Chapter 2

Vulnerability and Adaptation

Authors: William Solecki,[1,2] Lee Tryhorn,[3] Art DeGaetano,[1,3] and David Major[4]

[1] Integrating Theme Lead
[2] City University of New York Institute for Sustainable Cities
[3] Cornell University
[4] Columbia University Earth Institute Center for Climate Systems Research

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Introduction

The objective of this chapter is to introduce the issues of vulnerability and adaptation as a framework for analysis of the potential impacts and adaptation responses to climate change in New York State. Within the ClimAID assessment, vulnerability and adaptation are key integrating themes and are examined directly by each of the sectors.

New York State is increasingly faced with a changing climate that is beyond the range of past experiences (See Chapter 1, "Climate Risks"). Determining the potential consequences of climate change and possible responses is a complex task, as the effects of changes in climate will vary over space, through time, and across social groups.

This chapter outlines definitions and concepts associated with climate change vulnerability and adaptation (**Box 2.1**; Schneider et al., 2007). It also provides background on approaches to vulnerability and adaptation assessments and the different factors that contribute to both in the context of New York State. Details of the approaches used in the ClimAID assessment, as well as a description of the stakeholder engagement undertaken, are provided. Toward the end of the chapter, guidelines for evaluation and prioritization of vulnerability and adaptation actions are introduced.

It is reasonable to expect that adaptation to climate change will not always be a smooth process nor will it always be optimal or ideal. Adaptation will be ongoing, with mid-course corrections in response to the evolving context. The goal of the ClimAID assessment is to provide information that will help the people of New York to better understand climate change in their own context and to decide on effective policies.

The objective of the ClimAID process was to define the vulnerability and adaptation potential within each of the eight sectors. Critical to the process was identifying the opportunities and challenges within each sector now and in the future. Because of the widely varying impact levels and adaptation possibilities, study of comparative vulnerability and adaptive capacity was not explicitly included in this assessment. Connections between the sectors (e.g., communication and energy, and ecosystems and agriculture) were made as part of the analytical process, but large-scale comparisons were deemed outside the scope of the study.

Vulnerability plays an essential role in determining the severity of climate change impacts. In ClimAID, *vulnerability* is defined as the degree to which systems are susceptible to, and unable to cope with, adverse impacts of climate change (Schneider et al., 2007).

A variety of approaches can help to reduce vulnerability to climate variability and extremes, including participatory planning processes, private initiatives, and specific government policies. Thus, there is an urgent need to understand the factors that affect the climate vulnerability of the state's residents, ecosystems, and economy. It is recognized, however, that efforts to reduce current vulnerability will not be sufficient to prevent all damages associated with climate change in the long term, and that the reduction of atmospheric greenhouse gas concentrations will be necessary as well.

Box 2.1 Definitions

Vulnerability
Vulnerability to climate change is the degree to which systems are susceptible to, and unable to cope with, adverse impacts of climate change.

Adaptation
Actions that reduce the level of physical, social, or economic impact of climate change and variability, or take advantage of new opportunities emerging from climate change.

Exposure
The degree to which elements of a climate-sensitive system are in direct contact with climate variables and/or may be affected by long-term changes in climate conditions or by changes in climate variability, including the magnitude and frequency of extreme events.

Sensitivity
The degree to which a system will respond to a change in climate, either beneficially or detrimentally.

Adaptive Capacity
The ability of a system to adjust to actual or expected climate stresses or to cope with the consequences.

Source: Derived by authors from Easterling et al. 2004; Schneider et al. 2007; Smit et al. 2001

Connected to the concept of vulnerability is the capacity and capability of a society to adjust its functioning to better respond to actual and projected climate changes. This condition is broadly defined as climate change *adaptation*. Adaptation, in this context, includes those strategies and policies that can make both human and natural systems better able to withstand the detrimental impacts of climatic changes, and also potentially take advantage of opportunities emerging with climate change. Adaptations can take place at the individual, household, community, organization, and institutional level, and are defined broadly in ClimAID as actions of stakeholders.

2.1 Stakeholder Interactions

Addressing vulnerability requires merging expert and decision-makers' knowledge to capture the complexity of the vulnerabilities that influence priorities, preferences, opportunities, and constraints (NRC 1996, 2005). Accordingly, a key component of this assessment was early and continuous participation from stakeholders in the identified sectors. Stakeholders were defined broadly as individuals or groups that have anything of value that may be affected by climate change or by the actions taken to manage climate vulnerability. Examples include owners as well as practitioners, such as policy-makers, communities, and natural resource managers.

The assessment began with stakeholder-driven identification of climate change vulnerabilities through both past experience and visualized (anticipated or predicted) damage. ClimAID took this approach because the stakeholders themselves are in the best position to understand their own challenges, to decide their own course of action, and to take responsibility for those decisions (Lynch and Brunner, 2007). This type of ongoing stakeholder engagement avoids the pitfall of researchers assigning their own values to an assessment. The many specific values that figure in the interests of stakeholders vary greatly across each scale and are subject to change. But typically the values include community, property, other tangible and intangible cultural artifacts, and the animate (living) and inanimate (nonliving) natural environment, in addition to minimizing the costs of protecting such things. Issues of equity—winners and losers—and more specific environmental justice questions were also critical to understanding the full character of the sector-specific vulnerabilities (see Chapter 3, "Equity and Economics").

Given this spatial and sector-specific variability, the format and scope of stakeholder interaction varied among the ClimAID sectors. Nonetheless, a general framework was followed by all sector teams that included the following:

1) An initial stakeholder meeting with presentations that described the ClimAID project, climate change, and likely types of impacts. At this meeting the researchers solicited input on the types of impacts and vulnerabilities likely to be faced by each stakeholder. This meeting focused on the identification of key climate vulnerabilities and associated climate variables for each sector.
2) Each sector developed a survey instrument and administered it either formally or semi-formally to elicit key sector vulnerabilities and potential adaptation strategies from a broader group of stakeholders across the state.
3) Focus groups were convened with key stakeholders for ongoing discussion and advice throughout the assessment. This entailed follow-up meetings and discussions to get feedback on the progress of the assessment and refine the analysis of sector-specific climate variables and vulnerabilities. These addressed vulnerabilities and climate variables and began a dialogue on adaptation alternatives and opportunities.
4) A final stakeholder meeting was conducted by each sector team to present the results of the assessment and to identify the steps required to act upon the findings.

Within individual sectors the form of this stakeholder process varied; these differences reflected the makeup of the stakeholder base for each sector. In the Energy sector, for instance, private industry comprised the majority of stakeholders, so stakeholder meetings tended to be one-on-one interviews with individual power generators. However, the Agriculture and Ecosystems sectors were a mix of government organizations, non-government organizations, citizens, and grower associations; broad workshops were followed by targeted focus-group sessions. Additional details on the sector-specific stakeholder engagements can be found in each sector chapter.

The stakeholders added vital insight about the range of risks and uncertainties they face and how they currently manage these challenges. Local experience was integrated with scientific knowledge from a variety of disciplines and used to identify key climate variables that were particularly relevant to each sector. The ClimAID Climate team then developed sector-specific "climate products" to guide scientific inquiry, such as the detailed analysis of flooding criteria in Chapter 4, "Water Resources." This decision-focused science led the assessment of vulnerability and the development of adaptation strategies to expand the range of informed choices for stakeholders.

2.2 Vulnerability

The concept of vulnerability is useful for organizing an investigation into the impacts of climate change on the human–environment system. This perspective is particularly pertinent because it is inclusive, and human and natural systems are viewed as intimately coupled.

2.2.1 Vulnerability Concepts

Any system's vulnerability to climate change is fundamentally determined by its exposure to shocks and stresses and its baseline sensitivity to those stresses (**Box 2.1**; Smit et al., 2001), concepts that are related to each other (see **Figure 2.1**). *Exposure* is the degree to which elements of a climate-sensitive system are in contact with climate and may be related to long-term changes in climate conditions or by changes in climate variability, including the magnitude and frequency of extreme events (Easterling et al., 2004). For example, as the population of New York State moves toward coastal areas, the state's exposure to sea level rise and coastal storms increases. *Sensitivity* refers to the degree to which a system will respond to a change in climate, either beneficially or detrimentally. For example, corn is more sensitive to hot and dry conditions and is less able to take advantage of higher carbon dioxide levels than wheat, making it more physiologically sensitive to climate change (Easterling et al., 2004).

Furthermore, any system's ability to cope with exposure and/or sensitivity depends on its level of *adaptive capacity*. Adaptive capacity describes the ability of a system to adjust to actual or expected climate stresses or to cope with the consequences. Capacity, however, does not ensure positive action or any action at all. Although New York State has considerable adaptive capacity, people and property have not always been protected from adverse impacts of climate variability and extreme weather events, such as winter ice storms and extended heat waves.

Exposure and sensitivity give information about the potential impacts of climate change, while adaptive capacity is a measure of the extent to which a sector or group can respond to those impacts. The significance of climate impact depends on both the climate change itself and the characteristics of the system exposed to it (Ausubel, 1991; Rayner and Malone, 1998). The characteristics of any system—both the physical properties of its environment as well as the socioeconomic context (Smit et al., 2001; Tol and Yohe, 2007)—determine its vulnerability. These elements are place- and system-specific and are similar to those that influence a system's adaptive capacity.

Human systems are distinguished from natural systems by their capacity to anticipate environmental changes and respond accordingly so as to best prepare for expected future conditions. The vulnerability of the people in New York State is largely determined by several key factors: behavioral norms that have been institutionalized through building codes, crop insurance, flood-management infrastructure, water systems, and a variety of other

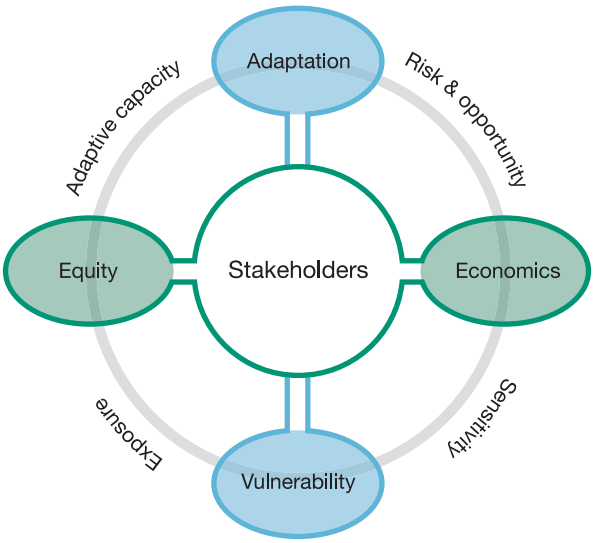

Figure 2.1 Vulnerability and adaptation

programs; socio-economic factors that affect access to technology, information, and institutions; geographic climate-sensitive health risks due to the proximity of natural resources, dependence on private wells for drinking water, and vulnerability to coastal surges or river flooding (Balbus and Malina, 2009); and biological sensitivity related to pre-existing medical conditions, such as the sensitivity of people with chronic heart conditions to heat-related illness (Balbus and Malina, 2009).

Natural systems are potentially more vulnerable to climate change than human systems because of their limited ability to adapt. Although biological systems have an inherent capacity to adapt to changes in environmental conditions, given the rapid rate of projected change, adaptive capacity is likely to be exceeded for many species (Easterling et al., 2004). Moreover, the vulnerability of ecosystems is increased by the effects of urbanization, pollution, invasion by exotic species, and fragmentation (or isolation) of habitats, all of which have already critically stressed ecosystems independent of climate change itself. An understanding of these components is essential for the formulation of effective climate policy.

2.2.2 Vulnerability Assessment Approaches

There are many different approaches to vulnerability assessment (Carter et al., 2007; Fussel, 2007; Polsky et al., 2007; Hahn, 2009). The main approaches are a risk-hazard approach (visualize future damages), a policy approach (visualize desired future), an adaptive capacity or resilience approach (assess current and future response capacity), and an integrated approach that combines aspects of these different approaches (e.g., the Center for Clean Air Policy Urban Leaders Adaptation Initiative). The risk approach is used for assessing the risk to a particular system that arises from exposure to hazards of a particular type and magnitude (e.g., Yohe, 1989; Preston et al., 2009). The policy approach is a goal- or problem-oriented approach in which analysis focuses on stakeholder-determined desired outcomes or solutions and analyzes the effectiveness of policies under climate change (e.g., Lynch et al., 2008; Tryhorn and Lynch, 2010). The adaptive capacity approach concentrates on the resources available, either actually or potentially, to cope with changes in the system (e.g., Vásquez-León et al., 2003; Brooks et al., 2005).

The ClimAID assessment uses an integrated approach that combines aspects of a risk-hazard approach and a policy approach. This approach aims to investigate vulnerability across a broad range of sectors and scales with a specific focus on the regions of New York State. Key interactions and feedbacks are represented through the use of climate scenarios (see Chapter 1, "Climate Risks") in combination with the assessment of the effects of biophysical and socio-economic stresses on society and ecosystems. The incorporation of climate change scenarios into these types of assessments is still relatively new, and few protocols (e.g., building codes and standards, flood-protection guidelines) have yet been established by practitioners and their governing bodies (e.g., engineering associations, insurance providers).

2.2.3 Vulnerability Measures and Metrics

There is a great diversity of methods and approaches for measuring vulnerability (Adger, 2006; Polsky et al., 2009). Because vulnerability reflects both social and physical aspects of systems, it is not easy to reduce to a single metric and is not easily quantifiable.

Specific variables do not measure vulnerability directly, so many assessments attempt to quantify vulnerability by using indicators as proxies. This is because focusing on purely physical or social variables may not capture the issues that make individuals or localities vulnerable to multiple stresses. Many assessments combine indicators to create a single numeric index (e.g., vulnerability to flooding and the Livelihood Vulnerability Index) (Speakman, 2008; Hahn et al., 2009). For example, the Human Development Index uses life expectancy, health, education, and standard of living as a measure of national well-being (UNDP, 2007). If this approach is used, variable and causal linkages between indicators (e.g., between standard of living and health) must be well established to ensure that the relationship is valid. The indicators that are chosen to represent vulnerability need to be sensitive to redistribution of risk within a vulnerable population or system (Adger, 2006).

While composite indices can provide valuable insight into current patterns of physical and socioeconomic vulnerability, they can also lead to a loss of information about how the different indicators contribute to vulnerability and are unable to incorporate changes in

the larger national and global context. Patterns of vulnerability have become increasingly dynamic as the result of rapid, ongoing economic and institutional changes. The dynamic character of vulnerability means that it is particularly difficult to assess, as the factors that shape vulnerability—both the physical properties of a system and the socioeconomic context—are in a constant state of flux (Adger and Kelly, 1999; Thomas and Twyman, 2005). Under these circumstances, a flexible approach based on place-specific local variability within the broader state/federal policy guidelines and frameworks is suggested (Cutter and Finch, 2008). This requires replacing traditional indicators (e.g., share of drought-resistant crops, rainfall, per-capita staple food production, population density, infant mortality index) with dynamic indicators (e.g., change in access to credit, change in crop subsidy policies, change in national trade or investment policy stance, change in soil fertility, change in climate variability). (For more examples and explanation of the differences between traditional and dynamic indicators, see Leichenko and O'Brien, 2002.)

2.2.4 Evaluating Vulnerability in ClimAID

Throughout New York State, climate impacts and vulnerabilities vary widely by region and sector, as do the resources available to respond to climate change, necessitating regional solutions to adaptation rather than the proverbial one-size-fits-all approach. The ClimAID approach to assessment attempts to simplify the complex issues associated with climate change by dividing problems geographically and sectorally bringing into focus realities that are often discounted or overlooked in the development of the national- or state-level frameworks. Although detailed quantitative vulnerability studies were beyond the scope of this assessment, specific case studies for key vulnerabilities within each sector used a qualitative approach. A focus on key vulnerabilities is necessary to help policy-makers and stakeholders assess the level of risk, evaluate, and design pertinent response strategies.

The ClimAID assessment categorizes vulnerability through an evaluation framework and associated mapping activities (see Chapter 3, "Equity and Economics") across eight sectors and seven regions of the state. General conclusions and recommendations regarding vulnerability and potential vulnerability-reduction and adaptation strategies were then developed for each sector.

Within each sector chapter, vulnerabilities have been evaluated depending upon those systems or regions whose failure or alteration is likely to carry the most significant consequences. More details can be found in the sector chapters. In most instances, evaluation was qualitative, based on stakeholder input and the degree to which the relevant climate parameters were shown to change in the downscaled projections. A common set of criteria for evaluating vulnerabilities was used within each sector. The factors that were considered characterized anticipated impacts based on the "reasons of concern" developed by the IPCC Fourth Assessment Report (Schneider et al., 2007) (see **Box 2.2**).

The ClimAID assessment has not specifically identified vulnerability indices for New York State as a whole. Instead, each sector has worked individually to identify stakeholder characteristics that could potentially lead to climate vulnerability. The assessment uses different physical, socio-economic,

Box 2.2 Factors used to evaluate vulnerability in New York State

Magnitude (e.g., the area or number of people affected) and the intensity (e.g., the degree of damage caused)

Timing (is this impact expected to happen in the near term or in the distant future?)

Persistence (e.g., are previously rare events becoming more frequent?)

Reversibility (over the time scale of generations)

Likelihood (estimates of uncertainty)

Confidence in likelihood estimates

Distributional aspects within a region or among socio-economic groups

Importance of the at-risk systems—If the livelihoods of many people depend on the functioning of a system, this system may be regarded as more important than a similar system in an isolated area (e.g., a mountain snowpack system with large downstream use of the meltwater versus an equally large snowpack system with only a small population downstream using the meltwater)

Potential for adaptation (the ability of individuals, groups, societies, and nature to adapt to or ameliorate adverse impacts)

Thresholds or tipping/trigger points that could exacerbate change or initiate policy

Source: Schneider et al., 2007

and ecological indicators to measure vulnerability for different systems within the sectors. For example, the Coastal Zones sector uses coastal vulnerability index maps (Thieler and Hammer-Close, 2000; Gornitz et al., 2004) to illustrate the vulnerability of the New York State shoreline to sea level rise by considering a number of contributing geomorphological, geological, and oceanographic factors. The Water Resources sector has demonstrated that vulnerability to flooding in parts of New York State has often been related to socioeconomic factors. Similarly, the Public Health sector shows that those at higher risk for heat-related mortality are among the most vulnerable urban residents: elderly, the low-income populations, those with limited mobility and little social contact, those with pre-existing health conditions and belonging to certain racial/ethnic groups, and those lacking access to public facilities and public transportation or otherwise lacking air conditioning.

2.3 Adaptation

Adaptation to climate change focuses on actions that take place in response to a changing climate. Adaptation strategies do not directly include actions to reduce the magnitude of climate change, generally referred to as climate change mitigation, but instead present actions to lessen the impact of climate change or take advantage of changes caused by a shifting climate. In the context of the ClimAID project, two categories of adaptation strategies were examined, those that 1) reduce the level of physical, social, or economic impact of climate change and variability; or 2) take advantage of new opportunities emerging from climate change.

2.3.1 Adaptation Concepts

Adaptation strategies and actions have a direct connection to the risk and hazards management tradition. Individuals and organizations attempt to reduce their vulnerability and exposure to threats. Stakeholders and decision-makers within each ClimAID sector have developed extensive protocols to avert and manage hazards and to promote greater disaster-risk reduction. In many ways, adaptation to climate change fits into this tradition. How adaptation strategies are now being developed reflects, in turn, both historical risk management and the emerging understanding of the magnitude and significance of ongoing climate change. In this way, climate change represents either an increased manifestation of established hazards (e.g., possibly longer and more intense droughts) and/or new hazards (e.g., emergence of a new type of pathogen moving northward with climate change).

Potential adaptation strategies can be further defined within a range of elements, including economics, timing, and institutional organization. Economic issues include the costs and benefits of adaptation and the relative distribution of both (see Economics section in Chapter 3, "Equity and Economics" and additional economic analysis in Annex III). A critical issue is the overall cost-to-benefit ratio and how much economic advantage there is to taking a specified action. There are difficulties in calculating these costs due to the issues in determining the "social rate of time discount," that is, the rate used to compare the well-being of future generations to the well-being of those alive today. Potential opportunity costs also are important to determine, given what is understood about the rate of climate change and the sensitivities of the system in question. A primary question is whether the adaptation strategies take place in the short-term (less than 5 years), medium-term (5 to 15 years) or long-term (more than 15 years).

Crucial to the issue of timing is whether there are tipping points associated with dramatic shifts in the level of impacts and/or vulnerabilities and whether these tipping points become triggers for new policies and regulations. A tipping point can be defined as a moment in time when the operation of a system would move to a new phase as a result of changes in internal dynamics or a perceived need by associated managers. An example of a tipping point could be the occurrence of a major heat-mortality event such as occurred in Europe in 2003. Over 25,000 people, many of them elderly, died due to a heat wave that was five standard deviations away from normal (IPCC, 2007). This event triggered a massive public health adaptation response to heat waves in European countries that is in place today.

Another primary category of adaptation is the institutional organization of the entity responding to climate change. A key issue here is whether the stakeholder is administratively organized to collect and

monitor climate change conditions and to incorporate this information into decision-making analysis on a regular and ongoing basis. These conditions are necessary for the development of adaptation strategies that enable flexible responses to evolving scientific understanding and uncertainty; that is, putting in place adaptations that can be adjusted or shifted over time (i.e., years or decades) as new information and evidence indicate the need for shifts in strategies and policies to better respond to emerging climate threats and opportunities.

2.3.2 Adaptation Assessment Approaches

Adaptation to climate change includes a wide diversity of issues and considerations that are important for assessing the context and need for adaptation strategies and their potential success. Broadly speaking, two primary sets of considerations for adaptation strategies can be defined during an assessment: 1) those associated with the entity implementing, proposing, and/or planning the adaptation; and 2) those associated with the character of the adaptation strategy itself, and its (potential) impact.

Within the scholarly literature on adaptation assessment, these two sets are further refined into several elements of the adaptation development, planning, and implementation process. These elements include focus on the type of entity from which the adaptation emerges, the character of the strategy (e.g., timing, extent, impact), and adaptation financing.

Public and Private Sectors as Agents of Change

In the first category, a key element focuses on whether the adaptation emerged from the private sector or from the public sector. A related consideration is whether the stakeholder is traditionally proactive or reactive with respect to decision-making, in general, and issues of risk and vulnerability, specifically. Some ClimAID sectors—especially public health and water resources—spend extensive time and resources preparing for crises and, in turn, could be seen as having heightened capacity to plan and respond to climate change. Additional adaptation strategies can be implemented during times of crisis, because these moments open a policy window during which an opportunity for administrative reform and change can occur.

Gradual vs. Transformative Change

Some stakeholders have pre-existing trigger points for regulatory and administrative action, such as those that are embedded in heat and drought advisories and alerts. These trigger points can become the administrative structure within which adaptation to climate change can be developed. Related to this point is the question of whether climate change adaptation can be implemented simply as an extension or adjustment of existing rules, guidelines, or regulation, or if it must be implemented as a more significant transition within the stakeholder organization or operation. For example, stakeholders in all of the sectors have climate- or weather-risk policies, some of which are more developed than others. (In the Transportation sector, this could vary from New York City Transit's flood-mitigation policies to rural municipalities' road salting and plowing schedules to deal with snowfall.) Another related consideration is the possibility that the adaptation can be derived as an extension of existing codes, standards, or practices, or it can require a more significant reorganization of the entities' management structure and agenda.

Technical vs. Non-technical Adaptations

Another key element is whether the adaptation is technical in nature (e.g., engineering modification, hard option) or non-technical in nature (e.g., non-structural, soft option), such as policy and/or regulatory change. A connected issue is whether the strategy involves a simple adjustment to how the climate hazard is managed or involves a larger, system-wide change. An example could include increased efforts to provide shoreline protection from increased flood frequency (structural) as opposed to a more dramatic staged retreat from the coast (non-structural). Other elements associated with the character of the adaptation strategies include the timing of adaptation and its consequence. For example, is there a trigger point for action when the likelihood of a negative impact becomes sufficiently great such that a stakeholder response becomes necessary? Critical related questions are: How is the trigger point defined, and who determines that the trigger has been reached? Underpinning these considerations are questions of uncertainty and system complexity that result from the fact that, at the sector level, the organization and structure of a system, in

many situations, are not fully understood and the potential response to climate change remains only partially known.

Financial Elements

In regard to the character of the adaptation strategy itself, funding and expected benefit-cost ratio are two of the most important elements. The issue of liability is important as well because it directly relates the climate-hazard information to action. As information about climate change and its impacts becomes available, decision-makers are increasingly faced with the question of when and with what caveats to present this knowledge to the public. Will withholding information make them liable for potential future damages? Or will actively responding to the information result in liability issues if certain parties are more adversely affected as a result of the actions taken? For example, who will pay the costs of increased air conditioning? And who will pay for the costs associated with the loss of property use if sea level rise projections place additional property within the 100-year flood zone?

2.3.3 Assessing Adaptation in ClimAID

Within the ClimAID project, the investigators assessed adaptation strategies within New York State in a way that reflected the specific interests and information requirements of climate change stakeholders and decision-makers within the state. The assessment frame was distilled from the considerations and elements defined in Section 2.4.2 and translated into particular categories relevant to each ClimAID sector. The categorization procedure set the stage for the adaptation strategy evaluation process that followed.

To perform the adaptation assessment, ClimAID sector investigators inventoried a set of the sector stakeholders' present and planned adaptation strategies (the set does not include every possible adaptation strategy but highlights representative ones). As part of the analysis, each ClimAID sector team defined potential adaptation strategies that were identified by engaging in discussions and holding meetings with the stakeholders. The sector analyses focus both on those adaptations designed to limit exposure to increased climate risk as well as those that enhance the stakeholder's ability to take advantage of opportunities presented by climate change, such as a switch in crop choice or shifts in water availability (e.g., water shortages may occur in other parts of the country while water supplies may increase overall in New York; see "Agriculture" and "Water Resources" chapters).

Adaptation Categories

The adaptation strategies developed through the stakeholder process were first divided into categories: type, administrative group, level of effort, timing, and scale (**Box 2.3**). "Type" includes whether the strategies were focused on management and operations, infrastructural change, or policy adjustments. "Administrative Group" defines the strategies as either emerging from the public or private sectors and the level of government (e.g., local/municipal, county, state, national) to which they pertain. "Level of Effort" indicates whether the strategy represents an incremental action or a larger-scale paradigm shift. "Timing" highlights the period during which the adaptation strategy will be implemented—short-term (less than 5 years), medium-term (5 to 15 years), or long-term (more than 15 years)—as well as the speed of implementation and the presence of established or known tipping points and policy triggers. "Scale"

Box 2.3 Categories of adaptation strategies

Type
- Behavior
- Management/operations
- Infrastructural/physical component
- Risk-sharing
- Policy (including institutional and legal)

Administrative Group
- Public or private
- Local/municipal, county, state, national government

Level of Effort
- Incremental action
- Paradigm shift

Timing
- a) Period
  - Short-term (less than five years)
  - Medium-term (five to 15 years)
  - Long-term (more than 15 years)
- b) Abrupt Changes
  - Tipping points
  - Policy triggers

Scale
- Widespread
- Clustered
- Isolated/unique

includes the overall spatiality of the adaptation impacts, specifically cataloging if the adaptation strategy impact is widespread, clustered, or isolated/unique (e.g., impact associated with a specific site or location) throughout the state.

Adaptation Strategy Evaluation

Once adaptation strategies have been categorized, evaluating them is a critical yet complex task. Strategy evaluation can help stakeholders to determine an order to implement strategies and aid in developing a broader agency- or organization-wide adaptation plan. Criteria that can be used to help evaluate strategies include cost, feasibility, efficacy, timing, resiliency, impacts on environmental justice communities, robustness, and co-benefits/unintended consequences (Major and O'Grady, 2010). These are briefly described below:

- Cost—What will be the economic impact of the strategies, including an estimate of short-, medium-, and long-term benefits and costs?
- Feasibility—How feasible is the strategy for implementation both within an organization and from perspectives such as engineering, policy, legal, and insurance? Are there expected technological changes that would impact future feasibility?
- Efficacy—To what extent will the strategy, if successfully implemented, reduce the risk?
- Timing—When is the strategy to be implemented? What factors affect the implementation schedule?
- Resiliency—To what extent is the strategy, when implemented, able to withstand shocks or stresses—either physical or social (e.g., policy) in character?
- Impacts on environmental justice communities—Will strategy impacts be negative or positive for communities already stressed by environmental risk exposures?
- Robustness—Is there the potential to install equipment or upgrade infrastructure that is designed to withstand a range of climate hazards? Are there opportunities for flexible adaptation pathways, i.e., incremental management adjustments associated with the pre-determined objective of updating adaptation based on emerging science and management needs?
- Co-benefits/unintended consequences—Will any strategies have positive or negative impacts on another stakeholder or sector? Is there potential for cost sharing? Are there impacts on mitigation of greenhouse gases? Are there impacts on the environment or a vulnerable population?

Through meetings and discussions, sector leaders and stakeholders evaluated adaptation strategies via the criteria defined above. However, the quantification of benefits and costs was often confounded, particularly when sectors were represented by multiple stakeholders with diverse interests and values. This was particularly true in the Ecosystems sector, where the values of factors such as diversity of species and the preservation of natural areas are extremely difficult, if not impossible, to quantify. In many cases, net benefits to one group may be viewed as losses by a different stakeholder group; for example, warmer winters may benefit homeowners due to reduced heating costs and, at the same time, cause losses for the winter recreation industry. Finding the common interest under these circumstances is a complex task. Other topics to emphasize are the spatial and temporal character of the adaptation strategies and how easily modified they may be in response to a changing climate through time, i.e., do they contribute to the development of flexible adaptation pathways.

2.4 Outcomes

A major aim of the ClimAID assessment is to help New York State manage, rather than eliminate, uncertainties related to a changing climate. Drawing

Box 2.4 ClimAID vulnerability and adaptation assessment approach with links to the five integrating themes

1) Identify current and future climate hazards	C
2) Conduct risk assessment inventory	C, V, EEJ, E
3) Characterize risk of climate change	C, V, EEJ, E
4) Develop initial adaptation strategies	A
5) Identify opportunities for coordination	A
6) Link strategies to capital and rehabilitation cycles	A, E
7) Prepare and implement adaptation plans	C, V, A, EEJ, E
8) Monitor and reassess vulnerability and adaptation	C, V, A, EEJ,

C = Climate (Chapter 1);
V = Vulnerability (Chapter 2);
A = Adaptation (Chapter 2);
EEJ = Equity and Environmental Justice (Chapter 3);
E = Economics (Chapter 3)

on the work done as part of other state- and local-level adaptation assessments, especially the New York City Panel on Climate Change (Rosenzweig and Solecki, 2001; Rosenzweig et al., 2007; Rosenzweig et al. 2007b; NYCDEP, 2008; Major and O'Grady, 2010; NPCC, 2010), the ClimAID assessment developed an approach (see Annex II) that together can help stakeholders to evaluate adaptation strategies and to develop adaptation plans through a series of steps (**Box 2.4**). This basic approach is broadly applicable to each of the sectors. The framework allows knowledge about climate, vulnerability, adaptation, equity and environmental justice, and economics to be closely integrated with the needs of stakeholder decision-making as climate adaptation policy is developed by the State.

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