Chapter 3

Equity and Economics

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Introduction

The ClimAID assessment evaluates a number of critical issues that transcend all of the sectors. These integrating themes include vulnerability, adaptation, equity, and economics. Each merits special attention because they are vital to the development of meaningful and effective policy and regulatory responses to climate change. This chapter focuses on two of these themes, namely equity and economics, and describes how they are used within the assessment. The chapter also presents some of the key overarching findings of these two themes.

The equity theme, which emphasizes both equity and environmental justice, focuses on distributional and procedural inequalities that may be associated with climate change vulnerability and adaptation. Within New York State, vulnerabilities to the impacts of climate change and the capacity to adapt to these changes are highly uneven across urban and rural regions, sectors, and demographic groups. Heat waves, for example, typically have a disproportionately negative effect on low-income, elderly populations living in urban areas. These populations may have limited ability to afford air conditioning and may be unable or reluctant to seek relief from the heat outside due to lack of mobility or fear of crime. The equity and environmental justice element provides a means to identify inequalities associated with both climate impacts and adaptation strategies and also helps to ensure that underprivileged or underrepresented constituencies have a voice in climate policy at the local and state levels.

The economics theme, which concentrates on cost-benefit analysis of selected climate change impacts and adaptation options, presents critical information about the potential financial expenditures associated with different adaptation strategies. The economics theme explores the costs and benefits of adaptation strategies via case studies from each sector. Concerning heat waves in New York City, for example, some types of adaptation strategies, such as provision of subsidization of air conditioning for low-income urban residents across the state, will entail new financial outlays. Such outlays may be offset by health-related cost savings due to the reductions in heat-related morbidity (illness) and mortality (death). The economic costs of climate change in New York State are described in more detail in a related study titled "An Economic Analysis of Climate Change Impacts and Adaptations in New York State." This study, which is presented in full in Annex III, assesses of the costs associated with the impacts of climate change and evaluates the costs and benefits of various adaptation options for each of the ClimAID sectors.

Although both of the themes employ distinct methods and perspectives, both entail a common set of tasks, including:

1) *Development of general assessment statements for each sector.* These statements, which are grounded in the existing social science and policy literatures, describe the general characteristics of each sector and highlight key equity and economic issues within them.
2) *Execution of case studies.* In concert with the sector teams, analyses of equity and economic implications for a select set of in-depth case studies were also conducted.
3) *Development of synthesis statements.* Drawing from the general assessments and case studies, these statements identify vital policy issues that are common across the sectors.

Taken together, the themes present multi-faceted evaluations of the equity challenges and economic costs of impacts and adaptations presented by each sector. The themes not only permit analyses of distinct aspects of the vulnerabilities, climate risks, and adaptation options of each sector, but also help integrate the assessment by contributing to a common framework of analysis.

3.1 Equity and Environmental Justice

In recent years environmental change issues have been increasingly framed in relation to equity, drawing on some of the debates originating in the environmental justice movement (Cutter, 1985; Cutter and Solecki, 1986). Among equity-based analyses of climate change, the focus is typically on issues including responsibility for the mitigation of greenhouse gas emissions, vulnerability and capacity to adapt to climate change, and inter-generational equity (Müller, 2002; Kemfert and Tol, 2002; Tonn, 2003; Brown, 2003; Gardiner, 2004; Adger et al., 2006; Farber, 2007; Roberts and Parks, 2007; Beckman and Page, 2008; Paavola, 2008). A growing awareness of the equity issues surrounding

climate change is not surprising, given widespread recognition that the effects are likely to be highly uneven. Some individuals, households, farmers, or communities will experience significant negative effects, such as the loss of life and property due to climate extremes, loss of agricultural productivity, increased water stress, and so on. Others may experience only minor negative effects, and still others may experience net benefits, such as lower winter heating costs due to warmer temperatures, a longer agricultural growing season, increased forest productivity, or an expansion of tourism due to land-use changes (O'Brien and Leichenko, 2006 and 2010). Within New York State, climate change impacts are likely to be highly uneven across regions, sectors, and households, and already-disadvantaged populations may be particularly vulnerable to climate change. These issues are incorporated into the ClimAID assessment via an emphasis on equity and environmental justice.

3.1.1 Concepts and Definitions

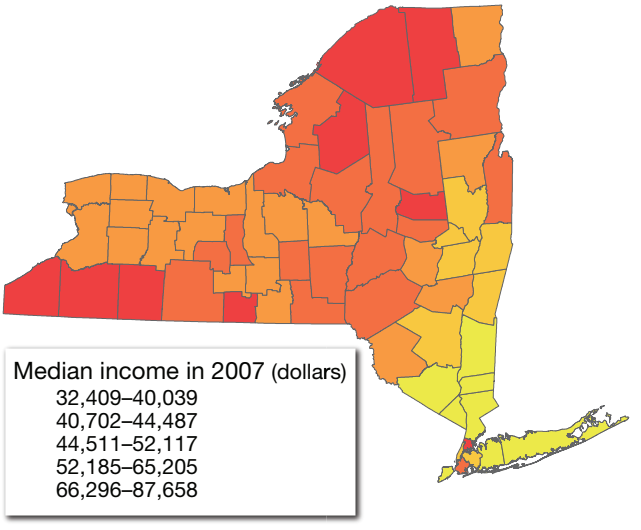
Differences in climate change vulnerability are partly the result of differences in physical exposure to climate extremes or shifts in temperature and precipitation patterns across regions. They also emerge as the result of differences in ability to respond and adapt (IPCC, 2007). Vulnerability to extreme heat, for example, is influenced by differences in age, income, and health status. The ability to withstand business interruption as the result of a lengthy power outage following a storm is affected by differences in capital resources and the availability of climate-risk insurance among different firms and industries. Adaptation to sea level rise among coastal cities is affected by differences in financial resources for relocation or hardening (i.e., the construction of structures such as seawalls, bulkheads, storm surge barriers, and dikes) of vulnerable transportation infrastructure (Leichenko et al., 2010).

Although environmental justice efforts have historically focused on the inequitable distribution or concentration of environmental burdens such as brownfields and/or industrial facilities, these efforts have broadened in recent years to include consideration of equity and justice issues surrounding global pollution issues, particularly climate change (Ikeme, 2003; Agyeman et al., 2003). Connecting environmental justice with climate change raises questions such as whether adaptation policies have disproportionate impacts on low-income communities, whether such communities will have to bear a disproportionate share of adaptation costs, and whether low-income communities will be subject to a disproportionate share of the negative impacts of climate change.

Mapping Spatial Inequalities in New York State

Inequalities surrounding climate change often play out in terms of differences in the ability to engage in adaptation planning. Over the past several years, a number of large U.S. states and major cities have developed plans for climate change adaptation (Thomas, 2009). Yet, even within a relatively wealthy country such as the United States, there are dramatic differences in household income between urban and rural portions of the country, where median household incomes in typical urban counties may be double, triple, or even quadruple those of rural places. Some of the poorest counties in the United States are located in rural areas of states such as Mississippi, Alabama, and West Virginia and in areas that are home to Native American Indian reservations (U.S. Census, 2009).

Within the state of New York, the median household income in 2007 was $52,944. However, the variation across counties is noteworthy, with higher-income counties concentrated in the southeastern portion of the state and lower-income counties concentrated in the northern and western parts of the state (**Figure 3.1**).



Source: American Community Survey (2007), U.S. Census

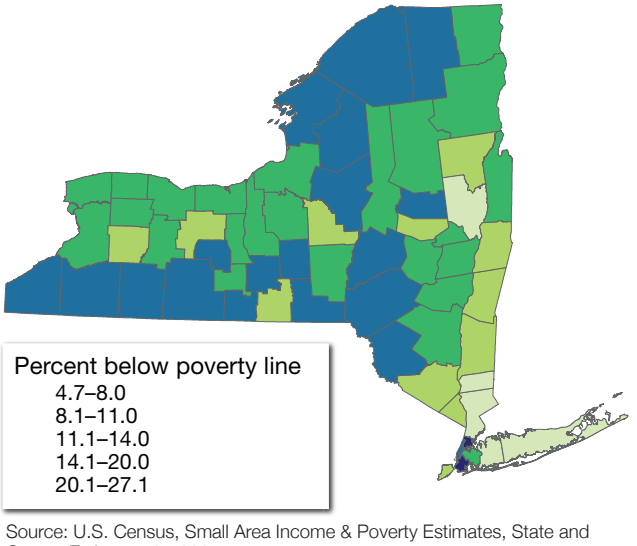
Figure 3.1 New York State income disparities reveal spatial differences in a region's ability to adapt to climate change

Although income levels are generally higher in the New York City metropolitan area, this is also the region of the state with the greatest income disparities. County incomes in the New York metropolitan area range from Nassau County with a median household income of more than $87,000—among the richest in the United States—to Bronx County with a median income of just over than $32,000 (U.S. Census, 2009). Such differences in income are indicative of differences in relative wealth within regions of New York State, which influences factors such as property values and local tax revenue and may translate into differences in the adaptive capacity of particular locations. In sector chapters, the equity and environmental justice analysis considers differences in vulnerabilities and adaptive capacities at finer levels of spatial resolution, including census block groups and tax parcels.

The success of adaptation strategies frequently hinges on the ability to change behavior, to access new capital inputs, and to manage new technology and knowledge. The interrelated problems of persistent poverty and low rates of educational attainment critically limit the intellectual and financial resource base that a household can draw on to adapt successfully. Furthermore, at a collective level, these problems can segregate communities and regions from access to social networks and cultural assets (i.e., social capital) that could expand their adaptation efforts through innovation and partnerships with outside industries and government.

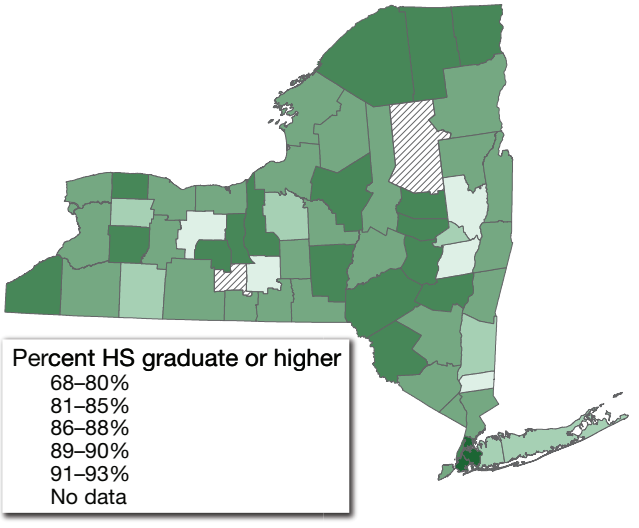
In New York State, regional inequalities in wealth, education, and poverty tend to overlap (**Figures 3.2** and **3.3**). Estimates of county poverty levels are based on household poverty thresholds, as defined by the U.S. Census. In 2007, the poverty threshold for a family of four with two dependent children was $21,027 (U.S. Census, 2010). The highest rates of poverty and lowest rates of education are concentrated in urban counties such as the Bronx and Brooklyn. These extremes are all the more notable given that residents of neighboring counties, such as Nassau and Westchester, enjoy some of the highest average rates of educational attainment and lowest poverty in the state. Poverty also is endemic in rural counties in other regions, such as those north of the Adirondacks and in the Southern Tier.

Vulnerability and adaptation are also related to spatial differences in economic structure. Although New York State's economy is highly diversified, there are important differences in natural-resource dependency. In particular, the socioeconomic base of a number of rural counties is tied to employment in climate-sensitive industries (**Figure 3.4**). For example, in both Lewis County and Yates County, more than 10 percent of employment is based in agriculture and natural resources. The density of these jobs in the local economies underscores how certain regions may face disproportionate need for adaptation planning, raising critical questions about who is responsible for adaptation and how to equitably distribute adaptation-related resources.



Source: U.S. Census, Small Area Income & Poverty Estimates, State and County Estimates for 2007

Figure 3.2 Poverty rates by county as an indicator of a region's ability to adapt to climate change

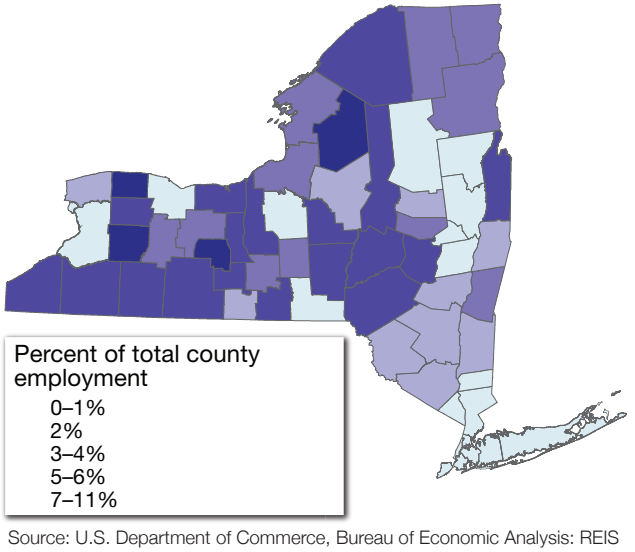


Source: U.S. Census American Community Survey, 2007

Figure 3.3 Educational attainment as a potential indicator of a region's ability to adapt to climate change

Defining Equity and Environmental Justice within ClimAID

The maps below draw attention to spatial differences across New York State in the ability of communities to adapt to climate change. These differences, which are likely to influence climate change vulnerability and adaptation, emphasize issues of distributional equity. Within the climate change literature, distributional equity may be defined as the fair distribution of outcomes or impacts associated with climate change (Kasperson and Dow, 1991). However, an emphasis on environmental justice requires attention to and recognition of both distributional and procedural equity. Within the broader literature on environmental justice, distributional equity emphasizes securing benefits and amenities such as access to parks and greenspace to offset environmental burdens that specific communities face. Procedural or process equity entails an equitable approach to environmental decision-making (Lake, 1996). In the context of climate change, procedural equity may be defined as inclusion of representatives of all affected communities and groups in decisions about climate change adaptation, including emergency preparedness and emergency response. Efforts to achieve procedural equity include mechanisms to ensure participation of affected actors in policy decisions (O'Brien and Leichenko, 2010).



Source: U.S. Department of Commerce, Bureau of Economic Analysis: REIS Table CA25N

Figure 3.4 Employment in agriculture and forestry, fishing, and other related activities as a percentage of total county employment

In defining the equity and environmental justice element within the ClimAID assessment, the study draws insights from both distributional and procedural approaches used within the environmental justice and climate change literatures. In terms of distribution, 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. While the equity and environmental justice analysis for some sectors emphasizes commonly recognized groups within the environmental justice literature (including lower-income, minority, and Native American populations), there is also consideration of equity effects across other units of analysis, such as rural regions versus urban areas, small versus large firms, or small versus large cities, as appropriate for the type of analysis conducted for each of the sectors.

For all of the sectors, the analysis of distributional equity issues includes consideration of:

- Inequalities in vulnerability to climate change;
- Inequalities in the capacity to adapt to climate change;
- Inequalities in adaptation policy benefits; and
- Inequalities in the effects of the adaptation policies.

In terms of procedural equity elements, key considerations include the incorporation of equity issues in adaptation discussions and policies, the mechanisms for broad and meaningful participation in future adaptation planning and policy efforts, and the incorporation of input from the equity and environmental justice stakeholders in the ClimAID assessment.

These distributional and procedural definitions of equity and environmental justice are used in various components of the assessment. The broader aims include consideration of potential inequalities associated with climate change along 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.

3.1.2 Approach for Equity and Environmental Justice Assessment

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 review of background literature in these areas; 2) development of integrated case studies; and 3) attention to input from environmental justice groups or representatives in the sector meetings with stakeholders. Descriptions of each of these elements are presented below.

General Assessment for Each Sector

The first task for the equity and environmental justice element entails the creation of assessments for each sector that identify the key, relevant equity and environmental justice issues based on review of past studies. (Elements of these sector-specific assessments, including references to the studies reviewed, are presented in the sector chapters.) Each of the sector assessments addresses the same general questions. The questions, which emphasize equity and environmental justice issues surrounding both vulnerability and adaptation within each sector, are as follows:

1) Are there preexisting socioeconomic or spatial inequalities that make certain regions, communities, or groups of individuals systematically more vulnerable to the impacts of climate change on the sector? What groups or areas are likely to shoulder a disproportionate share of the burden from these impacts? Potential differentiations by group include socioeconomic status, education, health/disability, race, age, gender, culture, or citizenship. Community differentiations include the extent of segregation, access to health care, unemployment, and poverty/wealth/assets.
2) Are there groups, communities, or regions that are less able to adapt to the impacts of climate change and, therefore, merit special attention during adaptation planning?
3) Within the range of adaptation strategies in each sector, which strategies are more likely than others to exacerbate underlying socioeconomic disparities? Could some strategies change social and environmental dynamics so as to create emergent or unintended disparities? Are there situations in which strengthening adaptive capacity in one area or for one group may, in turn, create, reinforce, or exacerbate maladaptation or vulnerability (either in an absolute or relative sense) in other groups or areas?

Each of the above questions was considered in a broad review of prior work on environmental justice and climate change. The questions also guided work on the integrated case studies, as discussed below. The sectoral assessments also touched on two additional questions related to the equity and environmental justice consequences of adaptation planning:

1) Are there certain groups, communities, or regions that may be systematically underrepresented during adaptation planning, unable to access or influence the process and procedures of decision-making, or otherwise disempowered, unable, or disinclined to consider adaptation when it is likely to be in their interest to do so?
2) When designing adaptation strategies, are there ways to insert mechanisms that encourage or ensure fair outcomes, whether preventive (e.g., avoiding and adjudicating disputes), corrective and compensatory (e.g., payments to an affected party to compensate for loss of access to a resource), or retributive (e.g., sanctions and penalties)?

Although a full assessment of these latter two questions was beyond the scope of the present study, raising these questions nonetheless represents an important starting point for incorporation of equity and environmental justice issues into future adaptation planning and policies in New York State.

Role in Integrated Case Studies

The equity and environmental justice component also entails participation in integrated case studies for each sector. (These case studies are presented in full in each of the sector chapters.) In some instances, these case studies explore impacts of past climate extremes, such as a past flood event or heat wave. Such cases serve as historical analogues, whereby the research teams may consider the equity and environmental justice consequences of a past climate event in order to extract lessons on how to reduce distributional inequalities in planning for future climate change. Other case studies project future climate change impacts on various sectors and industries and explore potential future equity issues

that may arise under various scenarios. Generally speaking, the historical and scenario-based case studies are also intended to provide guidance on what to plan for in order to ensure that disadvantages do not fall disproportionately on specific groups or individuals, or to develop appropriate compensation mechanisms.

The equity and environmental justice contribution to each of the case studies entails a combination of descriptive and mapping analyses of existing data to explore potential inequalities in vulnerability or adaptive capacity, and also includes a qualitative evaluation of suggested future adaptation plans to identify potential equity and environmental justice issues.

The descriptive analysis explores such questions as: Are there systematic inequalities in spatial patterns of vulnerability based on income and demographic characteristics of the affected populations? Are there other types of systematic inequalities associated with vulnerability or adaptive capacity among firms within the sector or communities that depend upon the sector?

The qualitative analysis emphasizes future adaptation plans and considers the potential equity impacts of various adaptation options and policies. Questions include: Are the negative effects or costs of adaptation policies likely to be felt or borne by particular spatial areas, communities, or groups? What options are available to mitigate or compensate for these effects?

Although a full assessment of past environmental justice activities and activism for each case study topic was beyond the scope of the present study, in-depth examination of lessons from past experiences with responding to environmental issues represents an important area for further research. It is likely that past experiences with addressing local environmental concerns will offer lessons for efforts to adapt to climate change, particularly in those regions of the state that have a strong and vibrant history of community activism around environmental topics.

Stakeholder Participation

The third component of the equity and environmental justice theme entails putting procedural elements of equity and environmental justice into place as part of the execution of the ClimAID assessment. More specifically, the goal of this component is to encourage broad stakeholder participation, particularly from members of environmental justice groups throughout the state and from other groups that may be disadvantaged as a result of climate change or negatively affected by adaptation policies. To accomplish this goal, sector leaders were asked to include, where possible, environmental justice representatives in their stakeholder meetings. Results of the stakeholder discussions are incorporated into the sector chapters.

3.1.3 Key Findings of Equity and Environmental Justice Assessment

This section highlights some key equity and environmental justice findings from each of the sector assessments and case studies and identifies a number of common themes that cut across all sectors. As noted above, the full equity and environmental justice assessment for each sector and the case study analyses are presented in each of the eight sector chapters.

Water Resources

Communities using larger water systems in New York State are generally less vulnerable to drought and other types of water supply disruption than the 1.9 million people who rely on domestic well water and several hundred thousand others connected to small public water systems. Because larger systems have greater storage capacity, they are more able to withstand drought-related shortages. Increased flood risks as the result of more frequent and severe storm events are a concern in many areas of the state, and there are also disparities between small and large communities in their capacity to respond to flood events. Among different population groups, the elderly and disabled tend to be more vulnerable to immediate flood hazards due to limited mobility, while renters may be more subject to long-term displacement following a flood event. Adaptation efforts need to take into account differences in community and population flood vulnerabilities.

Within the state's urban areas, two other critical water-related equity concerns include siting and operation of waste treatment facilities and the widespread use of combined sewer systems. Wastewater treatment facilities are often located in lower-income, minority communities. Under climate change, such facilities may

need to be relocated due to rising sea levels or expanded to address new threats to water quality. Combined sewer systems, which collect and treat both municipal wastewater and stormwater, are disproportionately concentrated in the state's older, urban areas (and particularly in neighborhoods with high concentrations of low-income, minority residents). Combined sewer systems contribute to localized flooding and serious water quality problems during periods of heavy rainfall. These flooding events, known as combined sewer overflows (CSOs), are likely to become worse with more frequent heavy rainfall events under climate change. Adaptation planning needs to take into account the concerns of environmental justice communities that are affected by siting decisions and/or CSOs.

Coastal Zones

Coastal zone populations in New York State are increasing and becoming more dense relative to other regions in the state (see discussion of coastal zones in the economics section below). Coastal populations living within floodplains in New York City and Long Island tend to be more affluent than populations living outside the floodplains. These differences are largely due to amenity appeal, which makes property near the water more desirable. However, there are pockets of poverty across the New York State coastal zone, and many of these areas are home to concentrations of minority populations. These areas are also often the sites where infrastructure facilities such as wastewater treatment plants and solid waste management facilities are located. Within the coastal zone, elderly and disabled residents and households without cars are particularly vulnerable to flood hazards. Adaptation strategies, such as relocation of critical infrastructure away from coastal areas, need to take into account the needs of disadvantaged environmental justice populations.

Ecosystems

Outdoor recreation regions and communities dependent on natural resources may be negatively affected by higher temperatures and reduced snowfall or snowpack as the result of climate change. Communities in the Adirondacks region that depend on tourism associated with cold-water fisheries (e.g., trout) or wintertime snow-based activities (e.g., skiing and snowmobiling) may be particularly vulnerable. The difficulty in putting economic values on ecosystem goods and services may make some issues of concern for ecosystems more challenging to develop as policy priorities as compared to climate change impacts in other sectors. One area of policy priority for low-income communities living in flood-prone regions throughout the state is re-evaluation of local land use and development policies in order to prevent the destruction of natural buffers such as wetlands and dunes. These natural buffers help prevent flooding and offer protection to these communities from future flood hazards associated with climate change.

Agriculture

Differences in farm characteristics, including farm size, productivity, and production costs, are likely to play a significant role in determining which farmers and which regions are most vulnerable to the negative effects associated with climate change. Smaller farms are particularly vulnerable to climate change, because they typically have less capital to invest in on-farm adaptation strategies (such as stress-tolerant plant varieties or increased chemical and water inputs) and less ability to take advantage of cost-related scale economies associated with such measures. While climate change is also likely to create new opportunities for farmers that have enough capital to take risks on new crops or new production technologies, many of the state's farmers may lack the resources or information needed to make strategic adaptations (such as increased irrigation or cooling capacity on dairy farms) that will be required to remain profitable.

For low-income communities throughout the state, the connection between climate change and issues of food justice is an area of growing concern. Food justice issues, such as lack of access to grocery stores in lower-income urban and rural communities, and inability of lower-income individuals to afford healthy, fresh foods, may be exacerbated if adaptation to climate change leads to substantial increases in food prices. Increased incidence of extreme heat or prolonged droughts may also undermine community gardens and other local food production systems that serve lower-income areas.

Energy

Climate change is likely to increase summer energy demand for air conditioning throughout the state. For

lower-income residents, increased energy costs associated with air conditioning may be difficult to afford. Residents living in urbanized areas that are already subject to urban heat island effects may bear a disproportionate burden with respect to energy costs. Potential synergies exist between adaptation and equity strategies for developing smart grids and solar power as well as for combining retrofitting with local green jobs programs. The siting of new energy facilities, including those producing alternative energy, such as wind farms, may raise new environmental justice concerns.

Transportation

Transport-disadvantaged populations, including the elderly, the disabled, and those without a car, are vulnerable to climate-change-related disruptions in public transportation systems. Within urban areas of the state, lower-income individuals without cars who depend on public transportation to get to work may be especially at risk. Making roads and transportation infrastructure climate-resilient (e.g., by relocating roads or public transport lines and financing such improvements via higher tolls or fares) has the potential to reinforce existing inequalities in access or to create new patterns of inequalities.

Telecommunications

The availability of communication services in New York State is largely a function of the uneven density of the state's population. Cell phone coverage and broadband service tend to be more complete and comprehensive in urban areas than in rural areas. Restoration of communication services following a storm event (e.g., an ice storm) typically happens first in urban areas and then in rural areas, with smaller, remote communities likely to be restored last. Within remote rural areas, elderly, disabled, and health-compromised populations are especially vulnerable to communication service disruptions associated with storm events.

Public Health

Increasing temperatures and increasing frequency of heat waves raise a number of equity-related issues in the health sector. Those at higher risk for heat-related mortality (death) and morbidity (illness) include elderly and infirm populations, children, low-income residents of urban areas, certain racial groups, and communities in the northern parts of New York State that are not yet well adapted to heat (e.g., rates of air conditioning are 30 percent higher in New York City than in Buffalo) (U.S. Census Bureau, 2004 and 2003). Diseases such as asthma are also highly climate-sensitive. The threshold of asthma severity differs by socioeconomic status, in large part due to differences in health-care access. lower-income residents and racial minorities living in urban areas tend to have a higher incidence of asthma and may be adversely affected by higher temperature regimes.

Cross Cutting Equity and Environmental Justice Results

The equity and environmental justice analysis reveals a number of crosscutting issues that are common to many of the sectors. Most notably, the analysis shows that the same New York State regions and populations are often at risk for adverse impacts of climate change across multiple sectors. Concerning spatial regions, communities located in the state's coastal zones are vulnerable to sea level rise and storm surge. Densely populated urban coastal areas, where rapid evacuation may be difficult in the event of hurricanes or other large storms, are especially at risk. Rural areas, in general, and small rural towns, in particular, tend to be more vulnerable and have less capacity to cope with all types of extreme climate events (e.g., floods and ice storms) and other types of climate stressors, such as droughts or changes in snowfall or snowpack. Small rural communities with limited government resources and rural areas that depend on outdoor tourism (e.g., cold-water fishing) or on agricultural industries (e.g., dairy farming) may be especially in need of adaptation assistance. Within the state's urban areas, lower-income neighborhoods, particularly those subject to urban heat island effects or located in flood-prone areas, typically have limited local institutional capacity to cope with climate risks and may, therefore, need adaptation assistance.

Among demographic groups, elderly, disabled, and health-compromised populations tend to be more vulnerable to climatic hazards, such as floods and heat waves. Low-income groups are also vulnerable on several counts, including limited ability to meet higher energy costs, dependence on public transportation, and

lack of access to affordable health care for management of climate-related diseases such as asthma. Although there is little evidence of a distinct pattern of vulnerability to flood hazards along traditional environmental justice lines (i.e., race and ethnicity), there are notable pockets of vulnerability, particularly in New York City, with respect to the impacts of coastal storms. It is also important to note that mental stress associated with climate change is an issue for underprivileged, environmental justice populations. These populations are already concerned about how everyday environmental stresses are affecting their neighborhoods; climate change adds another layer of uncertainty.

Across firms and industries, the general pattern is that smaller enterprises (e.g., small farms, small tourism operators, small retail businesses) are less able to cope with climate-related business interruptions and stresses than larger enterprises. Smaller firms tend to have more limited capital reserves and are, therefore, less able to withstand loss of revenue associated with power and communication service disruptions. Small businesses also tend to have less capital available to make investments to promote adaptation, such as the use of snowmaking machines in ski areas.

In addition to overlapping vulnerabilities across regions, populations, and firms, another common theme across the sectors concerns the need for attention to the secondary equity and environmental justice effects of adaptation. Many adaptation strategies have indirect equity and environmental justice impacts. For example, increased air conditioning usage during heat waves is an important adaptation from a public health standpoint. However, more air conditioning will also mean increased energy demand, which may potentially increase air pollution and asthma cases among vulnerable groups. Within the agriculture sector, increased use of pesticides as an adaptation to climate change may lead to increased chemical exposure for farm workers (many of whom are international migrants or members of minority groups).

Finally, concerning the legislative process, there is a need for attention to distributional environmental justice issues in all climate-change-related legislation; just as important, there is a need to ensure that environmental justice groups have a voice in the policy process. Climate policy formation should take into account the needs of disadvantaged populations in adaptation planning and should also include representatives of these communities in the adaptation planning process.

3.2 Economics

Economics plays a critical role in understanding climate change impacts, vulnerability, and adaptation. Climate change will bring additional economic costs to New York State. Fundamental to this discussion are questions of: How much will climate change impacts and related adaptation measures and vulnerability issues cost? How will these costs be distributed throughout the state? In the ClimAID assessment, potential economic costs are analyzed broadly across each sector and within the case studies in more detail. The focus is largely on direct costs rather than indirect or secondary/tertiary costs. Where relevant, the economic benefits of climate change impacts and adaptation are also highlighted. As noted above, the economic costs of climate change for the ClimAID sectors are examined in more detail in Annex III.

3.2.1 Concepts

The way economists address the relationship between the economy and the environment —and, in particular, global climate change—can be framed in terms of three broad issues: 1) tradeoffs between natural capital, such as wetlands, and manufactured capital; 2) tradeoffs between the needs of the present and those of the future; and 3) tradeoffs between economic efficiency and equity.

Ecologists and economists address the tradeoff between natural capital (e.g., health of fish populations for recreation and commercial industries) and manufactured capital (e.g., dams, roads, factories) very differently. This tradeoff can be viewed through the lens of two alternative paradigms: the theories of weak sustainability versus strong sustainability.

With regard to the weak sustainability criterion, one analysis notes that "[t]he weak sustainability position, held by many mainstream neoclassical economists (such as Solow and Weitzman), is that almost all kinds of natural capital can be substituted by man-made capital" (Ayres, 2007). The neoclassical view of sustainability is

informed by a faith in the workings of markets coupled with a technological optimism. These premises assure society that as an exhaustible natural resource is depleted, its price will rise exponentially and demand will ultimately go to zero. During this inexorable process, society will make transitions to other technologies, and ultimately the use of the exhaustible resource will be displaced by an inexhaustible backstop technology (e.g., solar, wind, or hydrogen energy) that is expected to meet all our future needs(see Solow, 1974).

The strong sustainability criterion for sustainable development rejects the notion that natural and man-made capital are freely substitutable. The strong sustainability criterion requires that society preserves minimum quantities of natural capital stocks and ecosystem services, rather than allowing man-made capital to displace natural capital stocks over time. (For a full exposition of the ecological economic critique of neoclassical environmental economics, see Daly, 1997a; Solow, 1997; Stiglitz, 1997; and Daly 1997b.)

Another analysis clearly frames the implications of these alternative paradigms for climate change mitigation policy: A policy based on strong sustainability requires that a cap on greenhouse gas emissions be based on the assimilative capacity of the global ecosystem. A policy based on weak sustainability is based on the presumed tradeoffs between economic activities and the value of ecosystem services. For example, we might as a society accept a loss of biodiversity or an increase in coastal erosion if these costs are outweighed by other economic benefits.

In practical terms, cost-benefit analysis, which lies at the foundation of neoclassical economic policy analysis, acknowledges tradeoffs among human capital (e.g., labor), manufactured capital, and natural capital. This cost-benefit analysis must weigh the cost of adaptation and mitigation strategies against the costs associated with climate change.

The second point of contention in the climate change debate within economics is the tradeoff between the needs of the present and those of future generations. One report, the Brundtland Commission report, incorporates this tradeoff within the report's definition of sustainable development: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). This debate has practical implications for climate change policy and, in particular, the cost-benefit analyses that economists use to critique alternative adaptation and mitigation strategies. In applying cost-benefit methods to the study of global climate change, it first must be acknowledged that: 1) the costs of increasing atmospheric concentrations of carbon dioxide (and other greenhouse gases) will be felt gradually over a number of decades; and 2) the benefits of reducing greenhouse gas emissions will be realized over a long time period.

One economic analyst who explicitly addresses the issue of intergenerational equity argues that we should treat present and future generations equally; thus he proposes that we should weight the benefits of mitigation and adaptation policies equally, whether they occur now or in the distant future (Solow, 1974).

A recent analysis reviews the ongoing debate between those who believe that the discount rate used in climate policy studies should reflect the real return on investments (the "descriptive" approach) and those who feel that it should be based on intergenerational equity concerns, i.e., the relative weight placed on the needs of current versus future generations (Dietz and Maddison, 2009). In the context of the ClimAID assessment, the intergenerational equity approach would justify increased investments in greenhouse gas adaptation and mitigation policies.

Finally, an economic analysis of global climate change policy must account for distributional equity. Although cost-benefit analysis essentially compares the total costs of climate change versus the total costs of adaptation and mitigation strategies, any policy intervention will have winners and losers. In practice, neoclassical economists have focused on economic efficiency and have tended to neglect issues of equity as being outside the realm of their analysis. The equity and environmental justice analyses in the ClimAID assessment, however, explicitly address the issue of distributional equity.

3.2.2 Methodological Foundations of Cost-benefit Analysis

The standard neoclassical economic criterion for a Pareto-optimal allocation of resources requires that there be no possible reallocation of resources that could

make at least one person better off while making no individual(s) worse off (Bergson, 1938; Boulding, 1952; Tietenberg, 2000). As a rule, any policy change will have both winners and losers. Hence, the practical criterion for evaluating government policies and programs is whether the policies and programs result in a potential Pareto improvement, i.e., that, in principle, the winners should be able to compensate the losers. Consider, for example, a project to prevent riverine flood damage by selective retreat from the flood plain. If the projected benefits (avoided damage, ecosystem benefits) exceed the value of the property within the flood plain, the beneficiaries (society, in this instance) should pay the losers (property owners) to compensate them for their property losses, and create parklands or open space.

The social welfare maximization criterion does not require that any particular outcome will satisfy the ClimAID assessment's criterion for social justice (or distributional equity). Neoclassical welfare economics, however, enables the analysis to address the issue of equity within a market economy, as follows.

Economists often act as if the issues of economic efficiency and equity can be addressed independently. Economists prefer to leave issues of equity to the political process, through taxation and public finance. Once the government has addressed issues of equity through the budgetary process, the free market should be left to "work for itself" (Stiglitz, 1991). In practice, however, neoclassical environmental economists have addressed almost exclusively the issue of efficiency, arguing that actual compensation as it relates to equity issues is outside the realm of economics (Splash, 1993).

The basic tool of cost-benefit analysis in applied welfare economics is an implementation of this social welfare maximization criterion: If the benefits of a proposed policy change exceed their costs (i.e., if the benefit-cost ratio exceeds 1), then it would clearly be possible for the winners to compensate the losers.

It should be noted that an alternative framework for project evaluation has long been available that takes into account not only efficiency but also other objectives such as redistribution. (For an example of a classic study that takes this approach, see Dasgupta et al., 1972.) While this approach has many advantages, it is not used within the economics component, which is designed to study the efficiency costs and benefits of impacts and adaptations.

The choice of an appropriate social discount rate must accommodate the issues of economic efficiency, intergenerational equity, and the global nature of climate risk. As these issues remain unresolved, the ClimAID assessment performs sensitivity analyses with rates of 0 percent and 3 percent, reflecting lower rates of discount used in many climate studies, most notably in the Stern Report (Stern, 2007). Some analysts advocate higher rates, for example Nordhaus (2007a; 2007b). Stern (2009) argues that such higher rates are inappropriate for large-scale social decisions where the risks of inaction are to a significant extent unknown (and possibly very high), and the costs of present action are relatively low.

3.2.3 Economic Analysis in the ClimAID Assessment

For sectors whose goods or services are traded in organized markets, the ClimAID assessment relies on market data on observed input-output quantities and prices in order to directly estimate the social marginal benefits (i.e., the value to society of a small increase in the scale of an adaptation measure, such as an additional mile of shoreline protected from storm damage) and social marginal costs (i.e., the cost of that same adaptation measure, in this case the cost to protect an additional mile of coastline). With sufficient available data, social marginal benefits and social marginal costs can be estimated with conventional statistical economic modeling. When adequate data are not available, existing estimates from reliable sources are included in the analysis. In the case of sectors whose goods or services are not traded in markets, widely accepted techniques to represent values for such goods and services are used, as summarized below:

1) For sectors in which statistics on economic activity are available (e.g., energy, agriculture), a regression-based approach is followed. The relationship between demand and supply in a market are statistically estimated from price, quantity, and other data.
2) When market data are not available, the assessment follows a different approach, based on survey information and other sources. Various techniques are available to estimate the economic value of non-traded goods and services, including direct methods such as contingent valuation (surveys that provide a gauge of people's willingness

to pay, for example, to preserve a particular ecosystem from being developed). Indirect measurement techniques of consumer preference include the following:

- *Travel costs.* This approach may be used, for example, to estimate the economic losses associated with a decrease in tourism or sport fishing because of likely declines in trout populations in New York State.
- *Hedonic prices.* For example, we can compare the prices of similar houses within the flood plain and outside it, and estimate the economic value placed on the risk of flood damage.
- *Defensive expenditures* (e.g., costs incurred by wastewater treatment facilities to guard against flooding or costs to install cooling equipment at dairy farms).
- *Cost of illness/health production function* (morbidity/mortality). For example, in the public health sector, the economic assessment uses the Environmental Protection Agency's model of cost of illness and/or the human capital approach to estimate lost wages with appropriate modifications. Defensive expenditures to avoid illness, such as expenditures on air conditioning or inhalers for asthma sufferers, may also be estimated, as required.

3.2.4 Key Findings of Economics Assessment

This section highlights some key economics findings from each of the ClimAID case studies.

Water Resources

Flooding is already a major problem in the United States, with estimated damages of $50 billion during the 1990s. During that same period, flood losses in New York State were estimated at $441 million (Pielke et al., 2002).[1] It is possible that flood losses will be exacerbated by climate change. The majority of New York State flood events consistently occur in the ten Southern Tier counties. The case study for the water resources sector examines the 2006 flooding along the Susquehanna River within Broome County, with a specific focus on Binghamton, its population center, and surrounding rural areas. During the 2006 flooding, approximately 3,350 parcels with an aggregate value of $560 million were flooded. (The actual property losses were much less than the total value of property within the flood zone.) In the absence of adaptation measures, it is expected that flood losses may become both more frequent and severe. Planned withdrawal from the flood zone, together with floodplain management, is expected to minimize the risk to people and property.

Coastal Zones

The baseline metrics used to determine New York's vulnerability to storms and coastal flooding are the total population and value of real estate within the 100-year floodplain. Climate-change-induced sea level rise will, over the next century, increase the size of the 100-year floodplain. Moreover, at the current rate of natural population increase and residential construction within the coastal zone, an increase in both population and property at risk from a 100-year storm surge can be projected. Conservative estimates of the population and property at risk, based on the Long Beach and Great South Bay case studies, suggest that the population and property at risk will have increased by as much as 20 percent from 2000 to 2080. Within the two case study areas, the population at risk in 2080 may approach 150,000 and the value of real estate at risk may be approximately $9 billion. Coastal storms also cause considerable damage to beaches and dunes. For example, for the November 2009 Nor-Ida storm, the costs of beach replenishment and repair of damaged groins on a 5,000-foot segment of beach at Point Lookout totaled approximately $5.6 million (U.S. Army Corps of Engineers, 2010).

Ecosystems

Ecosystem services benefit millions of people both in the state of New York and beyond the region. These benefits include air and water purification, drought and flood mitigation, generation and preservation of soils, cycling of nutrients, maintenance of biodiversity, partial stabilization of climate, control of agricultural pests, and many others. Because most of these services are provided by nature free of charge, most economic indicators do not track their value. Nevertheless, there are other ecosystem services that are more pecuniary (able to be quantified financially) and/or that directly result from healthy ecosystems in New York State. Total

annual combined expenditures for these services in New York State are significant. In 2006, expenditures on these services surpassed $3.2 billion, including $926 million on fishing, $716 million on hunting, and $1.57 billion on wildlife-watching recreational activities (U.S. National Fish and Wildlife Service, 2008). Trout fishing is prominent in most of the state's major fishing areas, and trout is the second most popular species for recreational fishing in the state after black bass (Connelly and Brown, 2009a).

Potential adaptations to ameliorate rising temperature effects include maintaining or increasing shading vegetation along stream, river, and lake shorelines and minimizing disturbances that would impede water flows and groundwater inputs. More elaborate interventions for high-priority regions could include piping cold water from springs or lakes located at higher elevations to shoreline locations of lakes at risk for heat stress, and manipulations that might darken the color of the water and therefore increase the propensity to form stable thermal stratification. Adding lime to some Adirondack lakes has already been practiced in order to partially compensate for pollutant acidity and promote primary production. This practice also tends to darken water color, which shades deeper waters and allows thermal stratification to occur.

Coldwater fish habitat conditions are an important determinant in the extent of climate change impacts that these species are likely to experience. As a result, other studies have proposed a holistic approach to ensure that the integrity and diversity of habitat conditions are maintained or restored. Such strategies often focus on management of the entire watershed rather than improvements to particular streams or lakes (Williams et al., 2009). Costs for such comprehensive measures depend on the size of the watershed and/or the extent of the effort. An initiative to restore a 153,000-acre watershed in the Upper Colorado River Basin over the course of 10 years, for example, was estimated to cost close to $2 million. Similar costs ($2.01 million) were estimated for the 10-year restoration effort of the South Branch of the Potomac River (Williams, 2009).

Agriculture

In 2007, dairy products were ranked as the top agricultural commodity in New York State—valued at more than $2.3 billion and representing more than half of the state's total farm receipts.[2] However, increasing temperatures over the next several decades have the potential to affect milk production. As average temperatures increase, milk output is likely to decrease, in particular among high-producing herds (85 pounds per day per cow) with substantially greater sensitivity to heat stress. The decrease in milk production for cows that produce 65 pounds per day is estimated to be on the order of 30 percent, but the amount of lost production is more than twice that much for a cow producing 85 pounds per day by the end of this century.[3] By the 2050s and certainly by the 2080s, heat stress on cows alone is predicted to generate notable losses unless effective cooling systems are in place. While such systems represent added investments, the investment costs are relatively modest. For example, the cost of investing in a forced evaporative cooling system for a 48-cow milking herd was calculated at ~ $1,600. Total operating costs amounted to $0.23 per cow per day, including increased food intake of 5 to 6 pounds/cow/day and $0.20/cow/day for both water and electricity costs, assuming 800 hours of run time during the summer season. With an increased milk yield of 4 pounds/cow/ day, and the milk valued at $0.50/cow/day, the estimated payback period for the cooling system was 124 days, given a net income of $0.27/cow/day (Turner et al., 1997). These costs have a high likelihood of paying for themselves through increased milk production over a short time span (one to three years depending on the number of days that require farmers to use the cooling systems) (Turner, 1997). Many barns in New York currently have extensive ventilation systems to promote healthful conditions. Given the current animal types and barn configurations prevalent in New York's dairy industry, farms will increasingly need such cooling systems as temperatures increase.

Energy

Economic losses from electric service interruptions are not trivial, as indicated by estimates of damage costs resulting from major power outages, which have occurred in the past during extreme events such as heat waves and ice storms. The economic impact of the 25-hour blackout that affected most of New York City in July 1977 was assessed at $60 million,[4] while the cascading blackout on August 14, 2003, was estimated to affect approximately 22,000 restaurants, which cumulatively lost between $75 million and $100 million in foregone business and/or wasted food. In addition,

the City of New York reported losses of $40 million in lost tax revenue and $10 million in overtime payments to city workers.

Other localized service outages in New York City include the July 3–9, 1999, blackout that affected 170,000 Con Edison customers, including 70,000 customers in Washington Heights (New York State PSC, 2000), and the nine-day blackout that began on July 16, 2006, in Long Island City, Queens, and affected 174,000 residents (Chan, 2007). Total claims paid by Con Edison in 2006 as a result of the outage amounted to $17 million. An estimated additional $100 million was spent by the utility on recovery costs to repair and replace damaged equipment (New York State Office of the Attorney General, 2007). Preventing the losses described above, as well as the number of mortality cases due to heat stress, will require further strengthening the reliability of the electric grid in order to minimize the number of power outages under changing climate conditions.

Transportation

Among the consequences of coastal flooding resulting from a 100-year coastal storm surge are possible inundation of transportation infrastructure—including airports, bridge and tunnel access ramps, highway and rail tunnels, and marine ports. The economic losses associated with coastal flooding include damage to infrastructure, costs of service restoration, and economic activity that is lost for the duration of the storm and, to a lesser extent, the recovery period. The severity of coastal flooding and, hence, associated economic losses increase with sea level rise. The coastal storm case study estimates losses for three scenarios: a base-case scenario (current sea level), a 2-foot sea level rise scenario, and a 4-foot sea level rise scenario. (The 2-foot and 4-foot sea level rise scenarios are roughly equivalent to the GCM and rapid-ice-melt scenarios, respectively, for the 2080s.) The total costs—infrastructure damages and economic losses—for a 100-year coastal storm range from $58 billion in the base-case scenario to $84 billion in the 4-foot sea level rise scenario.

Telecommunications

The Telecommunications infrastructure case study examines the economic losses associated with a winter (ice and snow) storm in central, western, and northern New York. Because communication and power outages typically occur simultaneously in New York State, these loss estimates may be understood as the combined costs associated with an outage in both sectors. As is the case in the Transportation sector, the losses are associated both with damage to infrastructure as well as the economic losses associated with interruption of service. As data on telephone outages are limited, the estimates of service restoration times and economic losses are based on data collected for the electric utility sector. (Because telephone and electrical wires within the study area are co-located on the same telephone poles, this is a realistic assumption.) The analysis estimates that the time to fully restore service following a major winter storm is five weeks, with 10 percent of households restored in the first 24 hours and 50 percent restored within 10 days. The total estimated cost of a major winter storm is nearly $2 billion, of which nearly $900 million comprises productivity losses (due to service interruption) and $900 million comprises direct damage (e.g., spoiled food, damaged orchards, replacement of downed poles and electric and phone/cable wires, medical costs, emergency shelter costs).

Public Health

Prolonged heat waves have the potential to result in increased mortality cases, in particular in metropolitan areas such as New York City, where the heat island effect in the summer exacerbates the increased temperature periods. Mortality costs associated with heat stress in New York City can be estimated by multiplying the Environmental Protection Agency's value of a statistical life (VSL) estimate of $7.4 million (i.e., the economic value of a person's life based on earning potential) by the number of increased mortality cases (U.S. EPA 2010, 2004, 2000). While this estimate places a numeric value on the loss of a person's life, it is important to recognize that VSL measures do not take into account the emotional and social impacts and tolls that are incurred by a family and community following the loss of a loved one. Such impacts cannot be measured in quantitative terms.

A common adaptation measure during heat waves is the use of air conditioners.[5] While in New York City most people are prepared to endure heat waves (approximately 86 percent of New York City residents have some type of air conditioning system in place), one concern is that vulnerable populations (e.g., the elderly

and people with mental disabilities) require additional measures to prevent heat-stress-related mortality. New York City and several other cities across the United States have instituted emergency response plans to address increased mortality rates during extreme heat events. Within New York City, a network of cooling centers is currently in place to help residents cope with extreme heat. The city has also initiated a program to provide free air conditioners to elderly residents who are unable to afford them. Benefits associated with implementing such systems are seen to outweigh their costs (Ebi et al., 2004), and such systems may need to be expanded in response to climate change.

3.3 Conclusions

Attention to issues of equity and economics is vital to the development of responses and adaptations to climate change in all sectors of New York State. As described in this chapter, equity issues arise in terms of the distribution of the impacts of climate change, the capacity to adapt to climate change, the effects of mitigation and adaptation policies, and the processes associated with how decisions are made with regard to adaptation. Economic issues center around the costs associated with the impacts of climate change, the costs of adapting to climate change, and the residual effects associated with those impacts that cannot be avoided. The key findings from the equity and economic analysis are as follows:

- Within New York State, many regions are at risk for adverse impacts of climate change across multiple sectors. Coastal zones, small rural communities, and lower-income urban neighborhoods are especially vulnerable.
- Among demographic groups in the state, low-income residents and elderly, disabled, and health-compromised populations are generally more vulnerable to climatic hazards than other groups.
- Across the state's firms and industries, smaller enterprises are less able to cope with climate-related business interruptions and stresses than larger enterprises.
- Without adaptation, many sectors may experience significant economic losses as the result of climate change.
- There are adaptations in all sectors for which the benefits are likely to exceed the costs, especially if the adaptations are carefully planned, timed correctly, and tailored to conditions in each sector.

As New York State addresses climate change, incorporating equity concerns and balancing these concerns with economic efficiency will be a key challenge for adaptation decision-making. Ensuring broad and inclusive participation in adaptation decisions will be critical for ensuring that the outcomes of these decisions are both equitable and economically feasible. Further details of the equity and economic analyses are presented in each of the sector chapters.

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[1] Both estimates are in inflation-adjusted 1995 dollars.

[2] http://www.ers.usda.gov/StateFacts/NY.htm.

[3] As reported in the Dairy Farm Case Study in the Agriculture Chapter of this report.

[4] It is not clear whether the costs associated with the riots and looting during the blackout are accounted for in this estimate. Information from Blackout!; Spotlight archives, July 13, 2005; http://www.answers.com/topic/new-york-city-blackout-of-1977.

[5] This adaptation measure depends on the reliability of the electric grid system. As described in the energy section, increased electricity demand during a heat wave may cause power outages, thus the importance of investing in electric power infrastructure.