable
* Factors that are considered when determining the magnitude of consequence, defined as the combined impact of the occurrence should a given hazard occur, include: effects on internal operations, capital and operating costs, public health, the economy, and the environment, as well as the number of people affected. (see Annex II to the full report, "Adaptation Guidebook")

Energy

Main Climate Variable	Specific Climate Variable	Probability of Specific Climate Variable	Climate Variable Notes	Impact on Resource	Likelihood of Impact	Consequence without Adaptation	Magnitude of Consequence*
Energy Resources							
Temperature	Increased mean temperatures	Very Likely	Warming may be greater 1) in the north than south, and 2) in winter than in summer in the north	Changes in biomass available for energy generation	Medium	Decreased reliability of biomass as an alternative energy source	Low
Precipitation	Increases in mean precipitation	More likely than not	N/A	Availability of hydropower reduced	Medium	Decreased reliability of hydropower as an alternative energy source	Low
Precipitation	Cloud cover	Uncertain	N/A	Changes in solar exposure	High	Decreased reliability of solar power as an alternative energy source	Low
Extreme events	Wind	Uncertain	N/A	Availability and predictability is reduced with variation in wind	High	Decreased reliability of wind energy as an alternative energy source	Low
Generation Assets							
Temperature	Increase in mean temperatures	Very Likely	Warming may be greater 1) in the north than south, and 2) in winter than in summer in the north	Reduced water cooling capacity	Medium	Water-cooled nuclear power plants become more at risk for overheating and failure of equipment; the thermal efficiency of power generation is reduced	High
Sea level rise	Increased frequency, intensity, and duration of storm surge and coastal flooding	Likely/very likely	Will depend both on sea level rise and on uncertain changes in tropical cyclones and Nor'easters	Damage to coastal power plants	High	Reduced generation	Medium
Transmission and Distribution Assets							
Temperature	Increase in mean temperatures	Very Likely	Warming may be greater 1) in the north than south, and 2) in winter than in summer in the north	Sagging power lines	Medium	More frequent power outages	Medium
				Wear on transformers	Medium	Transformers rated for particular temperatures may fail more frequently	Medium
Precipitation	Snow storms	Uncertain	N/A	Transmission infrastructure damage	Low	Changes in power outage frequency	Medium
Precipitation	Ice storms	Uncertain	N/A	Transmission lines sagging due to freezing/collecting ice	Low	Changes in power outage frequency	Medium
Electricity Demand							
Temperature	Increase in mean annual temperatures	Very Likely	Warming may be greater 1) in the north than south, and 2) in winter than in summer in the north	Increased energy demand	High	Increase in number of instances of peak load during summer, winter, and shoulder season	Medium
Temperature	Increase in extreme heat events; decrease in extreme cold events	Likely	N/A	Overwhelmed power supply system	Low	Increased frequency of blackouts and brownouts and reduced availability and reliability of power for downstate regions	High
Buildings							
Extreme events	Hurricanes and nor'easters	Uncertain	N/A	Heightened storm regime may reveal weaknesses in building envelopes	Medium	Increased chance of structural failure	Low
Extreme events	Extreme wind events	Uncertain	N/A				
Extreme events	Increased intense precipitation events	More likely than not	N/A	Low lying areas susceptible to more frequent flooding	High	Potential for structural damage to boilers	High

Notes: N/A = Not Applicable
* Factors that are considered when determining the magnitude of consequence, defined as the combined impact of the occurrence should a given hazard occur, include: effects on internal operations, capital and operating costs, public health, the economy, and the environment, as well as the number of people affected. (see Annex II to the full report, "Adaptation Guidebook")

Transportation

Main Climate Variable	Specific Climate Variable	Probability of Specific Climate Variable	Climate Variable Notes	Impact on Resource	Likelihood of Impact	Consequence without Adaptation	Magnitude of Consequence*
Physical Assets							
Temperature	Increase in mean temperature	Very likely	Warming may be greater 1) in the north than south, and 2) in winter than in summer in the north	Freezing and thawing more common than steady below-freezing temperatures	Medium	Increased strain on road surface materials and potential for cracks and potholes in roads	Low
				Increased strain on A/C capacity	Medium	Increased strain on electricity grid	Medium
				Increased strain on runway material	Low	More frequent flight delays or cancellations	Medium
				Rail buckling	High	Delays in railroad schedules	Medium
				Increased strain on bridge materials	High	Sagging of large bridges	High
Precipitation	Increase in mean precipitation	More likely than not	N/A	Increased street flooding	Medium	Traffic delays	Low
						Delays in public transportation systems	Medium
	Amplified stream flow	More likely than not	N/A	Increased scour potential for bridge foundations	Medium	Reduced lifespan of current structures, potential need for new regulations	High
				Damage to road and rail embankments	Medium	Increased traffic and public transportation delays and rerouting	Medium
	Mudslides and landslides	Uncertain	N/A	Road and rail closures	Medium	Increased traffic and public transportation delays and rerouting, potential threat to lives	High
Temperature/ precipitation	Increase in droughts	Uncertain	Towards the end of the century, warm season droughts will more likely than not increase	Lower water level of lakes and canals due to higher rates of evaporation	Medium	Reduction in shipping capacity and increased costs of shipping due to required additional trips	Medium
Sea level rise	Increased storm surge and coastal flooding	Likely/very likely	Will depend both on sea level rise and on uncertain changes in tropical cyclones and nor'easters	Clearances of some bridges across waterways diminished below the limits set by the U.S. Coast Guard or other jurisdictions	High	Closure of bridges	High
				Flooding of bridge access ramps, tunnel entrances and ventilation shafts, and general highway beds	High	Traffic delays due to inundation	Low
				Reduced effectiveness of collision fenders on bridge foundations	High	Increase in impacts of ships or barges	Medium
				Flooding of roadways, railways, fuel storage farms and terminals, or maintenance facilities	Medium	Potential for equipment failure	High

Notes: N/A = Not Applicable
* Factors that are considered when determining the magnitude of consequence, defined as the combined impact of the occurrence should a given hazard occur, include: effects on internal operations, capital and operating costs, public health, the economy, and the environment, as well as the number of people affected. (see Annex II to the full report, "Adaptation Guidebook")

Telecommunications							
Main Climate Variable	Specific Climate Variable	Probability of Specific Climate Variable	Climate Variable Notes	Impact on Resource	Likelihood of Impact	Consequence without Adaptation	Magnitude of Consequence*
Transmission and Distribution Assets							
Temperature	Increase in extreme heat events	Likely	N/A	Increase energy demand causing power failures	High	Reduction in telephone and cable services	High
Sea level rise	Increased frequency, intensity, and duration of storm surge and coastal flooding	Likely/very likely	Will depend on both sea level rise and on uncertain changes in tropical cyclones and nor'easters	Flooded central offices and underground installations	Medium	Reduced service	Medium
Extreme events	Extreme wind events	Uncertain	N/A	Fallen trees and downed wires	Low	Increased disruption of telephone and video service	Medium
	Snow storms	Uncertain	N/A	Strain on trees and utility lines from wet snow	Low	Reduction and delays in wired and cellular telephone service, as well as cable services	Medium
	Hurricanes	Uncertain	N/A	Power failures caused by high winds and storm surge	Medium	Increased strain on rerouting abilities of emergency calling centers	High
	Ice storms	Uncertain	N/A	Damage to utility lines and electrical equipment	Medium	Increased emergency communications and reduction in cable-provided services	High

Notes: N/A = Not Applicable
* Factors that are considered when determining the magnitude of consequence, defined as the combined impact of the occurrence should a given hazard occur, include: effects on internal operations, capital and operating costs, public health, the economy, and the environment, as well as the number of people affected. (see Annex II to the full report, “Adaptation Guidebook”)

Public Health

Main Climate Variable	Specific Climate Variable	Probability of Specific Climate Variable	Climate Variable Notes	Impact on Resource	Likelihood of Impact	Consequence without Adaptation	Magnitude of Consequence*
Air Quality							
Temperature	Increase in mean temperature	Very likely	Warming may be greater 1) in the north than south, and 2) in winter than in summer in the north	Extension of pollen and mold seasons	High	Asthma, which exhibits strong seasonal patterns related to pollen and mold seasons, is exacerbated	High
				Dust mites and cockroaches thrive at high temperatures and especially high absolute air humidity, which they depend upon for hydration	High	Asthma exacerbations triggered by greater presence of indoor allergens	High
				Increase in emission of volatile organic compounds	Medium	Increase in the amount of ozone being ingested results in short-term, reversible decreases in lung function and inflammation in the deep lung; also, epidemiology studies of people living in polluted areas have suggested that ozone can increase the risk of asthma-related hospital visits, and premature mortality	High
	Increase in extreme heat events	Likely	N/A	Peak in air conditioning use	High	Greater amount of emissions and resulting pollution from power plants	Medium
				Loss of on-site electricity	Low	Increase CO poisoning as a result of non-evacuated residents without back-up power	High
Precip-itation	Increase in mean precipitation	More likely than not	N/A	Weather patterns influence the movement and dispersion of all pollutants in the atmosphere	Medium	Potential increase in severe ozone episodes	High
Disease/Contamination							
Temperature	Increase in mean temperature	Very likely	Warming may be greater 1) in the north than south, and 2) in winter than in summer in the north	Increased population density and increase in biting rates of mosquitoes and ticks	Medium	Increase in infectious diseases spread by contaminated foods and water as well as those transmitted by insects	Medium
				Greater rates of overwinter survival of immature mosquitoes	High	Greater abundance of adults the following year that could potentially spread WNv	Medium
Precipitation	Increase in mean precipitation	More likely than not	N/A	Increased runoff from brownfields and industrial contaminated sites	Medium	Increased exposure to toxins creates health problems in respiratory and gastrointestinal tracts	High
				Receding floodwaters release molds and fungi that proliferate and release spores	High	Inhaled spores can cause respiratory irritation and allergic sensitization	High
Sea level rise	Increased storm surge and coastal flooding	Likely/Very likely	Will depend both on sea level rise and uncertain changes in tropical cyclones and nor'easters	Greater frequency of flooding events	High	Greater potential for drowning, delayed health service delivery	High
Mental Health							
Sea level rise	Increased storm surge and coastal flooding	Likely/Very likely	Will depend both on sea level rise and uncertain changes in tropical cyclones and nor'easters	Increased property damage (e.g., loss), displacement/family separation, violence, stress effects	High	Increase in anxiety, depression, PTSD as a result of low resilience capacity, lack of access to evac transportation, low SES	High

Notes: N/A = Not Applicable
CO = Carbon Monoxide
PTSD = Post traumatic stress disorder
* Factors that are considered when determining the magnitude of consequence, defined as the combined impact of the occurrence should a given hazard occur, include: effects on internal operations, capital and operating costs, public health, the economy, and the environment, as well as the number of people affected. (see Annex II to the full report, "Adaptation Guidebook")

Adaptation

New York State has significant resources and capacity for effective adaptation responses, which are characterized by a wide range of types, actors, levels of effort, timing, and scales (**Table 12.3**). A critical resource for the state are the existing codes, standards, and regulations that could be enhanced in a comprehensive adaptation approach. Developing climate change adaptation plans requires input from a breadth of academic disciplines as well as stakeholder experience to ensure that recommendations are both scientifically valid and practically sound (see Annex II to the full report).

Identifying the co-benefits of adaptation strategies is important, since they are positive effects that adaptation actions can have on mitigating climate change (i.e., reduction of greenhouse gas emissions) or on improving other aspects of the lives of New York State citizens. An example of a mitigation co-benefit is the establishment of green roofs that keep residents cooler while reducing the use of air conditioners, thereby reducing fossil fuel emissions at power plants. An example of a co-benefit with other aspects is the upgrading of combined sewer and stormwater systems to reduce current water pollution, while helping to prepare for future climate change impacts.

Some adaptation options may either complement or negatively affect mitigation efforts to reduce greenhouse gas emissions. For example, avoiding adverse public health impacts related to heat waves may result in increased reliance on air conditioning. This could counteract mitigation options designed to reduce energy consumption and could potentially result in increased energy demand during summer peak-load conditions.

Key Sector Adaptations

Potential adaptation strategies for the identified climate vulnerabilities are summarized in **Table 12.4**. These are to be considered as options for adaptive measures and should not be considered as an exhaustive list. For each sector, selected adaptation strategies that respond to key climate risks are presented in terms of short-, medium-, and long-term time scales and by operations/management, capital investment, and policy categories. The three categories are presented as a way of illustrating the varying range and focus of potential adaptation strategies. It is recognized that in many cases there will be significant overlap among the categories when the strategies are operationalized.

The key adaptations are broken into time groups: 0 to 10 years (i.e., to 2020), 10 to 40 years (i.e., to 2050), and more than 40 years (i.e., beyond 2050) (see **Table 12.4**). The short-term adaptations that are identified in the tables will often be continued into the medium and long terms, but to facilitate a focused overview, they are not necessarily repeated in each column of the table. Thus, while a short-term operations/management strategy—one involving small adjustments to everyday practices—will probably be continued throughout the longer period, it is listed as short-term to indicate its earliest use/implementation. "Ongoing" refers to work that is taking place at present and expected to continue over time.

Adaptation Mechanism	Definitions
Type	Behavior, management/operations, infrastructure/physical components, risk-sharing, and policy (including institutional and legal)
Administrative group	Private vs. public; governance scale – local/municipal, county, state, national
Level of effort	Incremental action, paradigm shift
Timing	Years to implementation, speed of implementation (near-term/long-term)
Scale	Widespread, clustered, isolated/unique

Table 12.3 Adaptation categories

Table 12.4 Selected Adaptation Strategies by Sector

Selected adaptation strategies by sector responding to key climate risks	Type*	Timing**
Water Resources		
Build on the existing capacity of water managers to handle large variability	O/M	O
Expand basin-level commissions to provide better oversight of water supplies in systems with multiple users, address water quality issues, and take leadership on basin-level monitoring, conservation, and coordination of emergency response	CI, P	S
Update and enlarge stockpiles of emergency equipment, including mobile pumps, water tanks, and filters, to help small water supply systems and to assist during emergencies	CI	S
Establish streamflow regulations that mimic natural seasonal flow requirements to protect aquatic and ecosystem health	O/M, P	S
Increase water use efficiency through leak detection programs, low-flow devices, rainwater harvesting, and equitable water-pricing programs	O/M, P	S
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	O/M, P	S to M
Explore new economic opportunities for New York State's relative wealth of water resources	P	M
Upgrade combined sewer and stormwater systems to reduce pollution and mitigate climate change impacts	CI	M
Adopt stormwater management infrastructure and practices to reduce the rapid release of stormwater to water bodies	O/M, P	M to L
Relocate and rebuild aging infrastructure out of high-risk flood-prone areas; construct levees and berms where necessary to remain in the flood plain	CI	L
Coastal Zones		
Site new developments outside of future floodplains, taking into consideration the effects of sea level rise, barrier island and coastline erosion, and wetland inundation	P	O
Improve building codes to promote storm-resistant structures and increase shoreline setbacks	O/M, P	S
Use rolling easements to protect coastal wetlands (recognize nature's right-of-way to advance inland as sea level rises)	P	M
Use engineering-based and bio-engineered strategies to protect coastal communities from floods or to restore wetlands	O/M	M
Maintain and expand beach renourishment and wetland restoration programs	O/M, P	M
Relocate coastal infrastructure and small, rural developments to higher elevations	CI, P	L
Buy out land or perform land swaps to encourage people to move out of flood-prone areas	CI, P	L
Ecosystems		
Minimize stressors such as pollution, invasive species, sprawl, and other habitat-destroying forces	O/M	O
Develop reliable indicators of climate change impacts on biodiversity and ecosystem services, and cost-effective strategies for assessing climate change impacts	O/M	O
Manage primarily for important ecosystem services and biodiversity rather than attempting to maintain the current mix of species present today	O/M	O
Facilitate natural adaptation to climate change by protecting stream (riparian) zones and migration corridors for species adjusting to changes in the climate	O/M, P	S
Institutionalize a comprehensive monitoring effort to track species range shifts and to track indicators of ecosystem response to climate change	O/M, P	M
Develop cost-effective management interventions to reduce vulnerability of high-priority species and communities, and determine minimum area needed to maintain boreal or other threatened ecosystems	O/M, P	M
Agriculture		
Change planting dates, varieties, or crops grown; increase farm diversification	O/M	S
Develop strategic adaptation decision tools to assist farmers in determining the optimum timing and magnitude of investments to cope with climate change	CI, P	S
Increase control of pests, pathogens, and weeds and use of new approaches to minimize chemical inputs	O/M	S
Improve cooling capacity and use of fans and sprinklers in dairy barns	CI	M
Invest in irrigation and/or drainage systems	CI	M
Develop new crop varieties for projected New York State climate and market opportunities	CI	M
Build supplemental irrigation with good drainage capacity for high-value crops	CI	M

Note: The key adaptations are broken into time groups: 0 to 10 years (i.e., to 2020), 10 to 40 years (i.e., to 2050), and more than 40 years (i.e., beyond 2050). The short-term adaptations that are identified will often be continued into the medium and long terms, but to facilitate a focused overview, they are not necessarily repeated in each column of the table. Thus, while a short-term operations/management strategy—one involving small adjustments to everyday practices—will probably be continued throughout the longer period, it is listed as short term to indicate its earliest use/implementation.

* O/M = Operations/Management, CI = Capital Investment, P = Policy,

** S = Short-term, M = Medium-term, L = Long-term, 0 = Ongoing

Selected adaptation strategies by sector responding to key climate risks	Type*	Timing**
Energy		
Balance the need to make energy systems more resilient with the cost of such investments and changes	O/M	O
Improve system resiliency with the replacement cycle of energy system assets	CI	O
Use transformers and wiring that function efficiently at higher temperatures	CI	S
Maintain and expand tree trimming programs next to power lines	O/M	S
Adjust reservoir release policies to ensure sufficient summer hydropower capacity	O/M	S
Prioritize demand-side management, which encourages consumers to use energy more efficiently	P	S
Shade buildings and windows or use highly reflective roof paints and surfaces to reduce warming in buildings from sun exposure	O/M	S
Improve energy efficiency in areas likely to have the largest increases in demand, to reduce strain on electrical equipment during heat waves	O/M, P	S
Construct berms and levees to protect infrastructure from flooding; install saltwater-resistant transformers to protect against sea level rise and saltwater intrusion	CI	M to L
Transportation		
Adopt operational measures to cope with high wind speeds, such as allowing bridge traffic only at reduced speeds or, for higher wind speeds, suspending traffic	O/M, P	S
Form alliances among agencies to set performance standards and work together to reduce risks, such as through mutual insurance pools that spread risks across time, space, and type	O/M	S
Perform engineering-based risk assessments of assets and operations and complete adaptation plans based on these assessments	CI, P	S to M
Relocate critical systems to higher ground out of future flood zones	CI	M
Create strategies to protect against heat hazards, including increasing the seat length of expansion joints on bridges, lengthening airport runways, and increasing and upgrading air conditioning on trains, subways, and buses	CI	M to L
Devise engineering-based solutions to protect against coastal hazards, including constructing levees, sea walls, and pumping facilities; elevating infrastructure, including bridge landings, roads, railroads, and collision fenders on bridge foundations; and designing innovative gates at subway, rail, and road entrances	CI	M to L
Develop engineering-based solutions to protect against heavy-precipitation hazards, including increasing the capacity of culverts and other drainage systems; raising and/or strengthening road and rail embankments to make them more resistant to flood-related erosion and river scour; and creating more permeable surfaces or regrading slopes to direct runoff away from critical transportation infrastructure	CI	L
Telecommunications		
Reassess industry performance standards combined with more uniform regulation across all types of communication services; provide better enforcement of regulations, including uniform mandatory reporting of outages to regulatory agencies	O/M, P	S
Further develop backup cell phone charging options, such as car chargers, and create a charging interface that allows any phone to be recharged by any charger	CI	S
Develop high-speed broadband and wireless services in low-density rural areas to increase redundancy and diversity in vulnerable remote regions	CI	S
Trim trees near power and communication lines, maintain backup supplies of poles and wires to replace those that are damaged, and have emergency restoration crews at the ready to protect against outages	O/M	S, O
Assess, develop, and expand alternative communication technologies with the goal of increasing redundancy and/or reliability, including free-space optics (which transmits data with light rather than physical connections), power line communications (which transmits data over electric power lines), satellite phones, and ham radio	CI	M
Place communication cables underground where technically and economically feasible	CI	M
Decouple communication facilities from electric grid infrastructure to the extent possible, and/or make these infrastructures more robust, resilient, and redundant	CI	M
Minimize the effects of power outages on communications services by providing backup power at cell towers, such as with generators, solar-powered battery banks, and “cells on wheels” that can replace disabled towers; extend the fuel storage capacity needed to run backup generators for extended times	CI	M
Relocate central offices that house communications infrastructure out of future floodplains	CI, P	L
Public Health		
Integrate adaptation strategies into existing surveillance, prevention, and response programs	O/M	S
Better coordinate environment and health initiatives so they address both human health and ecosystem health and avoid the legislative divide that often exists between them	O/M, P	S
Increase use of air conditioning during heat waves for vulnerable individuals, but use alternative energy sources to avoid increased greenhouse gas emissions	O/M	S
Provide alerts regarding potential health risks, such as those from extreme heat events, which convey information and needed actions to vulnerable communities	O/M, P	S
Implement extreme-heat response plans, such as longer opening hours for air-conditioned community centers for seniors, reduced fares on public transportation, and neighborhood buddy systems to check on those most vulnerable	O/M, P	S
Plant low-pollen trees in cities to reduce urban heat without increasing allergenic pollen	CI	M
Invest in structural adaptations to reduce heat vulnerability, including tree planting, green roofs, and high-reflectivity building materials	CI	M to L

Note: See previous page

Equity and Environmental Justice

Certain groups, types of communities, and regions within the state are better able to respond to climate risk and vulnerabilities than others. Communities, groups, and locations currently at risk because of limited response capacity and resilience to climate hazards (e.g., those who are economically marginal) are, in most cases, those that will be most vulnerable to future climate change impacts. Such groups include the elderly and disabled, as well as people with low incomes and the underprivileged.

Elderly 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 healthcare 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 also vulnerable. Farm workers may be exposed to more chemicals if pesticide use increases in response to higher pest infestations brought about by a warming climate.

It is not clear at this time how the costs of adaptation will be distributed. In general, groups with more limited means to respond to increased risks or to provide funds for adaptation, such as smaller businesses, may be less able to cope. This condition extends across both the public and the private sectors.

Economics

The costs of climate change impacts will vary across and within sectors (see Annex III to the full report). Overall costs of impacts within the energy, transportation, and coastal zone sectors will be most significant, likely by many-fold, but impacts within each sector will be significant depending on the structure of that sector. This is well illustrated in the agriculture and ecosystem sectors, where particular components such as specific crops and modes of production or rare and endangered ecosystems and species could be significantly affected by climate change in comparison to other parts of the sectors.

There are several types of costs associated with climate impacts and adaptation. Direct costs include costs that are incurred as the direct economic outcomes of a specific climate event or aspect of climate change. Indirect costs are those incurred as secondary outcomes of the direct costs of a specific event or facet of climate change. Impact costs are direct costs associated with the impacts of climate change, and adaptation costs include the direct costs associated with adapting to those impacts. The direct costs of impacts that cannot be adapted to are the costs of residual damage.

The costs of adapting to climate change are already occurring and will grow over time. Adaptation response costs and benefits will not be evenly distributed throughout the state. For example, a significant amount of the benefits of adaptation to sea level rise will be experienced only by communities and property owners in the coastal zone.

Recommendations

This section presents recommendations for policy and management that arise from the ClimAID Assessment. Policy recommendations are aimed at statewide decision-makers, and management recommendations are associated with everyday operations within stakeholder agencies and organizations, as they respond to the challenge of climate change. Sector-specific knowledge gaps and information needs are identified, as well as recommended directions for further science and research activities.

Policy

Key policy recommendations, targeted for New York State decision-makers, are discussed in this section.

- Promote adaptation strategies that enable incremental and flexible adaptations within sectors, among communities, and across time.
- Analyze environmental justice issues related to climate change and adaptation on a regular basis.
- Evaluate design standards and policy regulations based on up-to-date climate projections.
- Consider regional, federal, and international climate-related approaches when exploring climate adaptation options. This is crucial because it is clear that New York State's adaptation potential (and

mitigation potential as well) will be affected by national and international policies and regulations as well as state-level policies.

- 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 the advantages of shared knowledge.
- Identify synergies between mitigation and adaptation. Taking steps to mitigate climate change now will help to reduce hazards and enhance opportunities for co-benefits. Conversely, many potential adaptation strategies present significant mitigation opportunities.
- Develop standardized, statewide climate change mitigation and adaptation tools, including a central database of climate risk and adaptation information resulting from ongoing partnerships between scientists and stakeholders.

Management

Management recommendations associated with everyday operations in stakeholder agencies and organizations are described here.

- Integrate climate adaptation responses into the everyday practices of organizations and agencies, with the potential for synergistic or unintended consequences of adaptation strategies taken into account.
- Take climate change into account in planning and development efforts.
- Identify opportunities for climate adaptation partnerships among organizations and agencies.

Knowledge Gaps and Information Needs

There has been great advancement in knowledge surrounding climate change, impacts, and adaptation over the past few decades. However, there are still areas where further research would complement and further the understanding, help to reduce uncertainties, and aid in better decision-making. Key areas of knowledge gaps and information needs for each sector are outlined in **Table 12.5**.

Table 12.5 Knowledge Gaps and Information Needs by Sector

Sector-specific and statewide knowledge gaps and information needs	Type (Climate science, impact, adaptation)
Water Resources	
Identification of critical pollutant-contributing areas and processes	Impact
More in-depth assessment of how fundamental hydrologic processes, such as groundwater recharge, stream low-flows, evaporation, and flooding, might be altered by a changing climate	Impact
Refinement of existing monitoring networks	Climate science
Updated estimates of streamflow and water temperature scenarios based on future climate changes	Climate science
Models of the impacts on the quality of water bodies receiving effluent	Impact
Coastal Zones	
Research on the response of barrier islands to accelerated rates of sea level rise	Climate science
Improved understanding of regional sediment transport processes along the coast and continental shelf	Climate science
Quantified and monitored land use and coastal water quality	Impact
Assessment of ecosystem services for natural and engineered shorelines	Impact
Monitoring program for submarine groundwater discharge	Impact
Systematic mapping (every two to five years) and standardized mapping protocols for all New York State coastal regions	Climate science
GIS-based data repository to facilitate interagency collaboration and future assessments	Impact
Improved hydrodynamic modeling capability for the Hudson River	Climate science
Ecosystems	
Reliable indicators of climate change impacts on biodiversity and ecosystem functions, and cost-effective strategies for monitoring these impacts	Climate science/impact
Cost-effective management interventions to reduce vulnerability of high-priority species and communities, and determination of the minimum area needed to maintain boreal and other threatened ecosystems.	Impact
Evaluation techniques for rapid and reliable assessment of vertebrate abundance at the landscape scale	Climate science
Improvements in techniques used to identify and target invasive species likely to benefit from climate change	Climate science
Development of citizen-science programs that can provide accurate and reliable data on change in species distributions and movements	Impact
Agriculture	
Non-chemical control strategies for weed and pest threats	Impact
New economic decision tools for farmers	Impact
Sophisticated real-time weather-based systems for monitoring and forecasting crop stress	Climate science
Crops with increased tolerance to climate stresses	Impact
Energy	
Review of thermoelectric power intake or discharge rules in light of a changing climate	Impact
Identification of temperature tipping points related to failure of the energy supply system	Impact
Potential impacts of climate change on wind patterns and speeds in selected areas currently used or proposed for wind farm development	Climate science/impact
Potential impacts of climate change on biomass-based heat production (either at a large central station or co-firing facilities)	Climate science/impact
Assessment of potential impacts of climate change on hydropower availability in different parts of the state	Climate science/impact
Evaluation of potential climate impacts on the demand for natural gas and other heating fuels given anticipated decreases in heating degree-days over the coming decades	Impact
Better understanding of the impact of extreme events on electricity demand	Climate science
Transportation	
Accurate, high-resolution LIDAR surveys to facilitate the development of digital elevation models (DEM) of sufficiently high vertical and horizontal resolution to perform forward-looking flood risk assessments and regional planning of sustainable developments	Impact
Development of updated climate information that includes climate change projections for standards and regulations	Climate science
Comprehensive program of research and technological development for advancing innovative, cost-effective, and climate-resilient urban and inter-urban transportation infrastructure	Impact
Telecommunications	
Creation of computerized (proprietary) databases that show the location and elevations of installed communication facilities and lifelines and their operational capacity and other details	Impact
Improved knowledge-sharing tools to disseminate information about service outages and expected restoration times to the public	Impact
Public Health	
Ongoing, state-based research to inform periodic policy developments, especially that which identifies cross-sectoral interactions and win-win options for adaptation/mitigation, including extensive health co-benefits assessments	Impact
Development and analysis of local health impact projections of climate factors and related disease outcomes	Impact
Information and capacity-building for integrating climate change into public health planning at all levels of government	Impact

Science and Research

This section presents recommendations for future science and research.

- Refine climate change scenarios for New York State on an ongoing basis, as results from new climate models and downscaled products become available.
- Conduct research on understanding climate variability, including stakeholder-identified variables, such as ice storms, extreme precipitation events, wind patterns, etc.
- Conduct targeted impacts research in conjunction with regional stakeholders.
- Implement and institutionalize an indicators and monitoring program focused on climate, impacts, and adaptation strategies.
- Improve spatial analysis and mapping to help present new data.
- Focus studies on specific systems that may enter into a phase change or similar shifts in process, known as ”tipping points.” Work should be encouraged to understand the potential for tipping points associated with climate change impacts on natural and social systems.
- Develop a better understanding of the economic costs of climate change and benefits of adaptations.

Responding to Future Climate Challenges

New York State is highly diverse, with simultaneous and intersecting challenges and opportunities presented by a changing climate. Among the people, sectors, and regions of the state, those that are already facing significant stress will likely be placed most at risk by the effects of future climate change. Responding to these challenges and opportunities will depend on how stakeholders develop effective adaptation strategies by connecting climate change with ongoing proactive management and policy initiatives within the state and beyond.

The adaptation strategies suggest several important perspectives: First, there is a wide range of adaptation needs across sectors. Second, there are many adaptation needs that can be undertaken or reviewed in the near term, in most cases at relatively modest cost. Third, there are some potential infrastructure investments—especially relating to the transportation sector and coastal zones—that could be needed in the long term and that may be expensive. These perspectives also suggest the need for increased interactions between scientists and policy-makers, and consideration of methods for ensuring that science better informs policy, as well as increased scientific and technical capabilities. The overall goal is the development of equitable and efficient climate resilience throughout New York State in the decades to come.