

CARBON AND COMMUNITIES

*Linking Carbon Science with
Public Policy and Resource Management
in the Northeastern United States*



A Science Links Publication of the Hubbard Brook Research Foundation



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The mission of the **Hubbard Brook Research Foundation (HBRF)** is to promote the understanding and stewardship of ecosystems through scientific research, long-term monitoring, and education. This publication is a contribution of the Hubbard Brook Ecosystem Study. Hubbard Brook is part of the Long-Term Ecological Research (LTER) network, which is supported by the National Science Foundation. The Hubbard Brook Experimental Forest is operated and maintained by the USDA Forest Service, Northern Research Station, Newtown Square, PA. Scientists participating in the Hubbard Brook Ecosystem Study have made discoveries regarding the ecology of forested watersheds and the effects of timber harvesting, climate change, acid rain, and other natural and human-caused disturbances. HBRF is a nonprofit 501(c)(3) organization, supporting ecosystem science at Hubbard Brook by operating housing and other facilities and by conducting educational programs.

Through its Science Links Program, HBRF develops strategies to leverage science for sound public policy by building bridges between research scientists, policymakers, land managers, government officials, environmental leaders, and members of the public. Previous Science Links projects have addressed acid rain, nitrogen pollution, long-term ecological monitoring, and mercury pollution. HBRF is supported in part by the Hubbard Brook Consortium, whose institutional members include: Cary Institute of Ecosystem Studies, Dartmouth College, Plymouth State University, Syracuse University, Urban Ecology Institute, USDA Forest Service/Northern Research Station, and Wellesley College.



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Executive Summary

Human activities emit 28 billion metric tons of carbon dioxide, a greenhouse gas, to the atmosphere each year contributing to climate change. As developing nations industrialize, these emissions will likely increase. In addition, the loss of forest resources for agriculture and development decreases the ability of the Earth to reabsorb, or sequester, some of this carbon dioxide. Today scientists believe that this system—releasing carbon dioxide into the atmosphere while reducing the landscape’s capacity to sequester it—may lead to changes in our global and local climate that could have large social, economic, and ecological consequences.

The Hubbard Brook Research Foundation (HBRF) convened a team of scientists to create detailed carbon budgets for eight counties and one city in the northeastern United States to better understand the magnitude of the release and removal of carbon dioxide at a scale meaningful for state and local officials. Analyses of carbon dioxide emissions from transportation, residential, industrial, commercial, and land-use sources are summarized to help communities understand which sources of carbon dioxide can most efficiently be decreased in order to achieve a smaller carbon footprint.

Communities are increasingly interested in addressing climate change at the local level, but require methods to compare the cost and effectiveness of different carbon mitigation strategies over time. HBRF has developed several resources to assist regional planning agencies, local governments, and lawmakers compare the costs and benefits of major carbon mitigation options to reduce net carbon dioxide emissions. These resources, accompanied by scientific information, are intended to help evaluate such key issues as forest management practices, regional planning strategies, land-use decisions, transportation, energy efficiency upgrades, and alternative energy sources.

Key Findings

The HBRF team completed detailed **case studies of eight counties and one city in the Northeast, using readily available information to estimate the amount of carbon stored annually in forests and soils and the annual emissions of carbon dioxide emitted from transportation, residential, industrial, and commercial activities.** Counties were selected to examine a broad spectrum of land uses found in the northeastern United States, including the industrial and privately owned forests of New Hampshire, mixed agricultural and residential landscapes of central New York and Vermont, the forested regions of Massachusetts currently undergoing expanding suburban and commercial development, and the city of Baltimore and its adjacent suburban county.

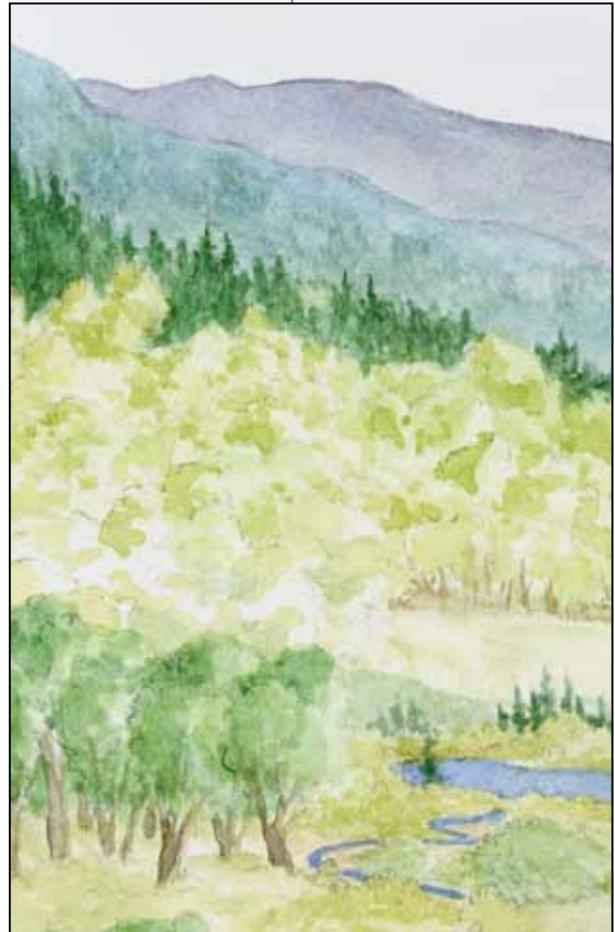
Communities are increasingly interested in addressing climate change at the local level, but require methods to compare the cost and effectiveness of different carbon mitigation strategies over time.

Most of the counties studied are net sources of carbon dioxide to the atmosphere, meaning that their total annual emissions from fossil fuel combustion exceed the amount of carbon dioxide removed from the atmosphere by vegetation and soils. The exceptions are the two counties in northern New Hampshire, where sequestration of carbon by growing forests exceeds carbon dioxide emissions. These case studies suggest that most counties in the northeastern United States are a net source of atmospheric carbon dioxide, with the strength of the source increasing primarily with human population density, although the per capita carbon emissions decline with increasing population densities. Only remote forested counties (for example, those located in the Adirondacks, White Mountains, and northern Maine) sequester more carbon dioxide than they produce.

Regional approaches to achieve “carbon neutrality” (defined as a balance between the emissions of carbon dioxide and its removal from the atmosphere) will best succeed by reducing emissions of carbon dioxide and by wisely managing forest resources and wetlands which store and sequester carbon in above-ground wood and in soils. **Most counties will need to reduce emissions and improve energy efficiencies in order to achieve carbon neutrality because most forests in the Northeast are aging and will not indefinitely sequester significant amounts of carbon.** Despite this pattern, carbon is already stored in large quantities in the Northeast. Since the abandonment of large areas of agricultural lands beginning in the late 19th century, forests have regrown and many northeastern communities are today stewards of important carbon resources. Protecting these forests in the face of encroaching residential development and other competing land uses will be challenging, but critical to reducing net annual carbon dioxide emissions.

Many sparsely populated counties may be able to achieve carbon neutrality at little long-term cost, since many investments in alternative energy and energy-efficiency improvements will pay for themselves over the lifetime of the product or service. **Counties of moderate population densities may find that roughly half of their emissions could be offset with low-cost mitigation investments, with the remaining reductions requiring greater expenditures. Despite lower per-capita energy use, high-density counties will likely need to invest heavily in mitigation opportunities to offset even half of their annual emissions,** but changes in national energy policy and other incentives could make these expenditures more cost effective.

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The Carbon Cycle: Major Sources and Sinks of Carbon Dioxide

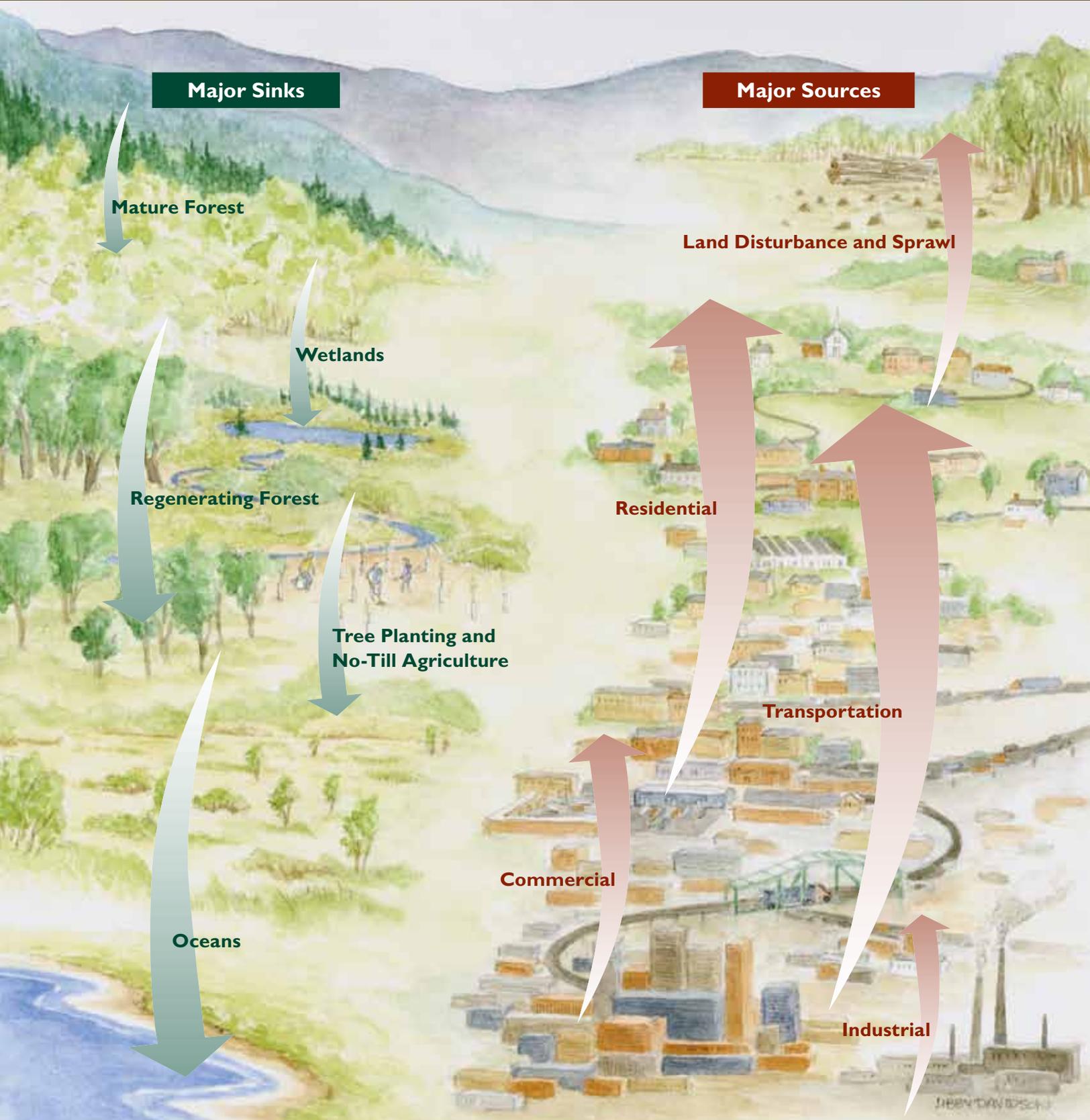


Figure 1. Although there are many sources and sinks of carbon dioxide, they can be grouped into the above major categories. The dynamic movement, or flux, of carbon throughout the land and ocean has been altered by human activities, adding more carbon dioxide to the atmosphere than can be reabsorbed by vegetation and the oceans. The sizes of the arrows correspond roughly to the relative magnitudes of regional (not global) carbon sources and sinks covered in this report.

What Is Carbon and Why Is Carbon Dioxide a Pollutant?

Carbon dioxide is the most abundant form of carbon in the atmosphere. It is a naturally occurring gas and is critical to life and most energy production. At higher atmospheric concentrations, however, carbon dioxide can be considered an air pollutant. By extracting fossil fuels from the Earth and burning them, and by converting forests to nonforest uses, humans have significantly increased concentrations of carbon dioxide in the atmosphere which are altering the climate by preventing heat that is radiated from the Earth from leaving the lower atmosphere.

Plants remove carbon dioxide from the atmosphere and use it to build their leaves, stems, and roots—their biomass. This carbon, when converted to plant tissue, especially wood, can remain separate from the atmosphere for years until the vegetation dies and decomposes, releasing the carbon dioxide back to the atmosphere through respiration. Fossil fuels are the remains of plants and animals that became concentrated and isolated through hundreds of millions of years of geologic processes. When we burn fossil fuels, we rapidly decompose them through combustion releasing the carbon dioxide (Figure 1). We also cause release of stored carbon when we disturb soils, or convert forests and wetlands to other land uses such as residential or commercial development. This land disturbance allows stored carbon to decompose, releasing carbon dioxide to the atmosphere. Humans have released millions of tons of carbon that had previously been removed from the atmosphere. These perturbations by human activities are the reason scientists have observed significant increases in atmospheric carbon dioxide in recent centuries (IPCC 2007).

As fossil fuel use increases globally and more of the Earth's vegetated surface is disturbed or converted to human uses, the atmospheric concentration of carbon dioxide will continue to increase. Humans today emit some 28 billion tons of carbon dioxide into the atmosphere annually and the United States is responsible for roughly 20 percent of the world's greenhouse gas emissions (EIA 2008). These inputs could lead to widespread changes in regional temperatures and precipitation in only a few decades (Frumhoff et al. 2007) and may already be having an effect (Figure 2).

Human sources of carbon dioxide are growing in magnitude as industrial and commercial activities increase globally and deforestation and changing land uses diminish the Earth's capacity to sequester carbon. Scientists now agree with a high degree of certainty that if these trends are not reversed the amount of carbon dioxide in the Earth's atmosphere will continue to increase, causing widespread changes to climate, rising sea levels, and disruptions to the economic activities that depend on a stable climate and environment.

Scientists are often called upon to make predictions based on current and past data. Although it is impossible to know exactly what the future climate will be, scientists have used computer models that show a range of possibilities, or scenarios, based on projected uses of fossil fuels and changes in land use. Most scientists now believe that even under scenarios of relatively low emissions of carbon dioxide, the Earth's climate will change in the coming decades—a prediction that has spurred an international coalition of scientists, government agencies, nonprofit organizations, businesses, and universities to call for a coordinated plan to reduce our net carbon dioxide emissions.

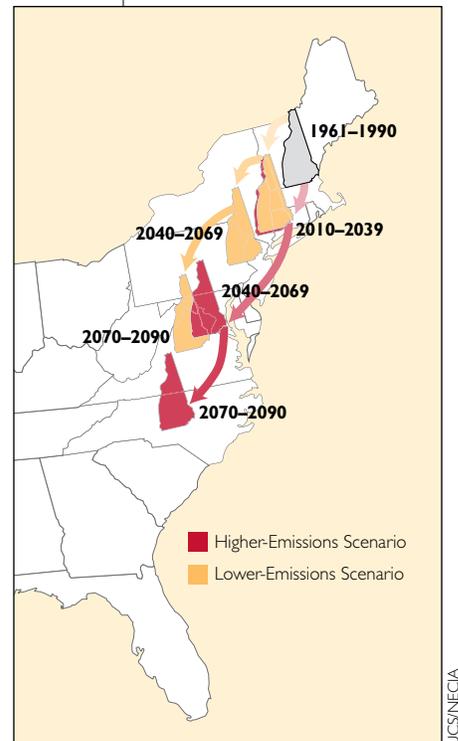


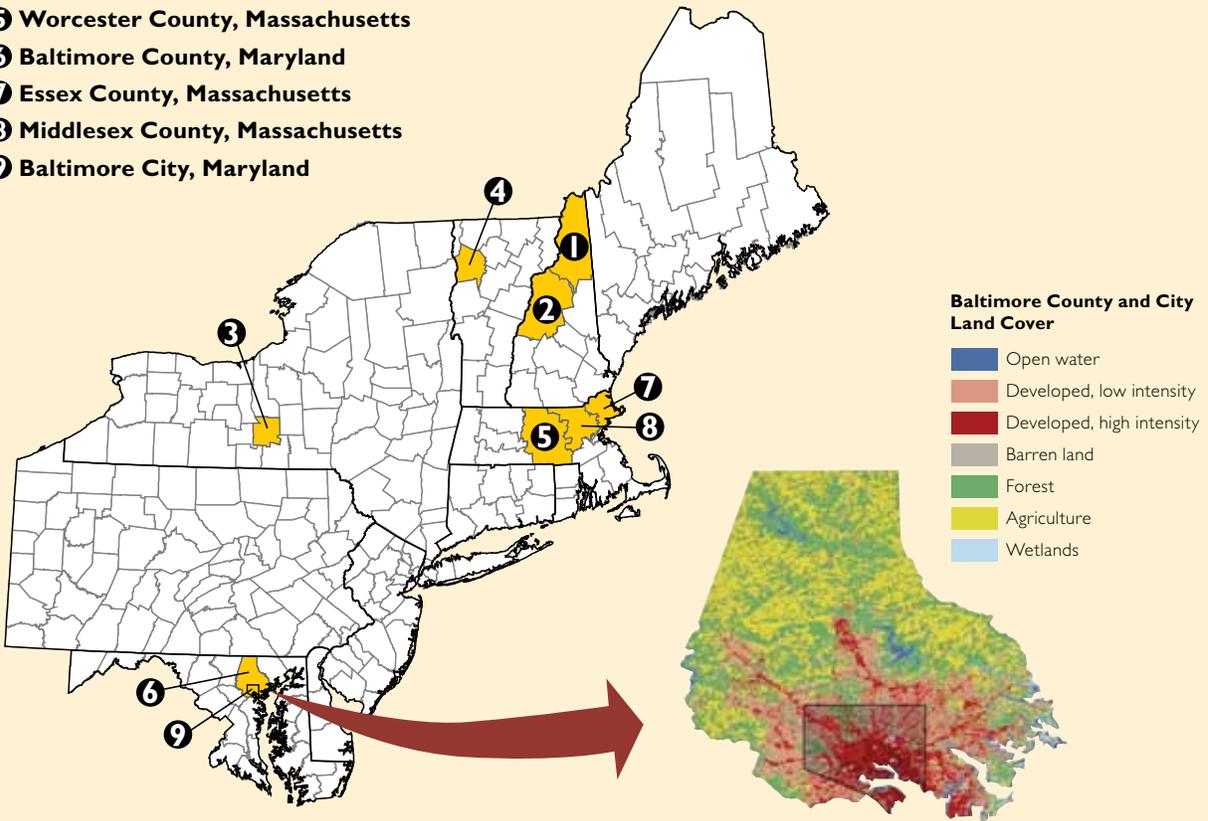
Figure 2. Average summer heat index—a measure of how hot it actually feels, given temperature and humidity—could change significantly due to increased carbon dioxide in the atmosphere. Red arrows track what summers could feel like in New Hampshire over the course of the century under high-emissions scenarios (in this case, New Hampshire summers would feel more like those now occurring in Virginia and North Carolina). Yellow arrows track what summers in New Hampshire could feel like under lower-emission estimates.

County Case Studies

HBRF scientists examined sources of carbon dioxide and how it is absorbed, or sequestered, by the landscape in eight counties and one city in the northeastern United States. As indicated in the table and the inset of Baltimore County and Baltimore City, the case studies reflect a broad range of typical population densities and land-use patterns.

County	Area (mi ²)	Population	Population Density (people/mi ²)	Forest	Land Use (%)		
					Agriculture	Developed Low	High
Coos	1,830	33,111	18	86.9	5.5	2.4	0.3
Grafton	1,750	81,743	47	86.8	5.6	3.6	0.5
Tompkins	492	96,500	197	42.9	31	3.9	3.1
Chittenden	620	146,571	236	72.8	13.8	9.1	4.3
Worcester	1,579	750,963	477	68	8.6	11.9	5.1
Baltimore	607	786,547	1,298	34.1	36.9	17	6.5
Essex	501	735,959	1,469	43.8	8.4	20.6	16.6
Middlesex	824	1,467,016	1,782	46.1	7.8	23.8	18.1
Baltimore City	80	639,493	7,912	8.3	2.4	39.9	46.9

- ❶ Coos County, New Hampshire
- ❷ Grafton County, New Hampshire
- ❸ Tompkins County, New York
- ❹ Chittenden County, Vermont
- ❺ Worcester County, Massachusetts
- ❻ Baltimore County, Maryland
- ❼ Essex County, Massachusetts
- ❽ Middlesex County, Massachusetts
- ❾ Baltimore City, Maryland



What Are the Major Sources of Carbon Dioxide in the Northeast?

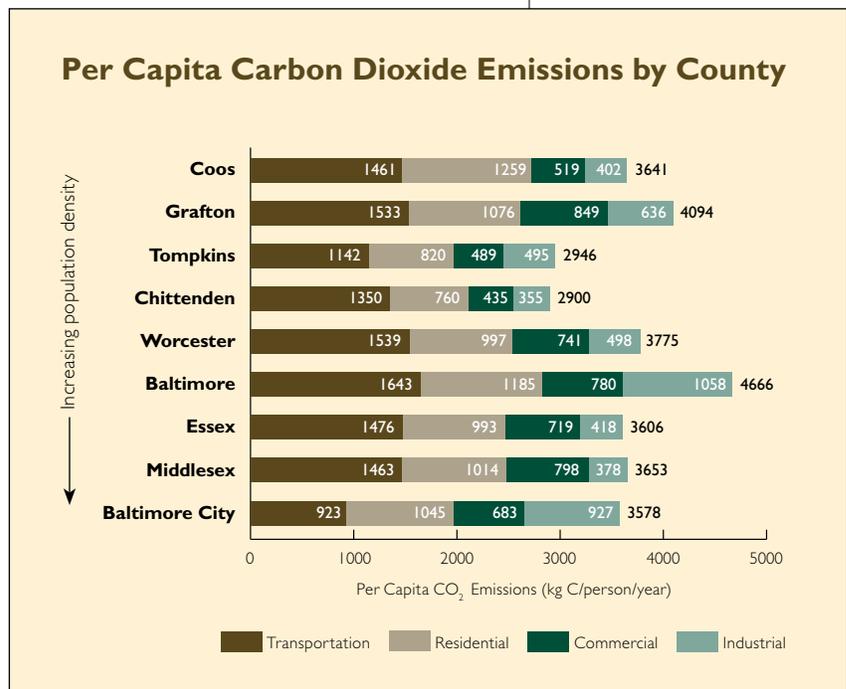
Based on analyses of carbon budgets completed for the nine case studies, the transportation sector is the largest source of carbon dioxide on a per capita basis, followed by residential, commercial, and industrial sectors. The HBRF team calculated emissions and forest uptake potential with readily available data as part of an effort to make this methodology transparent and easily applied to towns, counties, and regions.

The HBRF team created detailed budgets for eight counties and one city in the Northeast, representative of diverse conditions in human population density and land cover in this region. (Hereafter the case studies are all referred to as the “counties.” See facing page for map locations and other characteristics.) Counties were chosen as practical units for analyses, though they are not necessarily effective for large-scale policy decisions. To better understand the major emissions sources for each county, the team totaled the amount of carbon dioxide released into the atmosphere each year, then divided the total into four standard, broadly defined sectors: transportation, residential, commercial, and industrial. Most of the data used to calculate county emissions are available through the Department of Energy’s Energy Information Administration (www.eia.gov) and the U.S. Census Bureau.

Transportation

In every county studied by the HBRF team except for Baltimore City, emissions from transportation are the largest source of carbon dioxide per capita. Carbon dioxide emissions associated with vehicles whose primary purpose is moving people or goods from one location to another were considered, including automobiles, trucks, buses, motorcycles, and trains. Estimates did not include vehicles whose primary purpose is not transportation (such as construction equipment, farm vehicles, or warehouse tractors and forklifts).

Figure 3. This figure shows carbon dioxide emissions from each of the counties on a per-capita basis. The transportation sector accounted for the largest share of emissions from each county (35 percent to 47 percent) except for Baltimore City (26 percent). The greater availability of public transportation and closer proximity to places of employment may play a role in Baltimore City’s lower transportation emissions. The residential sector accounted for the second largest share of per-capita emissions in each of the counties (except Baltimore City, where it ranked first), accounting for 25 percent to 35 percent of total emissions. Residential emissions ranged from 760 kg C/person in Chittenden County to 1,259 kg C/person in Coos County. Several variables explain this wide range in residential carbon dioxide emissions, including local climate, housing mix, and the carbon intensity of fuels used for heating and electricity generation.



Per capita emissions in transportation are similar across the case studies (Figure 3), ranging from 923 kg C/person in Baltimore City to 1,643 kg C/person in adjacent Baltimore County. More abundant public transportation options and lower car ownership rates in Baltimore City account for the lower emissions there relative to other counties. Outside of urban Baltimore, counties show strikingly similar vehicle emissions regardless of road, housing, or population densities.

Residential

Total carbon dioxide emissions from private households were estimated, including from home heating, water heating, air conditioning, lighting, refrigeration, and cooking, and also from the use of a variety of home appliances.

New Hampshire's northern counties show the greatest per capita emissions largely because living quarters there require many more weeks of heating in the winter and the major source of heating fuel is carbon-rich oil. County sources of electricity can have a powerful effect on overall residential carbon dioxide emissions. For example, low-emission energy sources, namely hydroelectric and nuclear, are greater in Vermont than other states in the region, a fact reflected in Chittenden County's overall lower residential emissions. Not surprisingly, regions with few or no alternatives to fossil fuel energy sources tend to have higher residential carbon dioxide emissions. Less-efficient heating systems can also have a large impact on regional emissions. Maryland, which has more residents using electric power for space heating (36 percent compared to 13 percent in Massachusetts), uses considerably more electricity than other states. As a consequence of greater electricity use and an electric power sector that relies heavily on coal, the per capita residential carbon dioxide emissions associated with electricity are much higher in Baltimore County (639 kg C/person) and City (526 kg C/person) compared with the Massachusetts counties (350 kg C/person).

Commercial

Estimates of county commercial emissions consist of businesses; federal, state, and local governments; and private and public organizations such as religious and social groups. Included are emissions from generators that produce electricity and heating to support associated facilities. Emission estimates range from a low of 435 kg C/person in Chittenden County, Vermont, to 849 kg C/person in Grafton County, New Hampshire, with most counties averaging around 600 kg C/person. Heating costs and fuel choices for large facilities may explain the relatively high emissions for New Hampshire despite its lower development density relative to other counties. Declines in industrial sources of carbon dioxide emissions, following the loss of heavy industry throughout much of the Northeast beginning in the 1960s, have been compensated for by the expansion of a diverse commercial and retail sector.

Industrial

Estimates of industrial emissions consider all facilities and equipment used for producing, processing, or assembling goods, including agriculture, forestry, mining, and construction. Most of the energy demand associated with this sector is for heating, cooling, and powering machinery. The industrial sector, once large and diverse in the Northeast, has diminished considerably in recent decades; however, where industry still exists in the Northeast, its carbon emissions can rival those of the commercial and residential sectors, such as the comparatively high estimate of 1,058 kg C/person in Baltimore County.

Low-emission energy sources, namely hydroelectric and nuclear, are greater in Vermont than other states in the region, a fact reflected in Chittenden County's overall lower residential emissions.

Summary of All Sectors

Despite widely differing land uses, housing and population densities, and levels of agricultural and industrial development, the nine counties show strikingly similar profiles of carbon dioxide emissions by sector when calculated on a per capita basis. Although small variations do exist, most counties emit carbon dioxide in similar proportions among the four sectors assessed.

A strong relationship exists between total overall emissions and population density, with emissions increasing in more densely settled areas (Figure 4). Even though densely populated communities tend to have more public transportation and apartment houses (with a greater number of individuals sharing heating and electric utilities), they emit far more carbon dioxide per square mile than sparsely populated rural counties. Rural areas, however, have higher per capita carbon emissions than densely populated areas.

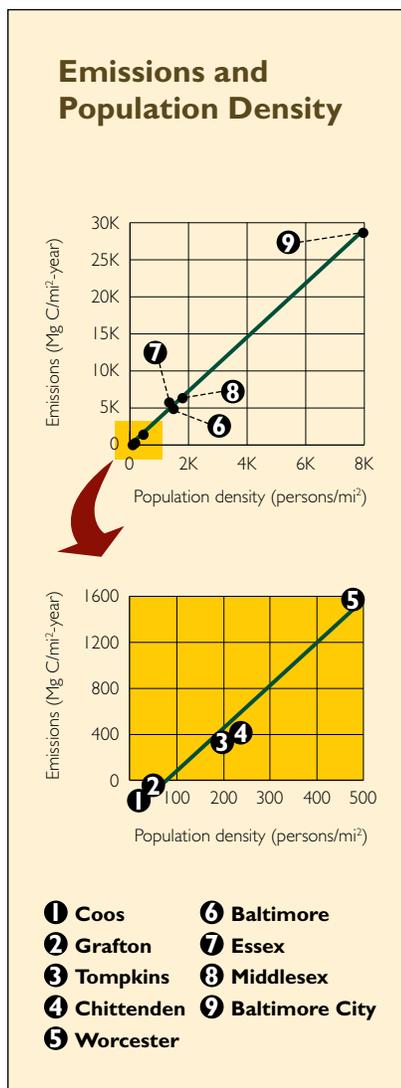


Figure 4. A strong relationship exists between total overall carbon emissions and population density, with emissions increasing in more densely settled counties.

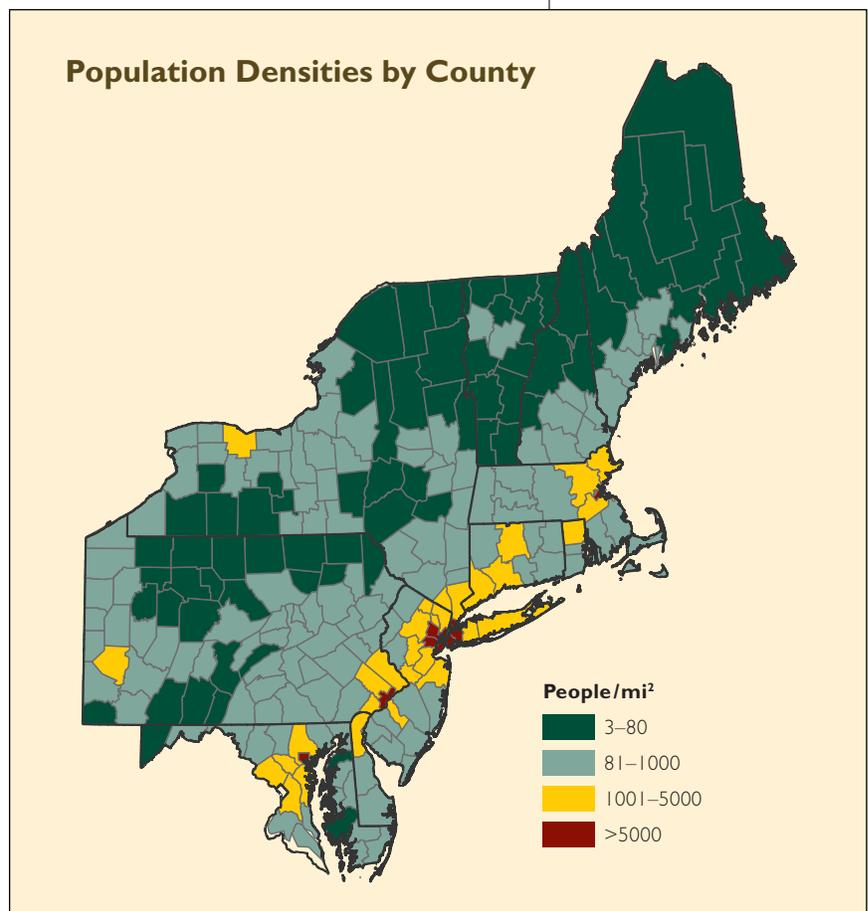


Figure 5. The general threshold in the Northeast at which carbon dioxide emissions are balanced by sequestration coincides with counties having a population density of 80 people per square mile. The mean population density of the region is about 360 people per square mile (U.S. Census 2000), suggesting that for most counties sequestration from forests and soils alone cannot absorb existing carbon dioxide emissions. Note that these emissions estimates exclude air travel and emissions associated with imported food and goods; the estimated “break even” population density would be considerably lower had these emissions been included in this analysis. While counties with lower population densities have lower total emissions, this effect is due solely to having fewer people; emissions from these counties are similar (and often higher) on a per person basis.

By examining emissions in each county, we can gain some understanding of the population densities at which northeastern counties are likely to be net sources of carbon dioxide. By comparing current emissions across counties with different population densities, we find that counties with population densities of 30 people per square kilometer (80 per square mile) are associated with limited emissions. That is, the carbon dioxide emitted from human activities is roughly in balance with the carbon sequestered in plants and soils. (For comparison purposes, Figure 5 indicates the relative population densities of counties in the Northeast, including those marked as dark green with fewer than 80 people per square mile.) The average population density for the Northeast is 350 people per square mile, suggesting that the region will have to reduce sources of carbon dioxide emissions if they hope to achieve carbon neutrality. It is important to note that this estimate does not include the carbon associated with the manufacture or transportation of goods that occur outside of a county's borders. Many of the products we import from other regions or overseas—lumber, foods, and appliances, for example—come with their own carbon impacts even though they are not accounted for in this study.

The Wind Energy Potential

The HBRF team of scientists evaluated the potential for commercial wind power in nine northeastern counties, focusing our analysis on terrestrial rather than offshore wind potential for undeveloped properties. The region has significant terrestrial wind resources that are largely concentrated in mountainous areas such as the White Mountains and Green Mountains. Rural, mountainous counties, such as Coos County, New Hampshire, have the potential to offset more than 100 percent of their carbon dioxide emissions through grid-connected, commercial wind power generation. This means that if it were possible to construct wind projects in every suitable place in the county, such counties could not only completely offset their annual carbon dioxide emissions with this one mitigation option, but could also offset carbon dioxide emissions occurring from sources outside of the county, state, or country. The potential for commercial wind power in less mountainous counties is considerably lower. In less mountainous counties with high population densities—namely, most of the eastern seaboard cities and suburbs—the potential is lower still, since wind resources are limited, land values are high, and a large proportion of the landscape has already been developed for other uses.

Figure 6 shows the percentage of land in each New England county that consistently experiences Class 3 or higher winds. Class 3 is defined as winds averaging 14.3 mph or greater at 50 meters (164 feet) above ground, and represents the threshold at which investments in wind infrastructure are likely to yield savings above the cost of implementation and maintenance. The highest potential for wind investment occurs in mountainous counties and near Cape Cod, where high winds occur both on- and offshore. Nearly all of New England's coastline has a high potential for wind power in addition to the highest peaks and ridges occurring in western and northern New England.

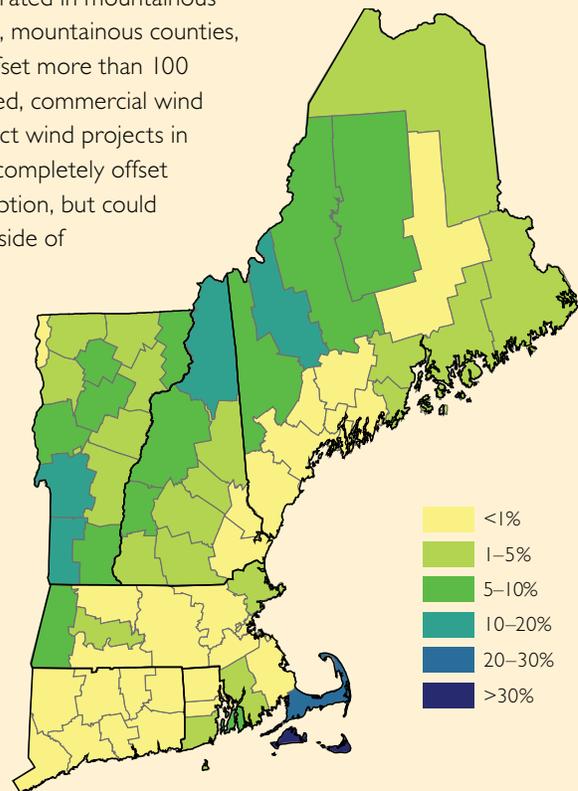


Figure 6. The percentage of land, by county, that consistently experiences Class 3 or higher winds and has not yet been developed for other uses.

How Much Carbon Does the Northeast Sequester?

Most counties sequester carbon in direct proportion to the amount of forested lands they contain, but rates of sequestration are slowing as forests approach maturity. New land management practices may maximize sequestration, but will be insufficient to reabsorb annual carbon emissions in all but the most sparsely populated northern counties.

Our forests, vegetated lands, and soils provide two key carbon mitigation services. The first is carbon storage—the amount of carbon already contained in standing woody biomass, roots, and soils. The second, sequestration, is the amount of additional carbon that plants draw from the atmosphere each year to create new woody biomass. The amount of carbon that the Northeast stores in its forests, soils, and other lands is large, roughly 7 billion metric tons. The removal of carbon dioxide from the atmosphere reflects recovery of forest biomass following peak timber harvest in the late 1800s through early 1900s and the expansion of forest cover on abandoned agricultural lands (Woodbury et al. 2007). The potential for additional sequestration is limited as many of the region's forests are approaching maturity.

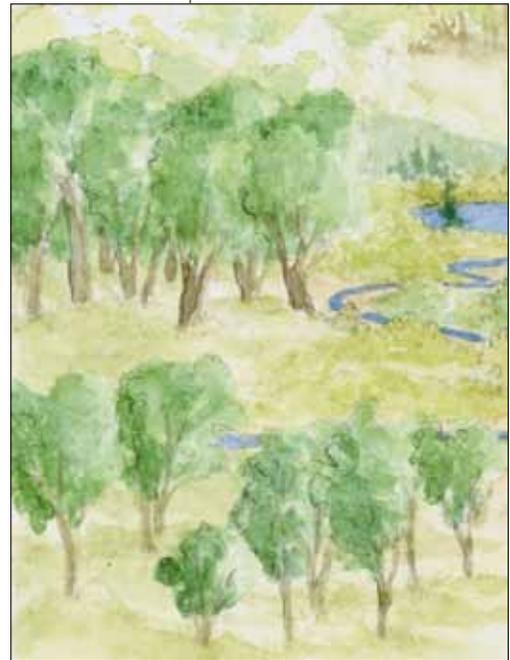
Two counties studied by the HBRF team annually sequester more carbon than they emit through combustion of fossil fuels—the two forested counties of Grafton and Coos in the White Mountains of New Hampshire. Our analysis suggests that these forested counties are atypical for the Northeast; most counties will not be able to achieve carbon neutrality by relying on sequestration from forests. In fact, even these two New Hampshire counties will eventually reach a time when the accumulation of forest biomass ceases (Rhemtulla et al. 2009).

Although forest regrowth cannot sequester all of the region's emissions, certain management practices will help prolong sequestration and provide incentives to protect valuable sinks. Sustainable forest management practices that emphasize the production of durable wood products, such as lumber and furniture, could increase the land's ability to sequester more carbon. In addition, managing forests for wood fuel to replace fossil fuels—by the forest industry itself and by homeowners and utilities—could reduce net carbon emissions if wood is harvested at sustainable rates (Perlack et al. 2005).

Continuing changes in the biotic environment (for example, pests, pathogens, invasive species) and abiotic environment (climate, carbon dioxide and nitrogen fertilization, other pollutants) will undoubtedly influence future growth of forests in ways that are very difficult to predict. Moreover, recent observations suggest that many older forests that had previously been regarded as nearly carbon neutral (that is, having attained maximum carbon storage) may actually be sequestering significant amounts of carbon, especially in soils and coarse woody debris (Luyssaert et al. 2008).

The lack of accurate scientific data on the maximum potential for carbon storage in northeastern forests is a challenge to policymakers hoping to use specific forest-management practices as part of carbon regulatory schemes. Continued study of patterns and processes of carbon accumulation in mature forests will be needed so that policymakers and landowners have a better basis for regulatory measures and management activities to optimize forest carbon sequestration.

Although forest regrowth cannot sequester all of the region's emissions, certain management practices will help prolong sequestration and provide incentives to protect valuable sinks.



Forest Management for Carbon Sequestration

Afforestation of non-forest land and using locally harvested wood as a substitute for fossil fuels together may offer significant potential to offset carbon emissions for rural counties of the Northeast if forest residues are used. (Afforestation is a process in which carbon is sequestered by trees planted on non-forested land.) Our analysis of forest resources suggests that sustainable harvest of wood for space heating or electric power generation could dramatically offset carbon emissions in some rural counties while providing a host of other societal and environmental benefits. Under continuous forest harvest, forest protection can be balanced with controlled harvests for low-grade timber as an alternative fuel source and high-grade lumber to supply durable wood products. In counties with large areas of inactive agricultural land, afforestation could provide additional carbon offsets.

One of the most interesting carbon policy debates involves creating incentives to encourage forest landowners to maximize the storage of carbon. Tens of thousands of landowners already contribute to sequestering carbon from the atmosphere by keeping forests on their lands, but they are not paid for this service. Under most carbon accounting systems, carbon sequestered by existing forests does not count as an emissions offset because this carbon is not considered “additional” compared to what would have been sequestered by these forests had no action been taken. Unfortunately, such financial incentives do not currently exist in the United States (Rey et al. 2009).

Carbon is traded in several existing markets, but the price for carbon is often too low for the average small landowner who owns too few acres. Often the monitoring and certification costs are too steep, thus making it difficult to turn a profit. Prices for carbon, like all commodities, fluctuate in response to market forces. If new carbon regulatory schemes compel large commercial and industrial carbon dioxide emitters to pay for their emissions, they may seek to “offset” their pollution by purchasing credits for carbon stored by afforestation projects. Trees that previously had explicit value only as standing timber or fuel, or intangible values such as wildlife habitat or scenery, may in the future also be valued for the carbon that they sequester from the atmosphere. Landowners seeking profits from their forests face a challenging and uncertain future. They must decide whether to sell their forest products now for a price certain, or else manage the forest to maximize carbon storage in the hope that future markets will pay a reasonable return in the offsets market. Market possibilities change almost weekly and will be strongly influenced by future regional, national, and international policies.

In the absence of a mandatory federal program, some regions and states have developed alternative emission reduction strategies. For example, ten states in the Northeast adopted the Regional Greenhouse Gas Initiative (RGGI), which establishes a cap-and-trade system similar to the Kyoto Protocol to reduce emissions from power plants. Under RGGI, afforestation projects (but not other forest practices) can be used as a credit toward a power plant’s emission reduction compliance.

Forest managers interested in receiving payment for managing their lands for carbon storage should note that the scope for forestry-offset projects under the current policy framework is likely to remain quite limited. Moreover, over the short-term the transaction costs for these projects are likely to be very high relative to the small revenue from the cap-and-trade carbon market. Afforestation projects must complete a detailed application that explains how carbon sequestration will be quantified, monitored, and verified, and general guidelines describe requirements for calculating baseline carbon storage and sequestered carbon. The carbon pools that must be quantified include above- and below-ground biomass as well as soil carbon, and the costs of measuring root and soil carbon will be particularly high.

Forest management can, in theory, accelerate the sequestration of carbon. Considering the possible future carbon-offset markets in managed forests, a better basis for quantifying management effects is needed. Government agencies would be in a better position to evaluate possible incentives to encourage forest management for carbon sequestration if they had a firm basis for evaluating the effects of those activities.

Transportation Strategies for Tompkins

To illustrate potential mitigation opportunities in the transportation sector, the Science Links team examined a range of practical options for Tompkins County, New York. As Table 1 shows, the opportunities with the largest potential to decrease emissions are improved passenger vehicle fuel efficiency, followed by carpooling, bus ridership, traffic signal upgrades, and a range of other fuel options. Taken in total, these improvements have the potential to decrease transportation sector emissions by 17–29 percent and total county emissions by 6–11 percent. The

Combined Heat and Power

Combined heat and power (CHP) provides the opportunity to use less fuel and reduce energy costs by producing electrical power while at the same time using the otherwise wasted energy in exhaust gases for another purpose. A wide variety of uses exist for waste heat, including space heating, steam production, space cooling (via absorption chillers), and dehumidification of buildings. These technologies have the potential to increase the overall energy utilization of a CHP system up to 85 percent (ERC 2010). CHP technology is becoming readily available in smaller scales; its feasibility, however, needs to be evaluated on a case-by-case basis.

One important variable to consider when considering CHP's potential to reduce carbon dioxide emissions and save on energy costs is the amount of energy needed to heat or cool associated buildings. Long operating hours and larger

building sizes increase the likelihood of lower payback periods. In terms of carbon dioxide emissions, heavy fuel oils such as petroleum will produce greater emissions than lighter fuels such as natural gas. The use of biofuels in CHP could provide even greater emissions reductions, depending on the fossil-fuel feedstock (Eriksson et al. 2007). Using these guidelines, good examples of high-potential CHP candidates typically include office buildings, hospitals, colleges, schools, retail applications, and hotels, as well as certain industrial buildings.

Table 2 shows the potential annual reduction of carbon dioxide emissions for each county case study. This analysis assumes that natural gas is burned and that 100 percent of all possible commercial heat and power in the county is utilized in the four categories of buildings.

County	Educational Facilities	Hospitals	Office Buildings	Lodging	Total as Percent of County Emissions
Coos	129	705	321	994	1.78%
Grafton	1,565	1,410	1,682	1,679	1.89%
Tompkins	4,699	235	1,354	583	2.42%
Chittenden	2,518	235	2,503	1,371	1.56%
Worcester	7,498	3,759	8,579	2,125	0.77%
Baltimore	9,346	1,645	9,926	1,611	0.61%
Essex	6,526	4,229	8,061	2,296	0.80%
Middlesex	18,365	7,989	24,500	4,078	1.02%
Baltimore City	7,484	3,994	8,314	1,234	0.92%

Table 2. Potential Carbon Emissions Reductions for CHP Installation (tons C).

County	Transportation Mitigation	(Mg C/yr)	% Transport Emissions	% Total Emissions
transportation mitigation options for other counties would vary according to local conditions, but increasing passenger vehicle fuel efficiency would reduce the most carbon emissions throughout the Northeast.	Vehicle fuel efficiency to 50 MPG	20,774	18.90%	7.30%
	Vehicle fuel efficiency to 35 MPG	7,226	6.60%	2.50%
	Increased carpooling to work	8,200	7.40%	2.90%
	Increased bus ridership	1,417	1.30%	0.50%
	Traffic signal upgrades	670	0.61%	0.24%
	Biodiesel	472	0.43%	0.17%
	Ethanol	391	0.35%	0.14%
	Hybrid electric buses	189	0.17%	0.07%
	Waste oil as fuel	73	0.07%	0.03%
	Total*	18,620–32,169	16.9%–29.2%	6.6%–11.3%

Table 1. Transportation Mitigation Options, Tompkins County, New York.

*Range based on 35 MPG vs. 50 MPG vehicle fuel efficiency scenarios.

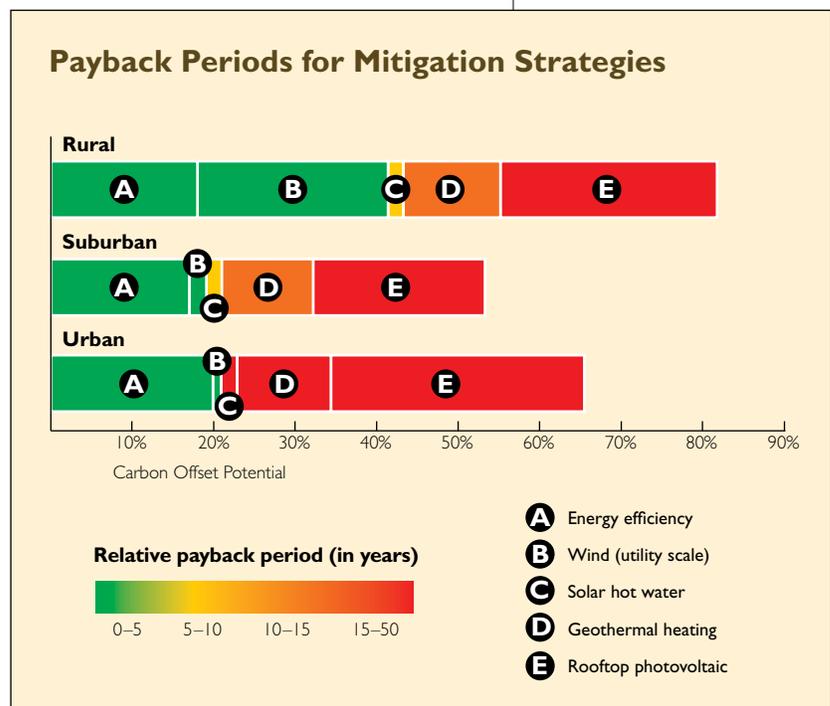
How Much Will It Cost to Reduce Our Carbon Dioxide Emissions?

Most rural counties will be able to offset all of their carbon dioxide emissions at a relatively low cost with options such as investment in wind power and fuelwood harvesting. Suburban counties may be able to reduce as much as a third of their annual emissions with low-cost solutions. Urban areas, however, will need to invest heavily to offset their emissions, though there will be some low-cost options in industrial, commercial, and residential energy-efficiency upgrades.

Many mitigation options exist for counties interested in reducing their carbon dioxide emissions. These options range in cost from the few dollars that individual households could spend for residential efficiency upgrades to many millions of dollars for large statewide or regional infrastructure projects. Of the many mitigation options, a relatively small number would significantly reduce carbon dioxide emissions in the Northeast (see Appendix on page 20 for a listing of these options). While precise prescriptions of which mitigation options each county should undertake is beyond the scope of this report, it's clear that the best carbon dioxide mitigation plans will likely depend on whether a county is primarily rural, suburban, or urban. What this analysis makes clear is that no single mitigation strategy will be cost-effective for all localities. By implementing a range of locally tailored management and technology options, substantial emissions reductions can be achieved at relatively low cost.

Some mitigation solutions provide win-win opportunities, decreasing carbon dioxide emissions while cutting back on energy bills and other costs. Many efficiency upgrades in county and municipal buildings, schools, and private homes, for example, tend to reduce utility bills enough to pay for those system upgrades over a period of one to five years (Figure 7).

Figure 7. This chart shows the relative cost and potential of carbon mitigation strategies for rural, suburban, and urban counties in the Northeast. The colors on the bars represent the relative payback period for each strategy, with the most economical strategies on the left and the most expensive strategies on the right. The length of each colored section represents its carbon offset potential as a percentage of county emissions. For largely rural counties, utility-scale wind power can provide large, cost-effective mitigation opportunities. For urban and suburban counties, energy efficiency measures (for example, home insulation) and energy saving technologies (for example, compact fluorescent bulbs) are most cost-effective. Please note that several land-intensive mitigation strategies (including biofuels and afforestation) are not represented in this chart, but could provide substantial carbon offsets in rural counties in most cases.



The figures on pages 16 and 17 show a range of mitigation options, by county, that are either “low cost” or “higher cost.” Mitigation options that pay for themselves over the lifetime of the option, so-called low-cost options, are available to some extent to all counties in the the Northeast. Some options provide multiple benefits; planting trees in urban areas, for example, sequesters carbon and provides shade that reduces the demand for air conditioning. Some mitigation options, however, are potentially expensive at least until technology or markets improve or national and regional policies are developed (Creys et al. 2007).

Rural areas have considerably more land-based, low-cost options available, which include most investments in wind power and in fuelwood harvest programs. All counties, regardless of land use or population density, can benefit from a long list of energy-efficiency upgrades that pay for themselves over the lifetime of the device or service, including installing compact fluorescent lights, improving insulation in buildings, upgrading to more efficient boilers and air conditioners, and encouraging residents to install Energy Star appliances.

Other carbon mitigation options may help counties offset their carbon emissions but come at a higher cost. It is difficult to say exactly how much these options will cost, particularly since many depend on the future price of fossil fuels. Several biofuels, for example, derived from willow, soybeans, and switchgrass, could be cost-effective investments for local communities, but only if fuel prices are high or if government policies exist to make these investments more attractive. Other examples of higher-cost options include planting trees to sequester carbon, installing residential, commercial, and industrial solar panels, and investing in geothermal heat. (Calculations show that geothermal is low cost for most counties, but just barely, reflecting the long payback period; SBI Energy 2009.)

A handful of rural counties with both low population densities and a high percentage of forest cover are already net carbon sinks. Many rural counties that are not already sequestering more carbon dioxide than they produce could likely become carbon neutral at a relatively low cost to residents. Wind power represents the largest potential emissions reductions for those counties that are properly sited to take

continued on page 18

A handful of rural counties with both low population densities and a high percentage of forest cover are already net carbon sinks.

Evaluating Biofuels as a Mitigation Option

Our analysis illustrates the significant potential for carbon mitigation associated with various biofuel options (fuelwood, switchgrass, and other crops) in the Northeast. To the extent that biofuels replace carbon intensive energy sources like coal and petroleum, their entry into the regional fuel mix can be a relatively cost-effective mitigation option. Simplistically, biofuels could be regarded as carbon neutral because new plant growth on harvested land could remove equal amounts of carbon from the atmosphere as that emitted from biofuel combustion. In reality, however, the situation is more complex. For example, extra fuel inputs are required to grow and process biofuels (for example, fuel used for tractors, fertilizer, and trucking). Our analysis has attempted to account for these “life cycle” carbon

costs, but significant uncertainty accompanies these estimates (Fahey et al. 2010). Moreover, under existing and proposed accounting rules, the large storage pool of carbon in existing forest lands could be under considerable risk (Searchinger et al. 2009). That is, if a biofuel uses carbon that would otherwise remain stored in forests, it temporarily adds carbon dioxide to the atmosphere in the same way as burning fossil fuels. By increasing demand for biofuels, the regulations could encourage overharvest of wood from forest land and conversion of forest to agriculture, both of which would reduce the amount of carbon storage in forests and result in net emission to the atmosphere. Hence, local, national, and global policies should be crafted to avoid such unintended consequences of expanding biofuel markets.

Mitigation Opportunities for Reducing Carbon Emissions

Low-Cost Opportunities

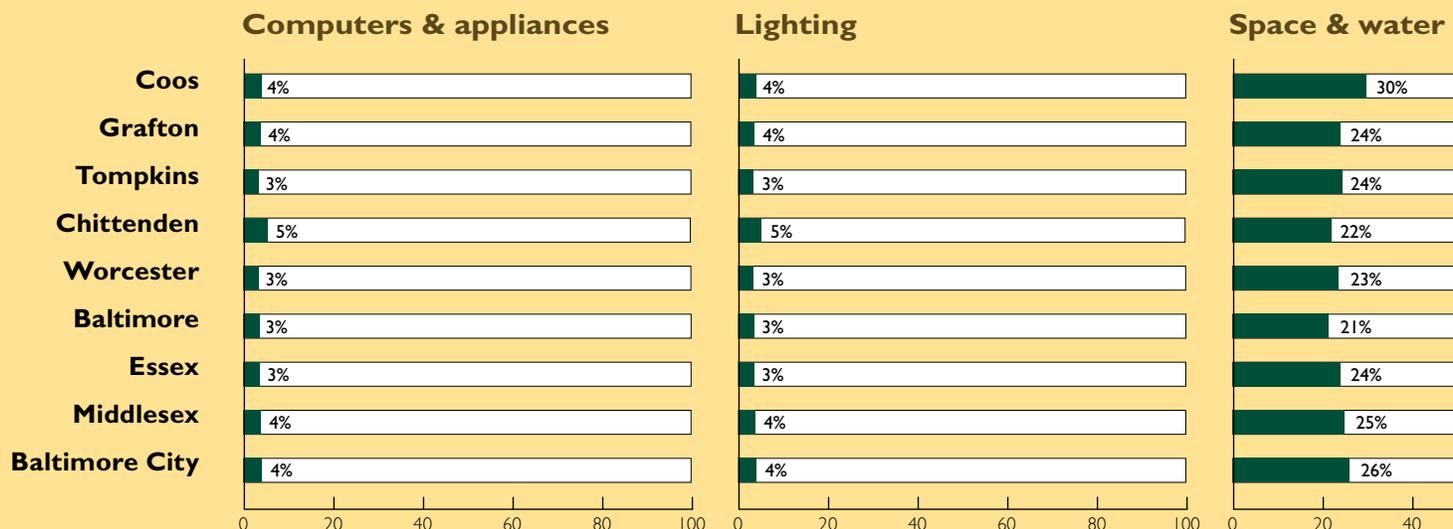


Figure 8. Low-cost mitigation opportunities are defined as activities that pay for themselves, from income generated or energy costs saved, over the lifetime of the product or service. These include land-intensive alternative power sources such as sustainable fuelwood from forests and utility scale wind power (which requires a “wind potential rating” of Class 3 or greater—

which is relatively windy—at installed sites). In the residential sector, low-cost opportunities include energy efficient lighting (replacing incandescent bulbs with compact fluorescent bulbs), increased home insulation, programmable thermostats, lowered thermostat temperature settings for heating, sealing air leaks, boiler maintenance or replacement, and US EPA Energy Star certified

Higher-Cost Opportunities

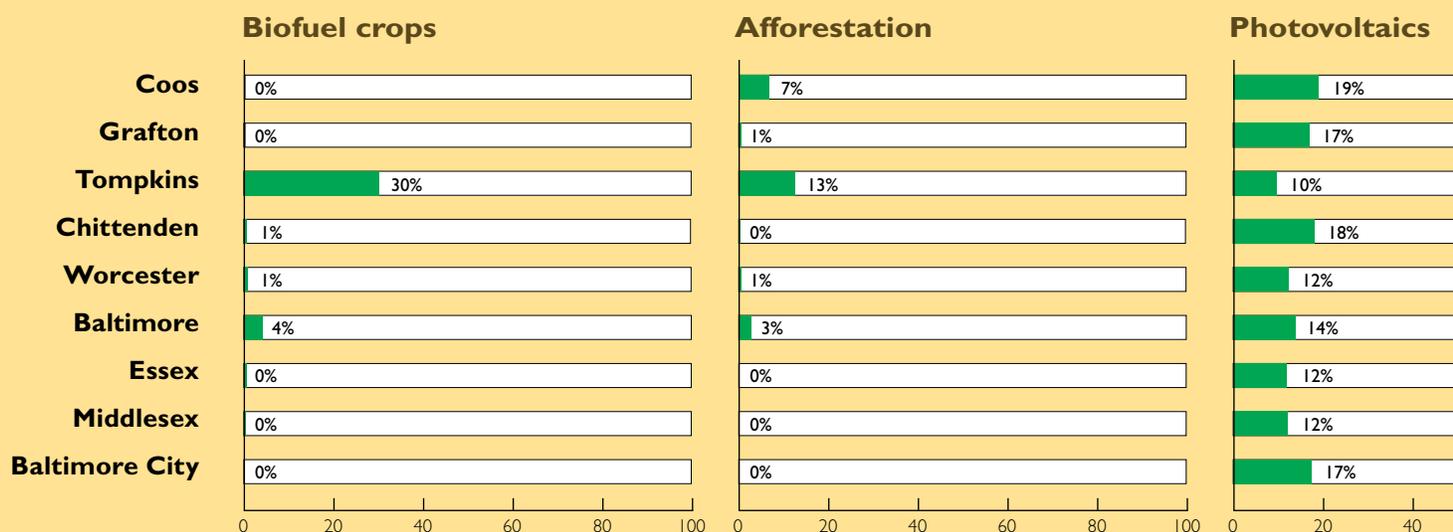
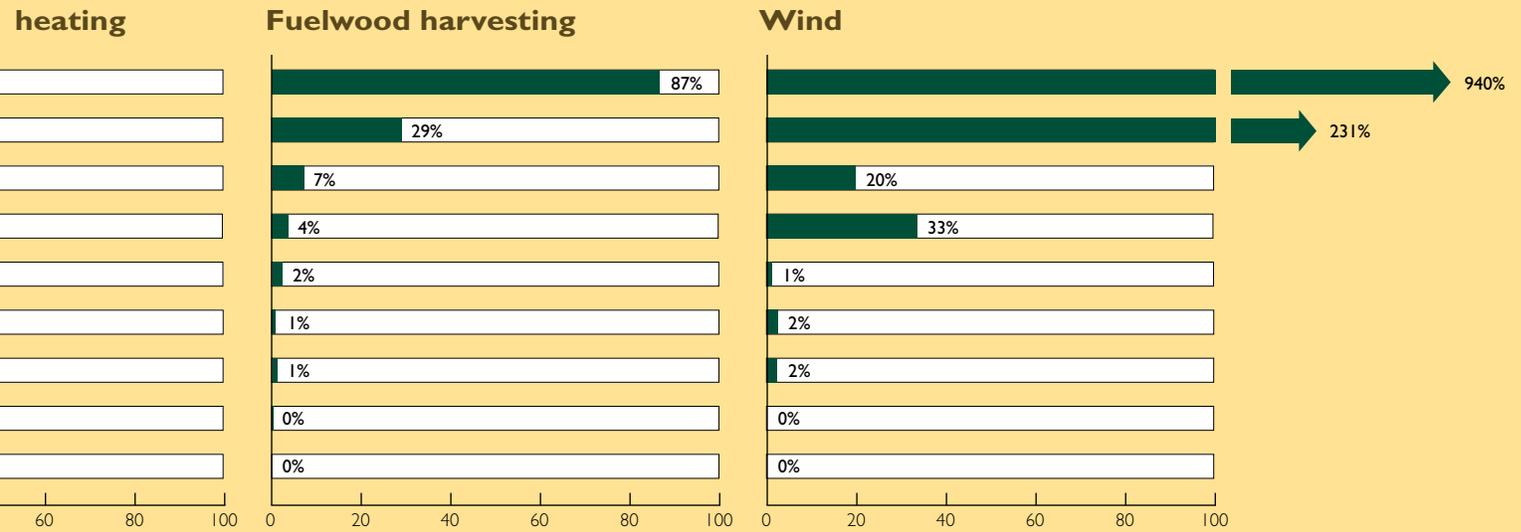


Figure 9. The higher-cost mitigation opportunities include afforestation of non-forest land and growing biofuel crops; and also installing photovoltaic systems on the rooftops of homes, businesses, and industrial buildings. The first of these options (afforestation and biofuel crops) has the greatest potential in rural

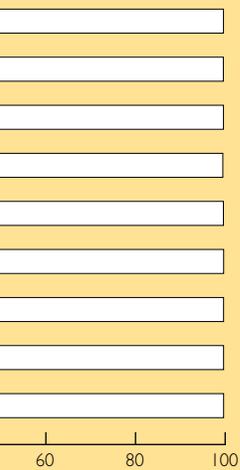
counties. For counties with significant areas of inactive agricultural land, afforestation and biofuels may be viable carbon mitigation strategies. Among the biofuels we evaluated, willow and switchgrass provide the greatest potential for offsetting carbon emissions while minimizing environmental impacts; both crops can be dried,

White bars represent 100% of a county's carbon emissions.



refrigerators and air conditioning units. In the commercial sector, the low-cost opportunities include computer energy savings and installing LED (light emitting diode) exit signs. Augmenting traditional heating systems with geothermal heat pumps can bring large, additional energy savings to the residential, commercial and industrial sectors, but the upfront costs are relatively high and

the payback periods typically range from 18 to 20 years. Counties with values above 100 percent possess the ability to reduce all of their annual carbon dioxide emissions with the value in excess of 100 percent representing a "credit" that could be used to offset emissions from areas outside of that county.



pelletized, and burned to generate electricity or heat homes and buildings. Corn and soybean can be used to produce ethanol and biodiesel fuels for the transportation sector; however, they provide fewer emissions benefits per unit of land area and may have greater environmental impacts. Photovoltaic systems have the

potential to offset a significant portion of electricity related emissions in each county, but solar resources in the region are not optimal, making these systems uneconomical without significant subsidies.

Forest Sequestration and Emissions

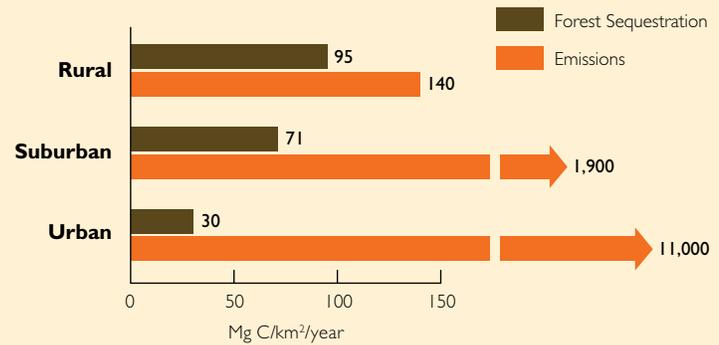


Figure 10. Forests absorb significant quantities of carbon dioxide in the counties studied. But as land is converted to development, the area in forest decreases as carbon dioxide emissions increase.

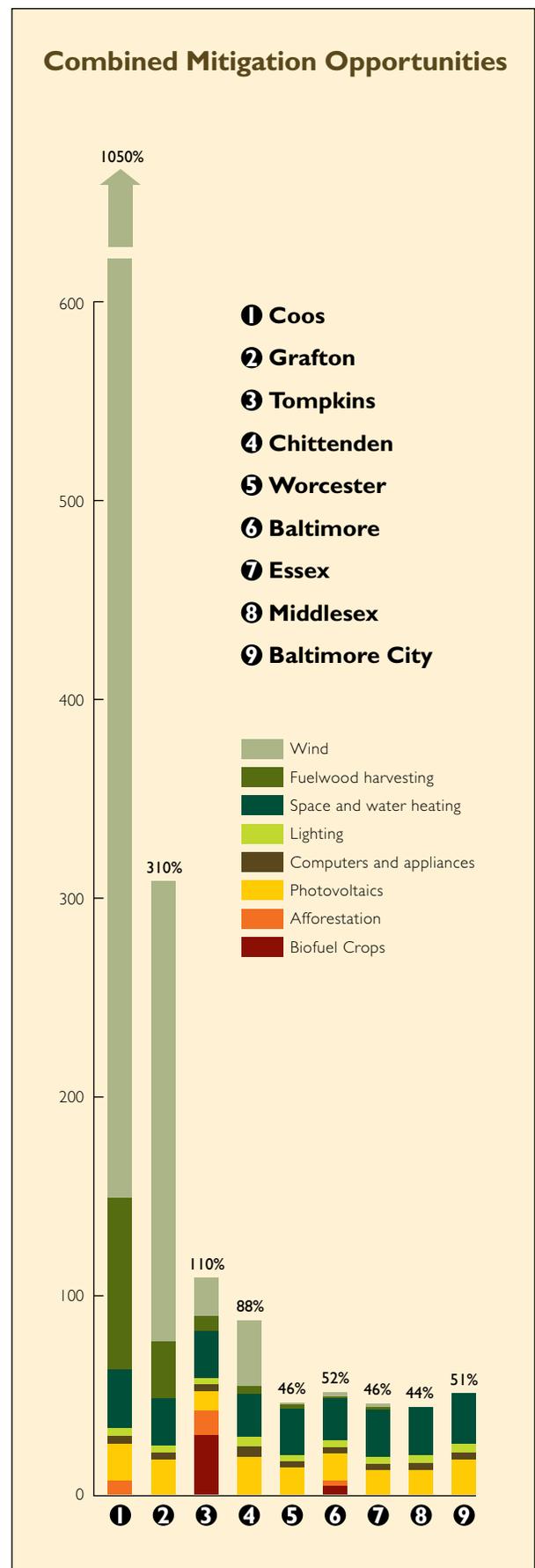
advantage of this alternative source of energy. Start-up costs will vary by location and site conditions, but in many cases initial investments in wind infrastructure will be repaid in energy savings or revenue generated over the lifetime of the technology (Bird et al. 2005). Fuelwood harvest represents another possible carbon-abatement strategy for rural counties which may use the wood primarily as a heating source to replace oil and natural gas. Wood fuel will only provide a carbon benefit if the supply is used locally and does not require large amounts of fossil fuels to transport it or to convert it to other products such as wood pellets (Malmsheimer et al. 2008).

Urban and suburban counties could offset as much as a third of carbon dioxide emissions at low cost. Installing compact-fluorescent lights and LED exit signs, for example, could reduce county emissions by 3 to 5 percent. Enabling computer energy savings settings for the 50 percent of commercial sector computers that are set to run constantly would reduce emissions by 1 to 3 percent (Webber et al. 2000; Karayi 2009). Boiler upgrades, programmable thermostats, energy efficient appliances, and better insulation in homes could reduce county emissions up to 15 percent. Finally, geothermal heating systems and solar hot water systems, which have a high initial cost but often pay for themselves over their lifetimes, could offset county emissions by another 10 percent.

To achieve even greater emissions reductions, urban and suburban counties will need to invest in higher-cost mitigation options. For instance, solar photovoltaic installations for homes and businesses could reduce carbon dioxide emissions up to 20 percent, but generally do not pay for themselves without government incentives. Afforestation could offset up to 3 percent of urban and suburban emissions, but relatively high land values combined with the low value of carbon offsets mean that, at present, this is a higher-cost strategy. Using existing forests in urban and suburban counties to absorb additional carbon is difficult because the area in forest decreases as emissions increase (Figure 10).

Combining low- and higher-cost strategies, urban and suburban counties could reduce total emissions by 40 to 50 percent (Figure 11).

Figure 11. By combining low-cost and higher-cost mitigation opportunities, counties can reduce carbon dioxide emissions considerably while minimizing economic costs. Despite these promising findings, it is important to note that fully implementing even the low-cost mitigation opportunities will be difficult or impossible without strong leadership, effective policies, and public support for reducing carbon dioxide emissions. Counties with values above 100 percent possess the ability to reduce all of their annual carbon dioxide emissions, with the value in excess of 100 percent representing potential credits that could be used in present and future offset markets.

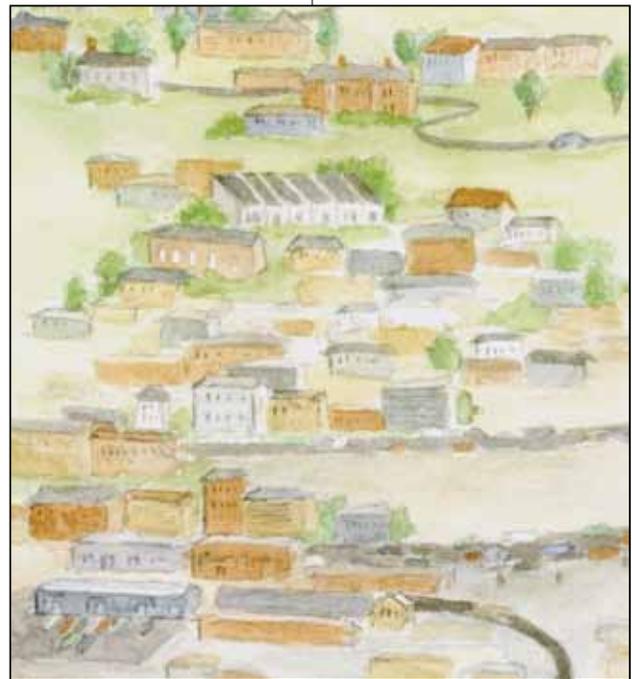


Conclusions

Although primary sources of carbon emissions vary regionally by land use and human activities, there are nonetheless clear conclusions that emerge from comparing carbon budgets from nine northeastern counties.

- ▶ Most counties in the Northeast are net sources of carbon dioxide emissions to the atmosphere, except for those in sparsely populated forested areas with fewer than 30 people per square kilometer (80 people per square mile).
- ▶ The largest source of carbon per capita for most counties is the transportation sector—emissions from cars, trucks, and buses used to move people and goods. The amount of carbon dioxide associated with transportation per person is similar across counties regardless of population density or land use, the exception being very large cities with good transportation systems. The most effective way to reduce those emissions is increasing vehicle fuel efficiency and promoting carpooling to work.
- ▶ Some rural counties could offset most of their carbon dioxide emissions at little long-term cost to residents, whereas suburban and urban counties will need to invest additional resources to offset the majority of their emissions. However, per capita emissions are generally lower for urban than rural areas.
- ▶ In rural counties, wind power and fuelwood harvest (for space heating and power generation) are the most cost-effective mitigation opportunities. Protecting rural forests, while not low cost, will be critical for balancing carbon emissions in the region.
- ▶ As counties develop, energy efficiency measures and technologies become more important (e.g., increased home insulation, energy efficient lighting and appliances, upgraded and well-maintained heating systems). The deployment of combined heat and power in certain large buildings could significantly reduce carbon emissions.
- ▶ Urban and suburban counties will not be able to achieve carbon neutrality by relying on growing forests. And even the most rural counties cannot count on forests to absorb emissions forever since forests will reach their maximum carbon storage potential. Nonetheless, wisely managing existing forests and protecting them from development will be key to ensuring that forest carbon sinks do not become emissions sources over time.

Wisely managing existing forests and protecting them from development will be key to balancing emissions over time.



Appendix: Mitigation Options to Decrease Carbon Dioxide Emissions

Because total carbon dioxide emissions are the product of countless local actions, any effective solution must involve decisions at local and regional as well as national scales. Each county, city, and town contributes to the global carbon cycle. The efficiencies of our homes, offices, and schools have impacts on carbon dioxide emissions, as do the cars and trucks we use and how much we choose to drive. Land-use decisions involving agriculture, forest management, and residential development all affect the carbon cycle (EPA 2009a).

There are numerous carbon mitigation strategies to consider, and this can be a vexing process for communities which are just beginning to explore carbon-reduction plans. But in the Northeast, a relatively small number of options have the most promise for reducing meaningful amounts of carbon dioxide emissions. They can be found under the broad categories summarized below.

Forest Management

For forests that are actively managed, the method of harvesting, time between harvests, and final use of the wood can have important implications for the carbon cycle (Ruddell et al. 2007). Carbon storage can be maximized on the landscape in three main ways: 1) maintaining forests as forests by using conservation easements or other long-term protection strategies; 2) using harvested wood for durable wood products; or 3) using wood harvesting residues as a substitute for fossil fuels.

Urban Forestry

Planting trees in urban areas not only sequesters additional carbon but increases the property values of real estate, improves air quality, provides habitat for urban wildlife, and cools and shades urban lands. Planners and managers interested in urban forestry may consult the U.S. Department of Agriculture and U.S. Forest Service's Urban Forest Effects programs. Here, users can access tools designed to assist in the mapping and assessment of urban forests, plan for

future tree growth and management, and receive answers to technical questions.

Alternative Energy

Finding and implementing alternatives to carbon-rich fossil fuels must be a cornerstone of the global effort to reduce carbon dioxide emissions. As models for energy production and distribution become increasingly decentralized, local and regional efforts will be key to establishing these alternatives (EPA 2009b). Many resources already exist to assist planners interested in investing in wind and solar, the two most popular alternative energy solutions. New research and markets on fuels produced from wood biomass and other sources of biomass (cellulosic ethanol, algae-based fuel, and methane from landfills or manure, among many other examples) are in some cases emerging now, require additional study, and in select cases offer potential alternatives to fossil fuels.

Residential

Residential heating and electricity usage can account for as much as one-third of a county's total carbon emissions. Reducing this demand for carbon literally begins at home. Communities can help reduce carbon emissions by improving the efficiency of outdoor lighting, while individual households should replace incandescent bulbs with more efficient compact fluorescents or LEDs. Resources exist to help people conduct home energy audits, which will indicate how to weatherize and better insulate homes so that heat energy is not wasted. People can also reduce the residential demand for power by purchasing energy-efficient appliances, furnaces, and air-conditioners. The U.S. government's Energy Star program certifies which newly constructed homes are energy efficient.

Commercial

Since the end of World War II, the Northeast's share of commercial space has steadily increased and in some

areas accounts for nearly one-quarter of carbon dioxide emissions. Commercial development requires heating, cooling, and illumination of large spaces, making these buildings a good target for planners interested in meaningful reductions in regional energy demand. Energy service companies may help planners perform energy audits for municipal buildings and schools and suggest a host of improvements to reduce fuel and electricity usage. The National Association of Counties has partnered with Energy Star to help counties improve the efficiency of their courthouses, administrative buildings, and other structures. Purchasing electricity from approved sources of green power can also greatly reduce a county's dependence on oil and gas. Combined heat and power (CHP) systems could significantly improve the energy efficiency of commercial buildings. A typical electric power plant is only 30 to 40 percent efficient in its conversion of fossil fuel energy into electricity. Much of the wasted energy is released as heat. CHP systems can use this heat energy to keep buildings warm in the winter, dehumidify the air, or even cool the air via absorption chillers. Overall, a CHP system can provide up to an 85 percent increase in energy efficiency compared to stand-alone heat and electric generation systems.

Industrial

County and regional planning offices often have a mandate to attract businesses and industries to their localities. Encouraging industries that employ alternative power sources, or more efficient uses of power and fuel, can have large impacts on a region's carbon dioxide emissions. Many of the energy efficiency upgrades that are available to residences can be scaled up to reduce emissions at industrial facilities. Also, industries have the ability to choose from a much greater number of alternative fuels and onsite electric or heat generation technologies.

Transportation

Since the invention of the automobile, the United States and other nations have structured development patterns, commercial spaces, homes, offices, and cities around the expectation of abundant and cheap petroleum. As global petroleum supplies diminish

and oil prices rise, pressure mounts to switch to alternative fuels and improve the efficiency of existing vehicles (EPA 2009c). Local governments interested in purchasing fuel-efficient vehicles or replacing existing fleets can compare various makes and models by consulting the EPA's Green Vehicle Guide (<http://www.epa.gov/greenvehicles/Index.do>). Federal incentives exist to purchase vehicles that run on biodiesel or on hybrid electric and gasoline. Reducing the need for single-passenger private transportation and total vehicle miles traveled will also decrease the growing global demand for standard and diesel gasoline. Planners can consider carpooling opportunities when drafting regional development plans; urban communities can encourage bike-to-work programs. Several northeastern communities have sought to reduce the need for buses and encourage more children to walk to school by developing programs such as Safe Route to Schools. Previous work has also demonstrated that even rural communities with help from state and federal funding can provide public transportation for its citizens.

Zoning

Since many Northeast states give counties or towns sweeping powers to define their own zoning and land-use regulations, local citizens and governments can have an enormous impact on shaping the carbon dynamics of their region. Local decision makers often have the power to site wind and biomass plants, to shape the density and pattern of residential development, and to design local transportation networks. Perhaps the most important first step for any community is to adopt effective zoning legislation if none exists. Below is a brief introduction to zoning mitigation strategies.

Urban Zoning. The density of urban communities lends itself to efficiencies in housing and transportation that are difficult or impossible in other areas. In addition to fostering large-scale public transportation, apartments and other dense housing, and centralized utilities, urban planners can undertake additional zoning practices to reduce carbon dioxide emissions. Redeveloping former industrial sites and adaptive reuse of historic buildings are two ways to capitalize

on existing infrastructure and utilities, alleviating the use of carbon-intensive building materials in new construction. Revising building codes to fast-track the installation of solar panels on rooftops could provide a means to utilize underused spaces and support clean and renewable energy.

Suburban/Exurban Zoning. Without careful design and planning, the sprawling resource-intensive development patterns of most suburbs and exurban areas will likely contribute ever larger carbon dioxide emissions to the northeastern United States. Zoning intended to redress this problem should focus on decreasing the number of miles needed to travel in single-passenger vehicles and on clustering development and services to maximize the landscape's ability to sequester carbon. Since much of the region's suburban infrastructure has already been built and planned around the automobile, high scrutiny should be placed on any new developments that are not designed with efficiencies in mind. Zoning regulations can be amended so that new subdivisions are required to include planning for cluster development. The practice of creating "smart growth" policies that manage economic and community growth with an eye toward protecting environmental resources can contribute to decreasing carbon dioxide emissions and capitalize on forest carbon sequestration. Encouraging infill of abandoned retail and commercial spaces can make the best use of land while creating mixed-use neighborhoods that require less driving and place residents closer to services and jobs (EPA 2008).

Rural Zoning. Rural towns and counties often contain most of the region's above-ground stored carbon and hold the greatest potential to manage growth since many areas are only now beginning to experience diffuse development pressures. Rural areas, however, are the least likely to have formal zoning and planning legislation in place, making them vulnerable to development patterns that negatively contribute

to carbon dioxide emissions (Irwin and Reece 2002). With proper planning, rural economies can encourage growth, manage forested lands as sources of income and for carbon storage, foster smart-carbon agricultural practices, and cluster housing and services. Discouraging conventional sprawl will protect carbon stored in wood, but also protect carbon reserves stored in the soil that are released when developers excavate foundations and grade housing lots (Weinert 2006). Rural town zoning boards can also assist alternative energy investment by streamlining the application process for wind projects. Zoning regulations that favor the construction of facilities to process and utilize biofuels and wood biomass as a substitute for fuel may alleviate dependence on fossil fuels.

Agriculture

Agriculture has steadily declined as a proportion of the Northeast's total economy and land area over the last century (Foster et al. 1998). But even in lightly farmed areas, poorly managed lands can have negative impacts on the regional carbon budget. No-till agricultural practices have been shown to reduce the amount of carbon lost from the soil compared to conventional plow-and-harrow agriculture (Wood et al. 1991), and such practices may be feasible among the many small-scale farms with high-value crops in the Northeast. In counties that actively support large dairying, new vaccines have been marketed for cattle to reduce methane produced in their digestion systems, a surprisingly significant source of greenhouse gas (Thorpe 2008). Larger farms with animal husbandry may choose to invest in anaerobic digesters that convert the energy stored in manure to a type of biogas that can be used as a substitute for fossil fuels. State and regional partnerships that encourage consumption of low-carbon local foods will not only support sustainable agriculture, but reduce the overall amount of fossil fuels needed to ship produce to local consumers from distant national and global sources.

Source Documents

The content of this report is based on peer-reviewed scientific papers written by its authors with support from the Hubbard Brook Research Foundation. Unless otherwise noted, all text, tables, and figures are adapted or reprinted from these papers:

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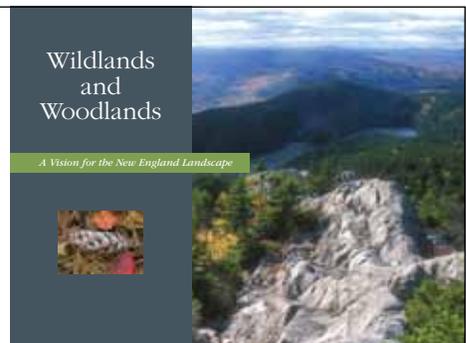
www.carbonandcommunities.org

Wildlands and Woodlands

Preventing forest loss offers one of the most important means of securing economic and environmental resilience in the face of climate change and other stresses. While forests vary in their capacity to sequester and store carbon depending on age, species, and past management, they provide far greater benefits to climate stabilization and other ecosystem services than the alternative of development—and at very low cost.

The remarkable return of New England's forests following a century of land clearing by early settlers presents both an opportunity and a great challenge. Today roughly 80 percent of the region is forested yet forest cover is declining in all six New England states for the first time in over 150 years. A team of scientists convened by the Harvard Forest has published *Wildlands and Woodlands: A Vision for the New England Landscape* to call attention to the national and global significance of retaining New England forests for carbon and other benefits. The report documents the climate benefits of forests relative to commercial development and other land uses and articulates the value of investing in the region's distinctive natural infrastructure.

Wildlands and Woodlands calls for retaining 70 percent of the region as forestland, permanently free from development. This three-fold increase in conserved land would include 7 percent wildlands and provide room for continued economic growth. Approaches to achieving the Wildlands and Woodlands vision will vary across the landscape and are likely to include a combination of conservation easements from willing landowners, paired with strategic conservation acquisitions and enhanced economic incentives to retain forestland. For more information on the project, go to www.wildlandsandwoodlands.org.



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