EXECUTIVE SUMMARY

Large cities are at the forefront of both vulnerability and adaptation to climate impacts. These cities are commonly located on coastlines and are home to a rapidly growing percentage of the earth's people. The need for understanding climate impacts in urban areas is growing, as urban dwellers and decision-makers are being challenged to devise new types of adaptations and adjustments. For a global city such as the New York Metropolitan Region, climate variability and change present complex challenges and opportunities.

The Metropolitan East Coast (MEC) Regional Assessment is one of the regional components of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change, organized by the U.S. Global Change Research Program. The goal of each regional assessment is to investigate potential impacts of climate variability and change on the natural systems and human activities of a specific geographical area of the United States. Major objectives are to identify sectors that are vulnerable to the additional stresses that climate change and increased climate variability will introduce and to examine feasible adaptation strategies. The Metro East Coast Regional Assessment focuses on climate variability and change in a major urban center.

The Assessment covers the 31 counties of the New York City Metropolitan Region (Figure E-1). The area consists of 13,000 square miles, with jurisdictions involving 1,600 cities, towns, and villages in the three states of New York, New Jersey, and Connecticut. The 2000 U.S. Census numbered the total regional population at 21.5 million, of which 8 million live in New York City.

The MEC Regional Assessment examines how three interacting elements of large cities react and respond to climate variability and change (Figure E-2). The three

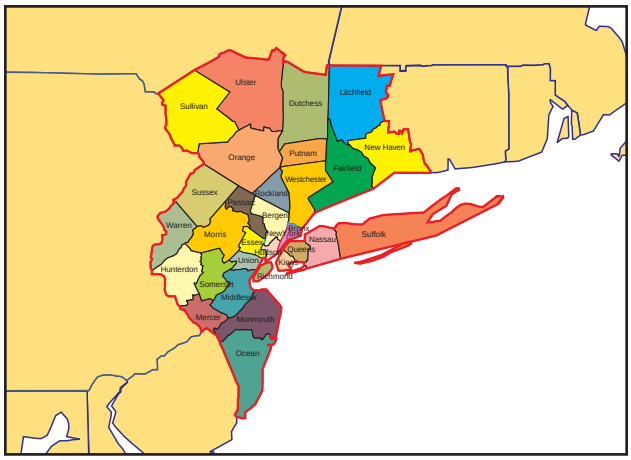

FIGURE E-1 Metropolitan East Coast Region.

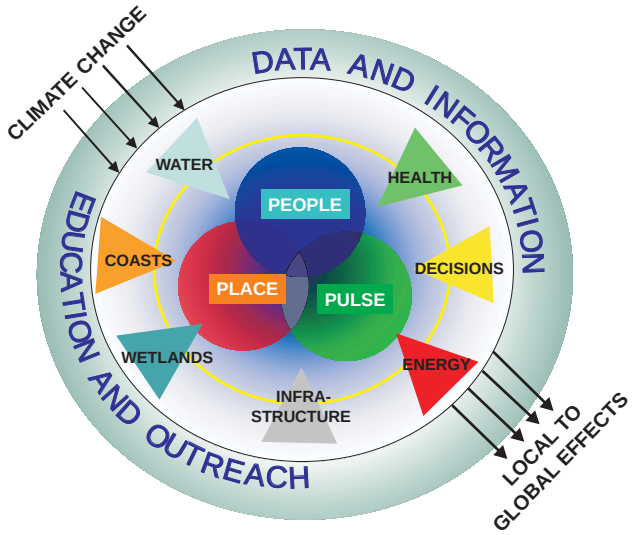

FIGURE E-2 Assessment framework and study sectors.

elements are: *people* (i.e., socio-demographic conditions), *place* (i.e., physical and ecological systems), and *pulse* (i.e., decision-making and economic activities). Seven sector studies form the core of the interacting elements: Sea-Level Rise and Coasts, Infrastructure, Wetlands, Water Supply, Public Health, Energy Demand, and Institutional Decision-Making. The sector studies address climate impacts through analysis of historical climate trends, responses to extreme climatic events, and scenario projections. Key to the assessment process is the focus on identification of vulnerabilities, adaptation strategies, policy recommendations, and gaps in knowledge. Each sector of the MEC Assessment collaborates with representatives from one or more relevant stakeholder institutions (Table E-1).

CLIMATE VARIABILITY AND CHANGE IN THE METROPOLITAN EAST COAST REGION

Climate is changing in the New York Metropolitan Region. Over the past 100 years, temperature in the region has warmed nearly 2°F. The rate and amount of temperature rise is projected to increase over the 21st century due to anthropogenic greenhouse warming. Gradual changes may be punctuated by changes in extreme climate events. A range of plausible climate change scenarios enabled the Metro East Coast Assessment researchers to project possible impacts created by climate variability and change as

Submitted as part of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change

TABLE E-1
Stakeholder Partners*

Sector	Partner
Coasts	New York District of U.S. Army Corps of Engineers
Infrastructure	Federal Emergency Management Agency, Region II The Port Authority of New York and New Jersey
Wetlands	National Park Service, Gateway National Recreation Area New York State Department of Environmental Conservation
Water Supply	Southeastern New York Intergovernmental Water Supply Advisory Council
Public Health	New York City Department of Health
Energy Demand	New York State Energy Research and Development Authority
Meta-Stakeholder	U.S. Environmental Protection Agency Region 2
General Stakeholder	Regional Plan Association

*Stakeholders are institutions whose activities are and will be impacted by present and future climate variability and change, and thus have a stake in being involved in research of potential impacts. Although stakeholders are an integral part of the research process, the findings that result from this research do not necessarily represent the opinions or policy positions of the stakeholder institutions.

well as to evaluate the region's responses. Such assessments are useful in improving preparedness for extreme climate events in the present, as well as developing readiness for a changing climate.

The results of the Metro East Coast Assessment indicate that the biophysical and societal impacts of projected climate change will be primarily negative over the long term. The impacts of climate change throughout the region and on its people will be widespread yet uneven. The costs of the impacts will be potentially significant and will increase as the amount of climate change increases.

Substantial uncertainties about climate change remain, including the rate and magnitude of projected regional changes. Possible changes in variability add to these uncertainties.

Key urban impacts of climate variability and change are likely to occur simultaneously at the intersection of sectors. For example, heat stress in the poor and elderly (a concern of the public health sector) will probably increase during energy blackouts (the responsibility of the energy sector). The varying impacts will be dynamic and their intersections will change over time.

KEY FINDINGS

Climate

- There is a long-term warming trend in the Metro East Coast region. While there are fluctuations on inter-annual and decadal time-scales in the average temperatures of the past century, the annual temperature (averaged over 23 stations, corrected for urban heat island effect) has increased by ~2°F since 1900 (Figure E-3). Over the past century, annual precipitation in the region has increased by ~1 inch.
- The rate and amount of temperature rise is projected to increase over the 21st century, due to anthropogenic greenhouse warming. The global climate models (GCMs) utilized in the U.S. National Assessment of the Potential Consequences of Climate Variability and Change project warming for the New York Metropolitan Region, ranging from 1.7–3.5°F in the 2020s, 2.6–6.5°F in the 2050s, and 4.4–10.2°F by the 2080s (United Kingdom

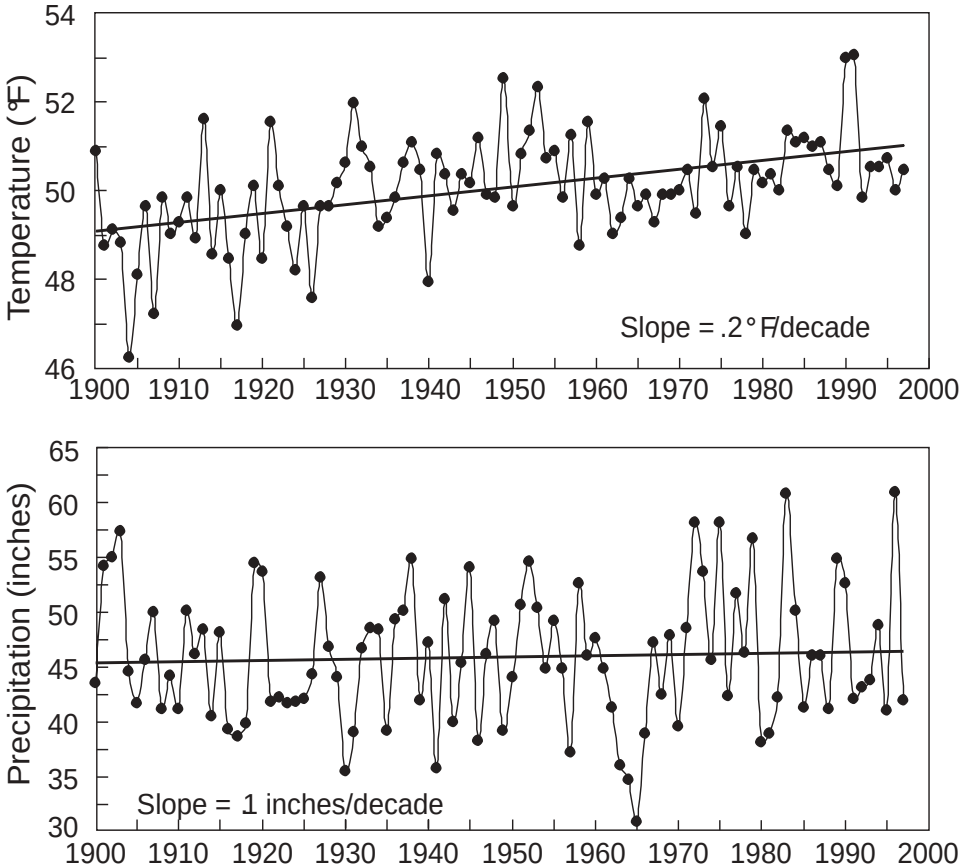

FIGURE E-3 Observed annual temperature and precipitation trends for the MEC region (1900–1997). Note: Twenty-three station average, corrected for the urban heat island effect. Source of data: NOAA NCDC/HCN.

Hadley Centre and the Canadian Centre for Climate Modeling and Analysis, Figure E-4).

- Precipitation projections of the global climate model scenarios do not agree in magnitude or direction (+1% to +9% in the 2020s; –16% to +14% in the 2050s, and –2% to +30% by the 2080s). The Hadley Centre scenarios show increasing levels of precipitation, while the Canadian Centre scenarios project varying precipitation changes over time. The Palmer Drought Severity Index in general shows more droughts in future decades, particularly for the Canadian Centre scenarios.

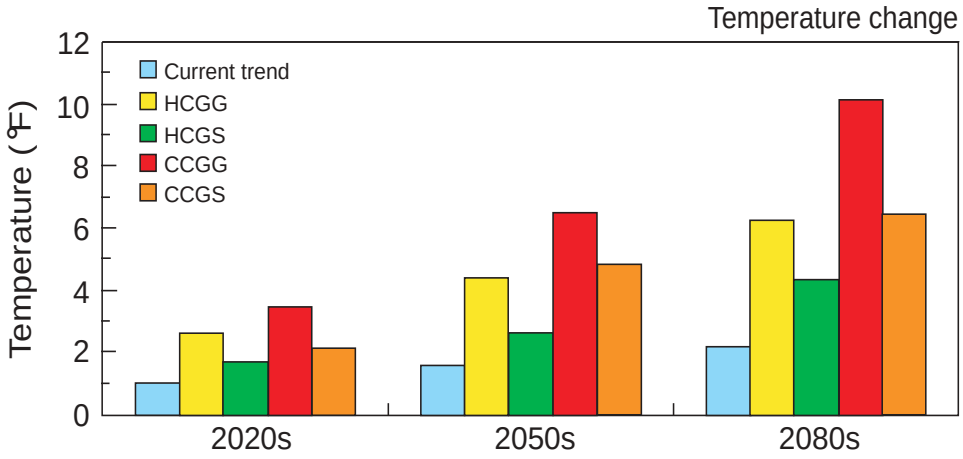

FIGURE E-4 Annual temperature changes in the Metropolitan East Coast Region projected by the Hadley Centre (HC) and Canadian Centre (CC) climate change scenarios with greenhouse gases (GG) and with greenhouse gases and sulfate aerosols (GS), and the Current Trends scenario.

- Climate change is projected by global climate models to cause warming in both winter and summer. In the 2050s, the range of winter temperature rise is 3.3 to 5.6°F. In the 2050s, summer temperature rise is projected to range between 2.7 and 7.6°F.
- Global climate models project that the number of days with the National Weather Service Heat Index (a combined index of temperature and relative humidity used as a proxy for the discomfort caused by heat waves) above 90°F will increase from 14 days (1997–1998 base) to a range of 24–40 days in the 2020s, 30–62 days in the 2050s, and 40–89 days in the 2080s.
- There is still considerable uncertainty about the rate and magnitude of projected climate changes. There is substantial potential that gradual changes could be punctuated by increases in extreme events such as floods and droughts.

Sea-Level Rise and Coasts

- Sea level has risen 0.09–0.15 inches per year in the Metro East Coast Region over the last 100 years. About half the observed rise is related to ongoing geologic subsidence following the end of the last glacial period and about half is related to the warming trend of the 20th century.
- With projected climate change, sea level in the MEC Region may rise 4.3–11.7 inches by the 2020s, 6.9 to 23.7 inches by the 2050s, and 9.5 to 42.5 inches by the 2080s.
- Future sea-level rise would lead to more damaging storm floods and a marked reduction in the flood return period in coastal regions. In the MEC Region, the 100-year flood would have a probability of occurrence, on average, once in 80 to 43 years by the 2020s, once in 68 to 19 years by the 2050s, and once in 60 to as often as every 4 years by the 2080s (Figure E-5).
- Rates of beach erosion would double at sites within the region by the 2020s, increasing 3 to 6 times by the 2050s, and 4 to 10 times by the 2080s, relative to the 2000s. Additional sand would have to be placed on the beaches to compensate for these losses. Beach nourishment will become significantly more costly as the century progresses, particularly in the case of the high-end warming scenarios.

Infrastructure

- Most of the region's low-elevation transportation infrastructure will be at risk to flooding in the 21st century (Figure E-6). By the end of this century, for two-thirds of facilities with elevations at or below 10 feet above sea level, flooding may occur at least once every decade,

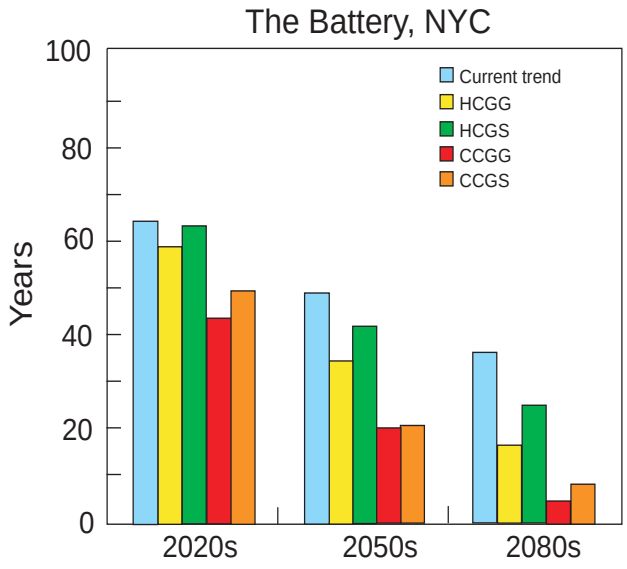

FIGURE E-5 Reduction in 100-year flood return periods due to sea-level rise in lower Manhattan.

and at some facilities it will occur every few years.

- While annualized losses from storms in the region are estimated to be only $100–300 million per year, losses from a single, devastating storm may be up to $100 billion, about 10% of the almost $1 trillion gross regional product.

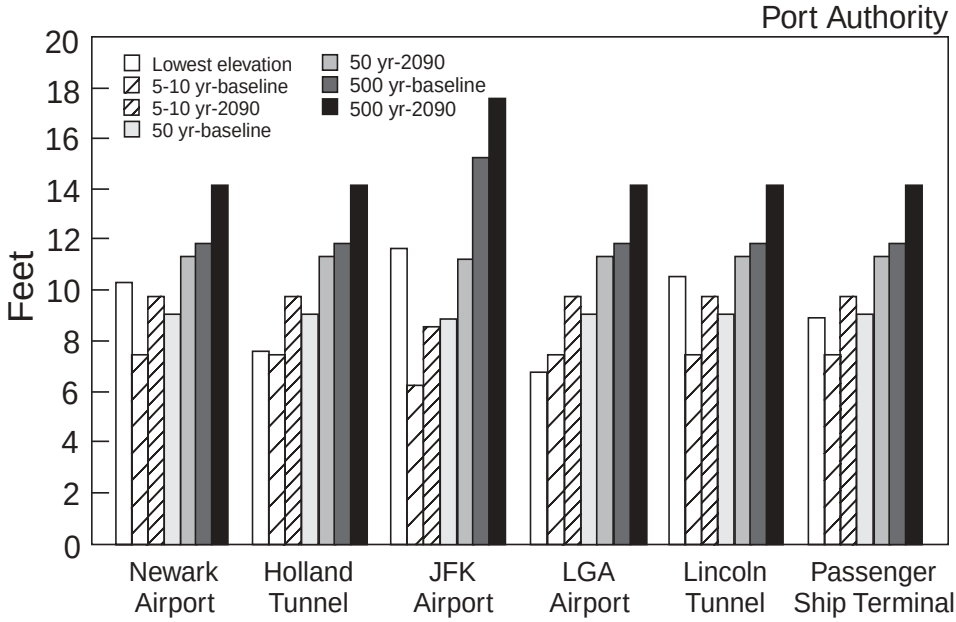

FIGURE E-6 Comparison of the lowest critical elevation for facilities of the Port Authority of New York and New Jersey with surge heights for three recurrence periods—5, 50, and 500 years—at the beginning (baseline) and end (2090s) of the 21st century.

Wetlands

- Studies of selected salt-marsh islands in Jamaica Bay Wildlife Refuge indicate that they have lost roughly 12% in area since 1959, with sea-level rise a possible causative factor (Figure E-7).
- Sea-level rise associated with global climate change brings a significant additional risk to already threatened coastal wetlands in the region.
- Salt marshes in Jamaica Bay are at risk to increased inundation under some scenarios of climate change and accretion rates. Projected mean sea-level rise exceeds observed historical rates of salt-marsh accretion in most GCM scenarios.
- Coastal wetland losses will disrupt current habitats of birds, fish, and other wildlife.

Water Supply

- Climate change projections indicate that the variability of the hydrological systems in the region will increase, with more frequent droughts and floods.
- New York City's water supply systems should be able to cope with climate uncertainty over the next several decades, but there will be significant challenges in the long term.
- Current fish populations and other ecosystem functions linked to watersheds are likely to be affected.
- Increased uncertainty will require a range of adaptations from water management institutions.
- An effective planning process needs to be organized soon in order to consider future adaptations. The implementation of new institutional and infrastructure measures is likely to require long-term institutional planning and resource commitment.
- Inter-regional cooperation offers opportunities to utilize water resources more efficiently (Figure E-8).

Public Health

- The most direct health effect to be associated with warming and more variable climate is an increase in summer-season heat stress morbidity and mortality, particularly among the elderly poor.
- Climate change in the MEC Region will contribute to at least three classes of indirect health outcomes: inci-

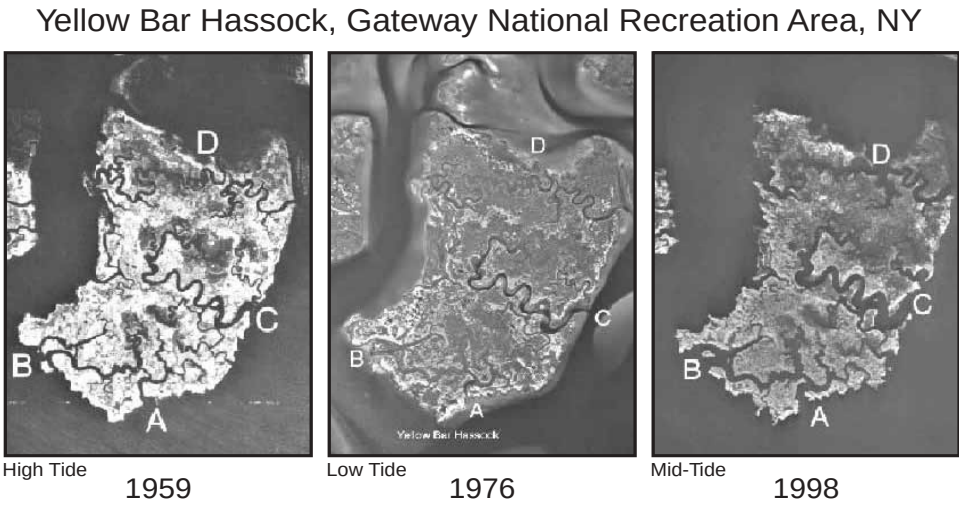

FIGURE E-7 Aerial photographs of Yellow Bar Hassock, part of Jamaica Bay Wildlife Refuge, dated April 7, 1959 (high tide), March 29, 1976 (low tide), and March 13, 1998 (mid-tide). Sources: Robinson Aerial Surveys, Inc. and AeroGraphics Corp., Bohemia, NY.

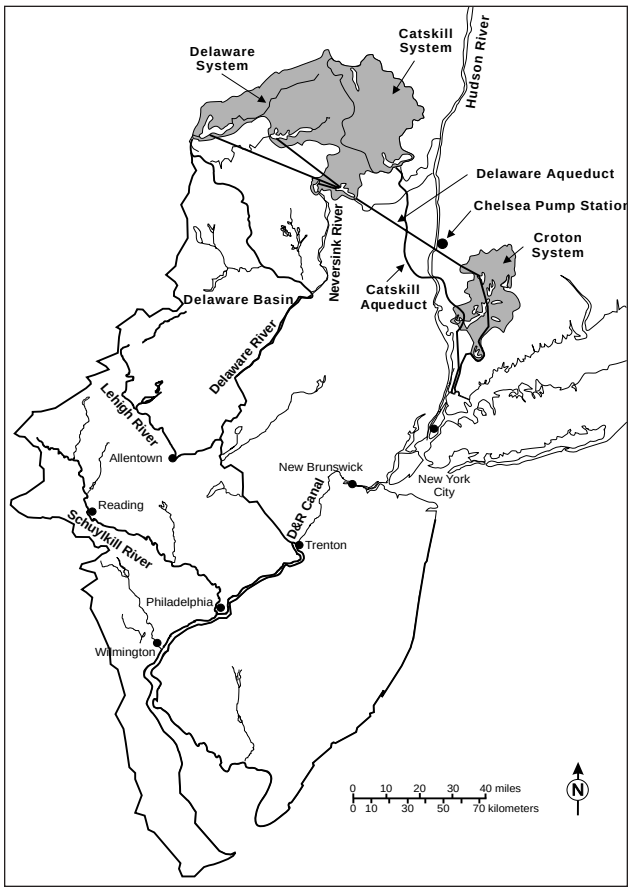

FIGURE E-8 Opportunities for inter-regional adaptation: New York City Water Supply System and the Delaware River Basin.

dence of certain vector-borne diseases may rise; waterborne disease organisms may become more prevalent; and increased formation of photochemical air pollutants may be fostered.

- Over the next several decades, impacts of climate change on ground-level ozone concentrations are not likely to be a major public health concern in the MEC Region. By the year 2100, asthma-related hospital admissions are expected to increase slightly (Table E-2).
- Health effects of climate change will be distributed unequally across the MEC Region's inhabitants, both spatially and socio-economically.

Energy Demand

- A warming climate will raise the demand for electricity because the increase in summer cooling outweighs the decrease in winter needs. Because peak summer electricity loads already far exceed winter peaks, the electric system will be increasingly stressed during summer heat waves.
- The urban heat island effect already causes cities to be warmer than the surrounding countryside due to the absorption of heat by buildings during the day and reradiation at night. Under a warming climate, the urban heat island effect will increasingly become an issue of regional concern in regard to energy demand and air quality.
- GCM climate change scenarios and an energy forecasting model project that daily peak load increases will range from 7 to 12% in the 2020s, 8 to 15% in the 2050s, and 11 to 17% in the 2080s (Figure E-9).
- The emphasis on adapting to climate change should be on improved energy efficiency, particularly to reduce summer peak electricity loads, and enhanced passive cooling in buildings and communities. Local lines that distribute electricity to customers need to be upgraded, and the adequacy of transmission lines to bring more power into the metropolitan area should be assured.
- The "weatherization" program that exists to save energy costs in housing for low-income people should be extended to provide summer cooling in urban areas as well as winter heating.

Institutional Decision-Making

- Involvement of decision-making institutions is critical in adaptation to or reduction of the consequences of global climate change.

TABLE E-2
Projected increases in hospital admissions resulting from increased ground-level ozone concentrations in 2030 and 2100 associated with climate change

Region	Hospital Admissions Category	2030			2100		
		O_3 Increase	New Hospital Admissions	Percent Change in Admissions	O_3 Increase	New Hospital Admissions	Percent Change in Admissions
MEC	Total Respiratory	12.15 ppb	995	*	50.65 ppb	4,149	*
	Asthma		819	*		3,319	*
NY State Counties	Total Respiratory		804	+0.6%		3,552	+2.5%
	Asthma		643	+1.6%		2,682	+6.5%

*Unable to calculate due to the unavailability of hospital admissions statistics for NJ.

- Responses to climate are triggered by sudden, large, extreme events. Institutions should prepare for the possibility of climate-related impacts in the future.
- Effective institutional response to climate change will require increased inter-agency cooperation and coordination.
- It is important to link adaptive response to climate change to opportunities for institutional change, such as new investments, relocation of structures, and major rehabilitation projects being undertaken for purposes other than adaptation to climate change.

POLICY LESSONS AND RECOMMENDATIONS

- Social and political responses to the impacts of climate variability and change have already begun and should accelerate and strengthen in order to avoid greater impacts in the future.
- Current major capital reinvestment activities and structural shifts in management in the Metro East Coast Region provide opportunities for integration of climate variability and change adaptation and mitigation strategies into stakeholders' decision-making practices.
- A regional Climate Awareness Program would be effective to inform decision-makers and the general public about current climate processes, lessons learned in responding to climate extremes, and future climate change.
- The development of a set of cost-based, urban-focused Climate Change Impact Indicators would make a significant contribution. For example, what will sea-level rise mean in terms of increased costs of beach renourishment and what will temperature increases mean to acute asthma sufferers.
- A regional Climate Inter-Agency Task Force should be formed to identify potential climate-related events and conditions (e.g., coastal infrastructure at risk, disease outbreaks, water supply vulnerabilities) and proactively propose responses. The taskforce should also consider events that would require emergency actions and/or large-scale societal responses.

THE CLIMATE CHANGE CHALLENGE

The complex nature of potential climate change impacts in urban regions poses tremendous challenges to urban managers to respond cooperatively, flexibly, and with far longer decision-making timeframes than currently practiced. Given the already fragmented nature of urban environments and jurisdictions, the political and social responses to the global climate issue in cities should begin at once. Transforming urban management to better prepare for climate change will safeguard against negative feedbacks in the Metro East Coast Region and around the world.

In summary, the Assessment illustrates that the future environmental conditions of the Metro East Coast Region will be much more dynamic than in the recent past. The environmental management and response strategies that evolved during the 20th century were based largely on the idea that the ecological and environmental baselines were static, although ranging within the conditions of dynamic equilibrium. Local environmental change was seen as being brought about largely through direct human action.

Global climate change forces a fundamental reassessment of these assumptions. In the 21st century, the baselines will change and local decision-makers will have limited ability to control the pace of this transformation. The gases already emitted into the global atmosphere are projected to cause some degree of warming and environmental change regardless of the implementation of any comprehensive policy designed to reduce greenhouse gas emissions (the root cause of projected climate change). For the citizens and stakeholders of the Metro East Coast Region, the challenge will be to adapt to and mitigate climate change simultaneously and equitably.

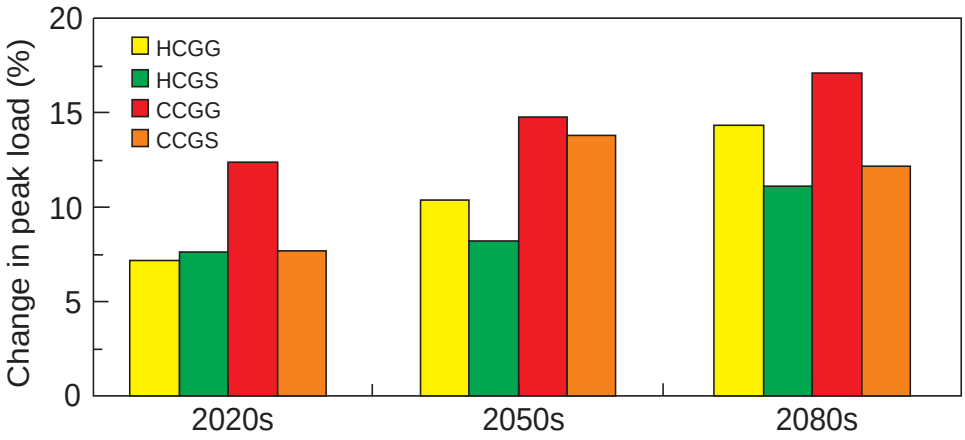

FIGURE E-9 Increase in peak electricity demand under July 1999 conditions with temperatures and relative humidity projected for future decades.

Note: Bars represent low and high range of two global climate models, the Hadley Centre (HC) and the Canadian Centre (CC) models.