NEW ENGLAND'S GLOBAL WARMING SOLUTIONS

A Study for:

World Wildlife Fund

Prepared by:

Tellus Institute
Resource and Environmental Strategies

August 2000

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Summary

The threat of global climate change and the challenge of averting it have important implications throughout the world. Scientists have shown that there is a serious risk of dangerous climate disruption if we do not dramatically reduce our emissions of greenhouse gases, especially carbon dioxide from fossil fuel combustion. In the minute amounts at which these gases occur naturally in the Earth's atmosphere, they cause the greenhouse effect which has kept our planet at the temperatures and climate with which life and civilization have flourished, rather than as a largely frozen mass. The greenhouse effect arises as these gases trap a portion of the thermal energy that the Earth, which has been warmed by the sun, would otherwise radiate outward into space. Global warming is caused by the continued buildup of excess amounts these gases in the atmosphere, which are now thirty percent above their pre-industrial levels and growing rapidly. The climate disruption that could ensue in the coming decades if this trend is not reversed, could unleash ecological, economic and social disruptions throughout the world, many irreversible or lasting for generations. It could have severe impacts in New England, which has a long coastline on the Atlantic Ocean, major forest, river and other natural environments, and various communities and economic activities that would be at risk.

Fortunately, there are promising resources, technologies and practices that could be mobilized to meet the challenge of climate change by implementing effective policies and measures. Such an initiative would help meet other social goals important to the nation and New England -- reducing local and regional air pollution, spurring technological innovation, improving productivity, reducing oil dependence and stimulating the economy.

A recent national policy study, *America's Global Warming Solutions* (Bernow *et al* 1999), outlined and evaluated an aggressive plan through which the United States could reduce its annual carbon-dioxide emissions by about 654 million metric tons of carbon (MtC) by 2010, 36 percent below business-as-usual (baseline) projections for that year. This would bring 2010 emissions to 14 percent below 1990 emissions, thereby exceeding the reductions required under the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC). The study found that these reductions could be obtained with net economic savings, almost 900,000 net additional jobs, and significant decreases in pollutant emissions that damage the environment and are harmful to human health, especially of children and elderly.

The proposed policies and measures are targeted to individual sectors. For *transportation* they call for stronger fuel economy standards and efficiency incentives for cars and trucks, a carbon content standard for motor fuels, and urban/regional demand management. For *industry* they include tax incentives, technical assistance and regulatory refinement to promote more efficient energy using equipment and cogeneration of electricity and thermal energy (often called combined-heat-and-power or CHP). For *electricity generation*, they entail a renewable portfolio standard with tradable credits, a tighter national sulfur dioxide cap, output based generation performance standards for emissions of nitrogen oxides, fine particulate matter and carbon dioxide, and a requirement for co-firing of biomass at coal plants. For residential and commercial *buildings*, they include stronger and expanded appliance and building standards, market transformation, manufacturer incentives and consumer education, and promotion of community energy systems using co-generation. There are also *cross-cutting* measures, such as research, development and demonstration of advanced, efficient energy technologies and clean energy resources.

New England contributes significantly to the threat of climate change, has ecological and economic vulnerabilities, and offers opportunities for carbon emissions reduction. If the region were a country its emissions would put it within those of the top twenty nations of the world. New England's economy, environment and citizens face a future of uncertainty and potential harm from climate disruption. Higher temperatures and precipitation changes could threaten its sensitive aquatic and terrestrial ecosystems, its vulnerable fresh water supplies, its citizens' health and it's economy. Climate change could also increase existing environmental and health problems in New England. Currently, areas throughout the region are in non-attainment of the National Ambient Air Quality Standards established by the Environmental Protection Agency (EPA) for ground-level ozone concentrations, largely from automobile and power plant emissions from both within and beyond the region. With further climate change, it is likely that these excessive levels would increase and their geographic extent would expand, thereby increasing respiratory illnesses and deaths, and further undermining forests, ecosystems and crops.

New England can contribute to and benefit from national policies and measures to avert dangerous climate change. It has long been an innovator and leader in forward-looking energy and environmental policies. It has local supplies of clean energy resources such as wind and biomass, and has significant potential for more efficient energy technologies in its industry, transportation, homes and offices. A shift to these clean resources and advanced energy technologies and resources to reduce carbon emissions would have ecological, economic and health benefits throughout the region. Moreover, with its strong high technology economy and academic institutions, New England could provide leadership in developing some of the advanced technologies for national and international markets that will grow as development, climate stabilization and environmental protection efforts gain momentum.

This report presents a new detailed analysis of the energy impacts, carbon and pollutant emissions reductions, and economic benefits in New England of the national policies and measures analyzed in *America's Global Warming Solutions*. That study indicated that the region would reap about one sixth of the net national employment created. As two years have passed since that study was begun, time has been lost for pursuing and implementing the policies and measures evaluated along the same temporal path. Now, achieving such benefits by 2010 would require an even more aggressive set and schedule of policies, or else the benefits would occur somewhat later in time. Nonetheless, these results show that a truly aggressive national policy commitment to the problem of climate change could achieve large near-term carbon emissions reductions along with environmental and economic gains.

While the analysis reported here is of the effect of national policies and measures in New England, some of these options could also be pursued within the region itself, appropriately tailored to its conditions and institutions, with similar results and benefits for its citizens. There are some initiatives underway in some of the New England states, including renewable portfolio standards (RPS), system benefits charges (SBC) and emissions performance standards for electricity, as well as low emissions vehicle (LEV) standards in transportation. The New England states could include greenhouse gas mitigation in carrying out their State Implementation Plans to meet EPA's air quality requirements. The region could thus harmonize its economic, environmental and public health goals with a national energy and climate strategy.

The national policies in *America's Global Warming Solutions* would shift New England toward more advanced, energy-efficient technologies and cleaner resources. This study finds that:

- ***Primary Energy Use and Carbon Emissions*** would decrease by 19 percent and 31 percent, respectively, below levels that would otherwise be reached by 2010.
- ***Renewable Energy Resource*** use would increase by 48 between 1990 and 2010, reaching about 22 percent of total primary energy use by 2010. Wind and biomass would provide about 15 percent of annual electric generation, and cellulosic ethanol would provide 7 percent of transportation fuels by 2010.
- ***Industrial cogeneration*** would increase by about 60 percent in 2010 instead of remaining roughly constant. Total cogeneration, including industry and district energy systems, double by 2010 and reach about 26 percent of projected electricity requirements in that year.
- ***Increasing Net Annual Savings*** would reach about $4.6 billion or $305 per-capita in 2010, averaging about $2.2 billion or $162 per-capita per year through 2010. New England would save about $21 billion over that period in present value terms.
- ***Employment in New England would increase*** by about 41,200 by 2010, with the largest gains in construction, services, miscellaneous manufacturing and agriculture.
- ***Air Pollutant Emissions*** in New England would decrease significantly by 2010; sulfur dioxide by 40 percent, nitrogen oxides by 17 percent and particulates by 11 percent.

Figure S.1 shows how the proposed national policies and measures would reverse the upward trend in New England's carbon emissions. It shows the contributions to the overall emissions reductions, from changes in energy consumption by each end-use sector -- transportation, industrial, commercial and residential -- with reductions in carbon emissions produced in electricity generation allocated to these sectors in proportion to their electricity use.

Figure S.1: Carbon Emission Reductions in New England Demand Sectors due to the National Policies

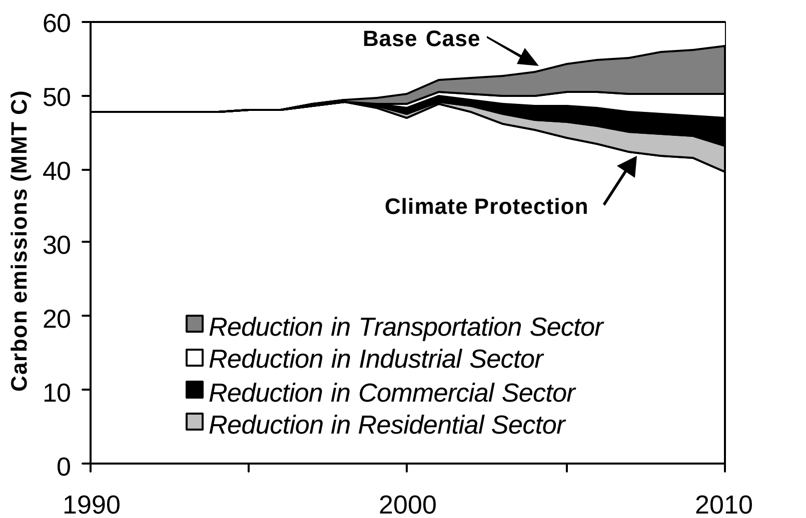


Table S.1 summarizes the reductions in energy use, the shift towards renewable energy resources and co-generation, the decreases and carbon and air pollutant emissions, and the economic benefits.

Table S.1: Summary of Policy Impacts in New England

	1990	2010 Base Case	2010 Policy Case
End-use Energy (Quads)	2.52	3.26	2.74
Primary Energy (Quads)	3.42	3.98	3.24
Renewable Energy (Quads)	0.48	0.59	0.71
Carbon Emissions (MtC)	47.7	56.8	39.2
Other Emissions ('000 tons)			
Sulfur Dioxide	664	440	264
Nitrogen Oxides	633	437	328
Fine Particulates (PM-10)	136	134	119
Net Savings (billion 1998$)			
In the year	--	--	$ 4.6
Cumulative (discounted)	--	--	$20.9

Quads: Quadrillion British Thermal units (Btus); There are 0.125 Million Btus per gallon of gasoline.
MtC: Million metric tons of "carbon equivalent" -- carbon in carbon dioxide.[1]

These changes in New England's energy system would help the U.S. reduce its global warming emissions, meet its Kyoto Protocol targets in the near term, and establish momentum for the deeper reductions needed for climate protection in subsequent decades. At the same time, they would contribute to the economic vitality, environmental integrity and quality of life in the region.

[1] As carbon dioxide consists of one molecule of carbon (atomic weight of 12) and two molecules of oxygen (atomic weight of 16), emissions of this gas is represented here in terms of its carbon. Thus, one kilogram of carbon would represent 3.67 kilograms of carbon dioxide -- (2x16 + 12)/12 = 44/12 = 3.67. Emissions of sulfur dioxide, nitrogen oxides and fine particulates are given here in short tons (2000 pounds), not metric tons.

1. Introduction

1.1. Global Climate Change

The international community of climate scientists has moved toward the consensus, expressed by the Intergovernmental Panel on Climate Change (IPCC), that "…human activities are having a discernible impact on global climate" (IPCC 1996). Concentrations of carbon dioxide (CO_2) in the atmosphere are now approximately 360 parts-per-million (ppm), about 30 percent above the natural, pre-industrial levels. This is unprecedented in many tens of millennia.

Annual global CO_2 emissions (measured as carbon) from human activities are about 6 billion metric tons from fossil fuel combustion and 1 billion from land-use changes (mainly burning and decomposition of forest biomass). Under a business-as-usual future, annual global emissions of carbon are expected to increase about threefold by the end of the next century, and atmospheric concentrations would approach three times pre-industrial levels (IPCC 1996). Climate models, recent empirical evidence and the paleo-climatological record indicate that this would cause global average temperature to rise between 1.4 to 2.9 degrees Centigrade (2.5 to 5.2 degrees Fahrenheit), with even greater increases in some regions (IPCC 1995; 1996).

The potential consequences of such change are myriad and far-reaching. Sea level rise could approach one meter (IPCC 1995; 1996), with severe implications for coastal and island ecosystems and human communities. Shifts in regional climates, and more frequent and prolonged extreme weather events (droughts, hurricanes and floods), could cause severe geophysical, ecological, economic, health, social, and political disruptions.

While the precise timing, magnitude and character of such impacts remains uncertain, our climate and ecological systems could undergo very large irreversible changes. The probabilities of extremely adverse outcomes in such complex and sensitive systems may not be extremely small as is normally the case in simpler systems (Shlyakhter *et al.* 1995). Global warming itself would increase the rate of greenhouse gas accumulation, thus accelerating global warming and its impacts. For example, runaway warming could be precipitated by the release of methane from a thawing of the arctic tundra and decreased uptake of carbon by a warming of the oceans. Moreover, large changes could occur very rapidly once a threshold is reached, perhaps on the time-scale of a single decade (Schneider 1998; Severinghaus *et al.* 1998). Rapid change could cause additional ecological and social disruptions, further limiting the abilities of natural and social systems to adapt. The rapid onset of climate disruption and its impacts could render belated attempts to mitigate climate change more hurried, more costly, less effective, or too late. The environment, economy and citizens of New England have unique vulnerabilities to such climate change impacts.

1.2. Regional Impacts

The potential damages from climate change will not likely be distributed evenly around the world; they will vary depending on geophysical, ecological and socio-economic factors (IPCC 1998; Harvell *et al*, 1999; EPA, 1999). The combination of sea-level rise and increased frequency and severity of storms would be especially problematic for regions with low-lying coastal communities, economies and ecosystems. Other extreme weather events such as prolonged intense droughts, as well as more general changes in regional weather patterns, could have profound effects on ecosystems and important impacts on local economies. In many regions, the fates of forests, water systems and agriculture, and the ecological and economic and social stability that depends upon their viability, will be affected by climate change.

New England's citizens, economy and environment could be harmed by climate change (IPCC, 1998; EPA, 1999; ISEOS, 1997; NE, 2000). In the absence of significant mitigation, global warming over the next hundred years would likely result in general changes in New England's climate and weather patterns. Average temperatures are expected to increase by 3 to 5^{o}C (about 5 to 9 ^{o}F), while precipitation would increase by 5 to 25 percent. New England has a large population already exposed to extreme weather events and air pollution, particularly ground-level (tropospheric) ozone. Climate change could exacerbate existing problems in sensitive ecosystems that are caused by pollution, sprawl and other forms of disruption, while creating new problems. The region's diverse ecosystems and economic activities, especially those associated with its forests, freshwater systems and coastal areas, with habitat-specific flora and fauna, are threatened by the magnitude and pace of climate change that could occur in the coming decades.

Changes in New England's climate and weather patterns could exacerbate some old and new problems known in the region. Higher sea-levels and increased frequency of intense storms would threaten roads and causeways, valuable residential and commercial properties, nearby small islands, and lucrative recreational and tourist areas, along New England's coasts. They could also disrupt the conditions sustaining tidal flats, wetlands, freshwater mashes, estuaries, and beaches, which are important habitats for numerous aquatic and nearby terrestrial birds, animals, fish and shellfish. Saltwater intrusion into freshwater systems could undermine habitats and drinking water supplies. Increased frequency of extreme weather events could also affect inland conditions throughout the New England states. The destructive ice storms of 1998, unprecedented in the region for generations, provide an example of what much greater global warming would bring more regularly to New England. The same changes in climate could increase the occurrence of extreme drought conditions in the region, with associated damages to crops and ecosystems.

Excessive levels of ground-level ozone, already a serious problem in various parts of New England (EPA, 1999; NESCAUM, 1998; Miller 1997), would likely increase with a warming trend, thus exacerbating its harmful effects on human health, ecosystems, forests and crops. Areas throughout Connecticut, Massachusetts and Rhode Island, as well as Portsmouth, New Hampshire, are now classified as being in "serious non-attainment" of the national ambient air quality standards for ozone, established to protect human health. Portland and nearby areas of Maine's southern coastal counties and southern areas of New Hampshire are in moderate non-attainment.

Tropospheric ozone is formed by reactions between nitrogen oxides (emitted largely from vehicles, power plants and industry) and volatile organic compounds (emitted largely from vehicles and released naturally from trees), in the presence of sunlight, with the highest levels usually occurring on the hottest days. Continued emissions of these pollutants in the context of increased warming and extreme temperature days would increase ozone concentrations and expand the areas of their unhealthful levels. Higher concentrations would likely increase the incidence of acute respiratory problems, asthma attacks and deaths, especially among the urban populations of the region. It could also affect the health of New England's forests, particularly trees in its elevated mountain ranges, which already suffer from excessive levels of ozone, owing in part to the long-range transport of nitrogen oxides from the Midwestern sources, especially power plants. Interestingly, many of sources of carbon dioxide, within and outside of New England, are also sources of the pollutants that form ground level ozone in the region. Thus, national (and regional) carbon dioxide mitigation policies would decrease both the climate conditions and pollutant precursors of tropospheric ozone in New England. The region's environmental, public and economic conditions could also suffer from other energy related pollutants, such as sulfur dioxide and fine particulate matter, which contribute to acid rain, health problems, and visibility degraded by haze. These, too, could be ameliorated by harmonized climate and pollution policies.

Inhabitants of New England's cities could also face increased suffering and death from the greater number of high temperature days. Heat related deaths could increase from about twenty percent to several-fold with even a modest global warming of about 1 ^{o}C in the region (IPCC, 1998; EPA, 1999). The elderly would face the greatest risk of increased heat-related illnesses and deaths, as the intensity and duration of its heat waves increase.

New England's forests would face an uncertain future with global warming as a result of temperature and precipitation changes, and potential changes in the incidence of wildfires, pests and diseases (EPA 1999; Bloomfield et al 1997; NE 2000). These changes could entail an overall decline as well as changes in its species mix. They could threaten the region's important forest products industries, including those providing paper and pulp, timber and maple syrup. With increased regional temperatures, the northward shift of the region's maple syrup industry into Canada would likely continue. Changes in regional climate, weather patterns, habitats, and species levels and composition, could undermine various recreational activities and enterprises that serve them. The economic activities and amenities associated with the region's skiing and winter sports, stream and lake fishing, hiking and autumnal foliage would be threatened.

Freshwater and drinking water supplies in New England could be diminished by temperature increases, precipitation changes, higher evaporation rates, and saltwater incursion from sea-level rise and increased storms near coastal areas. Stream flows could be reduced, and aquifer and lake levels could decline, depending on these various factors and their seasonal patterns. Greater irrigation requirements for agriculture could put additional demands on these more limited freshwater supplies. Warmer waters in streams and lakes, and changed oxygen levels, could modify aquatic metabolism, undermine some species while favoring others, and create conditions for invasions of new species. Harmful algal blooms in warmer lakes and ponds, as well in warmer seas (the well-known red and brown tides), could increase in occurrence, range and persistence. These conditions are toxic to humans and could harm the region's shellfish habitat and industry.

Agriculture contributes more than $2 billion to New England's economy through crops and livestock. Crop production would tend to move northward with global warming, while many factors associated with the region's natural conditions, the nature of the sector, and the complexities of climate change, render the future of agriculture in New England uncertain. Agricultural impacts, which are affected by farmers' adaptive responses as well as temperature, precipitation, soil conditions, and carbon dioxide levels themselves, could range from decreased production for some species and locations to increased production in others. Generally, it is expected that the yields of key crops, such as potatoes, hay and silage would decline significantly, with adaptation, increased land use, and farm income effects uncertain.

The geographic range and habitat of insects, such as mosquitoes that carry dengue fever and malaria, could continue to spread farther northward from more tropical areas and threaten residents of currently temperate climates (Epstein 1999; Patz et al 1996). For example, one study estimated between seven and fifteen weeks of potential dengue transmission in Boston with warming of 2 to 4^{o}C (IPCC, 1998. page 314), a condition unheard of under normal conditions. With warmer and wetter conditions in New England, mosquitoes that can carry eastern equine encephalitis and malaria, which now flourish in parts of Connecticut and Massachusetts, could increase and expand to more northern parts of the region. Connecticut is second in the nation and Massachusetts fifth in the incidence of the tick-borne Lyme disease, which could also increase its incidence and range climate change in the region.

1.3. Climate Protection

Reducing the ultimate magnitude of human-induced climate change and slowing down its rate would help to protect vital ecosystems, economies and communities. To avert dangerous climate disruption, the current global emissions of about 6 billion tons carbon equivalent, now projected to increase to about 20 billion tons by the end of the next century, would have to decrease to less than three billion tons by that time. Even then, the carbon equivalent in the atmosphere would reach about 450 parts per million, about 60 percent above pre-industrial levels, which would still entail some climate change, sea-level rise and ecological impact.

Already, the industrialized world contributes 4 billion tons per year, two-thirds of global emissions, with almost 1.5 billion or about one quarter of annual global emissions from the U.S. alone. For stabilization at 450 ppm, the world would have to decrease from about 1 ton per capita to less than 0.3 tons per-capita by the end of the twenty-first century. To match this global average per-capita target, the U.S. would have to reduce its carbon emissions intensity almost twenty-fold from its current level of about 5.4 tons per-capita. At about 3.5 tons per-capita, the carbon intensity of New England is about two-thirds that of the U.S. as a whole. Nevertheless, the New England region has ample potential for reductions of its greenhouse gas emissions and would benefit from national policies for emissions mitigation. Moreover, the region has the opportunity to substantially reduce its own carbon emissions and play an important role in the development of new emissions mitigation policies and technologies nationally and worldwide.

In December 1997, countries throughout the world adopted the Kyoto Protocol to the UN Framework Convention on Climate Change, as a first step towards stabilizing concentrations of greenhouse gases in the atmosphere to reduce the risk of dangerous climate change. The Kyoto Protocol requires that carbon emissions during the period 2008 to 2012 be reduced below 1990 levels by 7 percent for the U.S., 6 percent for Japan, 0 percent for Russia, and an average of 8 percent for the European Union.

The Protocol affords the U.S. and other industrialized nations considerable flexibility in meeting these reduction targets. These options include offsets amongst different greenhouse gases, offsets from biomass carbon sinks, the Clean Development Mechanism (CDM) that could create offsets from undertaking actions in developing countries, Joint Implementation projects, and industrialized nation trading of emissions allocations. Exploiting such options could allow the United States to undertake correspondingly lower reductions in carbon emissions from its own energy sector while still meeting its 7 percent net reduction commitment, at lower near-term costs. However, these flexibility mechanisms have certain problems that will need to be resolved before implemented on a large scale. Otherwise they could seriously threaten climate protection and environmental integrity (GACGC 1998), socio-economic development, and the credibility of the Kyoto Protocol.

Moreover, given the rather modest reduction targets of the Protocol relative to the much deeper long-term reductions needed for climate protection, use of the flexibility mechanisms may permit too slow a start and too weak a signal to spur the necessary technological transition in energy production and use (WWF 1998). The focus of our climate protection activities must thus be on where the heart of the problem and its solution lies – beginning a sustained process to achieve deep reductions in domestic energy-related carbon-dioxide emissions. In rising to that challenge, we could spur technological modernization and innovation, pollution reduction, increased productivity and economic benefits. By avoiding or diminishing such actions we could miss these opportunities.

Notwithstanding marked regional variation in its destructive potential, climate change is a global problem that requires solutions at all levels -- global, national, regional and local. The demographic, economic and political interconnection of peoples within nations and around the world could produce serious secondary impacts that would reverberate within and across national boundaries. Among such impacts could be decreased production, decline of markets for locally and internationally traded goods, increases in the number of environmental refugees, and exacerbated political instability and conflict. Moreover, both the scope of the problem and the moral interconnectedness of peoples demand cooperative action to curb climate change, based on the principles of adequacy, equity and capability embodied in the Climate Convention.

Arguably, as the limited carbon carrying capacity of the atmosphere has been nearly exhausted by the U.S. and other industrialized nations in amassing their economic power and wealth, both the responsibility and the capability for addressing climate change fall largely on their shoulders. As developing country economies will need to grow in the near term, early global carbon emissions reductions will have to come from the industrialized countries; this would both slow the rate of carbon accumulation in the atmosphere and inaugurate the technological and institutional transition to a low-carbon economies. At the same time, the industrialized countries could provide technological and financial assistance to the developing countries to help ensure that their economic growth is along a path of low-carbon intensity. The developing countries could thus advance in a manner that does not recapitulate the North's history of energy-inefficient, fossil fuel based economic growth; and there is already evidence that some have begun to pursue such a path (Reid and Goldemberg, 1997). The responsibilities of the U.S. and other industrialized countries come with opportunities -- for pollution reduction, improved public health and environmental quality, for technological innovation, productivity improvement and economic development, and for institutional and human capacity building that can help ensure sustainable development.

1.4. U.S. Policies and Measures

America's Global Warming Solutions showed that the U.S. could reduce its carbon emissions by 14 percent below its 1990 levels with solely domestic energy policies and measures, and enjoy net economic savings, increased employment and pollution reductions. Thus, the U.S. could significantly reduce its greenhouse gas emissions and go beyond its target under the Kyoto Protocol without use of the flexibility mechanisms, through policies and measures that would affect energy choices, resources, technologies and systems throughout the country. The economic and environmental benefits of these policies and measures would be widespread across the country. While there would be many common impacts in each region or state, there would be some variation that would reflect differences in current and projected energy and economic conditions.

This report provides an analysis of the impact that these national policies and measures would have in New England. The impacts that we estimate include changes in energy demands, energy supply technologies and fuel mix, carbon emissions, pollutant releases, costs, savings and employment.

2. Energy Use and Carbon Emissions in New England

New England's energy system and carbon emissions reflect its unique geographic, climatic and economic conditions. Thus, the region's relative contributions to national carbon-dioxide emissions and to national emissions mitigation will also reflect these conditions. So, too, will the opportunities for and impacts of emissions mitigation policies.

2.1. Current Energy and Emissions

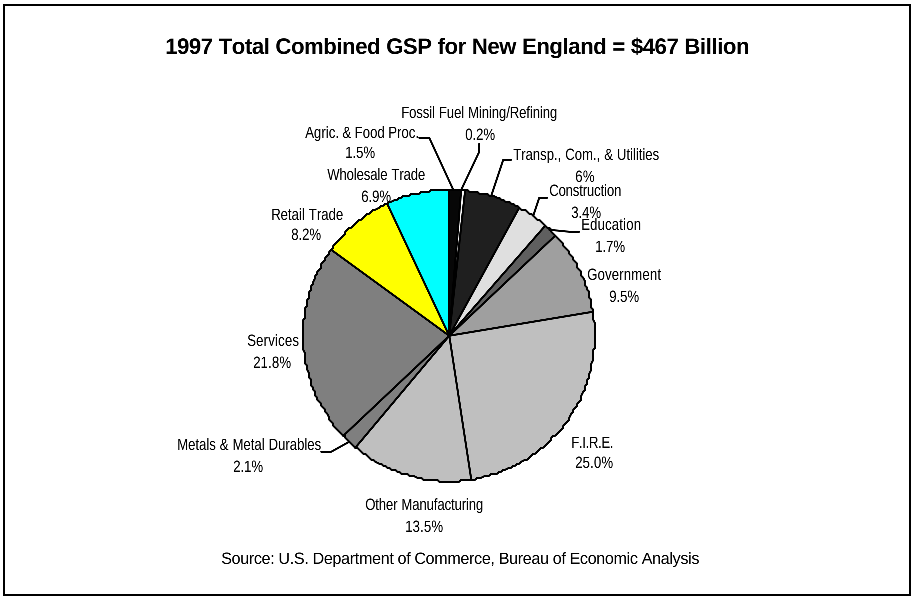
A few basic points about New England's economy, energy use and energy-related policies can set the stage for discussing the prospects for carbon emissions mitigation in the region. The region has great economic diversity. New Englanders comprise about 5 percent of the U.S. population and produce about 5.7% of the Gross Domestic Product (GDP) of the nation (ASM, 1998). Overall, the New England economy is dominated by services, at about 80 percent of its combined gross state product (GSP), including finance, insurance and real estate, wholesale and retail trade, health and education, and government. However, the region also has a strong manufacturing sector, specializing primarily in the manufacture of industrial machinery, electronic equipment and other instruments, as well as substantial agricultural, forest products and fishing industries. Figure 1 below provides a breakdown of the region's economic output.

Seventy percent of the population of New England is located in two states, Massachusetts (45%) and Connecticut (25%). Together, these two states account for 75% of the combined GSP of the region. In 1996, facilities in Massachusetts and Connecticut accounted for 56% the electric generation in the region, consumed nearly 80% of the coal used for electric generation, and emitted about 77% of New England's electric sector carbon emissions.

In 1996, New England consumed about 2.8 quadrillion Btu's (Quads) of fuels and electricity to meet their end-use energy demands in residential and commercial buildings, industry and transportation.[2] This was nearly 4.2 percent of national energy consumption. Since the New England population was about 5.1 percent of the national population in 1996, its end-use energy intensity of 209 million Btu (MMBtu) per-capita is about 82 percent of national energy intensity. The figures below show the composition of the regional end-use energy consumption by state, as well as the consumption per-capita for each state and the region as a whole.

[2] Here "end-use" electricity is expressed in Btu instead of the usual kilowatt hours (kWh) in order to combine it with end-use fuel consumption, by using the conversion factor of 3,412 Btu per kWh. The "primary" fuel consumption (of coal, oil, gas, etc) to produce this electricity is greater than this, as it includes losses in the conversion process in electricity generation (requiring about 7,500 to 10,000 Btu of fuel per kWh of electricity), as well as losses in transmission and distribution (about 10%).

Figure 1: 1997 Contributions to Combined Gross State Product in New England by Sector



While New England has a vigorous, diverse and innovative industrial sector, it is not as intensely industrial as other regions. Industrial energy use in the region is about 2.9 percent of national energy use, far below its population share. New England's transportation energy use is about 3.8 percent of national energy use, about 25 percent below its population share owing largely to its greater density. Its residential and commercial energy uses are 6.4 percent and 6.0 percent of national consumption, respectively, well above the region's population share.

New England has a different sectoral energy mix than the nation as a whole. Industry consumes about 25 percent of the region's total end-use energy, while nationally it consumes about 37 percent of the total. New England's residential and commercial energy uses comprise 41 percent of the Region's total, while for the nation it is about 27 percent. Transportation contributes about 34 percent of the total in New England and more than 36 in the country as a whole.

Figure 2.A: State Share of 1996 End-Use Energy Consumption in New England

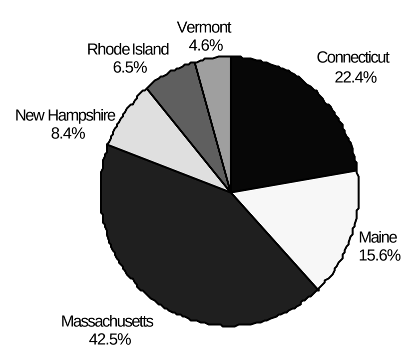
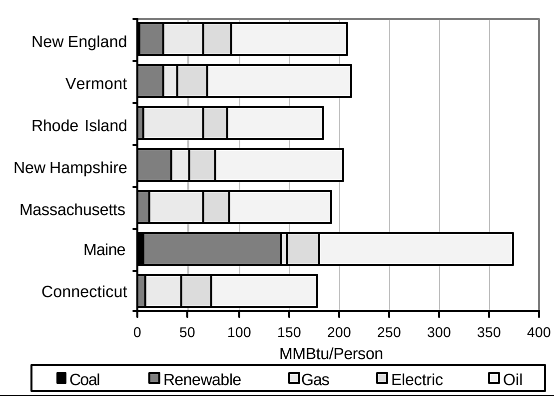


Figure 2.B: 1996 End-Use Energy Consumption Per Capita in New England



The end-use fuel mix in New England also differs from that of the nation as a whole. Oil dominates both the U.S. at 50 percent and New England at 55 percent. Gas provides 29 percent in the U.S and only 19 percent in New England, owing largely to high transmission costs, as well as pipeline capacity constraints which are now beginning to be addressed. In New England about two-thirds of end-use natural gas is consumed in buildings and one-third in industry, while in the U.S. about half is consumed by industry. Oil use in buildings is about 29 percent in New England and only 6 percent nationally. Thus, while 70 percent of end-use oil consumption occurs in transport nationally, it is about 60 percent in New England.

Electricity comprises 14 percent of end-use energy in New England and 15 percent in the U.S. In 1996 New England electricity generation was dominated by nuclear at 25 percent, with coal at 15 percent, natural gas at 19 percent and oil at 19 percent. Renewables (biomass, hydro) and municipal solid waste (MSW) contributed about 13 percent. In the U.S. about one half of electricity is produced by coal, about 20 percent by nuclear energy. While hydro-electricity contributed about 11 percent nationally, it was 7.6 percent in New England. New England's fuel mix for overall primary energy resources (taking account of the fuels for electricity) is 50 percent oil, 19 percent gas, 5 percent coal, 9 percent nuclear and 12.4 percent renewables. This is quite different from the nation, for which natural gas dominates at about 35 percent, followed by oil, coal, nuclear and renewables, at about 29, 24, 8, and 4.5 percent respectively.

New England's carbon-dioxide emissions reflect its overall energy use and fuel mix, about 48 million metric tons of carbon in 1996, about 3.5 percent of total national emissions of 1428 million tons. Thus, New England emits about 3.4 tons per-capita, only two-thirds of the national average of about 5.4 tons per-capita. A comparison of New England and U.S. carbon emissions is given in the figures below. Figure 3.A, shows emissions as driven by end-use demands by allocating emissions from electricity generation to the sectors in proportion to their demands. Figure 3.B, shows emissions at the points of fuel combustion.

Figure 3.A: 1996 Carbon Emissions - Electricity Allocated to End-Use Sectors

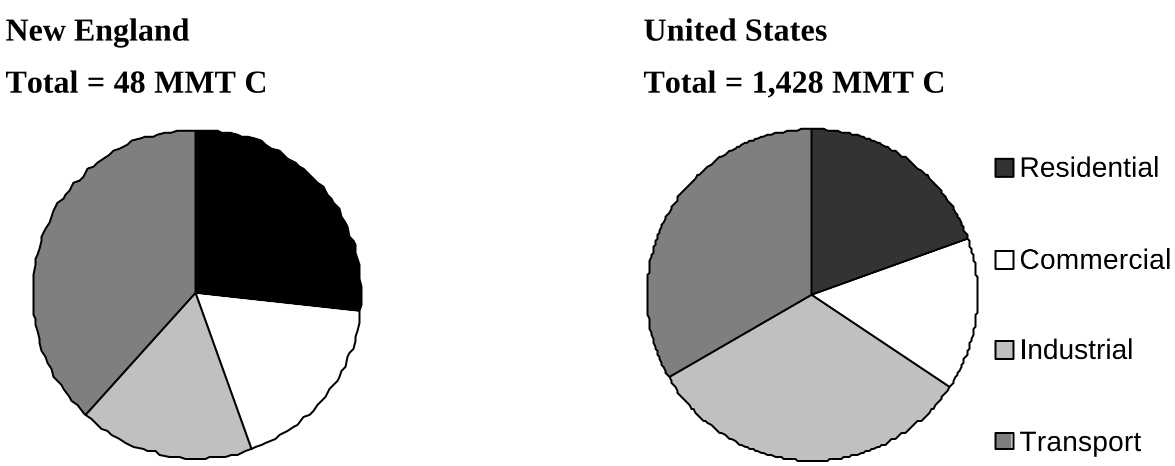
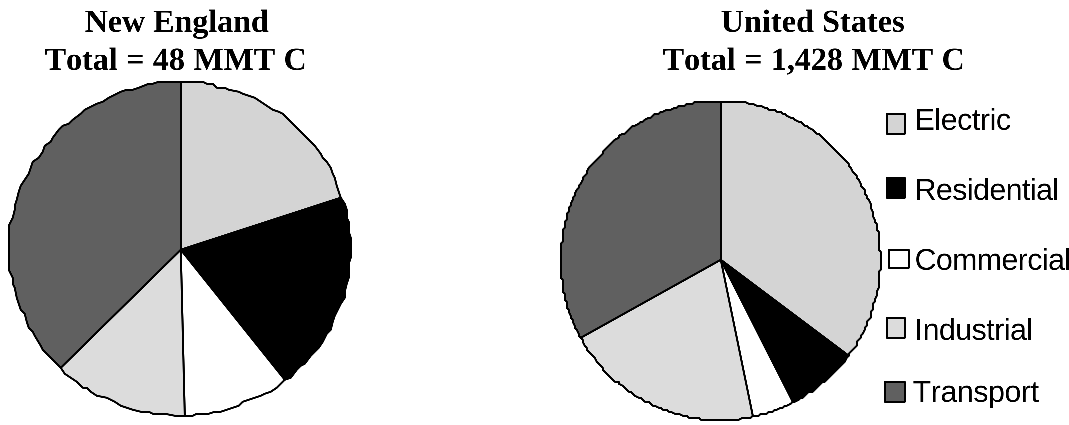


Figure 3.B: 1996 Carbon Emissions from Primary Energy Use by Sector



As can be seen in these figures, carbon emissions from electricity generation and industry play far smaller roles in New England than nationally, while emissions from buildings play a greater role.

2.2. Future Emissions and Mitigation Options

In the absence of new initiatives, New England's energy use and carbon emissions will continue to grow in the coming decade, notwithstanding substantial opportunities for technologies and practices that could bend these curves from their upward paths while saving money for households and businesses. Here we provide some of the energy, technology and policy context in New England, as background to our analysis of the impacts within the region of the national policies and measures of *America's Global Warming Solutions*. We do not analyze new state or regional initiatives here. We describe activities and policies underway within the region to promote energy efficiency, renewable energy resources and emissions reductions. Development of policies and measures in New England similar or complementary to the national initiatives studied here would help to realize the region's substantial untapped potential for greater energy efficiency and cleaner energy resources.

Fuel and electricity use in the region is projected to increase by about 29 percent between 1990 and 2010, a growth rate of 1.3 percent per year; from 1996 to 2010 the increase would be about 15.2 percent or 1.0 percent per year, reflecting a slowing of energy demand growth. Carbon and pollutant emissions will thus be likely to continue rising in the absence of national and State policies designed to mitigate them. Figure 4.A summarizes these trends.

From 1996 to 2010, under business-as-usual conditions, New England's carbon emissions would grow by about 19 percent, from 47.9 to about 56.8 million metric tons, while U.S. carbon emissions would grow by 25 percent from 1428 to about 1800 million metric tons. Thus, the New England share of the national total would decline slightly, from 3.4 to 3.2 percent. Figure 4.B summarizes these trends.

Figure 4.A: Base Case Primary Energy Use in New England

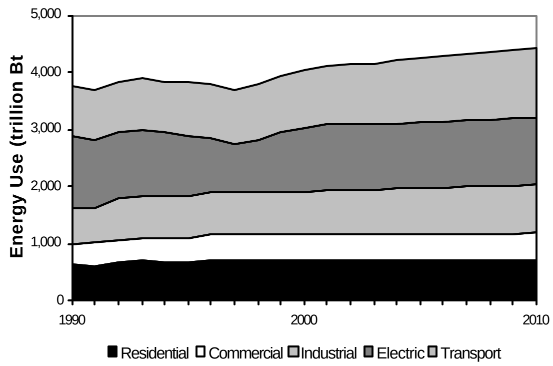
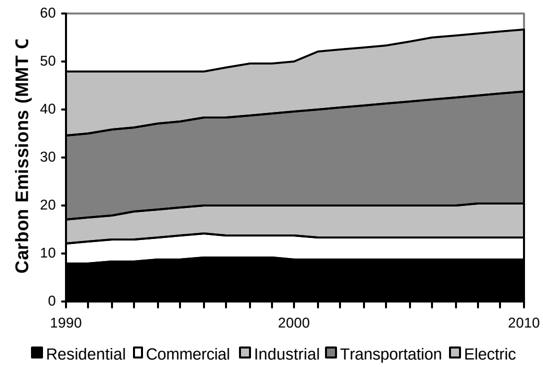


Figure 4.B: Base Case Carbon Emissions in New England



National and state policies could help to stimulate investments in energy efficiency and renewable resources to reverse the trend in New England of increasing carbon and other pollutant emissions. New England has the natural, human and economic resources to transform its energy system to a more modern, efficient, and clean technological basis that would reduce its emissions of carbon dioxide and other pollutants while improving its economy.

Analyses by various agencies and organizations have surveyed the potential for cleaner, more efficient energy use in New England, and have also identified policies to help to realize this untapped potential and reap its economic and environmental benefits. A report by Lawrence Berkeley Laboratory (Krause *et al*, 1992) found that energy efficiency, end-use fuel switching to gas, advanced combined cycle and cogeneration could achieve about 50 percent carbon reductions from the region's electricity generation by 2010, 15 percent below 1990 levels, at net reductions in costs. In that scenario, up to 20 percent of demand or 32 terawatt hours (TWh) would be met by energy efficiency and 5 percent (over 8 TWh) by cogeneration.[3] In a more aggressive scenario, in which modest net cost increases were found, up to 75 percent reductions were estimated for 2010 by increasing cogeneration (to about 8 percent) and adding biomass and wind (up to 14 percent of demand). Studies by Tellus Institute (1993a and b; 1997) also show substantial potential for efficiency and renewable in New England.

2.2.1. Electricity Generation and De-regulation

New England has made progress in recent years to reduce its emission of NO_x and SO_2. All the New England states are members of the Ozone Transport Commission (OTC), which also includes New York, New Jersey, Pennsylvania, Delaware, Maryland, the northern counties of Virginia, and the District of Columbia. It was established, following the passage of the 1990 Clean Air Act Amendments, to address the transport of ozone in the region from its sources (power plants and vehicles) and precursors (NO_x and VOCs) to its air quality impacts, in order to reduce summertime ozone formation in the region. Since 1990, the OTC states have reduced emissions of as well as SO_2. This has had the additional co-benefit of reducing CO_2 emissions from electric generation in New England by 26% overall between 1990 and 1996 (EPA, 2000).

[3] 1.0 TWh = a billion kilowatt hours kWh)

One result of the tightened federal Clean Air Act standards in the region has been the reduction in the region's reliance on coal in recent years, declining 8.5 percent overall between 1991 and 1996. However, the region is still over four times more reliant on oil for electric generation than the national average and 50 percent more reliant on nuclear power. At the same time, its use of renewable resources to generate electricity is 70 percent higher than the nation's. In 1996, Maine led the nation with more than half of its electricity generated from renewable sources, with biomass accounting for about 24 percent and hydropower nearly 28 percent of total generation statewide. The tighter emission standards in the region, along with New England's higher than average utilization of renewables and nuclear power, make its electricity generation among the least carbon-intensive in the country – with an overall emission factor for carbon of just 0.097 MtC/TWh, about two-thirds of the national average.

In the last three years, owing largely to technical problems, New England has closed three of its aging nuclear power plants (CLF, 1999). This has temporarily increased New England's reliance on oil even more to make up the generation deficit left by the nuclear units' retirement. New England also imports a significant amount of its power from Canada. This dependence will likely decrease in the future as the region continues to expand its pipeline capacity for natural gas - which is likely to become the region's primary fuel in the next decade.

Reliance on higher priced generation fuels such as nuclear has made the region's electricity prices among the highest in country. This has spurred the drive toward deregulation of New England's electricity markets. With the acceptance of its restructuring plan by the Federal Energy Regulatory Commission (7/97), the New England Power Pool became the first multi-state electric control region in the country to move to a deregulated market-driven system for the generation and transmission of electric power. All six of the New England states have since either fully deregulated or are following timetables to deregulate fully their retail electric markets as well. Rhode Island was the first state in the region to offer all industrial, commercial, and residential electric consumers in the state the opportunity to choose their electric supplier, beginning July 1998. Massachusetts followed in November 1998, New Hampshire in March 1999 and Maine in March 2000. Retail electric markets in Connecticut are opened to competition in the summer of 2000. Vermont too is moving to deregulate all retail electric sales, although restructuring legislation establishing a final date for competition there has not yet been passed into law. (EIA, 2000; NEGC, 1997)

One danger in deregulating an industry with such a significant impact on the environment as electric power supply is that price competition will not reflect environmental impacts, and "dirtier" generation would prevail. It is thus important to complement de-regulation with policies, regulations and initiatives, both within and as complements to restructuring legislation, in order to reflect environmental goals. Fortunately, the New England states, in general, have responded to this challenge to help guide the region's emerging competitive electric markets toward cleaner generation. Some of the legislators, governors and regulators in New England have taken steps to promote greater efficiency and reduced emissions (EIA, 2000, NECPUC, 1996, NEGC, 1998).

Massachusetts and Connecticut, which have the highest electric demand and the highest reliance on coal for electric generation in the region, include in their proposed restructuring laws environmental performance requirements for electric generators. Connecticut includes CO_2 along with other emissions performance standards, while Massachusetts has a CO_2 offset requirement. Finally, these two states have recently announced cuts in pollutant emissions at their dirtiest power plants, which will likely yield CO_2 reductions as well. This is not to say that the present restructuring laws in Massachusetts and Connecticut could not be improved. Nonetheless, they provide examples of how to establish standards and incentives for greater efficiency and to promote air quality goals in the context of electric deregulation. A federal standard based on the experience in New England would further help to smooth out the current unevenness at the borders between different states, each with slightly different emissions standards and other requirements for electric generators and retailers (Page, 1998). A brief summary of some of the climate-relevant energy policies reflected in the New England state's restructuring laws (or state plans) is given below (for further detail see NEGC, 1999):

1) Disclosure of associated emissions (including CO_2) on customer bills (all states).
2) Support for "green marketing" of renewable-content electricity products (all states).
3) Renewable Portfolio Standard for retail electric providers (CT, ME, MA).
4) Emission Performance Standard for generators (CT, MA).
5) Systems Benefit Charge to support renewables or energy efficiency in each state (NH, no renewables; VT now energy efficiency).
6) Support for Net Metering for customers with small-scale renewable generation (all states).

2.2.2. Cogeneration

The potential for highly efficient cogeneration, or combined-heat-and-power (CHP), in New England is substantial. Cogeneration is a well understood technology with a long history, which now has great potential for economic and environmental benefits in industrial and community energy systems, owing to ongoing technological advances. Instead of producing thermal energy for manufacturing processes on site, at efficiencies of about 70 percent, while purchasing electricity from central station power plants. These generating facilities currently operate at about 30 to 40 percent efficiency, with higher efficiency plants becoming available. With cogeneration, both thermal energy and electricity could be produced on site at overall efficiencies of 85 percent or higher. The "marginal" electricity generation, i.e., the generation obtained from the extra fuel above that need to meet the thermal loads, could range from about 70 to over 90 percent, far higher than that of efficient new power plants.

Cogeneration using natural gas in advanced combustion turbines, or fuel cells in the near future (which could also use biomass), would provide very high efficiencies coupled with low carbon fuels. Thus, primary energy consumption, carbon emissions, and pollutant emissions would be dramatically reduced, while satisfying heating, cooling and electricity needs. Cogeneration could also help to mitigate market power, and thereby unjustifiably high electricity prices, which could emerge in some regions under de-regulation when there are too few electricity suppliers dominating the markets.

Cogeneration units in 1998 supplied the energy needs of approximately 117 industrial and commercial sites, representing about 2.8 GW of total installed capacity, almost 10 percent of New England's total installed generation capacity (EIA, 2000). These units generated about 16.5 TWh, about 14 percent of the net electrical energy supplied in the region. About 41 percent of this generation was used on-site at and the remainder sold to the electric utilities for use in meeting system loads. Natural gas and renewables (primarily biomass) were the dominant fuels used. Nearly half of the region's CHP capacity is currently installed in Massachusetts. The rest is located in Maine (30 percent) and Connecticut (20 percent), with New Hampshire, Rhode Island, and Vermont together representing less than 5 percent. About half of all the cogeneration units currently installed are small reciprocating engine units less than 1 MW (which together represent only about 2 percent of installed CHP capacity).

With approximately 1.1 GW and 0.6 GW of total capacity respectively, New England's pulp and paper and chemical industries have benefited most from installation of on site CHP. Commercial and institutional sites have been slow in updating their existing heating and cooling systems to CHP units (likely due in part to new discounted electric rates available to many large energy users since deregulation). Commercial applications collectively make up about 250 MW of installed capacity. The food processing industry has also installed a significant amount of new CHP capacity in recent years, about 174 MW (Hedman, 2000).

A recent economic analysis of CHP potential for the U.S. Environmental Protection Agency projects only a modest amount of new CHP development in New England over the next decade (ICF, 1999, Gerhardt, 2000). The expected regional industrial steam and electricity demands were modeled, along with the various supply options for facilities that might benefit from co-generation, to project the likely economic viability of new CHP development in each state. The study projects that only an additional 600 MW of new CHP capacity is likely to be economic to develop in New England by 2010, based on its analysis of current and expected market conditions over the next decade. This represents a dramatic drop in new CHP development compared to the previous decade's boom.

A recent study for the U.S. Department of Energy (Hedman, 2000) on the total potential for CHP development in the U.S. indicates significant room for expansion of CHP capacity in New England to many additional industries and businesses. The study estimates a potential for additional development of up to 1000 MW of new capacity for large CHP units in New England. It also concludes that recent technological advances in smaller units (below 1 MW) provide additional potential in that market of about 8,700 MW of new CHP capacity in New England.

These results suggest that state or federal incentives to promote CHP development in New England could help to overcome the institutional, regulatory and informational barriers that have impeded its reaching its full potential. If the price of electricity in the region decreases, owing to ongoing technological changes or the arrangements established by de-regulation, the barriers to CHP and its environmental benefits could increase. Without policies to address these concerns, many industrial facilities over the next decade may decline to replace existing boilers with new CHP plants, thereby choosing less energy-efficient and more carbon and pollution intensive options. To promote further CHP development, Maine has included CHP in its definition of renewable energy sources that are supported through its renewable portfolio standard and other state renewable energy programs.

2.2.3. Renewable Energy

New England also has substantial potential for renewable energy development. Maine currently leads the country in electricity generation from renewable resources, owing to its large forests and forest products industries. In 1996, over 50 percent of the power generated in the state came from renewable resources, with biomass generation representing nearly 24 percent of the state's total electrical output and hydro representing almost 28 percent of its output. Maine's renewable development raises the average for the whole region. Car must be taken, however, to ensure that biomass energy is obtained using ecologically sustainable practices, and to ensure that hydro is small scale and low ecological impact. Regionwide, renewables accounted over 17 percent of New England's total generation, nearly 16 TWh in 1996. A recent study found that there is potential in Massachusetts and Rhode Island for an about another 5.3 TWh to be developed in those states alone by 2017 (assuming current capacity factors), with nearly one-third of the new capacity built coming from wind power (Donovan, 1997). Several New England states have included in their electric restructuring plans, renewable portfolio standards, systems benefit charges, net metering provisions, and other policies to promote more renewable energy development in the region.

2.2.4. Transportation

A number of factors, among them urban sprawl and cheap gasoline prices, have contributed to sharp growth in car registrations and vehicle miles traveled in New England. The increasing use of light trucks (SUVs), which are not subject to the same modest national fuel efficiency standards as cars, is contributing to rising gasoline consumption. Today, transportation is the highest energy consuming sector in the region, accounting for about 34 percent of all energy demand.

Several initiatives have aimed at diversifying the mix of fuels and reducing air pollution from energy use. The Energy Policy Act of 1992 mandated vehicle fleet owners to pursue targets for the use of alternative fuels. Cities throughout New England -- e.g., Boston, Portland and Providence -- are currently participating in the USDOE's Clean Cities Program. This program is a voluntary, locally based government/industry partnership that aims to mobilize local stakeholders in achieving greater market penetration of alternatives to the use of diesel and gasoline. Cities in the region have also joined the International Consortium for Local Environmental Initiatives (ICLEI), which encourages and assists actions to reduce greenhouse gas emissions in municipal operations and to promote reductions citywide. Massachusetts, Vermont and Maine have adopted the California Low Emission Vehicle (LEV) program for reducing mobile source emissions. This program requires vehicle manufacturers to provide emission certification to more stringent standards than the Federal Tier I standards for all cars sold in these states. Massachusetts has adopted the program for model year 1999 vehicles, Vermont for 2000 model year vehicles, and Maine for the 2001 model year. Connecticut, New Hampshire, and Rhode Island are participants in the EPA's National Low Emission Vehicle Program that vehicle emission certification at least to Federal Tier I standards.

2.2.5. Building Energy Use

In 1992, the National Energy Policy Act (EPAct) was signed into law. One of the law's many provisions calls on states to upgrade their building codes for new commercial and residential structures to the standard for energy-efficient construction set periodically by the U.S. Department of Energy (DOE). Although EPAct contains no specific sanctions for states that do not comply with its mandated commercial codes and recommended residential codes , as of this writing at least half of the states have updated their building codes to meet or exceed federal standards (BCAP, 2000).

All of the New England states except Maine have adopted new building code regulations that meet or exceed DOE's minimum standard for residential buildings. When EPAct was first passed, the standard for residential buildings was the 1992 Model Energy Code (MEC 92), which was updated in 1993 and 1995, and may soon be updated again. Maine's residential building code still does not even meet the old standard (i.e., MEC 92). On the other hand, Vermont has a new residential building code that is among the strictest in the nation, exceeding the MEC 95 standard by 5 percent. All New England states have commercial building codes that meet or exceed DOE's current standard for new commercial construction, known as the ASHRAE/IESNA 90.1-1989 standard.

An updated commercial standard is currently being evaluated by DOE (ASHRAE/IESNA 901999) for possible promulgation in 2001 (BCAP, 2000). If the new standard is adopted, states will have two years to adjust their commercial building codes (if the state's current code does not meet the new DOE standard) in order to stay in compliance with federal regulations. Revising building codes every few years to meet the new DOE standards may cost states a small amount, to pass new state regulations and train building inspectors and construction workers. However, each time a state updates its codes to the efficiency benchmarks set by DOE, the energy costs saved by its residents would far exceed the costs of switching to the new standard.

3. The National Policies and Measures

America's Global Warming Solutions presented analysis of national policies and measures within each sector that would stimulate faster adoption of more energy-efficient technologies and low-carbon energy resources, and induce innovation, learning and further diffusion. These policies and measures included a robust mix of complementary approaches, including incentives, market creation and transformation, regulatory modernization, technical assistance, efficiency and performance standards, research and development, and tax reform. Specifically they were:

For transportation:

- A vehicle efficiency initiative, including: progressively stronger fuel economy standards for cars and sports utility vehicles; an efficiency and emissions based rebate system for vehicle purchases; R&D for improved design, materials and technologies; public sector market creation programs for cleaner and more efficient vehicles; and standards and incentives for freight trucks and other commercial modes.
- Urban/regional transportation demand management and related incentives; pricing reforms, including congestion and emissions-based pricing; land-use and infrastructure planning for improved access to alternative and complementary travel modes, including transit, walking and biking; facilitation of high speed intercity rail development; pricing, planning and informational initiatives to promote intermodal freight movement.
- A progressively stronger cap on the carbon intensity of motor fuels, reaching a 10 percent reduction by 2010; R&D for cellulosic ethanol, other renewable fuels and associated vehicle technologies; renewable fuels commercialization programs in various market segments, including public sector procurement programs.

For industry:

- Tax incentives to stimulate more investment in new more efficient energy-using manufacturing equipment, and RD&D to bring down the costs and speed the availability of more efficient equipment;

- Regulatory refinement and technical assistance to remove disincentives for industrial combined-heat-and-power (CHP), whereby electricity is co-generated on-site, rather than imported from the grid, along with thermal energy for manufacturing processes.

For electricity generation:

- A progressively increased national renewable portfolio standard that would require suppliers to collectively provide 10 percent of generation by 2010 with renewable resources, with a credit trading system to ensure that the target is met with a regional distribution that results in lowest cost.
- A tightening of the 1990 Clean Air Act Amendment SO_2 cap, which now halves the sector's emissions from 1990 levels to 9 million tons by 2000, to reduce them further to about 3.5 million tons by 2010. A cap and trade system for NO_x and fine particulates to reduce their levels. These pollution restrictions would both reduce coal use and carbon emissions.
- A requirement for co-firing of biomass in coal plants, with credit trading, which is progressively increased to 10 percent by 2010, providing near-term carbon reductions and stimulating development of biomass resource supplies.
- A cap and trade (or tax) for carbon emissions to reduce the carbon intensity of the sector between 1990 and 2010 by about 40 percent.

For commercial and residential buildings:

- Appliance and building standards, which would establish norms for equipment, design and performance which, through purchases and practices, would reduce energy used to provide services in homes and offices.
- Market transformation incentives including technology demonstrations, manufacturer incentives, and consumer education to reduce barriers to energy savings and renewables.
- Initiatives to expand the use of combined-heat-and-power (CHP) for district energy systems (DES), to co-generate electricity along with thermal energy for heating and cooling in buildings.

4. Energy, Carbon and Cost Impacts

The national policies and measures examined in *America's Global Warming Solutions* were estimated to achieve a 22 percent reduction in annual primary energy use and a 36 percent reduction in annual carbon emissions by 2010 relative to the DOE baseline projections for the U.S. in that year. Carbon emissions is 2010 would thus be about 14 percent below 1990 carbon emissions. These carbon emission reductions are realized entirely through energy-related policies and measures, with net economic savings. The analysis showed that national savings in energy bills would exceed the net incremental investments in more efficient technologies and expenditures for low carbon fuels through by an average of about $150 per capita per year from 1998 through 2000. Cumulative discounted savings to the nation's economy would reach more than $300 billion over that period.

In New England, these national policies would reduce carbon emissions by about 31 percent below baseline projections for 2010. These reductions reflect a 19 percent reduction in primary energy use by 2010, owing to increased investment more energy efficient equipment, as well as a shift to less carbon-intensive fuels for electricity, transportation and industry. Net annualized savings were estimated to average about $162 per-capita from 1998 through 2010, reaching over $300 per-capita or $4.6 billion in that year. Cumulative discounted savings would be about $20.9 billion over that period.

This section presents a summary of the methods and assumptions for the national and New England analysis and more detailed energy, carbon and cost/benefit results.

4.1. Analyses and Results for Energy and Carbon

National and regional energy demand, supply and cost data for the both the Base Case and Policy Scenario were taken from the EIA projections and the models used for the analyses. These were benchmarked to recent energy demand, supply and price data for New England. The modeling approach for the national analysis is described in *America's Global Warming Solutions* (Bernow et al 1999) and its predecessor study *Policies and Measure to Reduce CO_2 Emissions in the U.S.* The National Energy Modeling System (NEMS) of the Department of Energy (EIA, 1996), which was used in the national analyses, provides detailed information and policy impacts on electric power supply by reliability region, including the New England Power Pool. Moreover, it provides building sector results for the North Central U.S. census region, which includes New England. Relative demographic and economic growth rates were used to allocate national and regional projections onto New England. The Long-Term Industrial Energy Forecasting (LIEF) model (Ross *et al*, 1993) was run for the Base Case and Policy scenario, benchmarked to New England fossil and electricity prices and industry structure. For transportation, we used regional data from NEMS projections for various modes and vehicle types, combined with New England data on the mode and vehicle mix and energy use. The policy variables were applied in a model to reflect transport demand, stock turnover, fuel-efficiency and costs.

4.1.1. Transportation

Analyses of the policy impacts in the transportation sector took account of vehicle stock turnover, fuel-efficiencies and travel indices, and were benchmarked to the structure, data and baseline projections of the EIA (1998). The analyses were further benchmarked to transportation data for New England. For light duty vehicles (LDVs), we assumed a progressively improving national fuel efficiency standard, increasing by 1.5 miles per gallon (mpg) per year from 1998 through 2010. This results in new cars at an average of 45 mpg and new light trucks at 37 mpg in 2010. For the entire fleet in operation, the average would be about 25 mpg, about 19 percent above baseline projections for that year. The demand management and mode shift policies (including planning and incentives for increased use of transit, walking and high occupancy vehicles) would reduce LDV energy use by another 8 percent. Some of the measures for achieving these additional savings include: reforming the workplace parking subsidy, adopting location-efficient mortgage guidelines to encourage infill and discourage sprawl, increasing transit services, and improving pedestrian and bicycle access. For heavy-duty freight trucks fuel efficiency improvements would be about 8 percent by 2010 relative to baseline projections.
We assumed that the carbon content requirement and cellulosic ethanol policies would result in a progressive increase to a 10 percent contribution of cellulosic (wood derived) ethanol as a blend with gasoline in cars by 2010. In New England, this would require about 62 trillion Btu (about 0.5 billion gallons). About 3.6 million dry tons of wood are required to provide this fuel, which

could be obtained from the region’s own biomass resources -- forest and mill residues, urban wood wastes and short rotation woody crops. It is anticipated that this demand could be met by using about 45 percent of the region's potential biomass resources that could be delivered at less than $50 per dry ton (about $3 per MMBtu) (Walsh *et al* 1999; Walsh, 1999). If resource constraints develop, biomass could likely be obtained from outside the region at comparable prices.

Figure 5A and 5B summarize the impacts of the national policies on energy use and carbon emissions in the New England transportation sector. Under the business-as-usual (baseline) projections, New England energy use for transport -- by cars, commercial and freight trucks, trains, airplanes and boats -- would grow by about 28 percent between 1990 and 2010, well below the national trend.

Figure 5.A: Transport Energy Use by Fuel Type -- Base Case vs. Policy Case

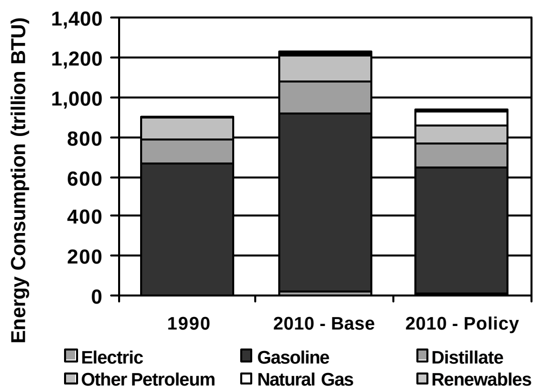
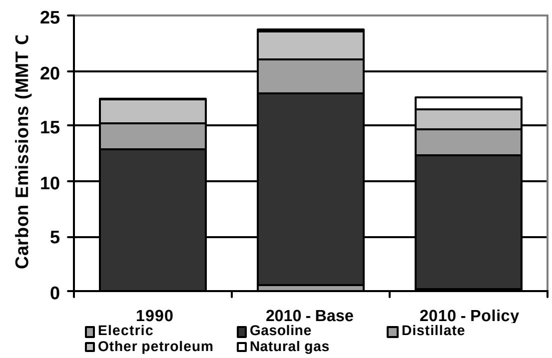


Figure 5.B: Transport Carbon Emissions by Fuel Type – Base Case vs. Policy Case



The efficiency and demand management policies would reduce transportation energy use in New England by increasing levels over time, reaching 24 percent below baseline projections for 2010. Reduction in gasoline use would be greater than this, at 31 percent, owing the use of 10 percent cellulosic ethanol blends.

The fuel use reductions from the efficiency and demand management policies would reduce the annual carbon emissions from the sector by about 5.4 MtC, a 23 percent reduction in the sector's projected baseline emissions in 2010. The carbon content/ethanol policy would reduce emissions by about 1.3 MtC or 5.6 percent in 2010, owing to the displacement of a portion of projected gasoline consumption. It would also displace an additional 0.2 MtC from displaced grid-based electricity owing to 1.6 TWh of electricity (1.7 percent of total electricity in the policy case) that is co-generated in the production of ethanol. An additional 0.3 MtC would be saved (largely outside of New England) owing to reduced energy use at refineries in producing less gasoline. Overall, then, transportation policies would reduce carbon emissions by 6.9 MtC in New England in 2010, about 30 percent of the region's transportation sector emissions and 12.3 percent of the region's total emissions projected for that year.

4.1.2. Industry

For industrial energy efficiency policies, we used the empirically based LIEF model, benchmarked to the baseline energy price and consumption projections of the DOE's 1998 *Annual Energy Outlook* (AEO, 1998). A high effective discount rate of 27.8 percent was used in the Base Case in order to match the LIEF model projections with observed energy demands. This rate is far higher than the cost of money, in order to reflect the market, informational, institutional and other barriers that impede investments in cost-effective energy using equipment. We assumed that this rate would be reduced to 12.3 percent by the policies of technical assistance, information, tax credits and R&D. We found that national industrial energy consumption could be decreased by more than 10 percent by 2010, relative to the Base Case, through investments in cost-effective energy efficiency induced by the policies.

For analysis of the impacts of the national policies on New England's industry, we benchmarked the LIEF model to data and projections for the contributions to economic output from the various industry sectors, industrial energy use and industrial energy prices in the region. We found that overall industrial energy consumption in the region would decrease by about 10 percent by 2010 owing to the national energy efficiency policies, with electricity consumption reduced by about 29 percent. Total fossil fuel and electric savings due to efficiency improvements for all industrial sectors combined were found to about 80 trillion Btus by 2010 (not includingCHP impacts). This represents an average savings of about 16 percent in fossil fuel plus electricity purchases in 2010, with electricity savings alone at about 28 percent in that year. Figures 6 A and 6 B show the percentage efficiency improvements within each industrial sector and the contribution of each sector to the total energy savings of 80 Tbtu in 2010 The contribution of each sector to the total depends on its efficiency savings and its relative energy consumption.

Figure 6.A: Share of Total 2010 Industrial Energy Saving by Sector (not including CHP)

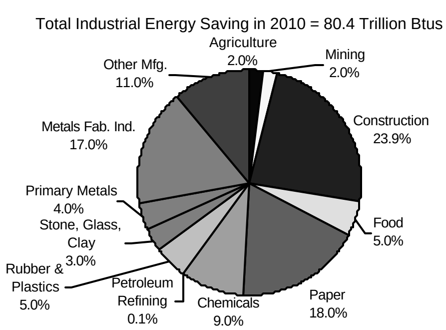
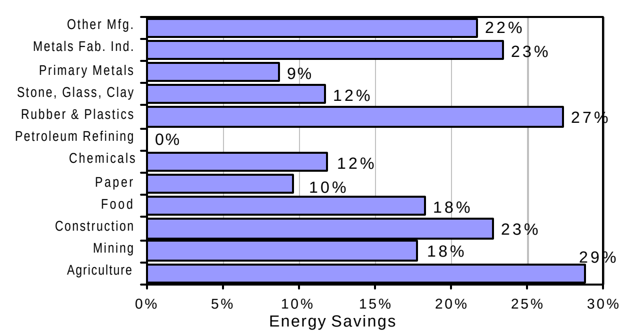


Figure 6.B: Percentage Reduction by 2010 in Energy Consumption within Each Sector from Efficiency Improvements



For industrial combined-heat-and-power (CHP) with advanced micro-turbines, we assumed that by 2010 twenty percent of existing manufacturing steam demand in the nation would shift to cost-effective gas-fired co-generation and fifty percent of existing co-generation in the paper and pulp industry would retrofit to advanced turbines. Nationally, this results in 38 GW of additional CHP capacity and 236 TWh electricity generated on site by 2010. For New England, it results in an additional 1.9 GW and 9.9 TWh (4.2 percent of the national CHP achieved and 10.5 percent of electricity generation in New England in the policy scenario). As might be expected, in New England about half of this additional co-generation would be in the paper and pulp industries, while for the U.S. as a whole these industries would comprise about 30 percent of the total.

The industrial demand for electricity purchased from the grid is reduced owing to this additional CHP by 33 percent in 2010. CHP does not appreciably affect overall end-use energy consumption in industry, since the on-site electricity generated requires additional fuel. But the additional fuel is far less than that needed for the grid electricity generation that it displaces, and its natural gas fuel is cleaner than the high-carbon avoided fuels, both on site and at the power plant. As a consequence, efficiency plus CHP reduce overall industrial fuel and purchased electricity use by about 9.6 percent by 2010, with purchased grid electricity alone reduced by 62 percent.

Figures 7.A and 7.B summarize the impacts of the national policies on energy use and carbon emissions in New England industry.

Figure 7.A: Industrial Energy Use – Base Case vs. Policy Case

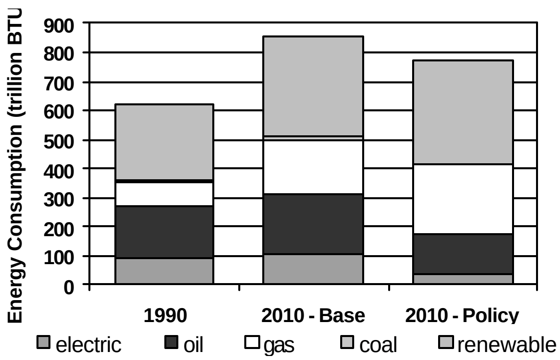
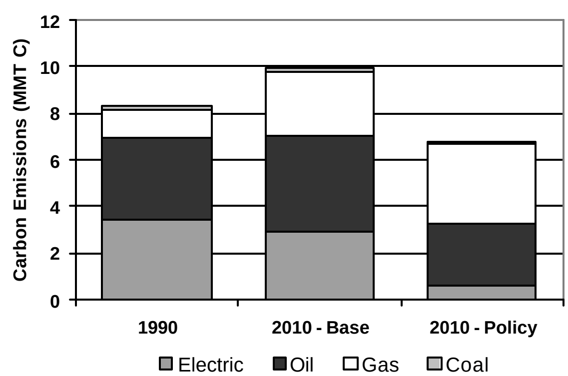


Figure 7.B: Industrial Carbon Emissions by Fuel Type – Base Case vs. Policy Case



The national energy efficiency policies would reduce on-site carbon emissions from New England industry by about 1.0 MtC in 2010, 14 percent of the total emissions from fossil combustion. They would also decrease emissions from industrial electricity use by 1.2 MtC, about 41 percent of the emissions caused by industrial electricity use. Thus, the efficiency policies would reduce carbon emissions from overall fuel and electricity use by about 22 percent.

The additional CHP would cause a decrease of 1.3 MtC in emissions from grid based electric generation, with an increase of 0.2 MtC in on-site emissions. Thus, the reduction in carbon emissions from efficiency and CHP, from both on-site fossil combustion and purchased grid electricity, would be 3.3 MtC or about one-third of the emissions caused by energy demand by New England industry in 2010.

4.1.3. Buildings

For residential and commercial building policies we used the NEMS model, which represents energy technologies and demand for each major fuel type and end-use, including air conditioning, space and water heating, and various types of equipment and appliances, based on building and technology characteristics and costs. The policies noted earlier were modeled though changes in the availability of new more efficient technologies and of the "hurdle" discount rates that reflect non-financial influences (e.g., information) on consumer choice. Overall national energy use in buildings was reduced 15.6 percent in buildings in 2010.

For New England the energy use reduction was found to be 12.8 percent overall, about 14.7 percent for residential and 9.9 percent for commercial buildings. These savings are mostly in reduced electricity demand from more efficient lighting, household appliances, office equipment, and heating and cooling systems. Thus, electricity demand is reduced 21.4 percent in residential and commercial buildings.

About 59 percent of carbon emissions from energy demands at households (where oil dominates) and commercial buildings (where gas dominates) in New England arise on-site from fossil fuel combustion, while about 41 percent arises from generation of purchased electricity. As the efficiency policies have much greater impact on electricity demands, and the mix of fuels in electricity generation are much more carbon-intensive than gas, the buildings sector carbon reductions arise almost entirely from decreased electricity demand. The national energy efficiency policies for residential and commercial buildings would reduce annual carbon emissions in New England by increasing amounts over time, reaching about 4.4 MtC or 19.1 percent below baseline projections for 2010.

The national policies also included initiatives to promote district energy systems (DES) using co-generation (CHP) to provide heating, cooling and electricity to high-density commercial buildings. The thermal energy that is co-generated along with electricity would be used to heat and cool buildings, replacing fossil combustion in on-site boilers and furnaces, and electric air conditioning and space heating systems. Nationally, district energy systems provide 152 TWh, about 5.8 percent of electricity requirements in the policy scenario. We assume that the New England share of this national potential is proportional to its share of national population; thus the region would have about 7.8 TWh from district energy systems (about 8.3 percent of total electricity in the policy case). Assuming that the DES is gas fired co-generation instead of simple gas turbines, they would contribute a net carbon reduction of 0.6 MtC in New England, by displacing fossil-based heating from boilers and furnaces, as well as electric heating and cooling, in commercial buildings with systems using co-generated thermal energy.

Figures 8 and 9 summarize the energy use and carbon emissions impacts of the national policies on the residential and commercial sectors in New England.

Figure 8.A: Residential Energy Use by Fuel Type – Base Case vs. Policy Case

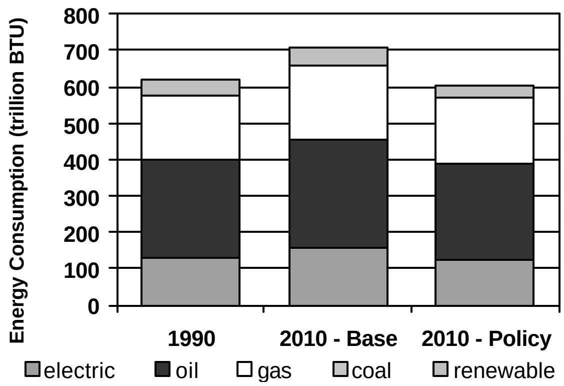


Figure 8.B: Residential Carbon Emissions by Fuel Type – Base Case vs. Policy Case

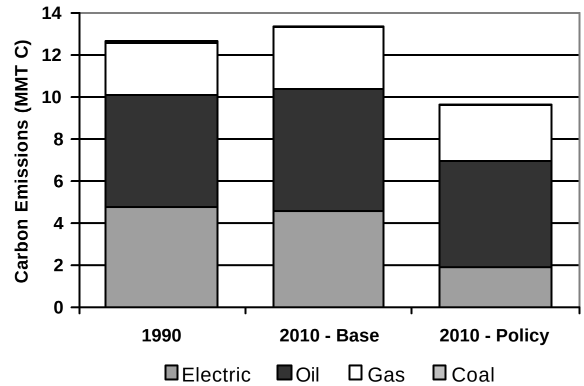


Figure 9A: Commercial Energy Use by Fuel Type – Base Case vs. Policy Case

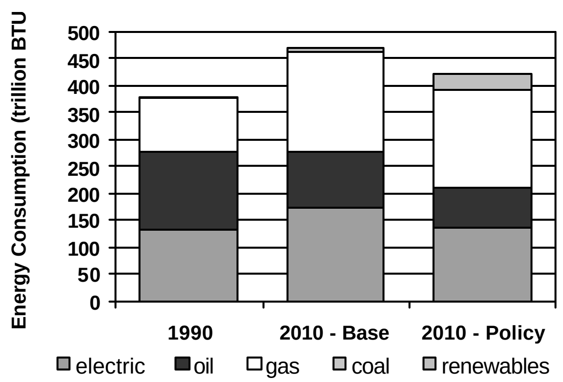
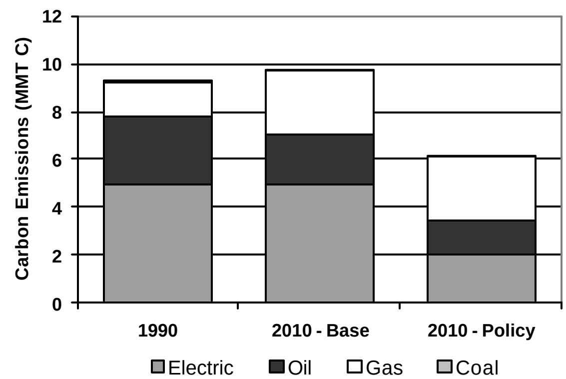


Figure 9.B: Commercial Carbon Emissions by Fuel Type – Base Case vs. Policy Case



4.1.4. Electricity Supply

The electric sector policies were modeled using the Department of Energy's National Energy Modeling System (NEMS). NEMS includes data for existing power plants in the thirteen Electric Reliability Council regions of the U.S. and neighboring Canadian regions. It simulates dispatch of these plants and new plants needed to meet the growing electricity demand in each region, taking account of regional exchanges and the characteristics of existing and new electricity supply options. NEMS was used to analyze a national renewable portfolio standard (RPS) set to ramp up to 10 percent of electricity generation in 2010 from solar, wind, biomass and geothermal power plants. It was also used to model the progressively tighter cap on sulfur-dioxide emissions, and generation performance standards by employing "externality" adders for particulates ($10,000 per ton), oxides of nitrogen ($2,500 per ton) and carbon ($50/ton CO_2). The results of the NEMS analyses for the NEPOOL region, comprising the electricity demand and supplies of New England states, were used to obtain the impacts of the national policies on electricity supply in New England. The national standard for biomass co-firing in coal power plants, to displace ten percent of existing coal generation by 2010, was modeled in New England based on the results of the NEMS analyses.

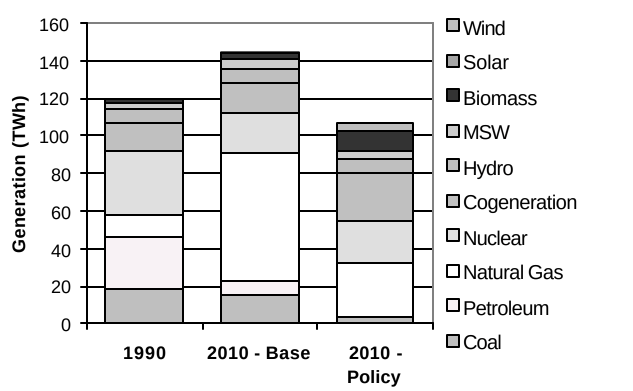
In our analysis, the national end-use efficiency and co-generation policies reduce annual electricity requirements in New England by about 33 percent in 2010, from a 1996-2010 growth rate of about 1.1 percent per year to a decline of about 1.5 percent per year. This reduces the need for construction of new power plants as well as emissions from the operation of new and existing By 2010, about 48 TWh less electricity is generated, 11 TWh less with coal (a reduction of 73 percent), 39 TWh less with gas (a reduction of 57 percent) and 7 TWh less with oil (a reduction of 100 percent).

As a result of the national RPS, New England's total electricity generation from renewables would reach 27 TWh in 2010, about 19 percent of total generation plus imports projected in the base case. Excluding those renewables that are not covered by the RPS (hydro and municipal solid waste) renewable generation in 2010 would be 14 TWh, 4 TWh from wind and 10 TWh from biomass, about 15 percent of total generation in the policy scenario. Another 0.4 TWh would by provided by biomass co-fired in New England's coal plants. Thus non-hydro renewables would more than double and the total would increase by about 50 percent in 2010.

About 74 trillion Btu of biomass resources (or 4.4 million dry tons) is needed by 2010 to provide the co-firing and biomass power generation. Combined with the 3.6 million for cellulosic ethanol vehicle fuel, this could come from the 8.0 million dry tons available within the region -- from forest and mill wastes, agricultural residues, urban wood wastes, and biomass crops -- at less than $3 per MMBtu (Walsh *et al*, 1999).

The national generation performance standards for particulate matter, sulfur dioxide, nitrogen oxides and carbon dioxide, would have a large effect on electric generation in New England. While much of the 73 percent drop in coal generation comes from the reduced electricity demand, arises from the performance standards. While the performance standards would by themselves cause a shift from carbon and pollution-intensive coal generation to generation from new efficient natural gas combined-cycle units, the demand reduction counteracts this. Thus, natural gas use for electricity generation in New England would roughly double from 1996 to 2010 in the policy scenario, rather than increase five-fold as in the base case projections. In this process, the shift from coal is accompanied by increased contribution from renewable resources and reduced generation overall from end-use efficiency.

Figure 10.A: Electricity Generation by Fuel Type – Base Case vs. Policy Case



Figures 10.A through 10.C summarize the impacts of the national electricity supply and demand policies on electricity generation and fuel mix in New England. The shifts in power plant fuels from the national electric sector policies would reduce carbon emissions by about 1.9 MtC or 14.5 percent of the total from electricity supply in 2010. The RPS would contribute about 1.0 MtC, the generation performance standards would contribute about 0.8 MtC, and the biomass co-fire would contribute about 0.1 MtC. An additional reduction of 6.5 MtC or 50 percent arises from end-use efficiency and co-generation policy impacts on generation.

Figure 10.B: Electric Sector Energy Use by Fuel Type – Base Case vs. Policy Case

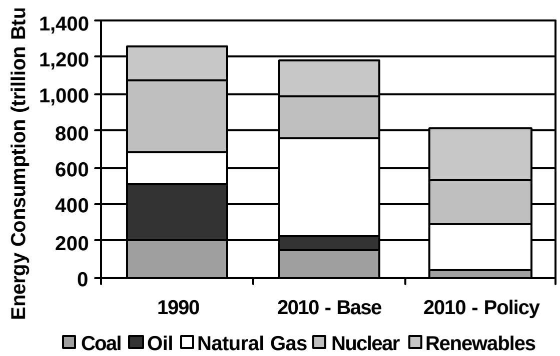
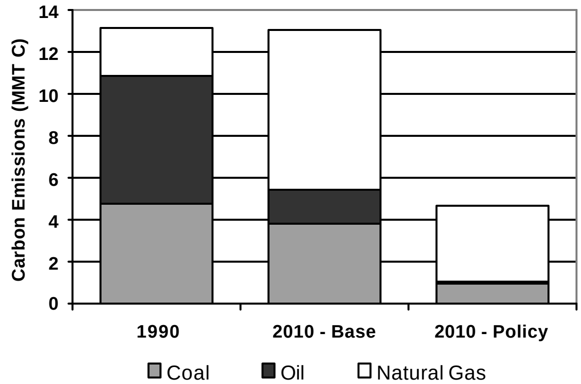


Figure 10.C: Electric Sector Carbon Emissions by Fuel Type – Base Case vs. Policy Case



4.2. Summary of Carbon and Pollutant Emissions Impacts

The two graphs below summarize the impacts of the national policies and measures on carbon emissions from energy use and supply in New England. The first shows the emissions reductions in the sectors of their origin, that is, in which the combustion of fossil fuels occurs. Thus, it shows emissions from on-site fossil fuel combustion in buildings, industry, transportation and electricity production. It is noteworthy that the largest reductions arise in the electric sector, owing to the end-use energy efficiency policies that reduce demand, plus the emissions and renewables policies for power supply that shift the fuels for electricity generation. The second graph shows the reductions across the end-use sectors only, that is, from which the demands for fossil fuel combustion on-site or at power plants arise. In this graph electric sector emissions are allocated to the end-use sectors proportional to their demands.

Figure 11.A: Carbon Emission Reductions in all New England Sectors

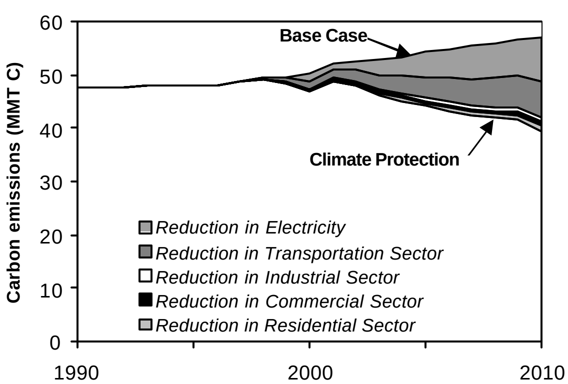
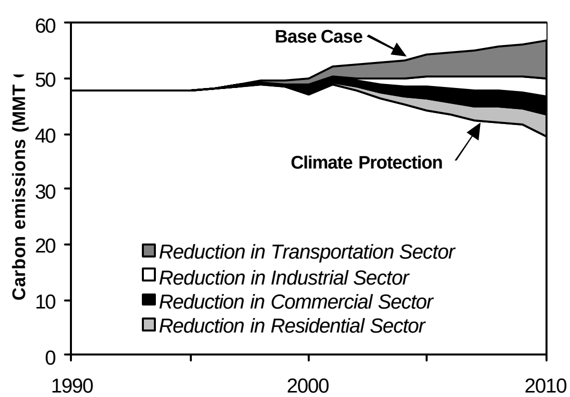


Figure 11.B: Carbon Emission Reductions in New England End-use Sectors



The carbon emissions reductions can also be reported by policy or by the sectors to which the policies are directed. Table 1 provides these results and compares them with the national carbon reductions realized by the policies and measures. Thus, for example: the electric generation emissions reductions and emissions increased on-site fuel use, owing to increased CHP are attributed to the industrial policies. As can be seen, New England's contributions to national emissions reductions are roughly 2.7 percent, lower than its 3.2 percent contribution to emissions in 2010, and lower than its 5.1 percent share of national population. This reflects in part the relatively lower carbon intensity of the New England region, especially in power supply, and the different sectoral mix of its energy demands. The largest reductions in New England relative to the national reductions arise from the buildings and alternative transportation fuel policies; the lowest are from the electricity supply policies, owing to the region's relatively low carbon intensity of electricity generation and the expected growth in generation with natural gas.

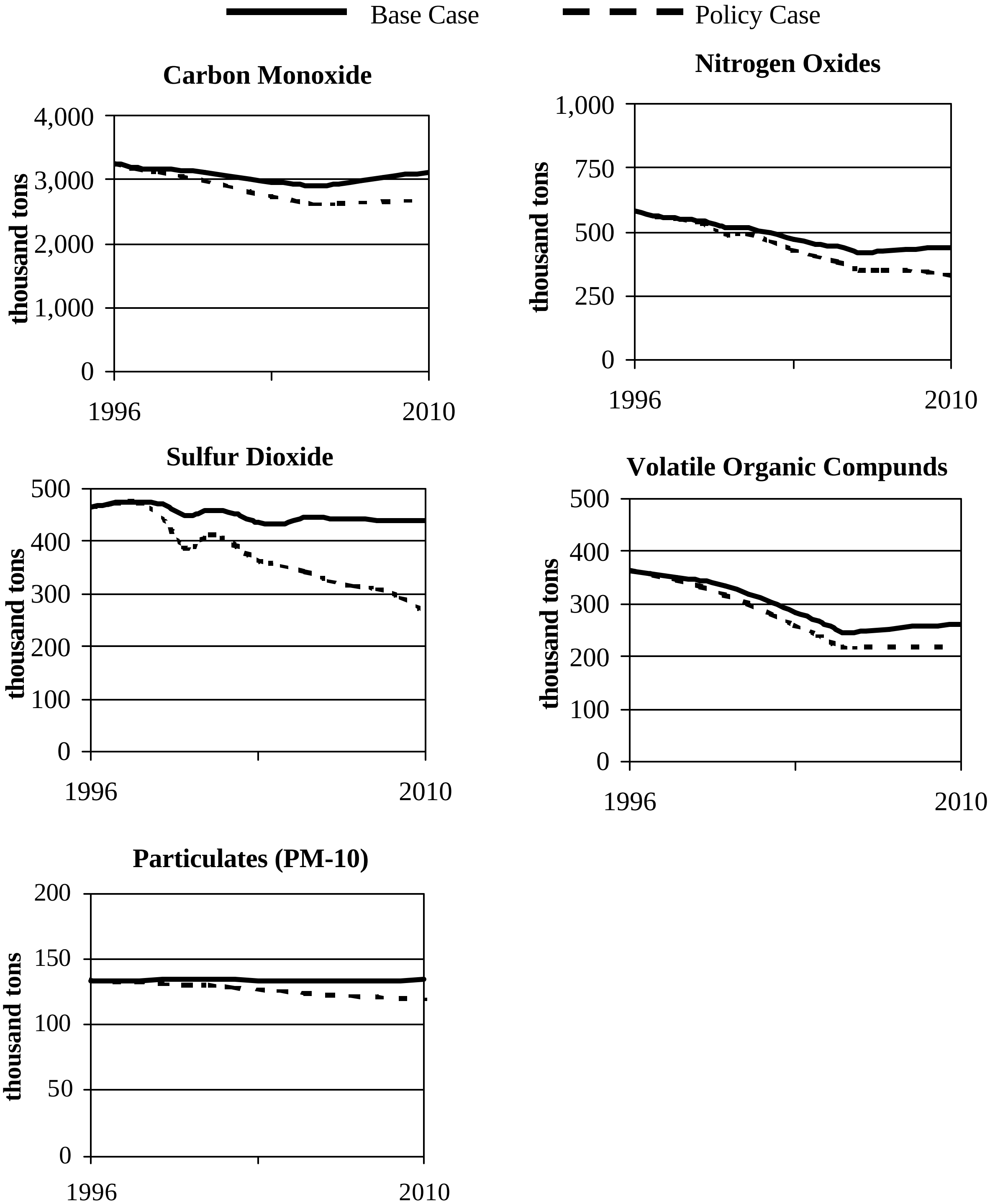
Table 1: Carbon Reductions by Sector and Policy, New England and U.S. (MMT C in 2010)

	New England	U.S.	% U.S.
TOTAL BASE CASE EMISSIONS	56.8	1,806	3.2%
Transport Sector Policies			
Vehicle Efficiency	3.3	105	3.1%
Transport demand	2.1	65	3.2%
Ethanol	1.5	31	4.8%
Total Transport Sector	6.9	201	3.4%
Industrial Sector Policies			
Industry Efficiency	2.2	77	2.9%
Industry CHP	1.2	34	3.5%
Subtotal Industrial Sector	3.4	111	3.1%
Residential and Commercial Sector Policies			
Building Efficiency	4.5	98	4.6%
District Energy	0.6	12	5.1%
Total Residential and Commercial Sector	5.1	110	4.6%
Electric Supply Sector Policies			
Renewable Portfolio Standard	1.1	34	3.2%
Biomass Co-firing	0.1	22	0.4%
Generation Performance Standards	0.9	178	0.5%
Total Electric Supply Sector	2.1	234	0.9%
Total Reductions	**17.6**	**656**	**2.7%**
TOTAL POLICY CASE EMISSIONS	39.2	1,150	3.4%

* Note: Emissions reductions at U.S refineries are not included in these results.

New England would also benefit from reduced combustion-related emissions of criteria air pollutants owing to the national policies, as shown in Figure 11. Air pollutants such as fine particulates, carbon monoxide, sulfur dioxide, and ozone (formed by a mix of volatile organic compounds and nitrogen oxides in the presence of sunlight) can cause or exacerbate health problems that include premature mortality and morbidity effects. Research shows that small children and the elderly are particularly at risk from these emissions (Dockery et al. 1993).

Figure 12: Emissions of major air pollutants: 1996-2010, Base Case and Policy Case



These emissions also account for damages to the environment from poor air quality and acid rain. The health of New England citizens, especially of those living in urban areas, who already suffer from these problems, is threatened poor air quality. By 2010, the national policies would reduce annual emissions of carbon monoxide in the region by 14 percent, oxides of nitrogen by 25 percent, sulfur dioxide by 40 percent, volatile organic compounds by 17 percent and fine particulate matter by 11 percent.

4.3. Analysis and Results for Costs and Savings

Analyses of the national climate change policies and measures of *America's Global Warming Solutions* found that they would cause shifts in energy related expenditures in New England. These shifts entail both costs and savings. The costs are the incremental investments in more efficient energy using equipment, power supply technologies and renewable energy resources, and the savings are the net reductions in the energy bills of households and businesses.

For this analysis, the investment costs and fuel prices were obtained from the NEMS model for residential, commercial and electric power sectors, the LIEF model for the industrial sector, and DeCicco and Lynd (1997) and Lynd (1997) for the transportation sector. (See Bernow *et al*, 1999 and EI, 1997 for further details)

The trajectories of cumulative overall costs and benefits (un-discounted) to New England are shown in Figure 13.A. By 2010 the cumulative net savings to households and businesses in the region would reach about $31 billion (1998$). On an annual basis, these net savings would reach $4.6 billion in 2010, or about $305 per capita. As shown in Figure 13.B, the cumulative discounted net savings would reach about $20.9 billion through 2010, and the average annual (levelized) net savings over that timeframe would be about $2.2 billion per year, about $162 per capita per year. The overall benefit to cost ratio would be about 3.1.

Figure 13.A: Cumulative Costs and Savings - All Sectors (undiscounted)

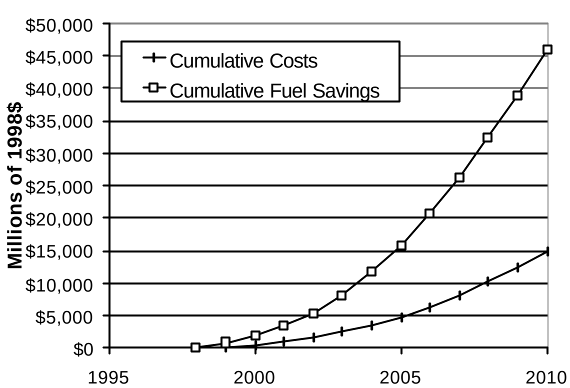
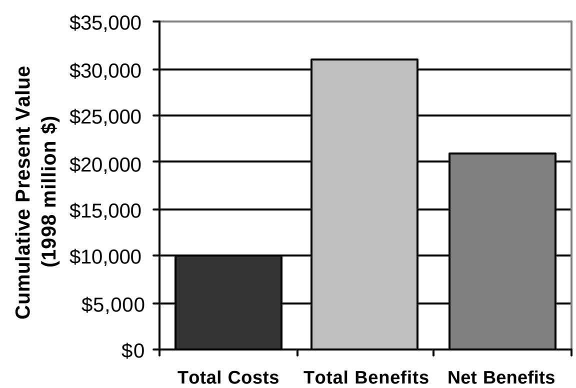


Figure 13.B: Cumulative Discounted Costs and Savings through 2010 - All Sectors



These overall costs and savings comprise contributions from policies that induce adoption of more efficient end-use technologies and policies that support less carbon and pollution intensive electricity and fuel supplies. The energy efficiency measures which produce large net savings, create the "economic space" to pursue currently more cutting edge measures for renewables and clean energy production, while maintaining overall economic savings. This would stimulate a process of human and institutional learning, diffusion and scale economies for these promising technologies that would enhance their accessibility, affordability and performance in the future when they will be needed to a far greater degree for climate protection and sustainable development.

5. Impacts on New England's Economy

The set of national policies and measures that affect the New England energy system and carbon emissions would also affect its economy. Many analyses of state-level policies that induce more efficient energy technologies and renewable resources show that the net economic impact -- on employment, incomes and output -- is positive. This occurs since savings in household and business energy costs generally exceed the incremental investment in more efficient energy-using equipment. One would expect that similar policies at the national level would achieve similarly positive impacts in New England.

Three indicators of the economic impact in New England of the national policies and measures were developed—net incremental jobs, wages and salaries and Gross State Product for the years 2005 and 2010. These impacts were estimated using IMPLAN (Impact Analysis for Planning), an input-output (I-O) model that represents interactions between different sectors of the economy. Changes in each sector’s spending patterns, owing to changes in fuel consumption and energy technology investments (energy using equipment and power supply facilities), induce changes in other sectors level of output (and inputs), and these are reflected in appropriate sectoral multipliers (jobs per dollar spent). The analytical approach used here is similar to that in Geller, DeCicco and Laitner (1992), Laitner, Bernow and DeCicco (1998), and Goldberg *et al.* (1998).

The analysis tracks changes in expenditures on more efficient lighting, residential appliances, commercial equipment, heating and cooling, building shells, motors, automobiles and trucks, industrial processes and other technologies. It also tracks the savings in energy bills to households, offices and factories owing to these investments. As the energy bill savings exceed the incremental investments, greater portions of incomes are available to be spent on non-energy goods and services.

The large increase in biomass resources and the refining of biomass into cellulosic ethanol would increase demand on New England's agricultural and chemical sectors, respectively. These effects would have positive impacts on those sectors of New England's economy. Some sectors that supply conventional energy and high carbon resources could decline in the near term. Overall, both the changes in investments and the re-spending of savings would stimulate the region's entire economy, as each sector must purchase materials and products from other sectors to be able to satisfy the increased demand for goods and services.

Table 2 summarizes the net economic benefits in New England of the set of national policies and measures of *America's Global Warming Solutions* that were analyzed here.. By the year 2010, wage and salary earnings in New England would increase by about $1.8 billion and employment would increase by about 41,200 jobs relative to the reference case for that year. At the same time, economic output, expressed as the sum of the Gross State Product of each state, is projected to increase by about $2.0 billion in 2010.

Table 2: Macroeconomic Impacts of the Policy Scenario

Year	Net Change in Jobs	Net Change in Wage and Salary Compensation (Millions of 1996$)	Net Change in GSP (Millions of 1996$)
2005	25,900	$920	$1000
2010	41,200	$1,970	$1,780

Table 3 provides detailed results for the New England economy, broken out into the 23 sectors analyzed in this study, for the year 2010. The table shows how each of the major economic sectors are affected in the year 2010 in the policy scenario. It should be noted that the results in this table are not intended to be precise forecasts of what will occur, but rather approximate estimates of overall impact. The sectors that benefit most are construction, services, miscellaneous manufacturing and agriculture.

As might be expected, the traditional energy supply industries incur overall losses. But these results must be tempered somewhat as the energy industries themselves are undergoing internal restructuring. For example, as restructuring takes place and the electric utilities engage in more energy efficiency services and other alternative energy investment activities, they will undoubtedly employ more people from the business services and engineering sectors. Hence, the negative employment impacts in these sectors should not necessarily be seen as job losses, rather they might be more appropriately seen as a redistribution of jobs in the overall economy and future occupational tradeoffs.

These analyses are approximate and indicative. They assume that labor, plant and materials would not otherwise be fully employed under baseline conditions and would be available with the policy-induced investments. They do not account for a variety of feedbacks, e.g. from price changes and inflation. The results of the analysis do not include other productivity benefits that are likely to stem from the efficiency investments, which could be substantial, especially in the industrial sector. They do not reflect the potential for policy-induced innovation and scale economies across all sectors. Finally, the analysis does not reflect the full benefit of the efficiency investments, since the energy bill savings beyond 2010 are not incorporated in the analysis.

While these increases are significant, the impacts are relatively small in comparison to overall economic activity. For instance, increasing the region's GSP by $2.0 billion in 2010 represents only 0.36 percent of the total regional economic output projected for that year. The net employment increase of about 41,000 jobs is about 0.44 percent in that year, while the net increase in incomes is about 0.49 percent. As the overall employment growth is projected to be about 900,000 from 1998 to 2010, the policies would increase that growth by about 4.5 percent percent. Nonetheless, the analysis indicates that in helping to achieve the national and international goals of climate protection, New England would not compromise its economic vitality. At the same time, the states in the region would shift their energy supply and use to a more advanced, efficient and productive basis, and would reduce its combustion of fossil fuels, thereby enhancing its environmental quality and public health.

Table 3. Macroeconomic Impacts of the Policy Scenario by Sector in 2010

Sector	Net Change in Jobs	Net Change in Wage and Salary Compensation (Millions of 1997$)	Net Change in GSP (Millions of 1997$)
Agriculture	3,800	70	130
Coal Mining	0	0	0
Construction	14,900	550	590
Education	300	10	10
Electric Utilities	(900)	(140)	(590)
Finance	2,100	150	250
Food Processing	0	0	0
Government	1,100	50	60
Insurance/Real Estate	200	10	60
Metal Durables	1,400	130	230
Motor Vehicles	600	40	50
Natural Gas Utilities	100	20	50
Oil Refining	0	0	(10)
Oil/Gas Mining	(200)	0	(40)
Other Manufacturing	5,200	360	500
Other Mining	300	20	30
Primary Metals	500	40	50
Pulp and Paper Mills	100	10	20
Retail Trade	700	20	30
Services	8,900	300	340
Stone, Glass, and Clay	500	40	50
Transportation, Communication, and Utilities	1,100	60	100
Wholesale Trade	500	40	60
TOTAL	**41,200**	**$1,780**	**$1,970**

6. Conclusions

Analysis and experience have shown that there are ample technological and policy opportunities for the U.S. to significantly reduce its greenhouse gas emissions at a net economic benefit. National policies and measures could overcome market, institutional and other barriers to the more rapid and widespread diffusion of advanced and more efficient energy technologies and cleaner energy resources. *America's Global Warming Solutions* showed that the U.S. could reduce its emissions 36 percent below projected levels for 2010, 14 percent below 1990 levels, with net economic savings to households, almost 900,000 net additional jobs, and significant reductions of pollutants that harm human health and the environment. These benefits would be widespread across the country.

This study has analyzed the impacts of this national strategy on New England, which has significant vulnerabilities to climate change, unique opportunities to help meet the challenge of climate protection, and thus substantial benefits to be reaped in taking and supporting action. The study finds that the national policies and measures of *America's Global Warming Solutions* would stimulate more rapid adoption of the new and more efficient energy technologies and cleaner resources in New England. As a consequence, carbon emissions in New England would be reduced by about 31 percent in 2010, bringing it about 16 percent below its 1990 level. Emissions of other pollutants would also be reduced, thus improving air quality, human health and environment quality in the region. Households and businesses in New England would enjoy annual energy bill reductions in excess of their incremental investments in more efficient and cleaner technologies. These net savings would increase over time, reaching about $305 per capita in 2010. The cumulative net savings would be about $31 billion (1998$) through 2010, about $21 billion in discounted terms, and about 41,200 additional jobs would be created in the region by 2010.

By focusing on domestic, energy-related carbon emissions reductions, going beyond the Kyoto target, and including cutting-edge technologies in an overall cost-effective portfolio, the proposed set of national policies and measures would serve as an effective transitional strategy to meet the long-term goals of climate protection. It could stimulate technological and institutional learning, scale economies and further innovation and invention, enhance economic productivity, and establish the basis for entry into markets for clean energy technologies and resources.

The risks of climate disruption to future generations throughout world, the U.S. and New England are too great to delay early and sustained reductions of greenhouse gas emissions. The U.S. can fulfill its historic responsibility to meet the challenge of climate change, by taking actions that fulfill its Kyoto obligations, while establishing momentum to achieve the deeper long-term reductions in greenhouse gas emissions that are required for climate stabilization. New England has a prominent role to play in this process. As previously noted, it can be a center in the renaissance in motor vehicle production for the U.S. and the world, focussed on highly efficient and ultra-clean transportation. It also has largely ample renewable energy resources and potential for efficient energy technologies in households, offices and industry, as well as the economic and technological capacities to develop them. The citizens and economy of New England could support the national policies and measures recommended in this report, as well as similar or complementary ones in each state, and thus derive economic and environmental benefits in the near-term and well into the future.

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Appendix

New England Energy Results by Fuel (and Electricity Used) and by Sector

Total Energy Consumption by Fuel and by Sector in 1990 (Quads)

	Residential	Commercial	Industrial	Transportation	Electricity	Total
Coal	0.002	0.002	0.008	0.000	0.203	0.214
Oil	0.272	0.143	0.176	0.898	0.309	1.798
Gas	0.176	0.100	0.084	0.002	0.170	0.532
Nuclear	0.000	0.000	0.000	0.000	0.389	0.389
Hydro	0.000	0.000	0.000	0.000	0.089	0.089
Non-Hydro	0.041	0.000	0.258	0.001	0.096	0.395
Primary Total	**0.491**	**0.245**	**0.525**	**0.901**	**1.255**	**3.416**
Indirect Electric	0.128	0.134	0.093	0.001		0.356
End Use Total	**0.619**	**0.379**	**0.618**	**0.901**		**2.517**

Total Energy Consumption by Fuel and by Sector in 2010 (Quads) - Base Case

	Residential	Commercial	Industrial	Transportation	Electricity	Total
Coal	0.001	0.001	0.008	0.000	0.151	0.161
Oil	0.293	0.104	0.206	1.189	0.073	1.866
Gas	0.205	0.187	0.191	0.015	0.533	1.131
Nuclear	0.000	0.000	0.000	0.000	0.233	0.233
Hydro	0.000	0.000	0.000	0.000	0.078	0.078
Non-Hydro	0.051	0.004	0.346	0.004	0.110	0.515
Primary Total	**0.550**	**0.296**	**0.751**	**1.208**	**1.179**	**3.985**
Indirect Electric	0.160	0.172	0.102	0.020		0.454
End Use Total	**0.710**	**0.468**	**0.854**	**1.228**		**3.260**

Total Energy Consumption by Fuel and by Sector in 2010 (Quads) - Policy Case

	Residential	Commercial	Industrial	Transportation	Electricity	Total
Coal	0.001	0.001	0.002	0.000	0.039	0.042
Oil	0.261	0.074	0.135	0.845	0.001	1.316
Gas	0.181	0.183	0.241	0.074	0.254	0.933
Nuclear	0.000	0.000	0.000	0.000	0.233	0.233
Hydro	0.000	0.000	0.000	0.000	0.078	0.078
Non-Hydro	0.036	0.028	0.355	0.003	0.212	0.635
Primary Total	**0.479**	**0.287**	**0.733**	**0.922**	**0.817**	**3.238**
Indirect Electric	0.126	0.135	0.039	0.015		0.315
End Use Total	**0.605**	**0.422**	**0.772**	**0.937**		**2.736**

New England Carbon Results by Fuel (and Electricity Used) and by Sector

Carbon Emissions in 1990 (million metric tons)

	Coal	Oil	Gas	Indirect Electric	TOTAL
Electric	4.79	6.12	2.28	NA	13.19
Residential	0.05	5.31	2.54	4.75	12.64
Commercial	0.05	2.82	1.44	4.98	9.29
Industrial	0.20	3.47	1.21	3.44	8.31
Transportation	0.00	17.39	0.03	0.00	17.41
TOTAL	5.08	35.12	7.49		47.68
Fossil Fuel Share	10.6%	73.6%	15.7%		
Electric Share				27.7%	

Carbon Emissions in 2010 - Base Case (million metric tons)

	Coal	Oil	Gas	Indirect Electric	TOTAL
Electric	3.84	1.56	7.68	NA	13.08
Residential	0.03	5.73	2.95	4.60	13.30
Commercial	0.02	2.05	2.69	4.96	9.73
Industrial	0.20	4.07	2.75	2.95	9.97
Transportation	0.00	23.01	0.22	0.57	23.80
TOTAL	4.08	36.42	16.29		56.79
Fossil Fuel Share	7.2%	64.1%	28.7%		
Electric Share				23.0%	

Carbon Emissions in 2010 - Policy Case (million metric tons)

	Coal	Oil	Gas	Indirect Electric	TOTAL
Electric	0.98	0.01	3.66	NA	4.65
Residential	0.02	5.11	2.60	1.87	9.59
Commercial	0.01	1.47	2.64	1.99	6.12
Industrial	0.05	2.66	3.47	0.57	6.76
Transportation	0.00	16.35	1.07	0.22	17.65
TOTAL	1.07	25.60	13.44		40.11
Fossil Fuel Share	2.7%	63.8%	33.5%		
Electric Share				11.6%	

New England Non-CO_2 Pollutant Emissions for Each Sector (thousand tons)

New England Base Case

	1996	2000	2005	2010
Residential				
CO	266	265	265	264
NO_x	4	4	4	4
VOC	63	63	63	63
SO_2	2	2	2	2
PM-10	33	33	33	33
Commercial				
CO	4	4	4	4
NO_x	19	18	18	18
VOC	1	1	1	1
SO_2	44	40	39	38
PM-10	70	70	70	70
Industrial				
CO	64	70	76	81
NO_x	60	63	67	71
VOC	7	7	8	8
SO_2	220	235	255	271
PM-10	16	17	18	19
Transportation				
CO	2,987	2,778	2,541	2,763
NO_x	422	345	264	257
VOC	272	276	195	185
SO_2	0	0	0	0
PM-10	13	13	11	11
Electricity				
CO	8	8	10	10
NO_x	74	87	88	87
VOC	2	1	1	1
SO_2	198	171	149	129
PM-10	3	2	2	2

New England Policy Case

	1996	2000	2005	2010
Residential				
CO	266	243	215	191
NO_x	4	4	3	3
VOC	63	58	51	45
SO_2	2	2	2	2
PM-10	33	30	27	24
Commercial				
CO	4	4	4	3
NO_x	19	17	16	15
VOC	1	0	0	0
SO_2	44	39	34	28
PM-10	70	70	69	69
Industrial				
CO	64	69	75	80
NO_x	60	61	61	60
VOC	7	7	8	8
SO_2	220	228	228	212
PM-10	16	16	17	16
Transportation				
CO	2,987	2,676	2,311	2,396
NO_x	422	336	245	227
VOC	272	268	180	162
SO_2	0	0	0	0
PM-10	13	13	10	9
Electricity				
CO	8	6	6	4
NO_x	74	70	55	23
VOC	2	1	1	0
SO_2	198	116	77	23
PM-10	3	1	1	0

TOTAL New England Pollutant Emissions

	1996	2000	2005	2010
BASE CASE				
CO	3,329	3,126	2,896	3,122
NO_x	578	517	441	437
VOC	344	348	268	258
SO_2	464	448	445	440
PM-10	134	134	133	134

	1996	2000	2005	2010
POLICY CASE				
CO	3,329	2,999	2,611	2,674
NO_x	578	489	381	328
VOC	344	334	240	216
SO_2	464	385	341	264
PM-10	134	130	124	119