

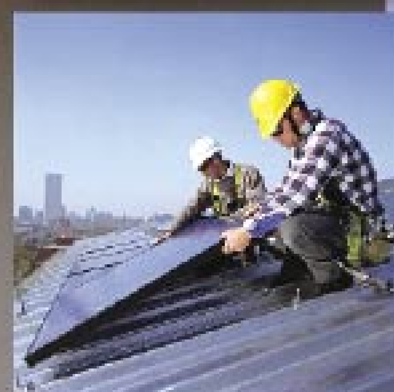

Tomorrow's Energy Today

How to Ease New England's Energy Crisis and Curb Global Warming Pollution, Starting Now

ENVIRONMENT MAINE RESEARCH & POLICY CENTER

NATURAL RESOURCES COUNCIL OF MAINE

Summer 2007

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How to Ease New England's Energy Crisis and Curb Global Warming Pollution, Starting Now

Environment Maine Research & Policy Center

Natural Resources Council of Maine

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Executive Summary

New England is heading for an energy crisis. Indeed, it may have already begun. Energy prices are high and increasingly volatile. The region's energy infrastructure is strained. The long-term outlook for oil and natural gas supplies is questionable. And our use of energy contributes to a variety of environmental and public safety problems, not the least of which is global warming.

A clean energy strategy that maximizes our region's near-term potential to use energy more efficiently and generate more of our power from clean, home-grown renewable resources can address New England's energy problems *and* dramatically reduce emissions of global warming pollutants – providing a "win-win" path forward for the region.

In this report, we describe some of the many opportunities New England has to reduce its use of energy and tap local sources of renewable energy. We focus on addressing the biggest sources of energy use in New England, using technologies that are feasible today.

Achieving the region's near-term energy efficiency and renewable energy potential could shave our energy consumption by at least 18 percent and reduce the region's emissions of carbon dioxide – the leading global warming pollutant – by at least 20 percent. (See Figures ES-1 and ES-2.)

Achieving New England's clean energy potential will not happen all at once. And it will take investment, creativity and hard work. But the availability of vast amounts of energy efficiency opportunities and renewable energy potential suggests that New England's energy problems are solvable – and that they can be addressed in ways that reduce our contribution to global warming and preserve the region's environment, public health and economy.

New England's energy challenges are real and they are serious.

- New England imports about 90 percent of our energy from other nations and other regions of the United States. If the region were forced to rely only on native resources we use today, our homes would be dark, our streets empty of cars and our businesses shut down for all but 2 hours and 15 minutes of every day.

- Energy prices have been rising and are extremely volatile. Natural gas prices have fluctuated by a factor of four over the last four years, New Englanders paid record (nominal) gasoline and heating oil prices in 2005 and 2006 and electricity prices have spiked as well. Long-term trends in the oil, natural gas, and electricity markets suggest that higher and more volatile energy prices could become more common in the future.

- New England's traditional energy supply alternatives each come with significant drawbacks:
    - Coal burning is a major contributor to global warming as well as local environmental harm. In 2004, coal accounted for 6 percent of New

Figure ES-1. Reductions in Fossil and Nuclear Energy Use from Energy Efficiency and Renewable Energy

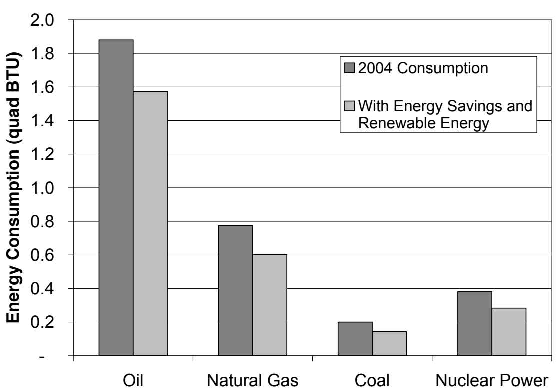
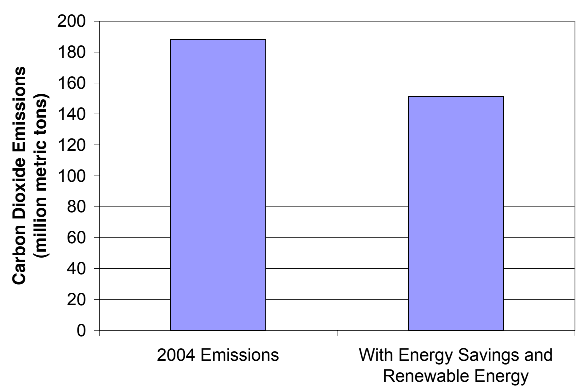


Figure ES-2. Carbon Dioxide Emission Reductions from Energy Efficiency and Renewable Energy Improvements



England's energy use, but 10 percent of its carbon dioxide pollution.
- Nuclear power has proven to be very expensive and poses long-term challenges related to public safety, waste storage, terrorism and weapons proliferation.
- Importation of liquefied natural gas from overseas poses potential public safety problems and would make New England more dependent on foreign nations for another major source of energy.

Energy efficiency and renewable energy can address the region's energy problems while reducing emissions of global warming pollution.

By implementing technologies available today, New England can significantly reduce energy use and global warming emissions. Such technologies include:

- Technological improvements to cars and light trucks that would enable vehicles to achieve average fuel economy of at least 33 miles-per-gallon over the next decade, and much better fuel economy in the years to come.

- Improvements to heavy-duty trucks that can reduce their fuel consumption per mile by 29 percent.

- Weatherizing homes in New England to reduce their use of fuel for space heating during the cold winter months and reduce air conditioning demand in the summer.

- Improved water heaters and other major appliances for homeowners that achieve significant reductions in energy consumption.

- More energy-efficient space heating, cooling and lighting equipment in commercial buildings.

- More efficient motors in industrial facilities, along with smarter integration of motors into industrial processes.

- Combined heat-and-power technology that allows business and industry to create heat and electricity at the same time – resulting in a large improvement in overall energy efficiency.

In addition, New England can begin to tap its vast potential for renewable energy development. New England's solar and wind energy resources are sufficient to power the entire region several times over. Taking advantage of only a small share of our renewable resources could enable us to replace 10 percent of the region's electricity generation with new renewable energy in the near future. One scenario for near-term renewable energy development might include:

- Building five offshore wind energy facilities of the same size as the proposed Cape Wind project off Massachusetts.

- Installing 1,860 wind turbines in onshore locations in New England, requiring temporary disruption of less than 0.03 percent of the region's land area and permanent impacts on only a small fraction of that area.

- Installing solar photovoltaic panels on less than one-half percent of New England's homes or 1.5 percent of its businesses.

- Using cost-effective biomass resources from mill wastes and low-quality wood from our forests.

A clean energy strategy for New England would have major benefits for the region.

- A scenario that takes advantage of the region's full near-term energy efficiency and renewable energy potential could:
  - Cut gasoline consumption by 21 percent.
  - Cut diesel fuel consumption by 13 percent.
  - Cut natural gas consumption by 22 percent.
  - Cut nuclear power production by 26 percent.
  - Cut coal consumption by 28 percent.

- In addition, such a scenario could reduce the region's emissions of carbon dioxide – the leading global warming pollutant – by nearly 20 percent, exceeding the near-term goals for emission reductions set out in the New England Governors/Eastern Canadian Premiers' 2001 Climate Change Action Plan and the Regional Greenhouse Gas Initiative. Reductions of this scale would put the region on track to achieve its share of the emission reductions scientists say are necessary to avoid the worst impacts of global warming.

- Further opportunities for energy savings and renewable energy development exist in the region, including in technologies that exist today but were not included in this analysis (such as solar water heating and geothermal heat pumps) and technologies that could emerge over the next decade (like plug-in hybrid vehicles, biofuels from plant residues and energy crops, and small-scale wind energy).

New England should pursue a clean energy strategy to provide an environmentally sound, economically wise, and long-term solution to its energy challenges. Specifically:

- New England states should cap global warming pollution – and support a similar cap at the federal level – to achieve the emission reductions that scientists believe are needed to prevent dangerous, human-caused global warming. Global warming emissions in the United States must be stabilized at current levels by the end of the decade, reduced by at least 15 to 20 percent by 2020, and be reduced by at least 80 percent by 2050.

- Each New England state should set concrete goals for energy savings and develop plans and marshal the necessary resources to achieve those savings.

- New England states should remove remaining financial and bureaucratic obstacles to cost-effective energy efficiency improvements and the expansion of renewable energy production.

- New England states should require utilities to devise and implement long-term, least-cost plans for securing electricity that take full advantage of energy efficiency and renewable energy.

- New England states should impose aggressive codes and standards for new buildings and equipment and revise those standards frequently as technology improves.

- New England's leaders should use their influence to pursue necessary policy changes at the federal level and should involve the public in efforts to move the region toward a cleaner energy future.

Introduction: A Region in Crisis

New England faces an energy crisis. Our dependence on oil and natural gas leaves us vulnerable to the wild swings of fossil fuel markets and increasingly susceptible to political instability abroad. Our use of coal for electric power poses massive public health and environmental problems. Our region's nuclear power plants have imposed billions of dollars in unwarranted costs on New England ratepayers and pose a continuing threat to public health and safety. Last but not least, our electricity system is groaning under the weight of increasing demand and could require massive investments on the part of ratepayers to preserve its reliability.

At the same time, New England contributes to and will feel the effects of a worldwide crisis: global warming. While the region has taken important steps to reduce our emissions of global warming pollutants in recent years, we must do more to reduce our pollution if we wish to avoid the worst impacts of global warming: rising sea level, increased threats to public health, and the loss of much of what makes our region special – from vibrant fall foliage displays to winter skiing to maple syrup production.

The energy and global warming crises are two sides of the same coin. The very dependence on fossil fuels that threatens New England's economic health also contributes to global warming. And the decisions the region makes as it seeks to solve its energy crisis will have dramatic impacts on our future emissions of global warming pollution.

As a coalition of local and statewide groups concerned about global warming in New England, the New England Climate Coalition has long urged clean energy solutions, such as improved energy efficiency and renewable energy as ways to reduce our region's contribution to global warming. But these solutions also increasingly make sense as solutions to the region's energy problems – providing New England with a "win-win" opportunity to ensure our environmental and economic future at the same time.

This report describes how New England could slash its consumption of fossil fuels and its emissions of global warming pollution using technologies and practices that exist today. New England cannot achieve all of these energy savings overnight, nor can it achieve them all cheaply. But energy efficiency and renewable energy can be much more than bit players in the region's energy future – if applied wisely and aggressively, they can successfully address many of the region's most difficult energy challenges.

At a time when decision-makers in New England are considering many dubious ideas – from new nuclear power plants to large new liquefied gas terminals to so-called "clean coal" power plants – as potential solutions to the region's energy crisis, we believe that energy efficiency and renewable energy are better, more reasonable and more sustainable options for solving those problems. The technologies to begin the transition to a clean energy economy for New England already exist. Most of them save money for consumers.

What is missing is a vision for making New England a clean energy pioneer and the political will to adopt policies that can pave the way for that transition.

This report lays out the first steps toward achieving a clean energy future for New England and what that future might look like. And it suggests some ways that policy-makers can put that vision into practice.

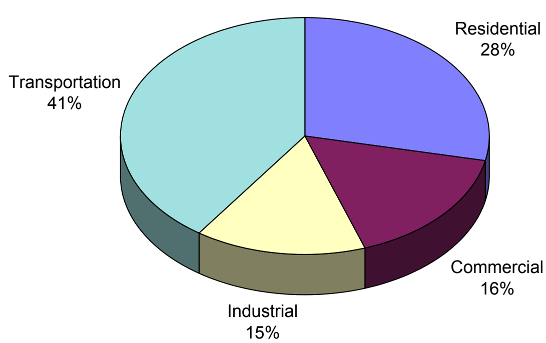
New England's Energy Challenge

New England is at an energy crossroads. Political and business leaders, academics, environmentalists and consumer advocates – as well as a growing number of New England residents – recognize that the region is heading for an energy crisis, if it has not already arrived. And while people may disagree about the causes of that crisis and the potential solutions, it is clear that continuing with "business as usual" is not an option if New England hopes to maintain the stability of the region's energy supplies and the vigor of our economy.

How We Use Energy in New England

Energy is the lifeblood of New England's economy. New Englanders use energy for many purposes – to heat and light our homes, power our businesses, and fuel our cars and trucks.

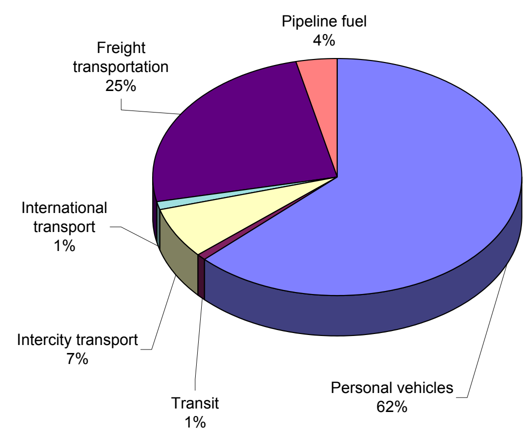
Figure 1. Energy Use in New England by Sector, 2004[1]



Thanks to federal agencies like the Energy Information Administration (EIA), we know quite a bit about *how much* energy is used in the New England states. We know much less about *how* that energy is used and for what purposes. The EIA and other agencies conduct regular surveys of energy use in homes, business, industry and transportation that enable us to assemble the rough outlines of how energy is used in New England. The data from those surveys are not always New England-specific, not always complete, and often several years old. But they do provide a window through which we can evaluate which activities consume the most energy in the region – and suggest places where we might start to look for energy savings.

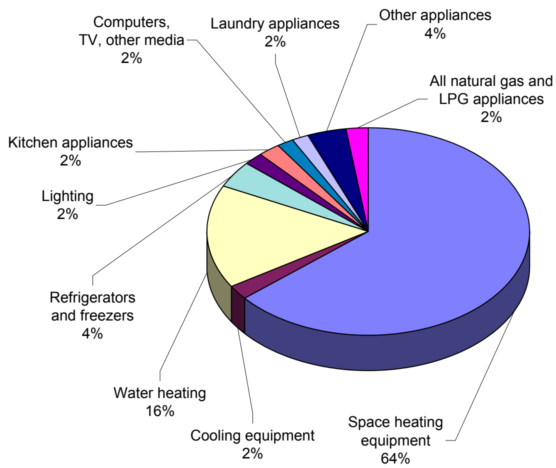
Transportation consumes the largest share of New England's energy, accounting for 41 percent of end-use energy consumption in the region in 2004.[2] National estimates of how energy is consumed in transportation enable us to estimate the amount of energy that is used in New England for various transportation purposes. Based on those estimates, about 60 percent of New England's transportation energy is used to power personal vehicles (as well as light-duty vehicles used for commercial purposes). About a quarter of the energy used for transportation is consumed in the movement of freight, with the remainder used for intercity transport by rail, bus, and air; transit vehicles; and natural gas pipeline fuel. (See Figure 2.)

Figure 2. Estimated Transportation Energy Use in New England by Function, 2004[3]



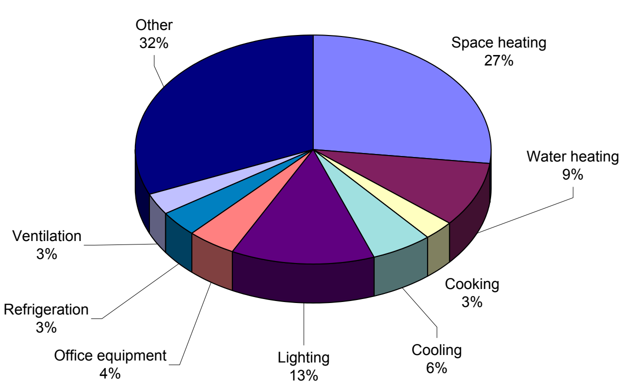
Residential energy use accounts for 28 percent of the region's energy consumption. Based on regional estimates of residential energy consumption for the Northeast region, about 60 percent of residential energy is used to provide heat for New England's homes. Another 16 percent is used to provide hot water. Appliances, ranging from refrigerators to home electronics, account for most of the rest of our residential energy use. (See Figure 3.) (Note that while Figure 3 and the other end-use energy charts in this section include electricity consumed in homes, businesses and industry, they do not include energy "lost" in the production and delivery of that electricity.)

Figure 3. Estimated New England Residential Energy Use by Function, 2004



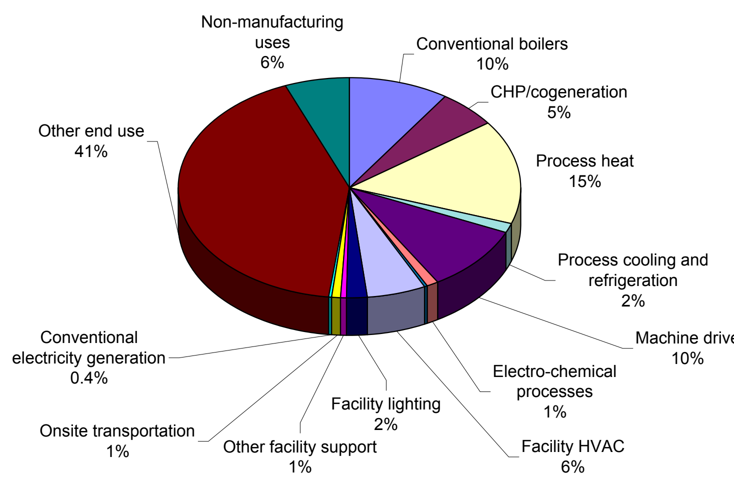
Commercial establishments, ranging from institutions like hospitals and schools to shopping centers, office buildings and big-box stores, consume 16 percent of the region's energy. Based on federal estimates of energy consumption in commercial buildings nationwide, more than one quarter of commercial energy is used to heat buildings, with lighting (13 percent), water heating (9 percent), air conditioning (6 percent) and office equipment (4 percent) also responsible for significant shares of energy consumption. (See Figure 4.) Since these estimates are based on national figures, it is possible that energy consumption for space cooling may be somewhat lower, and consumption for space heating somewhat higher in New England.

Figure 4. Estimated New England Commercial Energy Use by Function, 2004



Industry accounts for the remainder of New England's end-use energy consumption, about 15 percent. Federal energy consumption surveys provide an incomplete picture of energy consumption within the industrial sector, which is defined by the Department of Energy as including not only manufacturing, but also construction, agriculture, forestry and mining. Based on regional data for manufacturing energy consumption in the Northeast and rough national estimates for energy consumption in construction and agriculture, the creation of process heat (15 percent of industrial energy use) appears to consume more energy than any other identifiable purpose within the industrial sector. The operation of industrial machinery and the production of steam and hot water in boilers each consume about 10 percent of the energy used in industry. "Non-manufacturing uses," which include the consumption of diesel fuel by construction equipment and agricultural energy consumption, account for approximately 6 percent of industrial sector energy use. (See Figure 5.) The largest category of energy use in industry, however, as shown in Figure 5, is "unknown," illustrating the lack of complete, solid data on industrial energy use in New England.

Figure 5. Estimated New England Industrial Energy Consumption by Function, 2004



The data on how energy is consumed by end users in New England are far from perfect, but they do give us an idea of where we should start looking for energy savings. Personal transportation, for example, consumes nearly one-third of the region's energy (most of

Table 1. Top 15 Estimated End Uses of Energy in New England

Sector	End Use	Energy Consumption (billion BTU)	Percent of Total Consumption
Transportation	Personal Vehicles	821,709	30.1%
Residential	Space Heating	491,691	18.0%
Industrial	All Other End Uses	180,423	6.6%
Transportation	Freight	178,974	6.6%
Commercial	Other/Unspecified	140,747	5.2%
Residential	Water Heating	125,925	4.6%
Commercial	Space Heating	120,729	4.4%
Residential	All Appliances	89,493	3.3%
Transportation	Intercity	64,428	2.4%
Industrial	Process Heat	62,929	2.3%
Commercial	Lighting	58,579	2.1%
Commercial	Water Heating	41,185	1.5%
Industrial	Machine Drive	39,845	1.5%

it in the form of oil), and thus would be a prime target for efforts to reduce our energy consumption. Production of heat for residential and commercial buildings, freight transportation, and water heating in residential and commercial buildings also present prime opportunities for energy savings. (See Table 1.)

Electric generators represent a special category of energy users. While the electricity that is consumed in homes, business and industry is included in the energy-use figures presented above, electric generators consume large amounts of fossil and nuclear energy that is "lost" in the production and delivery of that power. For every unit of electrical energy used in a home or business in New England, two to three units of fossil fuel energy are consumed in a power plant to make that electricity. If electric generators are considered separately, they account for about 35 percent of the region's energy use – more than any other sector except the transportation sector – with nuclear energy accounting for 30 percent of that energy, natural gas 29 percent, coal about 16 percent, oil 10 percent, and waste, hydroelectric power and wood making small but significant contributions.[4] (See Figure 6.)

Where New England Gets its Energy

New England is nearly devoid of native fossil fuel resources. Virtually all of the oil, natural gas and coal we consume in the region (along with the uranium used in nuclear power plants) comes from elsewhere – either other regions of the United States or other countries.

More than half of the total energy we consume in New England is in the form of oil. Natural gas, which provides nearly a quarter of our energy, and coal, which provides about 6 percent, are the other major fossil fuels on which we rely in New England. (See Figure 7.) New England's production of these three fuels is so miniscule that it is not even tracked by the U.S. Department of Energy.

New England's native sources of energy, including wood, hydroelectric power, and (one might argue) waste, contribute only about 10 percent of the energy we consume in the region. Thus, New England can be said to import more than 90 percent of our energy from outside the region. Put another way, if New England relied solely on native sources of energy that we use today, our homes would be dark, our streets empty of cars, and our businesses shut down for all but 2 hours and 15 minutes out of every day.

Figure 6. Estimated New England Electric Generator Energy Consumption by Fuel, 2004

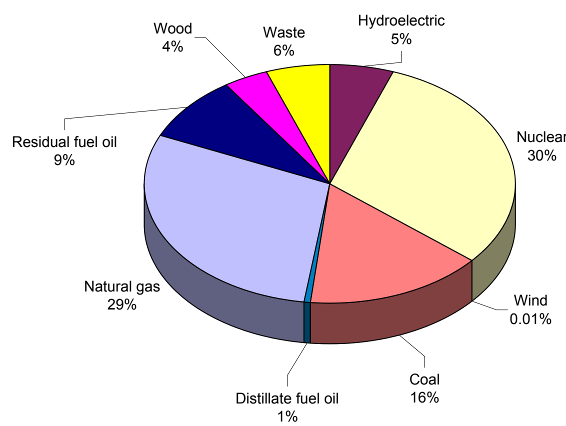
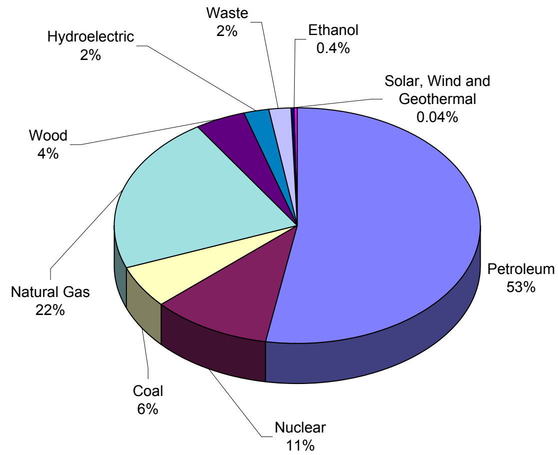


Figure 7. Energy Use in New England by Energy Source, 2004



New England Faces an Uncertain Energy Future

New England's reliance on other regions and other countries for our basic energy needs is one facet of our energy crisis. But the crisis goes deeper than that – encompassing the questionable long-term availability of fossil fuels, our exposure to volatile and rising energy prices, the contribution of energy use to environmental problems like global warming, the soundness of the infrastructure that delivers energy to our homes and businesses, and the health and safety of the public.

Declining Fossil Fuel Supplies

New England's economy is built on access to reliable, affordable supplies of oil and natural gas, among other energy sources. Yet, the long-term availability of those resources is increasingly in doubt.

Oil

There are growing concerns about the long-term viability of global petroleum supplies, with some analysts projecting that global oil production will peak at some point in the next few decades, leaving production unable to satisfy demand and triggering price spikes and economic instability.[5]

The problem is not that the world will someday run out of oil. Rather, it is that oil will someday become too hard to come by, and therefore too expensive, to reliably provide all the services for which we depend on oil today. There are varying theories about exactly when world oil production might peak, and whether the peak might come within years or within decades. (America's domestic production peaked in the early 1970s.) But warning signs are looming on the horizon.

Discoveries of new oil peaked during the 1960s and new discoveries have lagged behind production since the late 1980s.[6] In other words, every year the world consumes much more oil than we discover. And while technological advances have made it possible to squeeze more oil from existing fields — and to produce oil from non-conventional resources such as oil sands — extraction of oil will continue to become more difficult and expensive over time.

At the same time that global oil supplies are increasingly strained, world oil consumption is on the rise. Global oil consumption increased by 18 percent between 1995 and 2004.[7] And while much of the growth in oil consumption is in nations such as China, the United States remains the world's largest consumer of oil, accounting for 24 percent of world consumption in 2006.[8]

Even if production of oil worldwide does not peak in the near future, we will increasingly be forced to rely on nations in the Middle East for critical oil supplies. Middle Eastern nations such as Saudi Arabia, Iran and Iraq claim to have petroleum reserves that would last 75 years or more at current rates of production. On the other hand, at least 50 oil-producing nations are already past their production peaks.[9]

Continued dependence on oil will, at some point, leave New England competing with the rest of the world for increasingly scarce supplies and force us to pay higher prices. And it will certainly leave the region dependent on foreign nations – many of them unstable or hostile to the United States – for that oil.

Natural Gas

In the 1990s, New England, like many other regions of the country, increased its use of natural gas, particularly for the generation of electricity. Many saw natural gas as an ideal fuel for generating electricity because it produces fewer pollutant emissions than coal or oil and can be used in more efficient combined cycle power plants. As a result of these advantages, virtually all of the power plants built in the region within the last decade have been fueled with natural gas.[10]

Today, in part as a result of that expansion in natural gas generation capacity, more than one-quarter of the region's total energy comes from natural gas. Between 1990 and 2004, the region's consumption of natural gas increased by 73 percent, and our consumption of natural gas for generating electricity quadrupled.[11] Unfortunately, the expansion of natural gas-fired electricity generators has come at a time when the long-term supply picture for natural gas looks increasingly cloudy.

Domestic production of natural gas may be on the verge of hitting its all-time peak (if it hasn't already), just as U.S. oil production peaked in the early 1970s. Since hitting a 22-year high in 2001, U.S. natural gas production has dropped by 6 percent, even amid a massive increase in drilling.[12] In 2004, the number of producing natural gas wells in the United States hit an all-time high, yet total production decreased from the year before due to declining well productivity. The average natural gas well operating in 2004 produced 30 percent less gas per day than the average well in operation in 1989, despite improvements in extraction technology.[13]

Figure 8. New England Average Gasoline Prices (all grades average)[15]

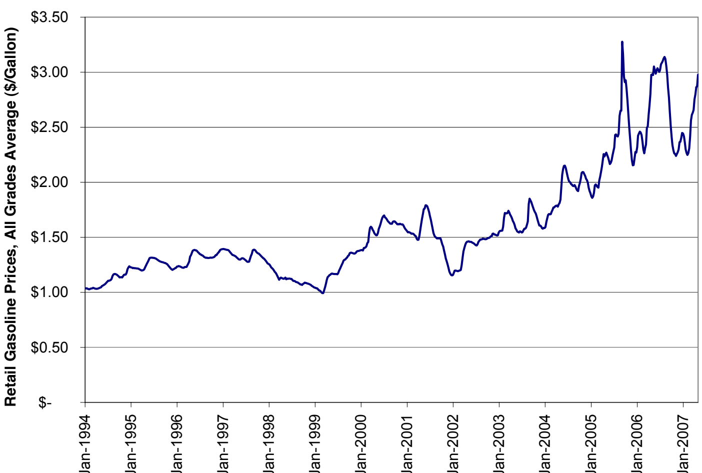
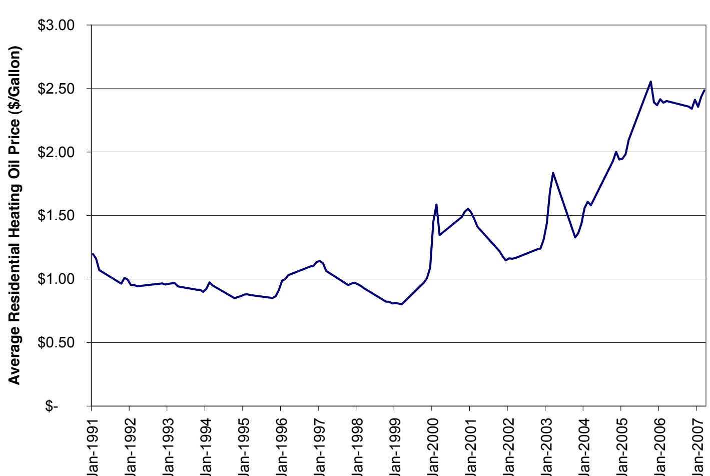


Figure 9. New England Residential Heating Oil Prices[17]



New England, like the rest of the country, has mainly received its natural gas via pipeline from other parts of the United States and from Canada, but that is about to change. There are currently several proposals for the construction of new liquefied natural gas (LNG) terminals in New England, in addition to the existing terminal in Everett, Massachusetts.[14] Construction of these terminals would allow New England to dramatically ramp up its imports of natural gas from nations around the globe.

Increasing our reliance on foreign nations for natural gas supplies exposes the region to the same challenges and risks that have accompanied our reliance on foreign oil, leaving us vulnerable to geopolitical instability, volatile world energy markets, and potential supply disruptions. These risks will only increase over time if the trends toward greater oil and natural gas consumption in the region continue.

Responding to New England's energy crisis will require investments in infrastructure as well as changes in public policy. Staking the region's long-term energy future on oil or natural gas means wagering that those energy sources will continue to be available to us at prices we can afford for the long haul. Such a wager appears to be a bad bet for oil, and only a marginally better one for natural gas, which will be readily available only at the cost of increasing dependence on imports.

Rising Energy Prices

New England's economy has been whipsawed in recent years by volatile, and generally higher, prices for gasoline, heating oil, natural gas and electricity.

Gasoline

Gasoline prices have been at or near historic highs (in nominal terms) in New England for much of the past several years, surging above the $3 per gallon mark during portions of 2005, 2006 and 2007. (See Figure

8.) Gasoline prices are a far cry from the $1.30 or less per gallon that New England drivers paid for gasoline as recently as five years ago. While higher gasoline prices have taken a toll on the finances of New England families, diesel fuel prices have roughly doubled over the last five years, making it more expensive for New England businesses to ship goods via truck.

Heating Oil

Rising oil prices have also taken a toll on New England homeowners. New England and the Northeast in general depend on oil for home heating more than any other region of the country. New England homeowners paid approximately twice as much for heating oil in the winter of 2005-06 as they did in the winter of 2001-02.[16] (See Figure 9.)

Natural Gas

Natural gas is an important fuel for household, business and industrial use, as well as for the generation of electricity in New England. Natural gas prices have been extraordinarily volatile over the past six years. Citygate (wholesale) prices in Connecticut, for example, have varied by a multiple of four over the past six years, with natural gas selling as low as $3.55 per thousand cubic feet (mcf) and as high as $15.14/mcf.[18] (See Figure 10.) These variations in price are eventually passed on to residential, commercial and industrial consumers, and indirectly to consumers purchasing electricity.

Electricity

Electricity prices are determined by a variety of factors. In states like Vermont, electricity remains regulated and prices set based on the cost of producing or purchasing power. By contrast, in states like Massachusetts and Maine, power is purchased on wholesale markets, with the cost passed on to consumers. Rising natural gas prices, among other factors, have caused electricity prices to skyrocket in New England over the past two years.[20] (See Figure 11.) And with natural gas-fired power plants now setting the price of power on New England's wholesale market most of the time, the volatility of natural gas prices is being passed through to New England residential, commercial and industrial consumers.[21]

Figure 10. Natural Gas Citygate Prices, Connecticut[19]

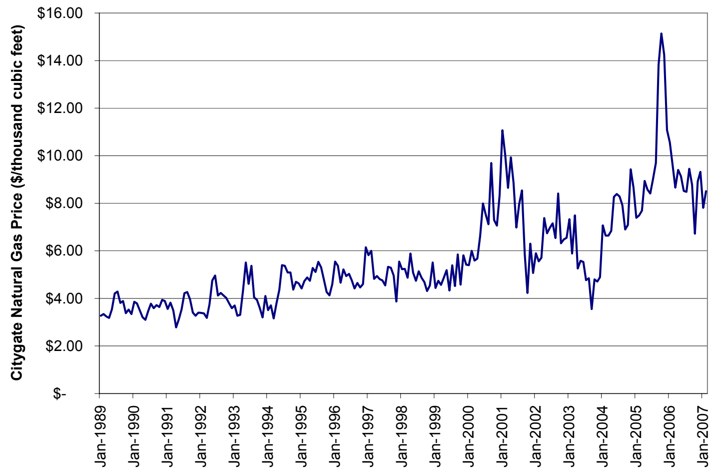
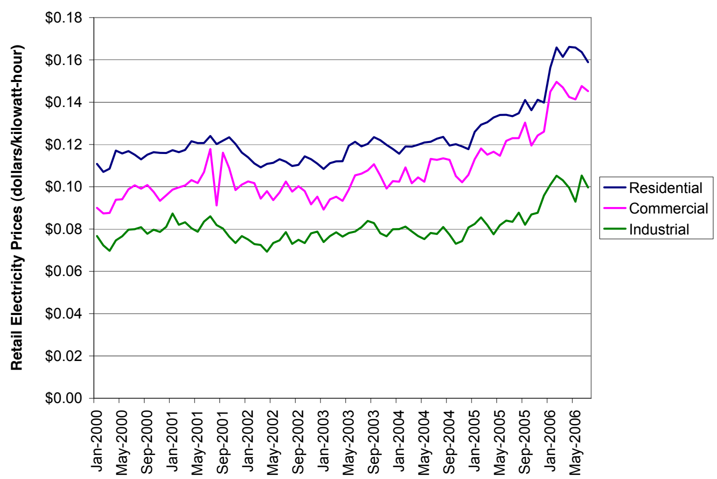


Figure 11. Average Retail Electricity Price, New England[22]



Future Price Trends

The underlying factors that have caused recent energy price spikes – including rising demand and tightening energy supplies – still exist. All it would take is another natural disaster like Hurricane Katrina, the threat of war in a key part of the world, an unusually cold winter or hot summer, or the intensification of current supply and demand trends to cause prices to skyrocket yet again. New England's current reliance on natural gas and oil and the structure of our electricity system leave us extremely vulnerable to these kinds of disruptions, which may become more common and more dramatic in the years to come.

Global Warming and Environmental Health

Even if New England could count on access to ample, cheap supplies of fossil fuels, we would still need to adjust our energy system to deal with another impending crisis: global warming.

New England has much to lose from global warming. A recent expert assessment found that if emissions of global warming gases worldwide continue to rise, summertime temperatures in Massachusetts and much of New Hampshire would resemble those of today's Carolinas by the end of the century.[23] Boston could experience more than 60 days each year above 90 degrees; snow cover region-wide could decrease; sea-level rise could threaten, or even submerge, many coastal communities; and the tree species responsible for the region's vibrant fall foliage displays could migrate northward.[24]

All fossil fuel use contributes to global warming, but the burning of coal is particularly damaging. Coal produces more carbon dioxide – the leading greenhouse gas – per unit of energy than oil or natural gas. In New England, for example, coal accounted for about 6 percent of our total energy consumption in 2004.[25] But, in that same year coal combustion accounted for 10 percent of New England's emissions of carbon dioxide, the leading global warming pollutant.[26]

Coal combustion also emits a wide range of other health-threatening pollutants, producing hazardous particulate matter that has been linked to premature death, as well as mercury, a neurological toxin that contaminates fish and poses special dangers to children.[27] New technologies, such as coal gasification plants, can reduce these health-threatening emissions sharply, but no technology currently exists that can reduce emissions of global warming pollutants from coal-fired power plants. (Carbon capture and storage, which may hold future hope for reducing global warming emissions from power plants, is likely to be very expensive and has yet to be demonstrated on the scale at which it would have to be used in order to significantly reduce the global warming impact of coal-fired generation.)

For all of these reasons, New England states have worked to limit pollution from coal-fired power plants. But the temptation to turn to coal could become strong, just as it has nationwide, where approximately 150 new coal-fired power plants are currently in the planning stages.[28] Unlike petroleum and natural gas, coal is a relatively abundant, relatively inexpensive, domestically produced fossil fuel.

Given the problems posed by our dependence on natural gas (and nuclear power, which we will address below) for electricity, some might be tempted to think that expanding coal-fired power generation would be the solution to New England's energy problems. But the environmental and public health problems posed by coal-fired power generation – and particularly its contribution to global warming – should make coal a non-starter.

Infrastructure Problems

Recent discussions of New England's energy challenges have often focused on the need for more energy infrastructure in the region – more power plants to generate electricity, more electricity transmission lines and natural gas pipelines to bring energy into the region from elsewhere, and more liquefied natural gas terminals on our shores.

The gravest warnings have come from operators of the region's electricity grid. ISO-New England has warned that the supply of electricity could prove inadequate to meet demand within the next several years.[29] Natural gas infrastructure is also a concern. During a severe cold snap in early 2004, the region teetered on the brink of not having enough natural gas to both heat homes and run power plants, a situation that could have left some New Englanders in the dark.[30]

Clearly, New England needs to make investments in its energy infrastructure in order to head off these looming problems, and these investments are likely to be very costly. But which investments should take priority? Is it more economically advantageous for the region to build a wave of new power plants or to find ways to use less energy? If we do need new power plants, is it better for the region to invest in wind turbines, solar panels, coal or natural gas-fired power plants, nuclear power plants or some combination of all of the above? Should we incur the financial and public safety costs (see below) of liquefied natural gas terminals on our shores, or should we find ways to reduce our dependence on a fuel that has proven to be very volatile in price and will increasingly come from abroad?

These are difficult questions for the region to answer. To date, however, the region's response has been haphazard. Several states have committed to an expansion in renewable energy production, yet one of the largest renewable energy facilities proposed in the region – the Cape Wind project off Massachusetts – has been held up by political disputes. And the region's planning for its transportation and electricity systems continues to assume increased demand for those services – thus justifying further infrastructure expansion – even though demand reduction and demand management are widely viewed as more cost-effective solutions to the problem.

In short, New England's energy infrastructure is generally viewed as inadequate for our future needs. But the real danger for the region is that no coherent, thoughtful response has yet emerged that would both enhance New England's economy over the long term while addressing the real environmental, public health and safety problems caused by our continued reliance on fossil fuels and nuclear power. In addition, too little effort has been made to investigate ways that we can reduce the need for massive infrastructure investments through reduction in demand for energy, achieved through improved energy efficiency and strategic development of renewable energy resources.

Public Health and Safety

New England's energy system also has potential impacts on the health and safety of the public. Ideally, our energy system should pose as few such threats as possible.

Importation of liquefied natural gas (LNG), for example, poses a threat to communities located near LNG facilities or along LNG shipping routes. A 2004 report by researchers with Sandia National Laboratories estimated that a large-scale breach in an LNG tanker (such as might be created by a terrorist attack), if ignited, could cause major injuries and significant damage to property within about one-third of a mile of the tanker, as well as lesser injuries and property damage within a radius of about one mile.[31] Should LNG facilities be located in or near population centers, the risk would be great: in Boston, for example, hundreds of thousands of people live and work within one mile of an LNG terminal and the shipping lanes used by LNG tankers.

Nuclear power plants are another example of a potentially dangerous source of energy. The American nuclear industry has experienced a series of "near misses" over time, including the partial meltdown of the Fermi nuclear reactor near Detroit in the 1960s, the Three Mile Island accident in 1979, and the discovery in 2002 of a football-sized cavity in the reactor vessel head of the Davis-Besse nuclear reactor in Ohio, a flaw that could have eventually led to leakage of radioactive coolant from around the reactor core and possibly a meltdown.[32]

Spent nuclear fuel also poses a potential danger. Nearly all U.S. nuclear reactors store waste on site in water-filled pools at densities approaching those in reactor cores. Should coolant from spent-fuel pools be lost, the fuel could ignite, spreading highly radioactive compounds across a large area. In 2005, the National Academy of Sciences (NAS) warned that "[s]pent nuclear fuel stored in pools at some of the nation's 103 operating commercial nuclear reactors may be at risk from terrorist attacks," and recommended a series of actions to reduce the danger.[33] One study estimated that a loss of coolant accident that resulted in a spent-fuel pool catching fire could result in between 2,000 and 6,000 additional deaths from cancer.[34]

New England's nuclear reactors have not been immune to problems. The region's nuclear reactors have been repeated targets of enforcement actions by the U.S. Nuclear Regulatory Commission, an agency that does not have a reputation for vigorous enforcement.[35] In 2005, for instance, regulators fined the owner of the Pilgrim nuclear power plant in Massachusetts after a control room supervisor was found asleep on the job and the company's managers failed to take required actions in response.[36] Also in 2005, the owners of the Vermont Yankee nuclear power plant were issued notices of violation by the NRC for failing to keep adequate track of spent nuclear fuel rods at the facility.[37]

Nuclear power plants have other problems that are unrelated to health and safety. In particular, they are expensive. The region's historic investment in nuclear power has been a disaster for electricity consumers, helping to saddle New England ratepayers with electricity rates well above the national average.[38]

Other sources of energy, most notably coal, pose serious public health and safety problems as well due to pollution from power plant smokestacks. And consumption of all fossil fuels contributes to global warming, which itself poses severe threats to public health. The particular public health and safety concerns posed by LNG and nuclear power demand that we minimize our reliance on those energy sources in New England as well.

Summary

New England faces a severe and seemingly intractable series of energy-related problems. Prices are rising. Our energy infrastructure is strained. Our use of energy contributes to a host of environmental and public health problems, not the least of which is global warming. And each of the traditional alternatives – coal, natural gas, oil and nuclear power – is problematic.

Is another path possible – one that solves New England's energy problems without creating additional problems for our economy or our environment?

The answer is yes. By using today's technologies to bolster the efficiency of New England's economy and aggressively develop renewable sources of energy, the region can begin to wean itself off of fossil fuels and reduce its contribution to global warming – and do so in such a way as to bolster the long-term viability of the region's economy.

New England may not have fossil fuel resources, but we do have the power of wind, sun, crops and water to provide a significant share of our energy needs. We also have the tools to use energy more wisely and the intellectual capacity to drive innovative solutions to our energy problems.

Solving New England's Energy Crisis: What's Possible Now

New England's renewable energy and energy efficiency resources can go a long way toward meeting the region's energy needs for the future, while also reducing the region's emissions of global warming pollution.

The analysis that follows seeks to answer a simple question: how much energy could New England save – and how much global warming pollution could we reduce – if we used the technological tools available *today* to use energy more efficiently and produce renewable energy here in the region?

This analysis differs from other energy analyses conducted in the region in several respects. First, we sought to evaluate potential energy savings by end use, focusing first on those uses that comprise the largest share of New England's energy consumption. The goal is to show, in practical terms, how specific changes in the way we use energy in New England can make a significant difference in our energy consumption profile.

Second, we looked only at technologies and practices that are feasible today. Thus, we excluded technologies (like ethanol from plant wastes and energy crops, "plug-in" hybrid vehicles, large expansions of the region's rail and transit systems, or a mechanism for storing electricity generated from the wind or sun) that could make a significant contribution to New England's energy needs within the next couple of decades, but cannot do so immediately.

Finally, we based our energy savings and global warming emission reduction estimates on the assumption that all of these improvements were to be achieved immediately. Obviously, that is not possible. But the energy savings estimates in this report show that there is a vast energy efficiency resource in New England that can play a major role in addressing our energy challenges. Policy-makers in New England should seek to tap these resources as thoroughly and quickly as possible.

(For more detail on the specific methods and sources used to arrive at these estimates, please see the "Methodology" section at the end of this report.)

Saving Energy in Transportation

Automobiles

More than one-fifth of all the energy consumed in New England goes to fuel cars, pick-up trucks, SUVs and other light-duty vehicles that run on gasoline. To address New England's energy challenges, curb our global warming emissions, and reduce our dependence on foreign oil, we need to reduce our use of oil in transportation. There are many ways to do so, with the most effective approaches combining efforts to reduce vehicle travel (through smarter land-use planning and provision of better transit and more transportation choices) with efforts to make vehicles more fuel efficient. While there are many short-term measures that can be taken to reduce vehicle travel – such as increased support for carpools and vanpools and reduced transit fares – we focus in this analysis on improving vehicle fuel economy.

Here there is good news and bad news. The bad news is that New Englanders consume more gasoline to fuel our cars and trucks than ever before. Between 1990 and 2004, the consumption of motor gasoline for transportation in the region jumped by 25 percent.[39] Increases in vehicle travel, coupled with stagnating fuel economy and the increasing popularity of less fuel-efficient vehicles like SUVs, have led us to consume more gasoline, thus increasing our emissions of global warming pollutants and our reliance on foreign oil. The good news, however, is that there are many technologies that can greatly improve the fuel economy of our cars, trucks and SUVs.

In 2002, the National Academy of Sciences (NAS) conducted a thorough review of fuel economy standards for automobiles, examining the potential for a variety of technologies to improve fuel economy. According a Union of Concerned Scientists analysis of the results of the NAS study, the automobile fleet could achieve average fuel economy of 33 miles per gallon (MPG) within a decade and 37 MPG in an additional five years.[40] Notably, the NAS study did not include consideration of hybrid-electric vehicles, which have become increasingly popular in recent years.

The technologies that can achieve these fuel economy improvements are neither new nor exotic. In fact, most are included in at least a small number of vehicles produced today. They include:

- **Efficient engines**, using technologies like variable valve timing, cylinder deactivation (in which engine cylinders are shut off when not needed, such as at highway cruising speeds), turbocharging, and the use of improved lubricants.

- **Efficient transmissions**, including 5- and 6-speed automatic transmissions and continuously variable transmissions.

- **Improved aerodynamics and reduced rolling resistance** to reduce the amount of energy lost to friction with the air and the road.

- **Enhanced electronics**, such as 42-volt electrical systems and integrated starter generators that allow the engine to be shut off when the vehicle is stopped.[41]

Were New England's light-duty vehicle fleet to achieve a 33 MPG average fuel economy, the region's consumption of gasoline by light-duty vehicles would be slashed by 23 percent. Further significant reductions in energy use are possible in the future using hybrid-electric and other high-technology vehicles, as well as future incremental improvements in vehicle energy efficiency.

New England states do not have the ability to impose their own fuel-economy standards on cars and light trucks; only the federal government has that authority. But there are several steps New England states can take to improve vehicle fuel economy:

- Five New England states (all except New Hampshire) have adopted the Clean Cars Program, which sets standards for carbon dioxide emissions from light-duty vehicles. There are several ways that automakers can comply with the standard, but improving vehicle fuel economy is one of them.

- Financial incentives for the purchase of more fuel-efficient vehicles (coupled, perhaps, with fees for the purchase of gas-guzzlers) can also encourage automakers to offer – and consumers to buy – cars with improved fuel economy.

- Even small steps, like requiring the sale of energy efficient replacement tires, can provide significant reductions in gasoline use.

In addition, to realize energy savings from improved fuel economy, New England will need to accelerate efforts to moderate growth in vehicle travel. Encouraging and investing in alternatives to automobile travel – including transit, telecommuting, biking, and walking – as well as the adoption of land-use patterns that encourage those alternatives, could help reduce or eliminate growth in vehicle travel in the region, thus saving gasoline and reducing global warming emissions.

Heavy-Duty Trucks

Improvements are also possible in the fuel economy of the heavy-duty trucks that carry freight on New England's highways. Unlike cars and SUVs, tractor-trailers are not currently subject to any federal fuel economy standards. But like those vehicles, the fuel economy of tractor-trailers has been on the decline for the last decade.[42]

Manufacturers have the technology to make tractor-trailers far more efficient than they are today, using tools like advanced electronics, better aerodynamics and transmission and engine improvements. The American Council for an Energy-Efficient Economy (ACEEE) estimates that heavy-duty trucks could be made to be 29 percent more energy efficient as soon as 2008 and 58 percent more energy efficient by 2015.[43] ACEEE also estimates that the savings in fuel costs would more than pay for the investment in more efficient vehicles over time.[44]

Assuming that New England could achieve the 29 percent near-term improvement in fuel economy for diesel tractor-trailers, the region could achieve a 22 percent reduction in diesel fuel consumption for heavy-duty trucks, further reducing the region's dependence on foreign oil and its emissions of global warming gases.

As is the case with cars, the adoption of state-by-state fuel economy standards for heavy-duty trucks may by impractical or impossible, but states should investigate ways to encourage energy efficiency improvements among freight trucks.

In addition to reducing the fuel consumption of heavy-duty trucks, the region should also make investments in transportation infrastructure that moves freight more efficiently. Shipping freight by rail, for example, consumes about one-tenth the energy of shipping by truck.[45] New England's freight rail system is antiquated and should be updated so that it can carry a greater share of the region's freight more efficiently.

Saving Energy in Homes

New England's housing stock is old by national standards. About half of New England's homes were built prior to 1960.[46] Old heaters and appliances use more energy than newer units, and old duct systems often leak energy to the outside. Fortunately, it is possible to address these problems, often with measures that save more money than they cost over the long run.

Space Heating

Residential space heating accounts for about 18 percent of end-use energy consumption in New England.[47] The Northeast, including New England, is the only region in the country in which oil is the dominant fuel for residential heating.[48]

The average oil furnace sold today operates at about 16 percent greater efficiency than the average oil furnace bought in 1970.[49] But big gains in energy efficiency are still possible for many New England homes – especially older homes and those with older furnaces and boilers. High-efficiency furnaces and boilers are available that can reduce energy use substantially. Programmable thermostats make it easy for residents to tailor their energy use to their actual needs, for example, by lowering the temperature at times when residents aren't home. Fixing leaky ducts, adding insulation and preventing drafts can all reduce energy use significantly – often while saving consumers money.

New England has long experience with improving the energy efficiency of residential buildings through state Weatherization Assistance Programs for low-income households. A detailed analysis of Vermont's program estimated average energy savings of 19 percent for homes heated with oil, 13 percent for homes heated with natural gas, and 19 percent for homes heated with propane.[50] The U.S. Department of Energy estimates that weatherization programs reduce space heating energy use by 25 to 30 percent for treated homes in the New England states.[51]

For older homes, which tend to consume more energy than newer structures, it is likely that per-home savings are achievable that are similar to, if not greater than, those reported in the Vermont study.[52] There are several reasons why the savings achieved through low-income weatherization programs may underestimate the energy efficiency potential of New England homes overall:

- The Vermont study dates from 2001, a time when home energy costs were lower than they are today. Because weatherization assistance programs only undertake measures that are judged to be cost-effective, greater savings are likely possible today.[53]

- Low-income weatherization programs work with extremely limited budgets and thus must choose whether to deliver greater energy efficiency improvements for fewer homes or to spread energy efficiency benefits over as many homes as possible. Thus, the amount of cost-effective energy savings possible at any one home may be greater than that actually realized by the program.

- Many low-income residents turn down the thermostat in order to save money during the winter. Improving the energy efficiency of their homes can enable them to keep their homes warmer and more comfortable, but at the expense of cutting into the energy savings they achieve through weatherization.

Using the Vermont experience as a very conservative guide to the energy efficiency improvements that are possible in New England overall, the amount of energy savings that can be achieved is significant. By adopting similar weatherization measures in all homes, New England could cut residential use of fuel oil by more than 15 percent, natural gas by 15 percent, and propane by 12 percent.[54]

These savings reflect only those possible with technologies currently widely used in New England. Other technologies can deliver even greater savings in residential heating energy consumption. Geothermal heat pumps, for example, use the relatively stable temperatures found just below the earth's surface to help provide heat to homes in the winter and cooling in the summer. Passive solar design, which uses building design to maximize the sun's role in heating and lighting buildings, can also reduce the need for fossil fuels.

Renewable energy and energy efficiency can be paired in "zero-energy" homes, which dramatically reduce the need for fossil fuel purchases. Because our analysis focuses exclusively on New England's existing housing stock, we do not factor in potential energy savings from zero-energy or other extremely energy efficient new homes. But improving the energy efficiency of new homes should also be an important part of New England's energy future.

Among the many public policies that can reduce energy consumption for space heating are the following:

- Expansion of the Weatherization Assistance Program, which improves insulation and weather sealing and provides other energy efficiency services to low-income residents. A study in 2005 estimated that the social benefits to the program were 2.5 times as large as the cost.[55]
- Improved furnace efficiency standards in states.[56]
- Better enforcement of building codes that cut energy use. Existing building codes are often not enforced, and could be upgraded in many places to save more energy and money. Less than half of new buildings in Massachusetts meet the energy codes, according to a recent study.[57]
- Requiring evaluations of home energy efficiency prior to home sales and making the information available to prospective home purchasers. Consumers have long benefited from tools that enable them to evaluate the energy efficiency of new cars and major appliances. Requiring "labeling" of homes for their energy efficiency would enable consumers to make better-informed choices and possibly make it easier for consumers to finance energy efficiency improvements through their mortgages.
- Encourage zero-energy homes, which use modern technologies to reduce their net energy usage to virtually nothing.

Water Heating

Home water heating accounts for nearly 5 percent of all on-site energy consumption in New England. As with space heating equipment, fuel oil is the most common energy source for water heating, followed by natural gas and electricity.

The simplest opportunities to improve the efficiency of water heating systems at home are replacing old units and making sure hot water pipes are properly insulated in unheated areas. Additionally, using less hot water reduces the need for fuel; efficient versions of appliances that use hot water such as clothes washers and dishwashers can significantly reduce energy consumption.

A 2000 study by five U.S. national laboratories estimated the "techno-economic" potential for energy efficiency for a range of residential, commercial and industrial energy uses. ("Techno-economic" potential includes measures that are both technologically possible as well as economically justified.) The "Five Labs" study concluded that efficiency savings of 27 percent were possible by 2010 for water heaters using electricity, 13 percent savings were feasible for natural gas water heating, and 15 percent savings were possible for water heaters using oil.[58] These savings only reflect improvements to water heaters themselves, not the additional energy savings that could be obtained through improved insulation of pipes and installation of appliances, such as high-efficiency clothes washers, that use less hot water. Thus, they represent a conservative estimate of potential energy savings.

As with space heating, using renewable energy from the sun and the earth can further reduce the need for fossil fuels for water heating. For example, solar hot water heaters use roof-mounted solar energy collectors to warm water in a home's hot water tank, reducing the need for fossil fuels by about two-thirds.[59]

Among the many public policies that can reduce energy consumption for water heating are the following:

- Tax breaks for extremely efficient water heaters such as solar hot water and geothermal heat pump systems, as well as appliances that consume less hot water.

- Expansion of the Weatherization Assistance Program, which includes installing more efficient water heaters and devices that reduce the need for energy for water heating, such as low volume shower heads.

- Improved state and national water heater efficiency standards, updated as technology improves.

Appliances, Lighting and Equipment

Household appliances, lighting and furnace fans account for about 5 percent of direct energy use in New England. Many appliances have become increasingly efficient as technologies have improved. Refrigerators, for example, have become about four times as efficient in the last three decades, and the average freezer has improved 145 percent.[60] And compact fluorescent light bulbs – which use about two-thirds less energy than incandescent bulbs – are becoming common fixtures in New England homes.

But further improvements are possible. The Five Labs study referenced earlier estimated the technical and economic potential for energy savings for a variety of appliances. For this analysis, we reviewed potential energy efficiency savings for the four highest energy-using appliances in New England homes – refrigerators, lighting, clothes dryers and freezers – plus furnace fans. Energy efficiency improvements could result in a combined 25 percent reduction in electricity use for those five categories of appliances and equipment.

Among the many public policies that can reduce energy consumption for appliances and equipment are the following:

- Stronger energy efficiency standards for major appliances.

- Tax incentives or consumer rebates for the purchase of ultra-efficient appliances.

Commercial and Industrial Energy Use

Commercial Space Heating, Cooling and Lighting

Space heating in offices and other commercial buildings in New England accounts for about 4 percent of New England's end-use energy consumption. Lighting is likely the second biggest source of energy consumption in commercial buildings, with space cooling third.

Commercial buildings hold many untapped energy efficiency opportunities. As with some residential properties, commercial builders and tenants have limited incentives to invest in energy efficiency improvements that pay off over the long haul. (For example, builders may be primarily concerned about minimizing building construction costs, while tenants may not want to make investments in energy efficiency that will outlive their occupancy.) In addition, energy costs tend to represent only a small portion of businesses' overall costs, meaning that energy-saving measures are often not a high priority for business owners.

The upside, however, is that there are many cost-effective opportunities to improve the energy efficiency of commercial buildings. Upgrading building shells, replacing inefficient furnaces and air conditioners with more efficient models, and other measures can significantly reduce energy use. The Five Labs study identified potential near-term energy savings of 14 to 27 percent for space heating and 29 to 38 percent for air conditioning in commercial buildings. Moreover, the Five Labs study did not include building shell measures (such as increased insulation) or changes in energy-consuming behavior (like turning off lights or reducing heating or cooling needs after business hours) in its assessment of energy efficiency improvements, meaning that the potential energy savings in commercial buildings could be much higher.[61]

Lighting provides another opportunity for saving energy in commercial buildings. The Five Labs study identified near-term energy saving potential of 20 percent for lighting in commercial buildings.

Among the policies that can help drive improvements in commercial energy efficiency are the following:

- Stronger energy efficiency standards for commercial heating, cooling and lighting equipment, as well as other types of equipment, updated frequently as technologies improves.

- Stronger building energy codes for commercial buildings, with increased emphasis on effective enforcement.

- Incentives or requirements for the construction of energy-efficient "green" commercial buildings, including requiring that new public-sector buildings meet stringent energy efficiency standards.

- Increased funding for energy efficiency programs designed to reduce commercial energy consumption.

Industrial Machine Drive

Machine drive is the largest identifiable source of electricity use in New England's manufacturing sector. Great energy savings are possible from improved motor technologies and practices. Improved motor technology is part of the solution, as is encouraging industries to design their manufacturing processes more efficiently. Using motors that are the appropriate size, maintaining them well, and installing variable speed motors where possible can all reduce energy demand for machine drive.

A 1998 U.S. Department of Energy analysis estimated that if industries took advantage of all cost-effective opportunities using mature technologies and practices, they could reduce electricity consumption for motor use by 11 to 18 percent.[62] These savings do not include new or improved technologies that have come onto the market since then or which may be developed in the near future. Assuming that New England industries could achieve savings in the middle of this range, the industrial sector could cut its electricity use for machine drive by approximately 14.5 percent.

Policies that can encourage industrial energy efficiency include:

- Continued upgrades in energy efficiency standards for industrial motors as technology improves.

- Expanded support for programs to improve the energy efficiency of industrial processes.

Combined Heat and Power

Generation of electricity at central power plants produces tremendous amounts of waste heat – heat that could be captured and used to heat homes and businesses or run industrial processes. Combined heat and power (CHP) combines electricity generation with the provision of useful heat, achieving great improvements in energy efficiency.

Industrial process heat is the biggest use of energy in the industrial sector and consumes approximately 3 percent of all New England energy. CHP can make a contribution to saving energy in commercial buildings and large residential structures. While CHP is not appropriate for all situations where process heat is needed, there are many more places it could still be used in New England. One estimate puts the technical potential for CHP in New England at 4,913 megawatts (MW), more than 10 percent of total electricity generation capacity in the region today.[63] This estimate of technical potential is likely conservative; a more recent analysis of CHP potential in Massachusetts estimated the technical potential within that state alone at 4,751 MW.[64]

Not all technically feasible CHP opportunities will be cost effective, however. The cost-effectiveness of CHP depends in large part on how it is treated by utilities. Many utilities in New England and elsewhere have historically been hostile toward CHP, imposing high standby power fees and other barriers that erode the practicality and cost-effectiveness of CHP. Reducing those barriers would allow the region to move closer to achieving the technical potential of CHP.

Assuming that the region could achieve even half of its full technical potential for CHP, commercial and industrial facilities in New England could produce as much as 13,500 gigawatt-hours of electricity annually, or about 10 percent of what the region consumes in a year.[65]

The most important step the New England states could take to promote CHP is the removal of remaining bureaucratic and financial barriers to CHP implementation. Targeted incentive programs for CHP use could also help spur the market for this energy-efficient technology. New England states should also ensure that CHP systems include state-of-the-art emission controls and meet minimum energy efficiency standards.

Summary of Energy Saving Measures

In 2004, New England used 2.7 quadrillion BTUs of energy to heat and light our homes and offices, power our industries, and fuel our vehicles. (This doesn't include the energy that is consumed to make electricity in the region, which we will address in the next section.) By implementing the technologically feasible, cost-competitive energy efficiency measures described above, New England could shave its use of energy in homes, business, industry and transportation by 12 percent. (See Figure 12.)

While a 12 percent reduction in energy use would be significant, it represents just the tip of the iceberg of what is achievable.

First, these savings only reflect energy efficiency potential for New England's largest sources of energy consumption – further reductions in energy use are possible for the myriad other sources of energy consumption in New England. Second, it reflects only savings that are both technologically feasible and likely to be economical *today* – it does not reflect the potential for further technological advances or the fact that many energy efficiency improvements are likely to be cost-effective in the current atmosphere of high energy prices. In addition, for every energy-saving measure included in this analysis, there is one or more that are also attainable, but for which the quantification of costs and benefits is not as solid. (See Table 2.) Finally, it does not include savings due to voluntary conservation or possible broader changes in how we use energy in the region.

Figure 12. Site Energy Consumption in New England With and Without Energy Saving Measures

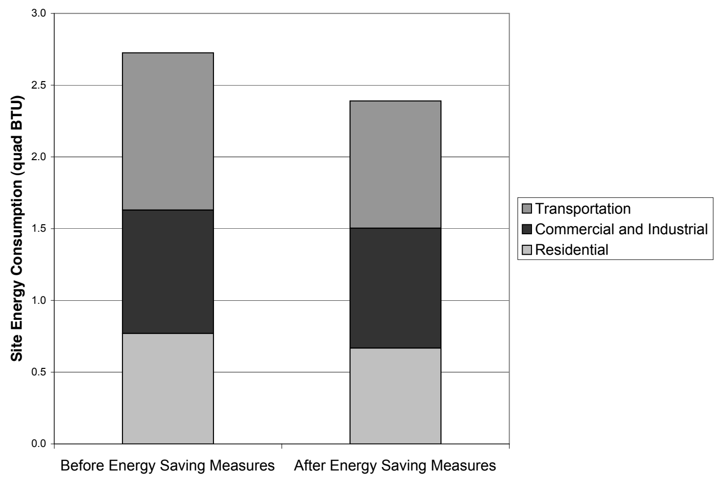


Table 2. Energy Saving Measures Included in this Analysis and Other Potential Measures

End Use	Energy Saving Measures Included	Energy Saving Measures Not Included
Transportation - personal vehicles	Vehicle fuel economy	Increased use of transit and other transportation alternatives
Transportation - freight	Heavy-duty truck fuel economy	Shifting freight to rail
Residential space heating	Home weatherization (including limited furnace replacement)	Geothermal heat pumps
Residential water heating	Water heater efficiency	Solar water heating
Commercial space heating and cooling	Equipment efficiency improvements	Building shell improvements, reducing heating/cooling loads during non-business hours
Commercial lighting	Lighting efficiency improvements	Daylighting, turning off lights during non-business hours
Industrial energy efficiency	Motor efficiency improvements	Improved thermal management

In addition, it is important to note that slightly more than one-quarter of the energy savings are in the form of avoided electricity consumption. Because it takes two to three units of energy at a power plant to produce one unit of electricity in a home or business, the reductions in electricity consumption above will leverage greater fossil fuel savings at power plants. We will discuss this issue in greater detail below.

Clean Electricity

Achieving a clean energy future for New England involves more than simply reducing our energy usage. We also need to find ways to use clean, locally produced energy to replace the polluting fossil fuels we currently import from other states and countries.

The good news is that there are ample opportunities to generate clean, renewable electricity here in New England. In this report, we focus on three of the most promising opportunities: wind power (both on- and offshore), solar power, and biomass energy.

Wind

New England is well endowed with wind resources capable of providing a significant share of our energy. Historically, most public attention has been focused on the region's on-shore wind resources, but a potentially even greater resource lies off of the region's coastlines.

According to the National Renewable Energy Laboratory (NREL), New England's offshore areas have the potential for as much as 220 gigawatts (GW) of electricity production, even when assuming that two-thirds of near shore (5 to 20 nautical miles offshore) areas and one-third of far offshore areas (20-50 nautical miles) are kept off-limits for environmental, recreational, commercial or other reasons. To put that figure in perspective, New England's total electric generating capacity from all sources is 32 GW – meaning that our total offshore wind resource, in terms of generating capacity, is nearly seven times larger than all our current power plants combined.[66]

Not all of this resource is available to us today, however. The technology currently does not exist to generate wind in offshore locations with water depths of greater than 20 meters and development of wind resources in far offshore waters is likely to be expensive.[67] Yet, significant wind resources do exist closer to shore and in shallower waters. Of New England's offshore wind resources, 9.9 GW of the generating potential is less than 20 nautical miles from shore and in waters less than 30 meters deep.[68] That is only a small fraction of the total offshore resource, but it is enough to make a large contribution to New England's energy needs. New England's inland regions also have significant wind potential – particularly on the windy coastlines of Cape Cod and parts of Maine and on ridgelines in western Massachusetts, Vermont, New Hampshire and northern Maine. The American Wind Energy Association estimates that the six New England states have nearly 11 average gigawatts of wind energy generating potential in areas with winds of Class 3 or greater.[69] (The wind resource is divided into seven classes. Areas with Class 4 winds and higher are currently suitable for utility-scale wind development, but technology improvements could make Class 3 wind resources competitive in the near future.) Were that potential to be tapped, New England could generate more than 70 percent of its electricity from onshore wind power.[70]

But while the region's wind resource is vast, taking advantage of the entire resource may be impossible. Despite the exclusions for environmental protection incorporated in the above estimates, some locations will prove to be poorly suited for wind turbines due to terrain, poor access to transmission infrastructure, interactions with wildlife or other issues. In addition, because wind is an intermittent resource and there is currently no economical way to store the power supplied by the wind, utilities must ensure that wind power is balanced with other resources. However, wind energy has a long way to go in New England before it begins to push up against the limits imposed by intermittence. Denmark currently generates more than 20 percent of its power from the wind, and a variety of recent studies have shown that America's electric grid can integrate at least 15 percent wind (in terms of capacity compared to peak load) at relatively low cost.[71]

Assuming that the region can develop merely one-twelfth of its on-shore Class 3 and greater resources and one-fifth of the shallow water, nearshore (5-20 nautical miles) resources off its coast, New England could generate more than 13 million megawatt-hours of power from the wind – about 10 percent of the electricity currently generated in the region.[72]

Is such a build-out of wind power feasible in the near term? With regard to offshore resources, we assume that the region can build 1,980 MW of wind generating capacity. The two offshore wind farms now in the planning or permitting phase in Massachusetts – the 420-MW Cape Wind project and a more recent 300-MW proposed wind farm in Buzzards Bay – could account for more than one-third of that total.[73] Together, New England would need to build five offshore wind farms of the size of Cape Wind. The region's offshore wind resources are more than sufficient to support that level of development.

On-shore, this scenario would require 916 average megawatts of wind generating capacity. Assuming that the turbines would operate at an average capacity of 33 percent, the region would need to build approximately 2,800 MW of nameplate wind capacity.[74] Making the further assumption that 1.5 MW turbines are used, New England would need to build about 1,860 wind turbines to achieve that target.

While 1,860 turbines seems like a large number, it is important to put it into perspective. First, nearly 1,000 MW of onshore wind power projects are already in the planning, permitting or construction phase in New England (though half of that proposed capacity is in one project in far northern Maine). If those projects were to be completed, New England would achieve more than one-third of the wind capacity expansion envisioned here.[75] Moreover, if properly sited, the impact on New England's landscape could be minimal. Assuming that each megawatt of wind power built in New England required 6 acres of land for initial construction (similar to the land requirement of an existing Vermont wind farm, but likely a high estimate given advances in turbine technology), the construction of 1,860 turbines would require approximately 11,200 acres of land – or about 0.03 percent of the surface area of New England.[76] Only a small fraction of that land would be occupied by the turbines themselves.

Solar Power

Photovoltaics, commonly referred to as solar panels, are a significant potential source of local energy for New England, thanks to the technology's flexibility and decreasing price tag.

Contrary to the popular perception of New England as having erratic, unpleasant weather, the region is actually an excellent place for solar power. The region's technical potential for solar power production is vast. A recent study estimated that the region would have the technical capacity to generate more than 27 peak gigawatts of electricity from solar power in 2010 – equivalent to more than 80 percent of the region's current electric generating capacity.[77] And while other areas of the country receive more solar energy each year than New England, the region's solar energy potential is at its highest at the time when we need electricity the most – during hot summer days when air conditioners are in greatest use. Particularly in southern New England and especially in Rhode Island and Connecticut, the availability of solar power matches very well with utility loads.[78]

To understand why solar energy is a good fit in New England, recall that the region faces a potential electricity crunch, with proposed investments in new generators failing to keep up with projected increases in demand. The deficit is greatest during peak periods – like hot summer afternoons – and greatest in specific areas where the demand for electricity is likely to be greater at peak periods than can be satisfied with local generation or electricity brought in from elsewhere. During these periods, not only do utilities strain to keep up with demand, but the cost of power on wholesale markets also soars dramatically. Improving energy efficiency, thus lowering demand, is one way to deal with this problem. The other way is to promote local "distributed generation" resources.

Solar photovoltaics provide a unique solution to the problem. They are located close to the places where electricity is consumed and they make their greatest contribution on hot summer days when demand is high. Thus, solar PV often makes economic sense for utilities since it can avoid other, more costly investments in new power plants and transmission lines. One recent analysis estimated that each kilowatt of new solar PV capacity provides benefits of between $3,500 and $6,000, depending on whether it was installed by the consumer or by the utility.[79] In some cases, this means that installing PV actually may *save* more money than it costs.

A 2004 report estimated the potential PV market in New England in 2010 in the event of a cost "breakthrough" that reduced the cost of PV systems by more than half. While the estimate of system costs in the analysis appears to be optimistic, it did not include public or utility-based subsidies that would be reasonable given the high value of solar PV to electric system reliability. Assuming that public or utility investments could reduce the effective cost of solar power to between $3 and $3.50 per peak kilowatt of capacity, the New England states could develop 60 MW (peak) of solar PV capacity on commercial and residential structures.[80]

Such a build-out of solar would leave plenty of room for further expansion of solar power as the price of solar panels continues to decline. Achieving the 60 MW target would require installation of solar power on approximately 24,000 homes – less than half of one percent of all the homes in New England.[81] Alternatively, the goal could be reached by installing larger solar PV systems on 3,750 businesses, or 1.5 percent of all the commercial structures in New England.[82]

Biomass

New England already relies on biomass – plant-based material – for a significant share of its electricity. Most of the region's biomass generating capacity is located in Maine, where the pulp and paper industry uses waste to provide electricity to its plants and to other users.

Not all energy that is labeled "biomass" is, in fact, clean. Municipal solid waste and construction and demolition debris, among other waste products, are sometimes labeled as "biomass," even though they can produce toxic pollution and other environmental problems when burned. In addition, the region must use its biomass resources carefully so as to protect important natural areas and wildlife habitat.

Nonetheless, there are ample opportunities to use clean biomass to supplant fossil fuel use in New England. Biomass can be used to create vehicle fuels such as ethanol, to fuel industrial combined heat-and-power systems, to fuel biomass-only power plants or to co-fire coal-fired power plants, among other uses. For the sake of this analysis, we assume that the region uses half of its available, cost-competitive mill waste and forestry residues and that this biomass is used equally to offset consumption of coal, natural gas and oil for electric power generation.[83]

Summary of Clean Electricity Measures

Replacing a significant share of New England's electricity generating capacity with renewable energy is one step in a larger suite of measures that reduce fossil fuel consumption and global warming emissions from electric generators.

The first two steps were detailed earlier in this report – improving energy efficiency and replacing a large share of centrally generated electricity with highly efficient combined-heat-and-power at industrial and commercial facilities. Taken together, these two steps would shave demand for centrally generated power by about 22 percent.

The renewable energy measures described above (excluding biomass) would produce about 13 percent of the region's centrally generated electricity, assuming that the region takes advantage of its potential for energy efficiency improvements and CHP. Note that this 13 percent represents a conservative estimate of the region's near-term renewable energy potential. In the long run, the region clearly has the potential to get an even greater share of its energy from clean, renewable sources.

The energy and global warming pollution savings that would result from these efficiency and clean electricity measures depend on which current sources of electricity generation are replaced. New England draws its electricity from a mix of resources, some that emit large amounts of global warming pollution per unit of electricity produced (coal-fired power plants), some that emit less pollution (natural gas plants), and others that emit little or none (renewable and nuclear generators). The actual decision of which power plants are retired or have their production curtailed first would be based on a range of economic factors, shaped in large part by public policy decisions. A detailed analysis of how those decisions would play out in the region's electricity system is beyond the scope of this report.

Instead, we make a couple of simple assumptions about how energy-saving and renewable energy technologies will affect the region's electric grid. First, we assume that every kilowatt-hour of electricity that is generated through combined heat-and-power offsets one kilowatt-hour of natural gas-fired central utility generation. Generation from natural gas sets the price for power much of the time in the New England market and one could therefore expect that natural gas-fired generation would be among the first to be curtailed should demand for power be reduced. In addition, natural gas is likely to be a common fuel for CHP in the region. Failing to offset the increase in natural gas use from CHP with reductions in centralized natural gas-fueled generation would leave the region *more dependent* on natural gas, an outcome that is both unlikely and inadvisable.

Beyond the assumption about CHP, we assume that every unit of energy saved or renewable energy produced offsets existing non-renewable generation in proportion to the percentage of New England's electricity that is generated by that fuel. For example, if, after adjusting for CHP, renewable energy and energy efficiency reduces the need for non-renewable electricity generation by 26 percent, the production of electricity from coal and nuclear sources would be reduced by 26 percent. This assumption is obviously simplistic, but provides a rough gauge of the kinds of fossil fuel and nuclear energy savings New England could achieve through a clean energy strategy.

Given these assumptions, the energy efficiency and clean energy strategies described above would reduce nuclear power production by 26 percent, consumption of natural gas in centralized power plants by 53 percent, consumption of coal for electricity production by 36 percent, and power plant consumption of petroleum by about 26 percent.

Achieving these shifts in the electricity system would lead to dramatic reductions in global warming pollution. In 2004, the region's electric power plants released approximately 54 million metric tons of carbon dioxide ($MMTCO_2$).[84] Under the landmark Regional Greenhouse Gas Initiative (RGGI), emissions from power plants are to be reduced by 10 percent below projected 2009 levels by 2019 in a 10-state region that includes all six New England states as well as Delaware, Maryland, New Jersey and New York. Achieving the energy savings and renewable energy targets described above (and assuming that power production is offset proportionally) would reduce emissions from electric power generation in New England by about 15.8 $MMTCO_2$ or about 29 percent – going well beyond the goals of RGGI.

Policies to promote renewable energy development include:

- Strong enforcement of existing renewable electricity standards in the states that have them, increasing existing renewable electricity standards, and enacting a standard in Vermont.
- Allowing utilities to sign long-term contracts with renewable power producers, which are necessary to provide reliable financing.
- Improving net metering policies to allow consumers with solar panels and other forms of local renewable generation to receive full value for the excess power they supply to the grid.
- Providing adequate financial incentives for the installation of solar panels in recognition of the benefits they provide to the stability of the electric grid.
- Requiring utilities to engage in long-term resource procurement planning that incorporates a significant role for renewable energy.
- Developing consistent and fair rules for the siting of wind turbines and other renewable energy facilities, both on- and offshore.

Putting it All Together: The Benefits of a Clean Energy Strategy for New England

The clean energy strategy described in this report would go a long way toward resolving New England's energy crisis while at the same time reducing the region's emissions of global warming pollution.

Achieving the region's near-term potential for energy savings in homes, business and industry and the use of renewable energy for electricity generation would reduce demand for many of the fossil fuels whose supply problems and price volatility threaten the region's economy. By fully taking advantage of the region's near-term clean energy potential, New England could:

- Cut gasoline consumption by 21 percent.
- Cut diesel fuel consumption by 13 percent.
- Cut natural gas consumption by 22 percent.
- Cut nuclear power production by 26 percent.
- Cut coal consumption by 28 percent.

Overall, achieving our region's near-term clean energy potential could reduce our region's emissions of carbon dioxide – the leading global warming pollutant – from fossil fuel use by nearly 20 percent, more than enough to meet the New England governors' 2001 commitment to reduce the region's global warming emissions to 10 percent below 1990 levels by 2020.

The ancillary benefits of achieving the region's clean energy potential are significant and include:

- Reduced exposure to price volatility on oil and natural gas markets. Such volatility can be expected to increase in future years given tightening world oil supplies and declining North American natural gas production.
- Reduced need for new liquefied natural gas (LNG) terminals to bring natural gas supplies from overseas into New England. LNG terminals have been opposed by many communities for public safety reasons and expanding the region's dependence on LNG will leave us reliant on foreign nations for another important source of energy.
- Reduced pressure to keep New England's aging nuclear plants open beyond the expiration of their current operating licenses or to replace them with new nuclear plants.
- Reduced need to invest in new fossil fuel electric generating capacity. No form of new fossil fuel capacity for New England – whether natural gas, oil or coal – is ideal. Meeting the region's elec-

Figure 13. Reductions in Fossil and Nuclear Energy Use from Energy Efficiency and Renewable Energy

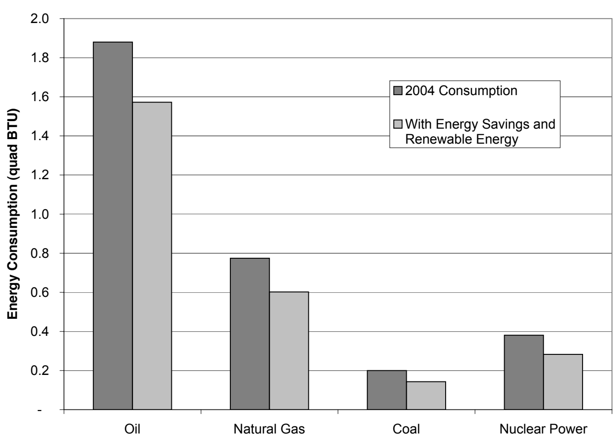
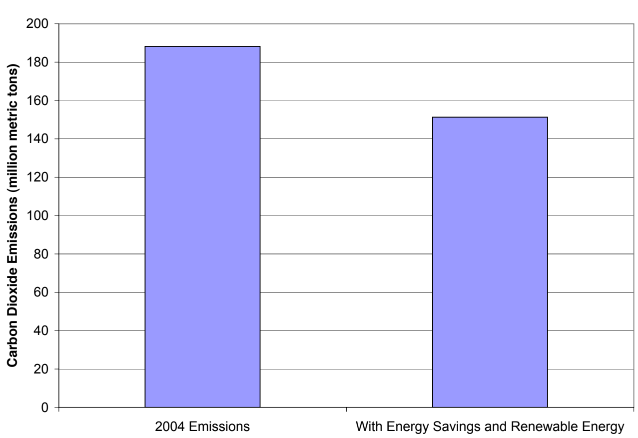


Figure 14. Carbon Dioxide Emission Reductions from Energy Efficiency and Renewable Energy Improvements[85]



tricity needs with energy efficiency, distributed resources and renewable energy can avoid demand for undesirable new power plants while enhancing electric reliability.

- Reduced pollution from power plants. Reducing electricity demand and expanding renewable resources could finally allow the region to retire some of the old oil and coal-burning units that contribute disproportionately to the region's air pollution problems.

- More jobs, greater energy security and better economic health. As noted above, New England currently imports more than 90 percent of its energy from outside the region. The money spent on that energy represents billions of dollars leaving the region every year. Increasing our reliance on homegrown resources like energy efficiency and renewable power can keep more dollars in local economies. In addition, energy efficiency and renewable energy have consistently been shown to be potent job creators. Adopting a strong clean energy strategy could play a major role in remaking New England's economy for the better.

Getting There: Achieving Our Clean Energy Potential

The energy and global warming emission savings described above represent a conservative view of the clean energy opportunities available in New England. But achieving the region's potential for clean energy will not be easy.

The scenario described here is conservative in that it includes only technologies that exist today and are cost-competitive. We already know how to make cars that go farther on a gallon of gas, to make appliances that use less energy, to winterize houses to reduce energy consumption, and to install wind turbines and solar panels to generate electricity. There are many other promising technologies and approaches that are newer – such as biofuels made from plant wastes and energy crops, "plug-in" hybrid cars, and "zero-energy" buildings – that could make a significant contribution to New England's energy security in the years and decades ahead. (Some of these technologies and practices are profiled in the "Next Steps" section below.) But the lesson of this analysis is that we don't need those technologies in order to make a significant change in New England's energy system starting today.

This analysis is also conservative in that there are many uses of energy in the region that we did not include. For example, there is a large category of energy consumption by business and industry that federal surveys do not break down into specific end uses. Other forms of transportation energy use, most notably air travel, also account for a large share of the region's energy consumption. Opportunities exist to reduce energy consumption in these areas as well.

Finally, we did not factor in voluntary efforts to save energy, which can potentially play an important role in achieving a clean energy future for New England. Voluntary conservation does not necessarily mean "shivering in the dark." Indeed, there are many opportunities to save energy that don't involve major sacrifices in individual comfort or economic productivity. For example, businesses can ensure that lights are turned off and thermostats adjusted to reduce energy consumption after business hours. They can also allow some of their workers to work from home or to work longer days on fewer days of the week in order to reduce the number of commutes. Public officials can encourage voluntary changes in energy habits; for example, during that state's energy crisis of 2000-01, California provided incentives to businesses that voluntarily reduced energy consumption by a certain amount. Similar approaches could be used in New England.

However, the clean energy scenario in this report is, in some ways, also quite optimistic. While all of the changes described here are feasible, they cannot all be achieved right away. Moreover, achieving them will require efforts of a greater scale and scope than previous clean energy efforts in the region. For example, while New England states have created programs that succeed in weatherizing a modest number of homes each year, the clean energy scenario assumes that we can weatherize *all* of the region's homes to a reasonable level of energy efficiency. Finally, achieving the changes envisioned in this scenario will require leadership from Washington, D.C., particularly on vehicle fuel economy standards, which New England states cannot establish on their own under federal law.

But, as the policy recommendations throughout this report demonstrate, there is a great deal that New England policy-makers can do to make the promise of a cleaner energy future a reality. We suggest the following immediate steps:

- New England states should cap global warming pollution – and support a similar cap at the federal level – to achieve the emission reductions that scientists believe are needed to prevent dangerous, human-caused global warming. Global warming emissions in the United States must be stabilized at current levels by the end of the decade, reduced by at least 15 to 20 percent by 2020, and be reduced by at least 80 percent by 2050.

- Each of the New England governors should set specific goals for energy savings in their states and direct state agencies to devise plans that would achieve those goals. For example, such a process might direct state transportation agencies to make investment decisions that are consistent with the goal of reducing oil consumption over time.

- The New England states should devise policies that eliminate the fiscal and bureaucratic obstacles to improved energy efficiency, clean combined heat-and-power, renewable energy development and other means of achieving a clean energy future for the region. Increasing funding for energy efficiency programs, "decoupling" utility revenues

If Clean Energy Makes So Much Sense, Why Aren't We Already Doing It?

There is an old joke in which two economists are walking down the street when one of them spies a $20 bill lying on the ground. He says to his friend, "Hey, there's a $20 bill on the ground!" To which the other economist replies, "That's impossible. If there were a $20 bill on the ground, someone would have already picked it up."

When it comes to clean energy in New England, there are $20 bills lying all around us – good opportunities to reduce our environmental impact, curb our dependence on imported energy and boost our economy, all at the same time. Yet most of these opportunities currently go unrealized. Why?

Here are 10 reasons why economically beneficial energy efficiency and renewable energy investments aren't made as often as they should be:

1. Bad incentives – The federal government spends billions of dollars annually on subsidies to the fossil fuel and nuclear industries, ranging from research and development funding to generous royalty arrangements for the extraction of fossil fuels from public lands. A 1999 study by the Department of Energy found that fossil fuels received nearly half of all federal energy subsidies in that year, with renewable energy receiving 18 percent (most of it going to promote ethanol) and conservation a scant 4 percent.[86] For another example, consider that current utility rate structures in most states reward utilities for selling *more* energy, sending a perverse signal that undercuts energy efficiency.

2. Split incentives – Often, the person who is the most logical candidate to install energy efficiency improvements is least likely to benefit from them. Consider landlords, who maintain buildings but whose tenants generally pay the energy bills. Or builders, who (in the absence of good consumer benchmarks, see #5) face incentives to minimize construction costs rather than make buildings as energy efficient as possible.

3. Missing incentives – Every consumer who saves energy reduces demand, which lowers the cost of energy for everyone. A homeowner who installs a solar panel on his or her rooftop reduces the need for a new power plant or transmission wire, thus saving other ratepayers money. However, individuals who pursue clean energy changes are rarely compensated for the benefits they deliver to the rest of society.

4. "Sticker shock" – Consumers often value lower sticker prices for vehicles, appliances and homes, even when they can save money in the long run by purchasing more energy-efficient models. This is particularly true when it is hard to differentiate between the efficiency of two different products (#5) or when it is hard to predict future savings. (#6)

5. Lack of knowledge – Even consumers who want to buy more energy efficient products sometimes find it difficult to tell which products are truly energy savers. While the Energy Star program helps consumers from energy sales, and eliminating punitive "stand-by" fees and other charges for combined heat-and-power applications are steps in the right direction.

- Each of the New England states should require utilities to devise long-term, least-cost plans for securing electricity for their customers that take full advantage of energy efficiency and renewable energy as tools for stabilizing costs to consumers and providing long-term electric system reliability. Several New England states, most notably Rhode Island, have taken steps in this direction and others should follow.

- The New England states should impose codes and standards for new appliances, buildings and equipment that will ensure that new development in the region is energy efficient. In addition, the states should provide tools for citizens to evaluate the energy performance of the decisions they make in the marketplace, for example, by requiring existing homes to be evaluated and "labeled" for their energy efficiency prior to sale.

- The New England states should continue to devise creative ways to finance the transition to a clean energy economy. The auctioning of carbon dioxide pollution allowances under RGGI, the opening of ISO-New England's Forward Capac-

make good choices for appliances and new homes, many products – including existing homes – are not "labeled" for their energy efficiency performance. In addition, consumers might not even be aware of new technologies that can tap renewable energy resources.

6. The "crystal ball" problem – Energy prices are notoriously volatile, making it hard for consumers and businesses to make educated decisions about future investments. Investing in a fuel-efficient vehicle, for example, appears a lot more attractive when gasoline prices are at $3 per gallon than when they are $1.50 a gallon. Yet, there is no guarantee that gasoline prices will remain high over any given period of time, thereby justifying the investment.

7. The "small potatoes" problem – For some businesses, energy costs are such a small part of their overall costs (compared, for example, to labor) that they attract little managerial attention. There may simply be no one whose job it is to look for ways to save energy cost-effectively – even when those opportunities exist. In addition, some businesses may lack access to capital to finance energy efficiency improvements.

8. Bureaucratic inertia – Bureaucracies are often slow to react when conditions in society change. Renewable energy sources such as wind power and solar energy are fundamentally different from the big, central-station power plants that preceded them, and the old rules that applied to those power plants do not always function efficiently.

9. The "chicken and egg" problem – Billions of dollars have been invested over the years in building up New England's energy and transportation infrastructure. These historical investments can make it difficult for new technologies to compete. For example, few people will buy vehicles that run on alternative fuels if there is no place to fuel them. But few gas station owners will install new infrastructure for alternative fuels if there are no vehicles to use them. This "chicken and egg" problem discourages research and investment in technologies that can dramatically change the way we use or produce energy.

10. The "pain in the neck" factor – For some individuals, time is a more precious commodity than money. If installing a solar panel or making energy efficiency improvements is too hard or too time-consuming, only the most dedicated consumers will do it.

Public policy can play a critical role in surmounting these barriers. Government can establish mandates for energy efficiency and renewable energy, thus setting a high "floor" for the penetration of clean energy in the economy. Government can also offer financial incentives, public education programs, energy audits and technical assistance to help individuals and businesses take advantage of their clean energy potential.

ity Market to demand-side resources, the region's existing market in renewable energy credits, the small systems benefit charges on consumers' electricity bills, and the "green power" options offered by some utilities are all means by which the region can help to finance energy efficiency improvements and renewable power. New England states should ensure that funding provided through these and other mechanisms is focused toward the goals of achieving a clean energy economy for the region, and should resist efforts by lawmakers or others to divert funding to unrelated activities.

Achieving New England's clean energy potential will take a concerted effort by government, business and individuals. But it is well worth doing for the sake of the region's economy, environment and long-term well-being.

Next Steps: Future Opportunities for Clean Energy in New England

Even as New England puts in place the policies, practices and technologies needed to capture our existing clean energy potential, we must prioritize measures to ensure a further transition to a more energy independent region that contributes far less to global warming. The following are among the most promising "next generation" approaches the region should be working to develop.

- **Zero-energy buildings** – The recent boom in "green building" has raised awareness of the tremendous possibilities for energy efficiency in new construction. Indeed, it may soon be possible to build so-called "zero-energy" homes and buildings, which use energy efficiency measures and small-scale renewable energy production to reduce net fossil fuel consumption to zero. New homes that approach zero-energy status are currently being built in California and some other states. The American Institute of Architects and the National Conference of Mayors have committed to a goal of dramatically reducing energy consumption in new buildings in coming years, with an ultimate goal of making all new buildings carbon-neutral by 2030.[87]

  New England states can help increase the spread of green and low-energy buildings by requiring that new state and state-funded structures meet strong environmental and energy efficiency criteria, and by continually updating building codes to require the construction of more energy efficient buildings over time.

- **Smart growth and better transportation choices** – The recent rise in gasoline prices led many New England drivers to look for alternatives to driving. Yet, for many New Englanders, even those living near major cities, alternatives to driving are few and far between. In part, the lack of options is due to the way we have built our communities, with spread-out, sprawl-style development replacing traditional village and town center development as the norm in much of New England. And in part, it has been due to transportation policies that emphasize automobiles at the expense of transit, ride-sharing, bicycling, walking and other transportation alternatives.

  The New England states should prioritize making more transportation choices available to a greater number of residents over the next couple of decades. Encouraging "smart growth" practices like focusing development in already built-up areas, orienting growth around transit stations, and promoting more compact development patterns are a start. Expanding transit options, perhaps by expanding passenger rail and light rail service to areas currently without it, would also move in the right direction, as would improving connections with current transit lines to maximize their use. The New England Climate Coalition's 2006 report, *Shifting Gears*, available at www.newenglandclimate.org, provides more ideas for how to reduce global warming emissions (and energy use) from the region's transportation system.

- **More energy efficient vehicles** – Improving fuel economy to an average of at least 40 miles per gallon and beyond is an achievable target over the next decade-and-a-half. And there are a number of potentially transformative technologies just over the horizon that could dramatically increase the fuel economy of cars and light trucks. Hybrid-electric vehicles are increasingly common on New

England highways and many deliver significant reductions in fuel consumption. A new generation of hybrids, called "plug-in" hybrids, builds on current technology by allowing consumers to recharge the vehicle's battery from their home electricity supply. Plug-in hybrids use far less gasoline than even today's conventional hybrid vehicles, and can reduce global warming pollution by 15 percent per mile compared with today's hybrids.[88]

New England states should adopt new approaches to reducing energy consumption and global warming pollution from vehicles. The adoption of California's tailpipe standards for vehicle global warming pollution is a start. States should also adopt policies that provide financial incentives for consumers purchasing fuel efficient vehicles and that give a jump-start to new technologies like plug-in hybrids that can achieve major reductions in energy use.

- **Recycling** – Recycling and re-use of materials uses less energy than making materials anew. Yet, after making rapid progress in the early 1990s, the recycling efforts of the New England states – particularly at the residential level – have stalled. Increasing the amount of paper, plastics, metals, asphalt and other materials we recycle can reduce the amount of energy needed to process those materials, and reducing materials use – such as through less material-intensive packaging – can save energy in a host of ways. New England states should take steps to maximize the amount of solid waste that is recycled within the region.

- **New sources of renewable energy** – Wind, solar and biomass power (along with hydropower) are the mainstays of New England's renewable energy economy, but there are many new or improved technologies on the horizon that can enable the region to take even greater advantage of our homegrown renewable resources. First, it could soon become possible to take advantage of existing renewable resources in new ways – for example, through small-scale (residential) wind turbines, low-impact hydropower, or the production of cellulosic biofuels, which make use of plant residues and "energy crops" like switchgrass to produce renewable transportation fuels. In addition, there may be opportunities to tap entirely new renewable resources, such as the power of ocean waves and tides. In any of these efforts, the New England states must be careful to balance the need for renewable energy against other social and environmental imperatives. But with continued support, it is likely that New England's ability to take advantage of renewable energy will only increase in the years to come.

Conclusion

New England has many opportunities to address its unique energy problems using energy efficiency and renewable energy. The region's home-grown renewable energy resources are vast, as is the potential to reduce our current use of energy through improved efficiency. Over just the past few years, the New England states have taken major steps forward. Most of the region's states have adopted carbon dioxide standards for vehicles, limits on global warming pollution from power plants, minimum renewable energy standards for electricity production, energy efficiency standards for appliances, and other policies that will move the region toward a cleaner energy future with less impact on the global climate.

But there is much that remains to be done. By recognizing the potential of clean energy strategies to solve New England's energy problems, and setting out to achieve that potential, the region's leaders can begin to catalyze government, business, and individuals behind the steps that will need to be taken to get there.

New England's energy situation looks gloomy at the present, but it doesn't have to. By driving the region toward clean energy solutions, we can both ensure the future viability of New England's economy and address the very real threat posed by global warming to the future of our region and the world.

Methodology

Energy Use Estimates

Estimates of energy use in New England in 2004 were based on data from U.S. Department of Energy, Energy Information Administration (EIA), *State Energy Consumption, Price and Expenditure Estimates* database, downloaded from www.eia.doe.gov/emeu/states/_states.html, 8 May 2007. The EIA state energy database breaks down energy use by fuel and by sector. We made one adjustment to the data, based on the EIA's inclusion of ethanol used as a blending component within its estimates of motor gasoline consumption. We reduced the motor gasoline consumption figure reported by the EIA by the ratio (by volume) between ethanol and motor gasoline consumption in the region.

In addition, we estimated the breakdown of fuel use within each sector by end use. Energy consumption data by specific end use is not collected on a state or regional level by the EIA; instead, we used a variety of other analyses and data sources to provide a more detailed estimate of how New Englanders use energy.

In general, we calculated the percentage of various fuels used in various end uses in each sector on a regional or national level, and then applied those shares of fuel use to New England's specific energy consumption profile to produce an estimate of the amount of energy used for various purposes in the region. So, for example, if the EIA's state energy data indicated that New England used 100 units of a particular fuel in 2004, and a national estimate of end-use energy consumption indicated that 70 percent of that fuel is used for a particular purpose, we assumed that 70 units of that fuel were used for that purpose in New England.

Residential Energy Use

Estimates of end-use residential energy consumption were based on Northeast regional data from U.S. Department of Energy, Energy Information Administration, *Residential Energy Consumption Survey 2001: Consumption and Expenditures Fuel Tables*, downloaded from www.eia.doe.gov/emeu/recs/byfuels/2001/byfuels_2001.html. For each of the major fuels, we divided the share of energy used for each end use by the total amount of fuel consumed in the Northeast region. We then applied this percentage to New England's consumption of each fuel in 2004. Fuels not specifically mentioned in the survey were assigned to end uses as follows: all coal, geothermal and wood energy consumption was assumed to be for space heating; all solar energy consumption was applied to "other appliances." For appliances, we broke electricity consumption down further into appliance types, using national electric end-use data from U.S. Department of Energy, Energy Information Administration, *Residential Energy Consumption 2001: End-Use Consumption of Electricity by End Use and Appliance*, downloaded from www.eia.doe.gov/emeu/recs/recs2001/enduse2001/enduse2001.html, 7 November 2006. All natural gas and other non-electric fuel use for appliances was applied to the "other appliances" category.

Commercial Energy Use

Estimates of end-use commercial energy consumption were based on U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *2006 Buildings Energy Data Book*, September 2006. Unfortunately, neither this data source, nor the EIA's Commercial Building Energy Consumption Survey (CBECS), produces end-use energy consumption estimates at the regional level. The breakdown of commercial energy consumption by end use in this report is therefore based on national data – and, as a result, these estimates should be interpreted as only a rough approximation of end-use energy consumption in the New England commercial sector. We assumed that the end-use shares of energy consumption for fuel oil from the *Buildings Energy Data Book* applied equally to distillate and residual fuel consumption. All energy consumption for fuels not covered by the end-use estimates was categorized as "other" energy use.

Industrial Energy Use

Estimates of end-use industrial energy consumption were based on Northeast regional estimates for fuel used as energy sources from U.S. Department of Energy, Energy Information Administration, *Manufacturing Energy Consumption Survey (MECS) 2002: Manufacturing Energy Data Tables*, Table 2.2 and Table 5.6, downloaded from www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html, 7 November 2006. The manufacturing sector data provided in *MECS* is an imperfect analog of total energy use in the "industrial sector," which includes agriculture and some other non-manufacturing activities. To partially account for non-manufacturing consumption of diesel fuel, we assumed that half of industrial sector distillate fuel use was for non-manufacturing purposes, based on U.S. Department of Energy, Energy Information Administration, *The Northeast Heating Fuel Market: Assessment and Options*, May 2000. We also assumed that 4.4 percent of industrial sector energy use was for agriculture, based on a national estimate from Brian Unruh, U.S. Department of Energy, Energy Information Administration, *Delivered Energy Consumption Projections by Industry in the Annual Energy Outlook 2002*, downloaded from www.eia.doe.gov/oiaf/analysispaper/industry/pdf/consumption.pdf, 6 June 2007. To break down agricultural energy consumption by fuel, we used national estimates for agricultural energy use from Elizabeth Brown and R. Neal Elliott, American Council for an Energy-Efficient Economy, *On-Farm Energy Use Characterizations*, March 2005.

Energy sources not included in the *MECS* data – including geothermal, wood, waste and many petroleum products – were assigned to the "unknown/other end uses" category.

Transportation Energy Use

Estimates of end-use transportation energy consumption were based on national-level data from Stacy C. Davis and Susan W. Diegel, Oak Ridge National Laboratory, *Transportation Energy Data Book: Edition 25*, Table 2.4, 2006. As was the case with the commercial sector, only national data were available, making the breakdown by transportation end use only a rough approximation of actual fuel use patterns in New England. The data broke down transportation energy use by vehicle type and mode. We recategorized the data as follows: 1) personal vehicles, including highway light-duty vehicles, motorcycles, general aviation aircraft and recreational vehicles; 2) transit, including transit buses, school buses, transit rail and commuter rail; 3) intercity transport, including intercity bus and rail and domestic air travel; 4) international travel, including international air travel; 5) freight, including medium and heavy duty freight trucks, air freight and rail freight; and 6) pipeline fuel. Transportation use of ethanol was assigned to personal vehicles; transportation use of lubricants was assigned to "other/unspecified."

Electric Generation Energy Use

Data on energy use by electricity generators was based on the EIA state energy database.

Energy Savings Estimates

Estimates of the energy or fossil fuel savings possible in New England were based on the following general assumptions.

First, we attempted to limit our estimates of potential energy savings to technologies that are commercially available *today* or will be available in the very near future. In other words, the purpose of the analysis was to estimate the fossil fuel savings that New England could achieve if it were to use all the tools available today to improve energy efficiency and increase the use of renewable energy. This objective imposed important limitations on our work. For example, we ignored the potential impact of some technologies that have been effectively demonstrated, but have not yet reached commercial application. We also did not include the energy savings that could be achieved through long-term, large-scale public investments and policy changes, such as expansion of transit and intercity rail networks and changes in land-use patterns.

Second, we attempted to limit our estimates to those technologies that are cost-competitive today. In some cases, such as assessments of energy efficient technologies and more efficient vehicles, detailed economic analyses provided estimates of cost-effective energy savings, which we used in this report. Assessments of other technologies, particularly the renewable energy technologies and combined heat-and-power, included only the technical potential with no screen for economic competitiveness. In these cases, we applied our own assumptions as to which technologies were likely to be cost-competitive and attempted to take a conservative view of the data. We detail these assumptions in the sections on the specific technologies below.

Third, we limited our scope of analysis to only the largest end uses of energy in New England. This was due to time and budget constraints. There are undoubtedly other opportunities for energy savings in New England that we did not address.

Fourth, our method represents a static analysis of New England's energy consumption at a particular snapshot in time (2004) and does not factor in projected changes in energy consumption patterns in the future, such as might result from population growth. In addition, while the energy efficiency and renewable energy technologies addressed here are available today, they could not all be implemented immediately and at once. Finally, New England states have a limited ability to affect policy changes that could lead to these outcomes – for example, states are not permitted under federal law to adopt their own fuel economy standards for vehicles. As such, this analysis should be seen as illustrative of the degree of energy and fossil fuel savings that could be achieved through an aggressive focus on energy efficiency improvements and renewable energy development and not a prescriptive blueprint for the region.

Generally, our method for estimating energy savings was to use published estimates of energy efficiency opportunities or renewable energy potential to estimate the percentage reduction in energy consumption for various end uses or the total amount of energy that could be saved or renewable energy that could be produced in New England. A more detailed description of the methods we used for each type of energy end use follows.

Transportation Energy Savings

Light-Duty Vehicles

Energy savings from light-duty vehicles were based on a near-term estimate of potential fuel economy improvements from cars and light trucks from Union of Concerned Scientists (UCS), *National Academies National Research Council Report on: Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*, downloaded from www.ucsusa.org/clean_vehicles/cars_pickups_suvs/nas-report-cafe-effectiveness-and-impact.html, 7 November 2006. UCS found that cars and light trucks could meet an average fuel economy standard of 33 miles per gallon (MPG) within a decade, using technologies largely available today. To estimate how such an increase would impact fuel use in New England, we multiplied the 33 MPG estimate by an on-road "degradation factor" of 0.79, which approximates the amount by which on-road fuel economy is less than the estimate of fuel economy used to calculate compliance with CAFE standards. The degradation factor was based on U.S. Department of Energy, Energy Information Administration, *Assumptions to Annual Energy Outlook 2006*, March 2006. We then compared this figure with the current national average for light-duty on-road fuel economy of 20.25 MPG from U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2006*, 14 February 2006. We then converted both MPG figures to gallons of gasoline consumed per mile, and divided projected fuel economy by current fuel economy to arrive at the percentage by which light-duty transportation gasoline use in New England could be reduced through fuel economy improvements. Finally, we multiplied this figure by our estimate of light-duty vehicle gasoline use to arrive at the total fuel savings that could be achieved through fuel economy improvements. We did not factor in the "rebound effect" (in which drivers purchasing more fuel efficient vehicles tend to drive more miles in them) or any mix-shifting effects in our analysis.

Heavy-Duty Trucks

Energy savings from fuel economy improvements in heavy-duty trucks were calculated in a similar manner to light-duty fuel economy savings. We obtained a baseline estimate of the current fuel economy of the nation's tractor-trailers from U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2006,* 14 February 2006. We then assumed that fuel economy for those trucks could be improved by 29 percent in the near-term, per Therese Langer, American Council for an Energy-Efficient Economy, *Energy Savings Through Increased Fuel Economy for Heavy-Duty Trucks*, prepared for the National Commission on Energy Policy, 11 February 2004. We converted both MPG estimates into gallons-per-mile and then divided the fuel economy after improvements by the baseline fuel economy estimate to arrive at the percentage energy savings from improving the fuel economy of heavy-duty truck fuel economy. Finally, we multiplied this figure by our estimate of heavy-duty freight truck diesel consumption in New England to arrive at the total fuel savings. Again, no rebound effect was assumed.

Home Energy Savings

Space Heating

Estimates of energy saved from residential space heating were based largely on methodology and data sources developed for Vermont Public Interest Research and Education Fund, *Building Solutions:*

Energy Efficient Homes Save Money and Reduce Global Warming, Fall 2006. The baseline estimate of how much energy could be saved through residential weatherization programs was based on estimated savings from Vermont's weatherization program, as detailed in Gregory Dalhoff, Dalhoff and Associates, *An Evaluation of the Impacts of Vermont's Weatherization Assistance Program*, November 2001. (One exception is with the baseline assumption for electricity savings, which was based on a small number of samples in the November 2001 Dalhoff report. For electricity savings, we referred to Jeff Riggert, Andrew Oh, et al., *An Evaluation of the Energy and Non-Energy Impacts of Vermont's Weatherization Assistance Program*, November 1999.)

Recognizing that the homes targeted by Vermont's weatherization programs tend to be older and less energy efficient than those that would be addressed by a regional home weatherization effort, we used the baseline energy savings estimate only for New England homes built prior to 1940. For newer homes, we adjusted the potential energy savings downward in proportion to the ratio of space heating energy efficiency (BTU consumed for space heating per square foot) for homes built during a particular time period to the efficiency of homes built prior to 1940. For example, if homes built between 1980 and 1989 consumed 45 percent less energy per square foot for space heating than homes built prior to 1940, we assumed that the potential energy savings (in percentage terms) would be 45 percent less for those newer homes. The end result of this assumption is that, while all homes are assumed to have some potential for weatherization improvements, the potential savings from newer homes is significantly reduced.

We then weighted the energy efficiency savings by type of fuel used for primary space heating in New England residences of various ages. The end result was an estimate of the percentage of each fuel used for space heating that could be reduced through weatherization efforts.

Data on the age and space heating efficiency of the New England housing stock was based on an analysis of public use microdata from the U.S. Department of Energy, Energy Information Administration, *2001 Residential Energy Consumption Survey*, downloaded from www.eia.doe.gov, 29 November 2006. Data on primary space heating fuel by age of residence was based on an analysis of public use microdata from U.S. Census Bureau, *American Community Survey 2005*, downloaded from www.census.gov, 27 November 2006.

Water Heating and Appliances

Estimates of potential energy efficiency savings in residential water heating and major appliances were based on estimates of techno-economic energy efficiency potential from Interlaboratory Working Group, *Scenarios for a Clean Energy Future*, November 2000, Appendix D. Savings for 2010 under the advanced case scenario were assumed. The percentage reductions in energy use by fuel and type of equipment were then applied to the estimates of end-use energy consumption in New England, calculated as described above, to arrive at total energy savings.

Commercial and Industrial Energy Savings

Commercial Space Heating, Cooling and Lighting

Percentage energy savings for commercial end uses were based on techno-economic energy efficiency potential estimates from Interlaboratory Working Group, *Scenarios for a Clean Energy Future*, November 2000, Appendix D. Savings for 2010 under the advanced case scenario were assumed. The percentage reductions in energy use by fuel and type of equipment were then applied to the estimates of end-use energy consumption in New England, calculated as described above, to arrive at total energy savings.

Industrial Machine Drive

Potential percentage energy savings for industrial motors were based on the midpoint of the range of 11 to 18 percent cost-effective energy savings using mature technologies and practices from U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *United States Industrial Electric Motor Systems Market Opportunities Assessment*, December 1998. Percentage savings were applied to electricity consumption for industrial machine drive in New England, estimated as described above.

Combined Heat-and-Power

New England's potential to add combined heat and power capacity at commercial and industrial facilities was taken from Energy and Environmental

Analysis, Inc., *Installed CHP in 2005*, Power Point presentation to Northeast Regional Biomass Program Steering Committee Meeting, 24-25 May 2006. We assumed that the region is able to achieve half of the technical potential identified in the EEA document. (No estimate of cost-effective capacity was given and cost-effectiveness of CHP systems depends to a great extent on public and utility policies.) The anticipated capacity factor of CHP systems was imputed from data in American Council for an Energy-Efficient Economy, *CHP: The Efficient Path for New Power Generation*, downloaded from www.aceee.org/energy/chp.pdf, 20 July 2006. The marginal increase in natural gas consumption that would result from CHP installations was estimated at 5,000 BTU/kWh, based on Western Resource Advocates, *A Balanced Energy Plan for the Interior West*, 2004.

Clean Electricity

Wind Energy

The estimate of offshore wind potential in New England is derived from Walt Musial, National Renewable Energy Laboratory, *Overview: Potential for Offshore Wind Energy in the Northeast*, PowerPoint presentation to the Offshore Wind Energy Collaborative Workshop, 10-11 February 2005. We included only those resources within 5 to 20 nautical miles of coastline and only those in waters less than 30 meters deep. In addition to the 67 percent exclusion in the Musial presentation, we further assumed that only one-fifth of those resources would ultimately be developed, for total offshore wind capacity of 1,980 MW. We assumed that the annual capacity factor for offshore wind turbines would be 38.4 percent, consistent with assumed capacity factor for Class 6 wind resources from U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs, FY2008 Budget Request*, March 2007, Appendix E.

For onshore wind potential, we relied on wind energy potential estimates for class 3 and better resources from the American Wind Energy Association, citing D.L. Elliott, L.L. Wendell and G.L. Gower, Pacific Northwest Laboratory, An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States, 1991. This assessment is more than a decade old and has been questioned for having inadequate exclusions for environmental and other reasons. To assure the conservatism of our estimate, we assume that New England develops only 8.3 percent of that potential, or 916 average megawatts (aMW) of capacity.

Solar Energy

Estimates of New England's near-term solar energy potential were based on Maya Chaudhari, Lisa Frantzis, Tom E. Hoff, Navigant Consulting, *PV Grid Connected Market Potential Under a Cost Breakthrough Scenario*, September 2004. For our estimate, we used a sensitivity case in which installed PV system costs fall to \$3.75 per peak Watt for residential consumers and \$3.00 to \$3.30 per peak Watt for commercial consumers. These cost estimates are well below the installed system costs currently prevailing in New England and elsewhere. However, a variety of studies have shown that PV installations provide significant value to utilities and utility consumers by shaving peak load, alleviating transmission congestion, reducing the need for capital investments in utility plant and other benefits. California and other states (including Connecticut, Massachusetts and Vermont), recognizing this value, provide substantial rebates for consumers installing PV systems. Moreover, increases in solar PV installations tend to create economies of scale that result in lower PV system costs in the long term. As such, we assume that, with aggressive public policy intervention, New England could achieve the cost targets included in the report.

In assessing the amount of electricity that would be produced from solar panels in New England, we assume a capacity factor of 21 percent (based on U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2006*, 14 February 2006) and a DC to AC derate factor of 77 percent (from Renewable Resource Data Center, *PVWatts: Changing System Parameters*, downloaded from rredc.nrel.gov/solar/codes_algs/PVWATTS/system.html, 6 December 2006).

Biomass Energy

Estimates of available biomass energy resources from mill wastes and forestry residues were based on Marie E. Walsh, et al., Oak Ridge National Laboratory, *Biomass Feedstock Availability in the United States: 1999 State-Level Analysis*, updated January 2000. We assumed that the region would be able to use half of the identified resource available at \$40 or less per delivered dry ton. Energy content of the biomass fuel was based on a heat rate of 8,600 BTU/dry ton from Zia Haq, U.S. Department of Energy, Energy Information Administration, *Biomass for Electricity Generation*, downloaded from www.eia.doe.gov/oiaf/analysispaper/biomass/, 6 December 2006. We assumed that biomass would be substituted for coal, natural gas and distillate fuel consumption in electricity generation in equal proportion based on BTU content.

Energy Savings from Offset Electricity Generation

Site electricity savings were translated into fuel savings by assuming an average 10% power loss in transmission lines from power plants to usage sites, including production of wind and biomass electricity. Solar electricity was assumed to be generated at the place of usage, and therefore did not incur transmission losses.

Electricity savings and generation of renewable electricity were assumed to offset existing generation in the following ways:

- Expansion of combined heat-and-power was assumed to offset existing central utility natural gas-fired generation on a kilowatt-for-kilowatt basis.

- Electricity savings through energy efficiency and new solar and wind energy were assumed to offset existing generation from various fuels in proportion to their contribution to the region's electricity grid.

- Use of biomass energy was assumed to offset equal amounts of natural gas, oil and coal used for electricity generation.

Fuel savings resulting from avoided electricity generation were calculating using heat rates imputed from two sources of data: energy consumption for electricity generation by fuel from the EIA's state energy database, and electricity net generation by fuel from U.S. Department of Energy, Energy Information Administration, *Electric Power Annual 2005*, state data tables, downloaded from www.eia.doe.gov/cneaf/electricity/epa/epa_sprdshts.html, 6 December 2006.

Notes

1. Based on data from U.S. Department of Energy, Energy Information Administration, *State Energy Consumption, Price and Expenditure Estimates* database, downloaded from www.eia.doe.gov, 8 May 2007. Note: this figure and all others in this section are based on end-use energy consumption, including consumption of electricity. Two to three units of energy are typically consumed in the process of generating one unit of electricity and delivering it to the end user. These energy "losses" are not accounted for in these charts, but will be discussed in the section on energy use in electric power plants, which follows.

2. U.S. Department of Energy, Energy Information Administration, *State Energy Consumption, Price and Expenditure Estimates* database, downloaded from www.eia.doe.gov/emeu/states/_states.html, 8 May 2007.

3. See Methodology for description of the sources of energy end-use estimates.

4. See note 2.

5. "Study: World Oil Forecast Beset with Reserves Shortfalls," *Oil and Gas Journal*, 12 April 2004, 28; A.M. Samsam Bakhtiari, "World Oil Production Capacity Model Suggests Output Peak by 2006-07," *Oil and Gas Journal*, 26 April 2004, 18.

6. C.J. Campbell, "Industry Urged to Watch for Regular Oil Production Peaks, Depletion Signals," *Oil and Gas Journal*, 14 July 2003.

7. U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 2005*, 27 July 2006.

8. U.S. Department of Energy, Energy Information Administration, *World Petroleum Consumption, Most Recent Annual Estimates, 1980-2006* (Excel workbook), downloaded from www.eia.doe.gov/emeu/international/oilconsumption.html, 10 May 2007.

9. David R. Francis, "Has Global Oil Production Peaked?" *Christian Science Monitor*, 29 January 2004.

10. Carrie Conaway, New England Public Policy Center, *Research Report: The Challenge of Energy Policy in New England*, April 2006.

11. See note 2, comparison based on BTU energy equivalent.

12. "6 percent" from U.S. Department of Energy, Energy Information Administration, *Natural Gas Gross Withdrawals and Production*, downloaded from tonto.eia.doe.gov/dnav/ng/ng_prod_sum_dcu_NUS_a.htm, 1 May 2007.

13. Data from U.S. Department of Energy, Energy Information Administration, *Natural Gas Gross Withdrawals and Production*, downloaded from tonto.eia.doe.gov/dnav/ng/ng_prod_sum_dcu_NUS_a.htm, 6 November 2006; U.S. Department of Energy, Energy Information Administration, *Number of Producing Gas and Gas Condensate Wells*, downloaded from tonto.eia.doe.gov/dnav/ng/ng_prod_wells_s1_a.htm, 6 November 2006.

14. Conservation Law Foundation, *Southern New England LNG Proposals*, downloaded from www.clf.org/programs/cases.asp?id=503, 6 November 2006; Conservation Law Foundation, *Northern New England LNG Terminal Proposals*, downloaded from www.clf.org/programs/cases.asp?id=746, 6 November 2006.

15. U.S. Department of Energy, Energy Information Administration, *New England (PAAD 1A) Gasoline and Diesel Retail Prices*, downloaded from tonto.eia.doe.gov/dnav/pet/pet_pri_gnd_dcus_r1x_w.htm, 1 May 2007.

16. U.S. Department of Energy, Energy Information Administration, *New England (PADD 1A) No. 2 Heating Oil Residential Price*, downloaded from tonto.eia.doe.gov/dnav/pet/hist/mhore1a4m.htm, 1 May 2007.

17. Ibid.

18. U.S. Department of Energy, Energy Information Administration, *Natural Gas Citygate Price in Connecticut*, downloaded from tonto.eia.doe.gov/dnav/ng/hist/n3050ct3m.htm, 1 May 2007.

19. Ibid.

20. Based on average of monthly revenue per kilowatt-hour (calculated by dividing revenue into kilowatt-hour sales) reported in U.S. Department of Energy, Energy Information, *Monthly Electric Utility Database, Form 826*, downloaded 3 August 2006.

21. Setting the price most of the time based on ISO-New England, *2005 Annual Markets Report*, 1 June 2006.

22. See note 20.

23. Union of Concerned Scientists, *The Changing Northeast Climate*, 2006, and U.S. Global Change Research Program, *New England Regional Climate Change and Variability Assessment*, March 2002.

24. Ibid.

25. See note 2.

26. U.S. PIRG Education Fund, *The Carbon Boom: State and National Trends in Carbon Dioxide Emissions Since 1990*, 11 April 2007.

27. Travis Madsen, Rob Sargent, U.S. PIRG Education Fund, *Making Sense of the "Coal Rush": The Consequences of Expanding America's Dependence on Coal*, July 2006.

28. Ibid.

29. Gordon van Welie, President and Chief Executive Officer, ISO-New England, *Remarks Presented to "Lights Power Action: Solutions for New England's Energy Future,"* 25 September 2006.

30. See ISO-New England, *Final Report on Electricity Supply Conditions in New England During the January 14-16, 2004 "Cold Snap,"* 12 October 2004.

31. Mike Hightower, et al, Sandia National Laboratories, *Guidance on Risk Analysis and Safety Implications of a Large*

Liquefied Natural Gas (LNG) Spill Over Water, December 2004.

32. "Loss of coolant" from Union of Concerned Scientists, *The Lessons of Davis-Besse: Overview*, downloaded from www.ucsusa.org/clean_energy/nuclear_safety/overview_db.html, 6 November 2006.

33. National Academy of Sciences, *Spent Fuel Stored in Pools at Some U.S. Nuclear Plants Potentially at Risk from Terrorist Attacks: Prompt Measures Needed to Reduce Vulnerabilities* (press release), 6 April 2005.

34. National Academy of Sciences, Board of Radioactive Waste Management, *Safety and Security of Commercial Spent Nuclear Fuel Storage: Public Report*, National Academies Press, 2005.

35. For example, former NRC commissioner Peter Bradford describes the situation as follows: "The NRC never errs on the side of safety, of environmental protection, or of public involvement. If we were discussing accounting regulation, this would be the SEC in the years before Enron." Source: Peter A. Bradford, *Nuclear Power's Prospects*, Power Point presentation to California Energy Commission Nuclear Issues Workshop, 16 August 2005.

36. U.S. Nuclear Regulatory Commission, *Escalated Enforcement Actions Issued to Reactor Licensees*, downloaded from www.nrc.gov/reading-rm/doc-collections/enforcement/actions/reactors, 6 November 2006.

37. Ibid.

38. In July 2006, the average residential electric rate in New England was 15.89 cents per kilowatt-hour, compared to the national average of 10.96 cents per kilowatt-hour. Source: U.S. Department of Energy, Energy Information Administration, *Electric Power Monthly with Data for July 2006*, 2 October 2006.

39. See note 2. Figure includes ethanol blended into gasoline.

40. Union of Concerned Scientists (UCS), *National Academies National Research Council Report on: Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*, downloaded from www.ucsusa.org/clean_vehicles/cars_pickups_suvs/nas-report-cafe-effectiveness-and-impact.html, 7 November 2006.

41. National Research Council, Board on Energy and Environmental Systems, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*, National Academy Press, 2002.

42. Stacy C. Davis and Susan W. Diegel, Oak Ridge National Laboratory, *Transportation Energy Data Book: Edition 25*, 2006.

43. Therese Langer, American Council for an Energy-Efficient Economy, *Energy Savings Through Increased Fuel Economy for Heavy-Duty Trucks*, prepared for the National Commission on Energy Policy, 11 February 2004.

44. Ibid.

45. Based on U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *Indicators of Energy Intensity in the United States*, Transportation Sector trends data, downloaded from intensityindicators.pnl.gov/trend_data.stm, 17 July 2006.

46. Based on an analysis of public use microdata from U.S. Census Bureau, *American Community Survey 2005*, downloaded from factfinder.census.gov/home/en/acs_pums.html, 27 November 2006.

47. "End-use energy consumption" includes consumption of energy in homes, businesses, industry and transportation. It does not include consumption of energy by electricity generators.

48. From Margaret J. Pinckard, et al., Lawrence Berkeley Laboratory, *Documentation of Calculation Methodology, Input Data, and Infrastructure for the Home Energy Saver Web Site*, July 2005.

49. Average heating efficiency of a fuel oil furnace sold in 1970: 70%. Average heating efficiency of a fuel oil furnace sold today: 81%. See note 48.

50. Gregory Dalhoff, Dalhoff and Associates, *An Evaluation of the Impacts of Vermont's Weatherization Assistance Program*, November 2001.

51. See U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *Massachusetts Fosters the Weatherization Spirit*, October 2001 and similar fact sheets for other New England states available at www.eere.energy.gov/weatherization/state_activities.html.

52. In calculating our estimate for total energy savings from home weatherization, we assumed that fewer energy savings were possible in newer homes. See "Methodology" section at the end of this report for more details.

53. A more recent study in Vermont estimated that the technical potential for residential oil savings in Vermont of 30 percent, with an achievable and cost-effective potential of 10.2 percent. See GDS Associates, Inc., *Vermont Energy Efficiency Potential Study for Oil, Propane, Kerosene and Wood Fuels*, prepared for the Vermont Department of Public Service, 16 January 2007.

54. See "Methodology" section at the end of this report for details on how these estimates were calculated.

55. Martin Schweitzer, Oak Ridge National Laboratory, *Estimating the National Effects of the U.S. Department of Energy's Weatherization Assistance Program with State-Level Data: A Metaevaluation Using Studies from 1993 to 2005*, September 2005.

56. American Council for an Energy-Efficient Economy, *U.S. Energy Department Proposes New Efficiency Standards for Home Furnaces* (press release), 6 October 2006.

57. William Prindle, et al., American Council for an Energy-Efficient Economy, *Energy Efficiency's Next Generation: Innovation on the State Level*, November 2003.

58. Interlaboratory Working Group, *Scenarios for a Clean Energy Future*, November 2000. Estimated levels of savings reflect the study's "advanced case." These figures do not reflect whether savings are "achievable" based on assumptions about the efficacy of public policies and programs.

59. Environmental and Energy Study Institute, *Renewable Energy Fact Sheet: Solar Water Heating: Using the Sun's Energy to Heat Water*, May 2006.

60. Side by side refrigerator-freezers sold in 1972 cooled on average 3.57 cubic feet per kWh, compared with 16.33 in 2002; General freezers sold in 1972 cooled on average 7.29 cubic feet per kWh, compared with 17.83 in 2002. See note 48.

61. See note 58.

62. U.S. Department of Energy, Office of Renewable Energy and Energy Efficiency, *United States Industrial Electric Motor Systems Market Opportunities Assessment*, December 1998.

63. Estimate from Energy and Environmental Analysis, Inc., *Installed CHP in 2005*, Power Point presentation to Northeast Regional Biomass Program Steering Committee Meeting, 24-25 May 2006; Electric generating capacity for November 2006 was less than 34,000 MW, from ISO-New England, *Seasonal Claimed Capability, 2006*, downloaded from www.iso-ne.com/genrtion_resrcs/snl_clmd_cap/index.html, 10 November 2006.

64. Lauren R. Mattison, University of Massachusetts Amherst, Department of Mechanical and Industrial Engineering, Center for Energy Efficiency and Renewable Energy, *Technical Analysis of the Potential for Combined Heat and Power in Massachusetts*, May 2006.

65. Electricity consumption from U.S. Department of Energy, Energy Information Administration, *State Electricity Profiles: 2004 Edition*, June 2006.

66. Capacity based on U.S. Department of Energy, Energy Information Administration, *State Electricity Profiles: 2004 Edition*, June 2006.

67. Massachusetts Technology Collaborative, *Offshore Wind Energy Collaborative*, downloaded from www.mtpc.org/renewableenergy/owec.htm, 6 December 2006.

68. Walt Musial, National Renewable Energy Laboratory, *Overview: Potential for Offshore Wind Energy in the Northeast*, Power Point presentation to Offshore Wind Energy Collaborative Workshop, 10-11 February 2005.

69. American Wind Energy Association, *Small Wind: State-by-State*, state pages for the six New England states, downloaded from www.awea.org/smallwind/states.html, 6 December 2006.

70. Comparison based on 131 million megawatts of net generation in the six New England states in 2004, from U.S. Department of Energy, Energy Information Administration, *State Electricity Profiles: 2005 Edition*, March 2007.

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