3 Findings, Principles and Strategies

Recognizing the risks posed by climate change, the Commonwealth of Massachusetts has and will continue to identify and implement measures to protect its social, economic, cultural, and natural resources. There is broad consensus that, even with ambitious global reduction of greenhouse gas emissions, some level of climate change is inevitable (IPCC, 2007). Therefore, in addition to providing strong leadership and action on mitigation, it is important for Massachusetts to continue a similar commitment on climate change adaptation.

The formation of the Climate Change Adaptation Advisory Committee by the Global Warming Solutions Act served as an important impetus and a forum for informed and broad-based dialogue on this issue. Based on the Committee's work, this chapter presents: (1) several key findings that articulate the central themes and challenges of adaptation in Massachusetts; (2) a set of principles that have guided and should continue to guide Massachusetts' approach to adapting to climate change; and (3) a series of common strategies that cut across several, if not all, sectors.

1. FINDINGS

The following findings—based on the common themes, challenges, opportunities, and needs identified through the Committee process—inform all strategies, including the cross-cutting strategies presented later in this chapter, and can continue to shape future climate change adaptation efforts in Massachusetts.

Climate Change Is Already Happening and Will Continue

Climate change is already having demonstrable effects in Massachusetts and the region. As described in Chapter 2, the Northeast has been warming at a rate of nearly 0.27°C (0.5 °F) per decade, and winter temperatures are rising at an even faster rate of 0.72°C (1.3°F) per decade (Frumhoff et al., 2007). These long-term warming trends are associated with other observed changes, including rising sea-surface temperatures and sea levels, more frequent days with temperatures above 32°C (90°F), reduced snowpack, and earlier spring snowmelt resulting in earlier peak streamflows.

While projected climate trends indicate that the situation will worsen, the range in scope and magnitude of these changes, as well as the impacts that they will cause, will be influenced by current and future levels of greenhouse gas emissions. Even with aggressive policies to reduce greenhouse gas emissions, however, efforts will be required to adapt to climate change impacts already in play due to past emissions.

Climate Change Impacts Are Wide Ranging and Affect Many Sectors of Society

From greater frequency of excessively hot days to increased flooding and habitat disruption, the impacts of climate change have broad implications. As an example, predicted sea level rise and the associated increases in flooding, erosion, and salt water intrusion into freshwater aquifers will have adverse effects on residential and commercial development, infrastructure and critical facilities, and natural resources and ecosystems. These impacts, in turn, will affect residents, landowners, private business, industry, government, and many others. Developing effective and efficient responses to climate change will require high levels of communication, coordination, collaboration, and integration across and within all levels of government, in close connection with private businesses and industries, non-governmental organizations, academic institutions, and stakeholder groups.

The Cost of Impacts Will Be High

Impacts from climate change will be very costly. Under the high emission scenario described by the Intergovernmental Panel on Climate Change (IPCC, 2007), the average annual cost of climate change impacts to the U.S. could reach 2.6 percent of the gross domestic product by 2100 (Ackerman et al., 2009). Lenton et al. (2009) estimate that a global sea level rise of 20 inches (0.5 meters) by 2050 would expose $25 trillion to $28 trillion in assets to a 100-year storm event in 136 port megacities worldwide—over $7 trillion in assets in 17 port cities in the United States alone. Boston ranks fourth among U.S. cities with the greatest predicted risk of asset exposure due to sea level rise, with predicted asset exposure from a mid-century 100-year storm event estimated to exceed $400 billion and current asset exposure to a 100-year storm estimated at $77 billion (Lenton et al., 2009). Adding to that, evacuation costs alone from sea level rise and storms in Massachusetts may range between

$2 billion and $6.5 billion, depending on the severity of the storm event (Ruth et al., 2007).

Responding to these impacts with solutions such as large-scale engineering would require significant capital investments, which would be costly to residents, businesses, and governments alike. Difficult decisions and trade-offs will potentially need to be made, therefore, about abandonment, relocation, and fortification of the state's natural and manmade systems. The construction of seawalls, which is one way to counter the effects of sea level rise (Lenton, 2009), could cost $5 to $21 million per linear mile (Union of Concerned Scientists, 2009)—and would come at the cost of other important natural processes. A physical barrier such as a sea wall can deprive beaches of necessary sediment that flows in with the tide, and many recreational beaches can be lost. Other structural solutions would also be expensive. For example, elevating a single family home by two feet could cost $22 to $62 per square foot (Union of Concerned Scientists, 2009) depending on a building's foundation type (Jones et al., 2006). Another option—managed retreat (allowing the coastline to move inland in specified locations as a response to sea level rise)—would affect property values as land and structures are subsumed by the rising sea.

The 1938 Category 3 hurricane that hit the Northeast raised high tide by 10 feet above normal, washed over most barrier beaches in the Narragansett and Buzzards Bays, killed over 600 people, and damaged property worth about $400 million in New York, Connecticut, Massachusetts and Vermont (Ashton et al., 2006). It was estimated that the same hurricane in 1998 would cost $20 billion in insured property damage. (Pielke and Landsea, 1998).

Climate change will continue to impact the future price, affordability, and availability of insurance coverage (Dailey et al., 2009). In many areas of Massachusetts—especially Cape Cod and the Southeast—home and business owners are already facing significant rate increases or denial of coverage as private insurance companies reassess their risk (and reinsurance rates) in the face of an increase in extreme weather events (causing greater risk of wind damage) and the effects of climate change (Breslau, 2007).

Given the uncertainty of future climate conditions and impacts, and the costs associated with certain alternatives to address these impacts, some strategies (or components thereof) are not presently practical or economical. Added to this scenario is the recognition that, over time, the cost of inaction may be even higher and more disastrous than the cost of implementing appropriate adaptation strategies. There is broad consensus that some viable adaptation options for certain sectors would result in lower costs or have low cost-benefit ratios and achieve significant cost savings if implemented sooner rather than later.

Even under current conditions, climate impacts are costly. Flooding of the Boston subway system in 1996 cost over $92 million in damages (Ruth et al., 2007).

Current and Accurate Information Improves Decision-Making

Effective planning and management at the regional and local levels is enhanced by current and accurate information. Although there is enough information to begin implementing many of the strategies outlined in this report, information gaps limit more focused assessments and decision-making. Also, while sector-specific information is necessary, there are certain types of data—such as the acquisition of high-resolution topography as generated by LiDAR (see Strategy #2 under cross-cutting strategies for description) technology—that could support multiple sectors concurrently. Compiling and synthesizing existing information and conducting region-specific analysis will help support the development of more specific strategies to adapt to climate change impacts. Through improvements in the science and methods of "downscaling" global climate models—and by expanding mapping, monitoring, and assessing specific parameters and ecosystem processes—more robust and precise information can be advanced to support the development of strategies targeted to changing conditions in both the built environment and natural resource areas.

Integrating Mitigation and Adaptation Strategies Provides Double Benefits

According to the IPCC (2007), "there is high confidence that neither adaptation nor mitigation alone can avoid all climate change impacts; however, they can complement each other and together can significantly reduce the risks of climate change". Massachusetts is actively striving to reduce greenhouse gas emissions and address adaptation because of its particular vulnerabilities to climate change. Massachusetts can set an example to others and do its part to minimize the degree to which climate change adaptation will be necessary in the future. Some climate adaptation strategies or responses to reduce risk and vulnerability also serve to reduce greenhouse gas emissions (and vice versa). Identifying these areas of mutual benefit was a core theme throughout the development of this report. There are also areas of potential conflict between

climate change adaptation and mitigation strategies that must be reconciled. As an example, an increase in ambient air temperature can lead to an increase in the use of air conditioning to provide relief during high heat days. This in turn increases the demand for electricity, which in Massachusetts is mainly generated through the burning of natural gas and coal.

Adaptive Management and Forward-Thinking Goals Should Be Built into Current Actions

The science of climate change is constantly improving, as predictions are refined with new data, research, and modeling. Addressing the challenges posed by a changing climate can seem daunting. Incorporating climate change into existing strategic, management, and fiscal plans and building upon existing efforts can, however, readily increase adaptation capacity. The concept of "adaptive management" is particularly suited to climate change response, where planning and decisions are made within a context of incomplete and imperfect knowledge. Adaptive management seeks to reduce risk and uncertainty over time through the deliberate development of iterative and flexible approaches. It relies on monitoring and evaluation to adjust these approaches based on what has been learned.

Long-term choices about climate responses can be segmented into shorter-term, more manageable steps and decisions. By ranking and prioritizing, leveraging resources and shared goals, and enhancing communication, collaboration, and partnerships, forward-thinking climate change responses can be built into current land-use and resource management plans, financial budgets and capital investments, regulatory processes, and similar implementation mechanisms.

Actions Addressing Climate Change May Present Opportunities

The need to adapt to climate change and mitigate the emissions of greenhouse gases could create economic opportunities in Massachusetts. These could include the expansion of sectors such as clean energy, restoration and management services, the construction industry, research and development in an array of high tech sectors, and development of drought- and pest-resistant crops.

2. PRINCIPLES

Each adaptation strategy will have specific elements and considerations. However, the development and implementation of climate change adaptation strategies should be guided by the following core principles.

Broad-Based Participation

The effects of climate change will be felt throughout Massachusetts. To address these challenges effectively, engagement of a wide array of stakeholders is necessary. The development of this report was informed by the active participation of more than 200 experts, representatives, and stakeholders, as well as input from the general public. As efforts to increase Massachusetts' capacity to adapt to climate change advance, diverse and broad participation will continue to be essential.

Best Available Science & Technology

Significant progress has occurred over the past decades in the scientific understanding of the earth's changing climate, its causes, and its impacts. The science and models that inform the understanding of global and regional climate change issues are evolving rapidly. Recognizing the value of this work, the options and strategies being considered in Massachusetts to adapt to climate change impacts should be grounded in the most current and established science and technology.

Strong Leadership

In order to prioritize and implement adaptation strategies, strong leadership will be necessary at the local, state, and federal levels. A national leader on clean energy, climate and environmental issues, Massachusetts is poised to be a pacesetter on climate change adaptation.

Coordination of Efforts

Climate change impacts occur across a range of issue areas. Consequently, developing effective and efficient responses will require strong coordinated efforts among various entities with different mandates and interests— from the private sector, to the state and federal agencies, cities and towns, non-government organizations, and academic institutions. In moving forward, current partnerships should be fostered and new ones developed.

Assisting Vulnerable Populations

Vulnerable populations are broadly defined as those who are more susceptible to the effects of climate change, and for whom adaptive change will be more difficult. Whether by virtue of economic status, social capacity and resources, health, age, or geography, adaptation efforts should be mindful of, and include, planning to meet the unique needs and conditions of people who are most vulnerable, protecting them during sudden extreme events, and helping them adapt to health issues, energy costs, and other chronic impacts.

Cost-Effective and Risk-Based Approaches

With the potential for large impacts from climate change, the current and future benefits and costs of various adaptation alternatives deserve careful consideration. There is explicit recognition that, given the uncertainty of future climate conditions, costs of impacts, and the costs associated with alternative responses, there may be particular strategies (or components thereof) that are not presently practical or economical. Investments of resources need to be made strategically, focusing on: climate-related impacts and their relative risks, timing of occurrence, and uncertainties as well as costs and cost-effectiveness of responses. Priority should be given to strategies that have clear, robust, and long-term benefits and significance, including those that,

- address known risks and vulnerabilities;
- support large portions of the public over special interests;
- promote public health, safety, security, and well-being;
- protect particularly vulnerable populations or those with unequal access to resources;
- build upon current programs and successes;
- protect critical habitats and key ecosystem services; and
- provide economic growth potential.

3. CROSS-CUTTING STRATEGIES

The technical subcommittees of the Climate Change Adaptation Advisory Committee—which were organized by general issue areas or "sectors"—made significant progress in their review of climate change impacts, general risks and vulnerabilities, and possible strategies. As is evidenced by the wide-ranging assembly of strategies for each sector in Part II of this report, there are numerous options and prospective pathways for improving capacity in Massachusetts to adapt to climate change. The following set of recommended strategies was informed by and developed directly from the information and ideas contained in the individual sector-specific chapters. These cross-cutting strategies emerged as common themes in several, if not all, sectors and were discussed extensively at the subcommittee and the advisory committee meetings. Guided by the principles and informed by the findings presented earlier in this chapter, these strategies represent a synthesis to direct and inform climate change adaptation efforts in Massachusetts.

Strategy #1 — Combine Mitigation and Adaptation Strategies

The committee discussed the connection between the state working to reduce its share of greenhouse gas emissions as part of a global effort, and the influence that will have on reductions in climate change impacts. The Committee found many strategies that would have the dual benefit of helping a sector adapt to a changing climate while also helping to reduce or mitigate greenhouse gas emissions. One such strategy is the acquisition or conservation of large forest blocks that would minimize stressors, and provide ecosystem resilience, while also serving as a carbon sink.

Another strategy is deploying measures such as the implementation of Smart Growth, including "low impact development" (LID) and Leadership in Energy and Environmental Design (LEED) building methods. LID and LEED techniques reduce the environmental and energy footprint of conventional residential and commercial buildings and provide for better site-design. With less energy, water resource, and material demands for both construction and operation, harmful emissions can be reduced. These strategies will reduce operation and maintenance costs over time, while conserving natural habitats, providing for better localized water recharge, and minimizing anthropogenic stress on ecosystems. Other examples of specific strategies that address both climate change adaptation and mitigation are reductions in allergens and asthmogens from decreased emissions, using tree plantings to reduce heat island effect and reduce heating and cooling costs, and increasing adaptive building techniques, such as white roofs, to reduce cooling requirements (and therefore emissions).

Strategy #2 — Identify and Fill Critical Information Gaps

Effective adaptation efforts require up-to-date and accurate information, models, and decision-support tools. Addressing the key knowledge and technological gaps to identify and predict vulnerability of both the built environment and natural resource areas is a high priority. Much of the information and products currently used for land-use and infrastructure planning, lending and investment decisions, and resource management reflect climate conditions from the last several decades and do not accurately reflect current risks of inundation, temperature change, and other climate-related impacts. Therefore, assessing future risk and developing strategies for adaptation poses significant challenges. Through improvements in the science and methods of "downscaling" global climate models

so that they reflect Massachusetts-specific conditions—and by expanding mapping, monitoring, and assessments of specific parameters and ecosystem processes—more robust and specific information can be advanced to support the development of strategies targeted to changing conditions.

The use of monitoring and modeling—including expansion, acceleration, and leveraging of existing efforts—is essential in following climate trends and simulating climate change scenarios. Other types of monitoring and models will be needed to address vulnerabilities of inland and coastal wetland resource areas; cultural, archaeological, and historic resources at risk; important infrastructure; and water quality and quantity. For all kinds of monitoring, it is important to have consistent methods, frequent sampling and long study durations since many climate-related phenomena are inherently variable and more data points over longer periods will provide a higher degree of confidence in discerning the effects of climate change. Consideration should also be given to providing a single entity or clearinghouse to better support, integrate, standardize, and disseminate these resources within each sector, or across multiple sectors.

A common strategy among all sectors was to collect or update information to better predict impacts from storm-related flooding and sea level rise, such as:

- LiDAR (Light Detection and Ranging) — LiDAR is an airborne laser sensor technology for collecting extremely accurate elevation data. It can be used to help predict the impact of flooding and sea level rise on estuarine marshes and to identify neighborhoods, businesses, and infrastructure at risk from coastal storms and sea level rise.

- Floodplain mapping — Maps of areas that have a 1 percent chance of flooding during a given year (i.e., the 100-year flood) should be updated. Massachusetts' regional equations used for estimating floods of various frequencies, which are derived from available U.S. Geological Survey streamgage data and basin characteristics, have not been updated in over 35 years and do not reflect current conditions (rainfall patterns and impervious surfaces)—much less what would likely occur given future climate change. These shortcomings are illustrated by the fact that many flood damaged areas lie outside the mapped areas at risk of a 100-year flood. In fact, according to the Federal Emergency Management Agency (FEMA), as many as 30 percent of flood damage claims lie outside these areas. It is recommended that various funding sources be pursued vigorously and more flexible and relevant formats for floodplain mapping be discussed with FEMA. Updating the flood maps to reflect current conditions is a first step toward developing maps that can also incorporate predictions of future conditions.
- Rainfall Intensity — It is recommended that the "design storms" (i.e., what qualifies as a 100-year storm or a 50-year storm) for Massachusetts be updated to reflect current conditions and those precipitation conditions predicted for the future. Transportation and environmental agencies and many local planning boards rely on the precipitation return frequencies derived by the National Weather Service in 1961, 1964, and 1977. Precipitation return frequencies are used in designing stormwater controls to attenuate the peak rate of runoff from land development and in sizing culverts. Local culverts are likely undersized, which can potentially cause culvert failure and damage due to flooding. This could get worse over time as rainfall intensity increases with climate change.

Strategy #3 — Advance Risk and Vulnerability Assessments

Risk and vulnerability assessments are used to determine the susceptibility and exposure of groups or communities of people, physical structures and assets, natural resources and the environment, economic conditions, and other resources and interests to changing climate conditions and associated impacts. These assessments can be conducted for various purposes, at different scales, for a range of subjects, and with a range of techniques. While the areas of interest and approaches may vary, these assessments all share the primary goal of quantifying and qualifying levels of risk and vulnerability.

This report provides an initial outline of some of the risks and vulnerabilities for general sectors. These overviews of vulnerability are useful starting points, but in some cases, more complete and detailed assessments are required to generate the necessary materials, information, and tools to support the development, prioritization, and implementation of targeted and robust—yet flexible—climate change adaptation plans and strategies.

Risk and vulnerability assessments can be conducted within the context of the uncertainties and complexities posed by climate change, and through the employment of scenarios, assignment of probabilities, and ranking of impacts. The utility of these assessment outputs, however, is greatly influenced by the quality and accuracy of the information available to drive the analysis. This recommendation is thus closely tied to the previous one. By identifying and filling critical information gaps, the process and products of risk and vulnerability assessments will be enhanced, and lead to better and more cost-effective adaptation plans, actions, and decisions.

Given limited available resources, undertaking a systematic, comprehensive risk and vulnerability assessment for each component of every sector examined in the report is not practical. Consequently, strategic choices must be made to determine the vulnerability assessments to be conducted. As derived from the sector chapters, thorough risk and vulnerability assessments are needed for the following:

- Existing critical infrastructure, including energy generation, transmission, and distribution; communication networks; drinking and wastewater facilities; roads and highways; railways and subways; shipping, transportation, and cruise terminals; ferry and water transportation terminals and facilities; dams, levees, flood barriers, jetties, and breakwaters; and health care facilities
- Economic sectors, including agriculture and aquaculture, fishing, health care and life sciences, technology, financial services, manufacturing, education, government, and tourism
- Vulnerable groups or populations, including economically disadvantaged communities; densely-populated areas (i.e., urban areas); the elderly, infirmed, and young; and non-English speaking or English-as-second language groups
- Natural habitats and ecosystems, including forested, freshwater aquatic, coastal, and marine ecosystems
- Community-specific analyses, including local hazards and threats; critical local facilities; local public and private water supplies; businesses; homes and the built environment; cultural and historical sites; and crucial local natural resources

Strategy #4 — Evaluate and Prioritize Adaptation Strategies for Implementation

Challenging decisions lie ahead regarding the options and alternatives for reducing risk to public infrastructure, private property, and human safety and welfare as a result of climate change. As evidenced from the collection of strategies identified in the individual sector chapters, a broad range of adaptation alternatives, opportunities, and measures exist for the vulnerabilities considered. The strategies vary by type, including monitoring and assessments, policies and regulations, and technical assistance and education; scale, including region, state, community, and neighborhood; scope, including specific economic sectors, elements of the built environment, various aspects of public health and safety, and ecosystem components and processes; and responsibilities, including government agencies, private business and industry, non-government organizations, academic institutions, and individual homeowners.

Given this array of options, there is a strong need to prioritize specific adaptation responses determined to be the most effective and efficient. Evaluation and prioritization of adaptation alternatives should consider many factors including, but not limited to, the probability and magnitude of potential impacts, the vulnerability of the groups or individuals affected, the range and feasibility of alternatives available, broad-based stakeholder input, and the opportunity to build upon current programs and successes. Careful consideration is warranted for examining the current and future benefits and costs—including capital and recurring, primary and secondary—of different adaptation alternatives.

While strategic prioritization is required, there are a number of approaches which—in light of established trends of certain climate conditions, the high probability of risk, and the potential for significant impact and adverse consequences—are clearly priority candidates for implementation. One example is the early implementation of adaptation strategies that could be encouraged through incentives and incorporated into existing programs. These are termed as "no regrets" strategies—strategies that are beneficial regardless of climate change that should be encouraged where cost-effective. Innovative efforts, such as the state's StormSmart Coasts Program's work to provide coastal communities with expertise in planning for storms, floods, sea level rise, and climate change, can be improved and expanded along the coast and inland before climate change impacts are fully realized.

Strategy #5 — Support Local Communities

Many of the State's communities are already grappling with flooding, pollution, erosion, repeated storm damage, heat impacts, and other problems

likely to be exacerbated by climate change. As a home-rule state, many of the land-use decisions in Massachusetts are made by cities and towns. Managers of key assets such as water supply infrastructure or local public safety resources may not have the technical capacity or the resources to plan for climate change. Consequently, to be successful, adaptation strategies must be connected with and directly support vulnerable communities. Addressing some of these challenges at the local level will require assistance—both, technical and financial—from state and federal governments, regional planning agencies, professional trade organizations, and non-profit partners. This assistance can help to ensure that revised operating procedures, best practices for analyzing risk, guidance for implementing adaptation measures, and updated design standards for new facilities are readily accessible to local government and businesses.

Communities can also learn from one another, as some already have experiences with climate change adaptation strategies to share. Adaptation support must also extend to key businesses and industries such as local employers and vital, but vulnerable, trades such as fishing and agriculture. Building upon current programs that have demonstrated successes and efficiencies, such as the Massachusetts Office of Coastal Zone Management's StormSmart Coasts Program (see Chapter 8 for more details) and the ICLEI (International Council for Local Environmental Initiatives)—Local Government for Sustainability network, will be important. In addition to technical and planning support, financial assistance to aid communities in their efforts to implement sound climate change adaptation strategies will be critical.

ICLEI—Local Government for Sustainability

Since the early 1990s, ICLEI has led an international member network to advance climate protection and sustainability. Member communities bring experience, leadership, and the ability to create solutions to a global problem while advancing measures at the local level. The ICLEI network includes 38 Massachusetts communities who represent coastal regions from Boston Harbor and Nantucket to areas inland, such as Amherst and Pittsfield, and communities in between. This expanding network of local governments from across the state can share successes and challenges and create resilient communities together with the larger ICLEI network.

Strategy #6 — Improve Planning and Land Use Practices

With increasing climate change impacts, particularly those related to coastal and riverine flooding, society will be faced with difficult decisions regarding risk to public infrastructure, private property, natural resources, and human safety and welfare. Criteria, priorities, and policies are needed to help better inform where protection of infrastructure and other investments are necessary. In order to help fortify existing structures and minimize and prevent exposure, sound land use decisions should be promoted through technical support to local communities on consistent and effective land-use standards and guidelines, model bylaws, and state permitting processes. (See Chapter 7 for more details on land use and planning.) The Department of Fish and Game's BioMap2, provides a proactive decision support tool to inform both conservation of resilient ecosystems and areas better suited for development.

Strategy #7 — Enhance Emergency Preparedness

Hazard mitigation, evacuation, and emergency response plans should be evaluated and updated to reflect changing climate conditions and new development. In general, emergency preparedness resources have evolved in response to past emergencies and storm events. The scope, magnitude, and frequency of historic emergencies have served as the basis for the design and development of the existing emergency preparedness infrastructure. As storms become more frequent and intense and sea level rises, new and increased levels of exposure may arise, and many areas that previously escaped storm impacts will likely be vulnerable.

Managers should assess and enhance emergency management tools and capabilities in order to respond to the predicted increased frequency and intensity of extreme weather events. These tools include the State Risk Assessment Inventory, the State Comprehensive Emergency Management Plan, the State Hazard Mitigation Plan, mapping and information systems, and other emergency management tools. (See Chapter 7 for more details.)

Strategy #8 — Encourage Ecosystem-Based Adaptation

Natural ecosystems provide resilience and reduce the vulnerability of the natural and built environments. Protecting resilient ecosystems also increases their ability to thrive, and strengthens the services they support. Using natural habitats as "green" infrastructure can help impede and potentially eliminate the risk posed by some climate change impacts while supporting crucial biota, enhancing quality of life, and serving as a carbon sink.

Strategy #9 — Continue to Seek Expert Advice and Stakeholder Input

Continued efforts should also be made to ensure broad-based expert and stakeholder input. Means to engage representatives, stakeholders, and the general public should include enhanced communication efforts, formal and informal public hearings, issue-based meetings with broad partners and interests, enhanced state agency presence in local communities, and advisory groups convened for deliberation on specific research topics and policy change proposals.

Strategy #10 — Ensure Agency and Regional Coordination

There is a need for strong communication, coordination, and integration across various state agencies. Massachusetts should explore options for policy and implementation coordination across executive agencies, state and local authorities.

Climate change adaptation also needs to be addressed nationally and regionally in the Northeast. Collaboration on adaptation within and across state and federal boundaries is essential to ensure coordinated data collection and modeling activities, thereby reducing costs and minimizing duplication. Collaboration is also essential to performing multi-state assessments, planning for shared natural and infrastructure resources, and to allowing climate adaptation planners to learn and build from each other's successes and challenges.

Massachusetts is actively participating in multi-state and regional coordination and collaboration efforts on climate change adaptation. The 2008 New England Governor's Conference Resolution 32-5 entitled 'Resolution Concerning Climate Change and Adaptation' recognized the importance of needing to adapt to climate change, and committed the New England Governors and Eastern Canadian Premiers to share data and information on vulnerable areas, and coordinate decision-making and planning processes to optimize regional adaptation and mitigation strategies. The Northeast States for Coordinated Air Use Management (NESCAUM) is actively facilitating a multi-agency coordination effort to discuss adaptation efforts occurring at state and federal agencies in the Northeast and assess the need for regional collaboration between these efforts. The goal of this group is to provide a mechanism for coordination, communication, and work across sectors and states, and to develop a framework for the Northeast to address adaptation to climate change.

Going forward, Massachusetts should continue to actively participate in on-going regional collaboration efforts, share this report with regional partners, collaboratively pursue federal funding for adaptation efforts in all the New England and northeastern states, participate in regional efforts to create an online clearinghouse for climate change adaptation information, work with other states to address specific issues that cross political boundaries, foster academic collaboration, and reach out to other organizations for inclusion in future information sharing and collaborative planning for the Northeast.

Strategy #11 — Promote Communication and Outreach

Because climate change adaptation is complex, it is imperative that targeted communication efforts are in place to inform local officials, the private sector, and citizens of the potential risks and consequences of a changing climate. An ongoing strategy should be the training and skill-building of decision-makers and environmental planners to promote fluency on climate change adaptation sufficient to initiate and perpetuate action. For this, an assessment of the current knowledge, perceptions, skills, and intentions of these constituents should be conducted so that communication is appropriately focused.

Strategy #12 — Start Now, Be Bold

Enough is known about climate change science and its impacts to start to address it now. Earlier action is often cheaper and could help prevent predicted future impacts to key infrastructure resources, public health, natural systems, and the economy.

4. MOVING FORWARD

This report presents a first step toward the identification, development, and implementation of strategies that will advance the State's ability to adapt more effectively and efficiently to a changing climate. Significant challenges remain, and there is much work to be done. Under the leadership of the legislative and executive branches, and with the assistance and collaboration afforded by a broad range of partners—cities and towns, non-government organizations, academic institutions, private businesses, and stakeholder groups and individuals, Massachusetts can strategically position itself to maximize opportunities and address threats. With the submittal of this report to the Legislature, the statutory obligations of the Committee are complete. The Committee now urges the Secretary of Energy and Environmental Affairs to consider the committee's recommendations and find opportunities for action—immediately, in the short run, and the long-term—and to consider how to maintain public, expert, and stakeholder input into the ongoing challenge of adapting to climate change in Massachusetts.

REFERENCES

Ackerman, F., E. A. Stanton, C. Hope, and S. Alberth, 2009. Did the Stern Review Underestimate US and Global Climate Damages? Energy Policy 37: 2717-2721.

Ashton, A., J. Donnelly, and R. Evans, 2006. A discussion of the potential impacts of climate change on the shorelines of the northeastern United States of America. Northeast Climate Impacts Assessment, Union of Concerned Scientists.

Breslau, K., 2007. The insurance climate change: Coastal homeowners in the East are losing their policies or watching premiums skyrocket. Carriers say that global warming is to blame. Newsweek, January 29. Online at http://www.newsweek.com/id/70119. Last accessed 01/27/10.

Dailey, P., M. Huddleston, S. Brown, and D. Fasking, 2009. The Financial Risks of Climate Change: Examining the financial implications of climate change using climate models and insurance catastrophe risk models. ABI Research Paper #19; Report by AIR Worldwide Corp. and the Met Office.

Eastern Research Group, 2010. Cost-Effective Greenhouse Gas Mitigation in Massachusetts: An Analysis of 2020 Potential. Draft Report. Prepared with Synapse Energy Economics, Inc., Cambridge Systematics, Inc., Abt Associates, Inc., Stockholm Environment Institute—U.S.

Frumhoff, P. C., J. J. McCarthy, J. M. Melillo, S. C. Moser, and D. J. Wuebbles, 2007. Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Synthesis report of the Northeast Climate Impacts Assessment. Cambridge, MA: Union of Concerned Scientists.

Hayhoe, K., C. P. Wake, T. G. Huntington, L. Luo, M. D. Schwartz, J. Sheffield, E. Wood, B. Anderson, J. Bradbury, A. Degaetano, T. J. Troy, and D. Wolfe, 2006. Past and Future Changes in Climate and Hydrological Indicators in the U.S. Northeast. Climate Dynamics 28:381-407, DOI 10.1007. Online at: www.northeastclimateimpacts.org/pdf/tech/hayhoe_et_al_climate_dynamics_2006.pdf.

IPCC (Intergovernmental Panel on Climate Change), 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Avery, M. Tignor, and H. L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, 996 pp.

Jones, C. P., W. L. Coulbourne, J. Marshall, and S. M. Rogers Jr., 2006. Evaluation of the National Flood Insurance Program's Building Standards. American Institutes for Research: Washington, DC.

Lenton, T., A. Footitt, and A. Dlugolecki. Major Tipping Points in the Earth's Climate System and Consequences for the Insurance Sector, 2009. World Wide Fund for Nature, Gland, Switzerland and Allianz SE, Munich, Germany. http://knowledge.allianz.com/climate_tipping_points_en.html.

Nakicenovic N., J. Alcamo, G. Davis, B. de Vries, J. Fenhann, S. Gaffin, K. Gregory, A. Grübler, T. Y. Jung, T. Kram, E. L. L. Rovere, L. Michaelis, S. Mori, T. Morita, W. Pepper, H. Pitcher, L. Price, K. Riahi, A. Roehrl, H. Rogner, A. Sankovski, M. Schlesinger, P. Shukla, S. Smith, R. Swart, S. V. Rooijen, N. Victor, and Z. Dadi, 2000. IPCC Special Report on Emissions Scenarios. Cambridge, UK and New York, NY: Cambridge University Press.

National Oceanic and Atmospheric Administration, 2009. http://co-ops.nos.noaa.gov/sltrends/sltrends.shtml.

Pielke, R. A., and C. W. Landsea, 1998. Normalized hurricane damages in the United States: 1925-95. Weather and Forecasting 13:621-631.

Ruth, M., D. Coelho, and D. Karetnikov, 2007. The US Economic Impacts of Climate Change and the Costs of Inaction. University of Maryland: Center for Integrative Environmental Research.

Union of Concerned Scientists, 2009. Climate Change in the United States. The Prohibitive Costs of Inaction.