

Executive Summary

Purpose

The New England Regional Assessment (NERA) is one of 16 regional assessments, conducted for the U.S. Global Change Research Program (USGCRP), as part of the National Assessment of climate change impacts on the United States. The National Assessment was conducted in response to the Congressional Act of 1990, at the request of the President's Science Advisor. The purpose of this regional assessment of potential climate change impacts on the New England Region (the six New England states plus upstate New York) is to provide a local perspective on a global issue. The intent in producing this *Foundation* document is to provide the most current insight on the topic of climate change, focused on local issues and concerns, in a relevant and accessible format of use to the public.

The overall goal of the NERA was to determine the potential impacts of future climate change by evaluating selected sectors (Forests, Water Resources, and Human Health) considered to be of importance to the New England region. For each sector we considered:

- the *current stresses* on these key sectors;
- how *additional stresses* associated with potential climate change and/or variability would impact these sectors;
- the *missing pieces* (knowledge and/or data) needed to more fully understand the potential impacts and how best to adapt to them;
- reasonable *adaptive strategies* that could be employed to reduce these impacts; and
- where possible, win/win approaches to adaptation, so that the impact of climate change is minimized and additional benefits are realized.

From the beginning, one of the goals of the assessment was to engage as many stakeholders as possible in the process. In so doing, a dialogue was initiated between research scientists, policy makers, and the general public. Regarding the important issue of climate change (past, present, and future) and its impact on the New England region, stakeholder feedback was instrumental in the identification of key sectors, specific regional concerns, perceived vulnerabilities, knowledge/data gaps, research needs for the future, and possible adaptive strategies. Well over 300 stakeholders, representing a broad range of interests, participated in the NERA effort.

The New England Regional Assessment (NERA)

The New England Regional Assessment (NERA) was initiated in September 1997, with the *New England Climate Change Impacts* Workshop, held at the University of New Hampshire (UNH). Additional Sector-specific Workshops were held in 1999. As defined by the National Assessment, the New England Region includes the six New England states (CT, MA, ME, NH, RI, and VT) and upstate New York. The NERA effort has been supported by the National Science Foundation, and focused on the analysis of existing data rather than initiating new studies.

Much of the region is heavily forested, but also includes some of the most productive agriculture (NY), especially cold-crop production, in the nation. The region has several major population centers, such as Buffalo, Albany, and Boston, but is noted for its rural setting and natural landscapes. When people think of the region, they envision spectacular fall foliage displays, winter activities such as skiing, and maple syrup production – all of which are highly sensitive to climate variables. While the common perception is of clean mountain air and sparkling streams and lakes, the reality is a region plagued by frequent episodes of poor air quality, polluted rivers, and seasonal red tides.

Stakeholders participating in the NERA identified the three key Sectors (Forestry, Water Resources, and Human Health) for detailed consideration, and three key concerns or issues likely to affect these Sectors if climate change continues (Air Quality, Seasonal Dynamics, and Extreme Weather Events). The Final Report of the NERA is offered in two forms: A *Foundation* document (this report) consisting of peer-reviewed research papers, and an *Overview* document consisting of summary statements and concepts taken from the *Foundation* document. Both documents are organized as follows. Following an introduction to key concepts (Chapter 1), necessary background information is provided on those factors which characterize the region's notorious weather (Chapter 2). The factors, both natural and anthropogenic, known to affect climate at the global and regional scale are presented in Chapter 3, and the two global climate models selected for use in this assessment are presented in Chapter 4. Detailed treatments of the Sectors are presented in Chapters 5 (Forests), 6 (Water Resources), and 7 (Human Health). Chapter 8 presents an analysis of the social and economic impacts that climate change will likely have on three regionally-important issues: the fall foliage display, regional tourism, and human health.

The Format

The format of this *Foundation* document of the NERA Final Report is designed to convey maximum information content in a technical and detailed manner. Each Sector Chapter is divided into *current stresses*, *additional stresses associated with potential climate change*, *missing pieces*, and *adaptive strategies*. Illustrative Case Studies are included in each Sector Chapter, again to provide the reader

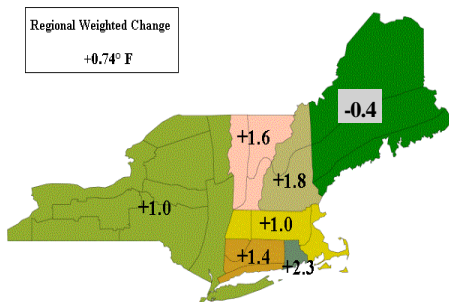
with a detailed treatment of how the Sectors are affected by present or future climate change. While many additional Case Studies could have been included, we selected only those which were illustrative of the effects of air quality, seasonal dynamics or extreme events. For the sake of readability, temperatures are given in °F.

The Key Findings

In the process of conducting the NERA, key findings were clearly identified.

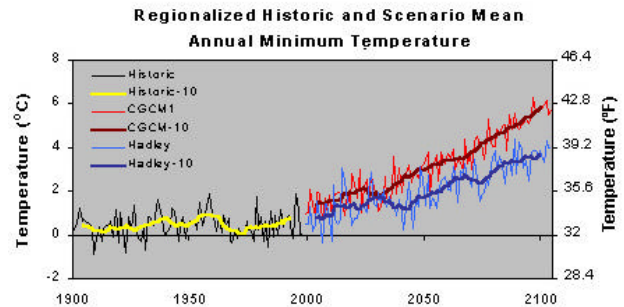
- The Regional Climate Has Changed Over the Past Century** – In an analysis of the historic temperature and precipitation records, by region and by state, the evidence indicates that the climate *has* changed over the past century (1895-1999). Overall, the region has warmed by 0.7° F, yet some states (RI, NH) have warmed by two to three times the regional average and one state (ME) has cooled. Warming in winter months (a regional increase of 1.8° F) has been greater than summertime warming (0.5° F increase for the region). Regional precipitation has exhibited a modest (4%) increase over the same time period, but as with temperature, the change has not been uniform across the region. While Maine’s precipitation has decreased by 12%, Massachusetts’ has increased by nearly 30%. We do not understand the heterogeneous nature of these historic trends.

New England & New York Temperature Changes (°F) Between 1895 and 1999



- The Models Project Significant Warming Over the Next Century** – The two models used in this regional assessment project varying degrees of temperature and precipitation increase by 2090. The Hadley Model projects a warming of 6° F in annual minimum temperatures and a 30% increase in precipitation for the region, while the Canadian Model projects a 10° F warming in minimum temperatures and a 10% precipitation increase (punctuated by periodic, long-term droughts) over the next century. Both models project a significant warming and a moderate to significant increase in precipitation. It is important to recognize that these models provide “what if” scenarios for us to con-

sider. Either temperature increase would be greater than any climate variation experienced by the region in the past 10,000 years. If either scenario occurred, the climate of the New England region would be profoundly different than the climate of today.



- The Impact of a Few Degrees Temperature Increase** – Although a 6-10° F increase may not seem to be very significant, a comparison of present-day temperatures is instructive. If 6° F were added to Boston’s 30-year average annual temperature (an average of 51.3° F between 1961-1990), the resulting temperature would approximate the 30-year annual average for Richmond, VA (57.7° F). If 10° F were added to Boston’s 30-year average, the 30-year average for Atlanta, GA (61.3° F) would result! An annual average increase of 6-10° F would have a profound impact on the climate of the region.
- Human Activities are Affecting Climate** - Our understanding of the factors, both natural and anthropogenic, which influence climate has improved dramatically over the past several decades. There is now strong scientific evidence that the global warming experienced in the last half of the 20th century is attributable to human factors including the build-up of greenhouse gases in the atmosphere. This finding is consistent with the idea that continued build-up of greenhouse gases will lead to additional climate change in the future.
- The Past and Present Changes Have Clearly Impacted the Region** - Many changes (milder winters, earlier maple sap flows, reduced snowfall, etc.) are likely to have occurred as a result of a “minor” increase in wintertime temperature (1.8° F for the entire region). The 6-10° F temperature increases projected for the region by either climate model used in this assessment must be viewed as serious.
- Regional Air Quality May Worsen** – Stakeholders identified air quality issues as the single most frequent regional concern. One significant finding of the assessment is that physical climate and chemical climate are closely related. Hot, dry summer months are ideal for converting nitrogen oxides (NO_x) from automobile traffic and volatile organic compounds (VOCs) into

ground-level ozone, a major component of smog. The same conditions provide the environment for power plant emissions of sulfur oxides (SO_x) to form sulfate haze. Both SO_x and NO_x combine with atmospheric water vapor to produce acid clouds and acid rain. If the climate becomes hotter and wetter, and automobile and power plant emissions remain the same or increase, regional air quality and acid rain problems will become worse in the future.

- **Such Future Warming Trends Would Profoundly Change the Sectors** – All three sectors analyzed in this assessment would be significantly impacted under the scenarios of climate change presented by the models. The human health impacts - both direct (health effects of poor air quality) and indirect (warmer winters facilitating expansion of Lyme disease-carrying deer tick habitat) - of physical and chemical climate change are likely to be the most significant. The Forest Sector, already under stress, will likely continue to be the most flexible and adaptive. The potential droughts (in the Canadian scenario) and/or flooding (the Hadley scenario) would have profound impacts on regional water quality and warming coastal waters will experience species shifts and toxic algal blooms. Sea-level rise will become a significant problem for low-lying coastal regions (Cape Cod, coastal areas of CT, RI, MA, NH, and ME), affecting both human infrastructure and coastal wetlands.
- **The Economic Impacts** – A very limited assessment of the economic impact of climate change was conducted on natural resources, tourism, and health care industries. The major conclusion from this initial economic analysis is that the impacts of climate change will vary and be significant. The economic impacts will be greatest on the Human Health sector, intermediate on tourism and least severe on the Natural Resource Sector. This initial economic assessment has identified the need for a more extensive analysis of a broader range of Sectors.

Missing Pieces

In the process of conducting the NERA, it was found that often something was missing, that if present, would have allowed a more complete assessment. Some missing pieces are technical and will require additional research, other missing pieces are simply a matter of needing to analyze existing datasets. Together these include:

- **A Regional Climate Model** - The National Assessment required each region to use two global climate models (Hadley and Canadian) as a minimum basis for their assessment of potential future conditions. However, because of their coarse scale, these models were down-scaled to better fit each region. Since the models were designed as global climate models, they

do not capture important fine-scale characteristics of the region (land cover, topography, etc.). A regional climate model parameterized for the New England region was not available for this assessment, but was recognized as a very important missing tool for future assessments. A significant research effort will be needed to produce a regional model from the ground up.

- **A Focused Research Effort** – The heterogeneity, both spatial and temporal, characterizing the current warming trend for the region is not well understood. A focused research effort is needed to identify and quantify those factors responsible for this heterogeneity.
- **An Expanded Economic Analysis** – A more thorough economic impact analysis, focusing on all sectors and accounting for expanded multiplier factors, is needed. The limited economic assessment conducted for the NERA had a narrow focus on only a few segments of the Forest, Tourism, and Human Health Sectors.
- **Public Knowledge about Climate Change** – The general public is often skeptical regarding climate change issues. The public believes that: 1. scientists don't agree on how and if climate change is happening; 2. the problem, if it occurs, will be 50-100 years in the future; and 3. the problem has no solution. All of these are false assumptions and must be addressed in a responsible and understandable way.
- **The Need for Educational Materials** – There is a present lack of clearly-stated (in plain English), well-documented educational materials for both the general public and the K-12 classroom. Such materials are key to informing the residents of the region about the potential impacts of climate change in the future. Such materials, once developed, must be made available to teachers, informal educators, policy makers, and the general public. Education was a recurring theme at all workshop discussions. It was agreed that education must start early if we are to change people's understanding, attitudes, and behavior – when you educate a third grader, you also educate the parents and grandparents of that student.

Adaptive Strategies

Given the nature of these findings, it will be important to identify and prioritize strategies for reducing uncertainties and mitigating potentially adverse impacts. Some actions that accomplish these goals may have other benefits to the region and are called “win-win” strategies. A partial list of “win-win” actions includes:

- Promoting the development of more extensive and efficient use of regional forests as carbon sequestration (enhanced CO₂ uptake and storage) tools, as well as more productive sources of wood products.

- Improving air quality by reducing CO₂, NO_x, and SO_x emissions, thus improving the human health and forest health, as well as lowering greenhouse gas emissions.
- The development of high efficiency/alternative energy sources that not only reduce CO₂ emissions but also other by-products (air pollutants).
- Investing in “green technologies” that reduce both CO₂ emissions and industry/business liabilities, thus strengthening their good neighbor image and creating a stronger regional manufacturing presence.

Next Steps

To address the above issues and concerns, a positive approach should be taken. By focusing on win-win strategies and avoiding “gloom and doom” predictions, we must begin to present a clear and compelling message to the public. Appropriate next steps include:

- **Development of an Expanded Regional Assessment** – Based on the results from this limited assessment, it would be prudent to conduct an expanded assessment that considers more sectors and improved tools, such as a regional climate model. Given the pace of the problem and the rapid developments in science and technology, such an expanded assessment should be conducted every 5-10 years. This assessment should include a more extensive economic analysis.
- **Reduction of CO₂, SO_x, and NO_x Emissions (Better Air Quality)** – Most steps taken to reduce CO₂ emissions will also reduce air pollutant emissions (SO_x and NO_x) as well. Such improvements in air quality across the region will bring benefits to human health and forest health. Such reductions will not only improve air quality, but would also reduce acid rain impacts, further improving forest health. Hybrid automobiles and alternative home energy systems offer such benefits.
- **Promotion of the Forests of New England as Potential Carbon Sinks (Sequestration)** – Forests are potentially significant carbon storehouses and the heavily forested New England Region could contribute to national efforts to reduce atmospheric CO₂ levels. The actual extent to which regional forests are able to act as CO₂ sinks in the future will depend on air quality, soil nutrient status, tree species sensitivity to temperature and moisture regimes, and other factors. Additional research is needed on this issue in order to fully understand the extent to which forests can provide carbon sequestration capabilities.
- **Development of Forest Management Practices to Maximize Carbon Sequestration** – Recent studies have identified the significant role that past land use practices have played in contributing to the present carbon storage capacity of regional forests. Developing future strategies to maintain or enhance current carbon storage capacity will be important. Not only will carbon storage capacities be improved, but economic benefits to the region would also result.
- **Development of Economic Incentives to Promote Alternative Energy Options** – Serious efforts need to be focused on creating economic incentives to promote the development of alternative energy options appropriate for the region. Solar-based and wind-based strategies should be considered and past regional reliance on water-power could be re-introduced. Due to our coastal location tidal action could prove to be a significant source of energy generation. These and other options will need to be supported by tax credits, subsidies, etc.
- **Development of Land Cover Strategies Which Minimize Climate Impacts** – Since forested land cover can act as strong absorbers of solar energy, a more focused effort is needed to educate the general public on the multiple benefits of maintaining and enhancing the region’s forests.
- **Conduct Impact/Risk Assessments to Minimize Potential Climate Impacts** – As with other potential risks (flooding, fire, storms, etc.) state and regional efforts are needed to address climate change risks identified in this report. Even in the face of perceived or real uncertainties, appropriate steps must be taken to reduce the risks posed by future climate change and variability.
- **Provide Broad Public Access to Information** – A series of hardcopy documents (such as this NERA report) are needed for distribution to a wide range of audiences. These hardcopy documents should include colorful, descriptive and compelling materials, designed for the public, not the scientist. Multifold Sector-specific brochures are needed, providing key graphics, major findings, and main take-home lessons in plain English for distribution to a general audience. A list of “Things You Can Do” must be provided at both the general level as well as for specific Sectors.
- **Make Difficult Decisions in the Face of Uncertainties** – While there are uncertainties associated with climate change issues, there is still a great deal of consensus among the scientific community regarding these issues. The uncertainties should not lead to inaction. Rather, rational steps should be taken to identify risks and make efficient decisions. Decision making in the face of uncertainties about the future is commonplace in people’s daily lives and businesses.
- **Focus on the Things We Can Change** – While many factors, both natural and human-induced, are known to affect the climate, we have no control over the natural factors. We do have control over the human-induced factors and must now consider what direction our future climate will take. The future is in our hands.

