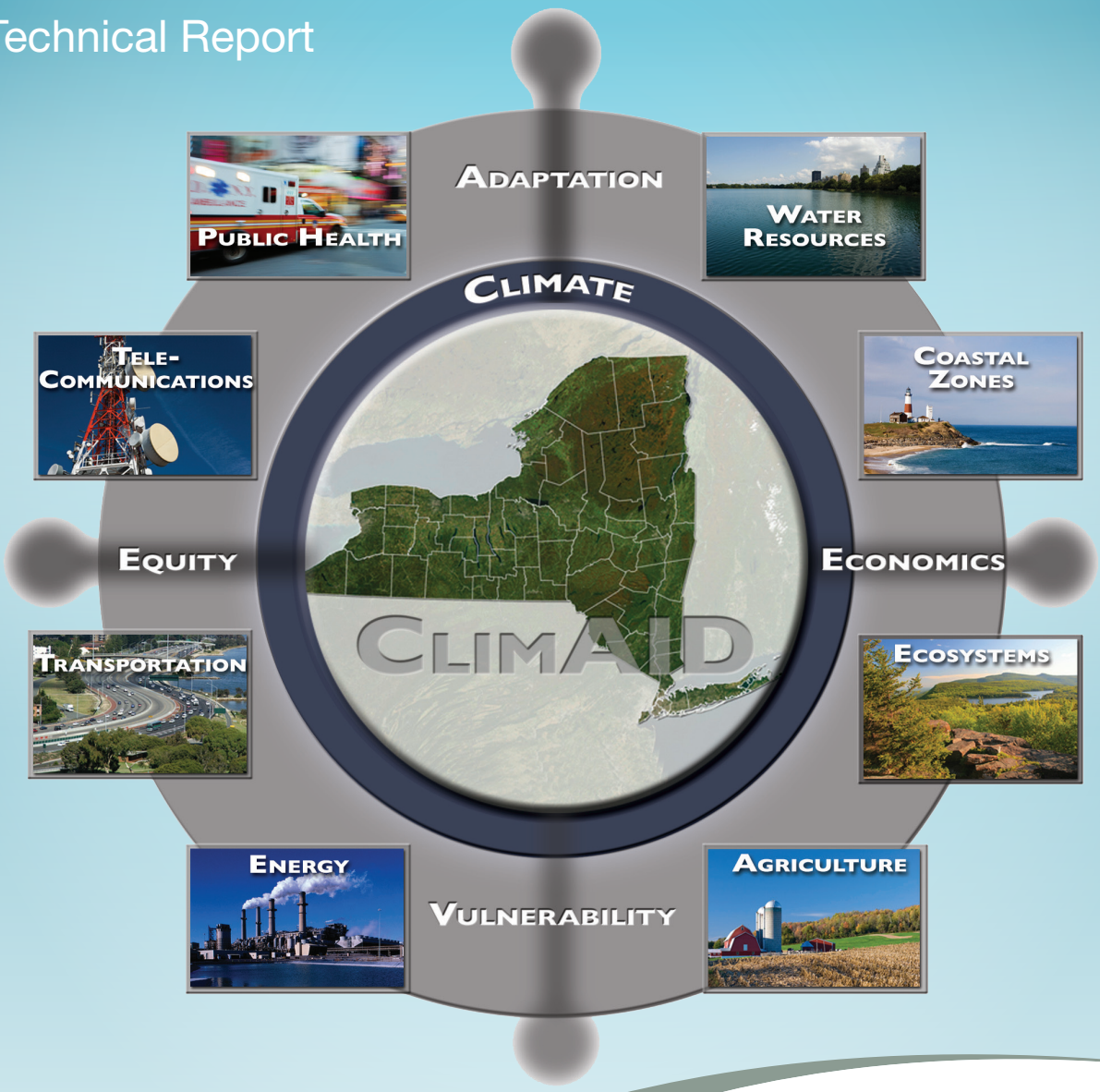
New York State Energy Research and Development Authority

Responding to Climate Change in New York State

Technical Report



Final Report
No. 11-18

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Responding to Climate Change In New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation in New York State

Final Report

Editors
Cynthia Rosenzweig, William Solecki, Arthur DeGaetano, Megan O'Grady, Susan Hassol, and Paul Grabhorn

Team Leaders
Frank Buonaiuto
Stephen A. Hammer
Radley Horton
Klaus Jacob
Patrick L. Kinney
Robin Leichenko
Andrew McDonald
Lesley Patrick
Rebecca Schneider
David W. Wolfe

Layout and Graphics
Joshua Weybright
Paul Grabhorn

Prepared for the

New York State Energy Research and Development Authority
Albany, NY

Amanda Stevens, Project Manager
Mark Watson, Program Manager

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Columbia University in the City of New York

CUNY The City University of New York

Cornell University

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ClimAID Leadership Team

Cynthia Rosenzweig (PI), NASA Goddard Institute for Space Studies and Columbia University
William Solecki (PI), City University of New York, CUNY Institute for Sustainable Cities (CUNY CISC)
Arthur DeGaetano (PI), Northeast Regional Climate Center, Department of Earth and Atmospheric Science, Cornell University
Amanda Stevens (Project Manager), New York State Energy Research and Development Authority (NYSERDA)
Mark Watson (Program Manager, Environmental Research), New York State Energy Research and Development Authority (NYSERDA)
Megan O'Grady (Project Manager), Columbia University
Lesley Patrick (Project Manager), City University of New York
Susan Hassol (Science Writer), Climate Communication, LLC
Paul Grabhorn (Graphic Designer), Grabhorn Studio, Inc.
Josh Weybright (Graphic Designer), Graphic Sky, Inc.

ClimAID Teams

Climate
Radley Horton (Lead), Columbia University
Daniel Bader, Columbia University
Arthur DeGaetano, Cornell University
Cynthia Rosenzweig, Columbia University
Lee Tryhorn, Cornell University
Richard Goldberg, Columbia University

Adaptation and Vulnerability
William Solecki, City University of New York
Lee Tryhorn, Cornell University
Arthur DeGaetano, Cornell University

Equity and Environmental Justice
Robin Leichenko (Lead), Rutgers University
Peter Vancura, Rutgers University
Adelle Thomas, Rutgers University

Economics
Yehuda Klein (Lead), City University of New York
Robin Leichenko, Rutgers University
David C. Major, Columbia University
Marta Panero, New York University

Water Resources
Rebecca Schneider (Sector Lead), Cornell University
Andrew McDonald (Sector Lead), New York State Water Resources Institute
Stephen Shaw, Cornell University
Susan Riha, Cornell University
Lee Tryhorn, Cornell University
Allan Frei, City University of New York
Burrell Montz, East Carolina University

Coastal Zones
Frank Buonaiuto (Sector Lead), City University of New York
Lesley Patrick (Sector Lead), City University of New York
Ellen Hartig, New York City Department of Parks and Recreation
Vivien Gornitz, Columbia University
Jery Stedinger, Cornell University
Jay Tanski, Cornell University
John Waldman, City University of New York

Ecosystems
David W. Wolfe (Sector Lead), Cornell University
Jonathan Comstock, Cornell University
Holly Menninger, Cornell University
David Weinstein, Cornell University
Kristi Sullivan, Cornell University
Cliff Kraft, Cornell University
Brian Chabot, Cornell University
Paul Curtis, Cornell University

Agriculture
David W. Wolfe (Sector Lead), Cornell University
Jonathan Comstock, Cornell University
Alan Lakso, Cornell University
Larry Chase, Cornell University
William Fry, Cornell University
Curt Petzoldt, Cornell University

Energy
Stephen A. Hammer (Sector Lead), Massachusetts Institute of Technology, formerly with Columbia University
Lily Parshall, formerly with Columbia University

Transportation
Klaus Jacob (Sector Lead), Columbia University
George Deodatis, Columbia University
John Atlas, formerly with Columbia University
Morgan Whitcomb, Columbia University
Madeleine Lopeman, Columbia University
Olga Markogiannaki, Columbia University
Zackary Kennett, Columbia University
Aurelie Morla, Columbia University

Telecommunications
Klaus Jacob (Sector Lead), Columbia University
Nicholas Maxemchuk, Columbia University
George Deodatis, Columbia University
Aurelie Morla, Columbia University
Ellen Schlossberg, Columbia University
Imin Paung, Columbia University
Madeleine Lopeman, Columbia University

Public Health
Patrick L. Kinney (Sector Lead), Columbia University
Perry Sheffield, Mount Sinai School of Medicine
Richard S. Ostfeld, Cary Institute of Ecosystem Studies
Jessie L. Carr, Columbia University

NOTICE

ABSTRACT

Climate change is already beginning to affect New York State, and these impacts are projected to grow. At the same time, the state has the ability to develop adaptation strategies to prepare for and respond to climate risks now and in the future. The ClimAID assessment provides information on climate change impacts and adaptation for eight sectors in New York State: water resources, coastal zones, ecosystems, agriculture, energy, transportation, telecommunications, and public health. Observed climate trends and future climate projections were developed for seven regions across the state. Within each of the sectors, climate risks, vulnerabilities, and adaptation strategies are identified. Integrating themes across all of the sectors are equity and environmental justice and economics. Case studies are used to examine specific vulnerabilities and potential adaptation strategies in each of the eight sectors. These case studies also illustrate the linkages among climate vulnerabilities, risks, and adaptation, and demonstrate specific monitoring needs. Stakeholder participation was critical to the ClimAID assessment process to ensure relevance to decision makers across the state.

KEYWORDS

Climate change; adaptation; impacts; vulnerability; climate risk; sector impacts

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This report is the product of the work of the dedicated sector and integrating theme leaders and the team members of ClimAID. We express our sincere thanks to each of them for their contributions.

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We thank the expert reviewers of the ClimAID assessment, without whom the independent provision of sound science for climate change adaptation cannot proceed.

Finally, we thank the many stakeholders who provided inputs and feedback to the ClimAID assessment. They generously shared their knowledge so that New York State can respond effectively to changing climate conditions.

Cynthia Rosenzweig, NASA GISS and Columbia University
William Solecki, Hunter College at City University of New York
Arthur DeGaetano, Cornell University

Integrated Assessment for Effective Climate Change Adaptation in New York State

Contents

ClimAID: Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State

Authors: Cynthia Rosenzweig, William Solecki, and Arthur DeGaetano

Contents

Introduction

New York State is already experiencing impacts as a result of climate change, and impacts are projected to increase with further warming. At the same time, the state has great adaptive capacity to address them. From the Great Lakes to Long Island Sound, from the Adirondacks to the Susquehanna Valley, climate change will affect the people and resources of New York State. Risks associated with climate change include greater incidence of heat stress caused by more frequent and intense heat waves; greater incidence of heavy rainfall events affecting food production, natural ecosystems, and water resources; and sea level rise leading to increased flooding in coastal areas. Climate change may exacerbate existing stresses on the people and activities of New York State and, in some cases, might provide opportunities such as enhancement of its water resources and agricultural potential. The goals of the Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State (ClimAID) are to provide New York State decision-makers with cutting-edge information on its vulnerability to, as well as its ability to derive benefits from, climate change and to facilitate the development of adaptation strategies informed by both local experience and scientific knowledge. Further aims of ClimAID are to highlight areas related to climate change and New York State that warrant additional research and to identify data gaps and monitoring needs in order to help guide future efforts.

Initiated in 2008, ClimAID is funded by the New York State Energy Research and Development Authority (NYSERDA) as part of its Environmental Monitoring, Evaluation, and Protection Program (EMEP). The assessment proceeds from the acknowledgement that the unique combination of natural resources, ecosystems, economic activities, and human population of New York State will not be immune to the impacts of climate change, and that local communities and the State as a whole, therefore, need to plan for and adapt to these effects. Climate change poses special challenges for New York State decision-makers related to the uncertainties inherent in future climate projections and the complex linkages among climate change, physical and biological systems, and socioeconomic sectors.

Working interactively with stakeholders, the ClimAID team focused on five integrating themes across a broad range of key sectors (**Figure 1**). The five integrating themes are climate, vulnerability, adaptation, equity and environmental justice, and economic costs associated with climate change impacts and adaptive measures, as well as the benefits of avoiding impacts. The five integrating themes were selected based on discussions with NYSERDA and sector stakeholders about factors of key relevance for responding to a changing climate in the state. The eight sectors are Water Resources, Coastal Zones, Ecosystems, Agriculture, Energy, Transportation, Telecommunications, and Public Health.

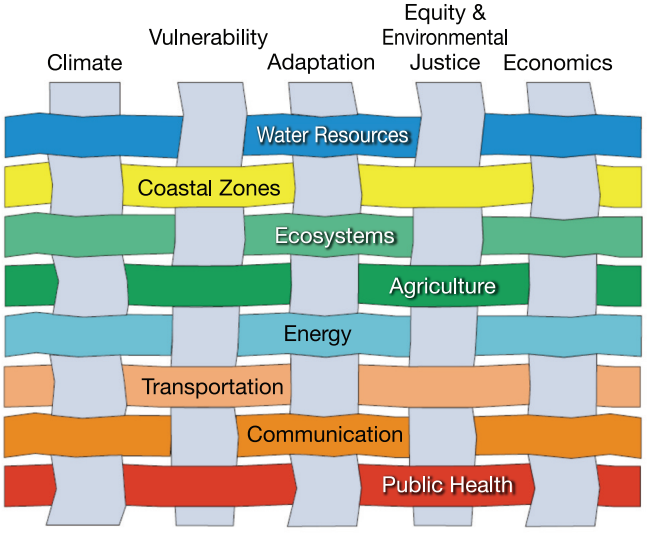

Figure 1 ClimAID integrating themes and sectors, illustrating the interwoven fabric of climate change assessment

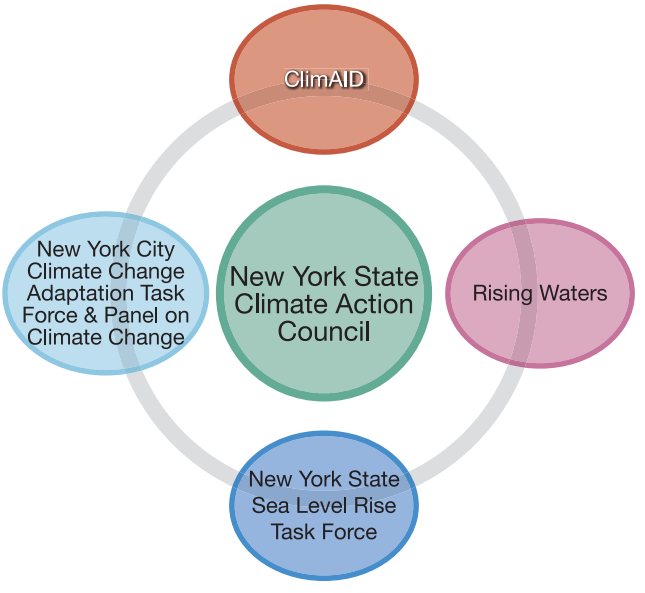

Figure 2 Interactions of ClimAID assessment with other climate change adaptation initiatives in New York State

Progress in reducing vulnerability and building adaptive capacity to respond to climate change depends on integrating the best available local and scientific knowledge with lessons learned from previous and current efforts. To that end, ClimAID built on key findings from prior assessments, and coordinated with concurrent research and policy initiatives on climate change adaptation, such as the Rising Waters project (a regional planning effort for the Hudson Valley convened by The Nature Conservancy and partners),[1] the New York State Sea Level Rise Task Force convened by the New York State Legislature,[2] the New York City Climate Change Adaptation Task Force led by the Mayor's Office of Long-Term Planning and Sustainability of New York City,[3] and the New York City Panel on Climate Change (NPCC) convened by Mayor Bloomberg of New York City[4] (**Figure 2**). The New York State Climate Action Council is preparing mitigation and adaptation policy recommendations for the Governor's Office.[5]

Climate Change in New York State

Climate change is already affecting and will continue to affect a broad set of activities across New York State. Its geographical and socioeconomic diversity means that New York State will experience a wide range of effects. There will be opportunities to explore new varieties, new crops, and new markets associated with higher temperatures and longer growing seasons. New York's relative wealth of water resources, if properly managed, can contribute to resilience and new economic opportunities. On the other hand, higher temperatures and increased heat waves have the potential to increase fatigue of materials in the water, energy, transportation, and telecommunications sectors; affect drinking water supply; cause a greater frequency of summer heat stress on plants and animals; alter pest populations and habits; affect the distribution of key crops such as apples, grapes, cabbage, and potatoes; cause reductions in dairy milk production; increase energy demand; and lead to more heat-related deaths and declines in air quality. Projected higher average annual precipitation and frequency of heavy precipitation events could also potentially increase the risks of several problems, including flash floods in urban areas and hilly regions; higher pollutant levels in water supplies; inundation of wastewater treatment plants and other vulnerable development in floodplains; saturated coastal lands and wetland habitats; flooded key rail lines, roadways, and transportation hubs; and travel delays. Sea level rise will increase risk of storm surge-related flooding, enhance vulnerability of energy facilities located in coastal areas, and threaten transportation and telecommunications facilities.

Across the varied geography of New York State, many individuals, households, communities, and firms are at risk of experiencing climate change impacts. Some will be especially vulnerable to specific impacts due to their location and lack of resources.

ClimAID Team, Meetings, and Reviews

Because New York is large and diverse, special emphasis in ClimAID was placed on integration and coordination so that climate change impacts and potential responses could be addressed coherently across the geographic regions and the multidimensional sectors of the state.

The ClimAID team was made up of university and research scientists who are specialists in climate change science, impacts, and adaptation. Researchers came primarily, but not exclusively, from Columbia University, Cornell University, and Hunter College of the City University of New York (See front matter for list of ClimAID team members). The team was organized into groups that addressed the five integrating themes and the eight sectors.

Approximately every six months over the period November 2008 to June 2010, ClimAID team members gathered from around the state for face-to-face meetings. The kickoff meeting was held in Albany in the fall of 2008 to present the scope of work, identify sectors and stakeholders, and set priorities. The second meeting was held early in 2009 at Cornell University and focused on initial findings, overall emerging messaging, and identifying common themes. The third meeting was again held in Albany in the fall of 2009 and provided a further update of the findings. The final ClimAID meeting was held at Hunter College CUNY to discuss the major conclusions. The team also held regular teleconferences, approximately every two weeks in the beginning and then once a month. The integrating theme groups interacted directly with each of the sector groups throughout the process.

A Project Advisory Committee, convened by NYSERDA, was made up of experts from the sectors covered by ClimAID (Appendix A). The committee met approximately every six months to review draft materials and to advise on the overall scope and direction of the assessment.

Besides the Project Advisory Committee reviews, external reviews were conducted for the sector chapters in the early summer 2009 and early in 2010. Each chapter was reviewed by multiple outside experts in relevant fields (see Annex I).

Stakeholder Interactions

To ensure that the information provided by ClimAID was relevant to the climate-related decisions made by practitioners, stakeholder interactions were a key part of the process (**Figure 3**). Working with NYSERDA and the Project Advisory Committee, the sector leaders identified relevant stakeholders from the public sphere (e.g., state and local agencies), nonprofit organizations (e.g., non-governmental community and environmental groups), private-sector entities (e.g., businesses), and academic institutions for each of the sectors, and organized the stakeholder interactions. (For a list of stakeholder organizations by sector, see Appendix B and the sector chapters).

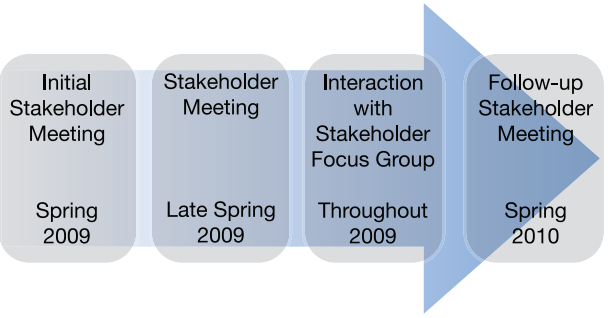

Figure 3 ClimAID sector stakeholder process

While each sector developed its own stakeholder process, sectors generally convened sector-specific stakeholder meetings in the first four-month period of ClimAID; developed, administered, and analyzed a survey to a wider group of sector stakeholders; formed a focus group of key stakeholders for ongoing discussion and advice throughout the assessment; and held a final stakeholder meeting in the third four-month period to present preliminary results and get feedback on draft conclusions and recommendations. See sector chapters for fuller descriptions of stakeholder interactions.

Integrating Themes

ClimAID developed five key themes to integrate across the eight sectors: climate, vulnerability, adaptation, equity and environmental justice, and economics.

Sector	Case Study Title
Water Resources	Susquehanna River Flooding, June 2006* Orange County Water Supply Planning
Coastal Zones	1-in-100-Year Flood and Environmental Justice* Modeling Climate Change Impacts in the Hudson River Estuary Salt Marsh Change at New York City Parks and Implications of Accelerated Sea Level Rise
Ecosystems	Hemlock—Cascading Effects of Climate Change on Wildlife and Habitat Creative Approaches to Monitoring and Adaptive Management—New York's Invasive Species Program as a Model Maple Syrup Industry—Adaptation to Climate Change Impacts Brook Trout—Reduction in Habitat Due to Warming Summers*
Agriculture	Frost Damage on Grapes Potato Late Blight Drought Dairy Heat Stress*
Energy	Impact of Climate Change on New York State Hydropower Climate Change-Induced Heat Wave in New York City*
Transportation	Future Coastal Storm Impacts on Transportation in the New York Metropolitan Region*
Telecommunications	Winter Storm in Central, Western, and Northern New York*
Public Health	Heat-related Mortality Among People Age 65 and Older* Ozone and Respiratory Diseases Extreme Storm and Precipitation Events West Nile Virus

*In-depth case study including economic and environmental justice analysis

Table 1 Case studies by sector

A group of ClimAID scientists focused on each of these themes, working with the sectors to ensure broad coordination across the assessment. Case studies of specific impacts and/or locations were selected for each of the sectors that provided special analysis of the five themes (**Table 1**). See chapters 1, 2, and 3 for detailed descriptions of the concepts and methods used in the integrating themes.

Climate

The Climate group analyzed both past and future climate in New York State (see "Climate," Chapter 1). Climate observations from across New York State obtained from the NOAA Northeast Regional Climate Center were used to analyze trends in key variables and thus to answer the question, "Is climate changing in New York State?" The Climate group also developed a set of climate change scenarios for New York State to facilitate the assessment of potential impacts under future conditions. The group assessed the degree to which current-generation climate models are able to replicate observed climate and climate trends over the past several decades in New York State and analyzed the relevant results for New York State of regional climate models and statistical downscaling. As part of this effort, results were analyzed from the North American Regional Climate Change Assessment Program (NARCCAP), which is conducting a coordinated set of current and future regional climate model simulations. The Climate group assessed global and regional climate model simulations on the basis of the availability of climate change simulations, spatial and temporal resolution, selection of climate variables, and accuracy in representing New York State climate.

The Climate group developed a set of climate change projections for New York State as a whole and for seven climate regions within the state based on 16 global

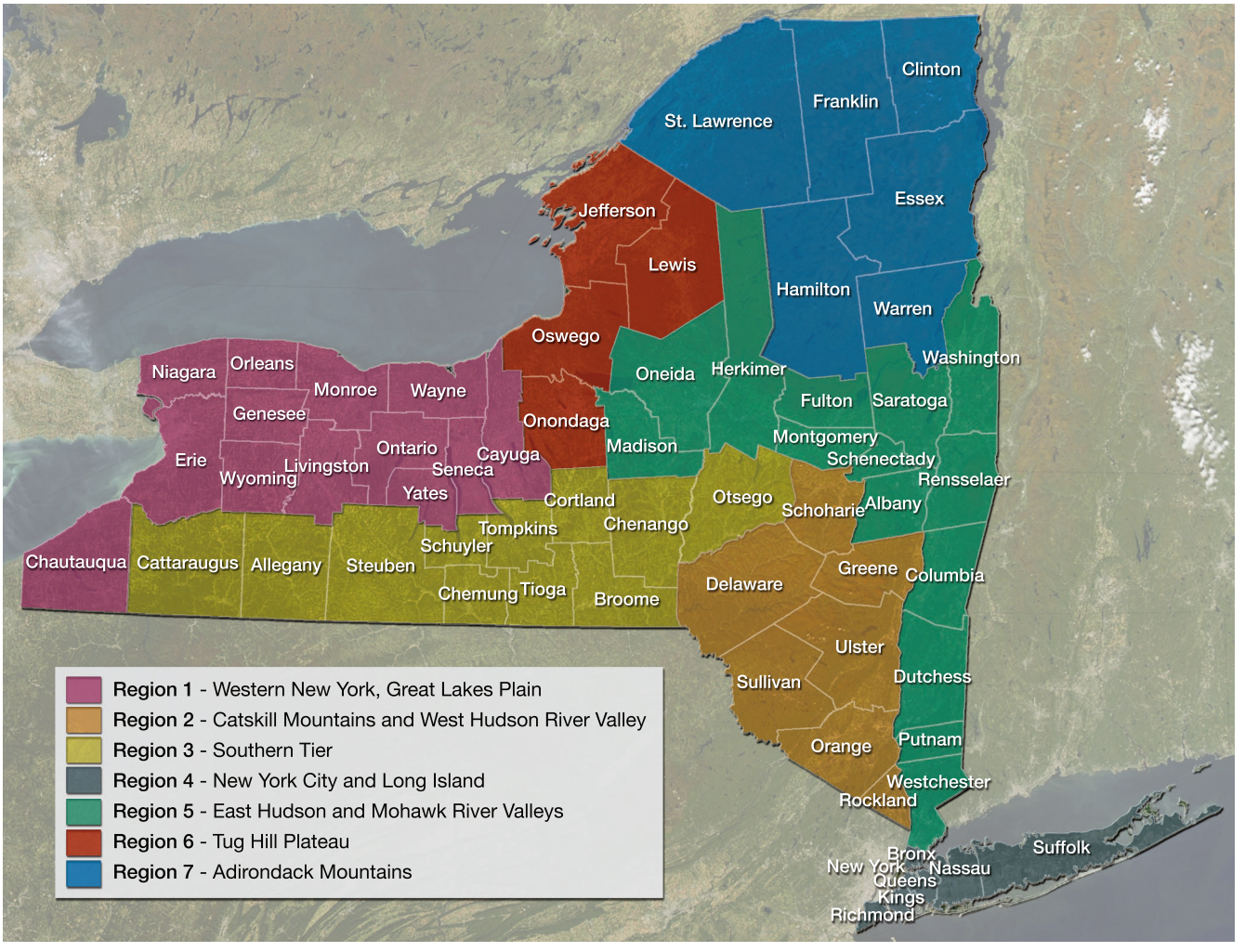

Figure 4 Climate regions of New York State

climate models and three emission scenarios (**Figure 4**). The outcomes are presented as model-based probabilities or "uncertainty envelopes"[6] around the projections. Because extreme climate events are associated with the greatest risks, the Climate group also developed model-based probabilities of the future occurrence of extreme events (e.g., heat waves, droughts, and floods) in New York State. The Climate group associated confidence levels with the projections, using a rating based on that employed by the Intergovernmental Panel on Climate Change Fourth Assessment Report (AR4) (IPCC, 2007). These ratings (e.g., "extremely likely," "very likely") are based on the correspondence between observations and climate model projections, agreement among climate models, and expert judgment.

For sea level rise, the Climate group developed a set of projections for the coastal area of New York State and conducted a historical analysis of current and historical storm damage on its infrastructure systems. The sea level rise projections were based on global climate models and methods with the addition of a "rapid ice-melt scenario" that takes into account current accelerated rates of ice melt in Greenland and Antarctica and documented rates of melting in paleoclimate records. The Climate group also analyzed tide gauge records, historical storms, future climate model simulations, and storm surge model simulations to assess the potential for changes in the spatial and temporal distribution of coastal storms (hurricanes and nor'easters) for the state.

Working with each of the sectors, the Climate group defined specific climate hazards as identified by stakeholders and produced tailored products for use in the sector assessments. Based on the vulnerabilities identified for each sector, the Climate group identified and developed a set of climate hazard indicators that could be monitored to track current climate trends and variability, and enable comparisons to historical data and future scenarios. These climate hazard indicators will help inform the development of appropriate adaptation programs and policies.

Throughout the assessment, the Climate group presented uncertainties surrounding climate modeling in general and in downscaling to regional levels within the state in particular, highlighting data gaps and monitoring needs, and indicating areas that require further research related to climate hazard and risk analysis, modeling uncertainty, and downscaling in New York State.

Vulnerability

The ClimAID Vulnerability group identified both near-term and longer-term climate vulnerabilities for New York State (see "Vulnerability and Adaptation," Chapter 2). To ensure that the assessment was aimed at the most pressing near-term climate impacts, the sectors worked with stakeholders to target vulnerabilities that currently affect the state, such as heat waves, floods, droughts, and coastal and inland flooding. The assessment also identified future climate vulnerabilities in order to provide information that will enable the state to take early action to reduce the possibility of catastrophic or large-scale climate impacts and/or to take full advantage of climate change opportunities.

Based on published literature and salience for New York State stakeholders, the Vulnerability group brought forward a range of criteria for identifying the climate change vulnerabilities in each sector. Key vulnerability criteria related to climate impacts in New York State include the following:

- magnitude
- timing (e.g., seasonality)
- persistence and reversibility
- likelihood (based on estimates of uncertainty)
- distributional aspects within a region or among socioeconomic groups
- importance of the at-risk systems
- thresholds or trigger points that could exacerbate the change

Through stakeholder interactions, analysis of previous studies, and case studies, the ClimAID assessment then evaluated how these and related criteria affect potential vulnerabilities in each sector. In communication with stakeholders, ClimAID then compiled a set of potential vulnerabilities related to climate change, highlighting those with higher impacts for New York State.

Adaptation

The ClimAID Adaptation group identified, developed, and assessed adaptation strategies for the eight sectors included in the assessment (see Chapter 2,

"Vulnerability and Adaptation"). Developing climate change adaptation strategies requires input from a breadth of academic disciplines as well as stakeholder experience to ensure that recommendations are both scientifically valid and practically sound. For each sector and in direct response to the climate hazards, key vulnerabilities, and stakeholder priorities identified in the assessment, the Adaptation group worked with the sector teams and stakeholders first to catalog existing adaptation practices already in place and then to develop and assess potential adaptation strategies to the expected climate impacts. The Adaptation group used empirical, quantitative, and qualitative methods, taking into account the relevant issues in each sector. To further expand the range of options, the group also conducted a benchmark study examining adaptation strategies such as health-alert systems already being implemented in other regions of the United States and the world.

The Adaptation group categorized existing and potential adaptations with respect to various mechanisms (see **Table 2**).

The potential for synergistic or unintended consequences of adaptation strategies was considered as part of the assessment process.

The Adaptation group also identified research gaps, data requirements, and monitoring needs in the area of climate change adaptation to help guide future research efforts in New York State. Of particular interest was the identification of existing linkages between climate science and existing and potential policy adjustments, as well as opportunities to enhance these science-policy linkages through the identification of co-benefits and other conditions. Co-benefits are positive effects that adaptation actions can have on mitigating climate change (e.g., 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 pollution, while helping to prepare for future climate change impacts.

Adaptation Mechanism	Definitions
Type	Behavior, management/operations, infrastructure/physical component, 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 2 Adaptation mechanisms and definitions

Equity and Environmental Justice

The equity and environmental justice component of ClimAID involves three types of parallel efforts: 1) development of equity and environmental justice assessments for each sector, based on a review of background literature in these areas, 2) participation in sector case studies, and 3) attention to participation of a broad range of groups or representatives in the sector meetings with stakeholders (see "Equity and Economics," Chapter 3).

For the selected case studies, the Equity and Environmental Justice group explored critical environmental justice issues with respect to intensity and extent of impacts and vulnerability and the potential for unintended consequences of adaptation. Both distributional and procedural aspects of equity and environmental justice were included in the assessment. In terms of distribution of climate hazards, there is an emphasis on identification of situations where particular groups may be systematically disadvantaged, either in terms of differences in vulnerability or capacity to adapt to climate change or in terms of the impacts of policies surrounding adaptation. Concerning distributional issues, the analysis is focused on inequalities in vulnerability to climate change, capacity to adapt to climate change, and effects of adaptation policies.

In terms of procedural elements, key considerations include incorporation of equity issues in adaptation discussions and policies, mechanisms for participation among a broad range of societal groups in future adaptation planning and policy efforts, and incorporation of equity and environmental justice stakeholders (such as associations of elderly, disabled, and health-compromised—for example, those suffering from asthma—people; low-income groups; farm workers; and small business owners) in climate vulnerability and adaptation assessments.

These distributional and procedural definitions of equity and environmental justice are used throughout ClimAID. The broader aims include consideration of potential inequalities associated with climate change along both traditional lines that have been identified within the environmental justice literature (e.g., underprivileged, minority groups), as well as along new lines that may emerge under an altered climatic regime (e.g., different-sized firms) or may result from the implementation of adaptation policies and plans.

Economics

The Economics group broadly surveyed the economic value of each of the eight ClimAID sectors as well as the potential damages and adaptation costs associated with climate change impacts. They also carried out a detailed economic assessment for a selected case study in each of the sectors regarding the monetary costs of climate change impacts and adaptation (see Chapter 3, "Equity and Economics"). The goal was to evaluate the economic costs associated with the impacts of and adaptations to climate change that are likely to affect the different sectors of the New York State economy. Where possible, variations in costs were calculated across time and space. Measures of economic impact reviewed in the analysis included human welfare losses incurred due to healthcare costs, lost income and wage differentials, and productivity and consumer losses.

The economic analysis builds on the impacts and adaptation information in each of the sectors as well as economic data from New York State and analyses of the costs of impacts and adaptation strategies elsewhere. Methods included interviews, risk-based assessment of key impacts of climate change on sectors, and the framework of cost-benefit analysis (recognizing its significant limitations in evaluating adaptation to climate change) to provide an overview of the costs of impacts and adaptation strategies.

For a selected case study in each sector, the Economics group worked with the sector groups and stakeholders to create a "short list" of potential impacts and adaptation strategies. The Economics group then ranked these impacts and strategies based on the potential costs and benefits (as avoided impacts from the vulnerability assessment) associated with each. Cost and benefit estimates were derived from standard pricing protocols and discount rate measures. For the selected case studies, the Economics group conducted economic analyses for different time horizons depending on the sector adaptations under consideration: short-term (i.e., actions within the next five years), medium-term (i.e., actions within the next five to 15 years), and long-term (i.e., actions to be taken beyond 15 years) responses. The Economics group, when possible, included the expected lifetimes (e.g., for capital-intensive infrastructure), amortization times (often linked to bonds that public entities use to finance public projects), and discount rates.

Sectors

ClimAID assessed how Water Resources, Coastal Zones, Ecosystems, Agriculture, Energy, Transportation, Telecommunications, and Public Health in New York State are currently affected by climate, how they may be affected by future climate change, and how they may adapt. Stakeholders provided key information about climate-related decisions for each sector. Each sector chapter begins with a description of the sector followed by sections that present the five integrating themes of climate hazards, vulnerabilities, adaptation, equity and environmental justice, and economics specific to the sector. A key focus of each sector chapter is a highlighted case study with in-depth analysis of potential adaptation strategies for a major climate hazard related to the sector. Case studies of other key climate vulnerabilities and adaptation methods are included in the sector chapters as well. An Appendix to each sector chapter describes how stakeholders were engaged in the assessment.

Water Resources

Water resources are dependent on multiple interacting climate factors, including air temperature and the timing and quantity of snow, rainfall, and evaporation. The Water Resources sector emphasizes in Chapter 4 that water resources in New York State are already subject to numerous human-induced stresses and these pressures are likely to increase over the coming decades.

Potential vulnerabilities for water resources and related infrastructure described in Chapter 4 include flooding, increase in duration and/or frequency of dry periods

affecting drinking water supplies in systems with low storage relative to demand, changes in demand for commercial and agricultural water related in part to climate-related factors, and declines in water quality due to higher water temperatures and decreased stream flows in summer. There may be enhanced opportunities for New York State as a potentially water-rich area in future climate conditions.

Examples of adaptation strategies for water resources detailed by the Water Resources sector for floods include 1) development of cost-effective stormwater-management infrastructure that enhances natural hydrologic processes (infiltration into soils, recharging groundwater, evaporation) and slows the movement of stormwater instead of rapidly conveying it to waterbodies, and 2) consideration of phased withdrawal of infrastructure from high-risk, flood-prone areas. For water supplies, adaptation strategies include establishment of guidelines for systematic management of water supplies under drought and implementation of an automatic gauging and reporting network to provide improved early-warning systems for supply shortages. For non-potable water supplies, the chapter suggests mechanisms for better coordination of water use in shared water bodies, the development of a public online system for tracing water usage across the state, establishment of minimum flow requirements for water withdrawals, and the preparation of a statewide water plan.

In regard to water quality, adaptation strategies evaluated in the chapter include design modifications to insure that regulatory requirements are met under current and future climate conditions; research and monitoring are needed to understand impacts of low-flows and higher temperatures on water quality, and potential changes to nutrient, sediment, and pathogen pollution in a changing climate.

Coastal Zones

The Coastal Zones sector in the ClimAID assessment focused on the regions close to the ocean, rather than on the coastal areas of the Great Lakes. Climate change vulnerabilities related to the Great Lakes are discussed in Climate Risks (Chapter 1), Water Resources (Chapter 4), Ecosystems (Chapter 6), Energy (Chapter 8), Transportation (Chapter 9), and Telecommunications (Chapter 10). Climate hazards related to coastal zones encompass the distinct but related factors of sea level rise, coastal storms, increasing coastal water temperatures, and changes in precipitation patterns. These hazards are likely to occur in combination. As highlighted in Chapter 5, coastal zones in New York State are already stressed by high levels of development, which tend to reduce groundwater recharge and degrade water quality in the region.

Potential vulnerabilities for coastal zones described in the Coastal Zones sector in Chapter 5 include more frequent coastal flooding over larger areas during storms, increased shoreline erosion leading to alteration of the coastline, changes in the location of the salt front in the Hudson River estuary, loss of coastal wetlands, and changes in fish and shellfish populations.

Examples of adaptation strategies for coastal zones detailed in Chapter 5 include incorporating climate change and sea level rise information into land-use planning (for instance, setback zones requiring that new coastal development be a minimum distance from the shore). Other adaptation strategies include preparation of a detailed inventory of shoreline assets located in at-risk areas; acquiring of open coastal land for storm protection, recreation, and ecosystems; development of design criteria for new infrastructure; design of retrofit and/or relocation options for existing infrastructure that are more flexible to changing conditions and periodic reassessment; creation of a dynamic framework for updating policy guidelines given the "moving target" of climate change; and establishment of a network of stakeholders and volunteers to assist in monitoring for sea level rise response and coordinating outreach and education efforts. Key tasks for climate change adaptation in the coastal zones are to monitor coastal hazard zones over time in order to determine optimal timing of adaptation measures and to coordinate efforts across the state.

Ecosystems

Climate hazards of particular relevance as detailed by the Ecosystems sector are warmer winter temperatures, increased frequency of summer heat stress, increased frequency of heavy rainfall events, and increased frequency of late summer droughts.

Chapter 6 characterizes the potential vulnerabilities of natural ecosystems to climate changes as the loss of

spruce/fir forests in the Adirondacks and major shifts in tree species composition across the state, the loss of hemlock stands as a result of the wooly adelgid insect pest expanding its range northward, the effects on coldwater fish with repercussions for sport fishing, and the impacts on ski and snowmobile businesses.

Examples of adaptation strategies presented in Chapter 6 for ecosystem management include creation of migration corridors, reduction of human impacts in particularly vulnerable areas, and creation of more protected areas.

Agriculture

The Agriculture sector describes the climate change hazards of particular relevance in Chapter 7. These include warmer summer temperatures and longer growing seasons, increased frequency of summer heat stress and warmer winters, reduced snow cover, increased frequency of late-summer droughts, and increased frequency of heavy rainfall events.

Chapter 7 characterizes the potential vulnerabilities for agriculture as increased insects and diseases, heightened weed pressure, and the effects of excess water and drought. Key agricultural industries in the state that may be affected include dairy and livestock (via heat stress effects on productivity and changes in feed availability and prices), and poor spring bloom and yields of apples and other temperate fruit crops because of inadequate winter chill hours.

Examples of on-farm adaptation strategies described in the chapter for dairy and livestock industries include diet and feeding management; use of fans, sprinklers, and other cooling systems; and enhancement of cooling capacity in housing facilities. For crops, on-farm adaptations include shifting planting dates; diversification of crop varieties and crops; chemical and non-chemical control of insects, disease, and weeds; expanded irrigation capacity and other capital investments; and freeze and frost protection for perennial fruit crops. Chapter 7 explores adaptation strategies beyond the farm through such mechanisms as information delivery/extension systems, locally available design and planning assistance, disaster-risk management and insurance, financial assistance, and policy and regulatory decisions.

Energy

Climate hazards of particular relevance described by the Energy sector in Chapter 8 include anticipated changes in heating and cooling degree days; changes in hydrology affecting hydropower potential, including increased flooding along the coasts and in rivers and declines in streamflow; higher water temperatures; ice and snow storms; and wind. Based on the climate change projections, the Energy chapter evaluated the implications of changing loads on energy system operations in different parts of the state.

The energy sector explored climate vulnerabilities for electricity generation, transmission, and distribution. Potential vulnerabilities for energy supply include impacts on thermoelectric power generation and power distribution, impacts on natural gas distribution infrastructure, and impacts on renewable power generation. Potential vulnerabilities for energy demand include changes in total demand, seasonal variability, and peak demand.

Examples of adaptation strategies for the Energy sector described in Chapter 8 include changes in power dispatch rules to de-emphasize the use of vulnerable system assets; establishment of larger incentives to promote energy efficiency in order to reduce energy demand during extreme heat events and associated peak load demands; strategies to promote the more rapid deployment of distributed generation technologies (including solar, on-site combined heat and power technology, etc.) to both reduce demand on the grid and reduce site-specific system vulnerabilities; construction of additional power generation capacity to offset anticipated periodic losses in hydropower availability; changes in flood protection land-use practices to site power generation capacity in areas less vulnerable to flooding or extreme weather events; and requirements that utilities begin upgrading their transmission and distribution systems to prepare for demand growth associated with changing temperature levels around the state.

Transportation

Climate hazards of particular relevance to transportation include warmer summer and winter temperatures, increased precipitation, decreased snowfall, sea level rise, increased likelihood of heat

waves, increased likelihood of coastal and inland floods, changes in extreme events including hurricanes and nor'easters, and potential changes in wind speed and patterns and associated changes in wave climate.

Examples of potential vulnerabilities for transportation from Chapter 9 include increased stress on materials from increased temperatures and precipitation, increased coastal flooding risks due to sea level rise and storm surges, increased inland flooding from more intense precipitation events (especially in urban and hilly areas), and potential impacts of saltwater intrusion on coastal infrastructure.

Examples of adaptation strategies for the Transportation sector described in Chapter 9 relate to coastal hazards, heat hazards, precipitation hazards, and winter storms including snow and ice. Strategies explored include raising the level of new critical infrastructure and essential service sites; including climate change adaptation knowledge when retrofitting older infrastructure; switching to more durable materials; changing land-use planning mechanisms; and creating increased resilience through flexible adaptation pathways in operations, management, and policy decisions.

Telecommunications

Climate hazards related to telecommunications described in Chapter 10 are extreme temperatures, heat waves, and intense precipitation; sea level rise, coastal floods, and storms; and ice storms. The primary vulnerability brought forward is communications outages caused by these climate hazards.

Adaptation strategies presented by the Telecommunications sector in Chapter 10 include tree trimming to avoid damage to existing wires, switching from aboveground to belowground infrastructure, the use of fiber optics rather than wires, and wireless systems instead of land lines. A general adaptive principle in the sector is to increase redundancy via the use of generators and backup solar-powered battery banks. Other useful adaptation strategies include relocation of central offices away from floodplains and diversification of telecommunications media, e.g., the continued development of high-speed broadband and wireless services throughout the state.

Public Health

Climate hazards described by the Public Health sector in Chapter 11 include increasing temperature (especially heatwaves), extreme precipitation and flooding events, and changing patterns of monthly temperatures and precipitation.

Vulnerabilities for public health detailed in Chapter 11 include illness and death associated with more frequent and severe heat waves. Cold-related death is projected to decrease, although increases in heat-related death are projected to outweigh reductions in cold-related death. Vulnerabilities related to climate change also include illness and death associated with ozone and fine-particle air pollution, asthma and other respiratory diseases including allergies associated with altered pollen and mold seasons, cardiovascular disease, and infectious diseases. Climate plays a strong role in the emergence and/or changing distributions of vector-borne diseases, such as those spread by mosquitoes and ticks.

Examples of adaptation strategies for public health from Chapter 11 include integrating specific information about climate-related vulnerabilities into ongoing programs of public health surveillance, prevention, and response, rather than developing new programs to deal with unique challenges; developing scenarios that integrate climate forecasts into planning around heat emergencies and heat-warning systems; and integrating climate forecasts into ongoing planning for air quality.

Case Studies

Case studies were done for each of the ClimAID sectors (**Table 1**) and are found at the ends of the chapters. Some of these served in particular as a crosscutting element across the sectors and as a way to highlight concrete climate change adaptation challenges and opportunities across the state. For these in-depth case studies, the ClimAID sectors identified, with input from stakeholders, high-priority vulnerabilities in each sector. The in-depth case studies targeted those areas, communities, subpopulations, or sub-sectors that experience frequent climate impacts under current climate conditions. The aim was to identify useful climate adaptation strategies, taking into account uncertainties in future climate projections. Through the case studies, the ClimAID team identified and

illustrated the linkages connecting climate hazards, vulnerabilities, adaptation strategies, equity and environmental justice, and economics. Specific monitoring needs were identified as well.

Assessment Outcomes

The ClimAID assessment identified key climate change vulnerabilities and presented potential adaptation strategies for eight sectors in New York State. The assessment developed a coordinated set of climate change scenarios for the state as a whole and for seven regions within the state. This information contributed to the New York State Climate Action Council (CAC) process through the creation of a generalized set of adaptation guidelines and sector templates (see **Table 3** and Annexes I and II for a description of the CAC adaptation process and the ClimAID Climate Change Adaptation Guidebook and sector templates). Further ClimAID economic analyses that contributed to the CAC process are included in Annex III of this report.

The generalized set of guidelines described in the guidebook could be used by practitioners around the state to develop flexible yet prioritized responses to the risks of climate change. The guidebook provides a stakeholder guide to climate change adaptation, including a series of steps that can help to guide the process of considering how to assess vulnerabilities and establish adaptation plans within an organization. These were developed and tested as part of the activities of the Climate Action Council Adaptation Technical Working Group. Such decision-support tools aid development of science-based adaptation strategies and describe a coordinated approach to the development of effective adaptations among and across sectors. In some cases, climate change might provide opportunities to the state; these were brought forward as well.

Another ClimAID outcome is the identification of information gaps and research needs developed in conjunction with stakeholders and decision-makers. The ClimAID data, climate change projections, reports, and findings are publicly available on the Internet.

A key lesson of the ClimAID assessment is that such a coordinated approach is useful in dealing with the challenges and opportunities inherent in climate change and the complexities of integrating adaptation into the myriad of New York State activities.

Appendix A. Project Advisory Committee Members

Name	Affiliation
Jim Austin	NYS Department of Public Service
Alan Belensz	NYS Department of Environmental Conservation
Adam Freed	New York City Office of Long-Term Planning and Sustainability
John Kahabka	New York Power Authority
Naresh Kumar	Electric Power Research Institute
Jason Lynch	U.S. Environmental Protection Agency, Clean Air Markets
Lisa Moore	Environmental Defense Fund
Christina Palmero	NYS Department of Public Service
Barry Pendergrass	NYS Department of State
Ron Rausch	NYS Department of Agriculture and Markets
Patricia Reixinger	NYS Department of Environmental Conservation
Victoria Simon	New York Power Authority
James Wolf	Consultant
John Zamurs	NYS Department of Transportation

Review and assess existing climate stress conditions. Clarify goals and identify intersections of climate trends and changes with respect to achieving goals.
Compare with climate trends and change projections for New York State. How will these affect particular sectors?
Characterize adaptation strategies for operations and management, infrastructure, and policies for thresholds and ranges of key climate variables (e.g., temperature, sea level, storm surge, and precipitation) needed to maintain resilience.
Evaluate potential adaptation strategies (cost/benefit, environmental impacts) for management, infrastructure, and policy in the short, medium, and long terms; assess effectiveness and costs relative to benefits accrued; evaluate human capacity to respond or implement the strategies.
Prioritize flexible adaptation pathways (over decades).
Review climate trends and scenarios (at regular intervals).

Table 3 Climate change adaptation assessment guidelines (see ClimAID Climate Change Adaptation Guidebook, Annex II, for full description)

Appendix B. Stakeholder Organizations Engaged in ClimAID Assessment (see Sector Chapters for complete lists)

Water Resources

NYS Department of Environmental Conservation, NYS Department of Health, NYC Department of Environmental Protection, county and local water and sewer departments, U.S. Geological Survey, U.S. Army Corps of Engineers, Delaware River Basin Commission, NYS Soil and Water Conservation Committee, Cornell Cooperative Extension, Susquehanna River Basin Commission, Directors of Lake Associations, American Wildlife Conservation Foundation, American Public Works Association, Federation of NYS Solid Waste Association, NY Forest Owners Association, Ontario Dune Coalition, Director of State Wetland Managers and State Floodplain, municipal engineers, town planners, watershed council program managers, private engineering consultants.

Coastal Zones

NY District of U.S. Army Corps of Engineers, NYS Department of State, NYS Department of Transportation, NYS Emergency Management Office, NYC Department of Environmental Protection, Metropolitan Transportation Authority, The Nature Conservancy, the Port Authority of New York and New Jersey, NYC Office of Emergency Management, FEMA Region II, National Park Service, Stony Brook University, Suffolk and Nassau Counties, NYC Department of Parks and Recreation, DEC Hudson River Estuary Program and NYS Climate Change Office, New York Sea Grant Extension, NYC Climate Change Adaptation Task Force, NYC Panel on Climate Change, NYS Sea Level Rise Task Force.

Ecosystems

NYS Department of Environmental Conservation; U.S. Geological Survey; U.S. Fish and Wildlife Service; Cornell Cooperative Extension; The Nature Conservancy; National Wildlife Federation; Audubon New York; Wildlife Conservation Society; Adirondack Mountain Club; NY Forest Landowners Association; Empire State Forest Products Association; Olympic Regional Development Authority; land, fish, and wildlife managers; maple growers.

Agriculture

Cornell Cooperative Extension, Cornell Integrated Pest Management Program, NYS Department of Agriculture and Markets, U.S. Department of Agriculture, Finger Lakes Grape Growers Association, Sweet Corn Grower Association, crop consultants, individual farmer collaborators.

Energy

Electric Power Research Institute, New York State Energy Research and Development Authority, New York State Department of Public Service, New York State Independent System Operator, Alliance for Clean Energy New York, Cogentrix, Con Edison, Dynegy, FirstLight Power, Suez GDF, National Grid, NRG Energy, NY Power Authority, TransCanada, Ravenswood, USPowerGen, Environmental Energy Alliance of NY, AES, Long Island Power Authority, NYS Department of Environmental Conservation, New York City Mayor's Office of Long-Term Planning and Sustainability.

Transportation

NYS Department of Transportation, Metropolitan Transportation Authority, Port Authority of New York and New Jersey, Amtrak, U. S. Army Corps of Engineers, CSX Corporation, NYS Emergency Management Office, NJ TRANSIT.

Telecommunications

Verizon, AT&T, Sprint Nextel, T-Mobile, UPS, FedEx, Time-Warner Cable, Federal Communications Commission, Cablevision, CTANY, National Grid, New York City Mayor's Office, Department of Homeland Security, NYS Emergency Management Office, NYC Office of Emergency Management, NYS Department of Environmental Conservation, Sea Level Rise Task Force, NYS Department of Public Service, NYS Energy Research and Development Authority.

Public Health

NYS Department of Health; NYS Department of Environmental Conservation; NYC Department of Health and Mental Hygiene; U.S. Environmental Protection Agency Region II; U.S. Centers of Disease Control; National Oceanic and Atmospheric Administration; city, State, and federal governmental agencies in the areas of environment, health, planning, and emergency management; non-governmental environmental organizations; academic institutions with research interests in public health and climate change; environmental justice organizations; clinical health sector organizations.

[1] http://www.nature.org/wherewework/northamerica/states/ newyork/science/art23583.html
[2] http://www.dec.ny.gov/energy/45202.html
[3] http://www.nyc.gov/html/planyc2030/html/plan/climate_task-force.shtml
[4] http://www.nyas.org/Publications/Annals/Default.aspx
[5] http://nyclimatechange.us/InterimReport.cfm
[6] The model-based probabilities do not encompass the full range of potential climate changes, since future greenhouse gas emissions may be higher than the emissions scenarios used in their construction.