COOL SOLUTIONS

Ten Emerging Technologies and Trends that Can Help Massachusetts Meet Bold Goals for Curbing Global Warming
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Executive Summary

Massachusetts has made great progress in reducing its contribution to global warming over the past decade. We use less energy in Massachusetts today than we did in the late 1980s, more of it comes from solar and wind power than ever, and our economy is growing in ways that are less energy-intensive than in the past.

Despite this progress, however, Massachusetts is not yet on track to hit our 2020 target for reducing greenhouse gas emissions – a target that we must meet in order to do our part to prevent the worst impacts of global warming. Massachusetts also has yet to set a new target for emission reductions for 2030, which is now just 15 years away.

To ensure that the Commonwealth stays on track to meet its target under the Global Warming Solutions Act of cutting emissions by at least 80 percent by 2050, Massachusetts should adopt a target of reducing greenhouse gas emissions to at least 45 percent below 1990 levels by 2030.

Achieving that goal will require Massachusetts to fully implement previous commitments to reduce global warming pollution. It will also require us to take full advantage of a new wave of game-changing opportunities – from cutting-edge technologies to emerging societal trends – that can help Massachusetts build on its position of national leadership in the fight against global warming.

Massachusetts is reducing greenhouse gas emissions, but still falling short of its goals.

- Greenhouse gas emissions in Massachusetts were 15 percent lower in 2011 than they were in 1990, due in part to improvements in the energy efficiency of buildings and vehicles and increasing use of clean energy sources such as wind and solar power.

- Massachusetts is not on track to achieve the 25 percent emission reduction (from 1990 levels) required under the Global Warming Solutions Act. A 2014 analysis by the Global Warming Solutions Project estimated that the Commonwealth will fall 20 percent short (about 4 million metric tons carbon dioxide equivalent, or MMTCO₂e) of the emission reductions needed to achieve the 2020 target.

Massachusetts should set a goal of reducing greenhouse gas emissions to at least 45 percent below 1990 levels by 2030.

- The Global Warming Solutions Act requires Massachusetts officials to establish an interim emission reduction target for 2030 – an important waypoint along the path toward the 80 percent emission reductions required under the law by 2050.

- Assuming that the Commonwealth achieves its 2020 emission reduction target, Massachusetts would need to reduce greenhouse gas emissions by an average of 1.7 MMTCO₂e per year after 2020 to achieve the 2050 target. By 2030, this would represent a reduction of 43 percent below 1990 levels. Setting a target of 45 percent emission reductions by 2030 would ensure that Massachusetts maintains or exceeds the pace of emission reductions needed to meet its climate commitments.
Massachusetts has a series of game-changing opportunities to achieve dramatic reductions in greenhouse gas emissions and meet an aggressive emission reduction target for 2030.

1. **Solar photovoltaics**: Massachusetts has 200 times more solar energy today than it did in 2008, with plenty of room for further growth. With prices for solar energy continuing to plummet, Massachusetts should commit to obtaining at least 20 percent of its electricity from the sun by 2030, and ensure that the benefits of solar energy are available to everyone.

2. **Offshore wind**: Massachusetts has enough offshore wind energy potential to power the Commonwealth 11 times over. Tapping just a small share of that potential would enable Massachusetts to get 20 percent of its electricity from offshore wind energy by 2030.

3. **Energy storage**: Repowering our economy with renewable energy will require investments in a more flexible, adaptable grid. States such as California are already beginning to integrate energy storage technologies into their electric systems, and with the cost of storage technologies falling, Massachusetts should commit to do the same.

4. **New energy efficiency tools**: LED lighting and “intelligent efficiency” measures that use information technology to better manage energy use are among the advancing technologies that can enable Massachusetts to maintain and build on its track record of national leadership in energy efficiency.

5. **Renewable heating and cooling**: Renewable energy sources can help reduce the amount of oil and gas we use to heat and cool buildings, as well as to heat water. Recent technological improvements and cost reductions have made technologies like air-source heat pumps increasingly attractive for homeowners and businesses.

6. **Net zero-energy buildings**: Massachusetts already has a small but growing number of buildings that produce as much energy as they consume over the course of a year. Stronger
building codes and adoption of new “stretch” codes can make zero and near-zero energy buildings more common throughout Massachusetts.

7. **Urbanization and smart growth**: Massachusetts is experiencing a sea change in development patterns, with more people moving to cities and walkable neighborhoods and slower growth in sprawling suburban areas. Residents of more compact neighborhoods tend to use less energy, especially for transportation.

8. **Reinventing public transportation**: Ridership on public transportation systems such as the MBTA is on the rise, yet a history of underinvestment has left transit systems unable to respond to the growing 21st century demand for new transportation options. Repairing and expanding our transit systems will give more Massachusetts residents the option not to drive.

9. **New transportation tools**: Carsharing, bikesharing, ridesourcing apps such as Uber and Lyft and other high-tech tools and apps are revolutionizing transportation and providing more Massachusetts residents with the option to reduce their dependence on private cars.

10. **Electric vehicles**: Plug-in vehicles powered in part or entirely by electricity are increasingly common sights on Massachusetts roads. By 2030, Massachusetts could accommodate more than a half-million electric vehicles, slashing our reliance on petroleum.

Massachusetts should aim to reduce greenhouse gas emissions by 45 percent below 1990 levels by 2030, and seek to achieve the goal by:

1. **Implementing key policies in the Commonwealth’s Clean Energy and Climate Plan**

The Commonwealth has failed to implement several key policies proposed in the 2010 Clean Energy and Climate Plan, including policies such as clean fuel standards and new pricing models for auto insurance with the potential to curb greenhouse gas emissions from transportation. Massachusetts should move...
quickly to implement those policies or adopt alternative approaches that can deliver equal or greater emission reductions.

2. Fulfilling existing clean energy commitments

Massachusetts has made bold commitments to take advantage of all cost-effective opportunities for energy efficiency, adopt the nation’s strongest building codes, triple the number of miles traveled by walking, biking and transit, and more. Implementation of those commitments, however, has not always followed fully or quickly. Massachusetts should ensure that these and other commitments to reduce energy consumption and greenhouse gas emissions are fully implemented.

3. Taking advantage of game-changing opportunities

Taking full advantage of the game-changing opportunities discussed in this report could reduce global warming pollution in the Commonwealth by an additional 14.1 million metric tons by 2030 – achieving most of the additional emission reductions needed to hit the 45 percent emission reduction goal.

To tap those opportunities, Massachusetts should:

- Set ambitious goals for adoption of renewable energy and lower the barriers that currently stand in the way of clean energy.
- Speed the introduction of next-wave energy efficiency technologies through utility efficiency programs, adoption of a new “stretch” building energy code, and other measures.
- Focus infrastructure investments on supporting low- or zero-carbon options for transportation and energy supply, rather than locking the Commonwealth into dependence on fossil fuels for the long run.
- Following the successful example of the Regional Greenhouse Gas Initiative, consider measures to put a price on greenhouse gas emissions, providing an economic incentive for individuals and businesses to take action to reduce their contribution to global warming.
Massachusetts has a great deal at stake in the fight against global warming.

Much of what makes the Bay State special – from our long, beautiful coastline to our famous fall and winter seasons – is vulnerable to the impacts of rising seas and warmer temperatures. Already, the northeastern coast of the United States is experiencing sea level rise three to four times faster than the global average. And Boston city officials have shown that if seas rise by just 2.5 feet – a conservative end-of-century prediction – a typical Nor’easter could put much of Boston and other coastal communities underwater.

Higher temperatures could kill off New England sugar maple trees, ending maple syrup production. Global warming could mute fall colors, while killing tree species and inviting new pests. Massachusetts’ ski industry may no longer be viable by mid-century, even with increased snowmaking. That’s not to mention the increased prevalence of huge rain and snow storms (such as the blizzards of 2015); far more frequent heat waves and days over 100 degrees; fish die-offs; damage to the dairy industry; and a host of other impacts.

In an effort to forestall these and other impacts, Massachusetts has taken bold leadership. In 2008, the Legislature adopted the Global Warming Solutions Act (GWSA), which committed Massachusetts to reducing its emissions of greenhouse gases to levels consistent with those scientists believe will be necessary to prevent the worst impacts of global warming.

And in the last several years, thanks to the GWSA, the Green Communities Act, and other laws, Massachusetts has made great progress. Just a few years ago, experts foresaw a path of continual increases in global warming pollution in Massachusetts and across the country. Since then, however, emissions have begun to fall.

Today, Massachusetts uses less energy overall than we did in the late 1980s – even though our economy and population have grown.
Today, Massachusetts uses less energy overall than we did in the late 1980s – even though our economy and population have grown. We have almost completely ended our reliance on high-polluting coal and oil for electricity generation, while boosting our use of renewable energy to record levels. Our cars and trucks use less oil and we are driving less on average and biking and taking public transportation more.

There is still, however, much work to be done, and many opportunities for further progress. New technologies and new societal trends are opening the door for reductions in global warming pollution of unprecedented scale and speed. These “game changing” opportunities, many of which are highlighted in this report, can help Massachusetts meet our obligations under the Global Warming Solutions Act and fulfill our responsibility to future generations.

There is no time to waste. Many of the appliances, cars, homes and buildings we purchase or build today will remain in place until 2030 and beyond, while the infrastructure decisions we make will have repercussions for decades to come.

By setting a bold goal for emission reductions by 2030 and working to unleash the power of new, transformative technologies and practices, Massachusetts can achieve dramatic changes in our economy … and prevent unthinkable consequences for ourselves and those who will follow us.
Since 2008, the Global Warming Solutions Act (GWSA) has helped make Massachusetts a national leader in the race to reduce global warming pollution. Under the GWSA, Massachusetts is required to reduce its emissions of global warming pollution to 80 percent below 1990 levels by 2050 – a level of emission reductions consistent with what science says is necessary to prevent the worst impacts of global warming.10

The GWSA required Massachusetts to adopt interim goals for each decade until 2050. In 2010, the Commonwealth committed to a 2020 target of cutting emissions by 25 percent from 1990 levels, to 71 million metric tons of carbon dioxide equivalent (MMT-CO₂e).11 (See Figure 1.)

As of 2011, Massachusetts had reduced its greenhouse gas emissions by 15 percent, to 80 MMTCO₂e.13 Preliminary figures suggest that emissions continued to fall in 2012, with emissions of carbon dioxide from energy use – the largest source of greenhouse gas pollution – likely falling by an additional 10 percent in 2012 alone.14

Figure 1. Massachusetts Greenhouse Gas Emissions, 1990-201112

![Figure 1. Massachusetts Greenhouse Gas Emissions, 1990-2011](image-url)
Those emission reductions have been driven by forward-thinking state policies and sweeping changes in technology and society:

- **We are using less dirty energy.** Massachusetts and other Northeastern states made a strong commitment to cleaning up the region’s power grid with the creation of the Regional Greenhouse Gas Initiative (RGGI), the United States’ first mandatory cap-and-trade program for global warming pollutants. The creation of RGGI sent a strong message about the future of high-carbon power plants in the region, which, coupled with changing economic conditions in fossil fuel markets, has led to a dramatic reduction in electricity production from the Commonwealth’s dirtiest power plants. Since 2005, carbon dioxide emissions from Massachusetts power plants have been cut by more than half. Additional changes are on the horizon: retirement of the Brayton Point coal-fired power plant, scheduled for 2017, is expected to yield a 3.7 percent reduction in Massachusetts 2020 greenhouse gas emissions.

- **We are using more renewable energy.** Massachusetts has seen a dramatic increase in wind and solar energy in recent years. Between 2008 and May 2015, Massachusetts’ solar energy capacity grew more than 200-fold, from 3.6 MW to 867 MW. (See Figure 2.) Massachusetts’ onshore wind capacity has also seen dramatic growth, increasing from 5 MW to 107 MW between 2008 and mid-2015. Massachusetts’ renewable electricity standard has helped to drive the growth of clean energy within the Commonwealth, as well as in neighboring states through the use of renewable energy credits.

- **We are using energy more efficiently.** Energy efficiency improvements, driven in part by a requirement under the Green Communities Act that utilities implement all cost-effective energy efficiency opportunities, have also helped drive down greenhouse gas emissions. Between 2010 and 2012, energy efficiency savings reduced greenhouse gas emissions by an estimated 1.4 million tons, while Massachusetts has earned...
four straight years of number one rankings in the American Council for an Energy Efficient Economy’s (ACEEE) state efficiency scorecard.\(^{20}\)

- **We are driving cleaner cars and driving them less.** Massachusetts has long been a national leader in cleaning up automobile pollution, becoming one of the first states to adopt the Clean Cars Program initiated by the state of California. Adoption of those standards by states such as Massachusetts ultimately led President Obama to adopt national standards for carbon dioxide emissions from vehicles. Those standards are now helping to make the vehicles sold in Massachusetts and elsewhere around the nation more energy efficient – since 2007, the average fuel economy of a light-duty vehicle sold in the United States has increased from 20.1 miles per gallon to 25.4 mpg.\(^ {21}\)

In addition, Massachusetts residents drove fewer miles on average in 2013 than we did in 1999 – part of a national trend toward slower growth in vehicle travel. (See Figure 3.) As a result of those changes, greenhouse gas emissions from transportation in Massachusetts – which had been projected to increase dramatically by 2020 – were lower in 2012 than in any year since 1998.\(^ {22}\)

Despite the Commonwealth’s great progress, however, Massachusetts is not currently on track to meet the Global Warming Solutions Act goal of cutting greenhouse gas emissions to 25 percent below 1990 levels by 2020. Several initiatives planned by the Commonwealth to reduce emissions have either failed to meet expectations or have yet to be implemented. A 2014 report by the Global Warming Solutions Project (GWSP) estimated that, without policy changes, Massachusetts will...
Massachusetts must take immediate action to ensure that the 2020 Global Warming Solutions Act emission reduction goals are met. But the Commonwealth must also begin laying the groundwork for the next step in the fight against global warming: setting and meeting strong emission reduction goals for 2030.

Massachusetts as a Leader in New England

As New England’s largest economy, the steps Massachusetts takes to limit greenhouse gas emissions have major repercussions for the region as a whole.

More than two-thirds of the reduction in carbon dioxide emissions that occurred in New England between 1990 and 2012 took place in Massachusetts. Massachusetts energy policy decisions also have important implications for other states. Currently, the Commonwealth faces decisions regarding the importation of natural gas from points west and hydroelectric power from Quebec via northern New England, as well as decisions regarding the future of offshore wind energy that could determine whether a viable offshore wind energy industry develops in the region.

Adopting strong measures to reduce greenhouse gas emissions in Massachusetts, therefore, can catalyze broader changes in the region, creating momentum for a lasting transition to a clean energy economy.
The Challenge Ahead: The Need for Additional Emission Reductions by 2030

Massachusetts and the world must accelerate the pace of emission reductions if we are going to prevent the worst impacts of global warming. The Global Warming Solutions Act requires the Commonwealth to adopt an interim emission reduction target for 2030 and to establish a plan to meet that target. With only 15 years remaining until 2030, now is the time to take action.

The good news is that greenhouse gas emissions in Massachusetts are falling and could continue to fall further in the years ahead thanks to policies already adopted in Massachusetts and at the federal level. But the road ahead remains challenging.

A New Goal: Reducing Emissions by at Least 45 Percent by 2030

In order to reach an 80 percent reduction of greenhouse gas emissions by 2050, Massachusetts will need to set ambitious intermediate emission targets. Setting these targets is required under the Global Warming Solutions Act and is necessary for ensuring that Massachusetts continues to put in place effective steps to reduce emissions in the medium term.

Massachusetts’ existing 2050 target is consistent with the analysis of the Intergovernmental Panel on Climate Change (IPCC), which determined that the U.S. and developed countries will need to reduce emissions by 80 to 95 percent by 2050 in order to limit global temperature rise to less than 2 degrees Celsius and prevent the worst impacts of global warming.

To achieve that 80 percent emission reduction target (assuming Massachusetts reaches its 25 percent emission reduction goal for 2020), will require emission reductions averaging 1.7 million metric tons carbon dioxide equivalent (MMTCO₂e) each year between 2020 and 2050. By 2030, following that trajectory would result in Massachusetts emitting 43 percent less global warming pollution than in 1990.
Setting a goal of reducing greenhouse gas emissions to 45 percent below 1990 levels by 2030, therefore, would ensure that Massachusetts remains on pace to meet its long-term emission reduction targets. Figure 4 below illustrates a trajectory for how Massachusetts might achieve those targets over the next several decades.

**A Head Start: Current Clean Energy Policies will Reduce Growth in Emissions**

In 2010, Massachusetts established a baseline estimate for greenhouse gas emissions in 1990 and “business as usual” assumption for emissions in 2020. The Commonwealth assumed that, barring any additional action, greenhouse gas emissions would increase over the next decade, nearly returning to 1990 levels and reaching 94 MMTCO₂e by 2020.²⁸

Five years later, government and other projections of energy use paint a different picture. Should Massachusetts and the federal government continue to implement clean energy policies already on the books, carbon dioxide emissions would hold roughly steady at today’s levels between now and 2030, even in the absence of other policy action, based on projected changes in energy use in New England by the Energy Information Administration (EIA). (See Figure 5.)

The expected stagnation in emissions – despite projected economic and population growth – is due to several developments:

- **Flattening growth in electricity consumption.** ISO-New England (ISO-NE), the operator of the region’s electricity grid, produces annual forecasts of demand for electricity. In recent years, ISO-NE has begun to issue forecasts that include the anticipated impact of energy efficiency programs.
ISO-NE’s 2015 forecast estimates that, net of energy efficiency programs, electricity consumption in Massachusetts will be slightly lower in 2024 than in 2015.29

- **Declining transportation emissions.** Stronger fuel economy standards for new cars, coupled with reduced expectations of future growth in driving, are now forecast by the Energy Information Administration (EIA) to lead to an absolute decline in gasoline consumption – and, by extension, transportation carbon dioxide emissions – in New England over the coming decades.30 By 2030, transportation carbon dioxide emissions in Massachusetts can be expected to fall to approximately the level of the late 1980s, even with no further policy action.31

- **Declining residential energy consumption.** Energy efficiency efforts are also expected to lead to declines in residential energy consumption, with the EIA forecasting that energy use in New England homes will decline by an average of 0.8 percent per year between 2013 and 2040.32

Assuming that all other sources of emissions remain stable between 2012 and 2030, Massachusetts would be expected to emit about 72.8 million metric tons carbon dioxide equivalent in 2030. With a 2030 emission target of 51.9 MMTCO₂e, Massachusetts will therefore need to find savings of 20.9 million metric tons in 2030 through additional public policy initiatives and other steps. (All projections of future energy use are highly uncertain, meaning that Massachusetts should identify and implement policies intended to deliver greater levels of emission reductions to ensure that the overall target is met.)

Emission reductions of that scale will be challenging to achieve – for example, 20.9 million metric tons is greater than the carbon dioxide emissions produced by all the electricity currently consumed in Mas-
sachusetts. Based on 2011 figures (see Figure 6), major opportunities for emission reductions exist in three categories:

- **Cleaner electricity:** Electricity consumption in Massachusetts was responsible for about 18 percent of the state’s greenhouse gas emissions in 2011 and about 23 percent of energy-related carbon dioxide emissions.\(^3\)\(^3\) Continuing to use energy more efficiently, while ramping up production of clean, renewable energy, can reduce emissions from electricity production.

- **Better buildings:** Direct consumption of fossil fuels in Massachusetts homes, businesses and industry accounts for about one-third of the state’s fossil fuel-related carbon dioxide emissions and 26 percent of greenhouse gas emissions. Improved energy efficiency and substitution of clean sources of energy for polluting fossil heating fuels can reduce emissions in this category.

- **Smart transportation:** Transportation emissions of carbon dioxide accounted for 43 percent of fossil fuel carbon dioxide emissions and 38 percent of greenhouse gas emissions in 2011.\(^3\)\(^4\) Promoting smart growth, expanding access to walking, biking and public transportation, and replacing gasoline-powered cars with clean, efficient electric vehicles can curb emissions from transportation.

Thankfully, game changing opportunities exist in each of these categories. By tapping these transformative opportunities, Massachusetts will have the ability to reach its emission reduction targets and establish itself as a global leader in the transition to a clean energy economy.
New and improving technologies, as well as changing societal preferences and economic conditions, create new emission reduction opportunities for Massachusetts, many of which would have been unimaginable just a decade ago. By taking advantage of these game changing opportunities, Massachusetts can achieve significant emission reductions by 2030 and put the state on track to achieve the even more ambitious emission reductions needed in the years to come.

Making Massachusetts a Renewable Energy Powerhouse

1: Solar Photovoltaics

Solar power is on the rise in Massachusetts and across the country. Since the Commonwealth first set an ambitious goal for solar energy development in the 2008 Green Communities Act, the amount of solar energy installed in the Commonwealth has increased more than 200-fold. As of the end of 2014,

Workers install solar panels at an installation in Westford, one of many solar energy projects installed throughout the Commonwealth in recent years.
Massachusetts had enough solar energy capacity to power 110,000 homes.\(^{37}\)

Solar energy is a powerful energy solution for Massachusetts:

- **Locally available.** Solar panels can be installed on rooftops and on unused land such as capped landfills and brownfields, generating electricity without disturbing natural areas. Solar energy can also be produced close to locations of demand, reducing the need for long-distance transmission lines. And because solar energy is distributed across the Commonwealth, it creates local jobs in installation that cannot be outsourced.

- **Increasingly affordable.** The price of solar energy has been falling dramatically. Since 1998, the installed price of solar energy systems has fallen at a rate of 6 to 8 percent per year, and prices have plummeted by more than one-third since 2009.\(^{38}\) Today, the price of solar electricity is, in many cases, competitive with that of conventional electricity generation, and analysts believe that solar prices still have room to fall.\(^{39}\) Indeed, analysts now estimate that solar power will cost half as much by 2020 as had been forecast just five to 10 years ago.\(^{40}\)

- **Huge potential.** According to the National Renewable Energy Laboratory (NREL), Massachusetts has the technical potential to generate 111,000 GWh of solar electricity per year – enough to provide twice the amount of electricity the state currently consumes.\(^{41}\) There are more than 700,000 home and business rooftops in Massachusetts that could host solar panels.\(^{42}\)

- **Zero-carbon and fossil fuel-free.** Solar panels produce no global warming pollution and can reduce Massachusetts’ dependence on fossil fuels, which are volatile in price.

After Massachusetts surpassed its 400 MW solar goal ahead of schedule, former Governor Deval Patrick upped the goal to 1,600 MW by 2020, which would require installing 194 MW per year for the rest of the decade. Massachusetts has already been installing solar energy at a faster pace, with 306 MW of solar capacity added in 2014 alone.\(^{43}\)

With solar energy prices continuing to fall, Massachusetts should spur growth in solar power by setting the ambitious but achievable goal of getting 20 percent of its electricity from solar by 2025 and at least maintaining that level thereafter. Hitting that goal would require total installed solar capacity of about 10 GW. Massachusetts could achieve that level by maintaining an annual percentage growth rate of solar energy slower than that of recent years.\(^{44}\)

Key steps to move Massachusetts toward a target of 20 percent solar electricity by 2025 include:

- Setting an ambitious solar goal for Massachusetts and ramping up the solar “carve-out” in the state’s renewable electricity standard.

- Immediately removing the cap on participation in net energy metering, the program through which solar panel owners receive fair compensation for the extra power they supply to the electric grid.\(^{45}\) Without access to net metering, Massachusetts customers will find it more difficult and more expensive to adopt solar energy, slowing the growth of clean energy in the Commonwealth.

- Ensuring that any ratemaking affecting solar energy considers the value that it provides to the grid, all ratepayers and society.

- Continuing and expanding programs such as Solarize Mass that make it easier and more affordable for Bay State residents and businesses to “go solar.”
2: Offshore Wind Energy

The recent struggles of the Cape Wind project following more than a decade of conflict and controversy are a blow to the development of wind energy off the New England coast. But offshore wind is already re-emerging as a vital source of zero-carbon energy in Massachusetts and the region.

Offshore wind has several important advantages for Massachusetts:

- **Tremendous potential**: Massachusetts has the potential to develop 200 GW of wind energy capacity in its offshore waters – enough to produce more than 11 times the amount of electricity the state consumes in a year. More than half of Massachusetts’ offshore wind capacity is located in waters less than 60 meters deep, which are considered feasible for non-floating turbine construction by the National Renewable Energy Laboratory.

- **Renewable and zero-carbon**: Offshore wind produces no carbon emissions and reduces the region’s dependence on fossil fuels such as natural gas that experience volatility in price.

- **Close to centers of demand**: Offshore wind energy is available in close proximity to the Northeast’s major sources of electricity demand, which are located along the coast, reducing the expense and disruption involved in bringing renewable energy to Massachusetts from other regions.

- **Proven**: Offshore wind has generated power in Europe for years and now generates nearly 1 percent of all European electricity, with large capacity additions on the way.

In its National Offshore Wind Energy Grid Interconnection Study, the U.S. Department of Energy created a feasible scenario for incorporating 54 GW of offshore wind into the U.S. grid. Included in the study were six offshore sites in Massachusetts, with 3.7 GW of total capacity – enough to cover 22 percent of Massachusetts’ total electricity demand in 2012. This is in line with the state’s written interest in developing up to 4 GW of offshore wind capacity, approximately enough to supply 20 percent of Massachusetts’ projected electricity demand in 2030.
The long lead time for offshore wind projects suggests that, if Massachusetts is to rely on offshore wind as a carbon emission reduction tool by 2030, the Commonwealth must lay out a pathway for offshore wind now.

One important step toward that end was the auctioning of areas off the Massachusetts coast for offshore wind energy development in January 2015. Full development of the areas that were leased could yield approximately 2 GW of wind energy capacity, enough to power roughly 700,000 homes.

But offshore wind development won’t occur without a market among the state’s electric utilities. Offshore wind energy remains more expensive than conventional sources of electricity such as natural gas, but it comes with big economic advantages. Offshore wind energy can diversify the region’s electricity supply, shielding Massachusetts consumers from the impacts of natural gas price spikes and supply shortages, while bringing jobs and economic activity to coastal communities.

Massachusetts’ enormous potential for offshore wind may one day be considered among our state’s most important assets. The Commonwealth should set a clear goal of obtaining 20 percent of our electricity from offshore wind energy by 2030 and enact policies designed to support the growth of offshore wind in the years to come.

3: Energy Storage

Renewable energy must play an important role in Massachusetts’ transition to a low-carbon economy. But the integration of large amounts of wind and solar power, which produce electricity intermittently, can pose challenges to the electric grid. Massachusetts’ current natural gas-fueled electricity generation capacity, coupled with strategies to manage electricity demand and strategic investments in transmission capacity, can enable the state to integrate much more renewable energy than is currently present on the grid.

Still, if Massachusetts is to receive more than 40 percent of its electricity from wind, solar and other forms of renewable energy by 2030, additional steps will need to be taken to accommodate that growth. Energy storage technologies can help resolve that challenge, capturing excess energy from the grid during times of high renewable energy production and releasing it back into the grid at a later time when those resources are not available. Storage technologies can be applied at utility scale or be distributed at a small scale throughout the grid.

Many technologies can be used to store energy; indeed, energy storage is already part of the New England grid in the form of the Northfield Mountain pumped-storage hydroelectric plant in Massachusetts, which was the biggest in the world when it went into service in 1972, with 1.1 GW of capacity. Other technologies, such as flywheels, thermal storage and compressed air storage can also be used to harness energy for later use.

Perhaps the most exciting prospects for energy storage, however, are in the realm of batteries. Driven by advances in consumer electronics, research for electric vehicles, and growing economies of scale, battery storage is becoming an increasingly feasible and cost-effective option. The price of electric vehicle batteries, for example, dropped by 40 percent from 2010 to early 2013. One recent analysis predicted that the lithium-ion battery market would quadruple from 2013 to 2020, and Tesla Motors expects that its newly announced “Gigafactory” alone will produce more lithium-ion battery capacity in 2020 than the entire global market produced in 2013.

California – like Massachusetts, a frequent clean energy pioneer – has adopted an energy storage requirement for utilities, requiring the installation of
an additional 1.325 GW of storage capacity by 2020, or 3 percent of California’s statewide peak electric load. But energy storage is proving to be economically competitive even without the mandate; energy storage technologies recently won bids to provide a share of the electricity currently provided by the retiring San Onofre nuclear power plant. Winning technologies included batteries as well as units that make ice during nighttime, off-peak hours and provide cooling to buildings during the daytime. Outside of California, Texas utility Oncor has proposed a $5 billion investment in energy storage beginning in 2018.

Massachusetts companies are also developing energy storage solutions. Tyngsboro-based Beacon Power has installed flywheel storage systems at three sites in the Northeast, while Cambridge-based startup Ambri is working to demonstrate and bring to market a new type of battery developed by research at the Massachusetts Institute of Technology. Regulators in Massachusetts are giving thought to the importance of energy storage. The Department of Public Utilities (DPU) issued a “grid modernization” order on June 12, 2014, which requires state utilities to submit 10-year plans for modernizing the grid. In May 2015, the Baker administration announced a $10 million Energy Storage Initiative intended to support the deployment of energy storage technologies and the development of an energy storage industry in the Commonwealth.

Massachusetts should evaluate the role energy storage can play in grid modernization efforts by supporting the demonstration of promising new technologies and considering whether it is appropriate to set a specific target for energy storage deployment, as California has done. Massachusetts should study the potential for distributed energy storage and plug-in electric vehicles (see page 36) to serve as a source of energy storage for the grid and, if they are found to have the potential to play such a role, the Commonwealth should design appropriate incentives and rate structures to encourage their deployment and use.

**Better Buildings**

Energy consumption in homes, commercial buildings and industry accounts for more than half of Massachusetts’ energy-related emissions of carbon dioxide.

Over the last decade, Massachusetts has made progress in improving the energy efficiency of our buildings. Massachusetts consistently ranks at or near the top among states when it comes to energy savings delivered through utility efficiency programs and updated codes and standards. Energy efficiency programs under the MassSAVE banner have helped thousands of Massachusetts residents save energy and money through building weatherization, installation of energy efficient lighting and appliances, and other measures.

Massachusetts’ commitment to energy efficiency can be expected to continue in the years ahead, due in part to the legal requirement that utilities pursue all cost-effective energy efficiency opportunities.

Energy efficiency improvements are often thought to get more difficult and expensive as time goes on and the “low-hanging fruit” savings – those that are easiest and cheapest to obtain – are realized. Indeed, ISO-New England’s forecast of energy efficiency resources for Massachusetts assumes that the real cost of every megawatt-hour saved through energy efficiency will increase by 5 percent per year.

However, recent experience has shown that low-hanging fruit doesn’t disappear once it is picked – rather, it grows back. Continued investment in energy efficiency yields new insights into how to save energy more cost-effectively, existing energy efficient
technologies become more cost-competitive over time, and new technologies find their way onto the market. In fact, the cost of energy efficiency savings in Massachusetts has remained largely stable in recent years, even as the amount of energy efficiency savings delivered by those programs has increased.\(^{67}\) (See Figure 7.)

Unfortunately, Massachusetts has failed to keep up fully with changes in the world of energy efficiency. Efforts such as Massachusetts’ “stretch” energy code for buildings – an optional, highly efficient building code that can be adopted by municipalities – were once cutting-edge, but have now fallen behind the times.

Today, an array of new, game-changing opportunities creates the potential for Massachusetts to ramp up the energy efficiency of our buildings. To take advantage of those opportunities, Massachusetts must once again take innovative steps to encourage energy efficiency.
4: New Energy Efficiency Tools

New innovations are occurring throughout the energy efficiency industry, some with the potential to transform markets and trigger dramatic reductions in energy consumption. In this section, we highlight two such innovations.

“Intelligent Efficiency”

The Internet and smartphones have revolutionized many aspects of American life, and now they are poised to revolutionize the way we use energy.

Improving energy efficiency has traditionally meant making technical changes to the design of buildings or specific pieces of equipment – for example, improving the aerodynamics of a car or installing insulation in an old house. Today, however, new technologies make it possible to improve the performance of entire energy systems – to see sources of energy waste that had once been invisible, to understand the impacts of changes in our behavior on energy use, and to enable our machines to respond instantly and intelligently to feedback they receive from users or the grid.

The American Council for an Energy-Efficiency has termed these energy-saving opportunities “intelligent efficiency” and they have the potential to transform how we use energy. In the home, for example, intelligent efficiency measures might:

- Enable you to control your furnace or appliances remotely and provide you with information on how to use your household equipment more efficiently.
- Enable “smart power strips” to automatically turn off electronics that are no longer in use or “smart windows” to shade windows on sunny days to keep rooms cool.
- Track your energy use in near-real time, enabling you to identify sources of energy waste and take action.
- Have your home’s energy consumption patterns assessed remotely by an efficiency expert, allowing for quick, inexpensive recommendations for improvements in home energy efficiency.
- Allow equipment to respond to signals from the grid – for example, by delaying a wash cycle.

Programmable thermostats are among the smart energy controls with which Americans are most familiar. New technologies enable consumers and businesses to manage their energy use far more intelligently, with big potential benefits for the environment.
during times when electricity demand and prices are high – thereby saving money and allowing for more efficient use of the grid.

These and other measures have tremendous potential for reducing energy use in homes, business and industry. An ACEEE study estimates that intelligent efficiency measures in the commercial and industrial sectors alone could save $55 billion in energy costs annually by 2035, with energy consumption reductions of 28 percent in the commercial sector and more than 20 percent in the industrial sector. Economy-wide, ACEEE estimates that intelligent efficiency measures could reduce energy use by 12 to 22 percent.

**Lighting: LEDs**

Light-emitting diodes (LEDs) are extremely energy efficient sources of light, consuming about 75 percent less energy than traditional incandescent bulbs. LEDs have other advantages as well: they are extremely long-lasting and do not contain mercury. LEDs, however, have been slow to make a major impact in the lighting market due to high costs.

That is beginning to change. Across Massachusetts, LED streetlights are becoming increasingly common, saving municipalities money on electricity. Meanwhile, prices for LED bulbs for home and business use are falling fast: Northeast Energy Efficiency Partnerships (NEEP) estimates that the prices for various LED products fell by 16 to 42 percent during 2014.

Replacing existing lights with LED lighting by 2030 would yield dramatic reductions in electricity use for lighting. As of 2012, lighting accounted for about 12 percent of U.S. electricity consumption. The U.S. Department of Energy estimates that, by 2030, LEDs could account for 84 percent of all light bulb sales in the United States and drive a 40 percent reduction in energy consumption for lighting relative to baseline forecasts. Massachusetts can tap the benefits of LEDs by ensuring that electric utilities fulfill their responsibility to take advantage of all cost-effective opportunities for energy efficiency improvements. NEEP estimates that, with LED prices falling, energy efficiency programs will find it more cost-effective to support LED programs than compact fluorescent lighting programs by 2016. Aggressive programs to encourage Massachusetts residents to switch to LEDs, beginning in 2016, could lead to significant drops in electricity consumption.

Taking advantage of these new opportunities will require Massachusetts to redouble its commitment to energy efficiency by ensuring that efficiency program administrators are identifying and pursuing all cost-effective energy efficiency improvements and ensuring that the value of energy efficiency to ratepayers and the environment is adequately reflected in calculations of cost-effectiveness.

**5: Renewable Heating and Cooling**

Renewable energy has become an important source of electricity in Massachusetts and elsewhere in recent years, but has yet to make major inroads as a source of heating and cooling for buildings. Recent advances in technology are about to change that, making renewable heat and cooling an increasingly attractive option for reducing our dependence on fossil fuels.

About one-third of energy expenditures by Massachusetts homes and businesses are for heating and cooling. The vast majority of that energy comes either directly from fossil fuels – oil and natural gas – or from electricity generated by fossil fuel-fired power plants. Yet, there are many technologies that can be used to replace some or all of the energy we use to heat and cool our buildings with energy from renewable sources. Among those technologies are:
• **Air-source heat pumps:** Electric powered air-source heat pumps extract heat from the ambient air and use it to heat a building, working in reverse to provide cooling during the summer months. Historically, air-source heat pumps have not functioned well in cold climates, requiring the use of inefficient electric resistance heaters as a backup source of heat on the coldest days. But recent improvements in technology have made them a viable option in the region. Powering air-source heat pumps with increasingly lower-carbon electricity can result in a dramatic reduction in greenhouse gas pollution from home and commercial heating.

• **Ground-source heat pumps:** Ground-source (geothermal) heat pumps use the near-constant temperatures found underground to warm buildings in the winter and cool them in the summer.

• **Solar thermal:** Solar thermal systems capture and store the heat of the sun’s rays to help heat or cool a home, or to provide hot water. Solar thermal systems come in a variety of forms – some large or neighborhood-scale systems have even been built that can store solar heat for use during cold-weather months.

• **Biomass heat:** High-efficiency biomass heat – such as that provided by wood pellets or biofuels – can replace fossil fuel heat and, depending on the source of the materials used, reduce global warming pollution. (Sourcing of biomass from sustainable sources is critical for ensuring that biomass heat provides net environmental benefits.) Methane from landfills and sewage treatment plants can, in some circumstances, also be used to offset heating load in buildings.

An analysis conducted by Navigant Consulting and Meister Consultants Group estimates that, with strong and aggressive state government support, Massachusetts could replace 30 to 32 percent of its thermal load with renewable thermal technologies by 2030.78

The rapid expansion of solar energy in Massachusetts in recent years is an example of how aggressive, smart policies to speed the deployment of clean energy can make a major impact. To achieve similar results with renewable thermal technologies, the Commonwealth must take bold action including:

• Setting an enforceable, long-term target for the percentage of thermal energy obtained from renewable sources. Such a target could be woven...
into a more aggressive Alternative Energy Portfolio Standard or established as a separate standard.

- Continuing to refine, expand and fund programs to support the installation of renewable thermal technologies.

- “Leading by example” through the installation of renewable thermal technologies at state facilities.

- Incorporating renewable thermal technologies into building energy codes, beginning with a revised “stretch” energy code.

6: Zero Net-Energy Buildings

The buildings we build in Massachusetts today will remain standing for decades, even generations. With science warning us of the need to slash greenhouse gas emissions by 80 percent or more by mid-century, it is imperative that the buildings we construct today use as little fossil fuel as possible.

Thankfully, it is now possible to build homes and commercial buildings that produce as much energy as they use. These zero net-energy (ZNE) buildings pair ultra-efficient designs with an on-site source of renewable energy – such as solar photovoltaics (page 18) or renewable thermal technologies (page 25) – to eliminate net consumption of energy over the course of a year.79

An increasing number of ZNE buildings can be found across Massachusetts. In late 2014, Massachusetts opened the new field headquarters of the Division of Fish and Wildlife, a 45,000-square foot facility in Westborough. The building uses approximately 60 percent less energy than similar buildings due to its highly efficient design, and relies on rooftop solar panels for the rest of its energy needs.80 Several residential builders in the state now construct zero net-energy homes of a variety of designs.

In 2010, the Massachusetts Zero Energy Building Task Force issued a series of recommendations, including setting high energy efficiency standards for new state-owned buildings, adopting strong performance standards for new buildings, and creating a series of incentives to encourage the development of highly efficient new buildings.81

The Commonwealth has made some progress toward these goals. In recent years, Massachusetts has:

- Adopted revised building energy codes as they have been updated at the national level. Building energy codes require new buildings and those undergoing extensive renovation to incorporate energy efficient technologies. Massachusetts’ adoption of the 2012 IECC residential energy code was estimated to cut energy costs by about 29 percent compared with

Photo: Massachusetts Executive Office of Energy and Environmental Affairs

A solar walkway helps generate clean energy at North Shore Community College’s Health Professions & Student Services Building – a zero net-energy building completed in 2011.
Empowered municipalities to adopt optional "stretch" energy codes that provide additional energy savings above and beyond the base code. Under the Green Communities Act, 146 municipalities adopted the Stretch Energy Code, which provided energy savings of approximately 20 percent beyond the 2009 IECC codes.

- Taken the first steps toward creating a rating system for commercial building energy performance — creating the equivalent of a new-car fuel economy label for buildings that would enable building owners, tenants and prospective buyers to understand a building’s energy performance and factor it into their decision-making. The Commonwealth launched a pilot program for commercial building energy rating in 2012, and the city of Boston adopted a rating requirement for large commercial buildings that affects nearly 1,400 buildings in the city.

- Built at least two new state buildings to zero-net energy standards.

Over the next 15 years, Massachusetts should take steps to move zero net-energy buildings from an occasional curiosity to a common sight to a universal phenomenon for new construction. Between 2010 and 2030, Greater Boston alone will add as many as 300,000 new units of housing, about one-third of which will be single-family homes, along with thousands of commercial buildings.

The average new housing unit in the Northeast that uses natural gas produces about 4.4 metric tons per year of carbon dioxide from gas use, while the average new oil-fueled home produces 7.7 metric tons from oil burning alone. Building new housing units to zero-net energy standards, therefore, could avoid hundreds of thousands of metric tons of carbon dioxide pollution each year, helping Massachusetts to achieve its emission reduction goals both in the short run and over the long term.

To move toward a zero-net energy building future, Massachusetts must take concrete steps now, including:

- **Continuing to lead by example:** Former Gov. Deval Patrick established a “lead by example” initiative for the Commonwealth, putting state government at the center of efforts to improve the energy efficiency of Massachusetts’ building stock. The initiative called for improvements in the energy efficiency of existing state buildings and required all new buildings to meet the Mass LEED Plus standard, which reduces energy consumption by 20 percent compared to the base building energy code. These and other efforts reduced the energy consumption of state buildings on a per square foot basis by 3 percent between fiscal 2004 and fiscal 2012. Gov. Charlie Baker should renew these efforts by establishing more ambitious energy efficiency targets for new state buildings and ensuring that an increasing share of state buildings meet ZNE standards.

- **Renewing the Stretch Energy Code:** Massachusetts’ Stretch Energy Code was a tremendous tool for municipalities to achieve greater energy efficiency performance from new buildings in their cities and towns, and helped prepare the way for adoption of stronger statewide energy codes. Today, however, the Stretch Energy Code is outdated, providing little to no savings versus the recently improved base energy code. Ratcheting up the Stretch Energy Code to exceed the updated state building code provides the next step toward zero-net energy codes.

- **Implementing the remaining recommendations of the Zero Net Energy task force.**

- **Requiring all new homes built in the Commonwealth to be “solar ready,”** thereby making it easier to integrate solar energy at a later date.
Smart Transportation

Transportation is Massachusetts’ number one source of greenhouse gases, accounting for roughly 40 percent of the state’s energy-related carbon dioxide emissions. Reducing transportation emissions – both through cleaner cars and reductions in motorized vehicle trips – will be a critical strategy for meeting the Commonwealth’s emission reduction goals.

As noted earlier (see page 16), transportation emissions are already likely to decline in the years to come due to slower growth in driving, improved vehicle fuel economy, and increasing penetration of electric vehicles. Massachusetts also has access to public policy tools like clean fuel standards and pay-as-you-drive auto insurance – included in previous climate action plans – that can drive down emissions if they are implemented. (See page 38.)

Changes in land-use and growth patterns, the emergence of new types of transportation services, and the potential for faster adoption of electric vehicles all create new opportunities for Massachusetts to achieve further reductions in emissions from transportation.

7: Urbanization and Smart Growth

The past decade has seen a sea change in patterns of residential and commercial development in Massachusetts. For decades after World War II, Massachusetts residents increasingly moved to the suburbs while older cities lost population. Between 1950 and 1980, for example, Boston lost 240,000 residents, Cambridge 15,000, Worcester 42,000, and New Bedford 11,000, even as Massachusetts as a whole was adding more than a million new residents.

In recent years, however, the trend toward far-flung suburban development has slowed. Between 1990 and 2000, according to data from the Metropolitan Area Planning Council (MAPC), the population of Greater Boston’s outer “developing suburbs” grew more than twice as quickly as the population of the region’s “inner core.” Since 2010, however, those proportions have been roughly reversed, with inner core

In the last several years, increased demand for homes and offices in city neighborhoods such as Boston’s Seaport District has led to an urban construction boom – helping to reverse long-standing trends toward accelerating suburban sprawl.
communities accounting for twice as much regional growth as the far-flung suburbs along Interstate 495. (See Figure 8.)

Land use and development patterns have major implications for greenhouse gas emissions. Compact, “smart growth” style development has been shown to reduce greenhouse gas emissions by as much as 35 percent compared with spread out, sprawl-style development. Smart growth reduces greenhouse gas emissions in several ways:

- **Less energy invested in infrastructure:** Compact development requires less asphalt for roads and less pipe for water and sewer lines. Those materials and others require energy to manufacture, transport, install and maintain. Research suggests that the construction of compact communities requires up to 76 percent less “embodied energy” in infrastructure relative to sprawling communities.

- **Less energy-intensive homes:** Residential energy use in compact neighborhoods also tends to be lower than that in sprawl-style neighborhoods, as homes are generally smaller and more people live in multi-unit or attached buildings.

- **Less travel and more travel choices:** Perhaps the greatest emission reduction benefit of compact development comes in the form of reduced transportation emissions. Compact neighborhoods – whether in a city or a suburban area – allow for many more services and destinations to be accessed nearby, resulting in shorter car trips and greater ability to conduct daily tasks via transit, on foot or by bicycle.

Residents of Greater Boston’s “inner core” communities, for example, drive an average of less than 5,000 miles per year, compared with more
than 10,000 miles per year for residents of the region’s sprawling “developing suburbs.” (See Table 1.)

Table 1. Average Vehicle-Miles Traveled Per-Capita by Community Type, Greater Boston

<table>
<thead>
<tr>
<th>Community Type</th>
<th>Per-capita Average VMT (2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing suburbs</td>
<td>10,159</td>
</tr>
<tr>
<td>Maturing suburbs</td>
<td>8,483</td>
</tr>
<tr>
<td>Regional urban centers</td>
<td>6,993</td>
</tr>
<tr>
<td>Inner core</td>
<td>4,693</td>
</tr>
</tbody>
</table>

Continued movement of people and businesses to compact neighborhoods can reduce the number of miles Massachusetts residents drive while increasing the number of people who can walk, bike or take transit to their destinations — especially if walkable, transit-accessible neighborhoods are within the financial reach of individuals and families of all income levels. The most recent population projections from the UMass Donohue Institute suggest that communities where people currently drive less than average are expected to grow more quickly than communities where people typically drive a lot. The city of Boston, for instance, is expected to add an additional 100,000 residents between 2015 and 2030, bringing its population close to the all-time peak of 1950.

The result of those changes alone would be a decrease in per-capita VMT of nearly 1 percent versus 2010 levels and nearly 8 percent compared with national forecasts for 2030. In reality, the effects of smart growth strategies would likely be even greater. The creation of mixed-use neighborhoods in suburban areas, acceleration of transit-oriented development, and revitalization of the Commonwealth’s “Gateway Cities” could allow for further reductions in vehicle travel. The building energy savings of more compact living, coupled with reduced energy use for the installation of new roads, water and sewer lines and other forms of infrastructure in “greenfield” suburban communities, would yield further opportunities for reductions in emissions.

The continuation of the recent trend toward walkable communities is not a given, however. State policymakers can play a key role in continuing and accelerating the trend by:

- Aligning state investments to support compact development and expand the number of Massachusetts residents with the ability to walk, bike or use public transportation.
- Supporting the expansion of housing, especially affordable housing, in walkable, compact neighborhoods, particularly near transit stations and stops.
- Reforming zoning to remove obstacles to walkable, mixed-use development.
- Expanding access to high-quality public transportation.

8: Reinventing Public Transportation

Massachusetts is one of the most transit-oriented states in the nation, ranking behind only New York and New Jersey for the percentage of residents who commute to work via transit. Ridership on Massachusetts’ flagship public transportation system, the Massachusetts Bay Transportation Authority (MBTA), has increased by 22 percent since 1992 and 11 percent since 2007. Nearly 10 percent of Massachusetts residents now commute to work via transit, up from 8.7 percent in 2000 — a gain of more than 50,000 transit commuters during that time.

Transit also plays a key role in reducing carbon dioxide emissions in the Commonwealth. According to research funded by the Transit Cooperative Research Program of the National Academy of Sciences, transit systems
in the Boston urbanized area reduces vehicle travel by as much as 6.7 billion miles per year by acting as a substitute for driving and supporting less auto-intensive patterns of land use. In the process, transit averts more than 2.4 million metric tons of carbon dioxide pollution each year.

Massachusetts’ transit system, however, is far from perfect. The MBTA service disruptions that occurred during the winter of 2015, the crowding and delays that often vex transit riders, and the lack of access to quality transit in many parts of the Commonwealth are evidence of the need for new emphasis on – and investment in – public transportation. Massachusetts officials and stakeholders must recognize that we have no choice but to simultaneously reform the T and grow public transportation.

Transit investments – especially transformative ones with the potential to help the Commonwealth meet its emission reduction targets – do not happen overnight. While some transit improvements can be made quickly, and new types of transportation services can help to reduce emissions (see page 35), major improvements in transit systems can take years to plan and execute. If public transportation improvements are to play a role in achieving an aggressive emission reduction target for the Commonwealth for 2030, we need to begin planning now.

Public officials in Massachusetts and across the Northeast have proposed major improvements to the region’s transit systems with the potential to reduce greenhouse gas emissions.

- **MBTA improvements** – The extension of the MBTA Green Line to densely populated Somerville, along with the addition of new “infill” stations (such as the recently completed Assembly station on the Orange Line), will expand and improve access to quality transit in the Boston area. Improvements to the capacity of the MBTA’s central subway system, as well as the expansion of South Station, will also be necessary to accommodate the new demand for transit created by the increase of jobs and residents in the region’s urban core.

- **Bus rapid transit** – The MBTA is in the process of extending Silver Line bus service from the Seaport District to Chelsea and East Boston. The project is one of several potential bus rapid transit (BRT) projects in the Boston area that could improve the quality of transit service to underserved communities and corridors. A recent report identified five corridors in the Boston area with potential for “gold standard” BRT service, in which buses travel on separate rights-of-way with priority passage at traffic signals, use off-board fare collection, and employ other improvements over traditional bus service.

The restoration of Amtrak service to Northampton – a product of track upgrades on the “Knowledge Corridor” line through the Pioneer Valley – is just one of several recent, ongoing and proposed projects to expand access to rail service in the Commonwealth.
• **Passenger rail expansion** – In late 2014, Amtrak kicked off service on the revitalized “Knowledge Corridor,” which connects Springfield, Holyoke, Northampton and Greenfield with Vermont, New York City and the rest of the Northeast. Commuter rail service on the corridor could follow. Preparatory work is underway for the South Coast Rail project, which would link Fall River and New Bedford to Boston via rail. State officials have also studied (with officials from neighboring states) rail service between Boston and Montreal and expanded service linking Boston with New York via the “Inland Route,” which passes through Springfield. Expanding and improving service on the Inland Route could ease capacity constraints along Amtrak’s busy Northeast Corridor while expanding access to the regional rail network for residents of central and western Massachusetts.

• **New urban rail service** – The MBTA is considering a new type of rail service in Greater Boston designed to facilitate new transit connections and to provide rapid transit service to areas beyond the core MBTA subway lines. The new service would use diesel multiple unit (DMU) vehicles – self-propelled vehicles that travel on commuter rail tracks and have the capability to provide quicker, more flexible and more frequent service than traditional commuter rail vehicles. The new service would allow for direct connections between a planned new “West Station” to be located in Allston and both of Boston’s current main train stations. It would also provide direct commuter rail service to Boston’s fast-growing Seaport district, and enable rapid transit-style service along the newly revitalized Fairmount Line as well as to Waltham and Lynn.

• **High-speed rail** – Amtrak has laid out an ambitious plan for improvement of high-speed rail service between Boston and Washington, D.C., which has the potential to reduce the number of high-emitting airplane trips in the Northeast. By 2040, Amtrak aspires to have a modern, fully-dedicated high-speed rail line in place capable of whisking passengers between Boston and New York in little more than an hour-and-a-half. In the meantime, however, Amtrak plans upgrades on the existing Northeast Corridor tracks that, by 2025, would shave 9 minutes off of the Boston to New York trip, and cut the time to travel from Boston to Washington, D.C., by 20 percent. The improvements would also add capacity to the line, which currently strains to accommodate demand.

The impact of these changes on emissions is difficult to quantify, but likely significant.

• A study of various options for the restoration of Inland Route and Boston-to-Montreal service estimated that the services could attract between 1 million and 1.5 million passengers per year boarding at Massachusetts stations, almost all of whom would be new riders.

• Extension of the Green Line is expected to reduce carbon dioxide emissions by more than 6,000 metric tons per year, while extension of Silver Line service to Chelsea would reduce emissions by a further 380 tons per year by 2035.

• Improvements in high-speed rail could increase the share of travelers between major East Coast cities using rail. Capacity improvements on the Boston-New York corridor would enable expansion of the popular Acela Express service, which often sells out during peak periods. Achievement of Amtrak’s 2025 vision for Northeast Corridor improvements would allow for trips from Boston to Washington, D.C., to take approximately as long as trips currently take from Boston to Philadelphia, enabling Amtrak to cut further into the market share of air travel on the Northeast Corridor.

Addressing the long-term challenges facing the MBTA and regional transit authorities is a critical first step in
supporting the growth of public transportation use in the Commonwealth. In the worst-case scenario, failing to invest in public transportation could drive away new residents and businesses attracted to Massachusetts by our diversity of transportation options and reduce the attractiveness of living and working in our cities, hampering future “Smart Growth” initiatives. (See page 29.) Reinvesting in our transit systems, on the other hand, can improve the reliability and quality of service, while providing more Massachusetts residents with access to high-quality transit.

The Commonwealth should continue to press forward with plans to expand the state’s rail network, including by providing quicker, more reliable service between Boston and New York via Springfield, improved service in the Pioneer Valley and to the South Coast, and an enhanced “urban rail” network in greater Boston. In addition, Amtrak should continue to pursue high-speed rail improvements along the Northeast Corridor, including improvements along the Boston to New York City portion of the route.

Achieving these improvements will require major investments – a difficult reality at a time of stretched transportation budgets. But with transportation representing Massachusetts’ number one source of carbon dioxide emissions, such investments must be priorities in the Commonwealth’s strategy to reduce global warming pollution. California, for example, is using revenues from its carbon cap-and-trade system to support a similar transformative investment in its transportation system – the construction of a high-speed rail line between San Francisco and Los Angeles – as well as smaller improvements in transit and other non-driving forms of transportation across the state.115 The state currently plans to dedicate 60 percent of cap-and-trade revenue toward low-carbon transportation projects and smart growth initiatives.116

**GreenDOT and Massachusetts’ Mode Shift Goal**

Improvements in public transportation, such as expansion and improvement of the state’s rail network, together with focusing future growth in cities or “smart growth” communities, can help Massachusetts achieve the state’s goals for reducing the impact of the transportation system on the climate. The state’s GreenDOT initiative made a host of environmental commitments regarding the operation of the state’s transportation system, perhaps the most important of which is the “mode shift goal,” which aims to triple the share of travel taking place on transit, by bicycle or on foot by 2030.

Assuming that half of the new travel on those modes would replace car travel, achievement of the mode shift goal alone would reduce greenhouse gas emissions by approximately 1.1 million metric tons per year.
9: New Transportation Tools

Information technology isn’t just creating new opportunities for energy efficiency in homes and buildings (see page 24), but it is also rapidly changing the way we get around our cities and towns.

The past decade has seen the emergence of a wave of new transportation technologies and tools – from carsharing to bikesharing to ridesourcing services such as Uber and Lyft – that are giving Massachusetts residents new options for transportation. To date, these new services have largely taken root in Greater Boston and on college campuses, but they are growing quickly and are likely to have a significant impact in the years to come.

Carsharing, ridesourcing and other new transportation tools can make it easier for households to live “car-free” or to live with fewer cars – steps that can dramatically reduce the number of miles that people drive and the amount of fossil fuels they consume. For example, research suggests that every carsharing vehicle replaces between 9 and 13 privately owned vehicles. About 2 percent of participants in bikesharing programs in several North American cities, meanwhile, report that bikesharing was important to their decision to sell or forgo the purchase of a vehicle.

Among those tools are the following:

- **Carsharing:** Massachusetts was a pioneer in carsharing, with Zipcar establishing one of North America’s first modern, technology-enabled carsharing services in 2000. As of 2013, Zipcar had nearly 80,000 members across the state, with other carsharing operators providing additional service, largely in Greater Boston, on college campuses and in the Pioneer Valley. New models of carsharing, such as free-floating one-way carsharing, are beginning to take root as well, with the city of Boston now considering a pilot on-street parking program for one-way and round-trip carsharing services.

- **Bikesharing:** Boston was also an early leader in bikesharing, launching the Hubway network in 2011. Bikesharing systems such as Hubway provide bikes for on-demand, short-term rentals that can often augment transit service. In 2013, Hubway bikes logged more than 1 million miles of travel.

- **Ridesourcing:** Services such as Uber and Lyft have come to play an increasing role in urban transportation, by allowing people to summon vehicles with their smartphones and pay through an online app. Similar smartphone hailing services are being employed by taxi companies as well.

New shared-use transportation services like Greater Boston’s Hubway bikesharing service make it possible for more Massachusetts residents to live without owning a car.
• **Innovative transit services:** The MBTA has provided real-time transit information to developers for several years, enabling the creation of apps that help transit riders know when their bus or train will arrive. Other Massachusetts transit agencies, such as the Pioneer Valley Transit Authority, are beginning to experiment with real-time information as well. The MBTA also employs electronic smartphone ticketing on commuter rail lines, providing yet another convenience for riders.

In addition, new services such as Bridj offer the potential to expand transit options to new routes not currently served. Bridj provides data-driven bus service shaped to the expressed needs of commuters. As of early 2015, Bridj served four on-demand routes within the Boston area. Smartphone-enabled, on-demand, flexible-route service could also be adopted by public transit agencies, expanding access to transit and improving service for customers across the Commonwealth.

• **Telecommuting:** Telecommuting has been increasing in popularity as technological advances make it possible for a larger number of workers to work efficiently from home. Between 2008 and 2013, the number of Massachusetts residents reporting that they work regularly from home increased by 13 percent, to more than 147,000.122 Many more workers, however, work from home one or two days a week – nationally, the percentage of people who worked from home at least one day per week increased from 7.8 percent to 9.5 percent between 1997 and 2010.123

• **Freight logistics:** Technology can even improve freight transport by routing trucks more efficiently. By reducing empty trips and maximizing the efficiency of routes, some estimate that billions of miles of vehicle travel can be averted nationally each year.124

Many of these technologies and services are in their infancy and their impacts have not been fully studied, but they have the potential – especially when combined – to create a new model of mobility that is less dependent on private cars while providing greater flexibility for users.

The American Council for an Energy-Efficient Economy (ACEEE) recently estimated that a suite of technology tools applied to transportation could save billions of gallons of gasoline each year by 2030 nationwide. Real-time transit information, carsharing, bikesharing and continued increases in telecommuting, they estimated, could save more than 7 billion gallons of gasoline per year nationally.125 Assuming that Massachusetts continues to consume the same share of the nation’s gasoline as it currently does, and that the Commonwealth achieves only half of the potential identified by ACEEE by 2030, Massachusetts could achieve carbon dioxide emissions of about 0.6 million metric tons.

Boston is already following a path toward reduced per-capita vehicle ownership and driving. Between 2008 and 2013, Boston added an estimated 27,000 people but shed approximately 50,000 registered vehicles.126 Expanding access to new transportation technologies and tools across the Commonwealth could enable Massachusetts to accommodate additional residential and commercial growth in compact areas while reducing the cost imposed on residents and governments for owning, maintaining and parking privately owned cars.

10: **Electric Vehicles**

Replacing gasoline-powered vehicles with plug-in electric vehicles (EVs) can reduce global warming pollution from cars and trucks – especially with Massachusetts’ increasingly clean and renewably powered electricity grid. Plug-in vehicles include those that run only on electricity, as well as plug-in hybrid vehicles that can be recharged with power from the grid, but that also use a gasoline engine.

Plug-in vehicles are just starting to appear in large numbers on Massachusetts roads. From July 2013 to
March 2015, the number of plug-in vehicles in Massachusetts increased by 170 percent, to nearly 5,000, with more than one-third of those vehicles operating on electricity alone. Despite the fast growth, plug-in vehicles still make up about 0.1 percent of all vehicles in the state, and Massachusetts will need to make a significant effort just to hit its existing goal of putting 300,000 electric vehicles on the road by 2025.

Meeting that goal is becoming easier due to several factors:

- **More choices:** There are now at least 23 plug-in electric vehicles available from a variety of manufacturers.

- **Falling prices:** The high cost of batteries has long been a barrier to the spread of electric vehicles. However, battery costs have been falling and analysts estimate that the cost of lithium-ion batteries could fall by as much as an additional 50 percent by 2020, bring the upfront cost of a plug-in vehicle within range of that of gasoline vehicles.

- **More places to charge:** The number of publicly available electric vehicle charging stations has been on the rise in Massachusetts, in part due to programs such as the Massachusetts Electric Vehicle Incentive Program (MassEVIP), which provides incentives for various public and private entities to acquire electric vehicles and install charging stations.

Massachusetts has already made a strong policy commitment to supporting electric vehicle deployment. On October 24, 2013, Governor Deval Patrick signed Massachusetts on to a multi-state action plan to get more zero-emission vehicles (including both electric and fuel cell vehicles) on the road. The plan contains steps like promoting workplace charging, providing consumer incentives, and working with car dealers to ensure that electric vehicles are aggressively marketed and promoted.

Programs such as the Massachusetts Offers Rebates for Electric Vehicles (MOR-EV) program are helping more Massachusetts residents to drive electric vehicles. The MOR-EV program provides rebates of up to $2,500 for the purchase or lease of zero-emission and plug-in hybrid light-duty vehicles.

Massachusetts has already set a goal of 300,000 electric vehicles in Massachusetts by 2025, which would be around 6 percent of all light-duty vehicles in the state. As the Commonwealth’s recent experience with solar power (see page 11) shows, early investments can position Massachusetts for rapid ramp-up in new technologies when prices fall, the pace of innovation increases, and manufacturers achieve economies of scale. As a result, Massachusetts should commit to hitting the goal of 300,000 EVs by 2025, and continue to ramp up electric vehicle deployment to have 600,000 electric vehicles on the road by 2030.

Putting close to 300,000 EVs on the road by 2025 could avert nearly 500,000 tons of global warming pollution that year. Putting 600,000 EVs on the road by 2030 should approximately double those savings, while putting Massachusetts within reach of fully phasing out gas-powered automobile sales by 2040.

The Commonwealth should lay a strong public policy foundation to ensure that Massachusetts achieves its 2025 goal of 300,000 electric vehicles, with rapid growth thereafter. Specifically, the Commonwealth should maintain its commitment to the Multi-State Zero-Emission Vehicle Action Plan and to key policies needed to implement the plan, including:

- Continuing and expanding incentives for the purchase of electric vehicles and installation of EV charging stations through programs such as MOR-EV and MassEVIP.

- Expanding the purchase of zero-emission vehicles for public fleets and build charging infrastructure to support those vehicles.

- As appropriate, requiring new buildings to be “EV-ready” with the capacity to accommodate electric vehicle charging infrastructure.
Massachusetts has much at stake in the fight to prevent the worst impacts of global warming. Through the adoption of the Global Warming Solutions Act, the Commonwealth has begun to do its part to address the threat.

But there is still much more to be done. To meet the Commonwealth’s 25 percent emission reduction goal for 2020 and achieve the even more ambitious target of cutting global warming pollution by 45 percent by 2030, Massachusetts must take immediate action on several fronts.

1. Implement Planned Policies to Reduce Greenhouse Gas Emissions

Massachusetts’ 2010 Clean Energy and Climate Plan provided a blueprint for the Commonwealth’s efforts to meet the Global Warming Solutions Act emission reduction targets. Many of the policy initiatives incorporated in that plan have been implemented and are currently working to support the transition to a clean energy economy.

Yet, several key initiatives in the plan – especially in the transportation sector – remain on the drawing board. According to a 2014 report by the Global Warming Solutions Project, Massachusetts is on track to achieve only 63 percent of the transportation emission reductions anticipated in the 2010 plan – the lowest of any sector of the economy. Key transportation sector policies such as clean fuel standards, new pricing strategies for automobile insurance, and driver education programs to improve vehicle fuel economy have either fallen by the wayside or have not yet advanced out of the pilot stage.

To ensure that Massachusetts hits its 2020 emission reduction goals, the Commonwealth must redouble its efforts to implement key portions of its climate plans that have lagged behind schedule.

2. Maximize the Impact of Policies Already on the Books

Massachusetts has adopted a series of policies that – at least in theory – commit the Commonwealth to continuous improvements in energy efficiency and expansion of clean energy. Among those policies and commitments are the following:

- The requirement that Massachusetts utilities take advantage of all cost-effective opportunities to improve energy efficiency.
- The requirement that the Commonwealth adopt an optional “stretch” energy code to enable
cities and towns to go beyond minimum state standards in making buildings more efficient.

- The Commonwealth’s transportation mode shift goal (see page 34), which sets targets for the growth of bicycling, walking and transit use.

But it is one thing to adopt a policy or a bold commitment and another to enforce it. And in key areas, Massachusetts has lagged in fully and faithfully implementing its commitments.

- Massachusetts has failed to tap all cost-effective opportunities for energy efficiency, in part because the Commonwealth’s measure of cost-effectiveness undercounts the damage to society caused by carbon dioxide emissions.

- The Commonwealth has failed to adopt a new “stretch” building energy code, leaving cities and towns with no option for going beyond the baseline provided by Massachusetts’ statewide energy code.

- Massachusetts remains without a clear plan to achieve the Commonwealth’s mode shift goal, which calls for a tripling of the share of miles traveled by transit, on bike or on foot by 2030. Without a clear plan for achieving the goal, and without clear guidelines to prioritize transportation projects that encourage non-driving alternatives, there is no guarantee that this goal will be met.

Massachusetts will only succeed in the fight against global warming to the extent that we keep our promises to reduce emissions and embrace clean energy. In these and other areas, Massachusetts must fully and faithfully implement previous emission reduction commitments.

Hydroelectricity Imports and Massachusetts’ Global Warming Emission Reduction Strategy

Clean energy imports – specifically, importation of hydroelectricity from Quebec – were envisioned to be a key strategy to achieve Massachusetts’ greenhouse gas emission reduction goals in the 2010 Clean Energy and Climate Plan, delivering emission reductions of 5.1 million metric tons of carbon dioxide. The strategy hinged on the completion of the Northern Pass transmission line from Canada through northern New Hampshire, which is now unlikely to be completed until 2019 at the earliest.

Hydroelectricity imports are not an ideal strategy for meeting Massachusetts’ global warming emission reduction goals. Hydropower creates significant greenhouse gas emissions from dam construction and the decomposition of biomass following the flooding of land for a reservoir, and has significant impacts on wildlife and natural communities. Hydropower from Canada may also compete with local investments in renewable energy that keep money and jobs within the Massachusetts economy.

Unlike expanded natural gas pipeline capacity (see page 42), which would set Massachusetts back in its efforts to reduce global warming pollution, imports of hydroelectricity could play a role in reducing carbon dioxide emissions in the short run. Massachusetts officials, however, should prioritize locally generated clean energy and energy efficiency improvements, while ensuring that any strategy to import hydropower has minimal environmental impact and does not interrupt progress toward the development of other clean energy resources.
3. Take Full Advantage of Game-Changing Opportunities

New technologies and emerging societal trends provide Massachusetts with new opportunities to reduce global warming pollution – opportunities that did not exist even seven years ago, when the Global Warming Solutions Act was adopted.

These “game changers” can provide the lion’s share of the additional emission reductions needed to meet a 45 percent emission reduction goal by 2030. Combined with actions taken to implement policies proposed in the 2010 Clean Energy and Climate Plan and full implementation of previous clean energy commitments, these measures can help put Massachusetts well on track to achieving its emission reduction targets in 2030 and beyond.

To illustrate the potential impact of these measures, we evaluated a scenario for fossil fuel consumption that assumed that Massachusetts would attain the following benchmarks by 2030:

- Sourcing of 20 percent of the Commonwealth’s energy supply from offshore wind energy and 20 percent from solar energy;
- Energy efficiency improvements – from lighting and other incremental improvements in existing technologies and programs – sufficient to maintain current annual savings from efficiency programs through 2030;
- Achievement of half of the 2035 energy savings potential from “intelligent efficiency” measures identified by the American Council for an Energy-Efficient Economy (ACEEE);
- Reduction of 10 percent in carbon dioxide emissions from home and commercial heating, attributable to conversions to renewable thermal technologies, construction of zero-energy buildings, and energy efficiency improvements;
- Population growth and distribution reflective of the UMass Donohue Institute’s 2015 population projections;\(^{138}\)

![Figure 9. Carbon Dioxide Emissions with Implementation of Game Changing Opportunities](image)
• Achievement of the Commonwealth’s goal for shifting travel to transit, bicycling and walking;

• Achievement of half of the potential emission reductions identified from emerging transportation technologies by ACEEE;

• Introduction of 600,000 electric vehicles to Massachusetts roads.

In many cases, this scenario represents a conservative estimate of the potential effects of these game changing technologies and trends. Even if these targets are achieved, Massachusetts will likely retain great potential to further increase renewable energy production and use and increase the energy efficiency of our economy in the decades to come.

Achieving those benchmarks would reduce Massachusetts’ carbon dioxide pollution from energy use by approximately 14.1 million metric tons below projected levels by 2030, achieving most of the emission reductions needed to achieve a 45 percent greenhouse gas emission reduction goal by 2030. (See Figure 9.) Implementation of previously proposed policies to reduce emissions, coupled with advances in other parts of the economy and in the reduction of greenhouse gases from sources other than energy consumption, could enable Massachusetts to meet that goal. Just as importantly, taking leadership in implementing new technologies and practices will position Massachusetts well for achieving the even more ambitious emission reduction target for 2050.

Massachusetts’ recent success at reducing global warming pollution while maintaining a robust and growing economy – success generated by bold policies such as the Global Warming Solutions Act and the Green Communities Act, and regional efforts such as the Regional Greenhouse Gas Initiative – has shown that creative thinking, smart investment, and concerted effort can yield big results in the fight against global warming.

Putting a Price Tag on Carbon

Massachusetts’ experience in the Regional Greenhouse Gas Initiative (RGGI) – the first mandatory carbon cap-and-trade program in the United States – demonstrates the important results that can be achieved by putting a price tag on carbon dioxide emissions. Massachusetts received more than $178 million of revenue from the sale of RGGI emission allowances between 2009 and 2012, of which the vast majority was invested in energy efficiency programs.139 As RGGI’s cap on regional carbon dioxide emissions from the electric power sector is tightened in the years to come, the rising cost of carbon emissions will drive the adoption of cleaner sources of energy in the electric power sector while continuing to provide revenue to support the expansion of energy efficiency programs in the Commonwealth.

Jurisdictions ranging from California to British Columbia are increasingly moving toward multi-sector or economy-wide programs to put a price on carbon emissions – either through cap-and-trade programs like RGGI or the adoption of a carbon tax. Either approach has the potential to support Massachusetts’ emission reduction efforts by adding an economic incentive for the adoption of low-carbon technologies and practices and by providing revenues for the major investments in clean energy infrastructure and programs that will be needed to achieve the Commonwealth’s 2050 emission reduction goal. Massachusetts leaders should consider measures to price carbon emissions throughout the economy.
This report identifies many specific policy tools and approaches Massachusetts can use to harness game changing technologies and trends to reduce the Commonwealth’s contribution to global warming. By setting a strong interim reduction goal for 2030 and bringing creativity, commitment and resources to the task of achieving it, Massachusetts can tap those opportunities and put itself on track to meeting its responsibility to take action against global warming.

To achieve the vision of a vibrant, clean and efficient Massachusetts, however, the effort must begin in earnest now. Time for action is short. The margin for error is narrow. Let’s get to work.

A Different Kind of Game Changer: Natural Gas Pipelines

The math is clear and undeniable: if Massachusetts is to meet the Global Warming Solutions Act goal of reducing greenhouse gas emissions by at least 80 percent by 2050, the Commonwealth will need to eliminate or nearly eliminate the use of fossil fuels for the generation of electricity, while dramatically scaling back fossil fuel consumption in every other aspect of the economy.140

Increasing the flow of fossil fuels into the region through long-lasting investments in pipeline infrastructure is contrary to that goal. Yet, officials in Massachusetts and elsewhere in New England are currently considering proposals to expand capacity to deliver natural gas into the region. Those proposals threaten near-term advances in renewable energy and energy efficiency as well as the Commonwealth’s ability to meet its long-term emission reduction goals.

Natural gas pipelines pose several problems:

- **Global warming impacts:** Natural gas contributes to global warming both through the combustion of the fuel and through leakage of methane – a potent greenhouse gas. Combustion of natural gas already accounts for 38 percent of Massachusetts’ energy-related emissions of carbon dioxide.141 Meanwhile, increased understanding of the volume of methane leakage from natural gas drilling, transmission and distribution has led some to conclude that natural gas-fired power plants have a similar impact on the climate as coal-fired plants.142

- **Other environmental impacts:** Pipelines proposed for Massachusetts would carry gas produced from “fracking,” the dangerous and controversial drilling technique that has been linked to groundwater contamination, public health damage and other environmental impacts.143

- **Importing energy = exporting money:** In 2012, Massachusetts spent more than $19 billion on fossil fuels, virtually all of which are imported from outside the state.144 Local energy efficiency and renewable energy solutions keep jobs and money in the Massachusetts economy, rather than exporting it to other states in the form of fuel purchases.

Natural gas is not a “bridge fuel” to a clean energy economy; rather, it is a direct competitor with truly clean sources of energy such as renewable power. Massachusetts must move quickly toward policies that reduce its use of natural gas, not increase it, if the Commonwealth is serious about achieving its greenhouse gas emission reduction goals.
Methodology


Future carbon dioxide emissions from energy use were projected as follows:

- Massachusetts energy consumption estimates for 2013 from the Energy Information Administration’s (EIA) State Energy Data System\textsuperscript{145} were projected forward using New England regional growth rates for each sector and fuel from the EIA’s *Annual Energy Outlook 2015*,\textsuperscript{146} and converted to carbon dioxide emissions based on carbon coefficients from the EPA.\textsuperscript{147}
- Carbon coefficients for all fuels except electricity were drawn from U.S. Environmental Protection Agency, *Emissions Factors for Greenhouse Gas Inventories*, 4 April 2014.
- For fuels other than electricity, we determined the share of fossil fuel consumption attributable to non-energy purposes, which are excluded from this analysis. We obtained our figures for the amount of each fuel that was consumed for non-energy purposes from the EPA’s inventory of U.S. greenhouse gas emissions.\textsuperscript{148} We assumed that the relationship between total fuel consumption and non-energy fuel consumption would remain constant over time and excluded the amount of fossil fuels used for non-energy purposes from our reference case.
- Emissions from motor gasoline consumption in the transportation sector were adjusted for the presence of ethanol in gasoline by deducting the energy value of transportation ethanol as reported in the State Energy Data System from the energy value of motor gasoline. The emission factor for pure petroleum gasoline was then applied to the remaining figure to estimate fossil fuel-related carbon dioxide emissions from gasoline.

The carbon dioxide emission figures for 2012 in this report are significantly lower than the preliminary figures in the *Massachusetts Greenhouse Gas Emissions Inventory* published in July 2014. This is likely due to revisions in energy consumption data in the State Energy Data System.

For electricity consumption, a slightly different method was applied:

- Electricity consumption was projected for Massachusetts in a method similar to that used for other forms of energy consumption above.
- Carbon dioxide emissions from electricity consumed in Massachusetts were estimated based on the assumption that the fuel mix used to supply electricity in Massachusetts is the same as the New England grid as projected in Energy Information Administration, *Annual Energy Outlook*.
2015 (AEO 2015), Electric Power Projections by Electricity Market Module Region, Northeast Power Coordinating Council / Northeast, Reference case, 2015. We used AEO 2015 data to arrive at a fossil fuel heat rate for electricity generated from various fossil fuels in New England for all years until 2030, and then multiplied that heat rate by the amount of electricity anticipated to be generated from each source and a carbon coefficient for each fuel to arrive at a total estimate for fossil fuel carbon dioxide emissions from electricity generation in New England for each year.\textsuperscript{149} This figure was then divided by projected electricity sales for each year to arrive at an emission factor that could be applied to electricity consumption forecasts to determine the carbon dioxide emissions impact of electricity consumption in each sector of the Massachusetts economy for each year.

Emission reductions from the various strategies discussed in this report were estimated by one of three methods:

- For estimates based on percentage or absolute reductions in direct fossil fuel consumption, emissions were reduced by that percentage or amount.

- For estimates based on reductions in electricity consumption or increases in the production of renewable energy, emission reductions were based on the average carbon intensity of the New England grid in the year in which the emission reductions were projected to occur. (Note: this method likely yields a conservative estimate of emission reductions, as clean energy strategies are more likely to offset electricity generated from fossil fuels than other forms of low-emitting or zero-emitting generation.)

- For a small number of strategies, only aggregate estimates of carbon dioxide emission reductions or energy savings were available. These were handled as described below.

The following section describes, in detail, the derivation of emission reduction estimates for the scenarios evaluated in this report.

- **Energy efficiency, electricity:** Electricity consumption savings were estimated as follows:

  - We assumed that new, incremental energy efficiency improvements (such as LED lighting) would allow Massachusetts utilities to continue to achieve energy efficiency savings consistent with the three-year (2011-2013) average energy efficiency savings in ISO-New England’s 2015 Energy Efficiency Forecast.\textsuperscript{150} These savings were added to ISO-NE’s forecast of electricity consumption reductions from “passive demand resources” (PDR), which is largely equivalent to energy efficiency savings, for 2015, and then subtracted from ISO-NE’s forecast of net energy for load without PDR or solar PV to arrive at an estimate of net energy for load that incorporates the increase in energy efficiency savings relative to ISO-NE’s forecast. Because the forecast only stretches to 2024, we extrapolated the trend in net energy for load minus PDR that prevailed in the 2015-2024 period until 2030.

- Intelligent efficiency measures were assumed to produce savings in addition to those calculated above, as such measures are just now beginning to make widespread inroads in the market. Commercial and industrial sector savings were estimated based on estimates for potential savings by 2035 due to intelligent efficiency in Ethan A. Rogers et al., American Council for an Energy-Efficient Economy, *Intelligent Efficiency: Opportunities, Barriers and Solutions*, October 2013. We assumed that the commercial and industrial sectors would each attain half of their 2035 potential by 2030. In the commercial sector, this implied energy savings of 14 percent and in the industrial sector, 10 percent (representing ACEEE’s estimate for potential savings
in industrial process energy use), with the percentage reductions applied to electricity consumption following the application of the savings from continued success of energy efficiency programs, described in the bullet above. Savings in the residential sector, which were not covered by the ACEEE report, were assumed to be the average of the commercial and industrial sector figures. Savings were assumed to accrue linearly between 2016 and 2030.

- **Offshore wind and solar energy:** To calculate the amount of offshore wind and solar energy that would need to be produced in a 20% wind/20% solar scenario, we deducted the amount of electricity saved by energy efficiency (as defined above) from projected electricity consumption. We then multiplied the remaining electricity demand by 20 percent to arrive at estimated additional production of offshore wind. For solar energy, we multiplied the remaining electricity demand by 20 percent and then subtracted Massachusetts’ estimated production of solar electricity in 2015, based on ISO-New England’s 2015 estimate of the ratio of behind-the-meter solar photovoltaic generation to net energy for load from ISO-New England’s 2015 load forecast.151

From these estimates of additional solar and offshore wind electricity, we deducted the estimated amount of additional renewable electricity required under the Massachusetts Renewable Energy Standard. We assumed that all RES-required renewables were incorporated in the EIA’s Annual Energy Outlook 2015 reference case. The net increase in renewable energy required in the reference case was then estimated by subtracting all post-2015 additions in renewable energy in the New England grid (which were assumed to be driven by the Massachusetts RES and parallel policies in other states) from the total offshore wind and solar power required to meet the 20%/20% threshold, with the additional renewable energy multiplied by average carbon dioxide emissions per unit of electricity on the New England grid to arrive at an estimate of carbon dioxide emission reductions.

- **Fossil fuel consumption in buildings:** We used data from Navigant Consulting and Meister Consultants Group, Commonwealth Accelerated Renewable Thermal Strategy: Final Report, prepared for the Massachusetts Department of Energy Resources, January 2014, to estimate carbon dioxide emissions resulting from thermal energy load in Massachusetts residential and commercial buildings. We then assumed that renewable thermal strategies could reduce carbon dioxide emissions from those loads by 10 percent by 2030 – an estimate far below the potential savings estimated under a “high state support” scenario in the Navigant/Meister report. Savings were assumed to accrue linearly between 2016 and 2030. We further applied the sector-by-sector energy savings resulting from intelligent efficiency, estimated as described above, to direct fossil fuel consumption in homes, commercial buildings and industry. These savings were discounted by 10 percent to account for the transition of thermal loads to renewable energy.

- **Transportation emissions:** The impact of Urbanization and Smart Growth was estimated using population growth scenarios from the UMass Donohue Institute and average annual vehicle-miles traveled data by town for Massachusetts from the Metropolitan Area Planning Council.152 To estimate the change in per-capita vehicle-miles traveled, we multiplied the population estimate in each scenario by the municipality’s average per-capita VMT and summed the totals to arrive at per-capita light duty VMT estimates for 2015, 2020, 2025 and 2030, assuming that average per-capita VMT by town remains flat throughout the period. We then compared this trajectory
with the national trajectory for per-capita VMT in *Annual Energy Outlook 2015* and applied the percentage reduction thus implied by projected emissions from motor gasoline use in the transportation sector (the vast majority of which is used to fuel light duty vehicles) to arrive at estimated emission reductions from this strategy.

The impact of *New Transportation Tools* was estimated by assuming that Massachusetts achieves a proportionate share (based on its share of U.S. motor fuels consumption, based on Federal Highway Administration data\(^\text{153}\)) of emission reductions delivered by carsharing, bikesharing, telecommuting and real-time transit apps, as estimated in Shruti Vaidyanathan, American Council for an Energy-Efficient Economy, *Energy Savings from Information and Communications Technologies in Personal Travel*, December 2014. We assumed that those tools would deliver half of the emission reductions identified in the ACEEE study for the sake of conservatism.

The impact of *Reinventing Public Transportation* and associated improvements in transit, bicycling and walking infrastructure were estimated based on the achievement of Massachusetts’ “mode shift goal,” which aims to increase bicycling, walking and transit use in the Commonwealth by 4.7 billion miles traveled between 2010 and 2030 according to the Massachusetts Department of Transportation.\(^\text{154}\) We assumed that half of those miles would replace private vehicle trips and their associated emissions.

Emission reductions for *Electric Vehicles* were estimated by doubling the emission savings estimated for achieving penetration of 300,000 electric vehicles in Massachusetts, as estimated in Elizabeth Ridlington and Travis Madsen, Environment Massachusetts Research and Policy Center, *Driving Cleaner: More Electric Vehicles Means Less Pollution*, June 2014. Emission reductions would likely be greater than estimated here as a result of transition to a cleaner electric grid.
Appendix: Emission Reduction Estimates from “Game Changing” Technologies and Practices

<table>
<thead>
<tr>
<th></th>
<th>2012</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
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<td><strong>Reference case energy-related CO₂ emissions (million metric tons)</strong></td>
<td>62.3</td>
<td>67.2</td>
<td>64.4</td>
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<td><strong>Reductions from game changing technologies and practices (million metric tons)</strong></td>
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<td><em>Energy efficiency improvements</em></td>
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<td>0.7</td>
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<td><em>Intelligent efficiency</em></td>
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<td>2.2</td>
<td>3.3</td>
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<tr>
<td><em>Renewable heating</em></td>
<td>0.9</td>
<td>1.8</td>
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<tr>
<td><em>Solar and offshore wind</em></td>
<td>1.1</td>
<td>2.2</td>
<td>3.6</td>
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<tr>
<td><em>Smarter growth</em></td>
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<td>0.9</td>
<td>1.3</td>
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<td><em>Shift to transit, bike, walk</em></td>
<td>0.5</td>
<td>0.6</td>
<td>0.7</td>
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<tr>
<td><em>Tech-enabled transportation tools</em></td>
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<td><strong>Total reductions</strong></td>
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<td><strong>Energy-related CO₂ emissions with implementation of game changing technologies and practices (million metric tons)</strong></td>
<td>62.3</td>
<td>61.8</td>
<td>54.9</td>
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Figures may not sum due to rounding.
Notes

To ensure that online materials referenced in this report remain available for public review, those pages have been preserved in the Internet Archive at archive.org.


4. Ibid.


15. Ibid.

16. See note 11.


19. See note 17.


22. See note 12.

23. See note 11.


25. M.G.L. Chapter 21N, Section 3(b)(2)

26. The IPCC has stated that to have a likely chance of keeping the global temperature increase caused by greenhouse gas emissions below 2°C compared to pre-industrial levels, the concentration of greenhouse gases in the atmosphere in 2100 must be held to about 450ppm CO<sub>2</sub>eq: Intergovernmental Panel on Climate Change, *Climate Change 2014: Mitigation of Climate Change: Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change: Summary for Policymakers*, 2014, 10; “likely” is defined as a higher than two-thirds chance, per Sustainable Development Solutions Network and Institute for Sustainable Development and International Relations, *Pathways to Deep Decarbonization: 2014 Report*, September 2014; in order to keep concentrations below this level, the United States and other developed countries will need to cut greenhouse gas emissions by 2050 by 80 to 95 percent relative to 1990 levels: Union of Concerned Scientists, *National Call to Action on Global Warming*, accessed on 6 February 2015, archived at web.archive.org/web/20150713201634/http://www.ucsusa.org/global_warming/solutions/reduce-emissions/national-call-to-action-on-gw.html; limiting global temperature increases to 2°C was set as a goal by the Copenhagen Accord, which stated “that the increase in global temperature should be below 2 degrees Celsius, on the basis of equity and in the context of sustainable development, enhance our long-term cooperative action to combat climate change”: The United Nations, *Report of the Conference of the Parties on its Fifteenth Session, held in Copenhagen from 7 to 19 December 2009*, December 2009.

27. Actual data: See note 12.


32. See note 30.

33. See note 12.

34. Ibid.

35. Ibid.

36. See note 17.


40. See note 38.


42. Ibid.

43. See note 17.

44. See note 41.


47. Offshore wind capacity: Marc Schwartz et al., U.S. National Renewable Energy Laboratory, Assessment of Offshore Wind Energy Resources for the United States, June 2010; total generation is estimated to be 650,000 GWh, based on a capacity factor of 37.1%, which was the expected capacity factor for the Cape Wind offshore wind farm: Massachusetts Department of Public Utilities, Petition of NSTAR Electric Company for Approval by the Department of Public Utilities of a Long-Term Contract to Purchase Wind Power and Renewable Energy Certificates, Pursuant to St. 2008, c. 169, § 83 and 220 C.M.R. § 17.00 et seq., DPU Docket No. 12-30, 26 November 2012; Mass. retail electricity sales: U.S. Energy Information Administration, Massachusetts Electricity Profile 2013, 8 July 2015.

48. The NREL Assessment of Offshore Wind Energy Resources for the United States considers 0-30 meters in depth “shallow,” from 30-60m “transitional,” and more than 60m “deep;” offshore wind built in more than 60m water may need to be built as floating turbines.


50. Capacity converted to generation using capacity factor of 37.1%, which was the expected capacity factor for the Cape Wind offshore wind farm: Massachusetts Department of Public Utilities, Petition of NSTAR Electric Company for Approval by the Department of Public Utilities of a Long-Term Contract to Purchase Wind Power and Renewable Energy Certificates, Pursuant to St. 2008, c. 169, § 83 and 220 C.M.R. § 17.00 et seq., DPU Docket No. 12-30, 26 November 2012; Mass. retail electricity sales: U.S. Energy Information Administration, Massachusetts Electricity Profile 2013, 8 July 2015.


64. Based on 2011 data on emissions from direct combustion of fossil fuels in the residential, commercial and industrial sectors, as well as emissions from consumption of electricity, the vast majority of which is used in buildings, see note 12.


68. Ibid.

69. ACEEE’s definition of “intelligent efficiency” includes some transportation-sector technologies and tools that are evaluated in the “New Transportation Tools” section beginning on page 35.


76. Ibid.


79. Some zero net-energy buildings rely on the electricity grid for power at times when usage is particularly high or renewable energy production is low.


95. Ibid.


99. Based on VMT estimates and population estimates for municipalities in greater Boston from Metropolitan Area Planning Commission and MassGIS, VMT for Passenger Vehicles, By Municipality (Excel workbook), accessed at www.mapc.org/sites/default/files/MAPC_VMTbyMuni_1_13_11.xls, 24 February 2015. Data were collected between 2005 and 2007. Total passenger miles driven and population were summed across the four community types defined by MAPC to arrive at an average per-capita VMT figure for each type of community.


102. See Methodology.


114. See note 110.


116. Ibid.


119. Membership figures based on data provided for the “37 Billion Mile Challenge,” a data analysis project coordinated by the Metropolitan Area Planning Council. All data are available at www.37billionmilechallenge.org.


133. Putting 286,000 EVs on the road would avert 0.48 million metric tons of greenhouse gas pollution: Elizabeth Ridlington and Travis Madsen, Environment Massachusetts Research and Policy Center, *Driving Cleaner: More Electric Vehicles Means Less Pollution*, June 2014. Emission reductions would be even greater than estimated here should Massachusetts make progress in the addition of large amounts of renewable energy to the regional grid.

134. See note 11.


138. See note 101.


140. This assumes that some amount of fossil fuels will continue to be used for purposes for which good substitutes currently do not exist, such as air travel and some industrial processes.

141. See note 14. Note that this estimate relates to consumption of fossil fuels for electricity generation in Massachusetts, not emissions related to consumption of electricity by Massachusetts homes and businesses from the New England grid.


150. See note 66.


152. See note 101.


155. Based on vehicle-miles traveled data from Federal Highway Administration, Highway Statistics (through 2013) and Traffic Volume Trends (2014) series of reports, and annual population estimates from the U.S. Census Bureau.