Pioneer Valley Planning Commission

Pioneer Valley Climate Action and Clean Energy Plan

Moving toward a carbon neutral future.
Adapting to create resilient communities.

Produced by the Pioneer Valley Planning Commission with the support of the U.S. Department of Housing and Urban Development Sustainable Communities Initiative Regional Planning Grant Program.

February / 2014

Catalyst for Regional Progress
pvpc

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ACKNOWLEDGEMENTS

This project was funded through a Sustainable Communities Initiative grant from the U.S. Department of Housing and Urban Development (HUD), received by PVPC in partnership with the Capitol Region Council of Governments (CRCOG). PVPC would like to thank HUD and CRCOG for an outstanding partnership, and in particular acknowledge the efforts of the following staff:

Dwayne Marsh, U.S. Department of Housing and Urban Development (HUD)
Kate Dykgraaf, HUD
Lyle Wray, Capitol Region Council of Governments (CRCOG)
Mary Ellen Kowalewski, CRCOG

The work that provided the basis for this publication was supported by funding under an award with the U.S. Department of Housing and Urban Development. The substance and findings of the work are dedicated to the public. The author and publisher are solely responsible for the accuracy of the statements and interpretations contained in this publication. Such interpretations do not necessarily reflect the views of the Government.

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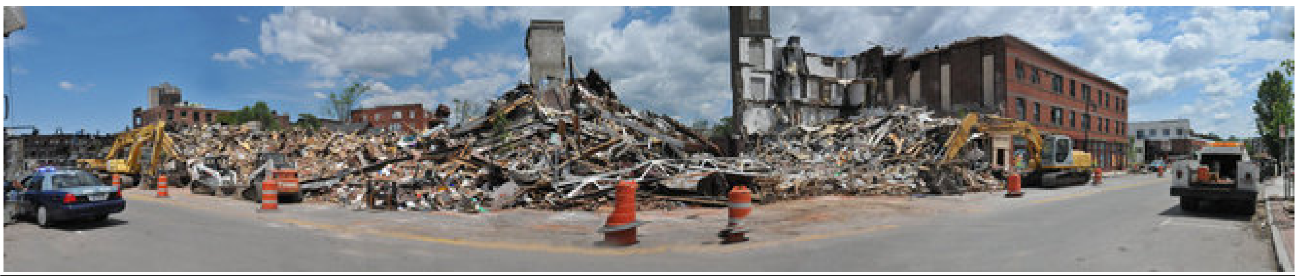
1 INTRODUCTION

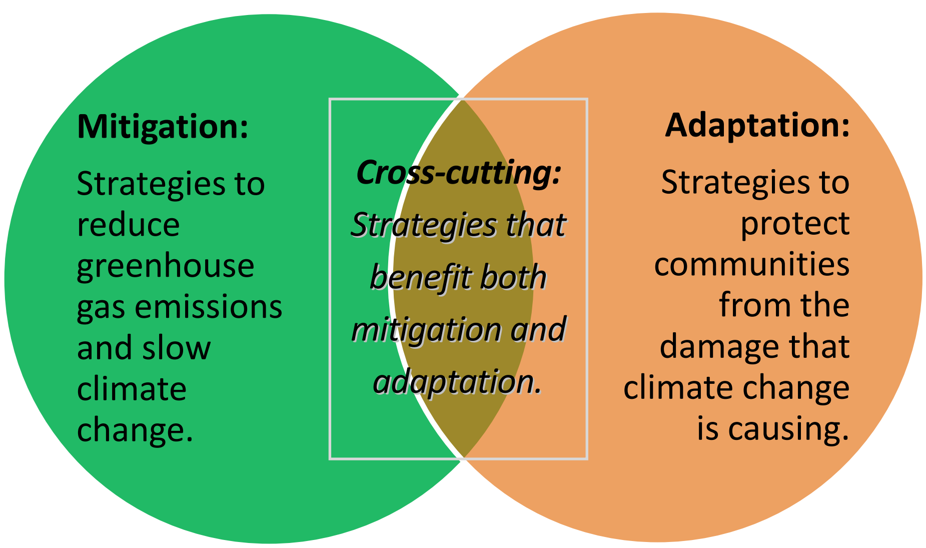
1.1 ELEMENT PLAN PURPOSE

The purpose of this Climate Action and Clean Energy Plan is to promote greater understanding of the causes and consequences of climate change in the Pioneer Valley. The plan is intended to help the people of the region respond to climate-related changes in their communities by creating workable strategies for local and regional actions to reduce greenhouse gas emissions, including greater use and production of clean and renewable energy, and protect their communities from climate-related damage.



Tornado Damage, Springfield, June 2, 2011. Extreme weather events, such as tornados and severe storms, are becoming more frequent and damaging as climate and weather patterns change. This plan offers information about the likely effects of climate change in the Pioneer Valley and the actions that will be most effective in adapting to these impacts in our region.

This plan identifies the amounts and sources of the Pioneer Valley's greenhouse gas emissions; offers regional targets for GHG reduction; and recommends strategies for both mitigating climate change impacts and actions to adapt our communities and infrastructure to the climate-related changes that are occurring and will continue to take place. The nature and relationships of these actions is illustrated below.



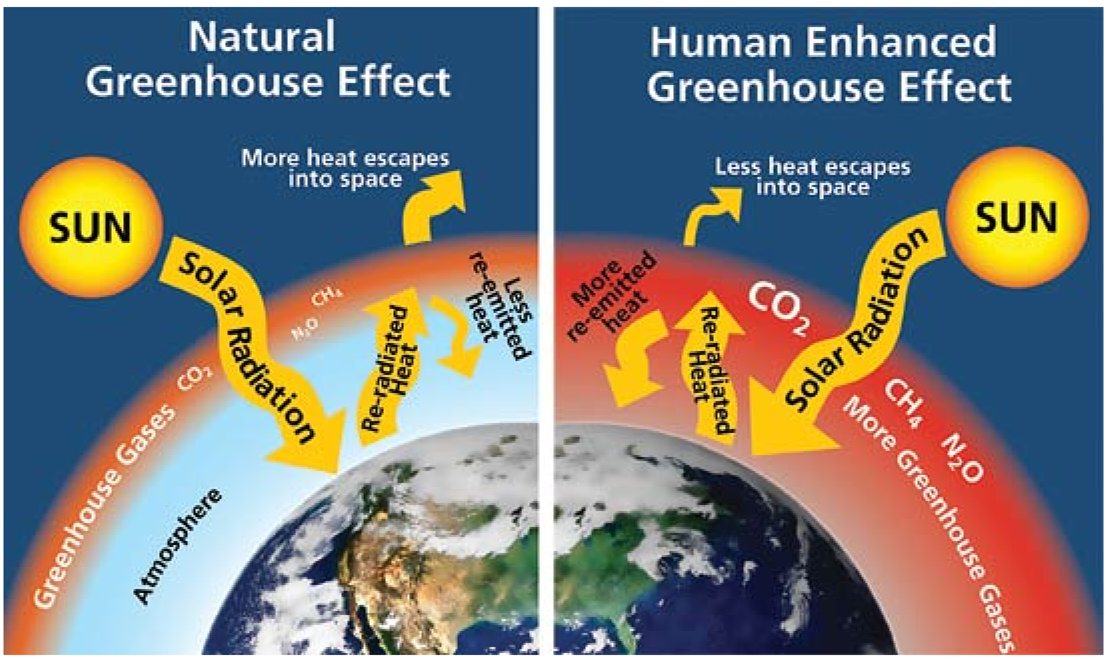
1.2 DESCRIPTION OF ISSUES

> **"Climate change is the challenge of our time, and we in Massachusetts are rising to that challenge."**
> *-- Massachusetts Governor Deval Patrick*
> *July 2, 2008*

Scientific evidence is overwhelming that our climate is changing. According to the Massachusetts Climate Adaptation Report, "climate change is already having demonstrable affects in Massachusetts".

In 2010, the National Academy of Sciences concluded that "there is a strong, credible body of evidence, based on multiple lines of research, documenting that climate is changing and that these changes are caused in part by human activities".

Figure 1-1: Natural and Human Enhanced Atmospheric Greenhouse Effect



Source: U.S. National Park Service.<http://www.nps.gov/goga/naturescience/climate-change-causes>

Even if global greenhouse gas (GHG) emissions are reduced, some climate change is inevitable. Therefore, addressing climate change requires action on two fronts: 1) the mitigation of GHG emissions, and 2) the strengthening of our infrastructure, social systems and other resources to be more resilient in the face of the severe weather events and other climate-related changes in the environment.

Climate change poses an extremely broad set of challenges. It affects not only our weather, but also our food supply, our landscape and wildlife, our infrastructure, our economy, and ultimately the world's socioeconomic conditions and stability.

Because climate change is a global problem, no individual government can unilaterally solve the problem, and effective solution will require the cooperative participation of federal, state, regional and local governments, as well as individuals and businesses.

1.2.1 OUR CLIMATE IS ALREADY CHANGING

Long-term observed climate warming trends in our region include:

- The Northeast has been warming at a rate of nearly .5 degrees F per decade, and winter temperatures are rising at an even faster rate of 1.3 degrees F per decade;
- There are more frequent days with temperatures above 90 degrees;
- Snowpacks are being reduced, with earlier spring snowmelts;
- Sea-surface temperatures and sea levels are rising;

One of the most significant predicted affects of climate change for our region is an increase in severe weather events. In 2011, a series of three severe weather events impacted the Pioneer Valley region:

- In June, a series of category EF-3 tornados struck Springfield and nine other communities, the region's worst outbreak of tornados in a century, causing $90 million in damages in Hampden County alone;
- In August, Tropical Storm Irene dumped as much as 10 inches of rain on the region, causing extensive flood damages totaling over $1 billion across the Northeast;
- In October, a record early snowstorm of 8-24 inches snapped branches and downed power lines, leaving 3 million people without power for up to 2 weeks, and causing $3 billion in damages across the Northeast

Figure 1-2: Tornado Strikes Springfield on June 1, 2011

Source: photos.masslive.com

Figure 1-3: Deerfield River Flooding in Shelburne Falls and Buckland on August 27, 2011

Source: photos.masslive.com

In July 2012, a brutal heat wave across much of the United States wilted crops, shriveled rivers, and fueled wildfires, and officially set the record for the hottest single month ever in the continental U.S. In addition, the first seven months of 2012 were the hottest of any year on record, and drier than average as well.

Public perception of climate change impacts is also changing. A poll by the Yale Project on Climate Change Communication and the George Mason University Center for Climate Change Communication released in April 2012 found that 72% of Americans believe that global warming has played a role in a series of unusual weather events during the prior year (2011).

1.2.2 CLIMATE CHANGE IMPACTS

The Pioneer Valley faces significant climate changes moving forward. These impacts include:

> **"Although Massachusetts would not likely be the place in the world to suffer most from a changing climate, the potential negative impacts here are many and serious".**
>
> *Rising to the Challenge*, MassINC, 2012

- Multiple sources predict that by mid-century, average temperatures will rise by 3 to 5 degrees Fahrenheit, with increases of 5-10 degrees Fahrenheit possible under higher emissions scenarios;
- More days of extreme heat in the summer, by century's end we will have 30 to 60 days per year with temperatures above 90 degrees Fahrenheit, compared to 5-20 degrees today. Moreover, 28 days will be above 100 degrees compared to 2 now;
- The occurrence of 100-year floods will increase to one every 2 to 3 years;
- Massachusetts is expected to experience a 75% in drought occurrences, which could last 1 to 3 months;
- At the same time, precipitation is expected to increase, but will likely occur primarily during winter as rain;

- Flooding and severe storms will continue to inundate and damage critical infrastructure such as wastewater treatment plants and water supplies

Extreme precipitation events – rainstorms and snowfalls that are among the largest experienced at a particular location – are now happening 30% more often on average across the contiguous United States than in 1948. New England has experienced the greatest change, with intense rainstorms and snowstorms now happening 85% more often than in 1948. (Environment Massachusetts Research and Policy Center*. When it Rains, it Pours, Global Warming and the Increase in Extreme Precipitation from 1948 to 2011*.)

The impacts from climate change are already costly, and will be increasingly so in the future. Under the "High Emission" scenario modeled by the Intergovernmental Panel on Climate Change (IPCC), average annual costs of climate change to the U.S. is likely to reach 2.6% of gross domestic product by 2100. Boston ranks fourth among U.S. cities at the greatest risk of asset exposure from sea level rise. Other economic and societal impacts include:

- Climate change will continue to affect the price, affordability and availability of insurance coverage.
- The region's winter recreation businesses will be adversely affected, due to 10-20% fewer skiing days.
- Rising temperatures will lengthen the growing season, but key crops such as apples, maple syrup and cranberries may disappear.
- Climate-related illnesses are projected to increase, including heat stress, respiratory and cardiovascular diseases and outbreaks of water-borne and vector-borne diseases, having a particular impact on elderly and vulnerable populations.

1.2.3 THE GLOBAL PICTURE

In considering local and regional actions to address climate change, it is important to understand not only the potential impacts to our region, but to global ecological systems.

Among the most ecologically sensitive areas of Earth that are already threatened by global climate change are:

- **Antarctica:** During the past 50 years, temperatures in parts of the Antarctic continent have jumped between 5 and 6 degrees F—a rate five times faster than the global average. In 2007, the IPCC reported that sea levels can be expected to rise between 7 and 23 inches by 2100. However, this estimate does not account for Antarctica's rapid ice melt. Now, researchers believe the sea could rise from 3 to 6 feet by 2011. Antarctica's ice cap holds 70% of the freshwater on Earth; if this ice melts, the oceans could rise 187 feet, decimating entire island nations worldwide (the Maldives, for example). Antarctica's wildlife is also at risk. Krill are essential to the marine food chain—fish, seals, and whales eat them—but the shrimp-like crustaceans' numbers have dropped 80% since the 1970s, disrupting the whole ecosystem.
- **The Great Barrier Reef:** Coral cover alone has been reduced by half in the last 50 years. The GBR as a whole has only a 50% chance of survival if global CO_2 emissions are not reduced by at least 25% by 2020. Climate change is partly to blame. When the ocean warms up, the higher temperatures harm the more than 2,900 coral reefs, along with its 1,500 species of fish.

Figure 1-4: The Great Barrier Reef, Australia

Source: www.greatbarrierreef.org

- **The Alps (Europe):** Increased carbon dioxide emissions are causing glaciers in the Alps to melt rapidly. Most Alpine glaciers could be gone as soon as 2030, resulting in large-scale flooding and economic damages due to the loss of the ski industry.
- **The Himalayas (Tibet and northern India):** The world's highest mountain range contains the planet's largest non-polar ice mass, with over 46,000 glaciers. And like in Antarctica, the ice is melting. Between 1950 and 1980, about half of the Himalayas' glaciers were receding. Global warming is just one reason—soot from millions of coal- and wood-burning stoves in India and China also take a share of the blame. The glacier loss will affect people living along Asia's 10 major rivers, who make up one-sixth of the total global population and who depend on glacial melt to stave off drought and starvation.
- **Venice, Italy:** Rising ocean levels resulting from global warming are a threat to the low-lying Venice, which is made up of 118 small islands on a lagoon that sits at sea level. Flooding from the Adriatic Sea's high tides has become dire in the last 60 years. In 1900, Piazza San Marco, Venice's central square, flooded seven times; in 2002, the number jumped to 108. The ocean's salt water eats away at Venice's historic buildings, among them the opulent Palazzo Ducale, which dates back to the 9th Century.
- **Amazon Rainforest (South America):** At current deforestation rates, 55% of the Amazon's 1.4 billion acres of rain forests could be gone by 2030. Expansion of agriculture, illegal logging, and climate change are primary causes. The rain forests, which are home to 30 million indigenous people and one-tenth of the world's known species, also sequester up to 140 billion metric tons of carbon, which helps stabilize the global climate.

1.2.4 OTHER IMPACTS

A wide range of other impacts from climate change are already occurring, and many will accelerate in coming years. The most urgent of these are summarized below.

HUMAN HEALTH IMPACTS

Human health impacts resulting from climate change include heat stress, waterborne diseases, poor air quality, extreme weather events, and diseases transmitted by insects and rodents. As temperature rise, so do the risks of heat-related illness and death for the most vulnerable human populations. In 2003, extreme heat waves caused more than 20,000 deaths in Europe and more than 1,500 deaths in India. Scientists have linked the deadly heat waves to climate change and warn of more to come. (Source: www.epa.gov/climatechange/pdfs/print_heat-deaths-2012.pdf)

In addition to heat-related illness, climate change may increase the spread of infectious diseases, mainly because warmer temperatures allow disease-carrying insects, animals and microbes to survive in areas where they were once thwarted by cold weather. Diseases and pests that were once limited to the tropics — such as mosquitoes that carry malaria — may find hospitable conditions in new areas that were once too cold to support them. The potential for transmission of diseases such as malaria, Dengue fever, West Nile virus and Lyme disease is expanded with warming as the habitats of disease-carrying insects expand. The World Health Organization (WHO) estimates that climate change may have caused more than 150,000 deaths in the year 2000 alone, with an increase in deaths likely in the future. Warmer seas could contribute to the increased intensity, duration and extent of harmful algal blooms, which damage habitat and shellfish nurseries and can be toxic to humans.

Ground level ozone is predicted to increase as a result of global warming. Ozone is well-known trigger for respiratory problems such as asthma, particularly in children. A study by the Mount Sinai School of Medicine in New York City predicted that climate change could cause a 7.3% increase in summer ozone-related asthma emergency department visits for children by the 2020s, over the 1990s.

ECONOMIC LOSSES

Climate change is affecting businesses and economies at home and around the world. If action is not taken to curb global carbon emissions, climate change could cost between 5% and 20% of the annual global gross domestic product, according to a British government report. In comparison, it would take 1% of GDP to lessen the most damaging effects of climate change, the report says.

In New England, the ski industry will face the threat of less natural snowfall and the inability to produce artificial snow, which requires temperatures of 28 degrees or less. Under a high emissions scenario, for example, only western Maine is projected to retain a reliable ski season. (Source: New England Climate Coalition).

WILDLIFE IMPACTS

Rising temperatures are changing weather and vegetation patterns across the globe, forcing animal species to migrate to new, cooler areas in order to survive. The rapid nature of climate change is likely to exceed the ability of many species to migrate or adjust. Experts predict that a quarter of the Earth's species will be headed for extinction by 2050 if global warming trends continue at its current rate. Due to melting ice in the Arctic, polar bears may be gone from the planet in as little as 100 years. In the tropics, increased sea temperatures are causing more coral reefs to "bleach," as the heat kills colorful algae that are necessary to coral health and survival. (Source: The Nature Conservancy 2010)

AGRICULTURAL IMPACTS

Changes to growing seasons, frequency and duration of droughts, increased frequency of extreme precipitation events, and heat stress will make some areas unsuitable for growing popular varieties of produce (e.g., apples, cranberries), depress milk production from dairy cows, and increase irrigation needs to maintain viable crop production. (Source: Mass. Clean Energy and Climate Plan 2010).

Figure 1-5: Nebraska Drought 2012

Severe drought across the United States in 2012 dramatically reduced corn production, as seen here in a drought-stricken Nebraska cornfield, which affects food prices and availability in regions throughout the county. Source: www.businessinsider.com

Crop and livestock production will be increasingly challenged. Agriculture is considered one of the sectors most adaptable to changes in climate. However, increased heat, pests, water stress, diseases, and weather extremes will pose adaptation challenges for crop and livestock production. (Source: U.S. Global Change Research Program 2010)

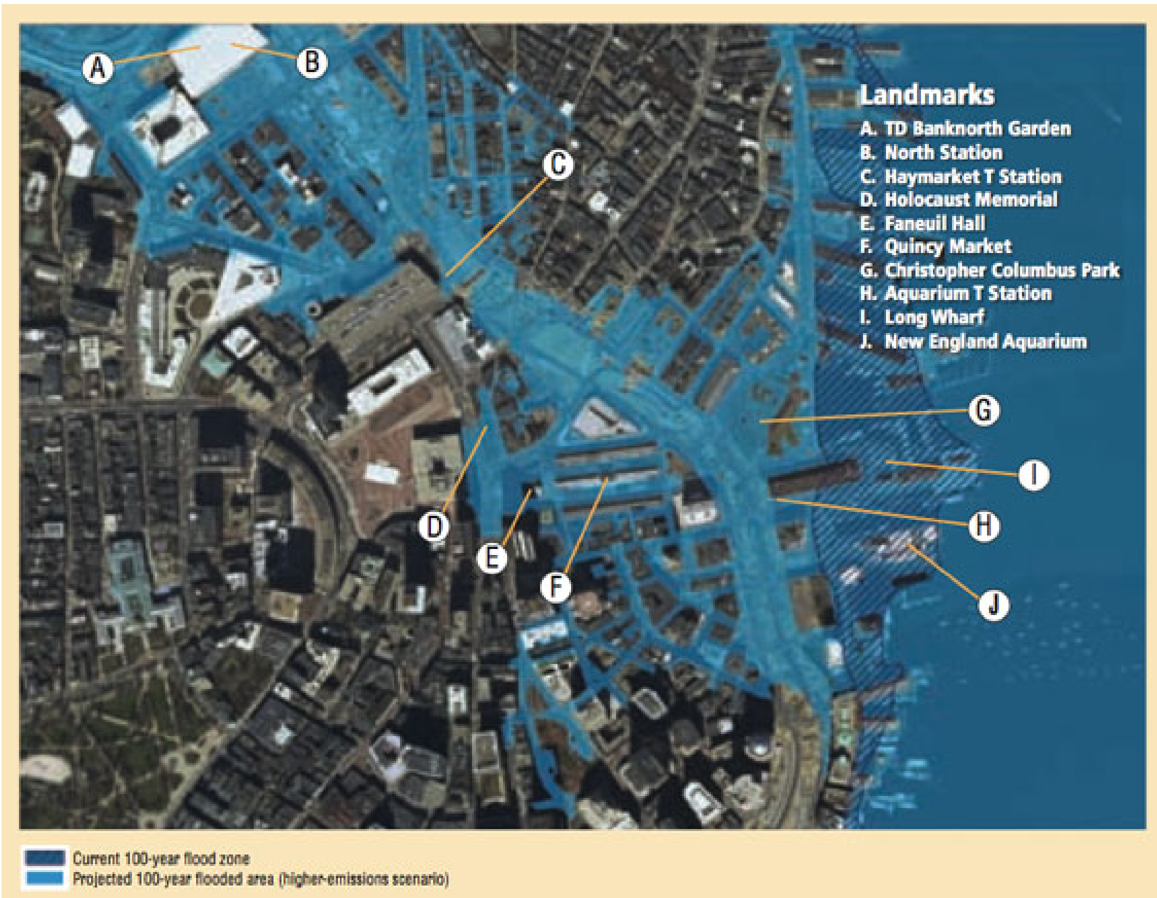
CHANGES IN LANDSCAPE

Worldwide, rising temperatures and changing patterns of rain and snow are forcing trees and plants around the world to move toward polar regions and up mountain slopes. In the tundra, thawing permafrost will allow shrubs and trees to take root. In the Great Plains of the United States, grasslands will likely become forests. And New England's fiery fall foliage will eventually fade as maple and beech forests shift north toward cooler temperatures. (Source: The Nature Conservancy). According to the New England Climate Coalition, temperature increases could affect New England's brilliant fall colors as trees migrate north or die out, and maple syrup production may be jeopardized because sap flow depends on freezing nights and warm days.

SEA LEVELS

In Boston, the sea level has risen 11 inches during the past 100 years due to climate change and land subsidence (sinking and settling). Sea levels in and around Boston could rise another 2 to 6 feet by 2100. Statewide, Massachusetts loses an average of 65 acres to rising sea levels each year. (Source: New England Climate Coalition 2008).

Figure 1-6: Projected Inundation of Boston Landmarks in a 100-year Flood Under High Emissions Scenario



Source: Kirshen, et. Al 2008. Coastal Flooding the Northeast United States Due to Climate Change

Many of Boston's neighborhoods and landmarks are built in areas that are highly susceptible to flooding and the effects of extreme weather. For example, under projected 100-year storms (based on a high emissions scenario), many of Boston's best-known landmarks are threatened, including Faneuil Hall, Quincy Market, North Station, Fan Pier, Copley Church, New England Aquarium, John Hancock Tower and the Public Garden. (Source: New England Aquarium).

1.2.5 MASSACHUSETTS EFFORTS TO ADDRESS CLIMATE CHANGE

KEY STATE LEGISLATION AND INITIATIVES RELATED TO CLIMATE CHANGE

Under Governor Deval Patrick, Massachusetts has taken important and innovative steps to address climate change, including:

- **Regional Greenhouse Gas Initiative (RGGI):** A regionwide, market-based program to reduce emissions from all power plants larger than 25 megawatts and to create an active carbon market and an auction that generates energy efficiency funding.
- **Green Communities Act:** The Green Communities Act of 2008 required utilities to undertake all investments in energy efficiency that are less expensive than purchasing additional power, strengthened the state's renewable portfolio standard (a requirement that electricity supplies get an increasing share of their electricity from clean energy sources), required utilities to enter into long-term contracts with renewable energy generating facilities, established a Green Communities Program, and included other provisions to support and increase net metering (a policy allowing customers to receive credit at retail rates for electricity they generate onsite) and green buildings.
- **Global Warming Solutions Act:** The Global Warming Solutions Act placed more specific legislative, regulatory, and administrative initiatives into an overarching framework and provided a legal mandate for greenhouse gas emission reductions. It established a statewide legislative goal of reducing emissions to 80% below 1990 levels by 2050. It directed the Secretary of Energy and Environmental Affairs to determine a 2020 goal, which was ultimately set at an ambitious 25% below 1990 levels, and to produce a plan to meet that goal. It also provided state agencies with broad authority to regulate greenhouse gas emissions and required them to issue regulations.

STATE CLIMATE PLAN

In December, 2010, Massachusetts released the Massachusetts Clean Energy and Climate Plan for 2020. The Global Warming Solutions Act of 2008 requires the Secretary of Energy and Environmental Affairs to establish a statewide limit on greenhouse gas (GHG) emissions of between 10% and 25% below 1990 levels for 2020, on the way toward an 80% reduction in emissions by 2050, along with a plan to achieve the 2020 target. Massachusetts has set that 2020 limit at 25%, and the Clean Energy and Climate Plan for 2020 contains the measures necessary to meet the limit. The state plan contains strategies to address climate impacts from many sources, including, for example:

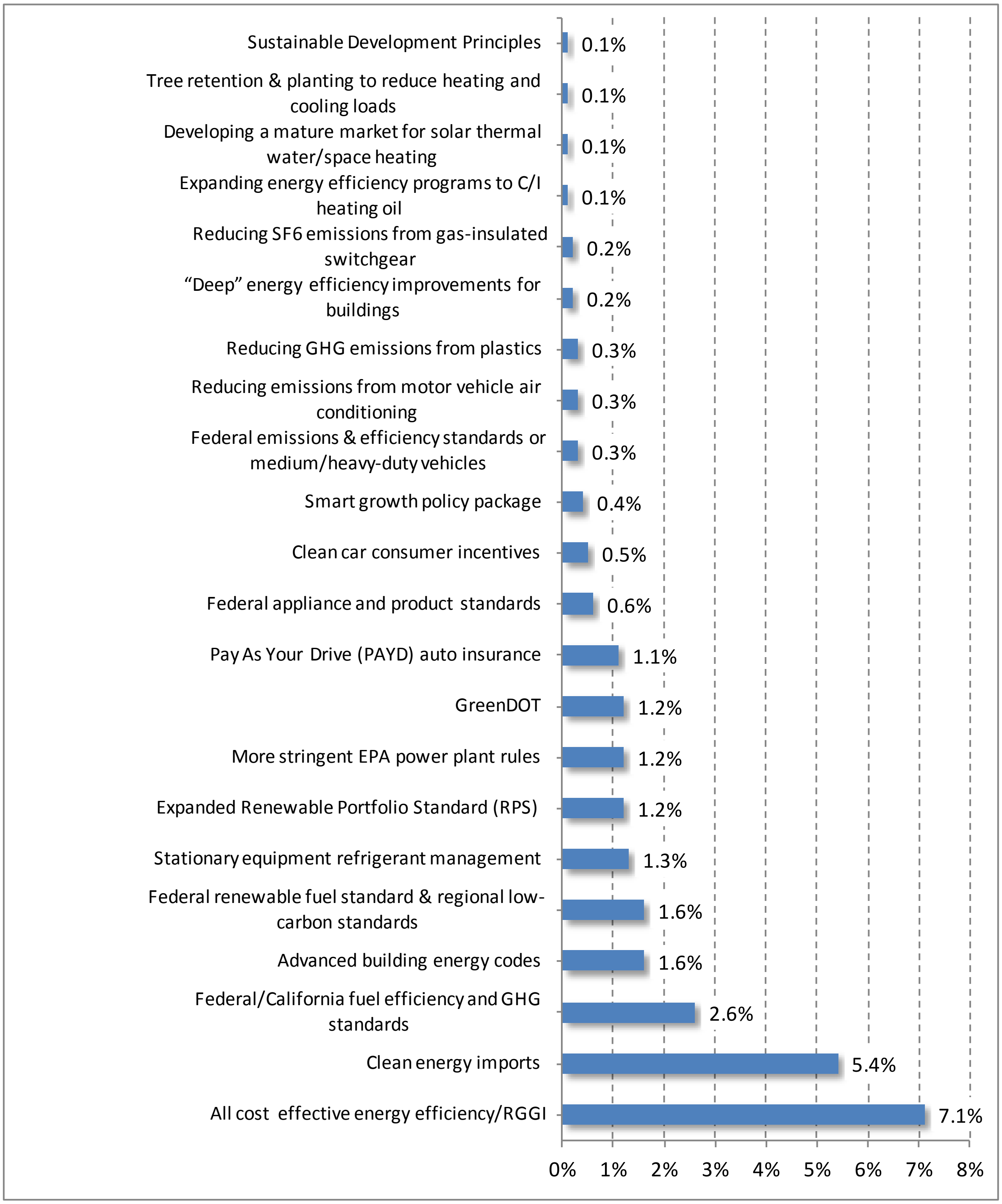
> Climate change is the challenge of our age. For the obvious reason – failing to respond could alter the environment with profound and dire consequences – but also because it is a critical test of government's ability to accomplish something complex for the common good. As this report shows, Massachusetts has been a true laboratory of democracy on this issue. Working across agencies, across levels of government, and across state and national boundaries, we have put in place an array of sophisticated programs and policies to curb our greenhouse gas emissions without inhibiting economic growth or degrading our quality of life. Our progress to date is truly astounding.
>
> *From "Rising to the Challenge: Assessing the Massachusetts Response to Climate Change" 2012*

- **Buildings:** Advanced building energy codes; building energy efficiency; building energy ratings; "deep" energy efficiency improvements, solar thermal and space heating; tree retention and planting;
- **Electricity Supply:** Increase in use of renewable energy sources; more stringent power plant rules; clean energy imports; clean energy performance standards;
- **Transportation:** Vehicle fuel efficiency and GHG standards; low carbon fuel standards; clean car consumer incentives; pay as you drive auto insurance; GreenDOT; and smart growth policies;
- **Non-energy Emissions:** Reducing GHG emissions from motor vehicle air conditioning, plastics, refrigerants and other sources;
- **Cross-cutting Policies:** State permitting and licensing approvals, Mass Environmental Policy Act (MEPA) regulations.

These strategies are focused on steps that state government can take to address climate impacts and clean energy. They do not include many actions that local and regional governments can take, which are complimentary to the state's strategy and are addressed in this plan.

The plan also sets state emissions targets for 2020 and 2050, and describes how those targets will be met by GHG reductions in specific sectors (see figure below).

Table 1-1: Massachusetts 2020 Climate Plan Reduction Targets by Category and Strategy



Source: Massachusetts 2020 Climate Action Plan. April 2010

SUCCESS OF STATE CLIMATE INITIATIVES

These new state initiatives are having significant positive impacts. Between 2007 and the end of 2010, solar photovoltaic (PV) systems installed and scheduled for installation in Massachusetts increased 20-fold - with jobs in solar manufacturing, installation, and services nearly tripling while installed wind energy increased 10-fold (Massachusetts Executive Office of Energy and Environmental Affairs).

In that same time period, Massachusetts launched the most aggressive energy efficiency program in the country, with estimated savings of over $6 billion for residential, municipal, industrial and commercial customers and 4,500 jobs sustained or created.

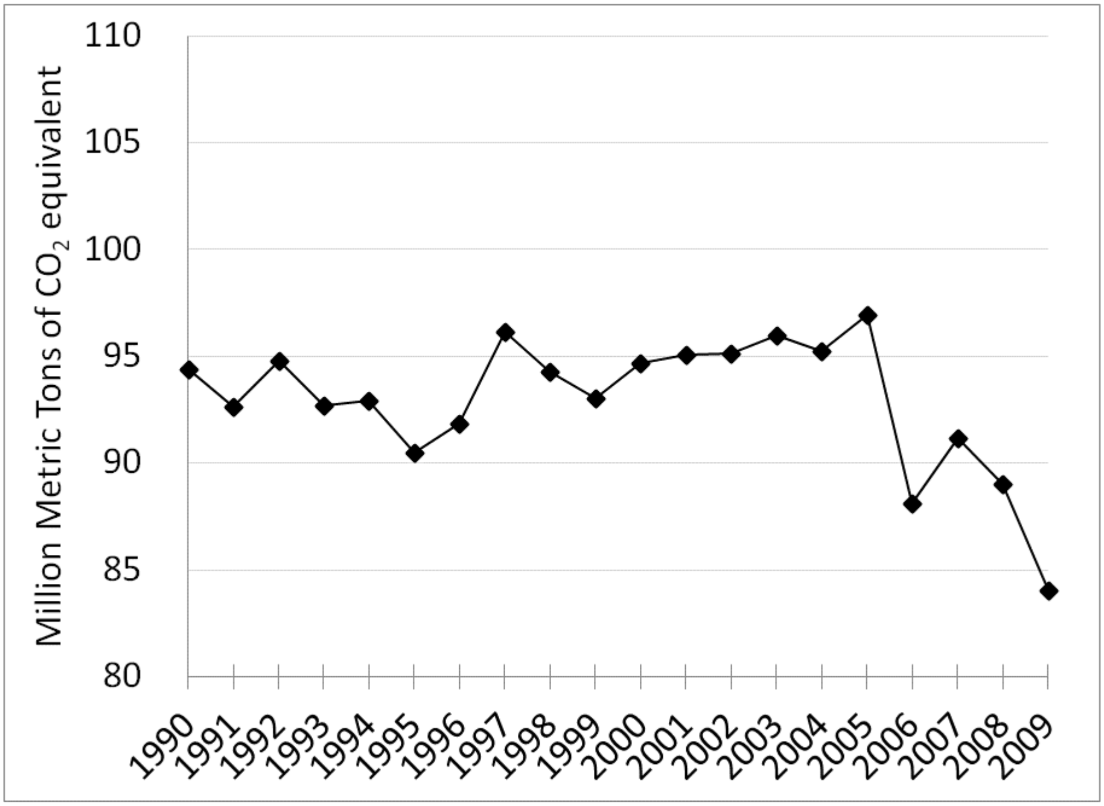
Massachusetts GHG Targets and Progress to Date

(*Excerpts from Rising to the Challenge: Assessing the Massachusetts Response to Climate Change, MassInc, April, 2012)*

Massachusetts has pledged to reduce greenhouse gas emissions 25% from 1990 levels by 2020 and 80% below 1990 levels by 2050. The report, Rising to the Challenge examines how far along the state is with implementing climate change actions to achieve these goals. Following are key conclusions from this report:

- "Massachusetts has been a true laboratory of democracy on this issue. Working across agencies, across levels of government, and across state and national boundaries, we have put in place an array of sophisticated programs and policies to curb our greenhouse gas emissions without inhibiting economic growth or degrading our quality of life. Our progress to date is truly astounding."
- "Among the initiatives that are generally progressing well are the state's energy efficiency programs, the renewable portfolio standard, the Green Communities program, and the Leading by Example program. Those programs are achieving meaningful results and appear to be effectively managed."
- "The implementation of new initiatives and activities is lagging. Among them are clean car consumer incentives, stationary equipment refrigerant management, pay-as-you-drive insurance, GreenDOT, deep energy efficiency improvements for buildings, and the regional clean fuel standard (low-carbon fuel standard). Because there are only eight years until 2020, these initiatives must be implemented quickly in order to achieve the desired results by that date."
- "Our overarching conclusion is that, although Massachusetts has implemented many effective and indeed nation-leading programs, there is a real likelihood that the state will fall short of its 2020 greenhouse gas reduction goal. To ensure Massachusetts hits the target it is legally bound to achieve, the state must accelerate its effort."

Figure 1-7: Massachusetts GHG Emissions



Source: Massachusetts Executive Office of Environment and Energy Resources 2010

1.2.6 LOCAL AND REGIONAL EFFORTS NEEDED

Our region is working toward reducing our fair share of GHG emissions. Federal and state governments alone cannot solve the climate crisis. Success will require efforts from local and regional governments, and indeed individuals and businesses, to reduce our carbon footprint.

Massachusetts has adopted legislation requiring the statewide reduction greenhouse gas emissions 25% from 1990 levels by 2020 and 80% below 1990 levels by 2050. To help achieve these goals, the Pioneer Valley region must establish similar GHG reduction targets and work to achieve them.

This plan focuses on local and regional actions that can be taken to address climate change and clean energy. These actions fall into two categories: mitigation of greenhouse gas emissions, and adaptation to the unavoidable consequences and damage of the present and future changes in climate. Strategies are described in Chapter 8, detailed in the Climate Action Toolbox, and summarized briefly here.

GHG MITIGATION STRATEGIES

Strategies to reduce greenhouse gas emissions, increase energy conservation and reduce dependence on carbon-based fuels are referred to in this plan as "mitigation strategies". GHG mitigation addresses issues such as:

- Land use and zoning strategies – to reduce GHG emissions by promoting more compact development, reducing auto trips, and planting and protecting trees.
- Clean energy strategies – to reduce GHG emissions by promoting energy conservation and use of renewable energy alternatives.
- Other municipal mitigation strategies – to promote community-wide planning and actions, including reducing landfill waste and emissions.
- Regional mitigation strategies – to coordinate inter-municipal cooperation and action on climate action, and to reduce the impacts of the transportation system and auto emissions.
- Mitigation strategies for individuals and businesses – to promote homeowner and business "best practices" for energy conservation, clean energy alternatives, tree planting, green vehicle purchases and composting.

CLIMATE ADAPTATION STRATEGIES

We must also adapt to the more extreme weather events of a changing climate and work to increase the region's resilience to withstand and recover from them. Strategies to achieve these goals are referred to as "adaptation strategies". They address issues such as:

- Promoting the ability to recover quickly from extreme weather events, such as extreme heat, heavy rains, hurricanes and tornados.
- Identifying and preparing for damage that is likely to occur to the region's critical infrastructure.
- Preparing vulnerable residents and businesses for floods, wind damage and heat waves.

Climate adaptation strategies for the Pioneer Valley are described in Chapter 8.

1.2.7 BENEFITS OF CLIMATE ACTION AND CLEANER ENERGY

Taking strong action to address climate change and adopt cleaner energy sources will benefit the Pioneer Valley region in ways that go far beyond reducing share of global carbon emissions. Some of these benefits include:

1. **Energy Independence:** Massachusetts is at the end of the energy pipeline, figuratively and literally. All of our fossil-based energy sources — oil, natural gas, and coal — are derived from other regions of the country (e.g., the Gulf Coast or Western states) and other parts of the world, many of them unstable or hostile to the United States. By transitioning to clean energy sources, we can achieve independence from the high economic, environmental and political costs of fossil fuels. (Source: Mass. Clean Energy and Climate Plan for 2020)

2. **Savings on Individual Energy Bills:** With the high cost of electricity and heating oil in Massachusetts, investment in building energy efficiency or the addition of renewable energy sources, such as solar photovoltaic panels, solar hot water systems, wind or geothermal systems, will result in significant direct savings in monthly energy bills for individuals and businesses. State and utility incentive programs reduce the payback period for renewables and energy conservation investments.

3. **Regional Economic Benefits and Jobs:** All of our spending on fossil fuel energy — whether to fuel power plants, buildings, or vehicles — flows out of state and fails to provide income to in-state businesses or employees. This exported economic value is significant, totaling almost $22 billion in 2008.1 In 2008, an average Massachusetts household spent about $5,200 for energy costs, of which about $1,700 was for heating (space and water), $1,300 for electricity, and $2,200 for gasoline. Almost all of these expenditures leave Massachusetts. With clean energy sources, we can produce our own power here in the region, create jobs, and keep our dollars in the region as well.

   Clean Edge, Inc., has found that Massachusetts is the leading state on the East Coast for clean energy innovation, investment, deployment, and jobs. According to a Massachusetts Clean Energy Center (MassCEC) survey of 471 local companies, more than 11,000 people are employed in clean energy at the end of 2010, up 65% since 2007.

4. **Environmental Benefits:** Stabilizing the climate and reducing emissions from burning fossil fuels will have enormous global and regional environmental benefits, including lessened impacts on species extinctions, on water bodies and coral reefs, reducing environmental impacts from severe weather events and droughts, improved water quality, and lower levels of air pollution.

5. **Health Benefits:** Climate action will reduce illness and deaths due to water-borne and vector-borne diseases, heat waves, extreme weather events, poor air quality and loss of crops and food sources due to prolonged droughts. Overall health care costs for all will be reduced as a result.

1.2.8 CLEAN ENERGY SUCCESSES IN THE PIONEER VALLEY

In 2008, PVPC released the Pioneer Valley Clean Energy Plan, which outlined strategies to promote energy conservation and use of renewable clean energy sources. The Clean Energy Plan lays out regional goals for reducing energy use, replacing fossil fuels, reducing greenhouse gases and creating local jobs. It also describes energy options for the region, including: energy efficiency and conservation; wind; landfill gas/co-generation; hydropower; solar electric photovoltaic; solar hot water; biomass; and biofuels.

This plan will include an update and report card on how the Pioneer Valley region is performing in achieving the goals of the Clean Energy Plan (see Chapter 4 for details). Some highlights of our clean energy successes to date are summarized below.

SOLAR

Since 2008, the solar energy generation capacity in Massachusetts has increased almost thirtyfold, from about 4 megawatts in 2007 to 110 megawatts in 2012. Western Massachusetts communities—most notably Holyoke, Amherst, Springfield, Northampton—are on the forefront of the solar energy movement in the state, according to a study released by the Environment Massachusetts Research and Policy Center. Holyoke's Mueller Street solar array is the largest in New England, according to the study, with 14,500 panels. Springfield has the largest amount of solar PV capacity per capita among large cities and towns (but may soon be surpassed by Hadley).

Figure 1-8: Holyoke Mueller Street Solar Array

Source: Holyoke Gas and Electric Company's Mueller Street Solar Array, the largest in New England

The region leads the state in number of solar arrays, with 1,015, as well as in total solar energy capacity, at 21,447 kilowatts (Massachusetts Clean Energy Center 2011).

Holyoke is second in the state, only behind Boston, in total solar energy produced by photovoltaic panels, followed by Pittsfield in third and Springfield in fourth. Holyoke's solar energy capacity is 4,527 kilowatts, while Boston's is 5,647. In terms of the number of solar installations, Northampton and Amherst are tied for fourth, with 81 arrays each. Greenfield is tied with Framingham for 12th place, with 44, and Hatfield and Montague are 38th in the state with 28 installations each. The report was compiled using the most recent data available, but does not reflect the impact of new solar arrays that have gone online in 2012 and 2013, such as Easthampton's 2-megawatt solar array on the capped Oliver Street landfill.

Table 1-2: Top Municipalities for Total Solar Photovoltaic Capacity

City/Town	PV Capacity	Statewide Rank
Boston	5,647	**1**
Holyoke	4,527	**2**
Pittsfield	4,326	**3**
Springfield	2,959	**4**
Dartmouth	2,808	**5**

Source: Massachusetts Clean Energy Center 2011

Table 1-3: Top Municipalities for Total Solar Photovoltaic Installations

City/Town	PV Capacity	Statewide Rank
Boston	**157**	**1**
Falmouth	**127**	**2**
Barnstable	**112**	**3**
Northampton	**81**	**4**
Amherst	**81**	**5**

Source: Massachusetts Clean Energy Center 2011

The Town of Amherst is about to significantly increase its ranking and surpass the 4.53-megawatt array in Holyoke with a 4.75-megawatt solar array on the capped Belchertown Road landfill. Several private large-scale solar PV projects in neighboring Hadley are also in the planning and construction phases, which will bring the total capacity of solar PV installations in that town to nearly 8 megawatts in 2014.

The city of Boston leads Massachusetts in both the total number of solar PV installations (157) and total installed solar PV capacity (5.6 megawatts). Several much smaller cities and towns—Falmouth, Barnstable, Northampton and Amherst—round out the top five municipalities for total number of solar installations. In addition, Holyoke, Pittsfield and Springfield are in the top five for installed solar capacity.

Western Massachusetts is the region of the Commonwealth with the most solar energy installations and the largest amount of solar generating capacity, while the Cape and Islands lead Massachusetts in per capita measures of solar energy deployment.

OTHER CLEAN ENERGY SOURCES

The region has not been as successful in advancing wind energy, biomass and hydro projects. According to data provided by the Massachusetts Clean Energy Collaborative (MCEC), there were no new regional projects using these clean energy sources between 2008 and 2012.

2 LESSONS OF OTHER CLIMATE PLANS

As public awareness about climate change increases, local and state governments throughout the United States have developed plans for how to address climate change in their respective jurisdictions. Municipalities and states have been most active in the development of climate plans, rather than regional planning agencies (RPAs). However, many aspects of climate change can be most effectively addressed on a regional level. While municipalities have the authority to implement many climate change strategies, most impacts of climate change are on a much larger scale than a single municipality and require coordination between multiple municipalities to be effective. For example, the traffic from roads and highways are one of the largest emitters of greenhouse gas, but travel through multiple municipalities and cannot be controlled by each one individually. Similarly, flood waters are directly caused by the amount of water flowing into rivers upstream, and must be coordinated through both the municipalities that are upstream and downstream.

This section showcases excellent examples of municipal and regional plans, in order to both understand the efforts undertaken by individual towns and cities, as well as highlight ways in which these efforts can be coordinated on a regional level. The plans described here also provide a foundation for the adaptation and mitigation strategies recommended for the Pioneer Valley. A private sector case study, Alcoa Inc. aluminum manufacturing, also provides strategies that businesses can utilize for reducing their GHG emissions.

2.1 MUNICIPAL PLANS

Many municipalities, both large and small, have also created plans for reducing their emissions of greenhouse gas and adapting to climate change. These plans generally focus on four different areas:

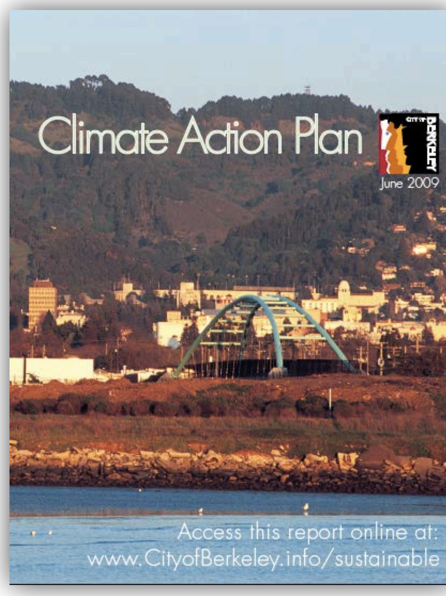
- **Awareness:** Facilitating understanding about climate change issues on the part of municipal officials and the general public
- **Assessment:** Inventorying existing conditions and projecting the impacts of climate change
- **Planning:** Recommending ways in which the general public, businesses, and government can reduce climate change and its impacts
- **Implementation:** Setting out strategies through which planning recommendations can be adopted, and providing updates on the progress of adoption

Below are examples from four municipalities that have created climate action plans.

The US EPA maintains a full list of municipal climate change action plans that have been developed nationwide and is available at: www.epa.gov/statelocalclimate/local/local-examples/action-plans.html.

2.1.1 BERKELEY, CALIFORNIA

Plan Title: Berkeley Climate Action Plan (2009)



Population: 112,000

Relevance to Pioneer Valley Climate Action Planning: Example of a mid-size municipal plan for creating a GHG emissions reduction target, and identifying a wide variety of ways to meet the target

In 2006, the residents of Berkeley, California approved a ballot measure for the City to reduce greenhouse gas emissions by 80% below 2000 levels by 2050, and an intermediate target to reduce GHG emissions by 33% below 2000 levels by 2020, and to develop a Climate Action Plan to meet these targets. The completed plan, which was adopted by the Berkeley City Council in 2009, outlines a broad range of public policy to reduce GHG emissions.

The plan provides an inventory of GHG emissions in the City of Berkeley, using data from a previous GHG emissions inventory that was conducted by the ICLEI – Local Governments for Sustainability in 2005. The inventory uses data on the vehicle-miles driven within the City, electricity consumed by residents, and natural gas consumed within the city limits. While the plan acknowledges that this does not account for all GHG emissions occurring within the municipality, the estimate provides a basic understanding of the different categories of GHG emissions that can be used for reduction efforts. Following the publication of the plan, the City has created annual progress reports on reducing emissions and measures progress on the plan with a set of metrics that include number of bike racks and number of trees planted.

The Berkeley Climate Action Plan can be found at http://www.ci.berkeley.ca.us.

EXEMPLARY RECOMMENDATIONS

Key recommendations from the City of Berkeley's plan fall into five major categories:

- **Promoting sustainable transportation and land use** by promoting funding to public transit, increasing public transit service through more routes and bus frequency, developing incentives for low-carbon vehicles, and implementing bicycle and pedestrian transportation plans**.**
- **Reducing building energy use** by striving for all new construction to be net-zero energy consumption by 2020, educating local residents for green jobs, increasing the local supply of renewable energy through subsidies and zoning.
- **Waste reduction and recycling** by promoting enhanced municipal recycling service, limiting the use of plastic bags, and expand the ability to recycle certain types of plastics.
- **Community outreach and empowerment** by initiating an awareness campaign to educate residents, businesses, and industry about reducing emissions, educating students in schools about climate change, and encouraging citizens to take an active role in reducing emissions through use of public transit, recycling, and using less energy in their homes.

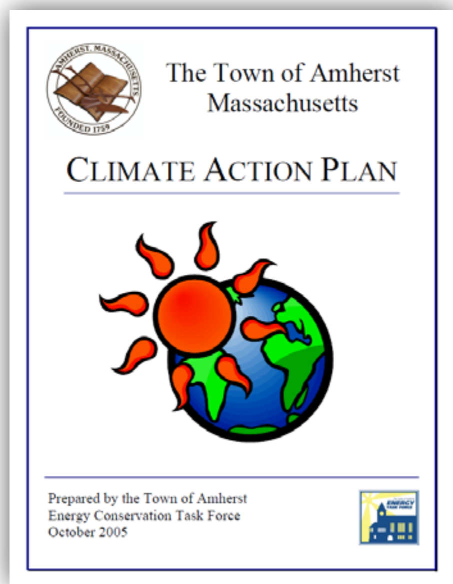
- **Preparing for climate change impacts** by encouraging rainwater recycling to address water shortages, increasing urban tree cover to reduce urban heat island effect, and partnering with local, regional, and state agencies to develop a climate adaptation plan.

2.1.2 AMHERST, MASSACHUSETTS

Plan Title: Amherst Climate Action Plan (2005)

Population: 37,000

Relevance to Pioneer Valley Climate Action Planning: Provides an existing example of a town in the Pioneer Valley that has developed a GHG inventory and has identified and is implementing climate adaptation and mitigation strategies



The Town of Amherst joined the ICLEI – Local Governments for Sustainability Campaign in 2000, and guided by an energy task force of community representatives, conducted a GHG emissions inventory in 2001. The inventory examined municipal, residential, commercial, industrial, and institutional sectors within the City and analyzed them with ICLEI-provided software.

Based on tracking annual GHG emissions since the inventory's baseline year of 1997, it was found that, other than a reduction resulting from the closure of the municipal landfill, GHG emissions were increasing annually in other sectors. With this in mind, the Town set a goal of reducing GHG emissions in 2009 to 35% below 1997 levels, and developed a Climate Action Plan to successfully achieve this goal. The plan includes recommendations for town government and the institutions of higher education located in Amherst, but not the commercial or residential sectors, since these were beyond the direct control of the Town.

The plan can be found at http://www.amherstma.gov/DocumentCenter/Home/View/612.

EXEMPLARY RECOMMENDATIONS

The Amherst Climate Action Plan provides a list of strategies being undertaken by the Town of Amherst, Amherst College, the University of Massachusetts – Amherst, and Hampshire College to reduce GHG emissions. The list of strategies is very specific, highlighting specific facility-level projects and programs with a narrow scope of focus.

- **Reducing energy use at institutional facilities** by installing energy efficient windows, renovations to HVAC systems in buildings, using programmable thermostats, and converting from electric heating to natural gas.
- **Creating more a sustainable transportation system** by increased service and availability of public transit, and promoting bicycling as a commuting alternative, allowing Amherst employees to work from home, providing parking incentives to owners of low-emissions vehicles, improving gas mileage of institutional vehicles, promoting carpooling programs, and using bio-diesel for all diesel-burning equipment.

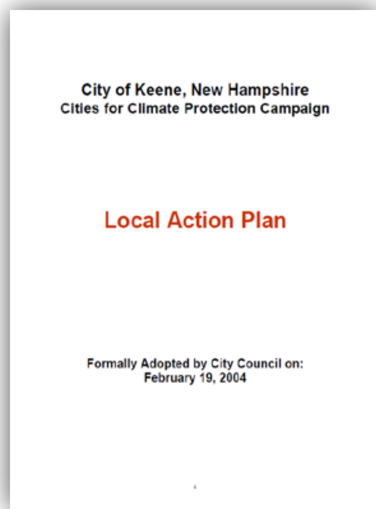
- **Reducing waste generation** by supporting responsible manufacturing of products with less packaging, recapturing methane from landfills, providing rain barrels to homeowners to reduce water consumption, increasing services of college recycling programs and creating a municipal composting program.
- **Promoting energy-efficient land use and planning** by protecting farmland through zoning laws, increasing density in land use regulations, connecting bike lanes to create a bicycle transportation network, and encouraging the construction of green building.
- **Engaging in community outreach** by marketing and promoting Western Massachusetts Electric Company's Energy Savings Programs for homeowners, festivals and fairs promoting awareness of sustainable businesses, and partnering with regional organizations such as the Hitchcock Center for the Environment, Center for Ecological Technology, and Massachusetts Technology Collaborative.

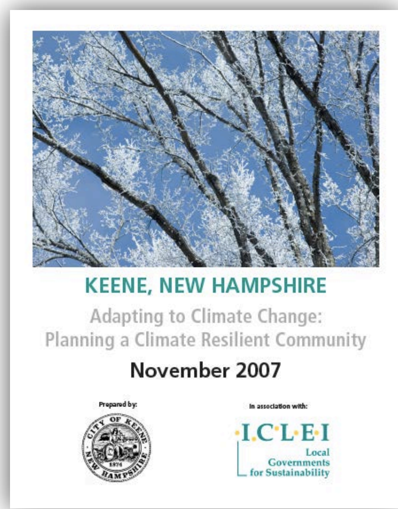
2.1.3 KEENE, NEW HAMPSHIRE

Plan Titles: Climate Change Action Plan (2004), Climate Adaptation Action Plan (2007)

Population: 23,000

Relevance to Pioneer Valley Climate Action Planning: Provides an example of a small New England municipality that has developed plans for both mitigation and adaptation of climate change





The City of Keene developed an initial climate action plan in 2004, with a focus on inventorying greenhouse gas emissions and reducing GHG to 10% below 1995 levels by 2015. The plan was conducted with the City's participation in the Cities for Climate Protection Campaign (CCP), administered by ICLEI – Local Governments for Sustainability. The efforts of this initial plan were built upon in 2007, with the creation of a Climate Adaptation Plan, the first adaptation plan that was developed in line with the guidelines of ICLEI's Climate Resilient Communities (CRC) project. This plan assesses the effects that climate change will have on New Hampshire and determines which areas of Keene will be most vulnerable.

The plan can be found at http://www.ci.keene.nh.us/sites/default/files/Keene%20Report_ICLEI_FINAL_v2_1.pdf

SELECTED RECOMMENDATIONS

The plan provides a prioritized list of strategies for reducing GHG emissions and adapting to climate change. Key recommendations are:

- **Reducing flooding damage to development** by preventing future development in the 200-year floodplain, encouraging new development to use pitched roofs and green building practices, and reducing sprawl.
- **Creating sustainable transportation infrastructure** by encouraging the use of public transit, requiring new development to have a grid layout to reduce vehicle miles traveled, and increasing the amount of permeable surfaces in new roadway designs.
- **Increasing the resiliency of energy infrastructure** by identifying areas to target burying of power lines, promote use of renewable energy through pilot projects, generate 50% of energy needs locally, and reduce energy usage by residents, businesses, and the city government.
- **Promoting wetlands protection and water quality** by protecting aquifer recharge areas, using less water through the use of greywater recycling systems, and creating a wetlands management plan.
- **Protect flora and fauna** by integrating New Hampshire wildlife plan into city policies and preserving forests through land use regulations.
- **Increasing resiliency of agriculture** by growing crops that can accommodate climate change conditions, developing a downtown food co-op, and developing a city food security plan.
- **Improving emergency services and public health** by educating the public about vector diseases and emergency preparedness, increasing community communication during emergencies through automatic calling systems, inventorying telephone land-line availabilities, creating a waste management program for debris from storms, and designating resources and facilities to serve as emergency shelters.
- **Promoting a local climate-appropriate economy** by encouraging use of sustainable building materials and energy conservation measures, creating an Economic Development Coordinator position at the City, incorporating sustainability into economic development policies such as working to attract environmentally-conscious businesses to Keene.

The plan also suggests several strategies to begin implementation:

1. Incorporating the plan recommendations into the City's next master plan, by coordinating policy and land use decisions to ensure they are consistent with the recommendations in the plan.
2. Hiring a Sustainability Coordinator to assist in tracking and implementing climate change efforts, reviewing greenhouse gas emission reduction targets, coordinating with City Departments, and evaluating programs for their effectiveness.
3. Creating a team of municipal officials that will collaborate and integrate adaptation measures into different municipal departments.
4. Prioritizing and assessing recommended actions fro the plan and determine potential funding sources.

2.2 REGIONAL PLANS

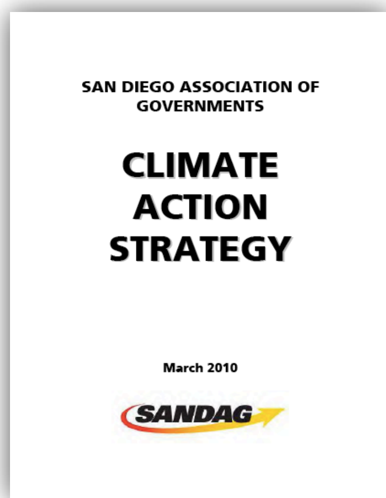
Regional plans, generally created by Regional Planning Organizations (RPOs), focus on the same four areas as municipal plans: awareness, assessment, planning, and implementation. As mentioned previously, while RPOs are well-equipped to coordinate municipal planning efforts in these four areas, they have generally not yet progressed very far in these efforts. This is confirmed by a study conducted by the National Association of Regional Councils surveyed 89 regional planning organizations. While the vast majority of RPOs responding to the survey were working on increasing awareness among their municipalities and staff, RPOs are less involved in other stages of climate change planning, with less than a third of RPOs responding indicating they are working on assessment, planning, or implementation.

The follow-up questions to specific stages of the assessment, planning and implementation phases provide insight into best practices. Key points are as follows:

- For the planning phase, RPOs are making recommendations for addressing climate change that can be categorized as "sustainability and/or smart growth planning" and "encouraging higher density development", especially encouraging higher density around transit. Only a third of RPOs involved in the planning phase incorporated climate change adaptation as part of regional plans.
- Regarding implementation, the most common strategy utilized by RPOs is to conduct outreach and education to municipal officials and the general public. Other strategies include infrastructure development and recommendations based on best practices.
- RPOs generally partner with other entities in developing their climate change plans, with colleges and universities being active in the assessment and planning phases, and state and federal agencies being active in the implementation phases.

The San Diego Association of Governments and the Metropolitan Washington Council of Governments provide two examples of regional planning organizations that have successfully progressed through the planning and implementation stages. They are discussed below, along with other inter-state regional efforts in New England.

2.2.1 SAN DIEGO, CALIFORNIA



Plan Title: San Diego Association of Governments Climate Action Strategy (2010)

Population: 3,200,000

Relevance to Pioneer Valley Climate Action Planning: Provides extensive recommendations for reducing greenhouse gas emissions, addressing infrastructure planning, and provides an example for development of systematic municipal GHG emission inventories.

The San Diego Association of Government (SANDAG), a regional planning organization composed of 19 local governments, published the Climate Action Strategy Plan in 2010. The report, funded through a grant by the California Energy Commission, focuses on climate mitigation but also includes transportation and energy strategies for adaptation. The report found that without new strategies to reduce emissions, land use and transportation plans in the San Diego region would create higher GHG emissions. The strategies included in the plan are meant to address this fact by providing local communities with tools they can implement for reducing GHG emissions.[1]

In conjunction with the Climate Action Strategy Plan, SANDAG's Energy Roadmap Program assists local governments in identifying ways in which they can save energy and reduce greenhouse gas emissions. The service which is offered free to all SANDAG member communities, involves an inventory of GHG emissions within the municipality and the development of a "roadmap" guide to how these can be reduced through various sectors, including building energy efficiency, municipal fuel use reduction, marketing energy programs to businesses and residents, and encouraging the use of public transit by public employees. [2]

The context of climate change policy in California greatly influenced the development of the Climate Action Strategy Plan. Since the state has state legislation requiring regional and local governments to address climate change in their plans, SANDAG envisioned the Climate Action Strategy as directly informing the agency's other plans, including the state-required regional comprehensive plan and the federally-required long-term transportation plan. In order to provide strategies that can be utilized in both of these documents, transportation is a primary focus of the plan. The requirement of climate change planning in the state has also meant that the amount of data on emissions and climate change impacts that has been developed in California is higher than in most states, and that many other governmental entities around the state are available for expertise in developing the plan. This benefit is one of many results from a state promoting climate change planning.[3]

The plan can be found at http://www.sandag.org/index.asp?projectid=337&fuseaction=projects.detail.

EXEMPLARY RECOMMENDATIONS

The Climate Action Strategy report provides a set of nine specific goals and associated strategies ranging from reducing vehicle miles traveled to protecting energy infrastructure from the impacts of climate change.

- **Reducing total miles of vehicle travel** by providing access to daily basic services and public transit by foot or on bicycle, offering incentives in transit-oriented areas for density, promoting infill development and mixed-use, reducing demand for single-occupancy travel
- **Minimizing greenhouse gas emissions** when vehicles are used by reducing traffic congestion and increasing efficiency of road network
- **Promoting use of low carbon alternative fuels** through streamlined permitting of electric car recharging facilities, developing an electric car recharging network, and incorporating electric cars into municipal fleets
- **Protecting transportation infrastructure** from climate change impacts through use of materials that are suited for higher temperatures, accelerating maintenance schedules and preparing for increasing maintenance costs, identifying highways that are susceptible to climate change flooding, and reduce construction in floodplains where possible

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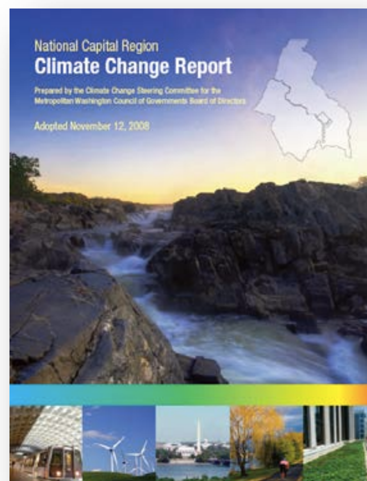
[2] San Diego Association of Governments. "Energy and Climate Change." http://www.sandag.org/index.asp?projectid=337&fuseaction=projects.detail. Accessed 11-13-12.
[3] National Oceanic and Atmospheric Association. "A Survey of Regional Planning for Climate Adaptation." 2012. http://narc.org/wp-content/uploads/NOAA_White_Paper_102912.pdf. Accessed 11-13-12.

- **Reducing energy use in residential and commercial buildings** by encouraging use of LEED design standards, increasing use of solar heating of water, encouraging development of energy rating systems for homes and businesses
- **Increasing use of renewable energy** by promoting the installation of large-scale renewable energy projects, encouraging local governments to streamline the permitting process for renewable energy construction, and identifying locations on a regional scale that can be used for siting of renewable energy
- **Reducing water-related energy use and greenhouse gas** by coordinating with the San Diego County Water Authority to reduce water use, reduce water used by toilets, irrigation, and laundry machines
- **Protecting energy infrastructure from climate change impacts** by reducing use of energy during peak times at government facilities, collaborating with the California Public Utilities Commission, and encouraging the public to use less energy during peak demand times
- **Incorporating energy efficiency measures into SANDAG** by conducting a GHG emissions inventory, assessing agency energy use, and encourage local governments to use clean energy, particularly through the SANDAG Energy Roadmap Program

2.2.2 WASHINGTON, D.C.

Plan Titles: Metropolitan Washington Council of Governments Climate Change Report (2007) and Climate Adaptation Guidebook (2013)



Regional Population: 5,000,000

Relevance to Pioneer Valley Climate Action Planning: Established Climate Action Steering Committee to help draft and implement plan, as well as initiated excellent outreach to include all stakeholders

The Metropolitan Washington Council of Governments (MWCOG) is composed of representatives from 21 local governments, the legislatures of Maryland and Virginia, and members of Congress. The MWCOG began work into a climate change plan in 2007, when its Board of Directors set forth a program with the following objectives:

- Development of a greenhouse gas inventory.
- Setting regional targets for greenhouse gas emission reductions.
- Identifying strategies for reducing emissions.
- Making recommendations on regional policies.
- Recommending a governance strategy for moving forward with climate change plans.

To begin implementing this program, the MWCOG created a Climate Change Steering Committee steering in 2008, to write the National Capital Region Climate Change Report. The report includes reduction targets of 10% below the projected "business as usual," case, in which no action is taking to reduce climate change, by 2012. Further goals include a 20% reduction below 2005 emission levels by 2020, and 80% below 2005 levels by 2050.

In addition to targets and recommendations for reducing emissions, the Climate Change Report included a section introducing climate change adaptation planning. To further adaptation planning efforts, the plan also recommended the formation of a Climate, Energy, and Environment Policy Committee (CEEPC), to address ways in which the region can adapt to climate change. With the assistance of this committee, the MWCOG applied for and received a grant from EPA's Smart Growth Implementation Assistance program. Under this grant, the US EPA hired a consultant on behalf of MWCOG to develop a climate adaptation guidebook, as well as provide MWCOG staff assistance in the development of the plan. The development of the Climate Adaptation Guidebook, which is scheduled to be published in 2013, has involved extensive research and outreach. This outreach demonstrates the need to engage a wide variety of stakeholders in addressing climate change and can be used as an example for the Pioneer Valley. Specific outreach strategies include: [4]

- Data collection and analysis of how projected climate change impacts will affect the region
- Research into national adaptation best practices
- Outreach to experts and stakeholders in the region on the four areas of adaptation strategies discussed in the plan (transportation, land-use, buildings, and water)
- NOAA assistance in training local municipal officials in best practices for conducting a vulnerability assessment
- A Climate Impacts Symposium held in 2012 and designed to provide municipal officials in the region more detailed explanations of the effects that climate change will have on the Washington D.C. metro region.

The Climate Change Report can be found at http://www.mwcog.org/store/item.asp?PUBLICATION_ID=334.

Information on the status of the Climate Adaptation Guidebook can be found at http://www.mwcog.org/environment/climate/adaptation.asp.

EXEMPLARY RECOMMENDATIONS

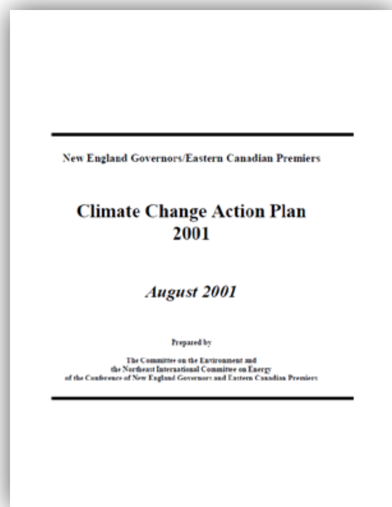
Mitigation strategies for reducing GHG emissions in MWCOG's Climate Change Report include the following:

- **Improving energy efficiency in buildings** by encouraging use of energy-efficient appliances, partnering with utility companies on conservation marketing programs, expanding recycling programs, adopting a goal of 20% renewable energy purchase by local governments by 2015, promote LED street lights, reduce emissions from wastewater treatment plants.
- **Increasing efficiency of transportation and land use** by promoting use of energy-efficient vehicles by local governments, expanding public transit, increasing tree planting, promoting infill development.
- **Promoting green economic development** by encouraging local government and business to use local vendors and suppliers for business needs, and promoting green businesses and jobs.
- **Adapting to climate change** by partnering with universities to research climate change, assisting local governments with development of vulnerability assessments for their infrastructure and development, researching national best practices for preparing for climate change.

[4] National Oceanic and Atmospheric Association. "A Survey of Regional Planning for Climate Adaptation." 2012. http://narc.org/wp-content/uploads/NOAA_White_Paper_102912.pdf. Accessed 11-13-12.

- **Developing ways to finance mitigation and adaptation strategies** by establishing a clean energy fund, participating in cap-and-trade program revenues, and developing a regional carbon offset fund for trees.
- **Conducting education and implementation of strategies** through a public education campaign, preparing an annual progress report to MWCOG Board of Directors on progress, creating a COG Climate and Energy Policy Committee, and evaluating the cost-effectiveness of proposed mitigation measures.

2.2.3 NORTHEAST UNITED STATES AND EASTERN CANADA


New England Governors/Eastern Canadian Premiers

Climate Change Action Plan
2001

August 2001

Prepared by

The Committee on the Environment and
the Northeast International Committee on Energy
of the Conference of New England Governors and Eastern Canadian Premiers

Plan Title: New England Governors / Eastern Canadian Premiers Climate Change Action Plan (2001)

Regional Population: 5,000,000

Relevance to Pioneer Valley Climate Action Planning: Demonstrates cross-jurisdictional governmental cooperation and the inventorying and reduction of GHG emissions through innovative programs

The Conference of New England Governors / Eastern Canadian Premiers (NEG/ECP) Climate Change Action Plan was created in 2001 for the purpose of reducing GHG emissions. The plan calls for GHG emissions to be reduced below 1990 levels by the year 2010, and 10% below 1990 levels by 2020. The NEG/ECP is composed of the governors of the New England states and the Premiers of the Canadian provinces of New Brunswick, Newfoundland and Labrador, Nova Scotia, Prince Edward Island, and Quebec. Meeting annually most years since 1973, the NEG/ECP's plan established the first regional emissions target reduction in the country and was also the world's first international reduction agreement. The plan is indicative of the regional collaboration that is possible for addressing climate change and reducing GHG emissions.

Among the plan's recommendations is the creation of regional GHG emissions tracking and inventory to establish the groundwork for a global warming cap-and-trade system. This recommendation led in part to the establishment of the Regional Greenhouse Gas Initiative (RGGI), a regional carbon trading system between ten states in the northeastern United States that began in 2008. The RGGI has been very successful, resulting in the Northeast reducing its per capita carbon dioxide emissions by 20% more than the rest of the nation during the 2000s. The RGGI has been very helpful towards meeting the target GHG emission levels of the NEG/ECP plan. By 2009, the six New England states that had participated reduced their carbon dioxide emissions to 7% below 1990 levels.

The plan can be found at http://www.iclei.org/documents/USA/NEG-ECP_CCAP.PDF.

EXEMPLARY RECOMMENDATIONS

The NEG ECP Climate Change Action Plan includes the following recommendations:

- **Establishment of a plan for reducing GHG emissions and conserving energy** through each state / province developing its own local reductions plan, reporting to NEG/ECP on annual progress, updating the overall plan every three years based on success of current efforts, and collaborating on reduction programs with other states / provinces.

- **Promotion of public awareness** through increasing dialogue between citizens, businesses, and non-government organizations, and requiring utility companies to describe to consumers the fuel mix they use to generate electricity.
- **State and provincial governments to lead by example** through implementing government energy reduction programs, using fuel-efficient vehicles, telecommunicating, and using sustainable building design for government buildings.
- **Reduction of greenhouse gases from the electricity sector**, with a specific goal of reducing carbon dioxide emissions by 20% below 2001 levels by 2020, and using renewable energy sources to do so.
- **Reduction of the total energy demand through conservation**, encouraging the construction of buildings with high-efficiency lighting and heating systems.
- **Reduction and/or Adaptation of Negative Social, Economic and Environmental Impacts of Climate Change** by creating a regional climate change monitoring network with the scientific community that documents impacts to infrastructure, monitors severe weather, determines the vulnerability of plant and animal species to climate change and encourages local food production.
- **Decrease in the transportation sector's growth in GHG Emissions** through promoting compact development, encouraging bicycling and walking, reducing automobile transportation demand where possible, and promoting the use of high efficiency vehicles that use low-carbon fuels.
- **Creation of a regional emissions registry and the exploration of a trading mechanism** by creating a registry of carbon emitters, a baseline inventory of current carbon emissions, and encouraging the development of green technologies through the US EPA's Environmental Technology Verification (ETV) program.

2.3 PRIVATE SECTOR

Private sector efforts to address climate change are also a important part of regional efforts to mitigate GHGs and adapt to climate change impacts. This section offers a relevant example from Pittsburgh, Pennsylvania.

2.3.1 ALCOA, INC., PITTSBURGH, PENNSYLVANIA

Title: Alcoa Climate Action Plan

Relevance to Pioneer Valley Climate Action Planning: Example of a private sector business tracking and reducing its own GHG emissions, in cooperation with government agencies

Alcoa Inc., based in Pittsburgh, Pennsylvania, is one of the world's largest manufacturers of aluminum, supplying the aviation, auto, and building construction industries. Aluminum manufacturing is an extremely energy-intensive process, with the industry producing 3 million metric tons of carbon equivalent emissions of greenhouse gas in 1998. However, there is great potential to reduce GHG emissions from the manufacturing process, both through recycling and improvements to energy efficiency.

Alcoa became involved in climate change mitigation in 1998, pledging to reduce GHG emissions 25% by 2010. The company met this goal by 2003, and established new goals to further reduce emissions. The company's current goal, established in 2010, is to reduce emissions 20% by 2020, and 30% by 2030, using a 2005 baseline.

EXEMPLARY ACTIONS

Key strategies that Alcoa has implemented to reduce its GHG emissions are:

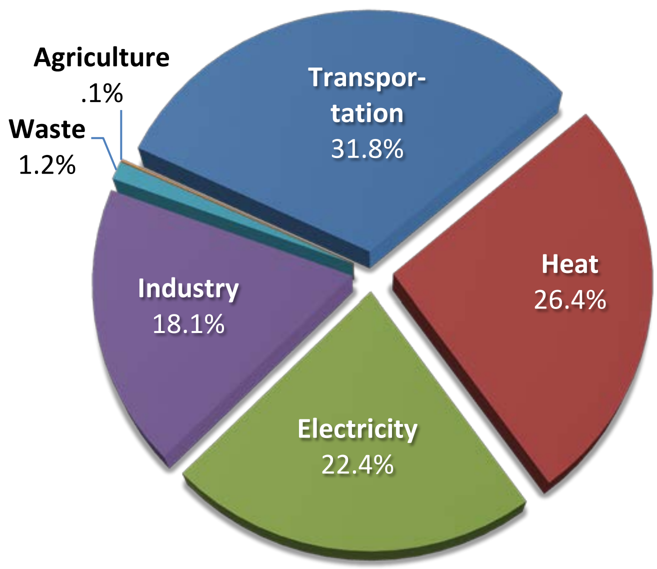
- **Measuring and inventorying significant GHG emissions**, through the establishment of a central database that is connected to the company's plant manufacturing data, and which allows for monthly reports of GHG emissions and evaluation of energy usage.
- **Reducing energy consumption from manufacturing**, with a current goal of reducing energy usage for refining and smelting by 10% in 2020 and 15% in 2030, using best practices that have previously included improving furnace efficiency and the electricity used by its smelters.[5]
- **Encouraging businesses and the general public to increase recycling** of aluminum cans from 58% in 2010 to 75% in 2015.[6] Creating aluminum from recycled material uses 95% less energy than creating it from raw material.
- **Collaborating with other businesses and the government**, through a partnership between the US EPA and other aluminum manufacturers in the country. The Voluntary Aluminum Industrial Partnership established a memorandum of understanding for reducing perfluorocarbons (PFCs). US EPA provided technical information about reducing PFCs and public recognition of Alcoa's efforts

[5] King, Marcus et al. "U.S. Business Actions to Address Climate Change: Case Studies of Five Industry Sectors." Numark Associates. 2004. http://www.numarkassoc.com/res/ISR.pdf. Accessed 11-28-12.
[6] Alcoa Sustainability Highlights Report. http://www.alcoa.com/sustainability/en/pdfs/2011_Sustainability_Highlights_Report.pdf. Accessed 11-29-12

3 GREENHOUSE GAS (GHG) INVENTORY

This is the first greenhouse gas (GHG) inventory for the Pioneer Valley (Hampden and Hampshire Counties). It finds that that total GHG emissions were approximately 9,201,933 metric tons of carbon dioxide equivalent (MCO2e) in 2010. This is approximately 10% of the Massachusetts statewide GHG emissions total (94.4 million MTCO2e) for that year, and about .13% of all GHG emissions in the United States. The Pioneer Valley's GHG emissions are comparable to those of small countries, such Uruguay and Luxembourg.

Figure 3-1: Pioneer Valley GHG Emissions by Sector 2010



Sector	$MTCO_2e$
Transportation	2,922,382
Heat for buildings	2,428,076
Electricity consumption	2,064,432
Industry	1,663,689
Waste	110,547
Agriculture	12,806
TOTAL	**9,201,933**

The proportion of GHG emissions in these sectors in our region differs from statewide sector averages in three important ways:

- **Transportation emissions are lower** (31.8% vs. 36.9% statewide)
- **Electricity emissions are lower** (22.4% vs. 30.3% statewide)
- **Industrial emissions are higher** (18.1% vs. 3.2% statewide)

Significantly, the Pioneer Valley's green areas are able to sequester almost one-third (32%) of all carbon accounted for in the inventory, versus a statewide average of 13%.

This indicates that preservation of tree cover, forest management, wetland conservation and maintaining of other vegetated areas can make a significant difference in the net quantities of GHG emissions produced in the Pioneer Valley.

Forest Park, Springfield. The Pioneer Valley has enough parks, forests, wetlands and other vegetated areas to soak up 32% of the region's carbon emissions. This is more than double the statewide average carbon sequestration capacity of 13%.

GHG INVENTORY CONTEXT AND DATA SOURCES

Climate action planning at any scale requires an understanding of existing greenhouse gas (GHG) emissions, historic emissions trends and sources. GHG emissions are generally estimated at the global, national and state scales. This chapter presents estimates of GHG emissions at the regional scale for the Pioneer Valley, the first time that such information has been produced.

Nationally, U.S. EPA has estimated and tracked GHG emissions since 1990. The agency's April 2012 report, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010, states:

> **In 2010, total U.S. greenhouse gas emissions were 6,821.8 million metric tons CO2 equivalent (MMTCO2e). Total U.S. emissions have increased by 10.5% from 1990 to 2010, and emissions increased from 2009 to 2010 by 3.2% (213.5 MMTCO2e). The increase from 2009 to 2010 was primarily due to an increase in economic output resulting in an increase in energy consumption across all sectors, and, much warmer summer conditions resulting in an increase in electricity demand for air conditioning [....]. Since 1990, U.S. emissions have increased at an average annual rate of 0.5%.**

Massachusetts emits 1.3% of all GHGs in the U.S. GHG emissions in the state are estimated and tracked in accordance with the Global Warming Solutions Act of 2008. Bucking the national trend reported above, GHG emissions in Massachusetts have been roughly stable since 1990, at approximately 93 MMTCO2e.

This first GHG inventory at the regional level in Massachusetts estimates that total GHG emissions for the Pioneer Valley (Hampden and Hampshire Counties) were 9,201,933 MMTCO2e in 2010. This is approximately 10% of the Massachusetts statewide total, or about .13% of all GHG emissions in the U.S.

This inventory presents the quantities and sources of GHG emissions produced in the Pioneer Valley ("direct" emissions), as well as GHG emitted outside the region to generate the electricity that is consumed within it ("indirect" emissions). This information is intended to help improve the understanding of the likely and potential effects of GHG reduction measures and to help establish initial benchmarks for tracking the effectiveness and progress of those measures in the future.

Chapter 3 summarizes three types of information about GHG emissions in the Pioneer Valley:

- **3.1 Regional Greenhouse Gas Inventory**—An estimate of total GHG emissions from the following six major sources: generation of electricity, heating of homes and businesses, motor vehicles and other transportation-related uses, industrial activities, agriculture and solid waste processing.
- **3.2 Carbon Sequestration from Vegetation**—An estimate of GHG reductions resulting from the absorption of carbon dioxide by the plants growing in the region.
- **3.3 Historic Carbon Emissions Estimates 1999-2008**—Annual estimates of carbon emissions produced in the region by the Vulcan Project, an index created by the University of Arizona and U.S. Department of Energy that uses multiple data sources to estimate carbon emissions in each county in the United States.

In addition, Section 3.4 presents information about energy efficiency measures adopted and renewable energy capacity for the municipalities in the region.

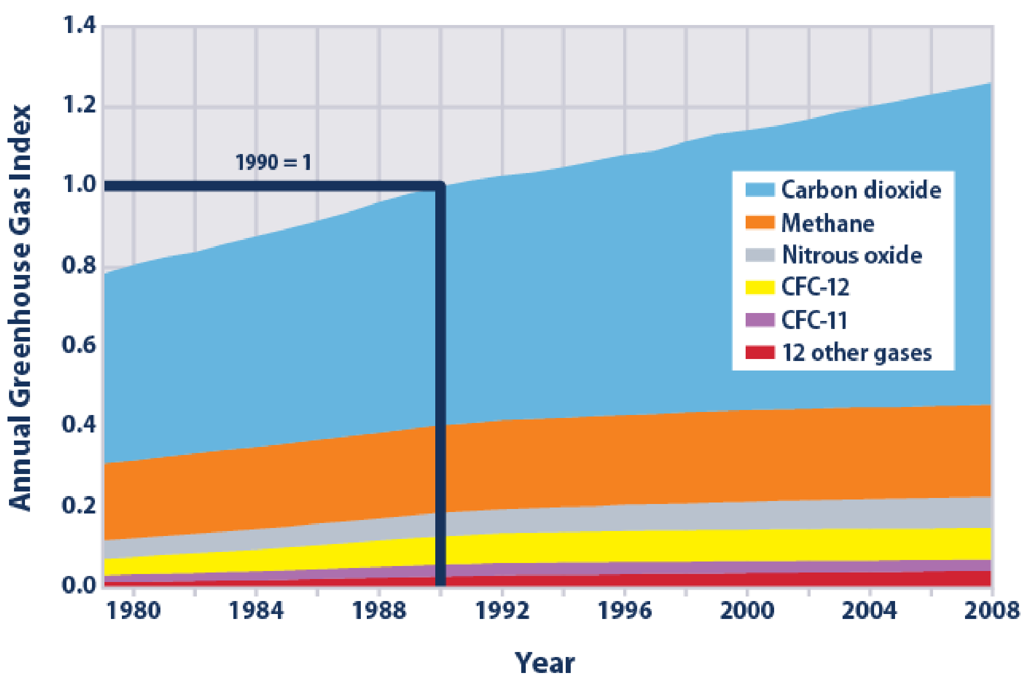
The method and data sources for the inventory information and estimates presented in Chapter 3 are provided in Appendix 1: GHG Regional Inventory Method.

3.1 PIONEER VALLEY GREENHOUSE GAS (GHG) INVENTORY

This inventory for the Pioneer Valley was developed to estimate GHG emissions in Hampshire and Hampden Counties using international and state best practices. The principal method and data sources used are those described by the Massachusetts Department of Environmental Protection in its July 2012 technical memo "Final 2006-2008 Massachusetts Greenhouse Gas Emissions Inventory" <www.mass.gov/dep/air/climate/ghg08inf.doc>. The full method and documentation for the Pioneer Valley GHG inventory are presented in Appendix 1. PVPC intends that this regional GHG inventory will be updated regularly to help track trends in GHG emissions and assess progress toward GHG reduction targets. The Massachusetts statewide GHG inventory is updated every five years and is available at: www.mass.gov/eea/air-water-climate-change/climate-change/massachusetts-global-warming-solutions-act/

This inventory presents GHG emissions in a common unit known as carbon dioxide equivalent emissions, or "CO2e." Because of the large quantities of GHGs involved in a regional scale inventory, this unit is sometimes also presented as metric tons of carbon dioxide equivalent emissions, or "MTCO2e." A common unit is necessary, as GHGs include five principal types of gases (and 12 others in lesser quantities) with varying heat retention characteristics in the atmosphere. While carbon dioxide makes up the largest proportion of GHGs in the atmosphere (approximately 80%), the gases in smaller proportion actually have greater heat retention properties. Methane, for example, is approximately 25 times as effective in retaining heat as carbon. Therefore, conversion of these different gases to a common unit (CO2e) allows an "apples to apples" comparison of all GHG emissions. The proportion of GHGs in the atmosphere is shown below.

Figure 3-2: Annual Greenhouse Gas Index 1979-2008



Data source: NOAA (National Oceanic and Atmospheric Administration). 2009. The NOAA Annual Greenhouse Gas Index. Accessed April 2009. www.esrl.noaa.gov/gmd/aggi.

This inventory presents emissions estimates in CO2e units for the following sectors:

Electricity	Indirect emissions from electric power that is generated for consumption in the region. Because the Pioneer Valley has only two major electrical power plants (coal-fired Mount Tom in Holyoke and natural gas-fired Berkshire Power in Agawam), electricity-related GHG emissions are estimated for power plants located both inside and outside the region based on the amount of electricity that is distributed via the electric grid and consumed in the region. Because this electricity is produced at many different plants using different types of fuel and with varying transmission efficiencies, this assessment is not able to provide the geographic locations and proportional shares of electric-related GHG emissions.
Heating	Direct emissions from heating with oil, natural gas, propane, and wood in buildings.
Transportation	Direct emissions from fuel combustion used in vehicles, trucking and public transit.
Industry	Direct emissions from industrial processes.
Waste	Direct emissions related to active landfills.
Agriculture	Direct methane emissions from livestock food digestion and manure management.

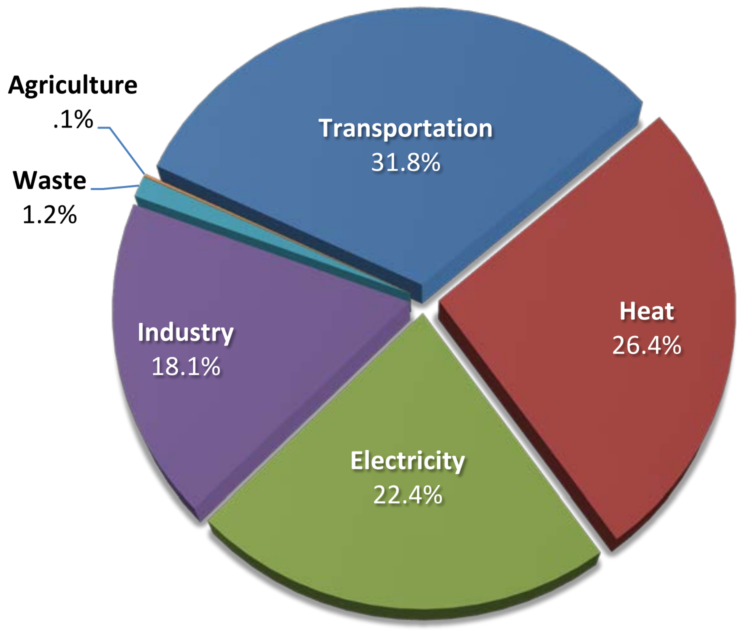
3.1.1 PIONEER VALLEY GHG INVENTORY

Total GHG emissions for the Pioneer Valley in 2010 were 9,201,933 MTCO2e. This is comparable to the total amount of GHGs emitted in 2008 by small countries, such Uruguay and Luxembourg.

The figure on the next page shows that of the six principal GHG sector categories, which are summarized below:

- **Transportation** was the biggest single source of GHG emissions in the region in 2010, accounting for 2,922,382 $MTCO_2e$, or 31.8% of total emissions.
- **Heating** for buildings was the second largest source, with 26.4% or 2,428,076 $MTCO_2e$.
- **Electricity** consumption accounting for a little less than a quarter or 2,064,432 $MTCO_2e$.
- **Industrial** processes were responsible for 1,663,689 $MTCO_2e$ or 18.1% of all emissions.
- **Waste and agriculture** were responsible for less than 2% of total emissions with 110,547 and 12,806 $MTCO_2e$ respectively.

Figure 3-3: Pioneer Valley GHG Emissions (9.2 MMTCO2e) Proportions By Sector 2010

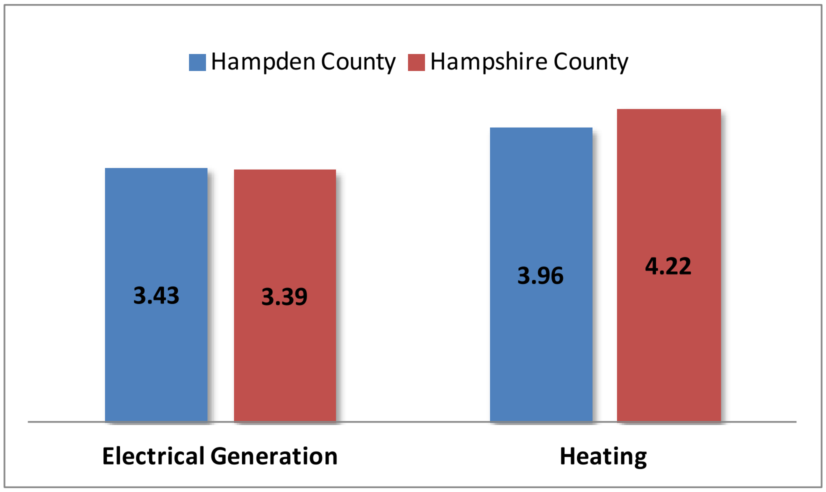


Source: Pioneer Valley GHG Inventory 2011

Though the transportation emissions are the largest single sector, it is the region's buildings, which consume both electricity and heat, that account for a combined total of nearly half (48.8%) of all GHG emissions in the region. Hampden County generates approximately 80% of the region's GHG emissions, which is not surprising, as it is home to about three-fourths of the region's total population (464,000 people versus 158,000 residents in Hampshire County), as well as the majority of the region's energy intensive industrial users.

Emissions from heating, the second largest source of GHG emissions, are also generated primarily in Hampden County. A total of 1,835,490 metric tons of CO2e were emitted in Hampden County, versus 592,587 metric tons of CO2e in Hampshire County. However, on a per capita basis, Hampshire County created more GHG emissions per person than Hampden County. This is likely a reflection of the fact that a much greater proportion of people in Hampden County live in multi-family structures, which tend to be more efficient to heat than single-family homes because of their shared interior walls, ceilings and floors.

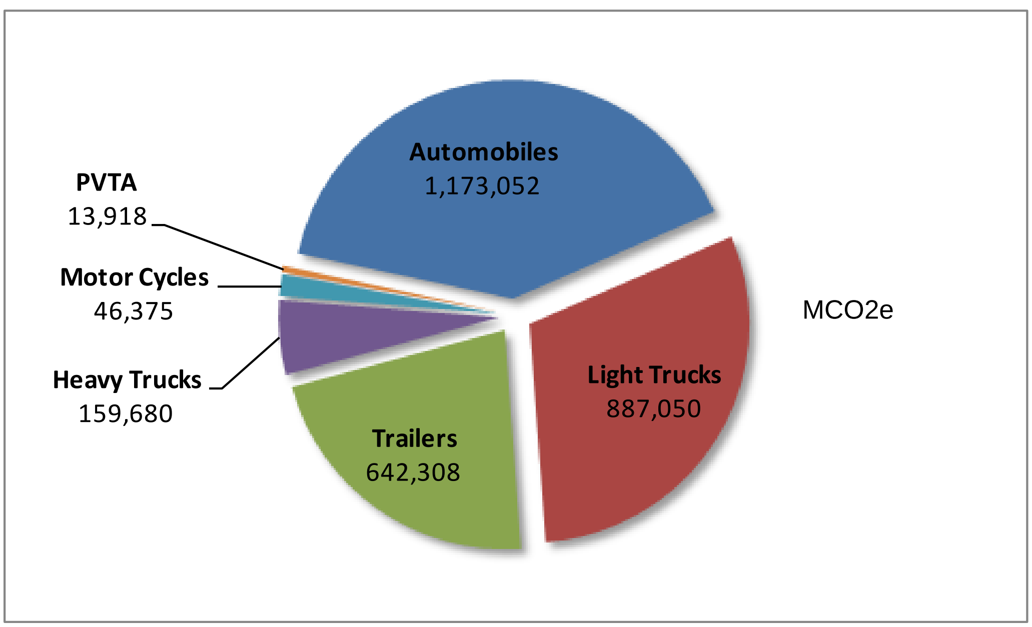
Figure 3-4: Per Capita GHG Emissions From Electrical Generation and Heating by County in MMCO2e



Source: Pioneer Valley GHG Inventory 2011

The largest contributor to GHG emissions in the region is the transportation sector. This includes passenger automobiles, light trucks and tractor-trailers. The Pioneer Valley Transit Authority (PVTA), which transports 15,000 to 20,000 riders every day to and from their destinations, is responsible for less than 1% of the region's GHG emissions. (At typical loadings, both the diesel and diesel-electric hybrid buses in the PVTA fleet achieve the approximate equivalent of 100 to 120 miles per gallon per passenger.) Transportation emissions are not available by county, but it would likely follow the same pattern as heating-related emissions, with larger totals in Hampden County, while Hampshire County would likely have higher per-capita emissions.

Figure 3-5: Pioneer Valley Transportation GHG Emissions by Vehicle Type for 2010



Source: Pioneer Valley GHG Inventory 2011

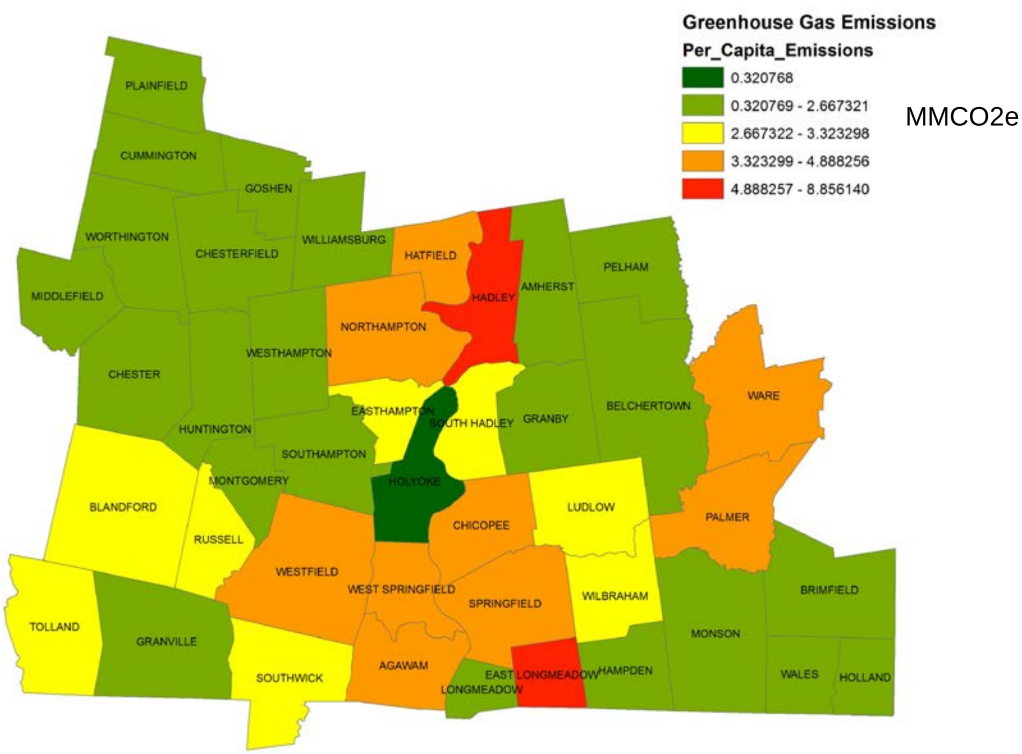
Landfill gas emissions account for a small part of the Valley's GHG emissions, although we know they are not fully accounted for given the lack of data for existing landfills. It should be telling that only five (5) active landfills are estimated to produce about 1.4% of the region's GHG emissions. The dozens of closed landfills would likely add significantly to that figure.

At less than 1%, GHG emissions from agriculture and livestock were a very small percentage of the region's total. Of all agricultural emissions, about 93% come from enteric fermentation (emitted through livestock belching and flatulence) and less than 7% come from manure management.

Determining the geographic locations of GHG emissions by sector is difficult. Transportation-related uses cannot reliably be assigned to location, as the vehicle types and miles traveled of auto drivers vary widely. While some GHG emissions can be monitored on and adjacent to roads, estimating motor-vehicle GHGs at the micro-scale is an evolving area of research and is beyond the scope of a regional inventory. However, direct GHG emissions from transportation, especially from gas- and diesel-powered motor vehicles, have significant effects on human health and are therefore important for future research and planning efforts.

GHG emissions released during electricity production occur at the plant where the electricity is generated, which can change on a daily or hourly basis, depending on the management of the regional power grid. However, understanding electrical use locations (for example, by municipality) is relatively straightforward, as electric use information is available from utility companies. Because nearly all GHG emissions from electricity are considered "indirect" (that is, occurring outside the region), identifying municipal consumption is one of the most useful methods for helping to understand where conservation and efficiency measures may have the most benefit.

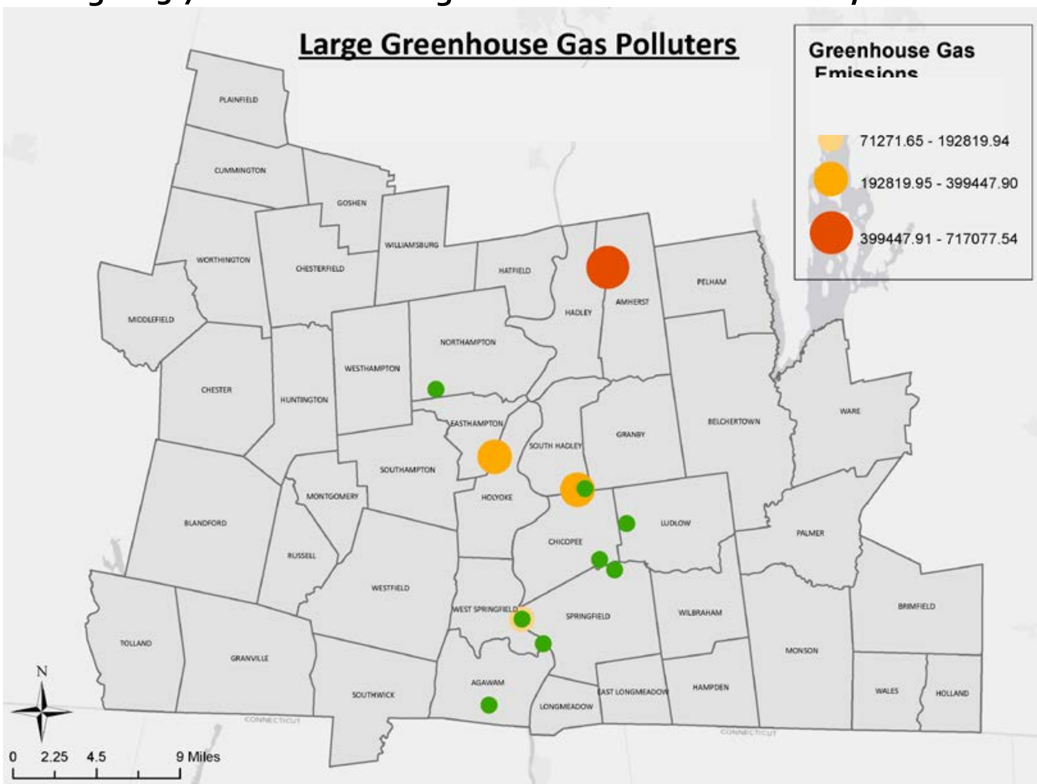
Figure 3-6: Per Capita GHG Emissions From Electricity Generation By Municipality 2010



Source: Pioneer Valley GHG inventory 2011

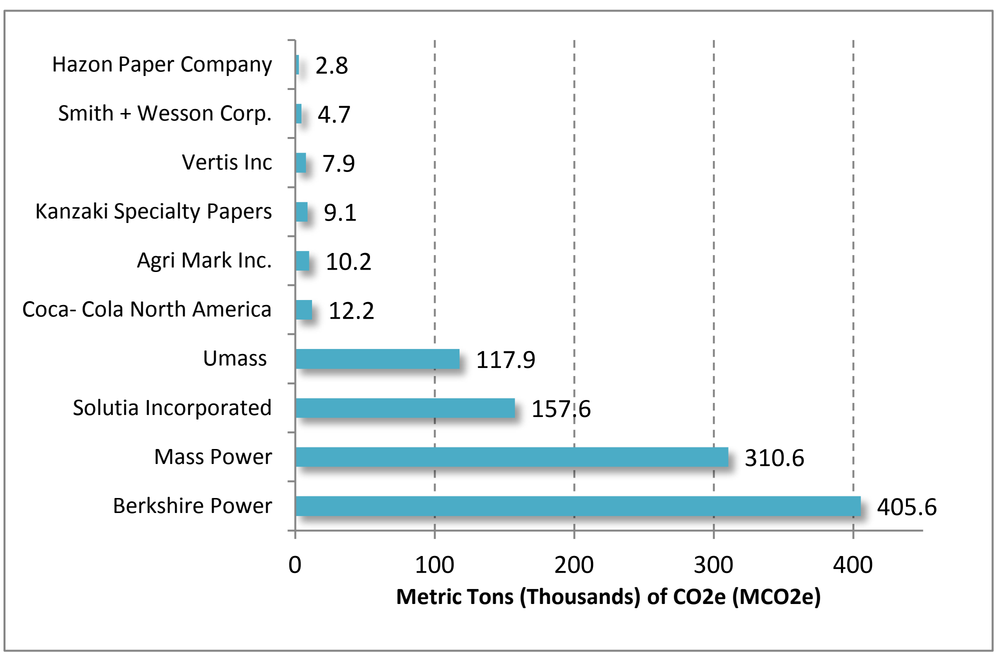
It is also helpful to understand where the largest sources of GHG emissions are located, as presented below.

Figure 3-7: Locations of Largest GHG Emissions in MCO2e, 2010



Source: Massachusetts Department of Environmental Protection 2010

Figure 3-8: Total Emissions by Top Large Emitters - 2010



Source: Massachusetts Climate Registry Information System (CRIS), of Mass. DEP

Significant findings about the region's largest GHG emitters include:

- Stationary combustion has the most impact on the total emissions among all categories.
- Berkshire Power, Mass Power, and Solutia Incorporated are the three largest emitters in the region.
- The top three largest emitters generate more GHG emissions than the next nine top emitters.
- The top three large emitters had significant increases in their emissions from 2009 to 2010.

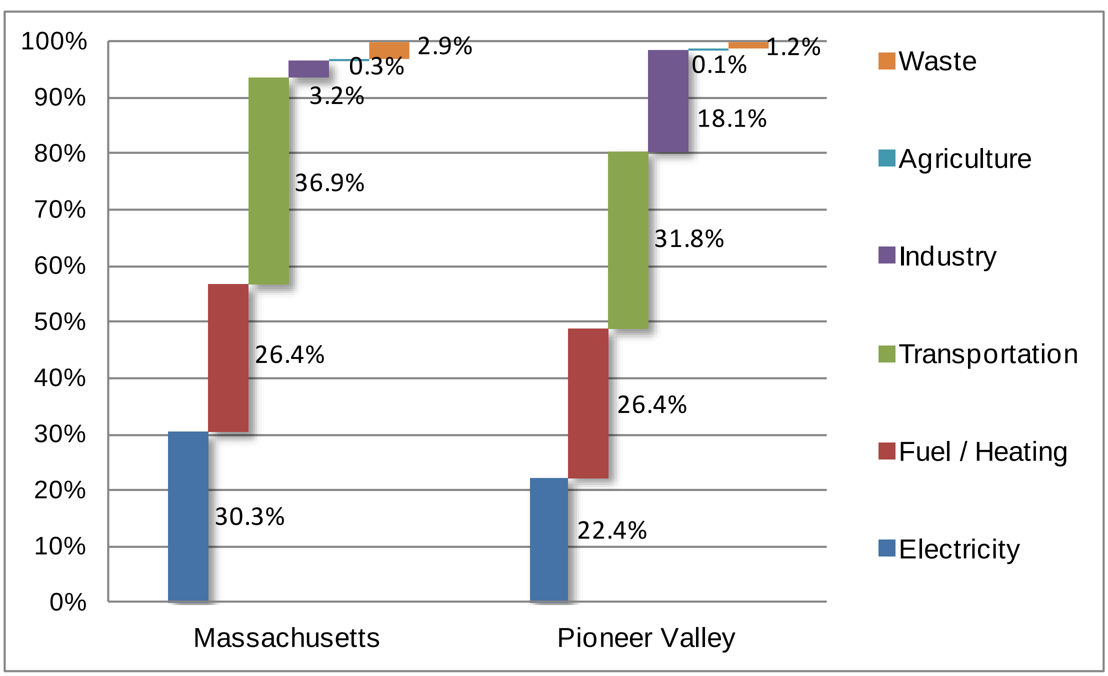
See Appendix 1: GHG Inventory Method and Data for detailed information on largest emitters.

3.1.2 COMPARISON OF REGIONAL AND STATE GHG SECTOR PROPORTIONS

The proportions of GHG emissions by sector is very similar to the Massachusetts state-wide emissions inventory for 2007 by the Massachusetts Department of Environmental Protection.[i] The figure below presents the state and regional proportions. The most significant difference is the inverse relation between electricity and heating. This may be due to the heating efficiency of the local housing stock and the lower concentration of developments requiring electricity (such as commerce and industry) when compared to the eastern part of the state.

While transportation only appears to represent a slightly higher proportion of the Pioneer Valley's emissions when compared to the state, this difference is undercounted because the state total includes additional modes of transportation for which there is no region-specific information, including freight rail, passenger rail, and aviation. Also, waste emissions are likely underestimated, as the Pioneer Valley regional inventory data is limited to active landfills; it does not include inactive landfills or water treatment plants, both of which emit GHGs.

Figure 3-9: Comparison of Proportions of Massachusetts and Pioneer Valley GHG Emissions By Sector 2010

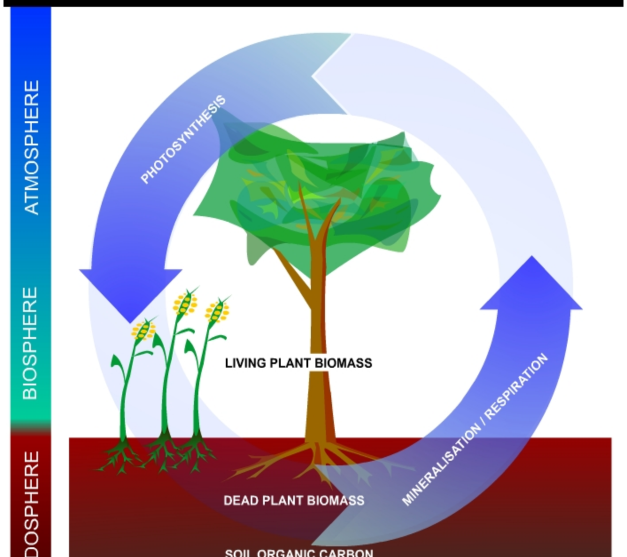


Sources: Massachusetts Climate Action Plan 2010; Pioneer Valley GHG Inventory 2011

3.2 CARBON SEQUESTRATION FROM VEGETATION

Carbon sequestration is the natural process in which living plants remove carbon dioxide (CO_2) from the air. Sometimes the term "carbon sink" is used to describe vegetated areas, such as farms and forests, that absorb large amounts of CO_2. (Carbon sequestration can also be accomplished through deliberate human actions, such as recapturing carbon by industrial measures and storing it underground. Ocean waters also absorb significant amounts of carbon from the atmosphere. However, because these activities are not planned or taking place in our region, this section refers only to natural carbon sequestration from vegetation.)

THE CARBON CYCLE IN VEGETATION AND SOIL



Plants absorb CO2 from the atmosphere to grow. As the plant grows, it accumulates carbon and fixes it in the soil. When its dies, it decomposes and releases carbon as CO2. In undisturbed ecosystems, the accumulation and release of CO2 is in equilibrium. <http://www.biochar.org/>

This analysis finds that carbon sequestration in the Pioneer Valley soaks up approximately 32% of carbon in the air. However, this may be carbon that was emitted by sources outside the region. Also, sequestration does not mitigate the effects of non-carbon GHGs, such as methane, which has approximately 25 times the GHG "insulating" effect of carbon. Therefore, consistent with the methods of the Massachusetts Climate Action Plan, reductions in carbon from sequestration are not factored into GHG emissions totals.

U.S. EPA states: "Although the net terrestrial uptake (of CO2) fluxes … offset about 30% of U.S. fossil-fuel CO_2 emissions, only a small fraction of this uptake results from activities undertaken specifically to sequester carbon. The largest net uptake is due primarily to ongoing natural regrowth of forests that were harvested during the 19th and early 20th centuries." This is because in mature forest areas, methane and other gases released during the decomposition of dead trees offsets the CO2 that is absorbed by new growth.

As of 2010, U.S. EPA estimates that natural carbon sequestration nationally offsets "approximately 12% of total U.S. CO2 emissions from the energy, transportation and industrial sectors."

Vegetation and Carbon Sequestration

- 819,404 acres of land in the Pioneer Valley
- 41,066 acres (**5%**) is impervious cover
- 564,067 acres (**71%**) has tree canopy
- Region has capacity to sequester **32%** of its annual carbon emissions
- State has capacity to sequester **13%** of its annual carbon emissions

Using the data obtained from the National Land Cover Database and I-Tree Vue analysis for the Pioneer Valley it is clear that the Valley scores drastically different than the state as a whole: while Massachusetts can sequester approximately 13% of its total annual emissions, the region can absorb approximately one third of its own annual emissions. This has implications for policies that deal with land use and conservation.

3.3 VULCAN REGIONAL CARBON EMISSIONS ESTIMATES 1999 THROUGH 2008

Carbon is a significant proportion of GHGs in the atmosphere—approximately 80%. Therefore, the ability to track carbon emissions over time at the regional scale is a critical benefit to GHG planning. However, carbon emissions information has not been available at the regional scale (usually a single county or groups of counties) on a regular basis until this year.

Annual county level carbon emission information is now available from the Vulcan Project (<vulcan.project.asu.edu>), a joint effort of NASA and the U.S. Department of Energy. Vulcan is funded by the North American Carbon Program (NACP) to quantify North American carbon dioxide emitted by the burning of fossil fuels. The purposes are to help quantify North American's carbon budget, support inverse estimation of carbon sources and sinks, and support the demands posed by higher resolution CO2 observations. The project is led by researchers at Arizona State University, Purdue University, Colorado State University and Lawrence Berkeley National Laboratory. The Vulcan Project uses multiple sources of carbon emissions reporting and monitoring data to quantify U.S. fossil fuel CO2 emissions at the scale of individual factories, power plants, roadways and neighborhoods on an hourly basis. However, it does not account for the other major greenhouse gases (methane, nitrous oxide, CFCs and others) which are a large component of industrial, agricultural and waste emissions. In addition to improvements in space and time resolution, Vulcan is quantified at the level of fuel type, economic sub-sector, and county/state identification. Perhaps the greatest benefit that the Vulcan estimates add to the GHG for the Pioneer Valley is that it provides a regularly updated metric that can be observed over several years to identify GHG emissions trends in the region.

Figure 3-10: Vulcan Project CO2 Emissions Estimates by Sector in Western Massachusetts

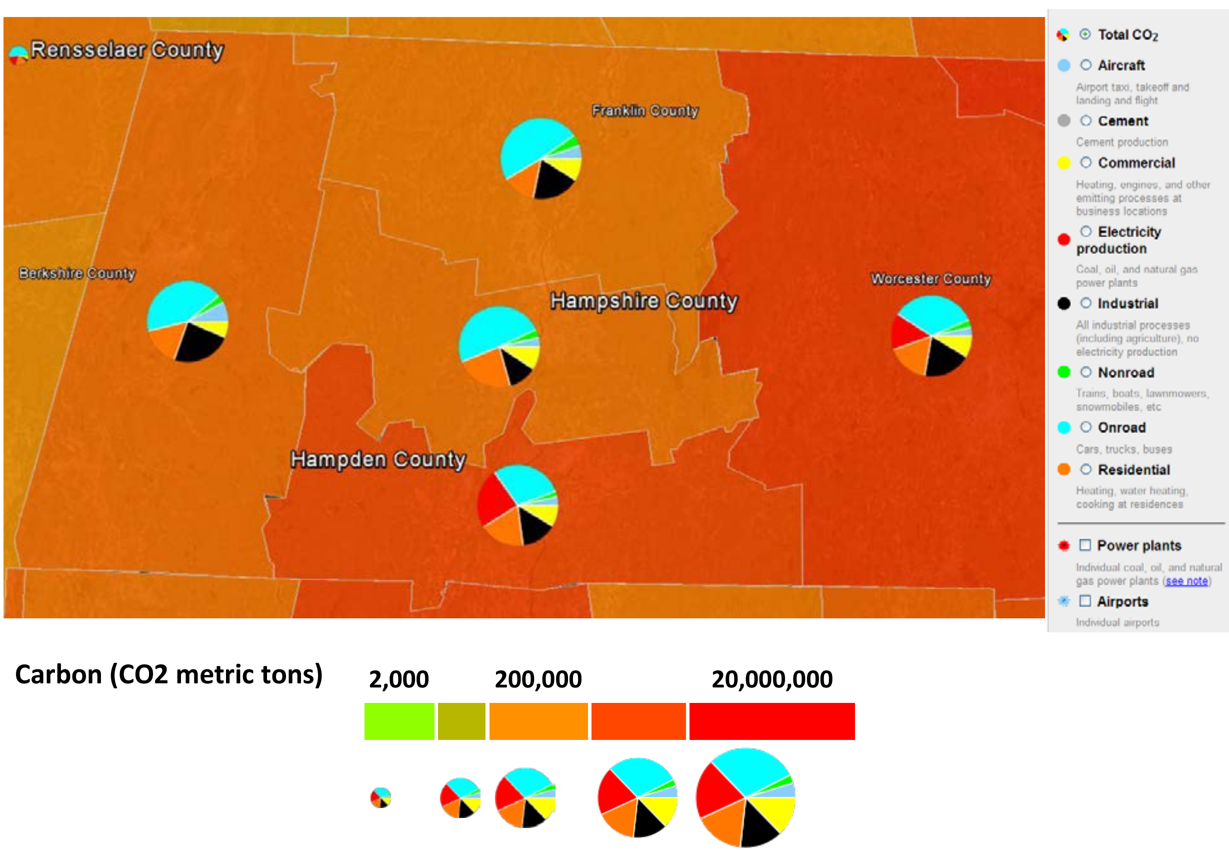
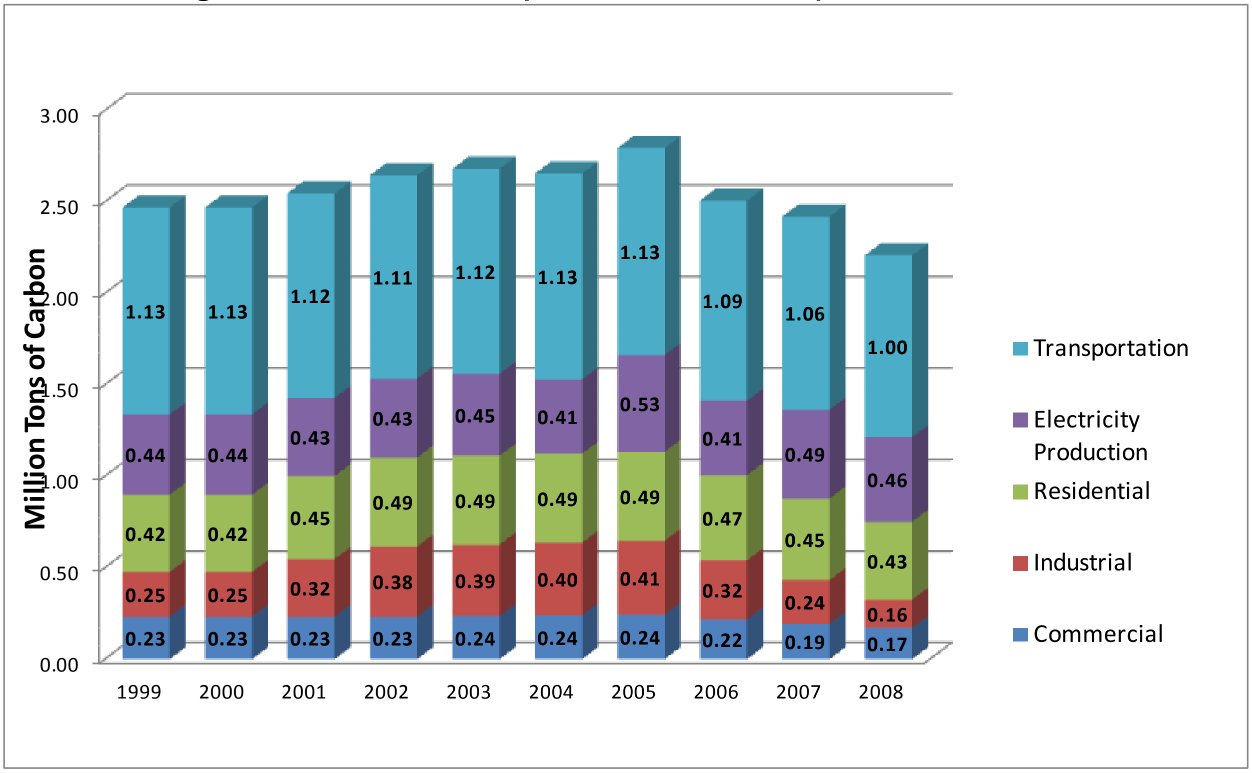


Figure 3-11: Pioneer Valley Carbon Emissions by Sector 1999-2008



Source: Vulcan Project Annual Estimates ver. 2.2 data release <vulcan.project.asu.edu> downloaded 9/5/2012

Figure 3-12: Vulcan Estimate of Total Carbon Emissions by County 1999-2008

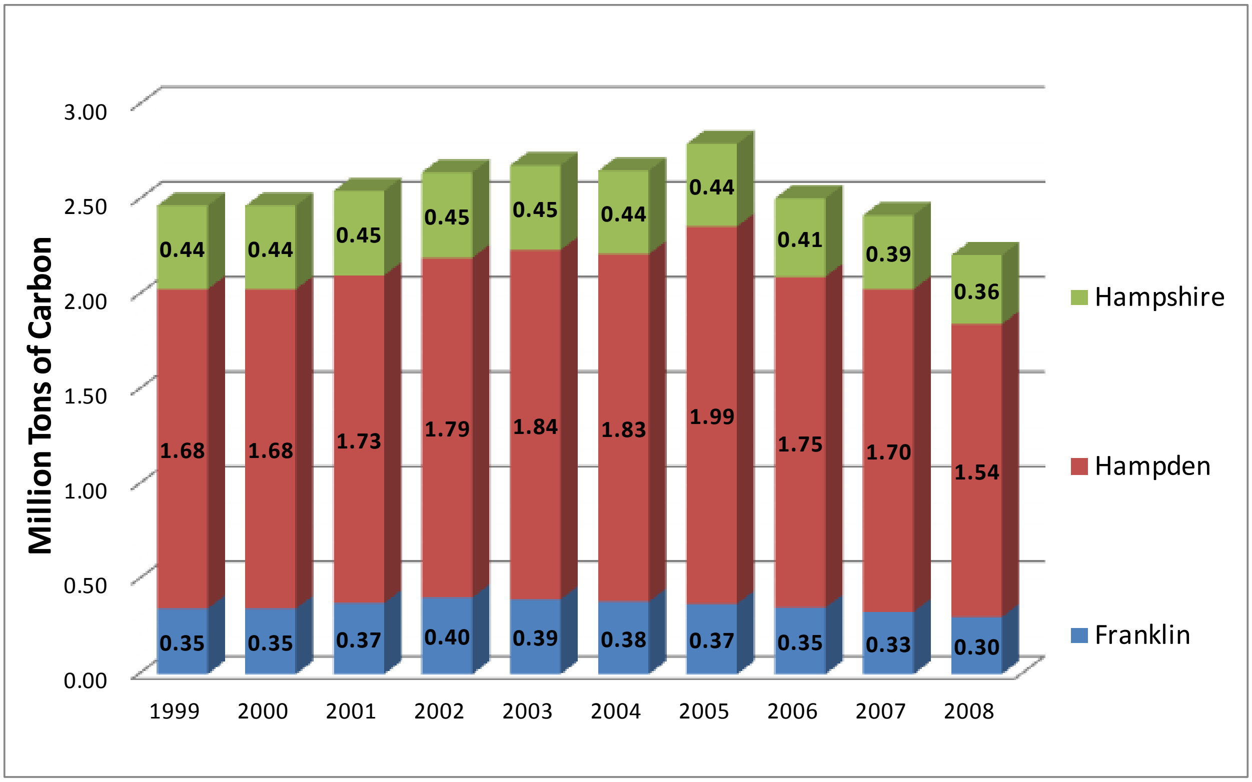
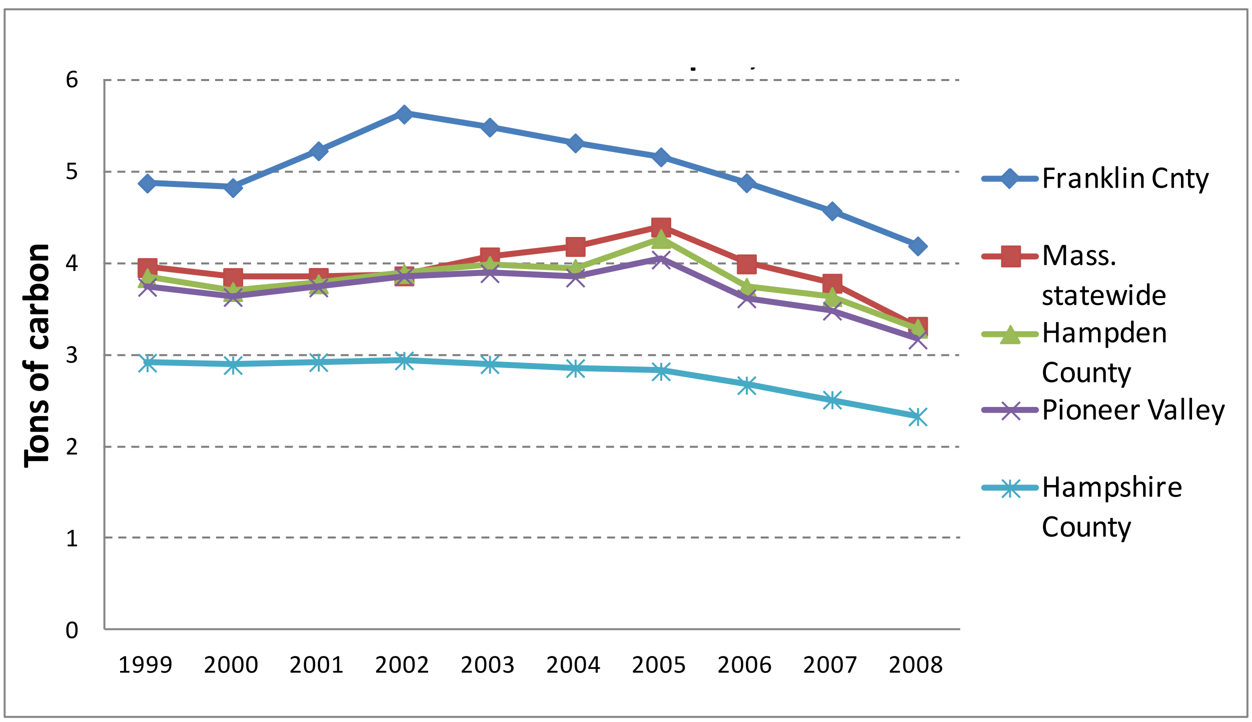
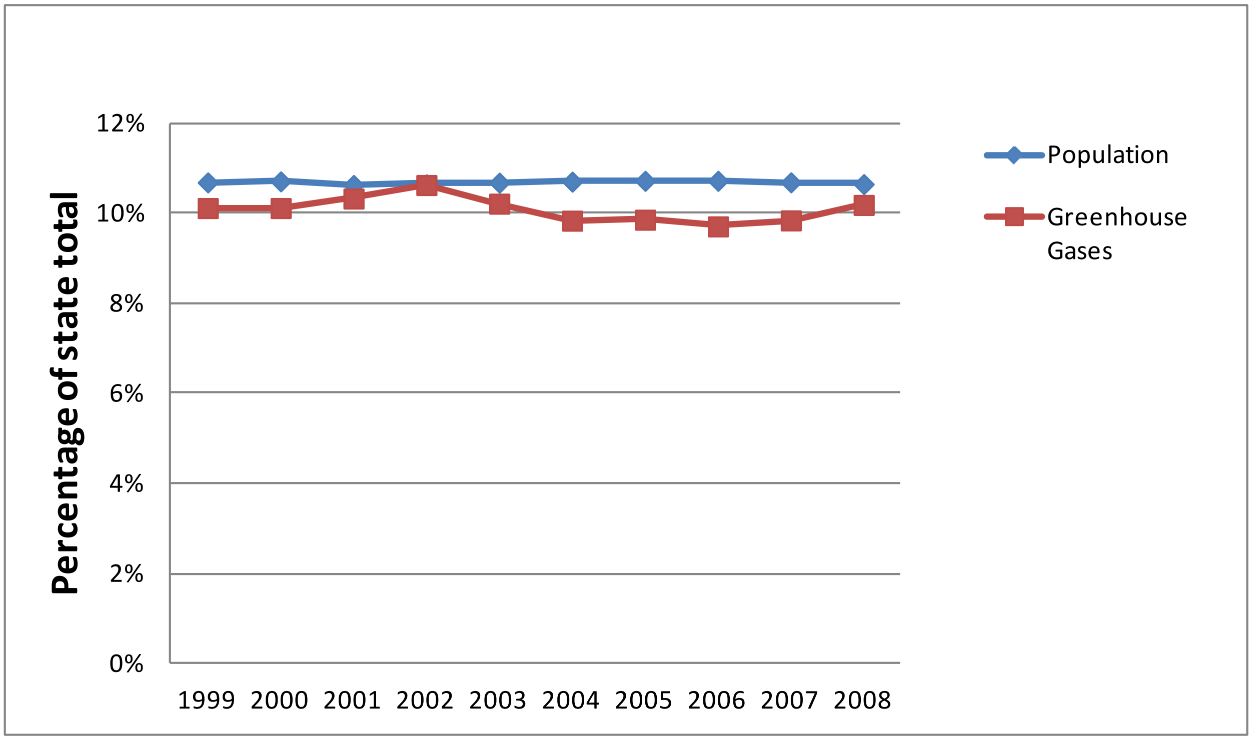


Figure 3-13: Pioneer Valley Carbon Emissions Per Capita, 1999-2008



Source: Vulcan Project Annual Estimates ver. 2.2 data release <vulcan.project.asu.edu> downloaded 9/5/2012

Figure 3-14: Pioneer Valley Share of MA Population and Carbon Emissions Per Capita



Source: Vulcan Project Annual Estimates ver. 2.2 data release <vulcan.project.asu.edu> downloaded 9/5/12

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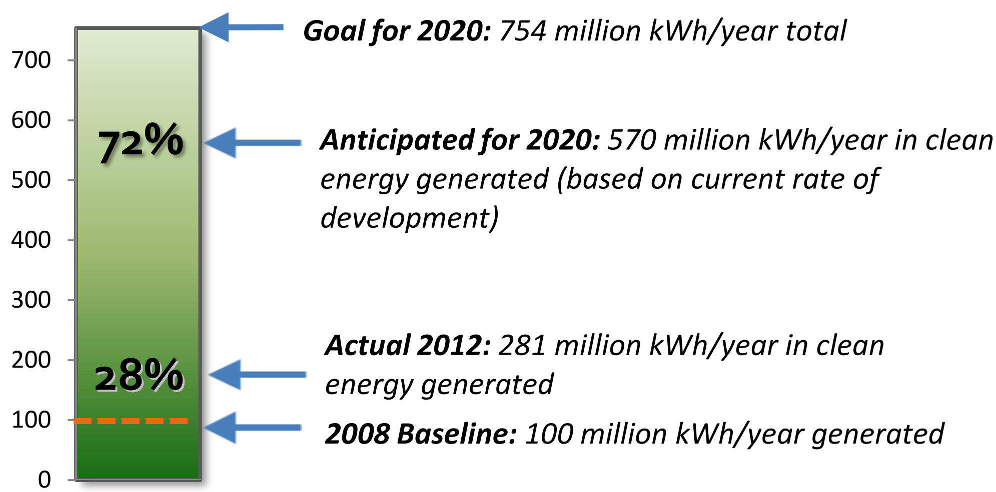
4 CLEAN ENERGY PLAN UPDATE

The 2008 Pioneer Valley Clean Energy Plan identified approximately 100 million kWh/year of renewable energy being generated in the region. The plan set a goal to increase the amount of clean energy produced in the Pioneer Valley by an additional 654 kWh/yr by 2020 to a total 754 million kWh/year. [1] This chapter summarizes our progress toward that goal.

Between 2008 and 2012, an additional 181 million kWh/yr in clean energy generating capacity was created in the region, bringing total clean energy generation to 281 million kWh/yr in 2012. Assuming this rate of clean energy development continues, it is anticipated that by 2020 the region will achieve 72% of its original goal, with a total of 570 million kWh/yr of clean energy being generated.

Figure 4-1: Pioneer Valley Clean Energy Generation: Progress Toward Regional Goal



At left is the Holyoke Gas and Electric Company's solar array on Mueller Steet, built in 2011. At 4.5 megawatts rated capacity, it is the largest solar installation in the region, contributing 585 kWh/year of clean energy—and about 1.5% of the utility's annual output.

[1] The 2008 Clean Energy Plan established a goal of installing new capacity to generate 214 million kilowatt hours of clean energy annually in the Pioneer Valley by the end of 2009, with another 440 million kilowatt hours per year by the end of 2020. The goal shown above (654 million new kWh/year) is the sum of the two goals stated in the 2008 Clean Energy Plan.

4.1 GOALS AND DEFINITIONS OF THE 2008 CLEAN ENERGY PLAN

The 2008 Pioneer Valley Clean Energy Plan describes two general goals for regional clean energy:

1. Reduce energy use.
2. Replace non-renewable energy sources with clean, renewable energy sources generated locally.

"Clean energy" is defined by the Massachusetts Technology Collaborative as solar, wind, low impact hydro, and biomass-fueled facilities that meet all Massachusetts Department of Environmental Protection Requirements. In addition to these, this report defines clean energy to also include landfill gas and waste to energy facilities. When we use locally produced clean energy instead of non-renewable energy sources like oil, coal, natural gas, and gasoline, we keep our air cleaner, reduce greenhouse gas emissions and support our local economy.

The energy quantities reported in the 2008 plan and this chapter are expressed in kilowatt hours per year (kWh/year) generated, which is the quantity of energy produced during a year, as opposed to the "rated capacity" of a facility, which is the maximum rate of energy output under perfect operating conditions.[2] For example, a solar photovoltaic array with a rated capacity of 1 megawatt (1,000 kilowatts) typically generates about 130 kilowatt hours of power per year (13% of rated capacity). This report card uses kWh/year as the standard unit for measuring energy across the different clean power technologies in the region.

Because the 2008 Clean Energy Plan placed a strong emphasis on energy production from biomass, it is important to note that new statewide biomass regulations went into effect in 2012. The regulation update process began in 2010, when the Department of Energy Resources (DOER) commissioned a Biomass Sustainability and Carbon Policy Study by the Manomet Center for Conservation Services. The findings presented by the "Manomet Study" suggested that the GHG impact of biomass power plants is complicated and "runs counter to previous and commonly-held views of biomass as 'carbon neutral'" (letter from Richard K. Sullivan, Secretary of the Massachusetts Executive Office of Energy and Environmental Affairs, to the Department of Environmental Protection and Department of Energy Resources).

Consistent with the Manomet Study findings, the new regulations establish more stringent requirements for biomass facilities, including rules that require biomass plants to operate with efficiency rates above 50% (i.e. turn at least half the energy created from burning into electricity) in order to qualify for incentives under the state's Renewable Portfolio Standard (RPS). Currently, many biomass plants are only about 25% efficient, wasting most of the heat generated by wood burning, and will no longer qualify for ratepayer-funded incentives. The new regulations also require that biomass plants rely predominantly on waste wood rather than whole trees, and that sustainable and ecologically sensitive harvesting practices are employed to support the role of forests in absorbing carbon from the atmosphere.

[2] A kilowatt, for example, is a unit of power that expresses a rate of energy production: One kilowatt is equivalent to 1,000 jules of energy per second. Energy plants are often described based on their rated capacity, or the facility's maximum possible rate of energy production.

4.2 DATA SOURCES AND METRICS

The majority of data for this update are provided by the Massachusetts Executive Office of Energy and Environmental Affairs, which maintains a database of all projects qualified by the Massachusetts Department of Energy Resources (DOER) within the Massachusetts Renewable Energy Portfolio Standard (RPS) Program. The data include built and permitted RPS Class I and II Renewable Generation Units, RPS Solar Carve-Out Qualified Renewable Generation Units, and RPS Class II Waste Energy Generation Units. These programs define New Renewable Generation Units as facilities that generate electricity using any of the following technologies: solar photovoltaic, solar thermal electric, wind energy, small hydropower, landfill methane and anaerobic digester gas, marine or hydrokinetic energy (not applicable to the Pioneer Valley region), geothermal energy, and eligible biomass fuel. In addition, waste energy generation units typically burn solid waste (mainly garbage) at extremely high temperatures to generate electricity or steam power. The data for RPS renewable energy programs were updated as of October 10, 2012, while the waste-to-energy data were updated as of August 4, 2010. These data include grid inter-tied clean energy systems. (Off-grid residential solar photovoltaic systems are not included, as information about capacity, use patterns and other aspects of their operation cannot be readily obtained.)

In addition to the DOER data, the Massachusetts Clean Energy Center (MassCEC) provided updated data as of October 2012 for renewable energy projects funded through MassCEC incentive programs. Although these data largely overlap with (and are less comprehensive than) the DOER data, they do provide data regarding installed solar thermal systems (such as rooftop solar hot water heaters), which are not included within the DOER data.

For this update, it was necessary to make some revisions to the data described above, including additions to include large planned or built clean energy facilities that were not yet included in the DOER or CEC data. To complete the analysis, estimates of actual annual energy production were made based on the rated capacity and energy source for each clean electricity installation. Rated capacity indicates the maximum power capable of being produced by a facility at any given time. A "capacity factor" is a ratio between the actual output of a power plant over a period of time and its potential output if it had operated at its full rated capacity during that time. In order to use the rated capacity of clean energy facilities to estimate annual energy production, capacity factors were established based on conversations with the Massachusetts Department of Energy Resources (DOER), as well as clean energy facility owners. Each clean energy facility type was assigned a different capacity factor, as shown in the figure below.

Table 4-1: Renewable Energy Generation Capacity Factors

Facility Type	Capacity Factor	Notes
Hydropower	0.4	Although the capacity factor for hydropower installations varies considerably by facility, .4 was established as a reasonable estimate based on discussions with DOER.
Landfill Gas	0.86	For new installations. A capacity factor of .85 was used for installations built before 2008 based on conversations with one owner of multiple landfill gas facilities in the region.
Solar Photovoltaic	0.13	Based on guidance from Mass. DOER and Massachusetts Clean Energy Center
Waste to Energy	0.85	Although the capacity factor for waste to energy installations varies considerably by facility. .85 was established as a reasonable estimate based on discussions with clean energy facility owners.

Wind	0.26	This estimate was provided by DOER for on-shore wind facilities.
Biomass Electric	0.85	This estimate is for facilities that do not recover thermal energy. For this study, electrical generation was estimated and then thermal generation figures were added separately where applicable.

For example, using these capacity factors, the estimated annual energy production of a solar photovoltaic installation with a rated capacity of 1MW (or 1,000 kW) would be estimated as follows:

1,000 kilowatts x 8,760 hours per year x .13 = 1,138,800 kilowatt hours of electricity generated per year (kWh/yr)

Note that this estimation method does not apply to facilities that produce thermal energy. Thermal energy production data was obtained or estimated as quantity produced per year in British Thermal Units (BTUs). This allowed for a simple conversion to electricity units in kilowatt hours per year. In sum, to the greatest extent feasible, the thermal and electric energy production of all new and existing hydroelectric, landfill gas, solar photovoltaic, waste to energy, wind, and biomass facilities is included in this clean energy analysis and is expressed in kilowatt hours produced annually.

4.3 PROGRESS TOWARD THE 2008 CLEAN ENERGY PLAN GOALS

The 2008 Pioneer Valley Clean Energy Plan set a goal of siting new capacity to generate 654 million kilowatt hours of clean energy per year in the Pioneer Valley by 2020. Analysis for this update includes all known new capacity planned and/or installed during this period. As of 2012, the region is 28% of the way toward meeting that goal (181 million kWh/year in new clean energy generating capacity created). If new clean energy generation capacity continues to be added at the same rate that occurred between 2008 and 2012, by 2020 the region will achieve 72% of this goal (470 million kWh/year in new clean energy generating capacity created).

Figure 4-2: Current Status (2012) of Progress toward Pioneer Valley Clean Energy Plan Goal

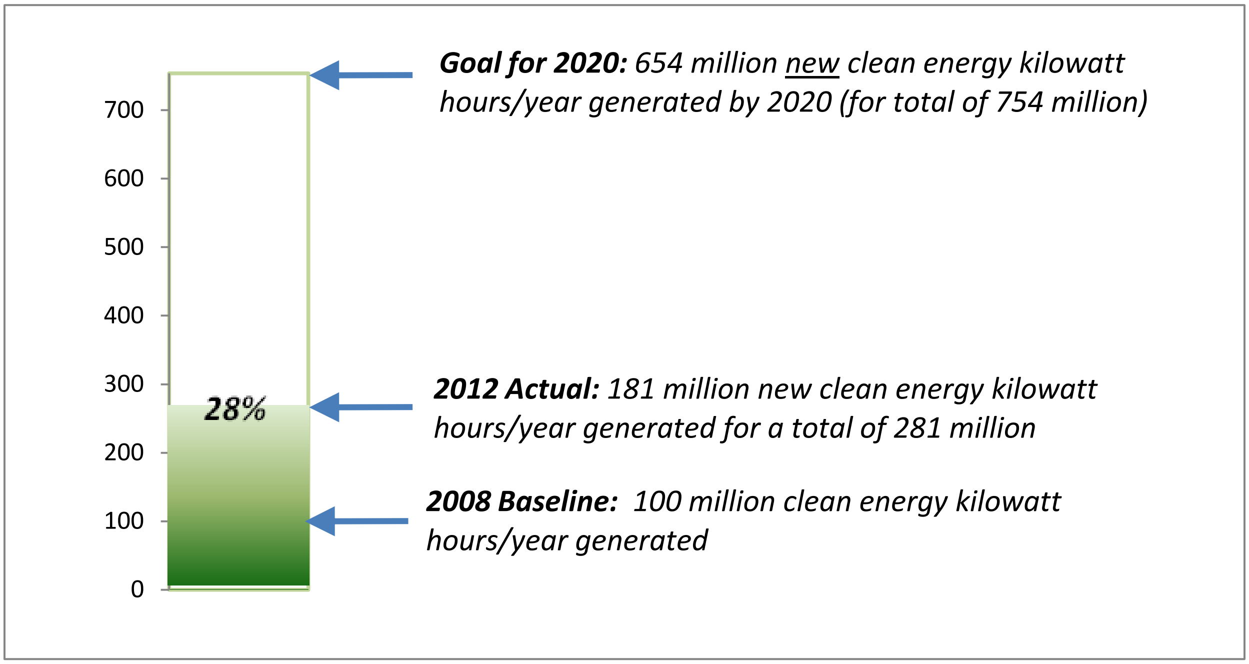
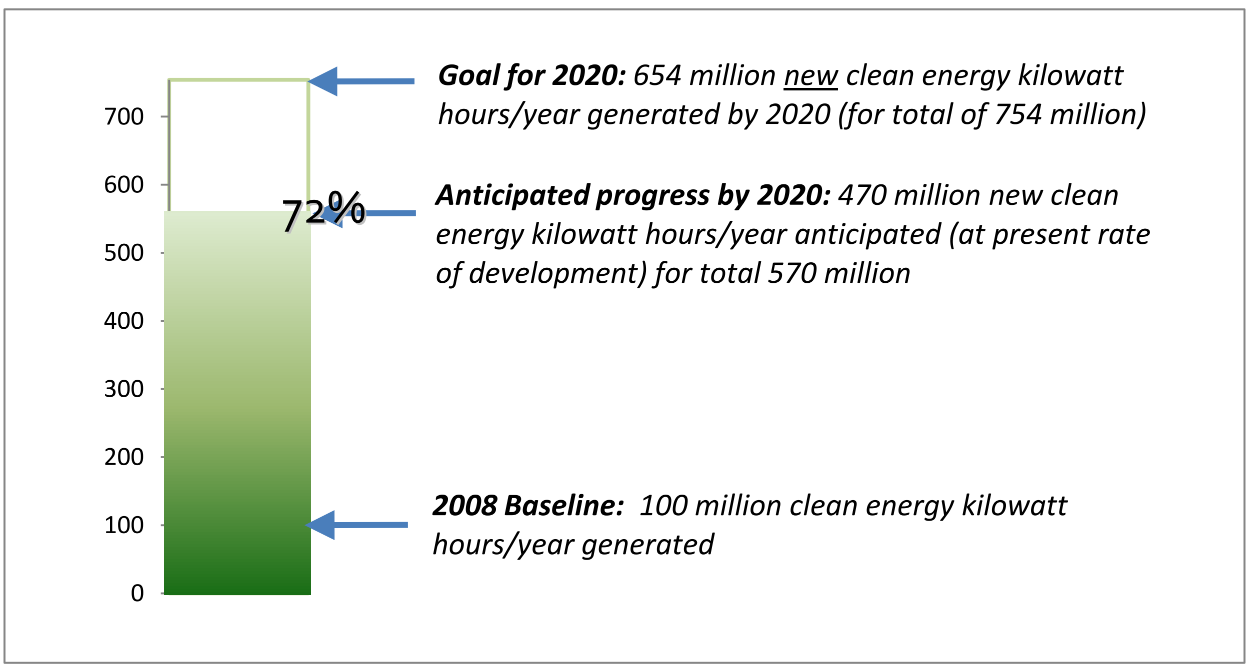
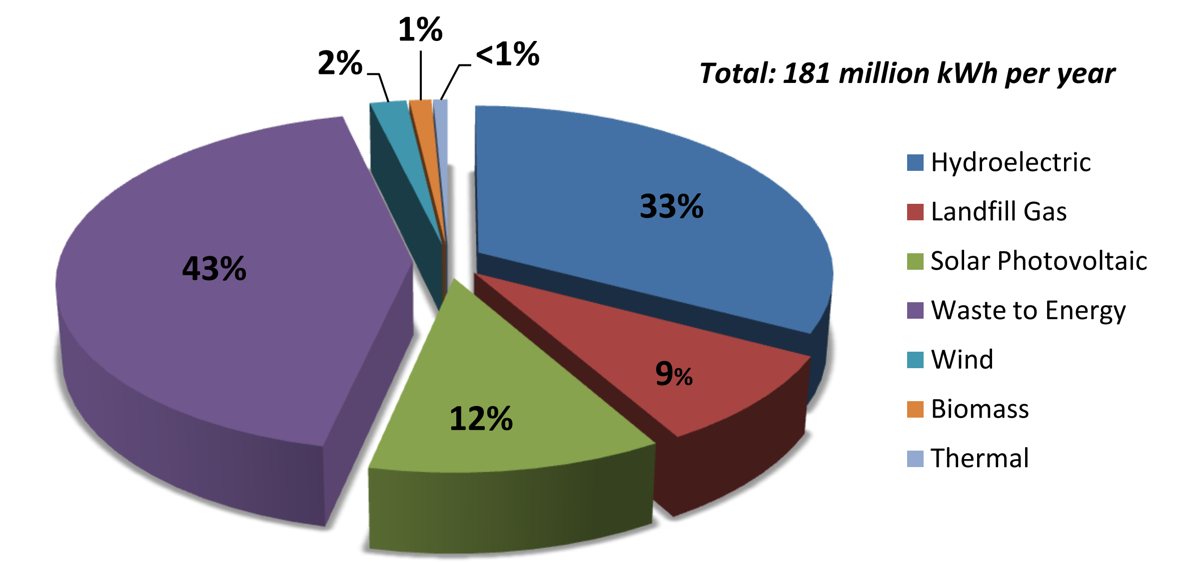


Figure 4-3: Anticipated Progress by 2020 toward Pioneer Valley Clean Energy Plan Goal



Based on the data compiled, between 2008 and 2012, 496 clean energy facilities were installed in the Pioneer Valley. The new clean electric and thermal energy installations in the region (including hydroelectric, landfill gas, solar photovoltaic, waste to energy, wind and biomass facilities) have a combined estimated annual electricity output of nearly 181 million kWh/year. The largest portion of this clean energy output is created by waste to energy facilities (43%) and hydroelectric plants (33%), followed by solar photovoltaic installations (12%) and landfill gas recovery facilities (9%).

Figure 4-4: New Clean Energy Production in the Pioneer Valley 2008 to 2012



*Includes clean electricity and thermal energy. Thermal energy has been converted to electricity units.

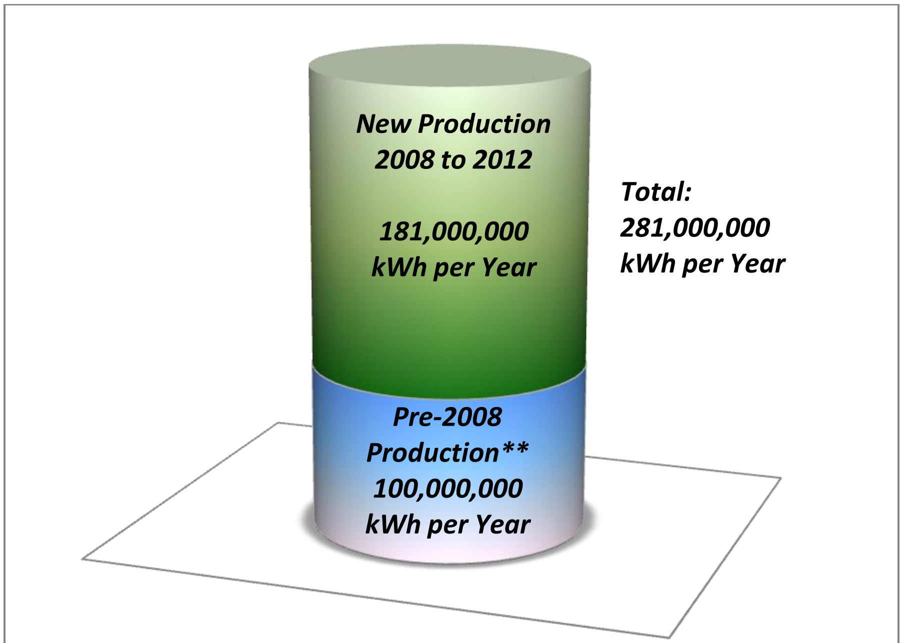
Table 4-2: New Clean Energy Production by Community, 2008 to 2012 (kWh/Yr)*

	Hydro	Landfill Gas	Solar PV	Waste to Energy	Wind	Biomass	Thermal**	Grand Total
Agawam	0	0	33,355	69,992,400	0	0	0	70,025,755
Amherst	0	0	347,403	0	0	0	105,506	452,909
Belchertown	0	0	385,684	0	0	0	8,792	394,476
Blandford	0	0	5,136	0	3,416,400	0	8,792	3,430,328
Brimfield	0	0	37,968	0	0	0	26,376	64,344
Chester	0	0	5,694	0	0	0	0	5,694
Chesterfield	0	0	68,089	0	0	0	0	68,089
Chicopee	0	16,148,009	115,702	0	0	0	0	16,263,711
Cummington	0	0	22,548	0	0	0	0	22,548
E.Longmeadow	0	0	55,881	0	0	0	0	55,881
Easthampton	0	0	2,645,856	0	0	0	8,792	2,654,648
Goshen	0	0	11,160	0	0	0	0	11,160
Granby	0	0	58,233	0	0	0	0	58,233
Granville	0	0	34,009	3,723,000	0	0	380,992	4,138,002
Hadley	0	0	3,645,243	3,723,000	0	0	662,341	8,030,584
Hampden	0	0	11,570	0	0	0	0	11,570
Hatfield	0	0	3,034,128	0	0	0	17,584	3,051,712
Holland	0	0	5,688	0	0	0	0	5,688
Holyoke	2,277,600	0	5,155,393	0	0	0	8,792	7,441,785
Longmeadow	0	0	77,142	0	0	0	8,792	85,934
Ludlow	0	0	49,179	0	0	0	8,792	57,971
Middlefield	0	0	21,068	0	0	0	0	21,068
Monson	0	0	59,821	0	0	0	0	59,821
Montgomery	0	0	16,285	0	0	0	17,584	33,869
Northampton	0	0	551,793	0	0	2,047,650	8,792	2,608,235
Palmer	0	0	628,925	0	0	0	0	628,925
Pelham	0	0	15,192	0	0	0	0	15,192
Plainfield	0	0	14,605	0	0	0	8,792	23,397
Russell	25,579,200	0	13,324	0	0	0	0	25,592,524
South Hadley	0	0	150,219	0	0	0	0	150,219
Southampton	0	0	23,733	0	0	0	0	23,733
Southwick	0	0	27,866	0	0	0	8,792	36,659
Springfield	0	0	3,378,717	0	0	0	0	3,378,717
Tolland	0	0	0	0	0	0	0	0
Wales	0	0	0	0	0	0	0	0
Ware	10,231,680	0	13,307	0	0	0	17,584	10,262,571
W. Springfield	0	0	236,142	0	0	0	0	236,142
Westfield	0	0	216,042	0	0	0	0	216,042
Westhampton	0	0	25,190	0	0	0	0	25,190
Wilbraham	21,024,000	0	50,449	0	0	0	17,584	21,092,033
Williamsburg	0	0	13,096	0	0	0	0	13,096
Worthington	0	0	18,033	0	0	0	0	18,033
Total (kWh/Yr)	**59,112,480**	**16,148,009**	**21,278,869**	**77,438,400**	**3,416,400**	**2,047,650**	**1,324,681**	**180,766,489**

*The capacity factors shown in Section 4.2 were used to estimate annual clean energy production.
** Includes residential solar thermal systems and thermal energy recovery at renewable energy facilities.

This analysis also compiled existing pre-2008 clean energy data in order to determine the total clean energy generating capacity in the region. As shown in the graph below, the new production capacity developed between 2008 and 2012 is estimated to generate significantly more clean energy than the installations built prior to 2008. The total annual clean energy production for the region, including clean energy developed across all years, is estimated to be 281 million kWh/yr.

Figure 4-5: Pioneer Valley Total Annual Clean Energy Production



*Includes clean electricity and thermal energy.
**Does not include Cooley Dickinson Hospital Thermal and Cooling Biomass System.

4.3.1 CLEAN ELECTRICITY INSTALLATIONS

Our region's clean energy capacity is comprised of both electricity and thermal energy installations. This subsection addresses clean electricity, and the next addresses thermal energy.

Of the 496 new clean energy installations in the region, 462 of the facilities generate electricity, with a combined generating capacity of 49,886 kilowatts, or nearly 50 megawatts. Many of these 462 installations are actually small solar photovoltaic installations. Some of the larger (over 200 kilowatt) facilities in the region include hydroelectric plants in Holyoke, Russell, Ware and Wilbraham; a landfill gas facility extension in Chicopee; built and planned solar photovoltaic plants in Belchertown, Easthampton, Hadley, Hatfield, Holyoke, Northampton, Palmer, and Springfield; Waste to Energy facilities in Agawam (trash burning), as well as Granville and Hadley (planned organic waste anaerobic digesters); a planned wind turbine in Blandford; and finally, an electricity generating expansion to an existing thermal biomass system in Northampton. The vast majority of our region's rated capacity for clean electricity is comprised of solar photovoltaic (37%), hydroelectric (34%) and waste to energy facilities (21%).

Figure 4-6: Pioneer Valley New Clean Electricity Capacity

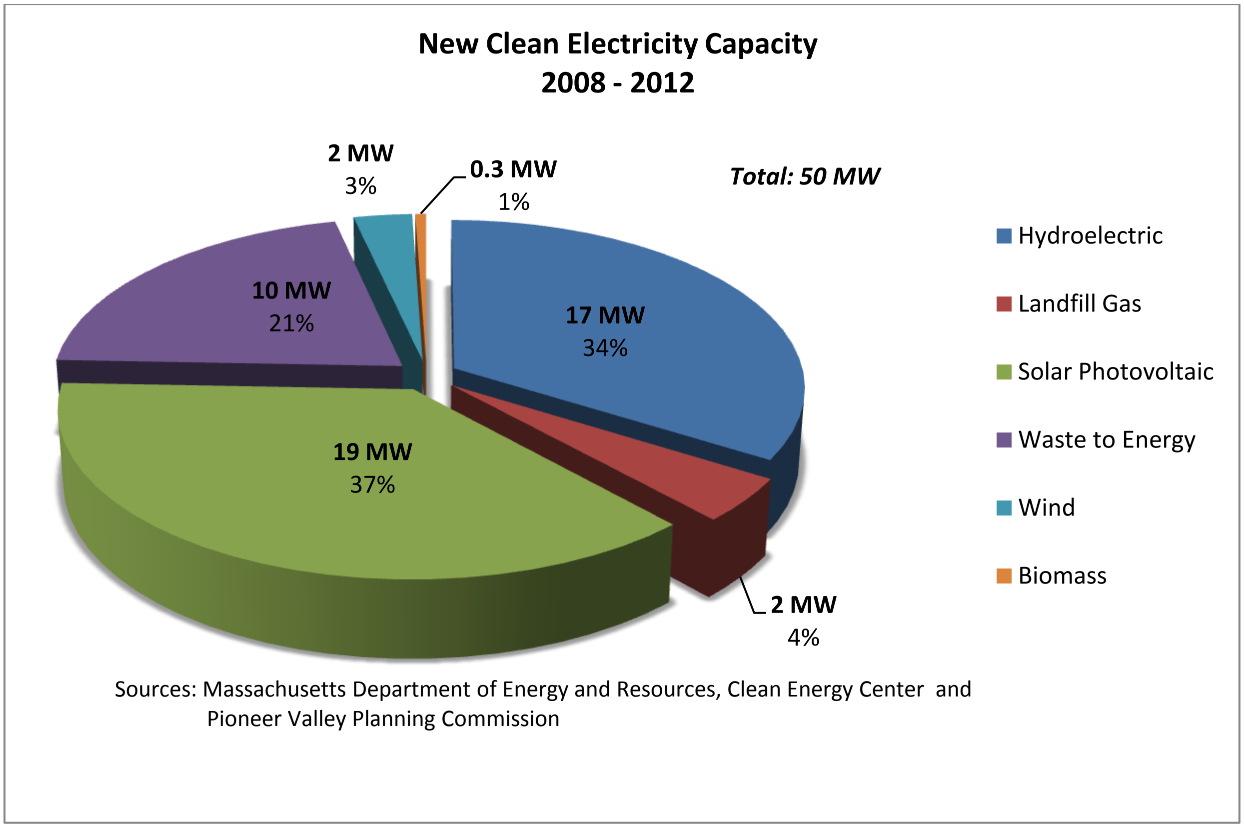
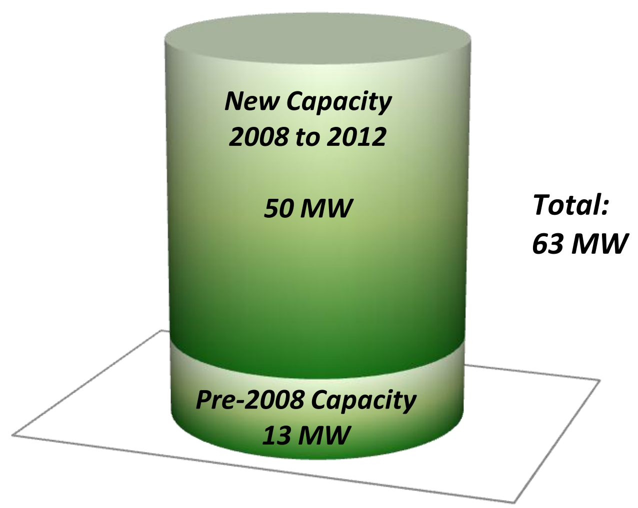


Table 4-3: New Clean Electricity Capacity by Community, 2008 to 2012

	Hydroelectric (KW)	Landfill Gas (KW)	Photovoltaic (KW)	Waste to Energy (KW)	Wind (KW)	Biomass (KW)	Grand Total (KW)
Agawam	0	0	29	9,400	0	0	9,429
Amherst	0	0	305	0	0	0	305
Belchertown	0	0	339	0	0	0	339
Blandford	0	0	5	0	1,500	0	1,505
Brimfield	0	0	33	0	0	0	33
Chester	0	0	5	0	0	0	5
Chesterfield	0	0	60	0	0	0	60
Chicopee	0	2,156	102	0	0	0	2,258
Cummington	0	0	20	0	0	0	20
East Longmeadow	0	0	49	0	0	0	49
Easthampton	0	0	2,323	0	0	0	2,323
Goshen	0	0	10	0	0	0	10
Granby	0	0	51	0	0	0	51
Granville	0	0	30	500	0	0	530
Hadley	0	0	3,201	500	0	0	3,701
Hampden	0	0	10	0	0	0	10
Hatfield	0	0	2,664	0	0	0	2,664
Holland	0	0	5	0	0	0	5
Holyoke	650	0	4,527	0	0	0	5,177
Longmeadow	0	0	68	0	0	0	68
Ludlow	0	0	43	0	0	0	43
Middlefield	0	0	19	0	0	0	19
Monson	0	0	53	0	0	0	53
Montgomery	0	0	14	0	0	0	14
Northampton	0	0	485	0	0	275	760
Palmer	0	0	552	0	0	0	552
Pelham	0	0	13	0	0	0	13
Plainfield	0	0	13	0	0	0	13
Russell	7,300	0	12	0	0	0	7,312
South Hadley	0	0	132	0	0	0	132
Southampton	0	0	21	0	0	0	21
Southwick	0	0	24	0	0	0	24
Springfield	0	0	2,967	0	0	0	2,967
Tolland	0	0	0	0	0	0	0
Wales	0	0	0	0	0	0	0
Ware	2,920	0	12	0	0	0	2,932
West Springfield	0	0	207	0	0	0	207
Westfield	0	0	190	0	0	0	190
Westhampton	0	0	22	0	0	0	22
Wilbraham	6,000	0	44	0	0	0	6,044
Williamsburg	0	0	12	0	0	0	12
Worthington	0	0	16	0	0	0	16
Grand Total (KW)	**16,870**	**2,156**	**18,685**	**10,400**	**1,500**	**275**	**49,886**
Grand Total (MW)	**16.9**	**2.2**	**18.7**	**10.4**	**1.5**	**0.3**	**49.6**

This analysis also included compilation of existing pre-2008 clean energy data in order to determine total clean electricity capacity in the region. Pre-2009 clean energy plants include landfill gas facilities in Chicopee, Granby, Westfield and Northampton.

Figure 4-7: Pioneer Valley Total Clean Energy Production Capacity



*Includes only clean electricity production.
Does not include thermal clean energy production.

Table 4-4: Large Clean Electricity Installations in the Pioneer Valley

Type	Before 2008	2008 – 2012
Hydroelectric		Holyoke, Russell, Ware, Wilbraham
Landfill Gas	Chicopee, Granby, Westfield, Northampton	Chicopee
Solar Photovoltaic		Belchertown, Easthampton, Hadley, Hatfield, Holyoke, Northampton, Palmer, Springfield
Waste to Energy		Agawam (trash), Granville and Hadley (organic waste)
Wind		Blandford
Biomass		Northampton

*Built and planned facilities >200 kilowatts rated capacity

Table 4-5: Large Clean Electricity Installations in the Pioneer Valley – Facility Identification

Type	Facility Name
Hydroelectric	Holyoke - Open Square Properties Russell - Woronoco 1,2 and 3 Ware - Pioneer Hydropower/Ware River Hydro Wilbraham - Collins Hydroelectric Project, LLC and Red Bridge Project
Landfill Gas	Chicopee - Chicopee 1,2, 3 and 4 Granby - Granby Sanitary Landfill and Granby LFG Off Grid Westfield - Westfield #1 and Ware Cogen Northampton - Ameresco Northampton Landfill Chicopee - Chicopee 4
Solar Photovoltaic	Belchertown – RANE (Rural Aggregators of New England) (Industrial) Easthampton - GLC-(MA) Easthampton, LLC (Municipal/Government/Public) Hadley – Mill Valley Road (permitted; in construction) Hatfield – Bridge Street (permitted; in development) Holyoke - HG&E Constellation 1 (Municipal/Government/Public), Holyoke-Southampton (Industrial) Northampton -Kollmorgen Electro Optical (Commercial/Office) Palmer – Palmer (Commercial/Office) Springfield - MA SREC Aggregation (Commercial/Office), Indian Orchard Solar Photovoltaic Facility (Other)
Waste to Energy	Agawam (trash) - Covanta Springfield Refuse Granville (organic waste) – Rockwood Farm Hadley (organic waste) - Barstow's Longview Farm
Wind	Blandford - Massachusetts Turnpike
Biomass	Northampton - Cooley Dickinson Hospital

4.3.2 CLEAN THERMAL ENERGY SYSTEMS

The region's 496 new clean energy facilities include 34 residential-scale solar thermal systems. Only two of the region's new clean energy facilities produce both clean electricity and thermal energy: these are the planned anaerobic (organic waste) digesters in Granville and Hadley, which will include a significant thermal energy component. The region's new and planned thermal clean energy facilities will produce an estimated 4,520 million BTUs annually, equivalent to just over 1.3 million kilowatt hours of electricity per year.

Table 4-6: New Clean Thermal Energy Production (BTUs) by Community, 2008 to 2012

	Residential Solar Thermal		Other Thermal	Grand Total
	# Installations	Residential BTUs	BTUs	BTUs
Agawam	0	0	0	0
Amherst	12	360,000,000	0	360,000,000
Belchertown	1	30,000,000	0	30,000,000
Blandford	1	30,000,000	0	30,000,000
Brimfield	3	90,000,000	0	90,000,000
Chester	0	0	0	0
Chesterfield	0	0	0	0
Chicopee	0	0	0	0
Cummington	0	0	0	0
East Longmeadow	0	0	0	0
Easthampton	1	30,000,000	0	30,000,000
Goshen	0	0	0	0
Granby	0	0	0	0
Granville	0	0	1,300,000,000	1,300,000,000
Hadley	2	60,000,000	2,200,000,000	2,260,000,000
Hampden	0	0	0	0
Hatfield	2	60,000,000	0	60,000,000
Holland	0	0	0	0
Holyoke	1	30,000,000	0	30,000,000
Longmeadow	1	30,000,000	0	30,000,000
Ludlow	1	30,000,000	0	30,000,000
Middlefield	0	0	0	0
Monson	0	0	0	0
Montgomery	2	60,000,000	0	60,000,000
Northampton	1	30,000,000	0	30,000,000
Palmer	0	0	0	0
Pelham	0	0	0	0
Plainfield	1	30,000,000	0	30,000,000
Russell	0	0	0	0
South Hadley	0	0	0	0
Southampton	0	0	0	0
Southwick	1	30,000,000	0	30,000,000
Springfield	0	0	0	0
Tolland	0	0	0	0
Wales	0	0	0	0
Ware	2	60,000,000	0	60,000,000
West Springfield	0	0	0	0
Westfield	0	0	0	0
Westhampton	0	0	0	0
Wilbraham	2	60,000,000	0	60,000,000
Williamsburg	0	0	0	0
Worthington	0	0	0	0
Grand Total	**34**	**1,020,000,000**	**3,500,000,000**	**4,520,000,000**
kWh/Year				**1,324,681**

4.4 MUNICIPAL ENERGY EFFICIENCY AND RENEWABLE ENERGY CAPACITY

To reach the 2020 regional goal of generating 4,403 million kWh per year (shown at left), renewable energy generating capacity will need to be increased significantly. Shown below, the left two columns are the present (2011) and anticipated electrical generation capacities in the region for wind and solar facilities; the two columns on the right indicate the proportions of additional clean energy generation capacity that would need to come from these two sources, based on their present proportions.

Figure 4-8: Anticipated Sources of New Renewable Energy Capacity Needed to Reach 2020 Goal

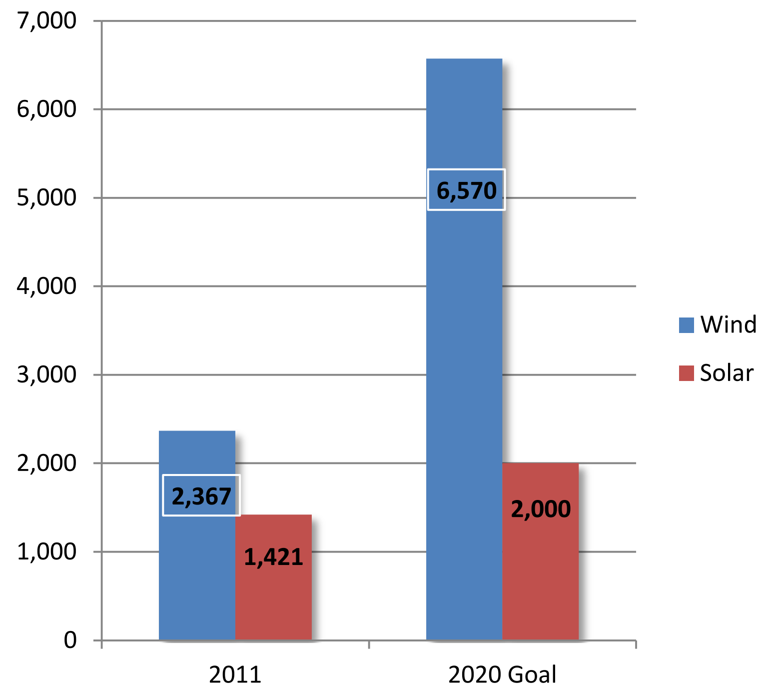
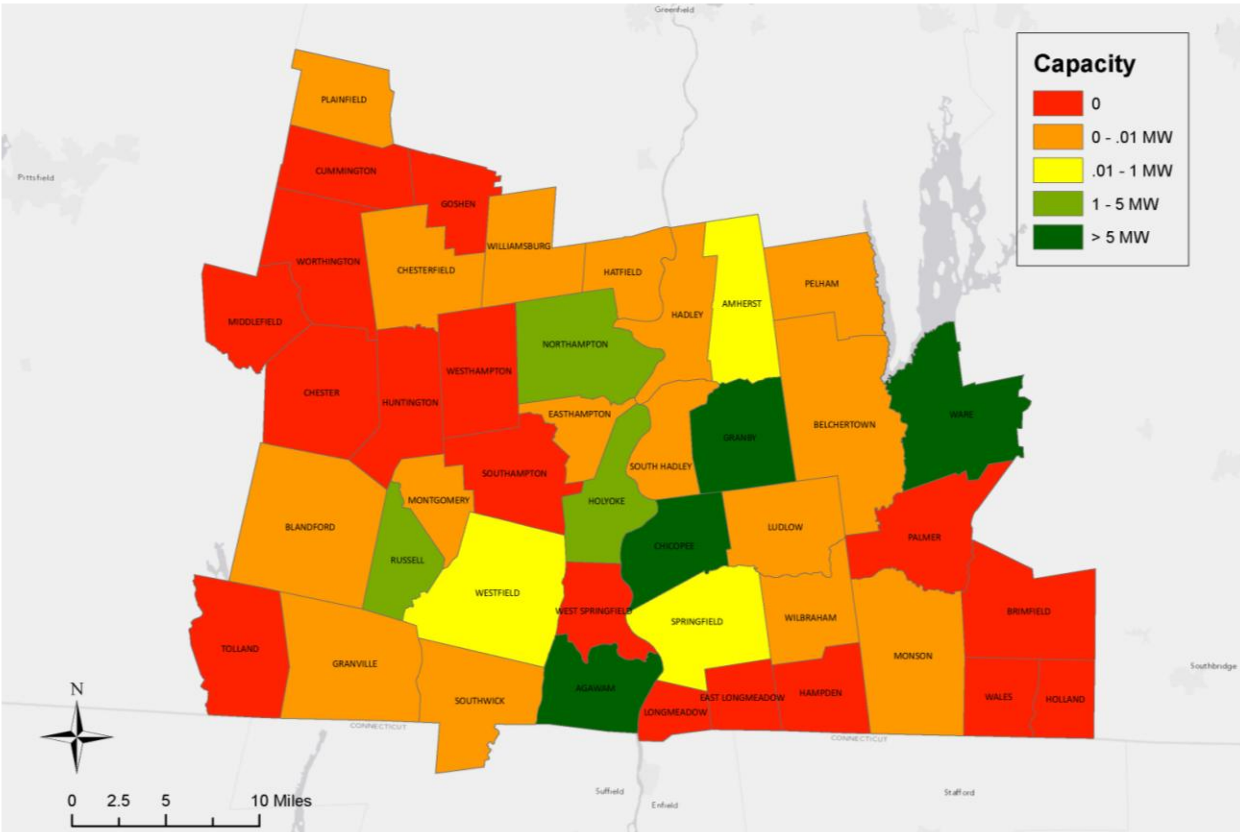
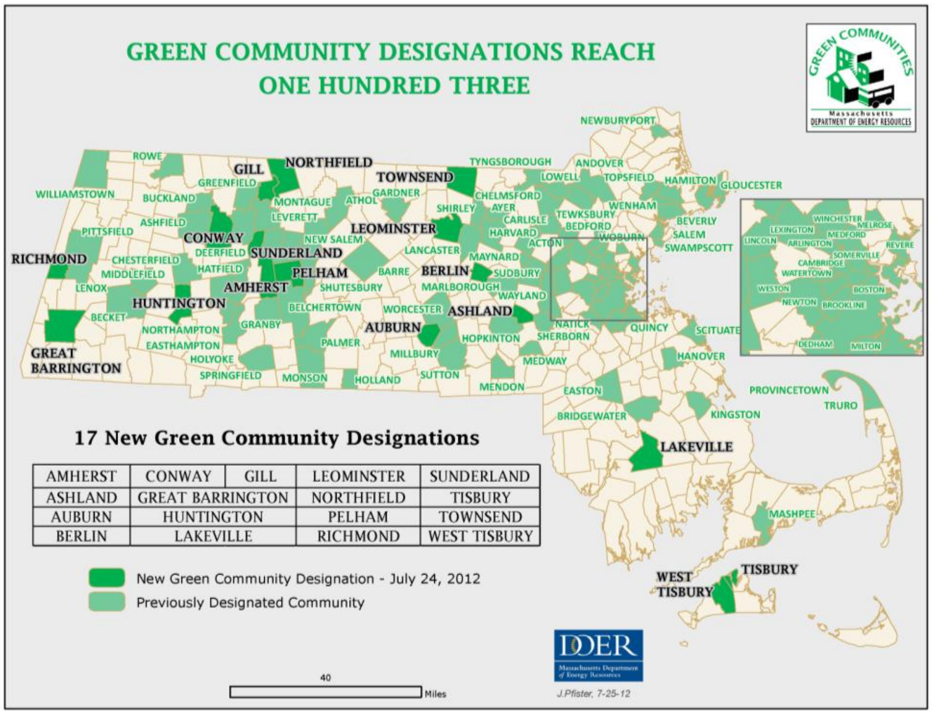


Figure 4-9: Renewable Energy Generation Capacity by Rated Facility Capacity by Municipality 2012



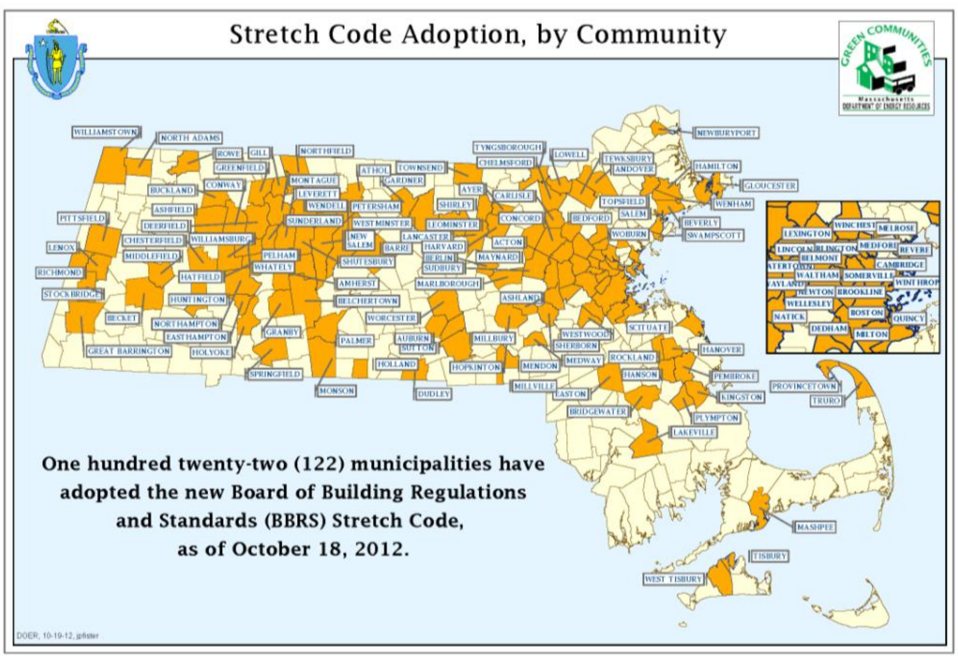
Source: Massachusetts Department of Energy Resources 2011 rated capacity of operating renewable energy facilities including solar photovoltaic installations, hydroelectric facilities, waste-to-energy plants, and wind power.

Figure 4-10: Massachusetts Green Community Designations by Municipality



PVPC Green Community-designated Municipalities: Amherst, Belchertown, Chesterfield, Easthampton, Granby, Hatfield, Holyoke, Huntington, Middlefield, Monson, Northampton, Palmer, Pelham, Springfield.

Figure 4-11: Massachusetts Stretch Code Adoption by Municipality



PVPC Municipalities that have adopted Stretch Code: Amherst, Belchertown, Chesterfield, Easthampton, Granby, Hatfield, Holyoke, Huntington, Middlefield, Monson, Northampton, Palmer, Pelham, Springfield, Williamsburg.

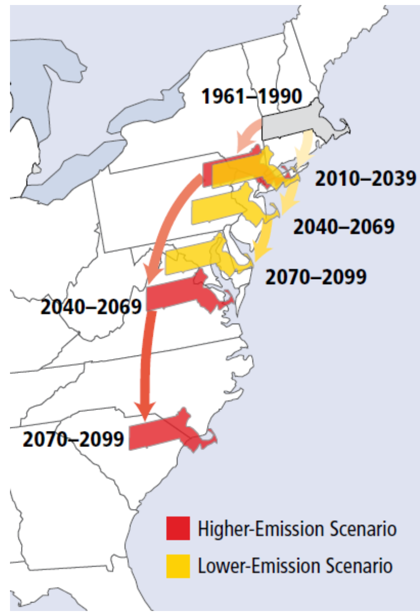
5 CLIMATIC AND WEATHER EFFECTS OF CLIMATE CHANGE ON THE REGION

Climate change is already having significant effects on the climate and weather of the Pioneer Valley. Summers are hotter. Winters are wetter. Storms are more severe. Flooding is more frequent.

"Climate" is generally considered to be long-term atmospheric conditions. "Weather" is what happens on a day-to-day basis. Both climate and weather are changing in our region because of the warming effect caused by greenhouse gases (GHGs) in the atmosphere worldwide. This warmth has increased airborne moisture over ocean areas, holding even more heat. While not geographically or temporally uniform, this additional warmth and moisture are accelerating the water cycle and changing weather patterns.

This chapter presents information about our region's climate and weather derived from accepted sources. Chief among these is the 2007 report of the Northeast Climate Impacts Assessment (NECIA) and numerous supporting scientific, government agency and ecological sources. NECIA is collaboration among the non-profit science advocacy group Union of Concern Scientists and 50 independent climate researchers.

General climatic changes in our region will cause higher temperatures and more precipitation. There will also be wider variability in weather extremes. We will have more days of extreme heat above 90 degrees, more heat waves, more floods, more droughts, and more tornados, hurricanes and heavy storms.



At current rates of greenhouse gas accumulation and temperature increases, the climate of Massachusetts will become similar to those of present-day New Jersey or Virginia by 2040-2069, depending on future GHG emissions.. *Source: NECIA 2006*

Table 5-1: Expected Climatic Variations Due to Climate Change

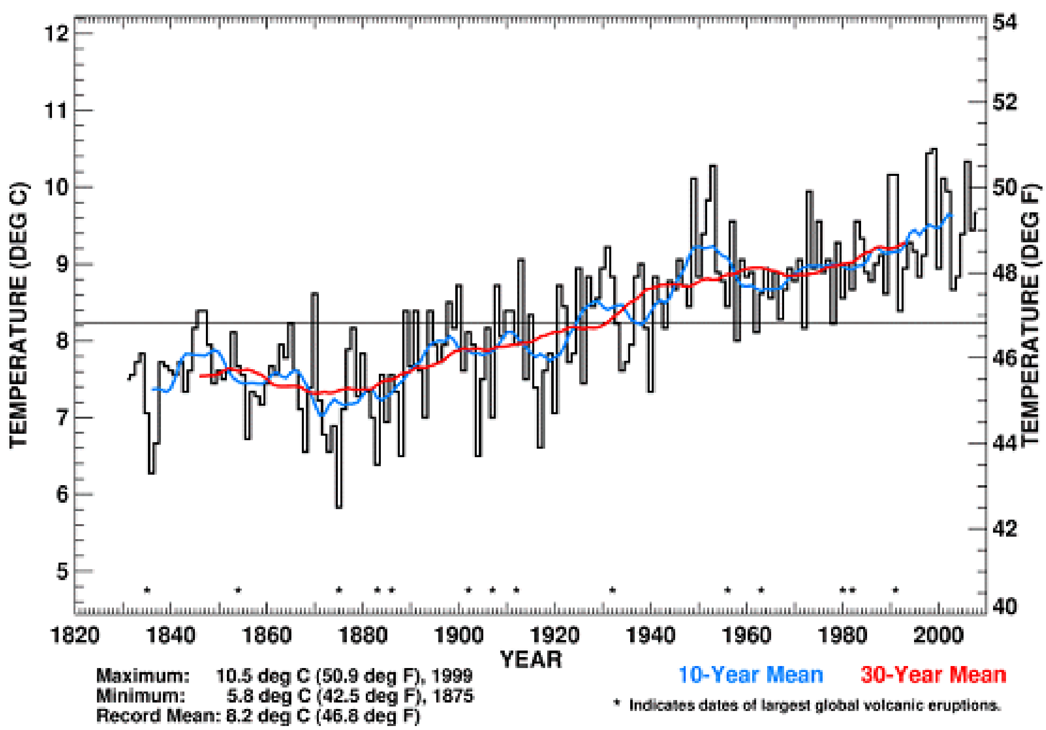
Category	Current (1961-1990 avg.)	Predicted Change 2040-2069	Predicted Change 2070-2099
Average Annual Temperature (°F)	46°	+4° to 5°	+5° to 10°
Average Winter Temperature (°F)	23°	+2.5° to 4°	+8° to 12°
Average Summer Temperature (°F)	68°	+1.5° to 3.5°	+6° to 14°
Days over 90 °F	5 to 20 days	-	30 to 60 days
Days over 100 °F	0 to 2 days	-	3 to 28 days
Annual Precipitation	41 inches	5% to 8%	+7% to 14%
Winter Precipitation	8 inches	+6% to 16%	+12% to 30%
Summer Precipitation	11 inches	-1% to -3%	-1% to 0%

Sources: Massachusetts Climate Adaptation Report 2011, NECIA

5.1 HIGHER TEMPERATURES

The climate of the Pioneer Valley is strongly influenced by the weather patterns of the larger Northeast United States, a region ranging from Pennsylvania to Maine. Average temperatures in the Northeast have been increasing since the late 1800s. The overall average annual temperature increase in this area has been approximately .9 degrees C (1.5°F) since approximately 1900. According to records of the United States Historical Climatology Network, most of this temperature increase has occurred recently, with an average increase of about 0.2 degrees C (0.5°F) per decade since 1970. These higher average temperatures have primarily been the result of warmer winters (December through March), during which there has been an increase of 1.3°F per decade since 1970. In addition to average temperature increases, the number of extremely hot and record heat days has also increased: the number of days with temperatures of 90°F and higher throughout the Northeast has doubled during the past 45 years. The northern portion of the Northeast currently sees about 5 days per year with temperatures over 90°F and no days over 100°F, while the southern portion sees up to 20 days over 90°F and 2 days over 100°F.

Figure 5-1: Northeast U.S. Region Annual Average Temperatures 1831-2008



From 1831 to 2008, there was a trend in temperatures steadily increasing at the National Weather Service's Blue Hill Observatory, the home of the oldest continuously recorded weather records in the U.S. *Source: Michael J. Iacono, Atmospheric and Environmental Research, Inc./ Blue Hill Observatory, MA. Plot includes temperature data for 1831–1884 from Milton and Canton that were adjusted to the Blue Hill summit location.*

The future rate and magnitude of temperature increases globally has been the subject of numerous scientific studies. Temperature is related to greenhouse gas (GHG) emissions because of their insulating characteristics, which reduce the amount of heat that can escape earth's atmosphere into space.

The most extensive climate analysis to focus on the New England region is the Northeastern Climate Impacts Assessment produced by NECIA in 2007. This analysis involved the development of two scenarios for temperature projections in the 21st Century:

1. **Lower Emissions Scenario:** Based on the reductions to the rate and quantities of greenhouse gas (GHG) emissions in the atmosphere consistent with currently implemented and proposed mitigation strategies and goals (see Chapter 5).
2. **Higher Emissions Scenario:** GHG emissions continuing at the present rate ("Business As Usual" or BAU).

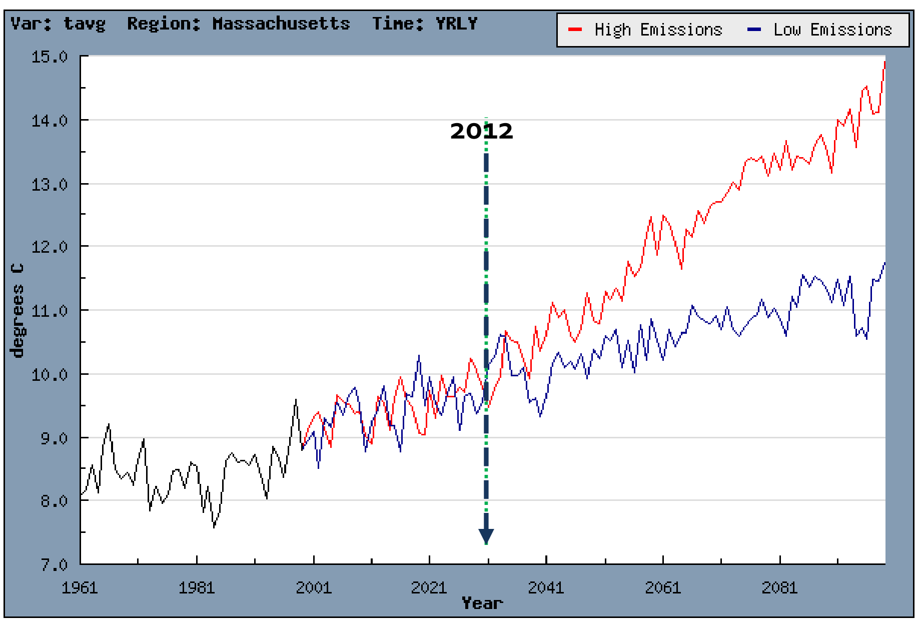
According to the NECIA estimates, during the next 25-50 years in Massachusetts, the range of temperature increases associated with these two scenarios is expected to be:

1. **Lower Emissions Scenario:** Temperatures increase at least 2.5° to 4°F in winter and 1.5° to 3.5° F in summer.
2. **Higher Emissions Scenario:** Temperatures increases 8° to 12°F in winter and 6° to 14°F in summer.

The number of very hot days is also expected to increase. By the end of the 21st century (when today's children have grandchildren) the Northeast will have an estimated 30 to 60 days with temperatures over 90°F, and 3 to 28 days with temperatures over 100°F.

Rising temperatures will effectively move the warm temperatures of the present-day southern United States to the north. NECIA estimates that the higher temperatures coming to Massachusetts in the coming decades will result in a new climate that is similar to that of New Jersey (lower emissions scenario) and Virginia (higher emissions scenario) by the end of the century.

Figure 5-2: Massachusetts Average Annual Temperatures 1961-2010 and 2011-2099 Projections (High and Low GHG Emissions Scenarios)



Under both low and high emissions scenarios, the average annual temperatures in Massachusetts are projected to increase. *Source: Northeast Climate Data <http://www.northeastclimatedata.org> accessed and plotted 8/1/12)*

Figure 5-3: Predicted Days Over 90°F in Boston, MA

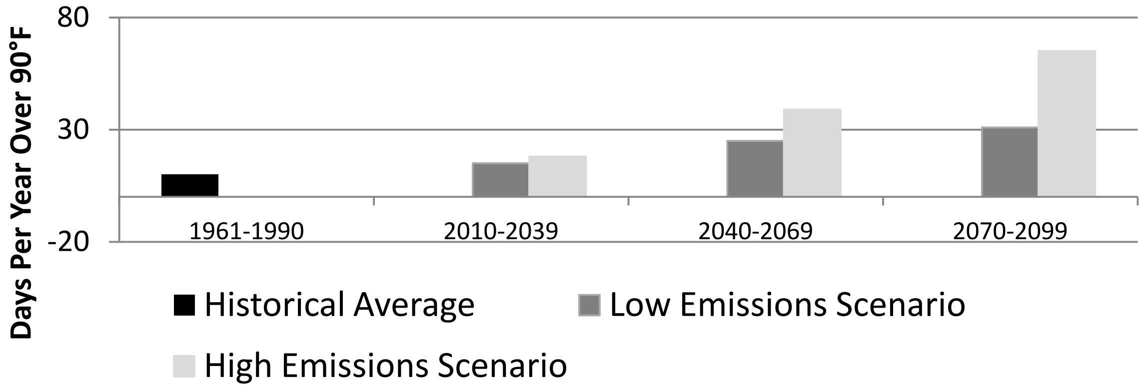


Figure 5-4: Predicted Days Over 90°F in Concord / Manchester, NH

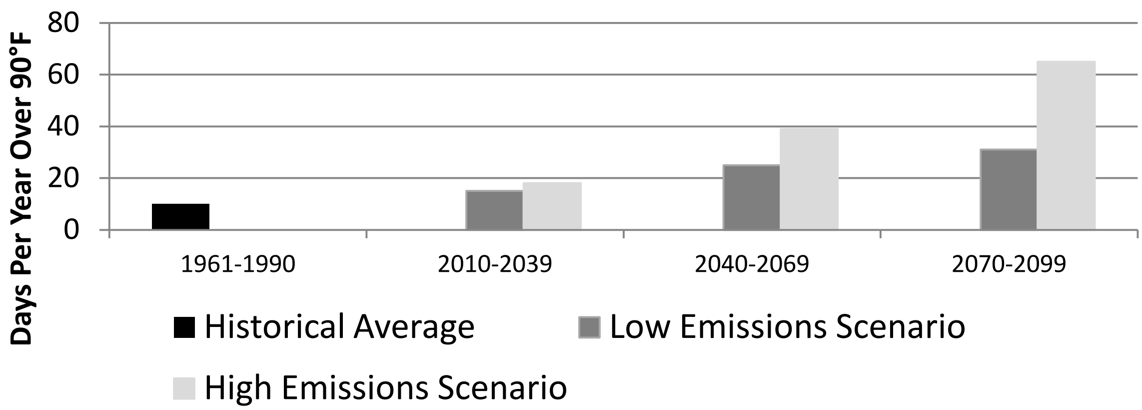
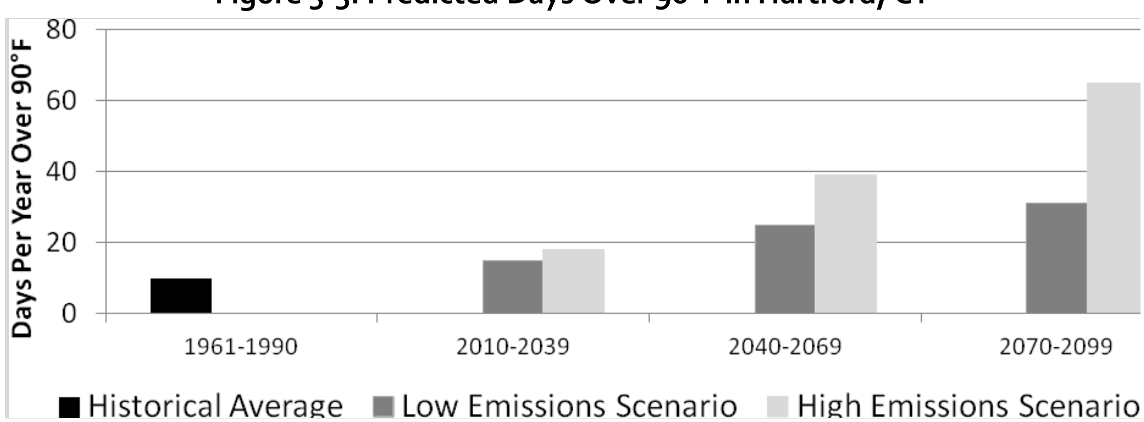


Figure 5-5: Predicted Days Over 90°F in Hartford, CT



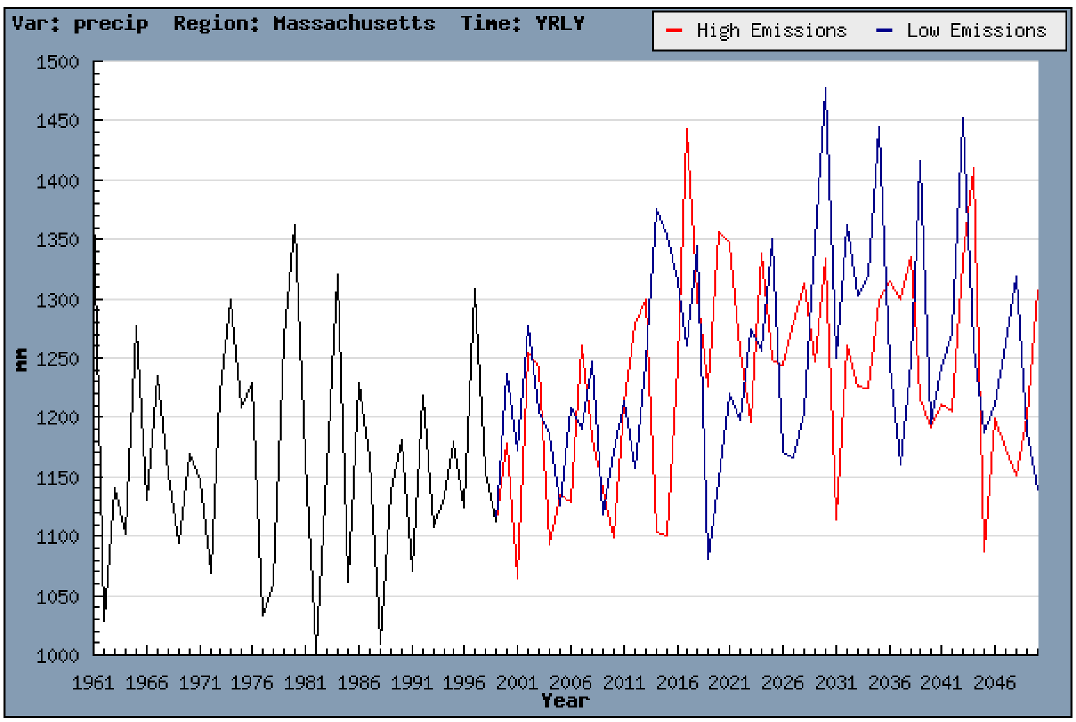
The number of days per year with temperatures over 90 degrees is projected to increase throughout various New England cities, including Hartford, Manchester, and Boston. *Source: NECIA*

5.2 INCREASED PRECIPITATION

Historic trends in precipitation in Massachusetts vary based on the time span that is studied. Going back over the past 200 years, there has been a slight decrease in precipitation. However, a more recent 50-year view reveals an increase in total precipitation by approximately 10%. Over a similar period, as a result of rising winter temperatures, more precipitation during the winter has been falling as rain. This has resulted in less snowfall and fewer days with snow cover throughout the winter in the Northeast.

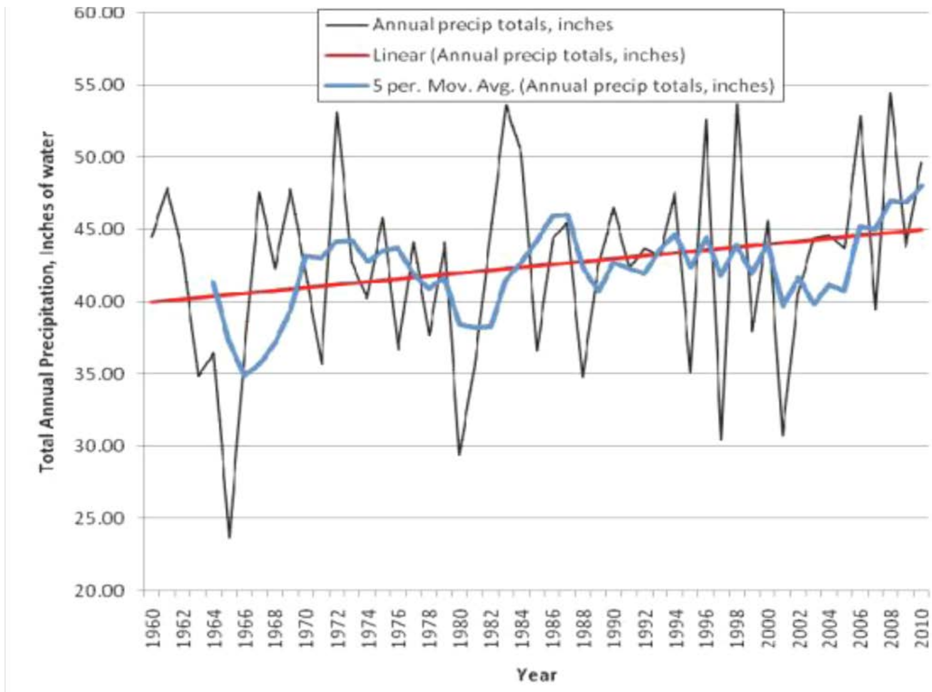
By the end of the 21st century, annual precipitation is expected to increase by 14% – however, this increase will be a result of more winter precipitation – an increase of 30%– while summer precipitation will actually slightly decrease. Additionally, most of this winter precipitation is projected to be in the form of rain rather than snow. This will result in a continuation of the current trend of an overall decrease in total snowfall, as well as the number of days that have snow cover.

Figure 5-6: Massachusetts Rainfall 1961-2050



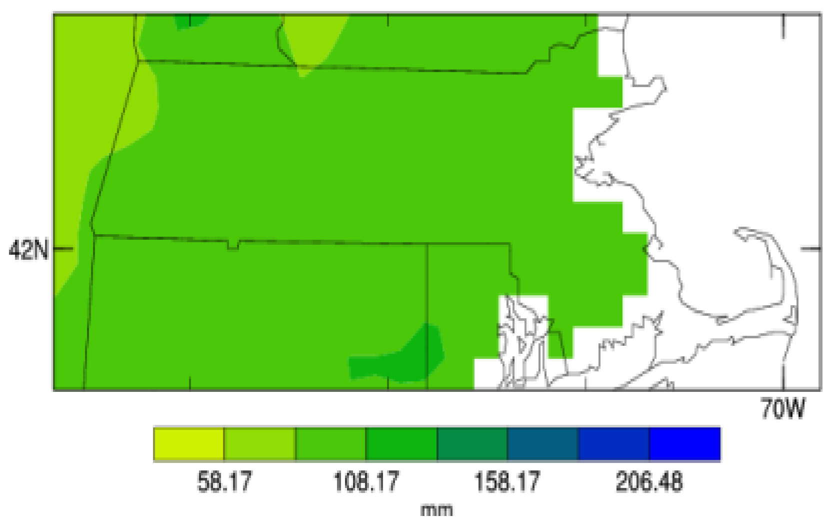
Rainfall has increased approximately 10% during the past 50 years, and is expected to continue to increase. *Source: NECIA*

Figure 5-7: Annual Precipitation for Boston, 1960 to 2010



Precipitation totals in Boston have steadily increased during the time period between 1960 and 2010. Annual precipitation also varies widely year-to-year. *Source: Mass. Climate Adaptation Report 2011*

Figure 5-8: Massachusetts 2010-2039 Yearly Precipitation Change Relative to 1961-1990



Increasing Rainfall: Under both High and Low Emissions Scenarios, average annual rainfall in Western Massachusetts is forecast to rise from average of approximately 46 inches per year (1981 to 2010) to 56 inches per year. *Source: NECIA High Emissions scenario forecast. (100 mm = 4 inches).*

Precipitation projections for the Northeast indicate that there will be changes to the amount, frequency, and timing of precipitation that occurs. The very largest storms have also increased in frequency. According to the Massachusetts Climate Adaptation Report and climate change studies, the large rain storm of October 1991 was once considered a greater than 1,000-year event, but is now considered a 200- to 500-year event. Furthermore, storms such as the Hurricane of 1938 are now considered two-year storms in Massachusetts.[1]

Table 5-2: New England Precipitation and Temperature Rankings: 2011-2012 Compared to Past 117 Years

State	Precipitation Rank since 1895 (Wettest to Driest)	Temperature Rank (Hottest to Coldest)
Connecticut	5th	1st
Maine	32nd	1st
Massachusetts	**6th**	**1st**
New Hampshire	13th	1st
New Jersey	5th	1st
New York	1st	1st
Pennsylvania	2nd	1st
Rhode Island	11th	1st
Vermont	5th	1st

This list shows the precipitation ranking of the one-year period from May 1, 2011 through April 30, 2012, as compared to the past 117 years. For example, the first line shows that Connecticut experienced its 5th wettest and 1st hottest year since 1895. *Source: National Oceanic and Atmospheric Administration Climatic Data Center*

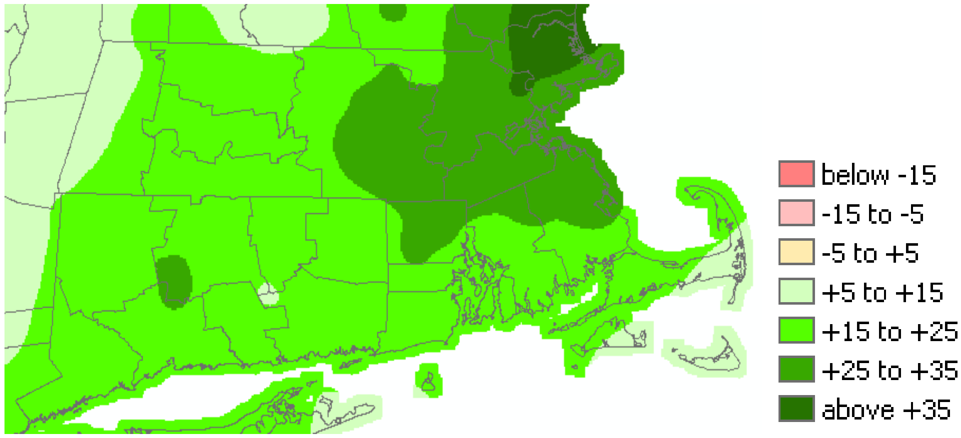
5.3 SEVERE (EXTREME) WEATHER

There has also been an increase in extreme precipitation events, categorized as over 50mm (1.9 inches) of rain in a 1-hour period, in eastern Massachusetts between 1949 and 2002. In recent years, Western New England has also experienced large annual precipitation totals. For example, the 2011 rainfall total at Bradley International Airport in Windsor Locks, Connecticut was 69.23 inches, whereas the average annual rainfall at this station between 1981 and 2010 was 45.85 inches. In 2008, total precipitation at the airport was also unusually high, 65.35 inches.

The baseline historic precipitation data upon which the "500-year storm" and similar thresholds for which single-event extreme precipitation estimates are determined and utilized for stormwater design standards have traditionally been taken from the National Weather Service's 1961 publication "Technical Paper 40" which relies on precipitation records from the first half of the 20th Century. Precipitation estimates have been revised using more recent data by project of the Natural Resource and Conservation Service and Cornell University. This new extreme precipitation study and method, known as "Hydro-35," includes information on precipitation in the Northeast through 2008.

[1] Massachusetts Executive Office of Energy and Environmental Affairs. Climate Change Adaptation in Massachusetts. September 2011. http://www.mass.gov/eea/air-water-climate-change/climate-change/climate-change-adaptation-in-ma.html. Accessed June 3, 2012.

Figure 5-9: Comparison of Precipitation Amounts for 24-hour Extreme Weather Events—Conventional Data (Technical Paper 40, through 1961) versus Updated Data (Hydro-35 through 2008)



This graphic compares the percentage differences in precipitation for 24-hour extreme weather events between the traditionally used precipitation amounts in the NWS 1961 publication "Technical Paper 40" versus the revised precipitation amounts recorded by the NRCS/Princeton Extreme Weather project model, Hydro35, which incorporates precipitation data through 2008. The Hydro35 model documents that precipitation for extreme weather events in the Pioneer Valley region is actually 15% to 25% greater than the conventional model predicts. (http://precip.eas.cornell.edu/)

NECIA projects that the number of thunderstorms that produce more than 2 inches of rain during a 48-hour period will increase by 8% in the Northeast by mid-century (estimated between the years 2040 and 2069).[2] The increased amount of strong precipitation events and overall increase in rainfall will likely result in more flooding in the region. At the same time as there is an overall increase in precipitation in the region, the increased inconsistency in weather, increased temperatures, and slight decrease in summer precipitation will result in an increase in the number of droughts. Short-term (1 to 3 month) droughts are likely to increase in their frequency in the Northeast to the level of once per year. According to the Connecticut Climate Adaptation Report, "Facing Our Future," the occurrence of drought in that state is already increasing, with shallower lakes drying up.[3]

Temperature and precipitation changes in the region will lead to increased severe and extreme weather events. In 2011 alone, the Pioneer Valley experienced several severe weather events:

- **Snowstorm** – The snowstorm of October 31, 2011 occurred after unseasonably warm weather, and many trees still had their leaves. When leaves became weighed down by the snow, branches broke and downed power lines throughout. More than 700,000 people were without power, many for more than a week, in Massachusetts, and the death of a Springfield resident was attributed to the storm. Snowfall totals exceeding 14 inches in Springfield and Chicopee and 30 inches in Plainfield.[4]

[2] Northeast Climate Change Impacts Assessment. Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. 2007.

[3] State of Connecticut Department of Environmental Protection. Facing Our Future: Adapting to Connecticut's Changing Climate. March 2009.

[4] Springfield Republican. Historic October snowstorm leaves thousands in Western Massachusetts without electricity, closes schools, damages trees. http://www.masslive.com/news/index.ssf/2011/10/historic_october_snowstorm_lea.html. Accessed June 3, 2012.

Table 5-3: Single Event Snowfall Total: October 30-31, 2011

Town	**Snowfall** (inches)
Plainfield	30.8
Chesterfield	28.0
Ashfield	25.5
Tolland	25.0
Worthington	24.0
Blandford	22.0
Shelburne	21.5
Chicopee	15.0
Southwick	14.1
Springfield	14.0
Greenfield	13.5

The snowstorm of October 2011 generated large amounts of snow unusually early in the year. Hill town communities generally received the most snow. Source: *National Weather Service*

- **Tropical Storm Irene** – The remnants of Hurricane Irene that ravaged most of the East Coast, the tropical storm hit western Massachusetts on August 28, 2011. Wind gusts were monitored at up to 80 mph and 10 inches of rain was reported in some communities. In western Massachusetts, the storm left 657,000 homes and businesses without power and generated significant flooding, particularly in western Franklin and northern Berkshire counties. The storm caused flooding of the Deerfield, Green, Chicopee and Westfield Rivers, and resulted in estimated economic damages of over $34 million for individuals and municipal infrastructure.[5]

- **Tornados** – Four tornadoes occurred during a severe thunderstorm on June 1, 2011. The tornadoes, which had a maximum wind speed of 160 miles per hour, killed three people and caused over $200 million in damages to homes and businesses. Affected communities in the Pioneer Valley included Monson, Brimfield, Southwick, Springfield, and West Springfield. 1,400 houses and 78 businesses in western and central Massachusetts were damaged.[6]

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[5] Massachusetts National Guard. Hurricane Irene Response. August 2011. http://states.ng.mil/sites/MA/PDF/Mass%20Guard%20Hurricane%20Irene%20Storyboard.pdf. Accessed December 13, 2012.

[6] Springfield Republican. "A Year Later, Monson Shows Signs of Recovery." <http://www.masslive.com/news/index.ssf/2012/06/monson_showing_signs_of_recove.html> Accessed June 3, 2012.

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Massachusetts Executive Office of Energy and Environmental Affairs. Climate Change Adaptation in Massachusetts. September 2011. http://www.mass.gov/eea/air-water-climate-change/climate-change/climate-change-adaptation-in-ma.html. Accessed June 3, 2012.

Massachusetts National Guard. Hurricane Irene Response. August 2011. http://states.ng.mil/sites/MA/PDF/Mass%20Guard%20Hurricane%20Irene%20Storyboard.pdf. Accessed December 13, 2012.

Northeast Climate Change Impacts Assessment. Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. 2007.

Northeast Regional Climate Center and Natural Resources Conservation Service. “Extreme Precipitation in New York and New England.” http://precip.eas.cornell.edu. Accessed multiple times, October 2012 through January 11, 2013.

Regional Climate Impacts. U.S. Global Change Research Program. http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/regional-climate-change-impacts/northeast. Accessed April 24, 2012.

Springfield Republican. “A Year Later, Monson Shows Signs of Recovery.” http://www.masslive.com/news/index.ssf/2012/06/monson_showing_signs_of_recove.html. Accessed June 3, 2012.

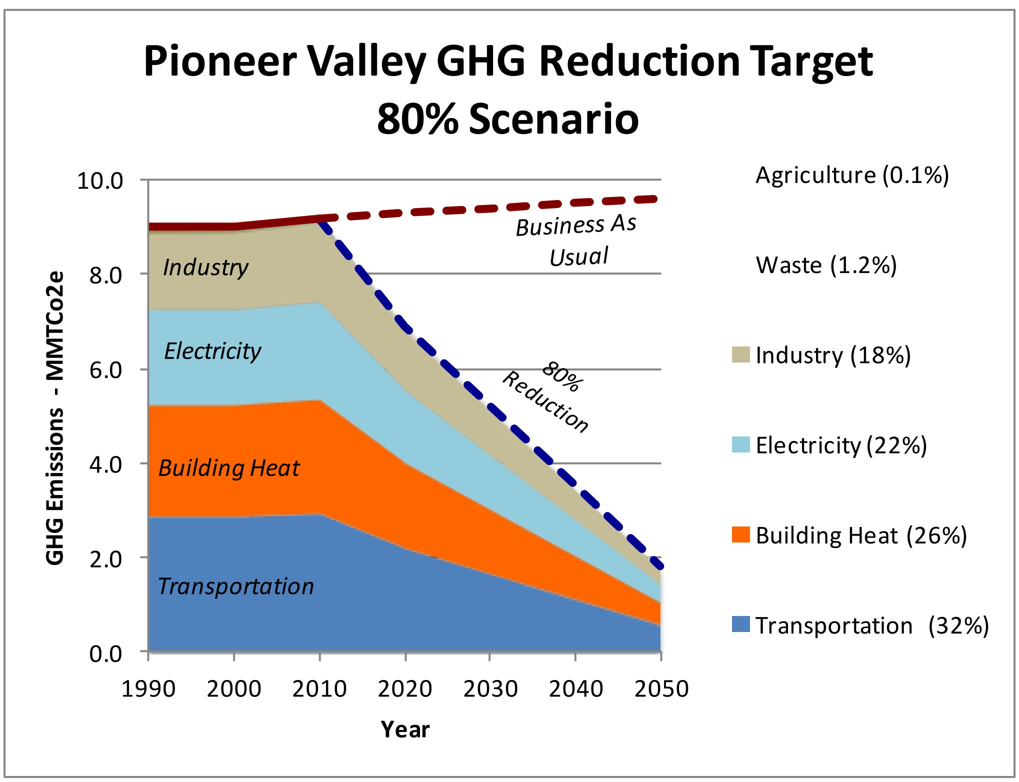
Springfield Republican. Historic October snowstorm leaves thousands in Western Massachusetts without electricity, closes schools, damages trees. http://www.masslive.com/news/index.ssf/2011/10/historic_october_snowstorm_lea.html. Accessed June 3, 2012.

6 GREENHOUSE GAS REDUCTION SCENARIOS FOR THE REGION

The Greenhouse Gas (GHG) inventory completed in 2011 (presented in Chapter 3) documented total GHG emissions in the Pioneer Valley for that year of approximately 9.2 MMTCO2e. This chapter offers two scenarios with target goals for reducing these GHG emissions: an 80% reduction consistent with statewide requirements, and a 100% reduction (carbon neutral) scenario.

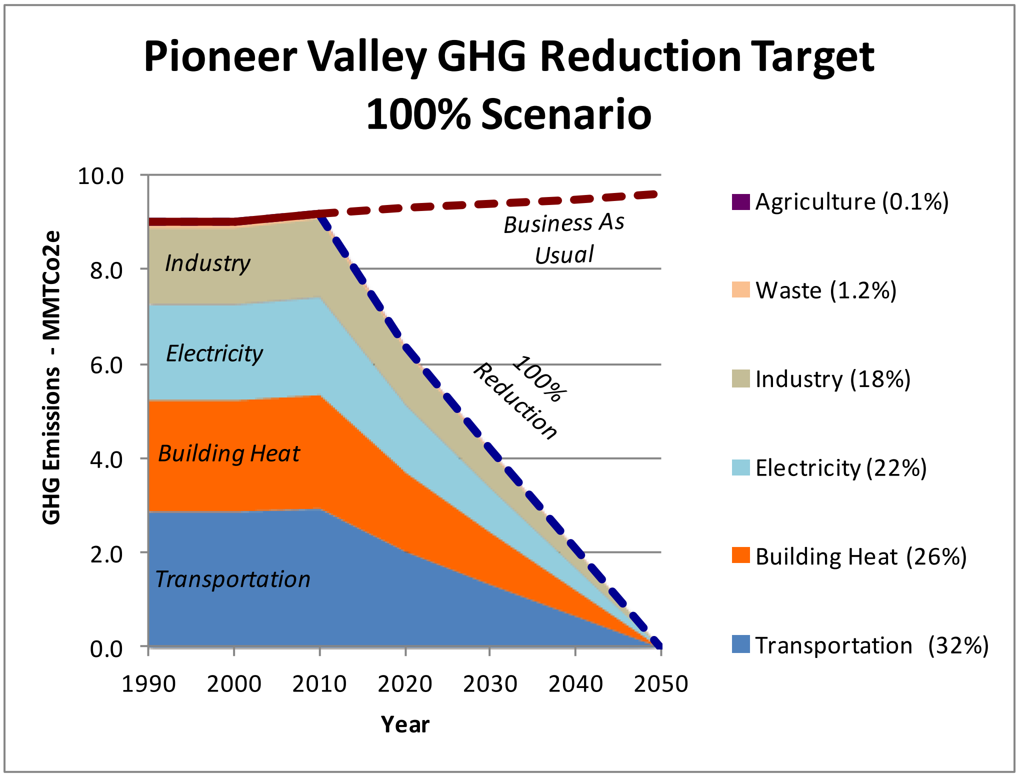
Both scenarios are ambitious. The best current technical estimates are that by 2020, statewide GHG emissions levels will be 13% to 18% below 1990 levels. This is significant progress (among the best in the U.S.), but still well short of the 25% reduction target required by the Massachusetts Global Warming Solutions Act of 2008 (GWSA). Specific GHG reductions achieved thus far from emitting sources in the Pioneer Valley region are not yet known, as the baseline regional GHG inventory of 2011 has not yet been updated. Regular updates of the inventory will be necessary to track regional progress toward these targets so that decision-makers, residents and businesses of the region are aware of the progress we are making toward GHG reductions and compliance with the GWSA.

1. 80% Reduction Scenario: This is a "Fair Share" scenario in which GHG emissions are reduced by 80% of 1990 levels by 2050 (from 9.2 to 1.8 MMTCO2e), with an interim goal of a 25% reduction by 2020 (from 9.2 to 6.9 MMTCO2e). These targets are identical to the statewide reductions stipulated by the Massachusetts Global Warming Solutions Act (GWSA) of 2008 and assume the region will do its "fair share" to contribute to them.



2. 100% Reduction Scenario: This is a "Carbon Neutral" scenario in which the region reduces its GHG emissions from 9.2 to zero MMTCO2e by 2050. To meet this more aggressive target, an interim goal of a 30% reduction from 1990 GHG levels by 2020 (from 9.2 to 6.4 MMTCO2e) is proposed.

This scenario assumes there are unique regionally based advantages in the Pioneer Valley that will allow it to exceed the GHG reduction proportions required for the entire state by the GWSA. These advantages include more sites that are readily available for renewable energy generation; more opportunities to cut transportation emissions by reducing auto trips through mode shifts; and greater potential to achieve building heating and energy savings through home energy retrofits because of a larger per capita proportion of single-family homes here than the eastern part of the state.



6.1 TOWARD 2050: CONTEXT FOR REGIONAL GHG REDUCTION TARGETS

This chapter presents the following information:

- A summary of GHG mitigation initiatives and targets that are relevant to the Pioneer Valley.
- A summary of progress toward statewide GHG reduction targets.
- Regional GHG emissions projections to 2050, based on present trends.
- Proposed regional GHG emissions reduction targets to 2050 for the Carbon Neutral and Fair Share Scenarios.

This chapter represents Steps 2 and 3 in a broader GHG mitigation process for the region, summarized below.

Step 1	**Step 2**	**Step 3**	**Step 4**	**Step 5**
GHG Inventory	GHG Projections	Set Regional GHG Reduction Targets	Identify and Implement GHG Mitigation Actions	Measure Progress Toward GHG Reduction Target
(Ch. 3)	(Ch. 6)	(Ch. 6)	(Ch. 8)	(Ch. 8)

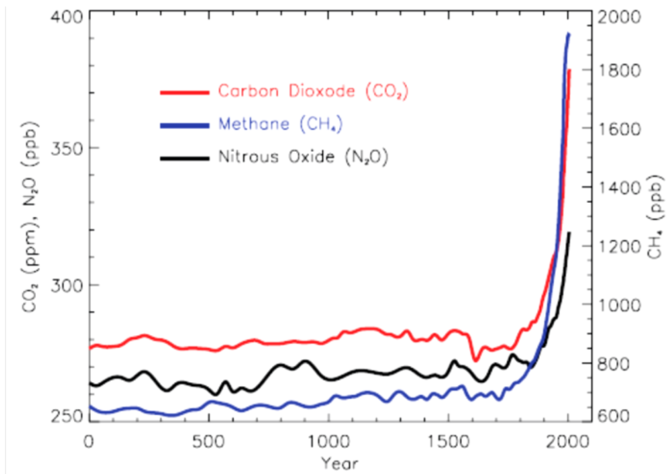
6.1.1 GLOBAL AND NATIONAL GHG REDUCTION CONTEXTS

GHG reduction efforts have been pursued for nearly two decades, yet global GHG emissions have continued to rise, most recently up 3.2% from 2010 to 2011. The proportion of carbon dioxide in the atmosphere, the gas that makes up the largest proportion of total GHGs in the atmosphere, has now reached approximately 380 parts per billion. This is significantly above the 350 ppb that is generally acknowledged by climatologists to be the maximum level at which global temperature rise can be limited to 2 degrees C (3.6 degrees F), which is the consensus goal for global temperature rise established by the 2011 U.N. Climate Change Conference. An increase of 2 degrees C would be the result of an addition of approximately 565 gigatons of carbon dioxide and equivalent gases emitted worldwide by 2050. The average global temperature is now already .8 degrees C higher since 1990, and it is now estimated that another .8 degree C rise will occur during the next 10-20 years, even if all GHG emissions were stopped immediately, because of the slow rate at which GHGs dissipate (IPCC 2010). However, the amount of untapped carbon-based reserves (mainly coal, oil and natural gas) that are presently owned or under contract to energy companies that are anticipated to be burned by 2050 is approximately 2,800 gigatons. This is more than five times the 565 gigatons of carbon that, if burned, will result in a rise of 2 degrees C by 2050.

The 2011 U.N. Climate Change accord, signed by 167 countries presents a global consensus that: "...we agree that deep cuts in global emissions are required... so as to hold the increase in global temperature below two degrees Celsius." However, the depth of those cuts and where they should come from are not specifically quantified or defined.

Currently, there is no GHG emissions reduction target or plan that is specific to the Pioneer Valley (Hampden and Hampshire Counties). The Massachusetts Global Warming Solutions Act of 2008 set targets for GHG reductions by 2020 (25% from 1990 levels) and 2050 (80% from 1990 levels). The implementation of state-level initiatives in energy conservation and renewable energy production to reach these statewide targets, and in 2012 the American Council for an Energy-Efficient Economy ranked Massachusetts the most energy efficient state in the U.S., based on the range and effectiveness of state-level polices enacted.

Figure 6-2: Historic Global Concentrations of Greenhouse Gases through 2005



Reproduced from Massachusetts Clean Energy Plan 2010

6.1.2 TYPES OF GREENHOUSE GASES (GHG) EMITTING ACTIVITIES

Greenhouse gases (GHGs) are emitted by activities in all sectors of the economy. The four general types of GHG-emitting activities are described below. (Categories grouped by the nature of the process that creates the GHG, not the economic sector or activity.)

Combustion of Fossil Fuels	The greatest contribution to carbon dioxide emissions comes from the burning of fossil fuels for heat, transportation, and electricity generation. Residential, Commercial, Industrial, Transportation and Electric Generation are the sectors in which fossil fuels are combusted. Fossil fuel combustion also generates methane (CH4) and Nitrous Oxide (N2O).
Industrial Processes	Cement Production, Lime Manufacture, Limestone and Dolomite Use, Soda Ash Manufacture and Consumption, Iron and Steel Production, Ammonia Manufacture, Nitric Acid Production, Adipic Acid Production, Aluminum Production, Hydrochlorofluorocarbon (HCFC)-22 Production, Consumption of Substitutes for Ozone-Depleting Substances (ODS), Semiconductor Manufacture, Electric Power Transmission and Distribution, and Magnesium Production and Processing. (USEPA) Not all of these occur in Massachusetts (or the Pioneer Valley).
Agriculture	Enteric fermentation (gases produced in the intestines of livestock), manure management, management of plant residues in soil, legume cultivation, agricultural fertilizer use, rice cultivation, and burning agricultural residues (USEPA). Not all of these activities occur in Massachusetts.
Waste Management	Municipal solid waste combustion, landfill methane generation, and wastewater disposal and treatment. (USEPA) All of these occur in Massachusetts.

Reproduced from Massachusetts Statewide Greenhouse Gas Emissions:
1990 Baseline and 2020 Business As Usual Projection. 2009.

6.1.3 EXISTING APPLICABLE GHG MITIGATION PLANS AND REDUCTION TARGETS

Efforts to mitigate GHG emissions that apply to the Pioneer Valley region have been ongoing for more than a decade. Following are initiatives and entities that are relevant to the GHG reduction efforts.

<table>
<tr><td>Massachusetts Clean Energy and Climate Plan for 2020</td><td>2010</td><td>This plan prepared as a requirement of the Massachusetts Global Warming Solutions Act of 2008 sets the following goals for GHG emissions reductions:

By 2020, reduce GHG emissions 25% below 1990 levels.
By 2050, reduce GHG emissions 80% below 1990 levels.</td></tr>
<tr><td>Pioneer Valley Clean Energy Plan</td><td>2008</td><td>The Pioneer Valley Clean Energy Plan focuses on reducing overall energy consumption, replacing carbon-based fuels with renewable energy, reducing GHG emissions and creating new jobs in renewable energy. The GHG reduction targets of this plan are:

2020: Reduce regional energy consumption 15% below 2000 levels.
2050: Reduce regional GHG emissions 80% below 2000 levels.

This plan assumes that the region (plus Franklin County) is responsible for achieving approximately 10% of the Massachusetts statewide GHG reduction targets (based on population). The plan’s proposed GHG emissions reduction goals are shown below.

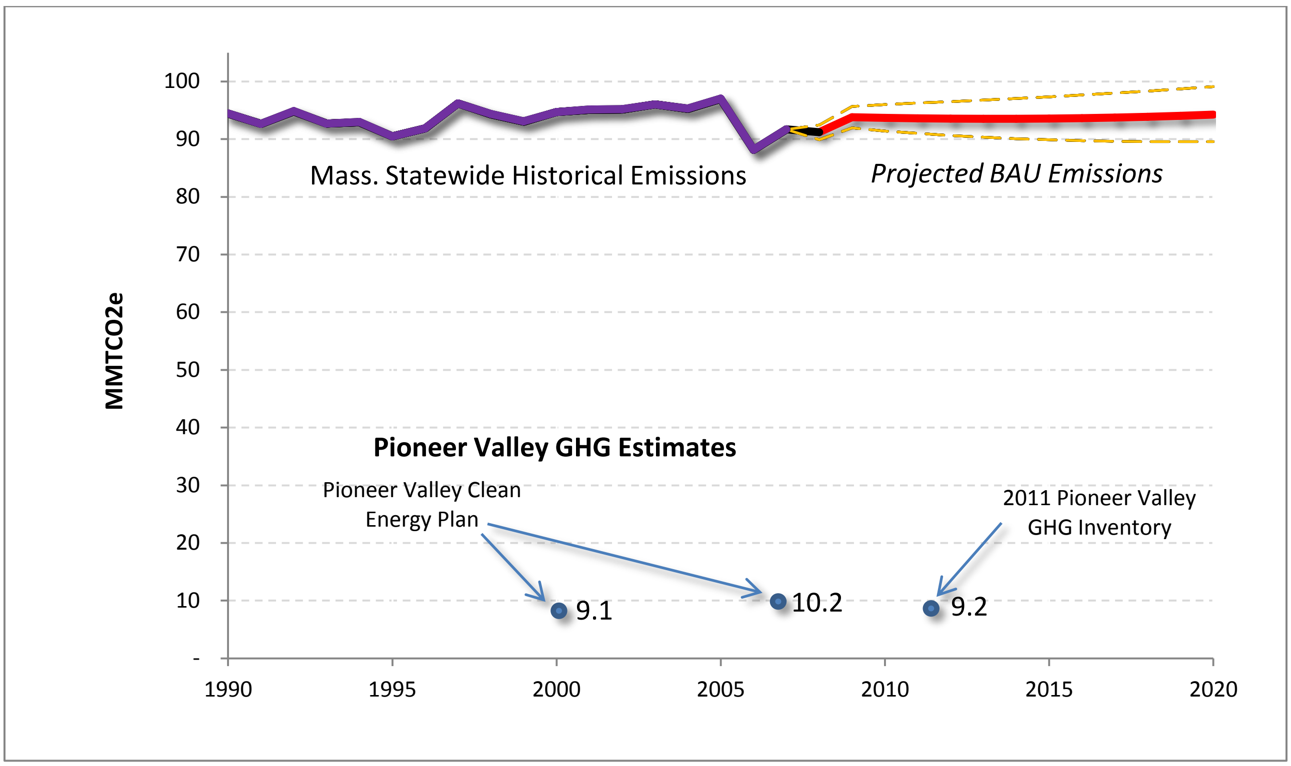
Greenhouse Gas Gross Emissions in the Pioneer Valley
<table>
<tr><th>YEAR</th><th>MMTCO2e</th></tr>
<tr><td>2000 (actual)</td><td>9.06</td></tr>
<tr><td>2007 (projected)</td><td>10.18</td></tr>
<tr><td>2010 Goal</td><td>9.60</td></tr>
<tr><td>2020 Goal</td><td>7.65</td></tr>
<tr><td>2050 Goal</td><td>1.81</td></tr>
</table>
Source: DOER 2007. Amounts differ slightly from 2011 GHG Inventory for this plan (Ch. 3) due to use of different sources and projection methods.</td></tr>
<tr><td>U.S. Conference of Mayors Climate Protection Agreement</td><td>2005</td><td>Signed by Mayors of Springfield, Greenfield, Northampton and 29 other Massachusetts mayors outside the Pioneer Valley, and more than 500 mayors nationwide, this agreement urged enactment of state and federal policies and programs to achieve GHG reductions of 7% below 1990 levels by 2012.</td></tr>
<tr><td>Regional Greenhouse Gas Initiative (RGGI)</td><td>2005</td><td>RGGI is a cooperative effort focusing on reducing GHG in the electric power sector among 11 Northeast and New England states. It is the first market-based regulatory program in the U.S. RGGI estimates that “together, these states have capped and will reduce carbon dioxide emissions from the power sector 10% by 2018.” RGGI is a parallel effort with the Conference of New England Governors and Canadian Premiers.</td></tr>
<tr><td>Northeast States for Coordinated Air Use Management</td><td>2005</td><td>NESCAUM is a nonprofit association of air quality agencies in eight Northeast states that supports regional efforts to reduce greenhouse gas (GHG) emissions, improve energy efficiency, and implement clean and renewable energy technologies. It has no specific GHG reduction target.</td></tr>
</table>

6.1.4 "BUSINESS AS USUAL" GHG EMISSIONS PROJECTIONS

This section is offered to help understand what would happen to GHG levels if no actions were taken to reduce them. This is known as a "Business-As-Usual" (BAU) forecast.

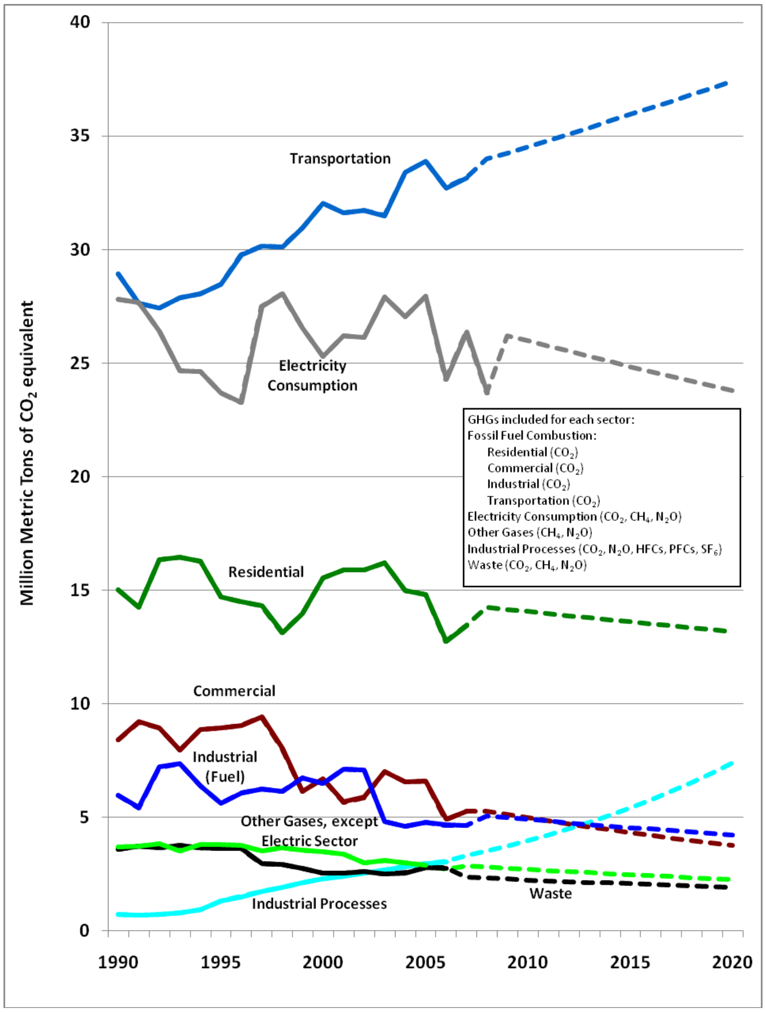
The BAU forecast for GHG emissions in the Pioneer Valley is derived from the statewide forecast estimates produced by the Massachusetts Department of Environmental Protection as part of statewide compliance with the Global Warming Solutions Act of 2008. The Massachusetts statewide BAU projections for total and major sector emissions to 2020 are shown on the following figures. The total statewide GHG emissions for these sectors in 2008 (the year this analysis was most recently produced) were about 94.4 MMTCO2e. These projections are based on the straightforward extrapolation of the historic trend of GHG emissions, rather than on a predictive model. Going forward, these estimates will be subject to a reasonable range of uncertainties that may be caused by economic growth or instability, changes in fuel prices, military conflicts and other events not related to GHG reduction. For reference purposes, the three known GHG level measurements for the Pioneer Valley alone are shown; however, because of differences in data gathering, sources and other assumptions, projected emissions for the region alone cannot be made.

Figure 6-3: Massachusetts and Pioneer Valley Historical Total GHG Emissions and Massachusetts Statewide "Business As Usual" GHG Emissions Projection



Sources: Statewide Greenhouse Gas Emissions Level: 1990 Baseline and 2020 Business As Usual Projection. July 1, 2009. Pioneer Valley Clean Energy Plan 2008. Pioneer Valley GHG Inventory 2011. Note: The state "Projected Emissions" line is based on a simple extrapolation of historical data, rather than modeling that attempts to predict future events. A +/-5% variation range for this project is shown to account for uncertainty.

Figure 6-4: Massachusetts Statewide "Business As Usual" GHG Emissions 1990 to 2020 By Sector



Reproduced from Massachusetts Statewide Greenhouse Gas Emissions: 1990 Baseline and 2020 Business As Usual Projection. 2009. Massachusetts Department of Environmental Protection.

Note: Some changes in Massachusetts policy that were adopted but implemented prior to January 1, 2009 are not reflected in this projection, including the Regional Greenhouse Gas Initiative (RGGI), the 2007 revised Federal Corporate Average Fuel Economy (CAFE) vehicle efficiency standards, and the Federal Renewable Fuel Standard (RFS). However, the extent to which such programs will reduce emissions in Massachusetts specifically is not known, as the programs are federal or regional in scope. Also, since some of the programs were not implemented by January 1, 2009, there are no actual data yet on which to base projected emissions.

6.3.3 ESTIMATES OF GHG REDUCTIONS ACHIEVED TO DATE IN MASSACHUSETTS

To date, there have been two significant assessments of statewide progress toward the GHG reduction targets established by the Global Warming Solutions Act of 2008. These are presented below. Significantly, both analyses demonstrate that the "Business As Usual" scenario is not occurring. GHG reductions are being achieved already and will yield further reductions by 2020. But both analyses show that the pace of actual GHG reductions is not enough to meet the statewide 25% GHG reduction target by 2020, with actual reductions expected in the range of 13% to 18.6%.

1) INITIAL ESTIMATES OF GHG EMISSIONS REDUCTIONS FROM EXISTING POLICIES RELATED TO REDUCING GREENHOUSE GAS EMISSIONS (EASTERN RESEARCH GROUP TECHNICAL MEMO OF MAY 2010)

This technical memo produced by the Eastern Research Group (ERG) for the Massachusetts Department of Energy Resources offers a preliminary estimate of the impact of all significant post-2007 state and federal GHG reduction policies on Massachusetts' GHG emissions by 2020, compared to the 1990 baseline. The post 2007 policies are estimated to yield approximately an 18.6% reduction of GHG emissions below 1990 levels, resulting in annual emissions of 76.9 million metric tons of carbon dioxide equivalent (CO2e) in 2020, compared to approximately 94 million metric tons in 1990.

At the statewide level, the greatest GHG reductions thus far have been achieved through energy efficiencies measures, especially in electricity. Most energy categories (except for appliance standards) are subject to state regulation, which may account for the relative success in this sector. The vast majority of transportation GHG reductions have been the result of federal actions, which are generally beyond the scope of the regional plan. The majority of reductions in the renewable energy category are from imports of renewable energy generated outside the region. Estimates of GHG reductions by 2020 based on existing state energy efficiency and GHG reduction programs are summarized on the figure below.

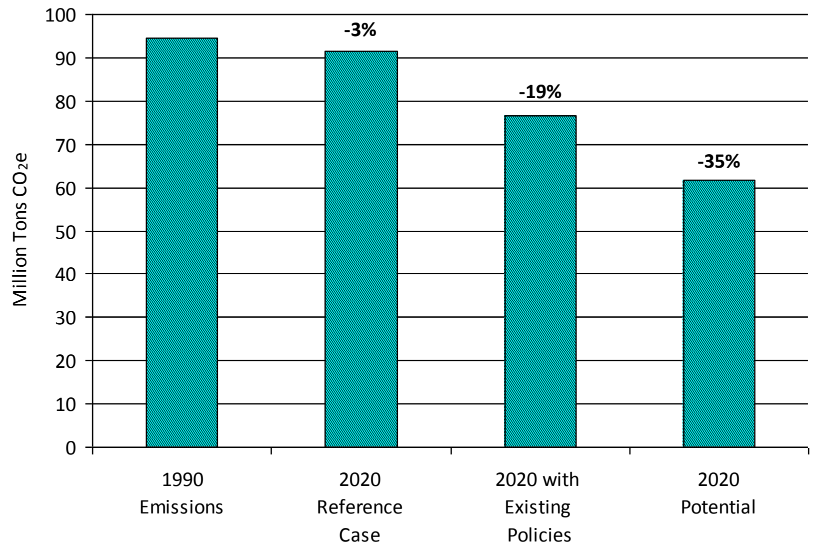
Table 6-1: Anticipated 2020 GHG Reductions from 1990 Baseline to be Achieved Statewide

SECTOR	Million Metric Tons of CO_2 Equivalent	% Change from 1990
1990	94.4	
2020 Business as Usual (BAU)	94.2	-0.2%
Transportation		
Federal and CA Vehicle Standards	-2.4	-2.6%
Federal RFS and Regional LCFS (including heating oil)	-1.8	-1.9%
Land Use / Smart Growth/GHG Criteria for Planning	-0.1	-0.1%
Energy Efficiency 9.4%		
Energy Efficiency – Electricity	-4.7	-5.0%
Energy Efficiency – Natural Gas and Oil	-2.0	-2.1%
Building Codes (Residential Heating)	-1.5	-1.6%
Appliance/Product Standards	-0.5	-0.6%
Mass. Environmental Policy Act	-0.1	-0.1%
Renewable Energy		
Renewable Portfolio Standard	-1.1	-1.2%
Additional Low-Carbon Electricity Imports	-3.1	-3.2%
2020 After Reductions from Existing Policies	76.9	-18.6%

Reproduced from Initial Estimates of Emissions Reductions from Existing Policies Related to Reducing GHG, Eastern Research Group 4/30/2010 Memo to MA EOEA.

May 3, 2010 assessment report for Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs by Eastern Research Group concluded: "...that the state's existing policies (along with federal policies and prospective state policies whose development is well underway) will bring the state most of the way toward a 25-percent reduction in 2020."

Figure 6-5: Initial Estimates of Emissions Reductions Massachusetts Statewide to 2020



Total GHG Emissions in Massachusetts (bars show total GHG emissions in Massachusetts, while percentages show reductions in each case as compared to 1990 emissions.) Reproduced from Initial Estimates of Emissions Reductions from Existing Policies Related to Reducing GHG, Eastern Research Group 4/30/2010

2) "RISING TO THE CHALLENGE" MASSINC REPORT. APRIL 2012

The April 2012 assessment of Massachusetts' GHG reduction efforts by MassInc in the report "Rising to the Challenge" concluded: "...although Massachusetts has implemented many effective and indeed nation-leading programs there is a real likelihood that the state will fall short of its 2020 greenhouse gas reduction goal. To ensure Massachusetts hits the target it is legally bound to achieve, the state must accelerate its effort(s)."

MassInc states that the amount of the anticipated shortfall cannot be precisely known. This is due to the fact that the state was expecting that at least 5.4% of the 25% GHG reduction goal for 2020 was to be achieved through the purchase of hydropower from Quebec, Canada via a transmission line that is now encountering development uncertainties. Another 7.1% of the statewide 2020 GHG reduction goal may not be reached because of the apparent inability of various programs and initiatives to reach their projected savings by that date. The reductions that can most reliability be applied toward the 2020 goal are a total of 7.1% from the state's all-cost energy efficiency programs and the Regional Greenhouse Gas Initiative (RGGI) program of industry carbon credit trading. Another 2.9% of reductions from building energy efficiency improvements and the expanded renewable energy portfolio (which is benefiting from increased solar photovoltaic installations. Therefore, it can reasonably be estimated that the actual statewide GHG reduction in 2020 will likely be in the range of 13 to 16%, which is less than the 18.6% reduction estimated by Eastern Research Group in2010.

To date, analysis of the progress toward GHG reduction has only been performed at the state level. This Climate Action Plan initiates a similar analysis for the Pioneer Valley region, which begins with the regional GHG inventory performed in 2011. Regular updates of the regional inventory will be necessary to track GHG emissions in the

Pioneer Valley, as statewide GHG reporting takes credit for GHG reductions from renewable energy imported by utilities in other regions of the state and is therefore not specific to the region.

6.3 REGIONAL GHG REDUCTION TARGET SCENARIOS

The preparers of this report believe that present GHG emissions trends and climatic consequences are creating an increasingly urgent situation that requires the decision-makers, residents and businesses of our region to more fully understand and anticipate the level of effort that is necessary to mitigate GHGs, which are the primary cause of climate change.

This section presents two regional scenarios for GHG emissions reductions by 2050:

80% Reduction Scenario: This is a "Fair Share" scenario in which GHG emissions are reduced by 80% of 1990 levels by 2050 (from 9.2 to 1.8 MMTCO2e), with an interim goal of a 25% reduction by 2020 (from 9.2 to 6.9 MMTCO2e). These targets are identical to the statewide reductions stipulated by the Massachusetts Global Warming Solutions Act (GWSA) of 2008 and assume the region will do its "fair share" to contribute to them.

100% Reduction Scenario: This is a "Carbon Neutral" scenario in which the region reduces its GHG emissions from 9.2 to zero MMTCO2e by 2050. To meet this more aggressive target, an interim goal of a 30% reduction from 1990 GHG levels by 2020 (from 9.2 to 6.4 MMTCO2e) is proposed. This scenario assumes there are unique regionally based advantages in the Pioneer Valley that will allow it to exceed the required statewide targets of the GWSA. These advantages include more sites that are readily available for renewable energy generation; more opportunities to reduce transportation emissions by reducing auto trips through mode shifts; and greater potential to achieve building heating and energy savings through home energy retrofits because of a larger proportion of single-family homes than the eastern part of the state.

The development of these two scenarios is based on the following assumptions:

- Projections of future GHG emissions under the "Business As Usual" (BAU) scenario are accurate.
- The statewide GHG reduction targets of Global Warming Solutions Act of 2008 remain in effect.
- Estimates of actual reductions already achieved are accurate (see Section 6.3.3).
- GHG reductions from carbon sequestration are not counted against the GHGs that are emitted. The impact of carbon sequestion is not part of the state GHG inventory method.

In Massachusetts, GHG emissions levels in 2010 were approximately 94.4 MMTCO2e, which was nearly the same as those of the original 1990 benchmark year established by the GWSA. However, because region-specific GHG emissions were not known in the Pioneer Valley in 2010, this plan uses the 2011 GHG Inventory (presented in Chapter 3) as the baseline year from which future GHG changes will be benchmarked.[i]

6.3.1 80% GHG REDUCTION SCENARIO: REGIONAL "FAIR SHARE" OF STATEWIDE TARGET

This scenario is intended to achieve reductions in GHG emissions that are consistent with the statewide targets of the Global Warming Solutions Act of 2008. This scenario uses the baseline GHG emissions for the Pioneer Valley of 9.2 MMTCO2e established by the 2011 GHG inventory. Reductions in each sector are assumed to occur in proportion to their current contribution to the total.

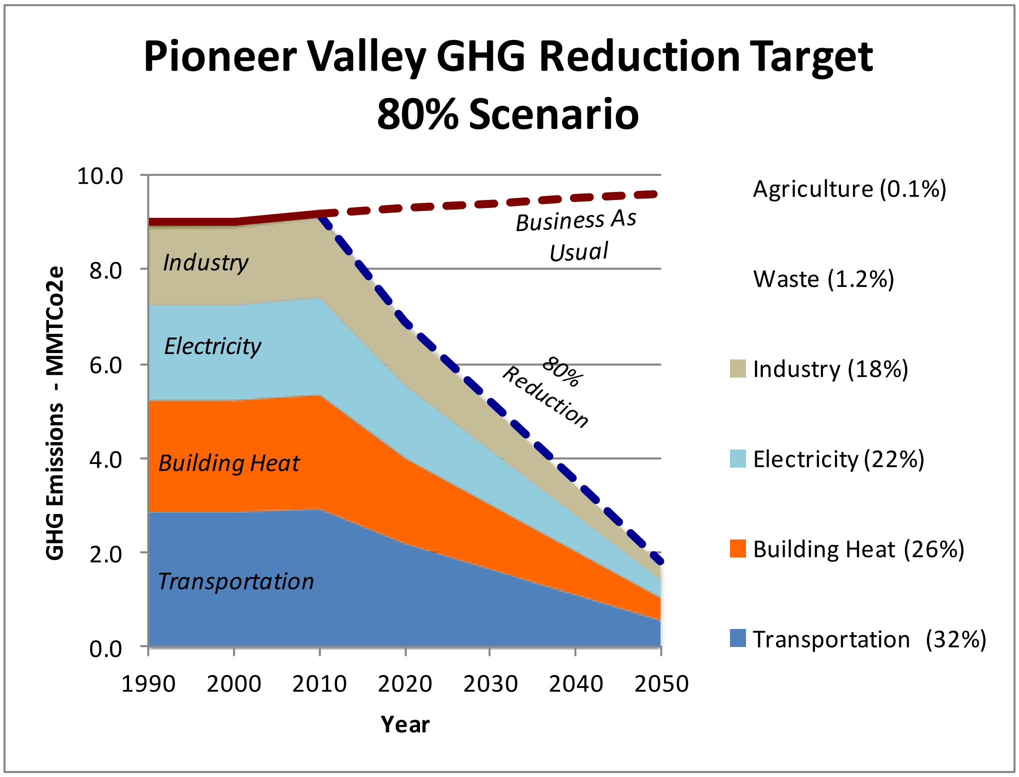


Table 6-2: Sector Breakdown for 80% GHG Reduction Regional "Fair Share" Targets

Sector	2011 Baseline MTCO2e	Sector % of Total	2020 Goal (25% Reduction)	2050 Goal (80% Reduction)
Transportation	2,922,382	31.8%	2,191,787	584,476
Heat for buildings	2,428,076	26.4%	1,821,057	485,615
Electricity consumption	2,064,432	22.4%	1,548,324	412,886
Industry	1,663,689	18.1%	1,247,767	332,738
Waste	110,547	1.2%	82,910	22,109
Agriculture	12,806	0.1%	9,605	2,561
TOTAL	**9,201,933**	**100.0%**	**6,901,450**	**1,840,387**

6.3.2 100% GHG REDUCTION SCENARIO: A "CARBON NEUTRAL" REGION

This scenario is intended to illustrate the reductions in GHG emissions that would be necessary to exceed the reductions required by the GWSA. This scenario is offered to promote consideration of the unique regional advantages that the Pioneer Valley may possess that would enable it to go beyond the "Fair Share" targets described above.

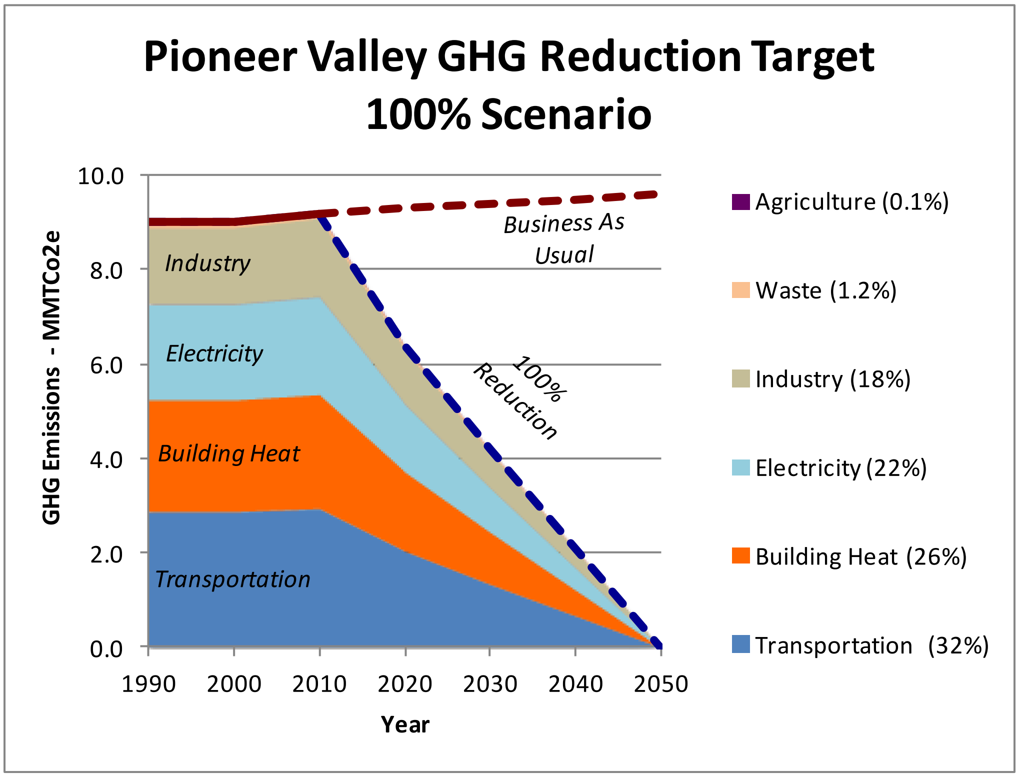


Figure 6-3: Sector Breakdown for 100% GHG Reduction "Carbon Neutral" Region Targets

Sector	2011 Baseline MTCO2e	Sector % of Total	2020 Goal (30% Reduction)	2050 Goal (100% Reduction)
Transportation	2,922,382	31.8%	2,045,667	0
Heat for buildings	2,428,076	26.4%	1,699,653	0
Electricity consumption	2,064,432	22.4%	1,445,102	0
Industry	1,663,689	18.1%	1,164,582	0
Waste	110,547	1.2%	77,383	0
Agriculture	12,806	0.1%	8,964	0
TOTAL	**9,201,933**	**100.0%**	**6,441,353**	**0**

6.3.3 SOURCES OF FUTURE GHG REDUCTIONS IN THE PIONEER VALLEY

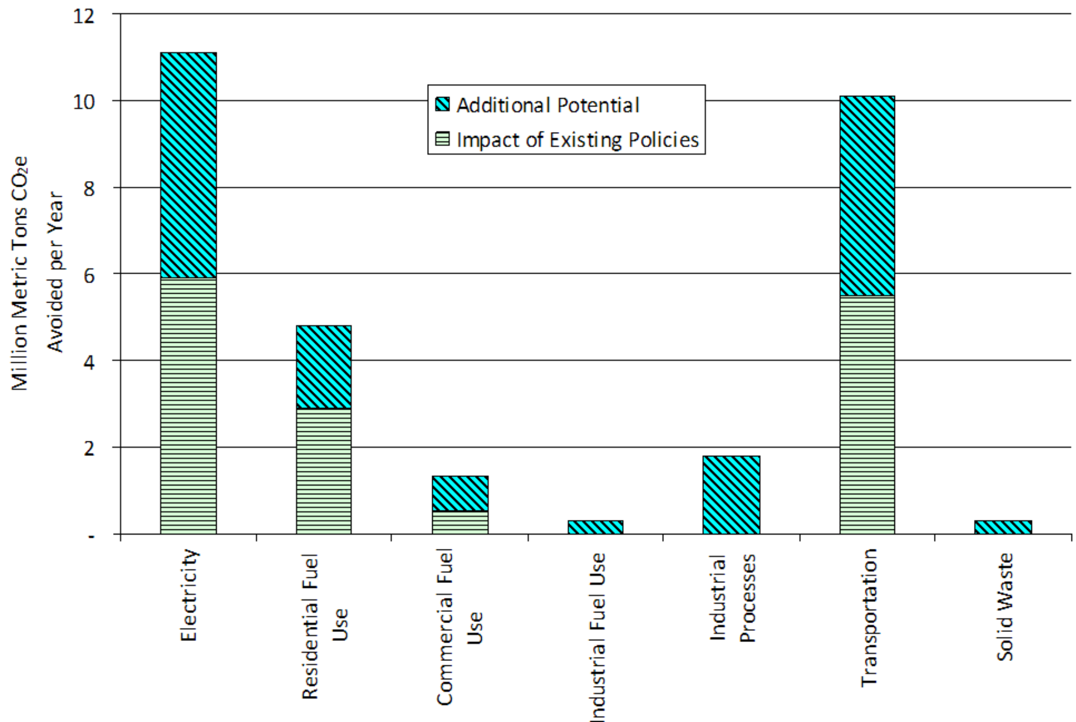
The Massachusetts Climate Action Plan reduction estimates for various sectors of the economy provide some guidance on how the Pioneer Valley can achieve the 25% reduction required by 2020. By focusing on the three largest sources of GHG emissions, electricity, heating and transportation, reductions of approximately 23% of GHG can be achieved. These would come from the following sectors.

Sector	Reduction Measures	% Share of Reduction	MMTCO2e
Industrial	Efficiency and technological improvements to private non-electric utility power plants, manufacturing processes	6.6%	.14
Building Heating	Cost-effective energy efficiency improvements that will reduce heating consumption in the region's buildings as well as implementing advanced building energy codes, such as the Stretch Code	38.3%	.88
Electrical consumption	Dependent on energy efficiency improvements and achieving a cleaner portfolio of energy sources through the utility by substituting high-carbon sources for low-carbon sources and/or renewable energy sources. An expanded state Renewable Portfolio Standard and more stringent US EPA power plant rules are also expected to provide emissions reductions.	29.4%	.68
Transportation	Normal turnover in the regional car fleet to more efficient vehicles, new vehicle efficiency standards and providing low or no-emission alternatives to vehicle transportation, namely improvements in walkability, biking and mass transit.	29.7%	.68
Waste	Composting	<1%	--
Agriculture	Reduced till practices, on-site renewable energy generation	<.1%	--
Total			**2.3**

Additional advantages may include:

- Large forested and vegetated areas capable of sequestering more carbon per acre than urban areas.
- More available open spaces for installation of solar electricity generating facilities than urban areas.
- A greater than average proportion of residents willing and able to install renewable energy equipment, such as solar panels, on their homes.
- More areas where wind-power is viable.
- Opportunities for reducing single occupancy vehicle trips, especially at large academic institutions.

Figure 6-7: Impact of Existing Policies Potential for Reducing Massachusetts GHG Emissions



Reproduced from Initial Estimates of Emissions Reductions from Existing Policies Related to Reducing GHG, Eastern Research Group 4/30/2010

Table 6-4: Projected Massachusetts GHG Emissions and Emissions Reduction Potential

Sector, Policies, Potential Areas	2020 Ref. Case ($MMtCO_2e$)	2020 Existing Policies ($MMtCO_2e$)	Potential Cost-Effective Reductions ($MMtCO_2e$/year)	2020 Potential Emissions ($MMtCO_2e$)
Transportation (Section 3.1)	**34.4**	**28.9**	**-4.6**	**24.3**
Reduce Vehicle Miles Traveled (VMT)			-1.6	
Improve Vehicle Efficiency (including Fuel-Efficient Driving Practices)			-3.0	
Electricity (Section 3.2)	**23.3**	**17.4**	**-5.2**	**12.2**
Residential & Commercial Bldgs. Efficiency			-1.9	
Industrial Efficiency			-0.3	
Increased Imports from Canada			-2.7	
Industrial Combined Heat and Power			-0.3	
Residential Fuel Use (Section 3.3)	**14.1**	**11.2**	**-1.9**	**9.3**
Natural Gas Efficiency			-0.3	
Oil and Liquefied Petroleum Gas Efficiency			-1.6	
Commercial Fuel Use (Section 3.3)	**5.3**	**4.7**	**-0.8**	**3.9**
Natural Gas Efficiency			-0.2	
Oil Efficiency			-0.6	
Industrial Fuel Use (Section 3.4)	**4.6**	**4.6**	**-0.3**	**4.3**
Industrial Processes (Section 3.4)	**6.3**	**6.3**	**-1.8**	**4.5**
Reduce Loss of ODS Substitutes			-1.5	
Reduce Loss of SF_6			-0.3	
Solid Waste (Section 3.5)	**1.5**	**1.5**	**-0.3**	**1.2**
Agriculture[a]	**0.3**	**0.3**		**0.3**
Wastewater Treatment[a]	**0.4**	**0.4**		**0.4**
Natural Gas and Oil Systems[a]	**1.3**	**1.3**		**1.3**
TOTAL	**91.4**	**76.6**	**-14.9**	**61.7**
Reduction Relative to 2020 Reference Case (%)		16%		33%
Reduction Relative to 1990 Emissions (% below 94.4 $MMtCO_2e$)		19%		35%

[a] No analysis of cost-effective potential emissions reductions was performed for these sectors.

6.3.5 OTHER SIGNIFICANT GHG CONSIDERATIONS RELATED TO REGIONAL TARGET SETTING

Scientific understanding, GHG mitigation technologies and governmental policies pertaining to GHG emissions reductions continue evolve rapidly. Those that may influence or affect the setting of a Pioneer Valley regional GHG mitigation target for 2050 include:

- Lack of specific global or U.S. GHG reduction goals or plans.
- Regulation of GHG by the U.S. EPA as a pollutant subject to Clean Air Act.
- European Union revision of its current goal for GHG reduction for 2020 from 20% to 30% below 1990 levels.
- State of Connecticut GHG reduction target for 2020 is 10% below 1990 levels and 80% by 2050.

6.4 MEASURING PROGRESS TOWARD THE REGIONAL GHG MITIGATION TARGET

Regular monitoring of GHG emissions in the region is essential to the success of this plan. Monitoring is an implementation activity that will be initiated during 2013.

- Regular updating of the Pioneer Valley Regional GHG Inventory of 2011. A program to include schedule, frequency funding and responsible agencies for performing these updates should be developed within the next six months.

- Local GHG monitoring capabilities should be developed for the region to help develop an better understanding of the GHG impacts of emitters in the various sectors, especially the large sectors of transportation, electric power generation and building heating.

- Regular updates to the regional Vulcan carbon emissions inventory and large emitter data, as they are made available.

- Limited GHG information is available from existing air quality monitors located in the region that are operated by the Massachusetts Department of Environmental Protection. Additional analysis of how the information from these monitors may be combined or used to enhance the GHG emissions information from the two sources above will further improve the quality of the ongoing GHG Inventory program.

The Pioneer Valley Planning Commission will continue to work and improve information sharing with the Massachusetts Department of Environmental Protect and Department of Energy Resources as the measurement and implementation phases move forward.

6.5 TOWARD GHG MITIGATION STRATEGIES

A program of GHG mitigation strategies to help region move toward the regional GHG emissions reduction target presented in this section are presented in Chapter 7 Recommended Strategies. General types of GHG mitigation measures include:

- More efficient and reduced use of carbon-based fuels for transportation and building heating.
- More efficient and reduced use of carbon-based fuels in power generation and industrial processes.
- Conversion of petroleum- and coal-burning facilities, systems and equipment to natural gas, which produces approximately two-thirds less GHG emissions.
- Increased energy conservation through better building design, retrofitting and insulation.
- Increased use of renewable energy (i.e., solar, wind, hydro, and geothermal).
- Increased use of nuclear power for electrical generation.
- Adoption and implementation of more compact urban development forms that reduce energy consumption in buildings and transportation.
- Expansion of the carbon dioxide "sink" capacities of vegetated areas by reducing deforestation; expanding forested growth areas; encouraging urban tree planting, gardens and parks; and modifying agricultural practices.
- Public policies and economic investment/divestment strategies to curtail the existing economic benefits of continued excess GHG emissions (i.e., GHG impact analyses, emissions fees or taxes, carbon offset credits, and cap and trade markets).

For the plan to be effective, adopted mitigation actions must cumulatively reach the GHG emissions reduction target identified in the inventory. To assess whether or not mitigations will be adequate to reach the target, they must be quantified. Estimating the emissions reduction associated with each mitigation action requires that assumptions be made about implementation, phasing, and emissions conversion factors (CARB, 2008; ICLEI, n.d., 2010; National Wildlife Federation, 2008).

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[i] This is a reasonable method as 1990 state levels are almost identical to state levels in the year 2010 (approximately 94.4 Million tons of GHG). Using 2010 as the benchmark year has the convenience of using the same figures as the baseline inventory for the region.

7 ADAPTING TO CLIMATE CHANGE

Climate change is already occurring on a global scale, and the Pioneer Valley region must be better prepared to adapt to local consequences. There are many actions that our communities can take to improve the resilience of their infrastructure and protect other public resources from the adverse consequences and high costs of the severe weather associated with climate change.

Climate change adaptation actions are steps that reduce the vulnerability and improve the resilience of humans and the natural environment to the adverse impacts of climate change. Adaption actions are generally intended to anticipate, respond to, and protect against the consequences of the increasing number and severity of extreme weather events, such as hurricanes, tornados, floods, droughts, heat and snowstorms. The one-time and cumulative effects of these events are costly, as the recent series of storms to strike New England and the region in 2011 and 2012 have demonstrated. Adaptation actions focus on reducing the costs of, and vulnerability to, these events.

Roadway and culvert wash-out on Camp Road in Chester, Massachusetts, September 2, 2011 during Tropical Storm Irene. Adapting infrastructure like this to withstand increased rainfall and extreme weather is essential to reduce damage costs.

This chapter presents anticipated impacts of climate change on the people and resources of the Pioneer Valley, and offers relevant adaption actions to address them. Given the region's climate, topography, natural features, and human settlement patterns, these actions focus on the following topics:

7.1	Water supply and water infrastructure	**7.6**	Buildings and the built environment
7.2	Wastewater infrastructure	**7.7**	Human health and safety
7.3	Dams and flood control infrastructure	**7.8**	Fish and wildlife
7.4	Transportation infrastructure	**7.9**	Agriculture
7.6	Energy and electrical infrastructure	**7.10**	Regional economy

For each of these topics, three types of information are presented:

- Vulnerable resources
- Threats
- Adaption actions

As the Massachusetts Climate Change Adaption Report (2011) notes, adaption actions and those actions that focus on mitigating emissions of green house gases (described in Chapter 5) "can complement each other and together can significantly reduce the risks of climate change. Some adaptation strategies, or responses [that] reduce risk and vulnerability, also serve to reduce greenhouse gas emissions (and vice versa)."

This plan for the Pioneer Valley acknowledges that some adaptation actions will be "crossing cutting" in nature; that is, they will also help reduce GHG emissions and thereby the severity of the adverse impacts resulting from increased GHG emissions. Therefore, actions with greater potential to achieve this type of mutual benefit receive greater priority in this plan.

7.1 WATER SUPPLY AND WATER INFRASTRUCTURE

7.1.1 VULNERABLE RESOURCES

The communities of the Pioneer Valley region receive their drinking water from surface water reservoirs and groundwater wells, in both public and private ownership. Of the region's 43 communities, 8 are served by central supply systems, 10 rely solely on individual on-site wells, and 25 receive water from a combination of these systems.

Surface water reservoirs provide virtually all of the water supply for three of the region's largest cities, Springfield, Chicopee and Holyoke. Groundwater is the sole source of water for eighteen non-urban communities. The remaining 22 communities utilize a combination of surface and groundwater sources.

Tighe-Carmody Reservoir Southampton (Holyoke Water Works)

The region's largest water supplier, the Springfield Water and Sewer Commission, provides drinking water from a series of reservoirs, through treatment, storage and distribution. It serves residents of Springfield, Ludlow, Agawam, East Longmeadow, and Longmeadow and provides partial service or peak service to Southwick, Westfield, and West Springfield.

The Commission can also provide water on an emergency basis to Chicopee and Wilbraham. Springfield's drinking water system includes Cobble Mountain Reservoir, a 22.8-billion gallon reservoir which is the City of Springfield's primary water supply source, and Borden Brook Reservoir which is an active water source and feeds into the Cobble Mountain Reservoir.

East Longmeadow Prospect Street water storage tank (Town of East Longmeadow)

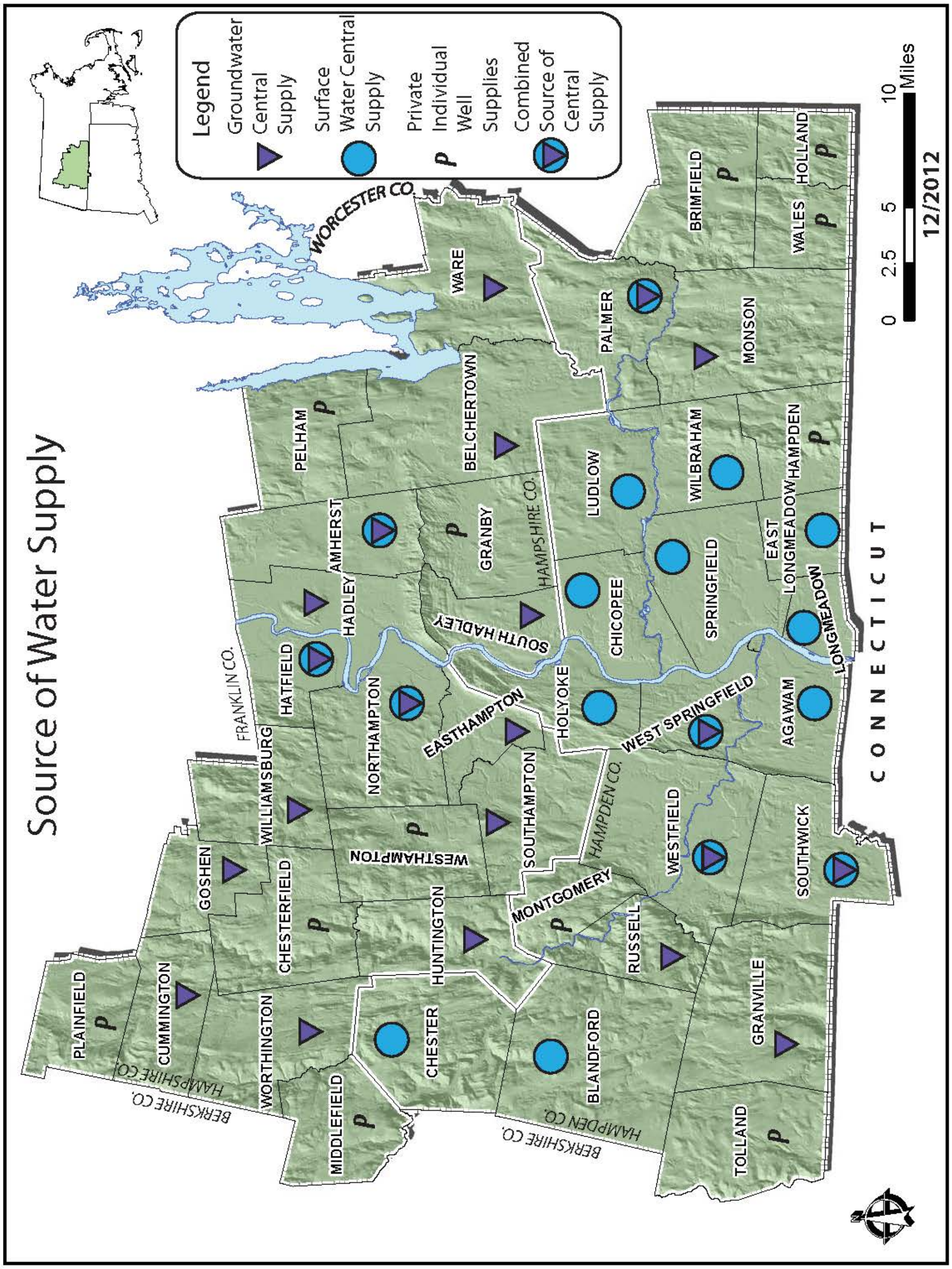
The Ludlow Reservoir is maintained as an emergency water supply.

The municipal water supply sources of the region are summarized on the following table on the next page.

Table 7-1: Pioneer Valley Sources of Municipal Water Supply

Municipality	% of Public Supply from Surface Water Sources	% of Public Supply from Groundwater Sources	Private Water Supplies	Active Public Water Sources
Agawam	100%	0%		Purchase from Springfield
Amherst	60%	40%		Atkins Reservoir, Amethyst Brook Reservoir, 5 wells
Belchertown	0%	100%		6 wells
Blandford	100%	0%		Long Pond Reservoir
Brimfield			All	
Chester	100%	0%		Austin Brook Reservoir, Horn Pond
Chesterfield			All	
Chicopee	100%	0%		Purchase from MWRA (Quabbin Reservoir)
Cummington	0%	100%		3 wells
Easthampton	0%	100%		6 wells
East Longmeadow	100%	0%		Purchase from Springfield
Goshen	0%	100%		1 well
Granby			All	
Granville	0%	100%		1 wells
Hadley	0%	100%		3 wells
Hampden			All	
Hatfield	74%	26%		Running Gutter Reservoir, 2 wells
Holland			All	
Holyoke	100%	0%		Manhan, Ashley, Whiting, McLean, White Reservoirs
Huntington	0%	100%		2 wells
Longmeadow	100%	0%		Purchase from Springfield
Ludlow	100%	0%		Purchased from MWRA (Quabbin Reservoir)
Middlefield			All	
Monson	0%	100%		4 wells
Montgomery			All	
Northampton	99%	1%		Ryan, Mtn St, Roberts Meadow, W. Whately Reservoirs, 2 wells
Palmer - Center	52%	48%		Graves Brook Reservoirs, 2 wells
Palmer - Bondsville	0%	100%		4 wells
Palmer – 3 Rivers	0%	100%		2 wells
Pelham			All	
Plainfield			All	
Russell	0%	100%		2 wells
South Hadley	0%	100%		2 wells, purchase from MWRA
Southwick	15%	85%		2 wells, purchase from Springfield
Southampton	0%	100%		2 wells, purchase from Holyoke
Springfield	100%	0%		Cobble Mtn, Little, Intake, Borden Brook, Ludlow Reservoirs
Tolland			All	
Wales			All	
Ware	0%	100%		4 wells
West Springfield	93%	7%		4 wells, Bear Hole Reservoir, purchase from Spfld
Westhampton			All	
Westfield	50%	50%		8 wells, Granville, Montgomery Reservoirs, purch. from Springfield
Wilbraham	100%	0%		Purchased from MWRA (Quabbin Reservoir)
Williamsburg	0%	100%		2 wells
Worthington	0%	100%		7 wells, 3 springs

Source: Massachusetts Department of Environmental Protection


Source of Water Supply
Legend
Groundwater Central Supply
Surface Water Central Supply
Private Individual Well Supplies
Combined Source of Central Supply
0 2.5 5 10 Miles
12/2012
WORCESTER CO.
FRANKLIN CO.
HAMPSHIRE CO.
HAMPDEN CO.
BERKSHIRE CO.
CONNECTICUT
PLAINFIELD
CUMMINGTON
GOSHEN
WILLIAMSBURG
HATFIELD
HADLEY
AMHERST
PELHAM
WARE
BELCHERTOWN
GRANBY
SOUTH HADLEY
NORTHAMPTON
EASTHAMPTON
WESTHAMPTON
SOUTHAMPTON
CHESTERFIELD
WORTHINGTON
MIDDLEFIELD
CHESTER
HUNTINGTON
MONTGOMERY
BLANDFORD
RUSSELL
WESTFIELD
HOLYOKE
CHICOPEE
LUDLOW
PALMER
MONSON
BRIMFIELD
HOLLAND
WALES
WILBRAHAM
HAMPDEN
SPRINGFIELD
EAST LONGMEADOW
LONGMEADOW
WEST SPRINGFIELD
AGAWAM
SOUTHWICK
GRANVILLE
TOLLAND

7.1.2 THREATS

Climate change presents a variety of threats to water supply infrastructure:

- Runoff from heavy precipitation events increases the risk of flooding, landslides, erosion and subsistence of soil, and slope failures – all of which may expose buried pipelines, or reduce the stability of dams.
- Stormwater runoff can pollute rivers and streams that are tributary to water supply reservoirs.
- Droughts can result in increased demands on drinking water systems for irrigation and other uses in excess of system capacity.
- Water infrastructure can be rendered dysfunctional or damaged by brief and extended power outages.
- Water supply facilities may be more susceptible to flooding, as some components are located in flood zones.

Municipal facilities for drinking water and waste water treatment include wellheads, pump stations, storage tanks or reservoirs, distribution systems, and drinking water treatment plants.

WATER SUPPLY INFRASTRUCTURE

Municipal facilities for drinking water and waste water treatment include: wellheads, pump stations, storage tanks or reservoirs, distribution systems, and drinking water treatment plants. Because many of these facilities depend on electricity, any power outages can damage them. These facilities are susceptible to flooding, as some components are located in flood zones.

DRINKING WATER QUALITY

Increased variations in storm severity and rainfall associated with climate change are already having adverse impacts on water quality in rivers and streams in the Pioneer Valley, and these are expected to worsen in coming years. Impacts on drinking water quality include degradation of water quality due to increased stormwater pollution, and drought-related drinking water shortages.

Fortunately, most of the region's large public reservoirs, such as the Quabbin Reservoir which is the principal drinking water supply for more than 100 communities in eastern Massachusetts, and the Cobble Mountain Reservoir which serves metropolitan Springfield, are located in rural forested locations and are significantly protected by large blocks of public watershed lands.

Water quality in public drinking water wells is subject to impacts from severe drawdown in droughts and flood-related pollution. Several important public wells in the Pioneer Valley are located immediately adjacent to streams, and are subject to flood impacts.

WATER CONSERVATION AND LEAK DETECTION NEEDS

Pioneer Valley communities should develop and adopt water conservation policies to prepare for droughts in advance of emergency declarations. In addition to helping municipalities maintain safe and reliable drinking water supplies, conservation helps the entire region by keeping water tables closer to their historic levels.

For home water conservation, the U.S. Green Building Council suggests a variety of guidelines for the construction of buildings—which are also appropriate as retrofits or practices for existing homes. These include:

- Install low-flow toilets, showerheads and faucets.
- Use rain and recycled water (from dehumidifiers, cooking and other household uses) for landscape irrigation.
- Reduced use of municipal water for landscape irrigation.

For municipal drinking water systems, reducing leaks is often the greatest opportunity for savings. Some municipalities experience leakage of 10% to 15%. Leak detection and elimination are often the most cost effective measures for reducing fresh water consumption. Other municipal opportunities to conserve water include policies to reduce lawn watering and pricing policies that reward low consumption.

7.1.3 ADAPTATION ACTIONS

ACTION: DEVELOP EMERGENCY INTERMUNICIPAL WATER CONNECTIONS AND AGREEMENTS

Communities without emergency back-up water supplies should identify options for creating emergency water supply inter-connections with neighboring communities, and seek formal agreements to purchase water in emergencies. Physical, piped emergency connections, and agreements to purchase water, should be put into place in advance of emergencies.

ACTION: PERFORM DRINKING WATER SUPPLY VULNERABILITY ASSESSMENTS

Conduct vulnerability assessments and increase resiliency of drinking water facilities. Assessments should review climate impacts on water supplies, droughts, severe weather, floods, temperature change, increased water demand, increased bacteria or nutrient loading, increased turbidity or eutrophication, dam or pipe failure, and reduced snowpack. Identify priority facilities for replacements and upgrades. Evaluate emergency backup water supplies.

ACTION: UPGRADE AND PROTECT VULNERABLE DRINKING WATER INFRASTRUCTURE

Use the results of the vulnerability assessment to begin upgrading and replacing the water infrastructure that is most at risk. Update treatment facility design standards as appropriate so that plants can continue to operate during storms and flooding.

ACTION: REPLACE OUTDATED DRINKING WATER INFRASTRUCTURE

Protect and upgrade aging water infrastructure, with particular attention to the potential for flood damages, and provide emergency backup equipment.

ACTION: USE STORMWATER FOR IRRIGATION AND NON-POTABLE USES

Incorporate water use reduction methods in residential and commercial construction and remodeling, including those found in the LEED certification program.

ACTION: USE LOW WATER INTENSIVE LANDSCAPING

Promote use of native plants, trees and shrubs in landscaping requirements in zoning bylaws/ordinances for new development projects to reduce water demand. Design and retrofit landscaping to redirect flow from traditional stormwater collection systems into low-impact design technology and restore natural hydrology. Increase the use of groundwater recharge to assist in reducing polluted runoff to surface waters, decreasing flooding, and enable flood controls to operate during a storm.

7.2 WASTEWATER INFRASTRUCTURE

There are two general types of wastewater: effluent from sanitary sewers; and stormwater runoff from impervious areas. The infrastructure to convey, treat and return both of these types of wastewater to the natural water cycle of the region are a vast network of underground pipes, detention and retention basins, wastewater treatment plants, outfalls to surface waters and other structures. With greater precipitation amounts expected in our region, especially from single storms, reducing the discharge of untreated stormwater and wastewater is a key adaptation need related to climate change.

7.2.1 VULNERABLE RESOURCES

The wastewater and stormwater infrastructure in the Pioneer Valley region that is most vulnerable to climate change events:

- Municipal wastewater treatment plants
- Combined sewer systems which cause combined sewer overflow (CSOs)
- Stormwater systems and discharges

MUNICIPAL WASTEWATER TREATMENT PLANTS

The region has 15 municipal wastewater treatment plants (WWTPs), which are listed below. Six of these WWTPs are located directly on the Connecticut River in areas that may be subject to flood damages in severe weather events, while three are located directly on the Westfield River.

The Springfield Regional Wastewater Treatment Facility is the second largest treatment facility in New England. The SRWTF is located at Bondi's Island, at the junction of the Connecticut and Westfield Rivers. The facility came on-line in 1977, and treats wastewater from the households, businesses, and industries within Springfield and surrounding member communities, including Agawam, East Longmeadow, Longmeadow, Ludlow, Wilbraham, West Springfield, and a small section of Chicopee. The SRWTF is designed to treat up to 67 million gallons of wastewater per day. Currently, a daily average of 40-42 million gallons of wastewater is cleaned, treated, and returned to the Connecticut River.

Table 7-2: Wastewater Treatment Facilities in Pioneer Valley Region

Name	Community(ies) Served	Location	Level of treatment	Design Flow / Ave Daily Flow
Amherst Wastewater Treatment Plant	Amherst	Mill River	Secondary	7.1 mgd / na
Belchertown Water Reclamation Facility	Belchertown	Lampson Brook	A	1.3 mgd / na
Chicopee Water Pollution Control Facility	Chicopee	Connecticut River	Secondary	15.5 mgd / na
Easthampton Wastewater Treatment Facility	Easthampton	Manhan River	Secondary	3.8 mgd / na
Hadley Wastewater Treatment Plant	Hadley	Fort River at Ct. River	Secondary	.5 mgd / na
Hatfield Wastewater Treatment Facility	Hatfield	Connecticut River	Secondary	.5 mgd / na*
Holyoke Water Pollution Control Facility	Holyoke	Connecticut River	Secondary	17.5 mgd/ na
Huntington Wastewater Treatment Plant	Huntington	Westfield River	Secondary	.2 mgd/ na
Ludlow Wastewater Treatment Plant	Ludlow	Chicopee River	Secondary	Na / na
Northampton Wastewater Treatment Plant	Northampton	Mill River	Secondary	8.7 mgd/ na
Palmer Wastewater Treatment Plant	Palmer	Ware River	A	5.6 mgd / 2.3 mgd
Russell Wastewater Treatment Plant	Russell	Westfield River	Secondary	.2 mgd / na
South Hadley Wastewater Treatment Plant	South Hadley, parts of Granby and Chicopee	Connecticut River	Secondary	4.2 mgd / 2.1 mgd
Springfield Regional Wastewater Treatment Facility	Agawam, E. Longmeadow, Longmeadow, Ludlow, Wilbraham, W. Springfield, parts of Chicopee	Connecticut River		67 mgd / 40-42 mgd
Ware Wastewater Treatment Plant	Ware	Ware River	Secondary	2.0 mgd / 1.0 mgd
Westfield Water Pollution Control Facility	Westfield , Southwick	Westfield River	Secondary	4.0 mgd / na

Source: TBD *Northampton Wastewater Treatment Plant

COMBINED SEWERS AND STORMWATER

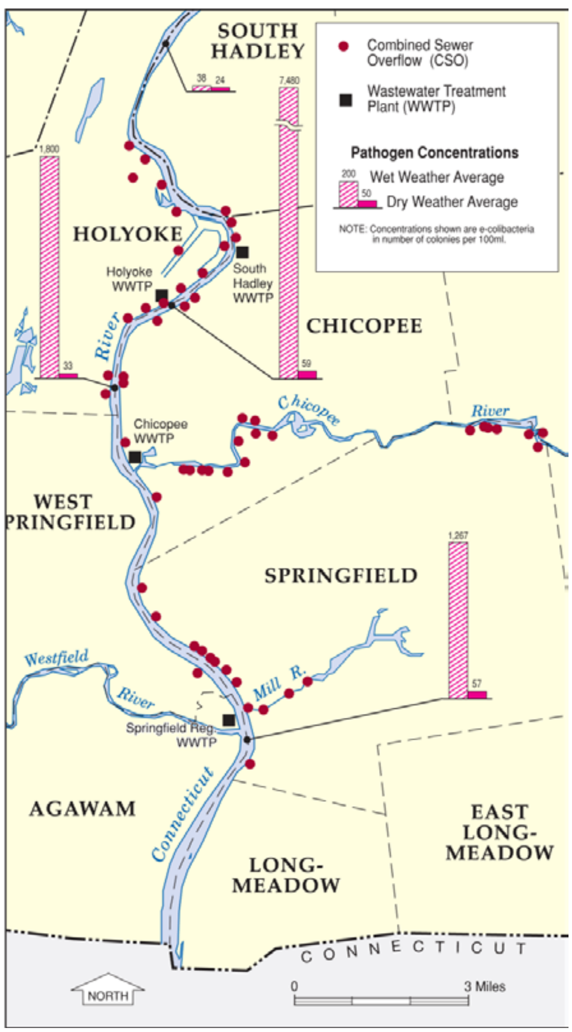
Without adaptation measures, climate change will result in increased stormwater runoff and more combined sewer overflows.

The cities of Chicopee, Holyoke, Springfield and Ludlow have sewer systems with combined sanitary and stormwater flows. During heavy wet weather, water treatment plants of these cities are unable to handle excess flows, which results in the discharge of untreated sanitary sewer effluent from combined sewer overflows into the Connecticut River – a total of 907 million gallons per year in 2009. This requires health alerts to the public, which is warned to stay out of contact with the water for at least 48 hours. Increased stormwater runoff has the potential to increase the frequency and volume of combined sewer overflows (CSOs).

In 1988, there were 134 combined sewer overflows (CSOs) were identified in the seven communities, Agawam, Chicopee, Holyoke, Ludlow, South Hadley, Springfield, located in the southern reach of the Connecticut River below the Holyoke Dam, in a 1988 engineering study completed for the Massachusetts Division of Water Pollution Control. The study determined that 90% of existing CSO discharges would need to be eliminated within the seven communities to achieve the fishable/swimmable goal, at a cost of $377 million. The CSO-affected communities have made substantial progress over the past 20 years in correcting CSO problems, working with the Pioneer Valley Planning Commission to meet the requirements of the Clean Water Act. In 2009, 67 CSOs in four communities (Springfield, Chicopee, Holyoke and Ludlow) remained, a 50% reduction in the numbers of CSOs since 1988. Agawam has eliminated all of its CSOs. Dry weather overflows were reduced from 31 in 1988 to zero in 2005.

Over $100 million has been expended over the past 20 years to improve the quality of water on the Connecticut River and reduce the number CSO outfalls by 50% (see below). However, increased stormwater from increased annual rainfall will require these cities to invest more to maintain their stormwater infrastructure and treat more stormwater.

Figure 7-1: Combined Sewer Overflow Outlets and Wastewater Treatment Plants



Source: http://www.pvpc.org/resources/landuse/CSO_Fact_Sheets.pdf

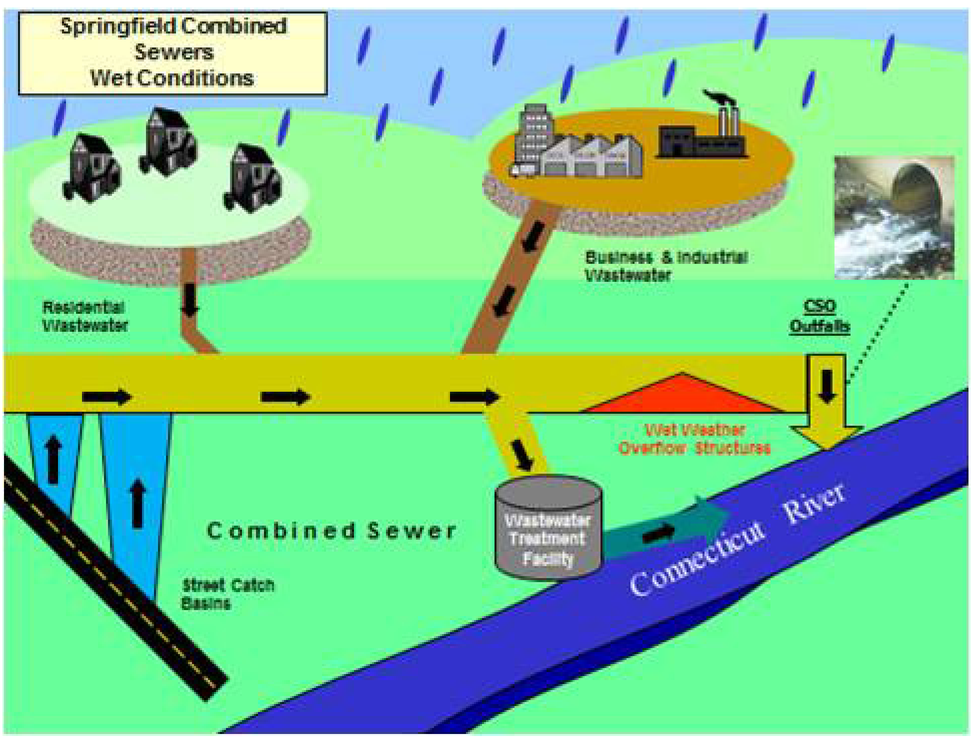
Current initiatives that include replacing combined sewers with separate sanitary and stormwater sewer systems are a critical step in the process of CSO reduction and adaptation, but will not necessarily be sufficient alone. In addition, runoff and CSOs must be reduced through the use of other strategies – stormwater utility fees, green infrastructure, and land use regulations. Combined sewer overflows continue to be a significant problem, both in terms of pollution.

Figure 7-3: Funds Needed vs. Fund Committed CSO Clean Up in the Pioneer Valley

Municipality	Funds Needed	Funds Committed (as of 1/10/2010)	Shortfall
Chicopee	$153 million	$84 million	$69 million
Holyoke	$35 million	$25 million	$10 million
Springfield	$250 million	$80 million	$170 million
TOTALS	**$438 million**	**$189 million**	**$249 million**

Source: http://www.pvpc.org/resources/landuse/CSO_Fact_Sheets.pdf

Figure 7-2: Springfield Combined Sewers and Impacts of Heavy Precipitation



Source: http://www.pvpc.org/resources/landuse/CSO_Fact_Sheets.pdf

STORMWATER

Climate change is increasing the number and severity of rainfall events in the region, a trend that will continue. Severe storms produce larger quantities of stormwater in a shorter period of time, which exacerbating adverse impacts of runoff, including:

- **Pollution –** Stormwater that runs over concrete and other impervious surfaces collects pollutants that include trash, fertilizer, soaps, and oil residue from cars. Pollution is worst during the initial runoff from impervious surfaces, also referred to as "first flush," as debris and chemicals that have had a chance to collect over time are swept away.

- **Flooding –** When stormwater does not drain properly it can flood streets, highways, rail lines—as well as man-made structures. Because most existing storm drainage systems were designed using historic rainfall records prior to 1961, their capacities are sized to accommodate less rainfall than is actually occurring and is projected to occur in the future. This creates a greater risk of flooding and washout of critical infrastructure. Also, groundwater tables in the Pioneer Valley are now generally higher than in prior years, the result being that less stormwater can be infiltrated on site and more stormwater runoff occurs. A study by David Boutt and Kaitlyn Weider at the University of Massachusetts Amherst of the water table in New England indicates that over the past 10 years the water table has been increasing and this can be connected to higher levels of precipitation and climate change.

- **Erosion –** Runoff erodes stream banks, roadbeds, and structural foundations. Erosion also deposits sediment in unwanted places, which can form damaging water channels through private property.

7.2.3 THREATS

Climate change poses a series of threats to wastewater infrastructure, including:

- Flooding of wastewater treatment plants, with resulting release of raw sewage to waterways.
- Flood-related erosion and damage to sewer lines, pump stations and related wastewater infrastructure.
- Electrical failures knocking out critical wastewater treatment functions, lack of back-up generators for many electric pump stations.
- Worker safety hazards from older electrical equipment in wastewater pump stations and other areas workers in the event of floods and other severe weather events.
- Increased storm flows in combined sewers result in large-scale overflows of raw sewage to waterways.
- Increased stormwater runoff from all impervious surfaces in urbanized areas, resulting in pollution of waterways.
- Increased turbidity and sedimentation in water flows entering treatment plants from heavy precipitation and flooding.
- Inability of stormwater management facilities for highways, bridges, rail, and airports to handle excess or peak flows from heavy precipitation events.

For much of the wastewater infrastructure, the key issues are power and safety. Power, meaning maintaining availability of electrical power supply is vital to maintaining the function of vital wastewater treatment plant functions and pump stations. Many communities need to install back-up power generators lacking in aging pump stations.

Safety is also a key issue in preventing human injuries or fatalities due to outdated electrical systems and equipment during flood events. Holyoke, for example, has older electrical equipment dating from the 1940s still in place in sewage pump stations. It is also important to reduce threats of human exposure or illness related to raw sewage discharges in a flood disaster. Human safety issues must also be considered in inspecting and making needed improvements to dams and flood control dikes.

Tropical Storm Irene demonstrated the severity of damages that can occur with catastrophic flooding due to major weather events in the region. While, the wastewater treatment plants in the Pioneer Valley region were largely undamaged, the Greenfield wastewater facility was inundated by floodwaters, knocked off line, and discharged raw sewage to the Connecticut River for several days, sending it downstream into the Pioneer Valley. The entire staff did a remarkable job to protect the plant and to help restore most of the essential infrastructure as soon as possible. The plant was able to be placed back on-line with primary treatment and disinfection within a few days to protect the Green and Deerfield Rivers. The plant consists of four stories, with the bottom two levels that contain the major pumping equipment completely inundated by flood waters. In addition, over 30 inches of flood water was on the main floor of the building that contains the process control center, laboratory, and administrative offices. The estimated total infrastructure damage in Greenfield as a result of Hurricane Irene was approximately $16 million, with approximately $600,000 attributed directly to repairing the wastewater treatment plant alone. Greenfield's repaired wastewater treatment plant now has doors that will hold back 142.5 feet of water, instead of 140 feet.

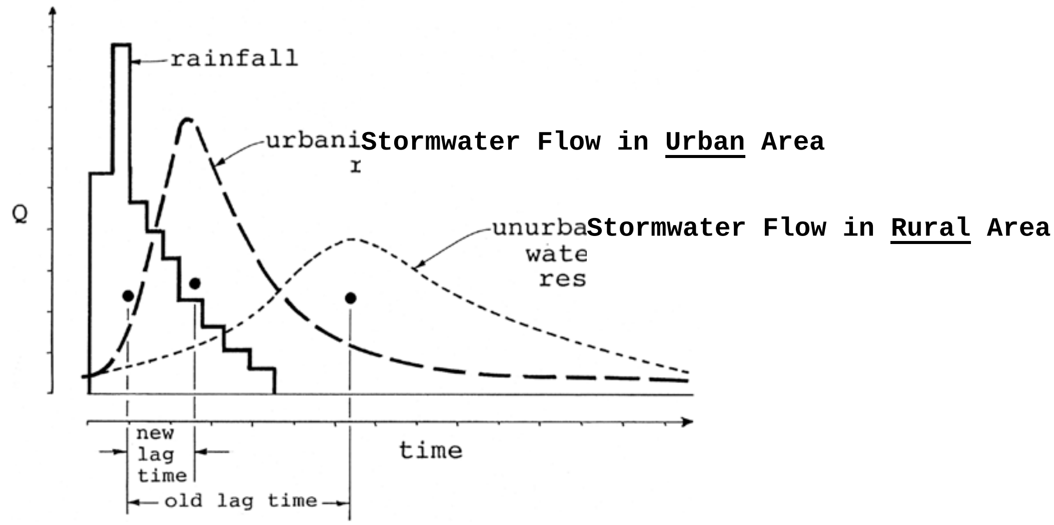
BENEFITS OF GREEN INFRASTRUCTURE

Green infrastructure generally refers to constructed and natural facilities that reduce or eliminate the amount of stormwater and associated pollutants delivered to rivers and streams by enhancing and complementing natural processes. Green infrastructure can include permeable pavements, rain gardens, tree box filters, green roofs, bioretention areas, and constructed wetlands. Better management of stormwater to eliminate adverse impacts, such as flooding, of properties and critical infrastructure (i.e., power plants, electrical distribution networks, waste water treatment and similar facilities) is a central goal of adaption.

Green infrastructure often involves construction, landscaping and retrofitting to reduce impervious surfaces, such as concrete, asphalt, brick, and roof surfaces. The intent is to allow more stormwater to infiltrate into the ground, which reduces runoff, replenishes groundwater, and improves water quality. Also, reductions in impervious surfaces help mitigate the urban heat island effect. In addition, the incorporation of vegetation in green infrastructure measures and structures helps reduce GHG levels through increased carbon sequestration.

In areas of high amounts of impervious surface, precipitation cannot permeate the surface therefore there is a high amount of runoff (sheetflow) that runs quickly through pipes and highly channelized waterways, as shown in the spike in the hydrograph below. Compared to urban hydrology, rural areas have more surface area for precipitation to be locally absorbed rather than channelized away from a location. The hydrograph shows a gradual and less severe increase in stream level in rural areas, because water has the opportunity to be absorbed by soil, rather than large and direct discharge into streams.

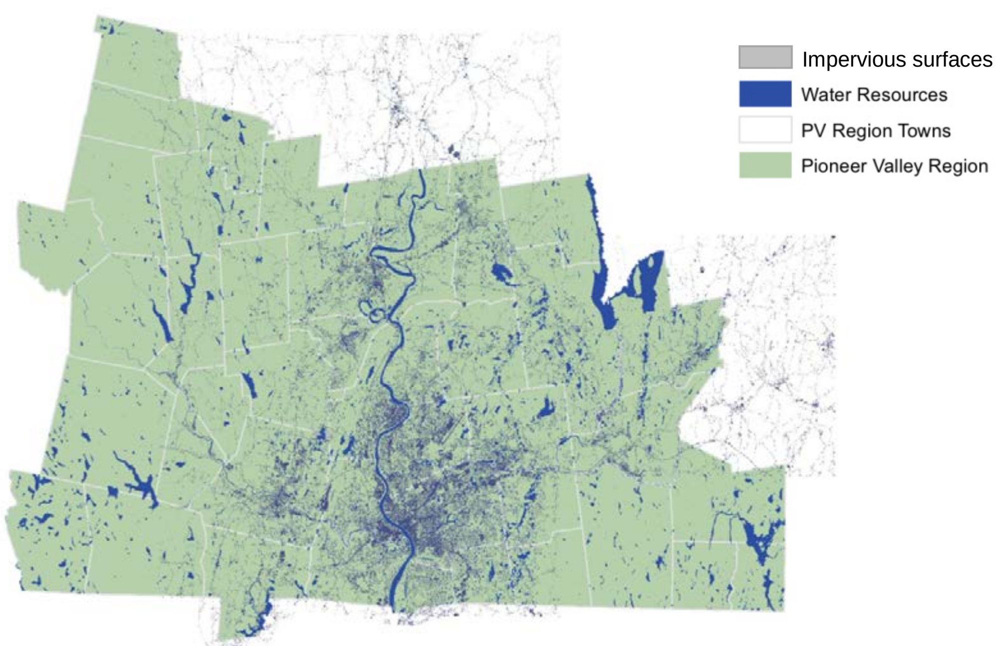
Figure 7-3: Hydrograph of Stream Flow in Urban Areas versus Rural Areas



Source: J. David Rogers, Ph.D < http://web.mst.edu/~rogersda/>

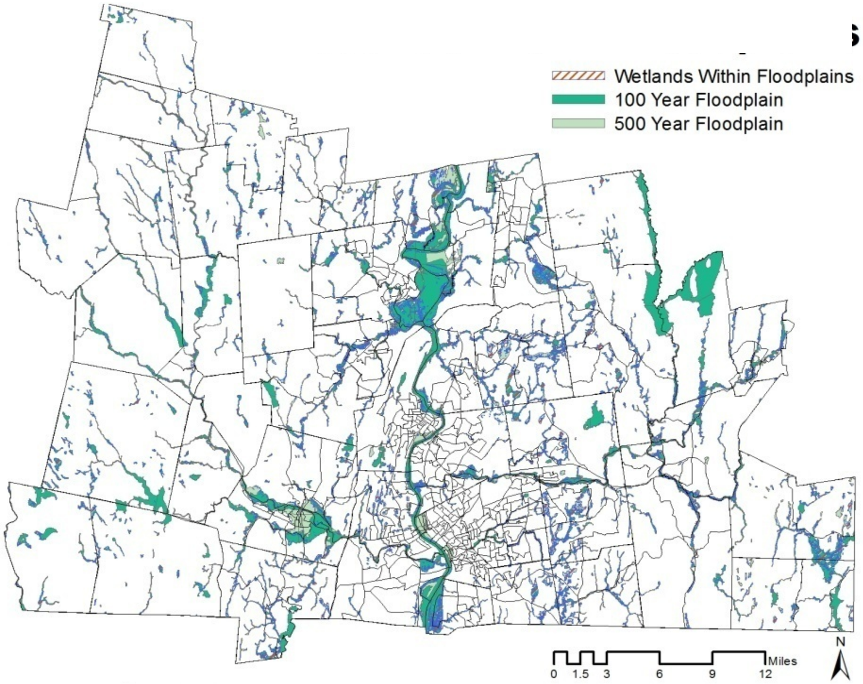
Guidelines developed by the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) program emphasize the reduction of impervious surfaces, including reducing the overall percentage of lot areas that are impervious, and replacing impervious concrete and asphalt surfaces with alternatives, such as natural vegetation and pervious pavement.

Fig 7-4: Impervious Surfaces in the Pioneer Valley



Source: MassGIS 2011. Impervious surfaces (shown in gray) are concentrated in urbanized areas. This increases the flood risk in these areas, as these surfaces impede the natural flow and infiltration of water. Concentrations of impervious surfaces also increase the Urban Heat Island effect.

Figure 7-5: Pioneer Valley Regional Watersheds



Source: Massachusetts Department of Environmental Protection 2009. Wetland types that make up the Pioneer Valley Region include bogs, deep marshes, open water, shallow marsh meadow or fen, shrub swamp, wooded swamp coniferous, wooded swamp deciduous, wooded swamp mixed trees, and vernal pools.

ALTERATION OF STREAM CHANNELS

The curvature and depth of stream and river channels are directly related to the ecological health and function of the water body, its tributaries and adjacent land areas. In an attempt to increase the developable area near streams, as well as to expand the capacity of streams to handle larger flows, the channel of streams may be straightened, as well as dredged for increased depth. For example, stream channels were altered on the Chickley River in Hawley and on the Deerfield River in response to Hurricane Irene impacts.

The process of straightening stream channels tends to increase the speed of the water, causing increased erosion. Additionally, downstream areas receive more flooding, as larger quantities of water are able to travel faster. Deepening streams has a similar effect, creating more erosion of the streambed and disconnecting the stream from its banks, having adverse effects on fish and wildlife that require shallow water near stream edges to live.

In Deerfield, Hurricane Irene severely damaged riparian buffers, and that, combined with post-flood armoring of the riverbank by many private landowners has increased the potential for greater damage in the next large storm. Because of soil washed away by Hurricane Irene last August, Deerfield Selectmen Carolyn Neff noted, "What's concerning to us is that our riparian buffers are 10 to 12 feet below what the level of the soil pre-Irene. We're much more vulnerable. If we have a large rainfall, coupled with the work that's been done that's armored the river, which would increase velocity, we're set up to have considerable damage."

The emergency reconstruction of 5 miles the Chickley River in Hawley, Mass. following Tropical Storm Irene in 2011 left the water body considerably straighter and with faster flows, which have created numerous concerns for water quality. While the reconstructed section of the river is outside the PVPC service area (in Franklin County), it is part of the Connecticut River Water Shed that flows through Hampshire and Hampden Counties – highlighting the importance of considering watershed boundaries, as well as political ones, in the development of water quality strategies.

(Photos: Connecticut River Watershed Council)

7.2.3 ADAPTATION ACTIONS

ACTION: SEEK FUNDING TO UPGRADE AGING WASTEWATER INFRASTRUCTURE

Communities should seek funds, through the State Revolving Fund (SRF), municipal appropriations, or other sources, to upgrade aging wastewater infrastructure. In particular, funds are vitally needed to upgrade aging and unsafe electrical systems in pump stations and provide back-up electrical generators.

ACTION: CONTINUE TO REDUCE COMBINED SEWER OVERFLOWS (CSOS)

Reducing CSOs in areas with combined sewers will result in major water quality improvements, especially with the larger frequency and intensity of storms from climate change. The Connecticut River Clean-up Committee, comprised of Springfield, Chicopee, Holyoke, Ludlow and PVPC should continue to play a lead role in this effort. CSOs can be reduced in several ways:

- Reducing stormwater inputs to combined sewers, through storage and infiltration of stormwater on individual properties before it enters the sewer system, stormwater management bylaws that encourage property owners to reduce stormater runoff, and zoning bylaws that restrict the amount of impervious surface.
- Separating combined sewer systems, a process which is currently being undertaken by all communities with CSOs in the Pioneer Valley, in conjunction with the US EPA.

The Connecticut River Clean-up Committee should continue work with state and federal legislators and officials to seek more federal funding and State Revolving Fund loans for CSO clean-up.

> ***Responsible Parties:*** *Municipalities, with assistance from Connecticut River Clean-up Committee, USEPA and DEP.*

ACTION: INCORPORATE GREEN INFRASTRUCTURE INTO STORMWATER MANAGEMENT

The increased rainfall resulting from climate change means that stormwater infrastructure will need to be designed to carry larger flows. The quantity of projected increase makes it infeasible to only expand existing gray infrastructure systems to meet new flows. Rather, the use of green infrastructure, to handle stormwater on the level of individual properties, must also be implemented.

Green infrastructure uses plants, trees and soil to reduce runoff and mimic pre-development conditions, with both small and large-scale benefits. On a micro scale, green infrastructure is able to store and infiltrate water on individual streets or properties. On the regional scale, these individual systems form a network that can handle large quantities of water. Other benefits of green infrastructure that will help the region adapt to other climate change effects include:

- Reducing urban heat island effect

- Improving air quality –U.S. EPA reports that trees and vegetation for stormwater management can yield up to a 5% reduction in carbon emissions in large urban areas.[1]
- GHG mitigation through carbon sequestration.

General green infrastructure technologies are described below.

Green Infrastructure Technology	Description
Blue Roofs	Storage of water on top of flat-roofed buildings, either for detention and slower release into stormwater system, or use on site for irrigation
Green Roofs	Vegetation planted on building roofs that absorbs rainfall. Drainage underneath vegetation conveys any excess water to stormwater system
Swales	Ditches or low-ground areas designed to collect stormwater to be infiltrated into the ground or slowly conveyed into the stormwater system
Rain Barrels and Cisterns	Containers that collect on-site stormwater and store it for irrigation or slower release into stormwater system
Pervious Pavement	Paving stones or pavement that allow water to pass through them and into the ground below, allowing for infiltration
Street Trees, Tree Box Filters	Absorb stormwater, releasing it into the air through evapotranspiration

ACTION: SIZE STORMWATER MANAGEMENT SYSTEMS TO ACCOMMODATE HIGHER FLOWS

With the climate changing, on-site stormwater management practices must be designed to accommodate larger rainfalls. A good design guideline can be found as part of the LEED (Leadership in Energy and Environmental Design) rating system, which awards a credit for designing on-site stormwater management practices that can accommodate large flows. In order to achieve credit 6.1 under LEED for New Construction, developments under 50% impervious surface must be designed to not exceed the pre-development peak discharge rate and quantity for the one and two-year 24-hour design storms. For developments with over 50% impervious surface, a 25% decrease in the volume of stormwater runoff from the two-year 24-hour design storm is required. The latest version of LEED for New Construction also allows the credit to be achieved through managing the 95th percentile of regional or local rainfall events using green infrastructure.[2,3]

In addition to properly sizing on-site stormwater systems and green infrastructure, municipalities should take into consideration increased rainfalls when maintaining and constructing additions to

[1] EPA Heat Islands Compendium (October 2008): Trees and Vegetation

[2] USGBC. "LEED Credit Library – Credit 6.1." <new.usgbc.org/node/1731618?return=/credits/new-construction/v2009> Accessed Oct. 10, 2012.

[3] Lots with less than 50% imperviousness can also meet the credit by creating a stormwater management plan that protects stream channels from erosion or implementing a stream channel protection strategy.

existing gray infrastructure systems. For example, any expansion plans for waste water treatment plants should take into consideration climate change, as should pipe capacities when designing new stormwater sewer lines.

Responsible Parties: *Massachusetts Department of Environmental Protection, municipal public works departments, private property owners*

ACTION: IMPLEMENT NEW STORMWATER UTILITIES AND FEES

Municipalities can encourage property owners to reduce stormwater runoff through the institution of stormwater utilities and stormwater fees. In the Pioneer Valley, the cities of Chicopee and Westfield have instituted stormwater utilities or fees. The City of Portland, Oregon and City of Chicago have been leaders in stormwater programs. Their initiatives provide a set of potential strategies that municipalities in the Pioneer Valley can implement:

- A stormwater utility fee, which assesses a fee to property owners based on the estimated amount of runoff generated, similar to that charged for water consumption. Portland has had a separate utility fee since 1977, with the rate based on a property's area and impervious coverage. The revenue from this charge is used to maintain stormwater infrastructure, as well as fund education and outreach programs about water pollution reduction.[4]
- Incentive programs that provide reduced stormwater utility fees for managing some or all stormwater on site. The Portland Clean Rivers Rewards program encourages property owners to retain stormwater on site through green infrastructure by reducing the utility fee they are assessed.[5]
- A fee for private construction in the public right of way, to be allocated to the construction of stormwater management, particularly green infrastructure. In Portland, the 1% Green program, assesses a 1% fee for all construction in public right of ways, with the revenue funding implementation of green infrastructure.[6]
- Subsidy programs that provide private property owners reimbursement or tax abatements for implementing green infrastructure on their sites. An example of an abatement program is New York City's Green Roofs Tax Abatement program, which provides property owners a one-year tax abatement of $4.50 per square foot of green roof, up to $100,000.[7] The City of Chicago has had a green roof construction program for over 15 years, and through its Green Roof

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[4] City of Portland. "Clean Rivers Awards Program." http://www.portlandonline.com/bes/index.cfm?c=41976&a=390568. Accessed October 10, 2012.

[5] City of Portland. "Clean Rivers Awards Program." http://www.portlandonline.com/bes/index.cfm?c=41976&a=390568. Accessed October 10, 2012.

[6] City of Portland. "1% Green." http://www.portlandonline.com/bes/index.cfm?a=341452&c=44407. Accessed October 10, 2012.

[7] NYC Green Roof Property Tax Abatement Program. October 2010. http://www.nyc.gov/html/dob/downloads/pdf/green_roof_tax_abatement_info.pdf. Accessed October 11th, 2012.

Improvement Fund provides a 50% grant match for the cost of green roofs in its central business district, as well as $5,000 grants for smaller commercial and residential projects citywide.[8]

Responsible Parties: *Massachusetts Department of Environmental Protection, municipalities, private developers*

ACTION: IMPLEMENT LOW IMPACT DEVELOPMENT PRACTICES INTO ZONING AND SUBDIVISION BYLAWS

Low impact development (LID) seeks to create development that does not produce a negative hydrological impact, such as runoff generation. Land use regulations are an important component of creating low impact development, and municipalities should consider adopting the following controls as part of their municipal zoning or subdivision codes, as a way of reducing runoff:

- Cluster development – Concentrate development in one portion of a site in order to preserve the rest of the land, reduces land disturbance and allows for more overall rainfall infiltration.
- Green infrastructure and impervious surface restrictions – Requiring that development maintain a lot as a certain percentage pervious, or that certain green infrastructure strategies are used.
- Stormwater runoff regulations – require new developments to not allow any additional runoff from pre-development conditions. For a redevelopment site, this requirement is often designed so that no additional runoff is created. For example, the State of Maryland's stormwater regulations require that infrastructure only be sized based on the disturbed land area of a redevelopment project, with only newly created impervious cover part of the calculations.

The Pioneer Valley Planning Commission's regional land use plan, Valley Vision 2, provides more information on low impact development land use practices.[9]

Responsible Parties: *Municipalities, developers*

ACTION: UTILIZE GREEN STORMWATER INFRASTRUCTURE SYSTEMS

Municipalities can encourage the use of green infrastructure by including it in the design and construction of public spaces, such as plazas and streets. Examples include swales on the sides of streets, and connected tree planters along the sidewalk that can retain and infiltrate large amounts of water. Municipalities can also encourage private development to use green infrastructure through incentive programs, as discussed in the recommendations below.

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[8] US Department of Energy. Building Energy Codes Program – Green Roof Improvement Fund (Chicago, IL 2006). http://www.energycodes.gov/resource-center/policy/green-roof-improvement-fund-chicago-il-2006 . Accessed September 18th, 2012.

[9] Pioneer Valley Planning Commission. "2011 Valley Vision 2 Update." <www.pvpc.org/activities/val-vision2.shtml> accessed 10/12/2012.

ACTION: *INCREASE ON-SITE STORMWATER INFILTRATION*

Encourage use of stormwater Best Management Practices to promote on-site stormwater recharge in new development, including: rain gardens; tree box filters; green roofs; and, porous pavement.

Responsible Parties: *Massachusetts Department of Environmental Protection, municipalities, private property owners*

ACTION: *STATE LOANS FOR GREEN INFRASTRUCTURE*

Seek changes in the State Revolving Fund (SRF) Program, which provides $100 million in low-interest loans to water and wastewater projects, to address climate and weather vulnerabilities, and promote green infrastructure

ACTION: *EMPLOY "SOFT STREAMBANKS" STANDARDS FOR REPAIR AND RECONSTRUCTION OF STREAMS AND RIVERS*

Protect riparian stream corridors through use of the following practices:

- Increase use of bioengineering techniques for stream bank stabilization.
- Prevent extensive use of armored stream banks and riprap dumping.
- Avoid dredging and straightening streams.
- Incorporate stream calming elements, such as rocks along banks, to replicate and restore natural conditions.

ACTION: *HELP IMPROVE DECISION-MAKING AND RESPONSES FOR STREAM RECONSTRUCTION AFTER SEVERE STORMS*

Provide more detailed information to municipal officials about the needs and benefits of environmentally appropriate and contextual stream reconstruction and maintenance. Providing this information is especially important during the period immediately following severe storms when these officials may be making decisions about stream repairs that involve channelization and water quality degradation.

ACTION: *ENACT LAND PROTECTION LEGISLATION*

Greenbelt and Land Protection Protect greenbelts, parklands, floodplains and forested areas. Municipal Conservation Commissions should collaborate with The Nature Conservancy and land trusts to protect intact forest blocks, preserve natural flood storage areas and land important to watersheds.

7.3 DAMS AND FLOOD CONTROL INFRASTRUCTURE

Dams and levees are essential to protecting the region's development and critical infrastructure from large storm damage. The state's dams and flood control infrastructure were designed to handle historic weather patterns, meaning more powerful, frequent storms and flooding will test these systems like never before. As the failure of a dam or levee can lead to major property damage and potential loss of life, it is essential that this infrastructure be adapted in preparation of climate change effects.

7.3.1 VULNERABLE RESOURCES

DAMS

There are 224 dams that are regulated by the Massachusetts Department of Conservation and Recreation's Office of Dam Safety (ODS). Dams are subject to regulation if they are in excess of 6 feet in height (regardless of storage capacity) and have more than 15 acre feet of storage capacity (regardless of height). There are also many dams in the region that fall below these parameters and are known as non-jurisdictional dams.

The ODS classifies dams based on the amount of damage to property and life that would result in case of a failure. The number of dams in each classification and the definitions for each class are:

- **42 – High Hazard** – where failure will likely cause loss of life and serious damage to homes, industrial or commercial facilities, important public utilities, main highways, or railroads.
- **90 – Significant Hazard** – located where failure may cause loss of life and serious damage to homes, industrial or commercial facilities, important public utilities, main highways, or railroads.
- **92 – Low Hazard** – located where failure may cause minimal property damage to others. Loss of life is not expected.

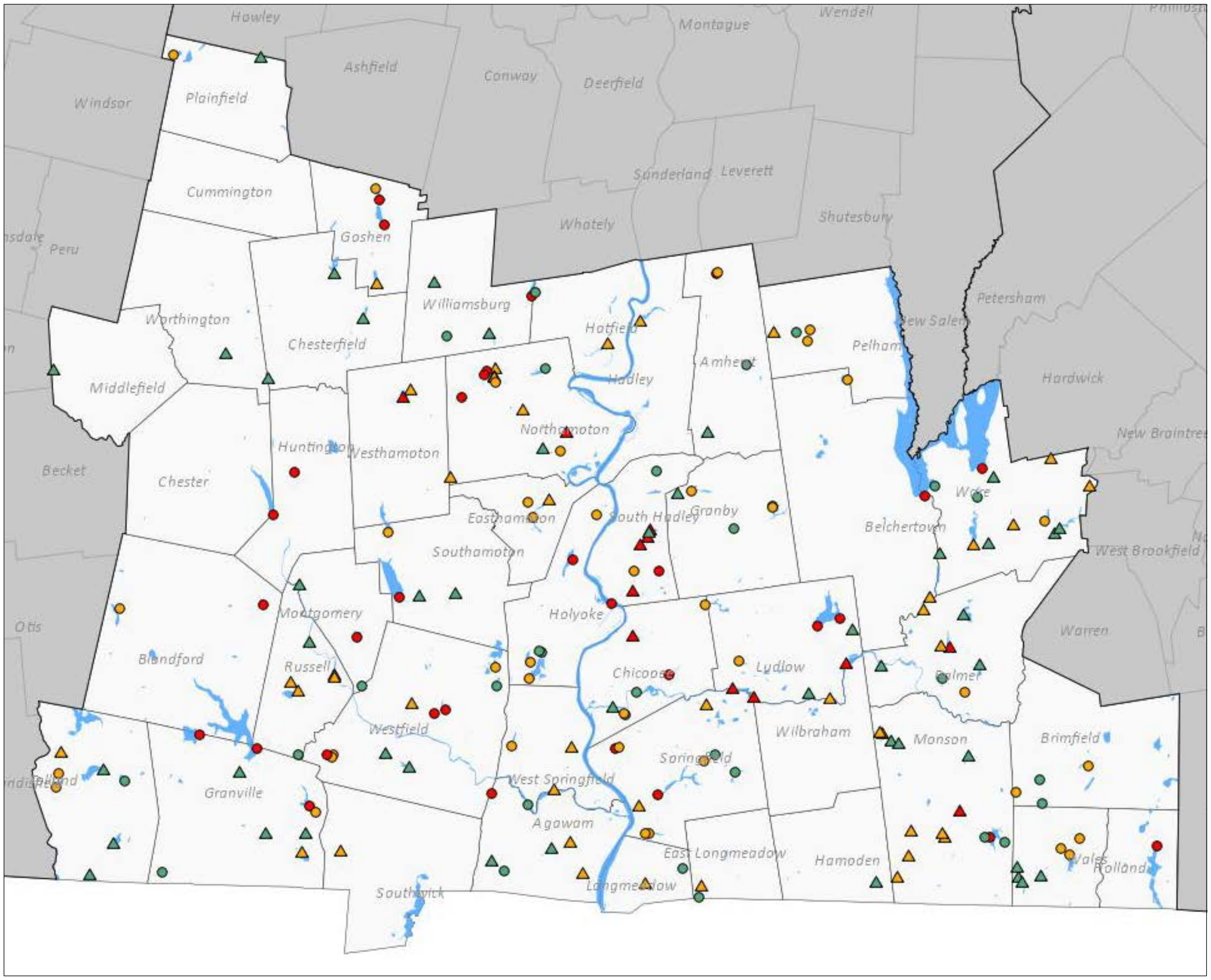
The following table lists areas where dam failures could create hazardous impacts.

Table 7-4: High Hazard Areas Downstream from Dams in Hampden and Hampshire Counties

Town	Name of Dam
Agawam	Provin Mountain Reservoir
Amherst	Factory Hollow Dam
Blandford	Borden Brook Reservoir
Blandford	Black Brook Dam
Chicopee	Mountain Lake Dam
Chicopee	Chicopee Reservoir Dam
Goshen	Upper Highland Lake Dam
Goshen	Lower Highland Lake Dam
Granville	Granville Reservoir Dam
Holland	Hamilton Reservoir Dam
Holyoke	Whiting Street Reservoir Dam
Holyoke	Holyoke Dam
Huntington	Littleville Lake Dam
Huntington	Knightville Dam
Ludlow	Ludlow Reservoir Dam
Ludlow	Cherry Valley Dam
Ludlow	Indian Orchard Dam
Ludlow	Red Bridge Dam
Ludlow	Ludlow Manufact. Assoc. Dam
Monson	Zero Manufacturing Company Dam
Monson	Conant Brook Dam
Montgomery	Westfield Reservoir Dam
Northampton	Roberts Meadow Lower Reservoir Dam
Northampton	Paradise Pond Dam
Northampton	Roberts Meadow Upper Reservoir Dam
Northampton	Roberts Meadow Middle Reservoir Dam
Palmer	Diamond International Corp Upper Dam
Russell	Cobble Mountain Reservoir Dam
South Hadley	Mt. Holyoke College Upper Pond Dam
South Hadley	Mt. Holyoke College Lower Pond Dam
South Hadley	Marcalus Manufacturing Company Dam
South Hadley	Leaping Well Reservoir Dam
South Hadley	Hillside Beach Dam
Southampton	Tighe Carmody Reservoir Dam
Springfield	Watershops Pond Dam
Springfield	Lower Van Horn Reservoir Dam
Ware	Quabbin Winsor Dam
Ware	Quabbin Goodnough Dike
Wareham	Mill Pond Dam
Wareham	Tihonet Pond #2 Dam
Wareham	Parker Mills Pond Dam
Wareham	Rte. #25 #1 Dam
Westfield	Arm Brook Dam
Westfield	Powdermill Brook Dam
Westfield	West Parish Filter #3 Dam
Westhampton	Pine Island Lake Dam
Williamsburg	Mountain Street Reservoir Dam

Source: Mass. Office of Dam Safety

Figure 7-5: Location of Public and Private Dams in the Pioneer Valley, by Hazard Level



Public	Private	
●	▲	Low hazard
●	▲	Significant hazard
●	▲	High hazard

This map shows the location of all dams in the Pioneer Valley for which there is information on the hazard level. High hazard dams are located near the highest population areas, near the Connecticut River. Sources: MassGIS, Office of Dam Safety.

LEVEES

There are over 22 miles of levees throughout the Pioneer Valley, with over 20 miles of this system located in the communities of Chicopee, Holyoke, Springfield, and West Springfield along the Connecticut River. The Mill River in Northampton and Springfield, the Chicopee River in Chicopee, the Ware River and Muddy Brook in Ware, and Little River in Westfield also have levees constructed.

The current levee system was constructed as a result of the Flood Control Act of 1938, which authorized flood control projects to be constructed by the United States Army Corps of Engineers (US ACE). The levees were also mostly constructed in the 1940s, in the wake of destruction caused by the 1938 New England Hurricane.

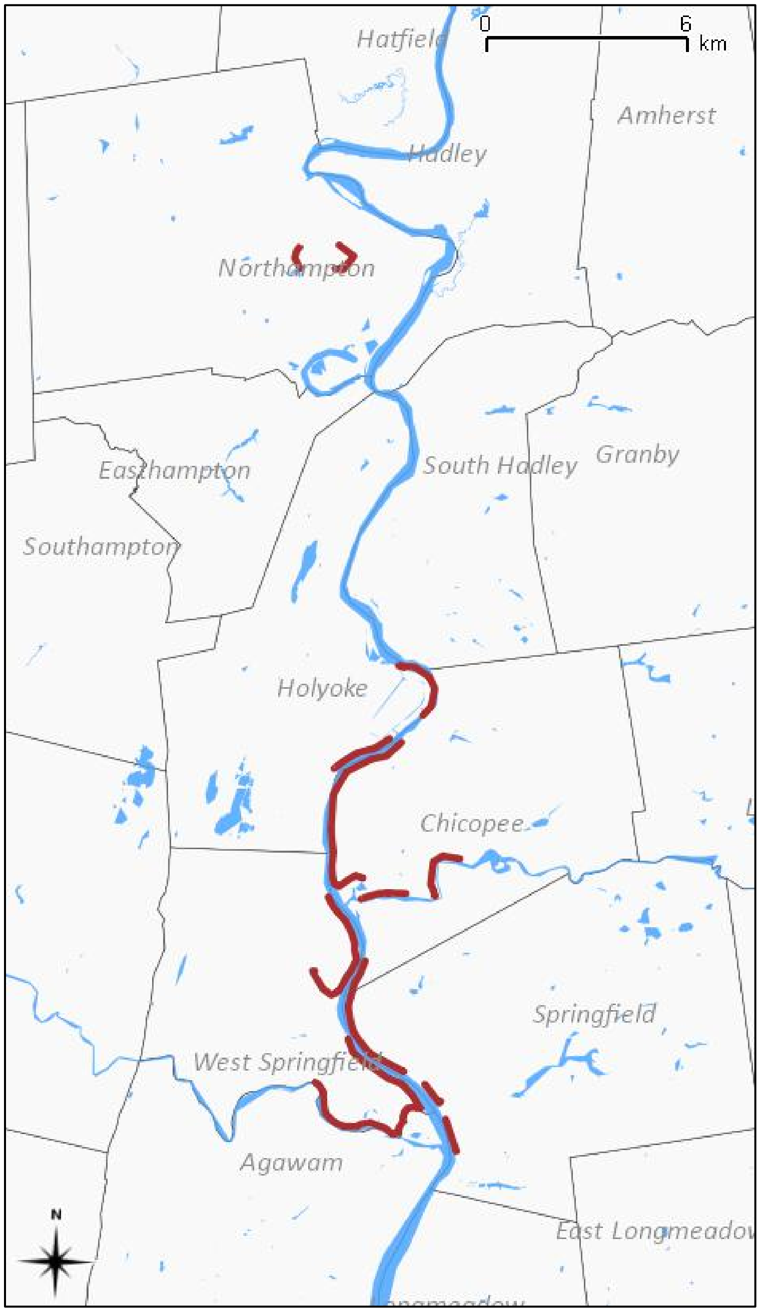
The US ACE regularly inspects all levees in the country, through the National Levee Database. Information and the location of levees in the Pioneer Valley are shown in the chart and map below. Some levees located in the upper Pioneer Valley are not included in this table, due to information about them being unavailable in the National Levee Database.

Table 7-5: Selected Levees in the Pioneer Valley

Municipality	River	Length (Miles)	Inspection Rating	Most Recent Inspection Date	Year Built
Chicopee	Chicopee River	0.96	Minimally Acceptable	4-Jun-09	1965
Chicopee	Chicopee River	0.98	Minimally Acceptable	4-Jun-09	1941
Chicopee	Chicopee River	3.81	Minimally Acceptable	5-Jun-09	1941
Holyoke	Connecticut River	1.05	-	-	1940
Holyoke	Connecticut River	2.86	-	-	1940
Northampton	Connecticut River	0.92	Minimally Acceptable	18-Sep-09	1941
Northampton	Mill River	0.46	Minimally Acceptable	18-Sep-09	1941
Chicopee-Springfield	Connecticut River	2.62	-	-	1948
Springfield	Connecticut River	0.95	-	-	1948
Springfield	Mill River	0.07	-	-	1948
Ware	Muddy Brook	0.02	Minimally Acceptable	5-Dec-08	1960
Ware	Muddy Brook	0.19	Acceptable	5-Dec-08	1960
Ware	Ware River	0	Acceptable	5-Dec-08	1960
West Springfield	Connecticut River	2.45	-	-	1942
West Springfield	Connecticut River	4.86	-	-	1942
Westfield	Little River	0.61	-	-	1984

Source: National Levee Database, US Army Corps of Engineers

Figure 7-6: Selected Levees in the Pioneer Valley



There are over 22 miles of levees that provide flood protection in the Pioneer Valley, with the majority located in the communities of Holyoke, Chicopee, West Springfield, and Springfield, along the Connecticut River. There are additional levees in the upper Pioneer Valley that are not shown, due to information about them being unavailable. Source: National Levee System, US ACE

7.3.2 THREATS

DAMS

Many dams in the Pioneer Valley were constructed and sized based on historic weather data, making them ill-equipped to handle the increased flows and volumes that will result from climate change. Dams are particularly at risk if they have not been maintained in good working condition, as they may not even meet their original design requirements. Increased precipitation may strain dams beyond their intended capacity, resulting in excessive water pressures and flows, and causing breaks and breaches. Furthermore, intense storms and other disasters such as earthquakes and landslides can damage flood controls with similar results to damage from precipitation. Tropical Storm Irene in August of 2011 caused two dams to fail in the Pioneer Valley. In Blandford, an unnamed private dam failed causing damage to nearby roads, and the Granville Reservoir Dam, owned by the City of Westfield, had its spillway fail due to high water levels, requiring $5,000,000 to repair.

There are several existing conditions that present challenges in preparing dams for more severe weather. These conditions are: a lack of regular inspections of some dams, many dams that are currently in poor or unsafe condition, and the absence of emergency action plans for some dam facilities.

Poor Physical Condition

The current age and condition of dams in the state is a serious issue. According to the American Society of Civil Engineer's (ASCE), 246 of Massachusetts' 1,630 dams are in need of rehabilitation to meet applicable state dam safety standards.[10]

In 2011, the Massachusetts State Auditor's Division of Local Mandates (DLM) published a report identifying 100 large dams that are rated in unsafe or poor condition and which would result in considerable damage if they were to fail. This identification is based on assessments by the Office of Dam Safety (ODS), which classifies dams as being in good, satisfactory, fair, poor or unsafe condition. The ODS also classifies dams as a low, significant or high hazard, based on the amount of damage that would result from a failure. The report states that the dams "could potential cause loss of life and significant property damage in the event of failure, *and* each of these has major deficiencies that increase the likelihood of failure."

A dam in poor or unsafe condition can entail very costly repairs, and a hazard index rating brings with it different requirements related to frequency of inspections and the need for emergency action plans (currently only required for high hazard dams). Of the dams identified in the State Auditor's report, six are located in the Pioneer

[10] American Society of Civil Engineers. "America's Report Card for Infrastructure: Massachusetts." http://www.infrastructurereportcard.org/state-page/massachusetts. Accessed October 10th, 2012.

Valley. An additional nine dams are known to be in poor condition and either a high and significant hazard.[11] All fifteen of these dams are shown in the following table. Dams in the area that are in poor or unsafe condition, but which are classified as a low hazard in the case of failure, are also shown.

Lack of Regular Inspections

The Massachusetts Department of Conservation and Resources Office of Dam Safety requires regular inspections of all dams in the state. Since 2005, this responsibility has been charged to individual dam owners. The required frequency of inspections is based on the structure's particular hazard level, with low hazard dams inspected at least every 10 years, significant hazard dams every 5 years, and high hazard dams every 2 years.

While inspection is an important part of ensuring that dams are safe over time, a 2011 report focused on municipal dams from the State Auditor found that the cost of complying with the new regulations presents serious financial challenges.[12] Dam owners sometimes do not perform inspections regularly due to a lack of resources and/or enforcement of the law. Financial burdens of these new responsibilities can vary greatly, depending on the number of dams for which an owner is responsible, and the dam's condition and hazard index rating. The Massachusetts State Auditor Division of Local Mandates estimates that each dam inspection costs approximately $5,000, with a report completed by the Pioneer Valley Planning Commission in 2011 estimated costs of $2,500 to $5,000.

The higher intensity and frequency of storms with climate change will increase stresses on dams and will make regular inspections more important than ever before. One alternative to regular inspections, especially if a dam is in poor condition, is removing it. This can be a wise fiscal decision if a dam is not providing a beneficial function such as water supply or power generation, since removal of a dam in poor condition can save money over the long term in comparison to inspections. With the increased possibility due to climate change that a dam in poor condition will fail, removal is an even more viable possibility.

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[11] This table is based on 2006 data from the Office of Dam Safety with which PVPC has been working with and updating for various projects since. Obtaining current data from the Massachusetts Office of Dam Safety is difficult given the reported lack of staffing and funding within that office.

[12] *Local Financial Impact Review: Massachusetts Dam Safety Law*, Auditor of the Commonwealth, January 2011.

Table 7-7: Dams in Poor or Unsafe Condition in the Pioneer Valley

Dam Name	Location	Hazard Index Rating	Physical Condition	Notes
Upper Highland Lakes Dam	Goshen	High	Poor	-
Lower Highland Lake Dam	Goshen	High	Poor	-
Robert's Meadow Upper Reservoir Dam	Northampton	High	Poor	MEPA filing for dam removal is expected by January 2013. An expanded environmental notification form will detail the impacts of the dam removal and restoration work.
Hathaway and Steane Pond Dam #2	Southwick	High	Poor	-
Van Horn Park Lower Dam	Springfield	High	Poor	-
Bondsville Upper Dam	Belchertown	Significant	Poor	Repair cost estimated between $359,000 and $548,500. $350,000 for repairs included in 5-year capital plan.
Knights Pond Dam	Belchertown	Significant	Poor	-
D.F. Riley Grist Mill Dam / Advocate Dam	Hatfield	Significant	Poor	-
White Reservoir Dam	Holyoke	Significant	Poor	Impoundment drained in 1982. Acts as retention basin currently and City has agreement with Mass. Office of Dam Safety to continue operating. Dam rated "poor" based on several improvements required.
Pulpit Rock Pond New Dam	Monson	Significant	Poor	-
Forest Park Upper Pond Dam	Springfield	Significant	Poor	-
Monsanto Upper Dam	Springfield	Significant	Poor	-
Van Horn Park Upper Dam	Springfield	Significant	Poor	-
Forest Park Upper Pond Dam	Springfield	Significant	Poor	-
Strathmore Paper Dam	West Springfield	Significant	Poor	-
Nine Lot Dam	Agawam	Low	Poor	-
Quenneville Dam	Granby	Low	Unsafe	Impoundment has reportedly been drained
Bahre Pond Dam	Granville	Low	Poor	-
Clear Pond Dam	Holyoke	Low	Poor	-
Virginia Lake Shore Dam	Middlefield	Low	Poor	-
Rocky Hill Pond Dam	Northampton	Low	Poor	-
Putnam's Puddle Dam	Springfield	Low	Poor	-
Vinica Pond Dam	Wales	Low	Poor	-
Norcross Pond Dam #2	Wales	Low	Poor	-

There are a total of 24 dams in the Pioneer Valley identified as in either poor or unsafe condition by the Massachusetts Office of Dam Safety. 15 of these are considered a significant or high hazard, meaning they would cause considerable damage to life or property if they were to fail.

LEVEES

Similar to the risks facing dams, the levee system in the Pioneer Valley will be threatened by a higher occurrence of severe weather and flooding from climate change. Specifically, these challenges include the levees being sizing based on historic storm data and maintenance.

Sizing Based on Historic Storm Data

Because most levees in the Pioneer Valley were built in the 1940s, they were constructed using climate data from that time. Levees were constructed to withstand a 100-year storm (a storm with a 1% chance of occurring in any given year) or 500-year storm (a storm with a 0.2% chance of occurring in any given year). However, the severity of a 100-year and 500-year storm is projected to increase significantly due to climate change rainfalls, meaning that the chance that levees will be breached or overtaken by flood waters has also increased.

Maintenance

While the U.S. Army Corps of Engineers (USACE) was responsible for the construction of the levees, responsibility for their maintenance falls on the municipalities in which they are located. The USACE regularly inspects these dams as part of the National Flood Insurance Program to assess flood risk throughout the country. Based on an inspection checklist that includes a range of criteria, such as structural integrity of culverts and drainage pipes, cracking, animal control, and erosion, the USACE rates each levee as one of the following:[13]

- **Acceptable** – All inspection items are rated as Acceptable.
- **Minimally Acceptable** – One or more inspection items are rated as Minimally Acceptable or one or more items are rated as Unacceptable and an engineering determination concludes that the Unacceptable inspection items would not prevent the segment/system from performing as intended during the next flood event.
- **Unacceptable** – One or more inspection items are rated as Unacceptable and would prevent the segment/system from performing as intended, or a serious deficiency noted in past inspections (previous Unacceptable items in a Minimally Acceptable overall rating) has not been corrected within the established timeframe, not to exceed two years.

In order to maintain eligibility for the National Flood Insurance Program, levees must maintain a minimally acceptable rating.

As shown in Table 7-5, most levees in the Pioneer Valley have currently met the minimally acceptable standard. However, during inspections carried out by the USACE after Hurricane Katrina in 2007, the levees along the Connecticut River in the communities of Holyoke, Springfield, Chicopee, and West Springfield were determined to be unacceptable. The USACE mandated that these communities improve their levee system through such

[13] The full US ACE Levee Inspection Checklist is available at http://www.usace.army.mil/Portals/2/docs/civilworks/levee/LeveeInspectionChecklist.pdf

tasks as clearing debris and trees along the levee banks. Springfield has hired a vendor that currently performs inspections, repairs, and maintenance along its levee system to meet USACE's new standards.[14]

While detailed information about the condition of specific levees is not publically available, there is evidence that in the long-term many of the levees in the Pioneer Valley will need to be upgraded and reconstructed. For example, in the North End neighborhood of Springfield, the levee is currently tilting and creating a slope that conveys water towards rather than away from the structure. Over time, this is eroding the levy material, a maintenance issue that cannot be easily fixed because the weight from any additional soil placed on the levee would simply exacerbate the problem. Eventually, the levee will need to be completely reconstructed, at a very high capital cost to the City of Springfield.

Figure 7-9: Connecticut River Levee in Springfield

The levee protecting Springfield's North End neighborhood has shifted over time, creating a slope that causes water to pool next to it. This is causing damage to the levee foundations and will eventually require costly improvements. Source: PVPC

[14] City of Springfield Municipal Budget, Fiscal Year 2013

7.3.3 ADAPTATION ACTIONS

ACTION: ***ENSURE ALL DAMS WITH A SIGNIFICANT OR HIGH HAZARD RATING HAVE EMERGENCY ACTION PLANS IN PLACE***

Currently, the state's Office of Dam Safety only requires dams with a high hazard rating to have EAPs. The failure of a significant hazard dam could generate significant property damage and lost of life, a problem that would be exacerbated by the lack of an emergency plan in pace. Municipalities and local emergency management directors should work to identify publically-owned significant and high hazard dams to ensure they have EAPs. For privately-owned dams, municipalities should work with the dam owners to develop plans.

ACTION: ***ENCOURAGE COOPERATION BETWEEN DAM OWNERS IN OPERATION OF FLOOD CONTROL INFRASTRUCTURE***

Dams and levees are regional infrastructure that goes beyond the boundaries of individual municipalities. Safety programs are an example of the need for regional coordination of dams and levees, as all areas downstream are potentially affected by a system failure. The need for coordination is further increased due to the fact that municipalities often own dams that are located in other municipalities. For example, Springfield and Ludlow have cooperated on dam safety planning, as Springfield owns two of the dams in Ludlow. The City of Springfield Water Department has coordinated review of their dam EAPs with Ludlow's Fire Chief, and copies of the EAP are shared between both involved parties.[15]

Inspection of publically-owned dams may be more effective on a regional level as well as the cost of individual dam inspections can decrease when multiple dams are inspected by a contractor at once. In 2011, the Pioneer Valley Planning Commission gauged interest in regional cooperation of dam inspections, as part of a state-led initiative to address this financial burden. While it was determined that generally, municipalities in the region were not interested in regionalization at the current time, cooperation between a small subset of municipalities may be more practical. Additionally, cooperation between private dam owners, for whom inspection costs may be more of a burden, could potentially increase the frequency and likelihood of dams being inspected regularly.[16]

ACTION: ***ENCOURAGE NEW PROGRAMS FOR FUNDING DAM INSPECTIONS, MAINTENANCE, AND REMEDIATION***

The report on dam safety issued by the State Auditors office in 2011 recommended that the Massachusetts Legislature establish a multi-year program of financing dams that are in poor

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[15] Pioneer Valley Planning Commission. "City of Ludlow Hazard Mitigation Plan." http://www.pvpc.org/web-content/docs/landuse/pdm_pdfs/ludlow_mitig_plan.pdf. Accessed October 10th, 2012.

[16] Pioneer Valley Planning Commission. "Regional Dam Services: Seeking to Reduce Financial Impacts on Municipalities." December 2011. http://www.pvpc.org/resources/landuse/dlta-fy-2011/Regional%20Dams%20Services%20Final%20Report.pdf

condition, and set up a revolving loan program to encourage their repair. Municipalities in the Pioneer Valley should encourage the adoption of this type of program, as well as encourage funding from the state for the development of Emergency Action Plans, and regular inspections.

ACTION: ***CONTINUE TO IMPROVE LEVEES TO MEET FEDERAL STANDARDS***

The current work being undertaken by communities along the Connecticut River in the lower Pioneer Valley to improve its levees, as per USACE standards, is an excellent start to adapting to climate change. Continuing this work to ensure the resiliency of the levee system will assist the region in preparing for more severe weather in the decades to come.

ACTION: ***IMPROVE FLOOD RESILIENCE THROUGH GREEN INFRASTRUCTURE***

The failures of levees and other flood protection infrastructure illustrate the limitations that walls, dikes and hard barriers can have in protecting development from floods. As climate change effects occur, levees will be tested more than ever before, and will continue to fail over time. Green infrastructure provides useful strategies for overcoming these problems. Municipalities and the US Army Corps of Engineering should consider, where possible, the use of natural floodplains and flood forests as a natural defense against floodwaters rather than walls, dikes and hard barriers.

7.4 TRANSPORTATION INFRASTRUCTURE

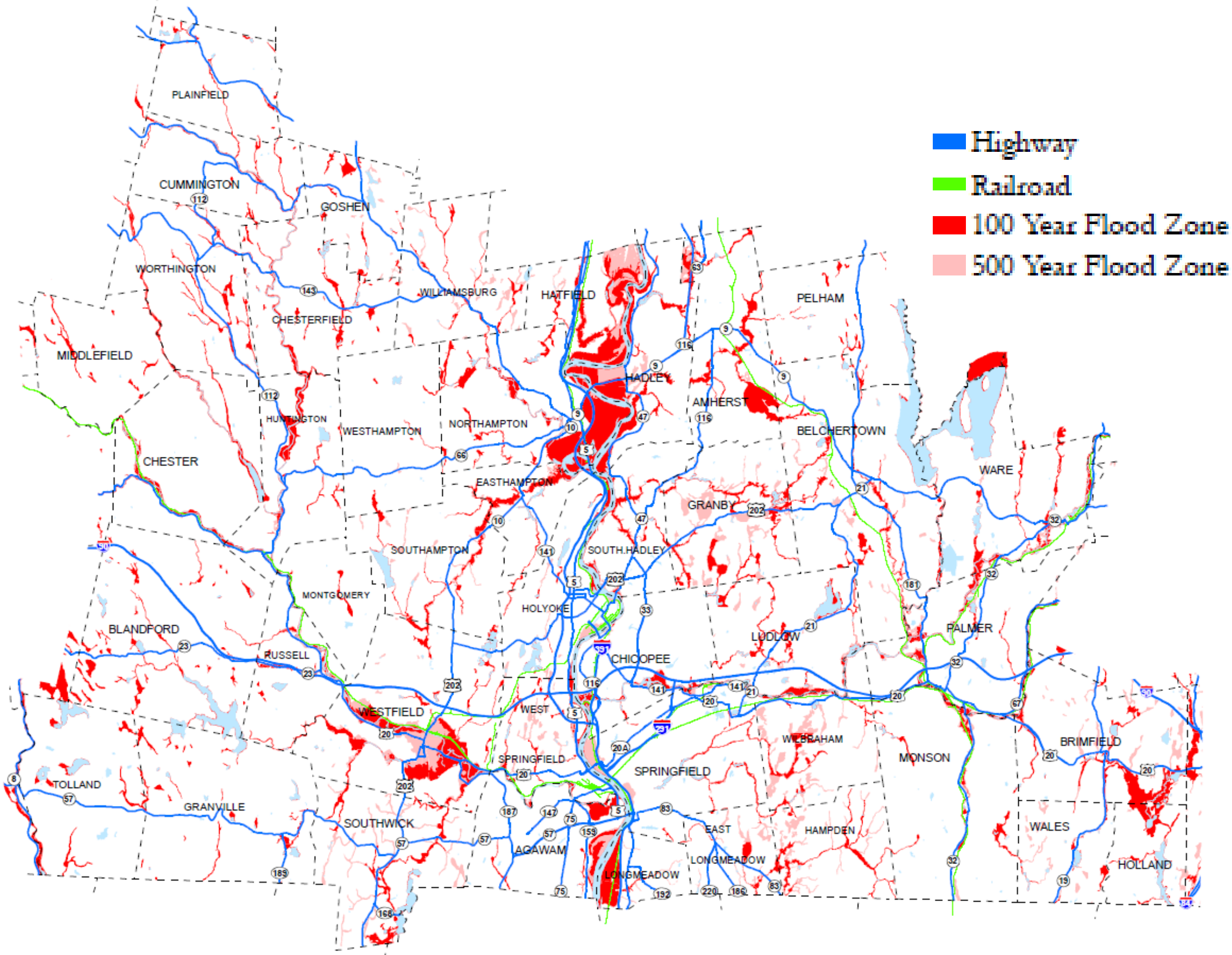
Transportation infrastructure is vital to the daily functioning of the Pioneer Valley. Significant adaption to climate change is necessary to maintain transportation facilities in safe and usable operating conditions. These facilities include roads, highways, bridges, stream crossing structures, railroads, airports and related construction. These facilities tend to be vulnerable to extreme weather, as they are constantly exposed to the elements. The greatest threats tend to be from high volume water flows during and immediately after heavy rain storms, high winds and temperature extremes. In particular, culvert and bridge crossings of roads, highways and rail lines are vulnerable to washouts and fallen trees. In addition, high heat can soften and weaken pavement. In all cases, damage to the transportation infrastructure of the region poses safety hazards, lost time, inconvenience, economic loss and other detriments to the people and businesses of the region.

7.4.1 VULNERABLE RESOURCES

ROADS AND HIGHWAYS

There are 4,364 miles of road in the region, 81% of which are maintained by city and town governments. The Massachusetts Department of Transportation (MassDOT) is responsible for 7%, most of which are state numbered routes and interstate highways. Other government agencies and private owners are responsible for the remaining 12%. Flooding poses one of the most frequent and common threats to passage and safety on these roadways. The figure below illustrates the locations where roads travel through flood zones. (Note: A road passing through a flood zone may be at an elevation above flooding levels and therefore is not at risk.)

Figure 7-10: Pioneer Valley Roads and Rail Lines in Flood Zones



The use of the "100-year flood zone" for planning purposes began in the 1960s when "the United States government decided to use the 1-percent annual exceedance probability (AEP) flood as the basis for the national flood insurance. The 1-percent AEP flood has a 1 in 100 chance of being equaled or exceeded in any 1 year, and has an average recurrence interval of 100 years, it is often referred to as the 100-year flood. The 500-year flood corresponds to an AEP of 0.2%, which means a flood of that size or greater has a 0.2% chance (or 1 in 500 chance) of occurring in a given year[17]."

As weather events during the past several years in the Pioneer Valley have demonstrated, even rain storms that do not reach the threshold for the 100-year and 500-year floods still require numerous road closures. Residents of the region have already experienced detours and reduced service on rail, air and public transit due to heavy rain, including:

[17] U.S. Department of the Interior, *General Information Packet 106,* April 2010

- Increased flooding of highways, local streets, rail lines, and tunnels.
- Overloaded drainage systems, causing backups and street flooding.
- Limited visibility because of heavy precipitation (snow and rain).
- Motor vehicle accidents and related safety problems due to decreased skid resistance of vehicle performance, including traction and maneuverability.
- Lower travel speeds and greater speed variability from differing driving habits and abilities of vehicle operators in heavy weather conditions.
- Reduced roadway capacity.
- Increase delays.

Snowstorms are a significant concern, as climatic predictions indicate increased winter precipitation (see Chapter 5). In addition to impeding vehicular operation, heavy snow causes downed power lines and trees that block roads. The most recent example is the snowstorm in October of 2011, during which thousands of the region's roads were fully or partially impassible. In Springfield alone, at least half of the City's 2,000 roads were partially closed due to downed wires and trees.

Extreme heat and temperature variation have the following effects on transportation infrastructure:

- Longer periods of extreme summer heat damage roads by softening the asphalt so that heavy vehicles create ruts in the pavement.
- Extreme heat deforms railroad tracks, which requires significantly slower travel speeds for trains to avoid derailments.
- Increases in very hot days, heat waves and associated poor air quality limit outdoor construction activities to protect the health and safety of highway workers.

CULVERTS AND BRIDGES

In the Pioneer Valley, severe storms are causing an increasing number of washouts of culverts and bridge structures. In 2011, Tropical Storm Irene caused more than $25 million of roadway damage in the region, including many culvert wash outs. There are 2,885 culverts and 673 bridges in the region. Of the bridges, 403 are maintained by MassDOT and other state agencies, and 270 by the region's cities and towns.

Culverts and bridges are structures usually built to carry a road, rail line or path over a stream or river. Culverts and bridges are usually located at points where the banks narrow, either naturally or as a result of man-made earthworks. In either case, the effect is to create a potential "choke point" in the downstream water flow.

When culverts and bridges are subjected to water flows that exceed their design capacities, the result can be catastrophic failure. Structures may be damaged or carried away, and the roads and rail lines above become impassible. Less immediately severe but longer term, problems include erosion of the streambed, as well as the accumulation of debris within the culvert or beneath the bridge—both of which block the flow of water. Also, if the diameter of a culvert is smaller than the width of the stream, water velocity increases through the culvert, which creates more turbulence and erosion. Therefore, it is critical that culverts and bridges are sized and designed to handle the large volumes and flows of water that occur during and immediately after large storms.

Culvert design is also critical to the habitat of many fish and wildlife that live near streams. Water temperatures are cooler in upstream areas and tributaries, and fish require the ability to transverse between upstream and downstream in order to regulate their temperature effectively. The design of many culverts does not accommodate this natural traveling between upstream and downstream. This may be due to the water being too shallow in the culvert, erosion, or debris obstructing the end of the culvert.

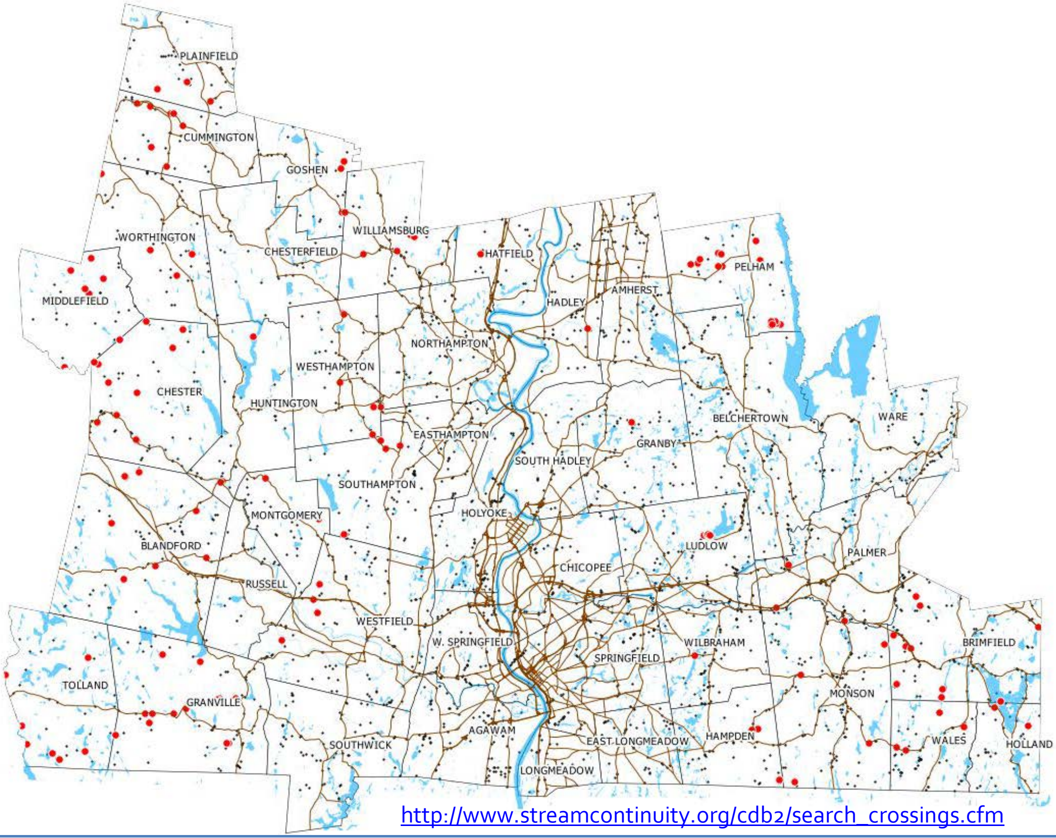
Effective adaption strategies for culverts and bridges require an inventory of the number and locations of these structures, as well as vulnerability characteristics and relative priority to maintaining balance in the watershed. There is already a significant effort under way toward these goals in the region: the River and Stream Continuity Partnership is a joint effort between the University of Massachusetts Amherst, The Nature Conservancy, the Massachusetts Riverways Program, and American Rivers. The partners are documenting the conditions at culverts around the Pioneer Valley and identifying improved designs. The Massachusetts Department of Transportation's Culvert Design Guidelines also provides a set of strategies for adaptation to larger storms, as well as accommodation of wildlife in changing climate conditions.

The design specifications for culverts and bridge abutments are usually based on engineering calculations that incorporate precipitation data to determine how large and strong the structures need to be to safely survive severe storms. Storm severity is usually described as "10-year," "25-year," "100-year," and "500-year" events, based on the amount of precipitation in a 24-hour period. The most common method to date for determining the design requirements for culverts and bridges has been to rely on a document produced in 1961 by the Weather Bureau of the U.S. Department of Commerce known as Technical Report 40, or TP-40, which is based precipitation records for the 50 years prior to its publication. However, during the 1990s, the precipitation estimates in TP-40, especially those for 24-hour rainfall events, were found to have underestimated many actual precipitation amounts (see figure below). The reason for the underestimates has generally be acknowledged to be a result of the fact that the 50-year period upon which TP-40's estimates are based included periods of long-term drought in North America. Therefore, many culverts and bridges that were previously thought to be adequately designed to handle extreme storm flows are actually under designed. Today, the National Weather Service has developed a more accurate database of historical precipitation known as Hydo-35 that incorporates records since 1961 to produce better estimates for extreme precipitation events.

When a culvert or bridge fails, they are generally replaced with structures that have similar design capacities, or somewhat larger greater capacities, for handling extreme storms. However, both these approaches are not adequate to address the underlying problem of precipitation amounts that are greater than previously estimated. Simply increasing the size of a culvert often creates very shallow flows of water through the bottom of the culvert, which adversely affects fish and other wildlife living in or near the stream that require continuous flows to survive. Also, because it does not slow the velocity of the water, a larger culvert continues to cause erosion that weakens and undermines the integrity of the design over time. This design often leads to repeated failure of the design and require repeated repairs after each storm event. The South River, for example, has been engineered away from its natural course through the center of Conway. The design incorporates a strong bend in the river that has failed repeatedly. Such flood practices can often have water quality implications as well. For example, the Chickley River was deepened four feet for a five mile span after Tropical Storm Irene, which has now made the water muddy and turbid.

There are 2,885 culverts in the region, which are shown below and summarized by municipality. The top 5% deemed most vulnerable to extreme weather and heavy rainfall are shown in red.

Figure 7-11: Culverts Roadway Stream Crossings in the Pioneer Valley and Top 5% for Ecological and Hydrologic Connectivity



http://www.streamcontinuity.org/cdb2/search_crossings.cfm

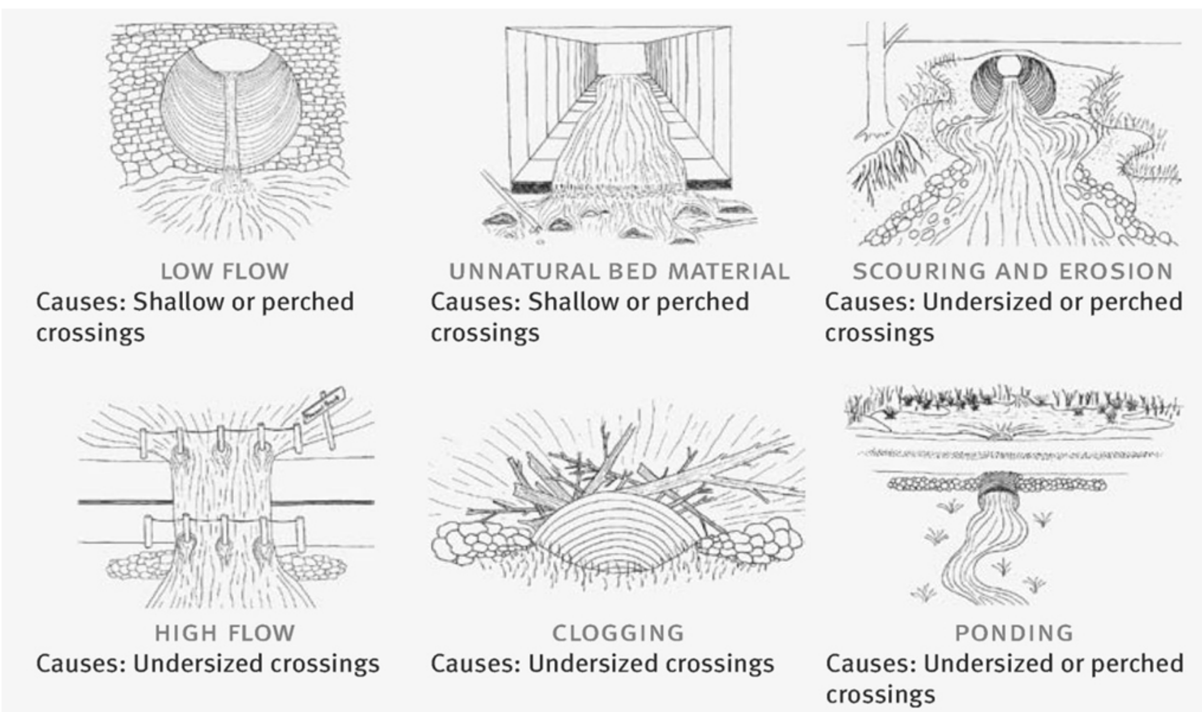
TOWN	Total	in top 5%	TOWN	Total	in top 5%	TOWN	Total	in top 5%
Agawam	100		Hadley	61	1	Plainfield	34	3
Amherst	87		Hampden	47	4	Russell	37	
Belchertown	146		Hatfield	32	1	South Hadley	46	
Blandford	74	10	Holland	35	2	Southampton	54	4
Brimfield	119	10	Holyoke	86		Southwick	72	
Chester	65	13	Huntington	41	3	Springfield	146	
Chesterfield	25		Longmeadow	35		Tolland	38	7
Chicopee	60		Ludlow	117	4	Wales	60	4
Cummington	44	8	Middlefield	29	5	Ware	95	
E. Longmeadow	45		Monson	124	4	W. Springfield	90	
Easthampton	45		Montgomery	32	2	Westfield	130	4
Goshen	27	3	Northampton	109		Westhampton	43	8
Granby	71	1	Palmer	92	3	Wilbraham	82	1
Granville	72	13	Pelham	36	16	Williamsburg	53	6
						Worthington	49	4
						TOTAL:	**2,885**	**145**

Source: Massachusetts Stream Crossing Inventory accessed September 2012

Figure 7-12: Common Consequences of Inadequate Design of Culverts and Bridges

Culverts can fail if stormwater flow exceeds their designed capacity.

Water flowing too shallowly through a culvert makes it difficult for wildlife to travel through it.



Common consequence of inadequately designed culverts and bridges are shown above.
(Source: Massachusetts Riverways Program 2011
<www.streamcontinuity.org/pdf_files/stream_crossings_poster.pdf>)
http://www.streamcontinuity.org/cdb2/search_crossings.cfm

AIRPORTS

There are three major airports in the Pioneer Valley:

- Northampton Airport, 160 Old Ferry Road, Northampton – General aviation
- Westover Metropolitan Airport, 255 Padgette Street, Chicopee – General aviation
- Westfield-Barnes Municipal Airport, 110 Airport Road, Westfield – General aviation

There are also two key military air facilities in the region:

- Westover Air Reserve Base, Chicopee (439th Airlift Wing)
- Barnes Air Force Base, Westfield (104th Fighter Wing)

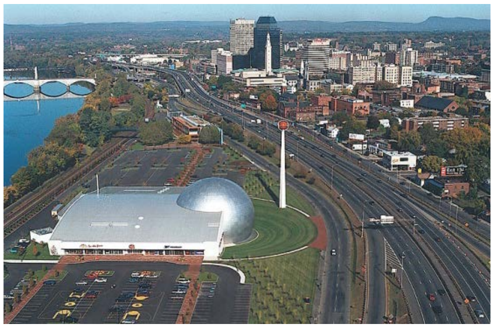
In practice, Bradley International Airport in Windsor Locks, Connecticut serves as the Pioneer Valley's primary commercial passenger and air freight facility.

7.4.2 THREATS

The principal threat to the region's transportation infrastructure is from flooding. Major roadways and railroad lines within and immediately adjacent to the 100-year and 500-year flood zones are considered to be at greatest risk. Shown below are the principle risks to transportation in the region identified in the Pioneer Valley Regional Transportation Plan 2012.

Hadley and Northampton: The western border of Hadley and the eastern border of Northampton have several areas of 100-year flood zones (seen in red) Connecticut River that intersect with numbered state highways. During flooding, road closures could potentially occur on Routes 5, 9, and 47. (I-91 is above flood high water marks, so is not affected.) Numerous local streets would be flooded, as well. Route 9 carries about 33,000 cars and trucks per day in this area.

Westfield: The commercial and industrial areas along Route 20 and Union Street are within the 100-year flood zone. This stretch of roadway carries about 14,000 cars and trucks per day. During flooding of the Westfield River, Route 20 and Union Street could be inundated (as seen during Tropical Storm Irene in August 2011 at left). The region's major east/west rail line, which parallels Route 20, could also be potentially flooded at lower points of elevation in Westfield. Route 20 carried about Also, downtown Westfield is within the 500-year flood zone; flooding in this area could affect Routes 10, 20, and 202, as well as local roads, and the rail mentioned above.



Springfield I-91 Ramps: While most sections of I-91 through the region are expected to be usable during floods because of the generally higher roadway elevation, a number of ramps in downtown Springfield are at a lower elevation and at risk of flooding from the Connecticut River. The most vulnerable ramps are Ramps 3 through 8, several seen in the northbound view in photo at left. This section of I-91 carries approximately 70,000 cars and trucks per day.

Rail Lines: Several rail lines in the region pass through portions of the 100-year flood zone. One key line is along the Connecticut River that, in addition to freight rail service, will be the new route of intercity and commuter rail passenger trains. Key points of vulnerability are north of Chicopee and the crossing of the river into downtown Holyoke; and through areas of Easthampton and Northampton adjacent to the river.

Airports: Of the general aviation airports in the region, the Northampton Airport (seen at left) is at greatest risk from flooding, as it is located within the 100-year flood zone. All other airports and military bases in the region are not in flood zones. Bradley International Airport (BDL) in Windsor Locks, Connecticut, the region's primary commercial passenger facility, is not in a flood zone. However, access to BDL via I-91 could be impeded by flooding of that roadway in Springfield (see above).

7.4.3 ADAPTATION ACTIONS

ACTION: TRANSPORTATION ASSETS VULNERABILITY ASSESSMENT

Perform an inventory that includes vulnerability assessments of critical transportation infrastructure to provide a baseline for future damage assessments and improvement recommendations. The Pioneer Valley Metropolitan Planning Organization (MPO) may wish to consider incorporating additional climate change vulnerability assessments in the regional transportation planning process and in the project ranking criteria for federally funded transportation projects on the region's Transportation Improvement Program (TIP).

ACTION: STORM-PROOF ROADS AND OTHER TRANSPORTATION INFRASTRUCTURE

Because roads are typically the used by travelers of any mode (auto, public transit, bus and pedestrian), it is essential that these facilities receive priority in efforts to increase resilience to severe storm events and flooding. The vast majority of roads and sidewalks in the region are owned and maintained by municipalities. Therefore, assistance to these communities in storm-proofing to withstand severe weather and flooding is critical to the overall resilience of the region's transportation system. The MPO's Regional Transportation Plan provides general assessments and appropriate strategies for this action.

ACTION: INVENTORY AND PRIORITIZE CULVERT AND BRIDGE STREAM CROSSINGS FOR UPGRADES AND REPLACEMENT

Continue to identify and prioritize culverts and bridges for replacement and design upgrades through the Stream Continuity Program. The main activities of this effort are:

- Identify structures that block movement of fish and wildlife.
- Set priorities for culvert replacement.
- Establish policies and standards for culvert replacement.
- Proactively address culverts with highest impact of stream connectivity.
- Work with FEMA to adopt policies to allow upgrade of structures in cases of failure.

ACTION: UTILIZE APPROPRIATE AND ADEQUATE CULVERT AND BRIDGE DESIGN STANDARDS

See Appendix 2: Best Management Practices for Stream Crossing Replacement.

ACTION: EMPLOY APPROPRIATE STREAM RECONSTRUCTION AND REPAIR DESIGNS AND METHODS

See Appendix 2: Best Management Practices for Stream Crossing Replacement.

ACTION: ENACT CLIMATE BOND BILL

Seek community support for a state climate action bond bill, similar to the Transportation Bond bill, to help communities pay for infrastructure improvements that address climate and weather vulnerabilities and protection needs.

7.5 ENERGY AND ELECTRICAL INFRASTRUCTURE

A variety of adaption measures are needed to protect and maintain the region's energy and electrical infrastructure from actual and anticipated effects of climate change. Increased summer temperatures under climate change projections mean that cooling needs will be higher and more electricity will be required. Electrical systems are already taxed during extremely hot days, and as the number of these days increases and become even hotter, the peak capacities of power plants are more likely to be exceeded. This can result in brownouts in which portions of the electrical grid do not have power. The electrical grid is also vulnerable to severe weather, such as when snowfall causes tree branches to fall on power lines. While snow is projected to decrease due to climate change, warmer weather later in the fall and the increasingly erratic nature of weather means that snow is more likely to fall while leaves are still on trees, resulting in more tree damage and downed power lines.

Washington and Eldridge Streets in Springfield after the heavy snowstorm of October 29, 2011. Tens of thousands of households in the region were without power for more than a week. (MassLive.com).

Heavy snowfall on trees that had not lost all their leaves lead to numerous power lines throughout the region in late October 2011.(Amherst, October 29, 2011 Nature Conservancy)

Western Mass Electric Company workers restore power in Longmeadow following the October 29, 2011 damage by an earlier snow storm.

The June 1, 2011 tornado caused extensive damage to power lines in many communities of the Pioneer Valley, including this area of Springfield.

7.5.1 VULNERABLE RESOURCES

There are three components of energy and electrical infrastructure – the generation system of power plants, the transmission system of large power lines that transport electricity over long distances, and the distribution system that provides power to individual buildings.

ELECTRICAL GENERATION

There are approximately 18 power plants located in the Pioneer Valley, with five of these producing over 100 megawatts of power, shown below.

Table 7-7: Largest 5 Power Plants in the Pioneer Valley by Megawatt Production

Plant	Town	Type	Electric Generation (megawatts)	Notes
Massachusetts Municipal Wholesale Electric Company – Stony Brook Power Plant[18]	Ludlow	Gas	530	Normal capacity is 354megawatts, with the ability during peak times to generate additional power
Consolidated Edison of Eastern Massachusetts – West Springfield Facility[19]	West Springfield	Gas	351	Facility only generates power during times of peak usage
Berkshire Power Company Power Plant[20]	Agawam	Gas	272	-
Masspower Facility[21]	Springfield	Gas, oil	262	-
Northeast Generation Services Company – Mount Tom Facility[22]	Holyoke	Coal	147	-

In addition to these larger energy plants, there are smaller plants that generate anywhere between approximately 1 and 30 megawatts of energy. These plants include a range of generation methods, such as the Chicopee Hydroelectric Plant along the Chicopee River, the Winsor Dam Electric Station next to the Quabbin Reservoir in Ware, or the Collins Hydroelectric Facility in Hampden. While these plants do not produce energy on the same scale as larger facilities, they are often renewable energy based, and because of the beneficial effects they have regarding GHG emissions, their protection is an important component of adapting to climate change.

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[18] http://www.mmwec.org/stony-brook.html

[19] http://www.wmeco.com

[20] http://www.nteenergy.com/About-Us/clients.html

[21] http://www.bg-group.com/MediaCentre/PressArchive/2007/Pages/040207-sx.aspx

[22] http://www.nu.com/aboutnu/timeline.asp

ELECTRICAL TRANSMISSION AND DISTRIBUTION

Detailed information about specific transmission lines is not available due to security concerns. However, overall the distribution system in the Pioneer Valley is operated by the ISO New England Inc, a non-profit organization that operates New England's power transmission system. ISO also creates forecasts of future annual energy use and peak loads, which it publishes in its annual strategy planning report. The ISO also plans for upgrades to individual transmission lines in its system, which are discussed below.

Regarding the distribution system, the majority of the region's local power lines are above ground, with small sections buried in more urban areas, such as Springfield.

7.5.2 THREATS

Extended and widespread loss of electric power is proving to be one of the most costly and frustrating consequences of severe weather, and will only increase as climate change worsens. Adaptation strategies to reduce the vulnerability of electrical generation, transmission, and distribution systems are essential to helping restore everyday life after a bad storm.

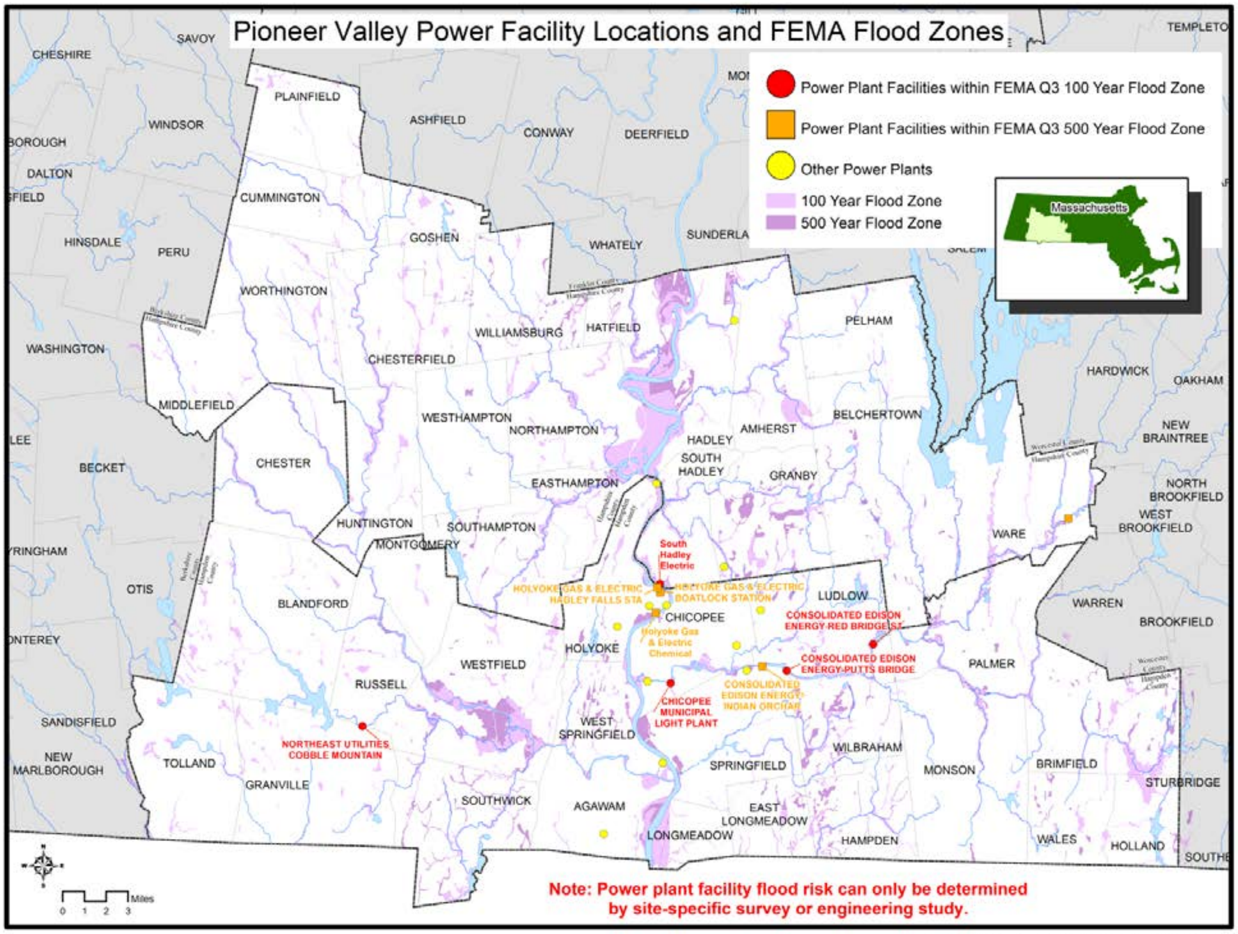
ELECTRICAL GENERATION

The need for power plants to be located near water sources for cooling purposes, such as the NGSC Mount Tom Power Plant in Holyoke, makes them frequently at a flooding risk. As shown on the map below, five of the region's power plants are located within the FEMA 100-year flood plain, and an additional four are located in the 500-year flood plain. It should be noted that the analysis in this plan does not take into account any property-level flood protection measures that may have been undertaken to protect individual power plants from flooding, even while the rest of their surroundings may be greatly affected by floods. This plan recommends that a full vulnerability assessment of the region's power plants be undertaken to determine what flood measures, if any, exist at these 9 power plants and ascertain their exact risk due to flooding and climate change. Such an assessment would involve identifying all the potential risks that would cause the power plant to fail, determining how likely these risks are to occur, assessing the human and financial costs that would be incurred due to failure, whether these costs are acceptable. Based on this information, a plan can then be developed to determine what improvements should be implemented, such as increasing flood protection around the power plant.

Similar to other types of dams, the increased flooding and river flows resulting from climate change will place hydrological power plants at a higher risk of damage or failure, placing the Chicopee Hydroelectric Plant along the Chicopee River, the Winsor Dam Electric Station next to the Quabbin Reservoir in Ware, or the Collins Hydroelectric Facility in Hampden at a higher risk.

Electrical generation facilities are also vulnerable to severe weather during periods of extreme heat. During very hot days and extended heat waves, the demand for electric power from air conditioning systems usually reaches historic peaks, and the existing system may be unable to meet this demand resulting in brownouts. This high demand, while it does not pose the same kind of threat of damage to power plants as described above, does have a similar effect because service to the customer is disrupted.

Figure 7-5-1: Pioneer Valley Power Facility Locations and FEMA Flood Zones



Prepared by Pioneer Valley Planning Commission, December 2012.

Based on FEMA data, there are five power plants in the Pioneer Valley located within the 100-year flood plain – Northeast Utilities at Cobble Mountain, Chicopee Municipal Light Plant, Consolidated Edison at Putts Bridge, Consolidated Edison at Red Bridge Street, and South Hadley Electric Power Plant.

Additionally, four power plants are located within the 500-year flood plain – Holyoke Gas and Electric Hadley Falls Station, Holyoke Gas and Electric Boat Lock Station, Holyoke Gas and Electric Chemical Plant, and Consolidated Edison Energy at Indian Orchard.

ELECTRICAL TRANSMISSION AND DISTRIBUTION

A primary threat facing the distribution system is breakage from ice accumulation or branches and trees falling during a severe storm. Since it is very difficult to keep this from occurring with raised power lines, the most frequently discussed strategy for addressing this threat is to bury the power lines underground. In some urban parts of the Pioneer Valley, electric lines are currently located underground. Consequently, much of downtown Springfield had power following the October 2011 storm, while areas with overhead wires lost power. However, the cost and resources involved in the burying of power lines in less densely developed areas is significant.

Western Massachusetts Electric Company estimates that the typical cost of an overhead electrical distribution system is approximately $600,000 per mile, while the cost for a comparable underground system is roughly ten times that cost, or about $6 million.[23] In 2009, the Edison Electric Institute released a study showing that the cost of buried power lines is generally 5 to 10 times that of overhead wires; however, as the density of development increases in urban areas, the cost efficiency benefits on a per capita basis increase.[24] Significantly, buried electrical systems require more maintenance than overhead systems and so wind up being more expensive over time. As a compromise and economic alternative to the complete burial of electrical infrastructure, critical segments of the electrical system can be selected for maximum utility and return on investment. Eastern Massachusetts municipalities have partially buried distribution systems, including Concord, Wellesley, Bedford, Duxbury, Nantucket, Holden and Needham.

In regards to regional transmission lines, the primary threat is the increased usage and power needs of the region due to population increases and more temperature extremes from severe weather and climate change. ISO New England creates annual projections of energy demand for New England. These predictions, shown in Table 7-X indicate the regular increase in energy demand over the past twenty years.

To address increased power concerns, the ISO New England regularly makes improvements to the transmission system in Western Massachusetts. These improvements, outlined in their annual Regional System Plan, include: [25]

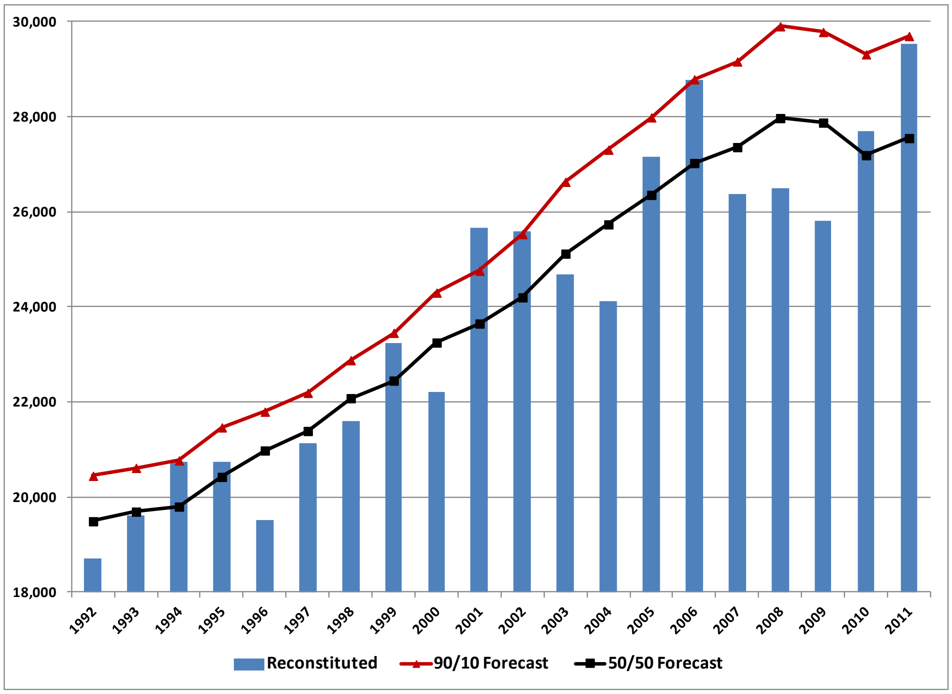
- Construction of new transmission lines, including a 345 kilovolt line to run between Ludlow, Agawam and North Bloomfield.
- Reconfiguration and splitting of existing transmission lines in order to increase capacity and system redundancy
- Upgrading and replacing of breakers, transformers, and switching stations, including replacement of two autotransformers in Ludlow, a switching station at the Cadwell station, and construction of a new switchyard and second autotransformer in North Bloomfield

[23] http://www.masslive.com/news/index.ssf/2011/11/power_outage_in_hampden.html

[24] Edison Electric Institute, Out of Sight, Out of Mind Revisited, December 2009.

[25] ISO New England, Regional System Plan 2012.

Figure 7-5-2: Actual Summer Peak Loads for ISO New England, 1992-2011



Peak loads in New England have continuously increased in the last 20 years. Each year ISO produces different energy forecasts based on weather scenarios. The 50/50 forecast has a 50% chance of weather conditions meaning more energy will be used, while the 90/10 forecast has a 10% chance of being exceeded due to weather. As climate change effects occur, the 90/10 forecast is likely to become more frequent and energy demand increase at a faster rate. Source: ISO New England Regional System Plan

7.5.3 ADAPTATION STRATEGIES

ACTION: CONDUCT VULNERABILITY ASSESSMENT OF ELECTRICAL GENERATION AND DISTRIBUTION SYSTEMS

In order to know how vulnerable each asset in the electrical distribution and generation infrastructure is, a more detailed assessment should be carried out. The assessment would include site-specific items such as the risks facing each component of the system, the likelihood that these risks would occur, and the financial and human costs resulting from failure.

ACTION: BURY POWERLINES

Investigate costs and feasibility of re-locating power lines underground, on a long-term phased basis. Determine the most cost-effective and resource-efficient locations for electrical line burying projects, to improve the resiliency of the overall electrical grid as much as possible.

ACTION: REDUCE ELECTRICAL CONSUMPTION ON PEAK DEMAND DAYS

Strategies for reducing electric power demand include advisories and requests to customers to reduce energy use on high heat days; encouraging development of more solar photovoltaic installations in the region, which typically generate their maximum output on summer days; home energy audits to help residential customers use less electricity; and cooperative efforts with commercial customers to balance demand for industrial and retail uses.

7.6 BUILDINGS AND THE BUILT ENVIRONMENT

Buildings and other structures can be significantly affected by weather extremes associated with climate change. Significantly, a greater proportion of the region's people of low-income and ethnic minority backgrounds live in buildings that are at risk of flood damage than the region as a whole.

The Pioneer Valley is fortunate in that it has no ocean coastal areas, as there are for numerous municipalities in the state, in which sea level rise and storm surges are the leading threat to buildings. In this respect, the proportion of the region's buildings and built environment may be considered to be relatively at lesser risk than coastal areas of Massachusetts. However, tornados, high winds, ice storms and heavy downpours have caused considerable damage to buildings in the region in recent years, and this trend is expected to continue.

Westfield: Commercial buildings on Route 20 damaged by flooding from Tropical Storm Irene. August 29, 2011. Source: Masslive.com

All types of public and private buildings are subject to extreme weather and flooding:

- Commercial
- Residential
- Industrial
- Institutional
- Governmental

In addition to buildings, the "built environment" includes facilities for telecommunications and solid waste recycling and disposal.

FLOOD INSURANCE RATE MAPS (FIRMS)

One of the most significant threats to buildings in the region is the lack of updated information about areas at risk for flooding. Flooding also has serious economic consequences. Damage to property and infrastructure is costly to public and private owners. Also, if municipalities do not meet certain flood control benchmarks, they are not eligible for flood insurance. Without insurance, property owners may incur huge costs for preparation, maintenance, and repairs after flooding.

Beginning in 1968, the U.S. government began producing Flood Insurance Rate Maps (FIRMs), which are used to determine flood insurance rates. (They are now often referenced in zoning codes and other local regulations as well.) Communities use these FIRMs, to receive reduced insurance rates for properties that may be in flood-prone areas. These FIRMs present an estimate of flood risk for specified geographic areas based on equations that account for local topography, proximity to water bodies, past flooding and precipitation history. However, in many cases these equations and in the information they utilize are outdated; this is because they do not incorporate the large proportions of impervious surfaces that have been created and the increased precipitation that has occurred during the past 20 to 30 years in our region.

In recent years, approximately 20% to 30% of damage claims in the region were for buildings outside of FIRM-designated flood zones—a strong indication that maps and calculations are outdated. In 2007, FEMA began a national process to update all its flood insurance maps. This effort will take many years, and it could be some time before the maps of the Pioneer Valley are updated. In the mean time, insurance coverage and payment decisions are being made on the basis of 30-year old maps and calculations. For example, FEMA has directed the City of Holyoke to continue using its 1979 Flood Insurance Rate Map until 2014.

7.6.1 VULNERABLE RESOURCES

The vulnerabilities of buildings and structures in the Pioneer Valley are similar to those statewide, with the exception of seawater flooding, which is limited to coastal areas. Therefore the statewide building vulnerability assessment provided by the Massachusetts Climate Adaptation Report of 2011 is relevant to this region: "Building design standards are based on historic climatic patterns. As climate patterns are likely to be very different in the future, the existing built infrastructure in the state could be adversely affected. Thermal stresses on building materials will be greater, cooling demands will be higher, existing flood-proofing may be inadequate, floodplains may extend to areas with unprotected structures, heat island effects may increase…"

Flooding is a primary risk to buildings in the Pioneer Valley.

- 10% of the region's area is a 100-year flood zone, but many of these areas are urbanized with larger population densities than the regional average.
- 2% is a 500-year flood zone.

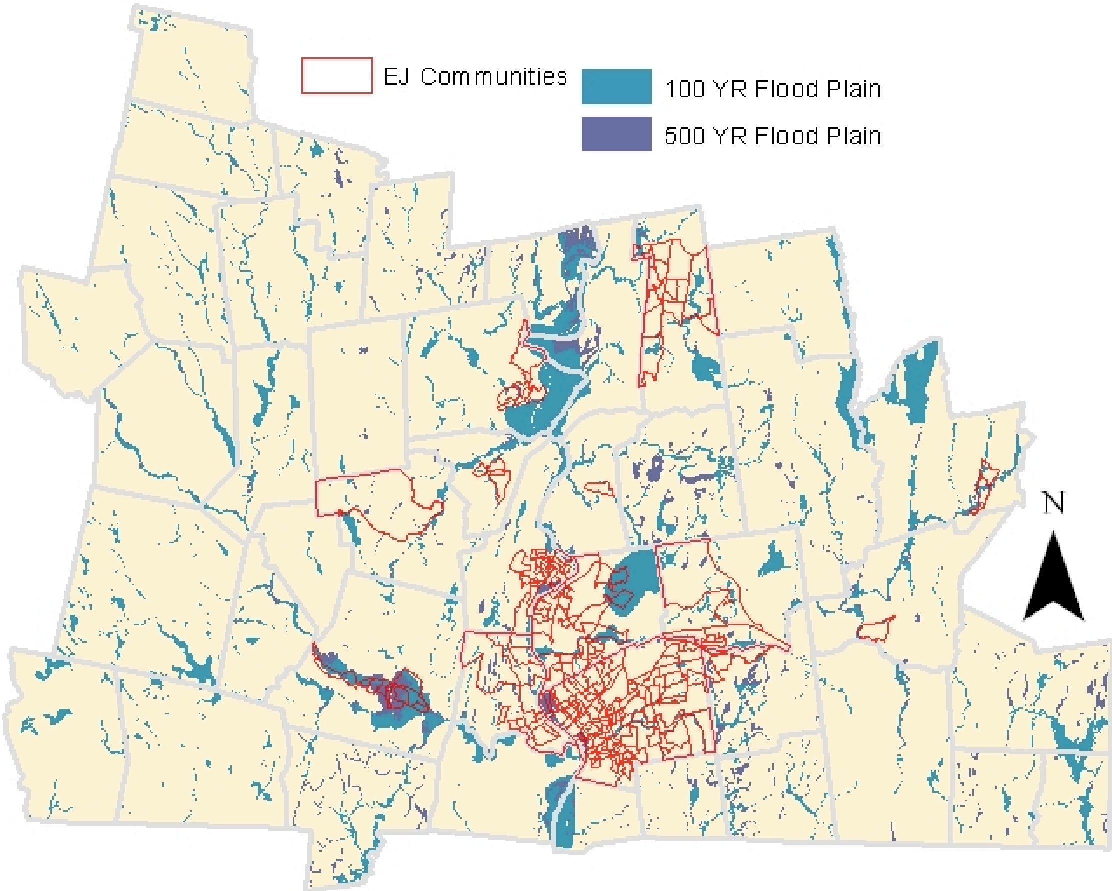
RISK TO ENVIRONMENTAL JUSTICE POPULATIONS IN THE REGION

Climate change will have a disproportionately adverse effect on specific populations which are more susceptible to severe weather. Vulnerable populations include those with disabilities, the elderly, and children, and those who may not speak fluent English.

Flooding, in particular, is a greater risk in the region in areas where low-income and ethnic minority residents live in greater proportion than the regional average (known in federal regulations as Environmental Justice, or "EJ" communities).

- Flood plains in the region are 48% of the land area of EJ communities, versus 14% of the land area in non-EJ communities and 10% for the regional average. The greatest concentrations are in Westfield.
- Several EJ communities in the region are entirely within 100-year flood plains.

Figure 7-8: Flood Zones and Environmental Justice Neighborhoods in the Pioneer Valley



Source: Pioneer Valley Regional Transportation Plan 2012 Environmental Justice Census Blocks and FEMA Flood Zones.

Flooding of EJ communities is a significant concern to the built environment because flooding affects public health, public safety, as well as public and private property. Chronic flooding can lead to damp basements, which harbor mold and affect structural soundness. Flooding can also impair the quality and availability of locally produced food. Flood water may carry raw or untreated sewage, as well as chemicals, petroleum products or other hazardous releases from upriver or upstream facilities. Damage caused to buildings can make them unsafe or undesirable places to live or work; "flood blight" can decrease property values and tax bases.

TELECOMMUNICATIONS

The vulnerability of telecommunications buildings and structures is similar to that of the entire state. The vulnerability assessment of the Massachusetts Climate Adaptation Report (2011) is: "Information and communications infrastructure that could be affected by climate change effects include mobile and fixed radio, TV and cellular towers, satellite dishes, central office facilities, switching and base stations and foundations, manholes, underground pits, and thousands of miles of surface and subsurface wires, cables, and conduits. Telecommunication networks are classified as either fixed (e.g., telephone and cable services using copper wire, coaxial cable, or fiber optics) or mobile (e.g., cellular and satellite connections). Information and communication technology services can be broken down into telecommunication services (broadband, mobile voice and data, and fixed voice) and broadcast services (television and radio)."

In the Pioneer Valley, there is one primary local exchange carrier (Verizon). There are two cable TV providers (Comcast and Charter) serving subscribers in the region's 43 cities and towns (MassDTC, 2009). The region has 3 licensed full- power TV stations, about 20 community cable access TV stations (MassHome, 2010)."

7.6.2 THREATS

Flooding is a major concern in the Pioneer Valley. The regional Hazard Mitigation Plan estimates that the damages from a 100-year flood would be higher than any other type of natural disaster.[26] While levees and other hard flood control systems can help prevent flooding, their large cost and potential for failure make them inadequate to address future increased flooding.

Flood plains are a critical component of streams and rivers, as they provide natural flood storage for waterways to exceed their capacity from very large storms. Development has also been located within flood plains, which makes them excessively vulnerable to large storms that naturally flood these areas. With increased severe weather, the risk to development in flood plains will increase. While it is difficult to remove development that is already located within floodplains, municipalities can employ measures that prevent further development of these areas through their zoning codes.

The primary threats to telecommunications infrastructure from climate change (Massachusetts Climate Action Plan (2011) are:

- Extreme weather events, including flooding, erosion, heavy rainfall, coastal storm surges, and hurricanes.
- High wind, lightning, and ice storms that could damage or destroy utility lines, poles, and towers.
- Increased temperatures and solar radiation that may place greater demands on cooling equipment.
- Wild fires and forest fires during seasonal droughts that infrastructure.

These varied events could adversely affect public safety, emergency, and transportation-related communications, as well as personal and business activities.

7.6.3 ADAPTATION ACTIONS

A variety of adaptation actions are effective in improving the ability of structures in the region to withstand weather impacts. In general the buildings of the region are similar to those of other regions in Massachusetts, so statewide guidance on adaption is appropriate for the Pioneer Valley, as well. The Massachusetts Climate Adaptation Report (2011) states: "Strategies designed to protect existing and future buildings from predicted

[26] Pioneer Valley Planning Commission. "Pioneer Valley Regional Natural Hazard Mitigation Plan." 2009. http://www.pvpc.org/resources/landuse/mit-plans-2011/Regional_Plan_final_12_23_09.pdf

climate change impacts should consider the location of the existing/proposed building, the timing of when a projected climate change impact is expected to occur, the life-span of the structure, historical significance of the existing structure, and the cost and engineering involved with moving, demolishing-recycling, or protecting the structure."

Floods are a leading cause of damage to buildings. There are two general types of proactive strategies for protection from floods: 1) Restrict or prohibit construction in floodplains and other high risk areas, and 2) Protect existing essential buildings from flooding by elevating the structures or creating flood barriers.

ACTION: UPDATE FEMA FLOOD MAPS

Work with FEMA to update flood insurance maps. Areas with historic flooding in recent years should be prioritized and updated first. These new maps should use state-of-the-art technology and practices, including Light Imaging and Distance Ranging (LiDAR) to update topographical contours and updated precipitation to generate floodplain maps that do not take into consideration changing climate conditions. In order to adapt to climate change, FEMA will need to redefine the storms and models used for floodplain mapping, to accommodate larger rainfalls and levels for the 100-year flood. This is potentially a significant challenge, since an expansion of floodplains will generate increased insurance costs for those who live near rivers and streams. Floodplain zoning and increased flood resilience will be important to reducing the development that is affected by floodplain expansion.

ACTION: PERFORM FLOOD VULNERABILITY ASSESSMENTS FOR BUILDINGS AND STRUCTURES USING LIDAR

Use the updated FEMA flooding maps and Light Detection and Ranging (LiDAR) technology to create more precise contour maps that include buildings and structures. The precision of LiDAR allows for floodplain maps to be significantly more accurate than using previous flood mapping and vulnerability assessment methods.

Responsible Parties: *US Geological Survey and Massachusetts Emergency Management Agency*

ACTION: DEVELOP AND IMPLEMENT IMPROVED FLOODPLAIN ZONING

The adoption of improved zoning to prevent development in flood zones is essential to help minimize damage to reconstructed and new buildings, especially by requiring protection of basements and first floors. Such regulations would not apply to existing buildings, but would be required for rebuilding or new construction. Example provisions for zoning code for construction in a flood zone include:

- Prohibit all structures in the regulatory floodway.
- Set minimum heights for lowest floors, scaled to flood risk and historic flood levels.
- Prohibit storage of flammable and hazardous materials.
- Protect onsite sanitary sewer/septic systems.
- Preserve wetland areas to create flood buffer areas around buildings.
- Preserve and maintain natural stream channels and sufficient bank width.
- Requirements for building and electrical inspections following a flood.

Further examples and standards are available in the American Society of Civil Engineers 24-05 design standards document.[27]

Responsible Parties: *US EPA, Massachusetts Department of Environmental Protection, municipal public works departments, private property owners*

ACTION: ENCOURAGE INSTALLATION OF ENCLOSURES FOR ROOFTOP EQUIPMENT TO PROTECT AGAINST SEVERE WEATHER

ACTION: PERFORM BUILDINGS CLIMATE CHANGE FEASIBILITY ASSESSMENTS

Many property owners would benefit from an assessment of the vulnerabilities their buildings face from climate change. Such assessments could be incorporated into existing home energy audits, now available in the region through the electric utilities' MassSave program. This would help owners improve the resilience of their homes by providing a cost/benefit analysis of existing buildings to determine whether it is more effective to fortify them for safe use or make plans to demolish them. Ideally, this action will be done proactively before a severe weather event, but should also be part of the post-storm structural analysis of damaged buildings.

ACTION: USE GREEN INFRASTRUCTURE BUILDING COMPONENTS TO ABSORB ADDITIONAL PRECIPITATION AND DECREASE COOLING NEEDS

Buildings that use green infrastructure measures to reduce wastewater and energy needs help reduce public demand for these services, which is a benefit to communities. Municipalities may wish to consider incentives for property owners to retrofit their properties.

ACTION: IMPROVE RESILIENCE OF TELECOMMUNICATION FACILITIES

A series of actions to help maintain telecommunications services during extreme weather events are recommended.

- Assist in inventory of communications facilities for vulnerabilities to climate change.
- Work with municipalities to incorporate climate change concerns into telecommunication facility design standards for local requirements for telephone pole placement, cable television service, cell tower placements and other related items.
- Assist in development of emergency plans for rapid repair of telecommunications infrastructure during climate events.
- Facilitate development of municipal emergency communications plans.

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[27] US Federal Emergency Management Agency. "Highlights of ASCE 24-05." http://www.fema.gov/library/viewRecord.do?id=3515. Accessed October 14th, 2012.

ACTION: *IMPROVE THE DESIGN CAPACITIES OF SOLID WASTE FACILITIES TO WITHSTAND SEVERE WEATHER*

Promote measures to ensure that all solid waste and hazardous material facilities are sufficiently protected against possible storms, natural disasters, and flooding risks, including.

- Use LiDAR and other technologies to identify solid waste land fills and hazardous waste sites that may be vulnerable to flooding.
- Ensure future siting of facilities include assessment of flood risk and locations outside of high risk flood areas
- Develop a regional contingency plan for household hazardous waste collection during flood events

7.7 HUMAN HEALTH AND SAFETY

Human health and safety in the Pioneer Valley will be significantly affected by climate change. Climate change consequences with direct impacts on humans include excessive and sustained heat, floods, insect-borne illnesses, damage to infrastructure and uncertainty of emergency response capabilities in natural weather related disasters. Yet this aspect of climate change planning is often an afterthought, with actions tending to be reactive in nature.

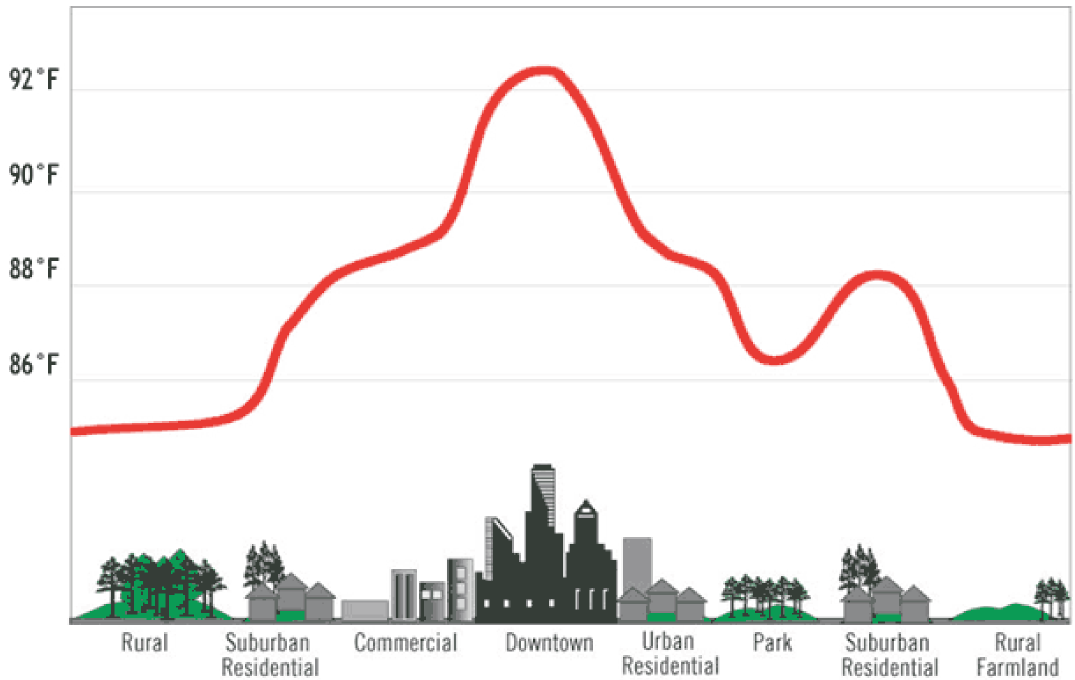
Because of historic settlement patterns in the region, large numbers of people and the urban cores of the region's largest cities are located on or near water bodies. As a result, many people live in homes that are in or near flood plains and therefore susceptible to flooding. Thus in addition to the impacts to infrastructure systems, homes and communities will be impacted. Overall in the region, flooding has increased over time as the region has grown and development becomes more widespread, largely a result of impervious surface drastically increasing during the past 40 years.

The increased storm frequency and increased temperature extremes associated with climate change are affecting public health and will continue to do so in the future. People who are particularly at risk are those already facing illness or disease. Longer growing seasons, and migration of animals and plants, may also result in an increased presence of insects and animals not traditionally experienced in the New England region; this will likely allow the spread of new vector paths for pathogens and increased incidences of transmission. Emergency events, disasters, illness and even death associated with climate change may also result in mental trauma, as could forced relocation or dislocation. Access to affordable counseling or other mental health may be important.

HEAT-RELATED HEALTH CONCERNS

The urban heat island effect is a concern for urban areas, but also possible in any area with a high concentration of impervious surface and sparse vegetation. Concentrated development in urban areas has many heat absorbing materials on the buildings and the ground that retain more solar radiation. This means that temperatures cool less in the evening than in the surrounding countryside. Also, there is less vegetation to provide shade during the day. Higher temperatures place a greater strains on the electrical grid as more and more residents turn to air conditioning for relief. The elderly and the very young are more at risk than the general population; especially those with underlying health conditions. It will be important to clearly communicate heat warnings and advisories, as well as air quality advisories and warnings through out the region, but especially to vulnerable populations.

Figure 7-9: Urban Heat Island Effect

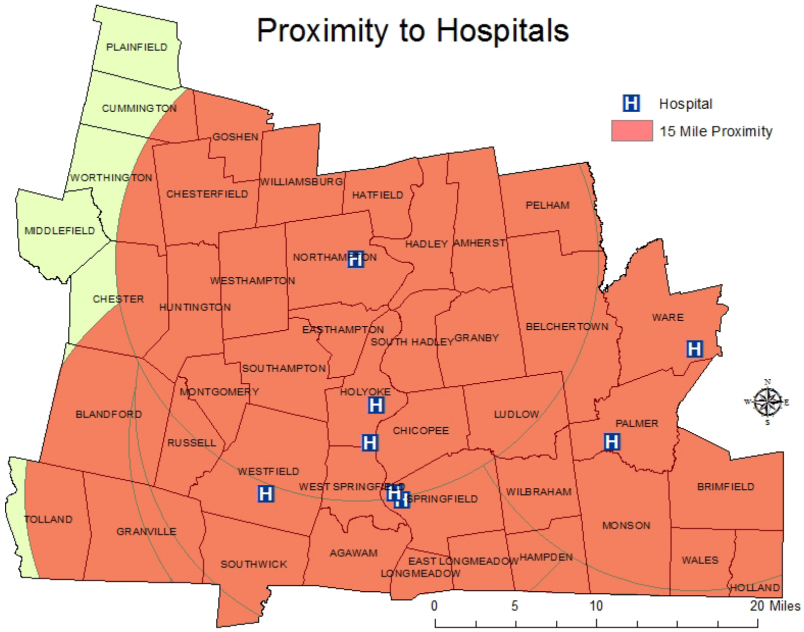


Many of the same actions that reduce water run-off also help reduce the effects of hot weather in urban neighborhoods. These include more trees, for both shade and evapo-transpiration; rain gardens; and green roofs. Source: U.S. EPA 2010

7.7.1 VULNERABLE RESOURCES

In addition to the need for more emergency resources, severe weather will have an effect on critical infrastructure that is important to emergency response efforts. Disruptions to the transportation infrastructure will make movement of emergency management officials difficult, as well as impede the ability to execute evacuations. A lack of functioning of water supply treatment facilities and wastewater treatment plants during a disaster can make distribution of potable water difficult. Much of the communications infrastructure that emergency management officials use to connect with each other and the public during an emergency is reliant on electrical systems that are easily disrupted by storms. According to the Pioneer Valley's Hazard Mitigation Plan, many of the region's emergency operations centers, used to command response efforts during a disaster, are located within the 100-year flood plain, as are many ambulances, town halls, and electric substations. The vulnerability of this infrastructure could make response to emergencies difficult.

Figure 7-10: Regional Hospitals and Proximity to Municipalities



The Pioneer Valley region has seven hospitals with critical care emergency rooms. These hospitals are relatively accessible to most of the region, though people in outlying communities and hill towns face more weather-related access difficulties than those in urban areas.
A 15-mile proximity buffer is shown from each hospital.

7.7.2 THREATS

Climate change will bring about increased occurrences of severe weather, and thus more natural disasters and emergencies. Emergency preparation is a critical aspect of being resilient to disasters and climate change, and this is a large area of focus by emergency management officials and volunteers in the region. For example, the Commonwealth of Massachusetts and U.S. Department of Homeland Security currently fund a wide variety of projects in the Pioneer Valley pertaining to ensuring its municipalities are resilient to emergencies, through addressing evacuation, sheltering, and emergency communications. Adaptation strategies should focus around preparation for emergencies, improvement of response efforts, and addressing the needs of vulnerable populations.

The effectiveness and efficiency of emergency response efforts will be affected by the effects of climate change, due primarily to the increased severity of flooding and severe storms. Disasters will require more resources applied to relief and response efforts, for items such as food and health supplies provided to shelters, staffing of shelters with volunteers, and the number of professional emergency management officials need on staff during a disaster.

INJURY AND ILLNESS

Climate change will have various effects on human health and weather-related illnesses, primarily due to the increased occurrence of extremely hot days and poor air quality. Specific adverse health impacts include the following:

- **Heat Stroke –** Climate change will bring more days with higher peak and record temperatures—days on which people who are not able to cool themselves adequately experience heat stroke. The increased number of high-temperature days increases the incidents of heat-related illnesses, as well as stress and exhaustion. Significantly, heat-related illness and stress affects a disproportionately higher percentage of vulnerable populations such as senior citizens and low-income residents. The urban "heat island" effect, as well as the more concentration populations in cities, means that the greatest number of heat related illnesses will occur in the region's cities and urbanized areas.

- **Asthma –** There will likely be more instances of asthma due to greater concentrations of ground-level ozone, which aggravates asthma, produced by atmospheric conditions on very hot days. This will also increase the intensity of asthma-related health problems for people who already have it. Ground-level ozone is already a significant problem in the Pioneer Valley which will get worse. This is because warmer weather leads to increased ground-level ozone, In the Northeast, air quality modeling estimates increases in ozone levels during 8-hour daily maximums of 10% under the NECIA Low Emissions Scenario and 10% to 25% under the High Emissions scenario. In addition, there is fine particulate matter (PMT) in the air. Both PMT and ground-level ozone result in increased occurrences in asthma, bronchitis, and emphysema. Massachusetts already has the highest rate of adult asthma in the United States, and therefore can be expected to worsen because of the effects of climate change.

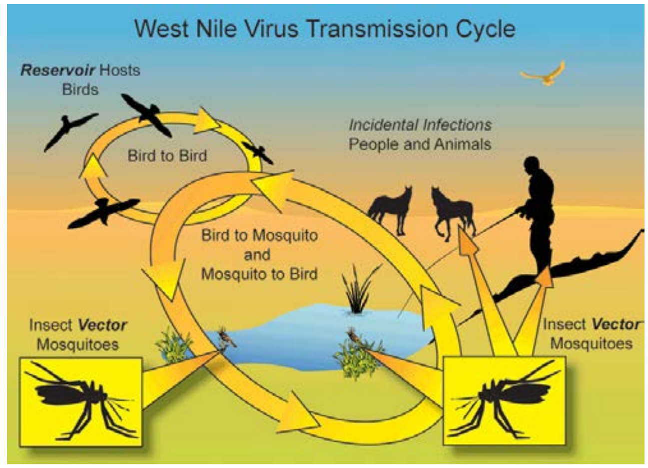
- **Allergies –** Allergies to pollen are exacerbated by air pollution. Increased carbon dioxide in the atmosphere is expected to result in more pollen production in the Northeast, which will increase the frequency and intensity of allergy symptoms for existing sufferers (17% of the population, according to national average). Many people who previously did not experience allergy symptoms will likely have some reaction in the future. Milder winters and continued warming trends since 1965 have been linked to earlier flowering and leafing for three woody perennials in the Northeast (grape, apple and lilac), and so earlier flowering of other species in the Northeast known to cause allergies is also likely. The "heat island" effect in cities and urban areas could cause plants to produce even more pollen than average in these populated areas.

- **Disease From Poor Water Quality –** The reduced water quality due to increased stormwater runoff and combined sewer overflows may lead to the spread of water borne viruses, bacteria, and pathogens. Gastroenteritis, respiratory infections, eye and ear infections, skin rashes, hepatitis, and other diseases occur from direct exposure to waters contaminated by combined sewer outfalls up to 48 hours after a rain storm.

- **Vector-Borne Diseases –** Vector-borne diseases are transmitted by carriers ("vectors") like insects and arthropods. Mosquitoe and tick populations will grow due to increased ponding after storms and floods. These insects carry Lyme Disease and West Nile Virus, which are already at significantly elevated levels in the region and will likely increase. Also, babesiosis, human granulocytic anaplasmosis, tularemia, and

Rocky Mountain spotted fever are spread by ticks. West Nile virus and Eastern Equine Encephalitis virus are spread by mosquitoes.

- Illnesses, particularly respiratory problems, caused by mold in buildings that flood more frequently may increase.
- Degraded surface water quality from sediments, pathogens, nutrients, and pesticides in stormwater and agricultural runoff.



Source: USGCRP (2009)

- Disruption of power and sanitary services, health care, and access to safe food, and which can damage property.
- Increased mental and physical health burdens from the need to cope with more extreme weather, disaster response, and uncertainty.

EMERGENCY IN-MIGRATION AND REFUGEES FROM COASTAL AREAS

While sea level rise is not a direct concern for flooding in the Pioneer Valley, the region's economy and social systems are linked to coastal cities in other regions, especially Boston and New York City. The Massachusetts Adaptation Plan cites a study that indicates a sea level rise of 26 inches in Boston by 2050 could damage assets worth an estimated $463 billion (Lenton et al., 2009). Therefore, severe weather impacts in these and other coastal areas will likely have secondary effects in the Pioneer Valley. Storm surges and flooding, such as those seen during Superstorm Sandy in late October 2012, as well as other storms along the Atlantic coast have required mass evacuations. In the future, it is possible that an even larger mass evacuation in those areas would create demand for emergency sheltering in our region.

7.7.3 ADAPTATION ACTIONS

ACTION: MAKE COOLING SHELTERS AVAILABLE DURING HOT WEATHER

Seek funding for existing and new cooling shelters at municipal buildings and other appropriate private locations for residents without air conditioning during days of extreme heat.

ACTION: INCORPORATE EXTREME WEATHER PLANNING IN EMERGENCY MANAGEMENT PLANS AND DOCUMENTS

Integrate climate change projections into hazard mitigation plans and emergency preparedness. Update "design storms' (i.e. what qualifies as 100-year storm or 50-year storm) used for stormwater calculations, to reflect current and projected conditions. This will involve coordination and integration with the Western Region Homeland Security Advisory Council (WRHSAC), an organization of local and state emergency responders which distributes U.S. Department of Homeland Security funding in western Massachusetts.

Responsible Parties: *US Department of Homeland Security, FEMA, MEMA, Western Region Homeland Security Advisory Council, emergency responders, municipalities*

ACTION: IMPROVE EFFICIENCY OF EMERGENCY RESPONSE

Better efficiency in response to emergencies will be critical to meeting the challenges of more extreme weather. Potential measures in coordination with the WRHSAC include:

- Coordination of evacuation plans between municipalities, through identification of regional evacuation routes, creation of arrangements with bus companies for transportation during an evacuation, and determining populations with special transportation needs, including schools, hospitals, and summer camps.
- Facilitation of agreements between municipalities to identify and plan for regional emergency shelters.
- Improvement of current public warning systems for extreme weather events by email, text or telephone.
- Creation of a communications Joint Information Center through which emergency responders can coordinate response efforts in an organized manner.

Responsible Parties: *US Department of Homeland Security, FEMA, MEMA, emergency responders, municipalities*

ACTION: ADDRESS THE EMERGENCY NEEDS OF THE MOST VULNERABLE RESIDENTS IN THE REGION

Special efforts are needed to protect vulnerable persons during times of crisis caused by weather events. Including:

- Education about how to respond to severe weather events, including floods, storms, heat waves. This could include support for a network of notification procedures for vulnerable populations, cooling centers (gathering places for people to get relief during heat waves) and "check your neighbor" programs.
- Setting up neighborhood cooling centers, at which people can find relief during heat waves.
- "Check Your Neighbor" programs.
- Create a registry of vulnerable populations. To protect privacy, such an effort should rely on self-reporting by individuals and therefore will have limited completeness.
- Consideration of likely healthcare facilities that will be called upon by vulnerable populations so that additional resources can be pre-positioned there in times of crisis.
- Include community and faith-based organizations in outreach and education efforts.

Responsible Parties: *US Department of Homeland Security, FEMA, MEMA, emergency responders, municipalities*

ACTION: IMPROVE EXTREME WEATHER WARNINGS

Establish and improve public warning systems for extreme weather events, including send emergency cell phone text alerts, voice messages, email, and telephone "robo calls."

ACTION: IMPROVE BUILDING AND LANDSCAPE DESIGN STANDARDS TO ADDRESS THE URBAN HEAT ISLAND EFFECT

- Educate builders and designers about new technologies and new construction materials used in retrofitting—some materials reflect heat rather than absorb it.
- Educate contractors, planners, and designers about the benefits of green roofs, and how to design and implement such installations.
- Incentivize tree planting, and educate neighborhoods on street tree care.
- Offer discounts on trees or plants to be used in urban plantings.
- Help public health boards, building, and zoning commissions draft new rules and regulations that require urban heat island mitigation tools.

ACTION: IMPROVE EDUCATION AND TRAINING FOR DECISION-MAKERS ABOUT PUBLIC HEALTH CONSEQUENCES OF CLIMATE CHANGE

- Provide regional or sub-regional training workshops for professional public health policy makers and providers on climate-induced health risks.
- Collaborate with non-profit organizations for data collection and public health outreach efforts.
- Equip local health boards with up-to-date climatic and health information.
- Offer discounts or subsidies to vulnerable communities for air conditioning, ceiling fans, and other cooling mechanisms.
- Enhance prevention outreach and programs to increase overall public health.
- Enhance mitigation outreach and programs, specifically for respiratory illnesses such as asthma. Certain practices at home and outside can reduce risk.

ACTION: ADDRESS VECTOR-BORNE ILLNESS THREATS

Short-term strategies (from Massachusetts Climate Adaptation Plan (2011) include:

- Continue requiring reporting of human cases and positive laboratory results of vector-borne diseases including diseases that are not currently endemic to Massachusetts.
- Work to improve capacity to respond to vector-borne diseases, streamline and automate reporting mechanisms, and stockpile supplies for prevention (e.g., insect repellent, repellent impregnated work clothing).
- Continue to develop and enhance electronic reporting procedures for laboratories.
- Maintain mosquito surveillance at multiple sites throughout Massachusetts.
- Continue testing to identify other, currently non-endemic, viral agents.
- Educate the public, particularly high-risk groups, about personal prevention practices, and encourage their adoption.

Long-Term Strategies (from Massachusetts Climate Adaptation Plan (2011) include:

- Evaluate a web-based disease reporting procedure for health care providers.
- Support health service providers in expanding their capacity to meet the needs associated with climate change induced increases in vector-borne diseases.
- Use community-based organizations and trade organizations for outreach and education about vector-borne disease risks and prevention.

7.8 FISH AND WILDLIFE

Climate change will have adverse effects on the diverse wildlife of the present-day Pioneer Valley. Wild animals in the region will be affected by a reduction in their natural habitats, due to changes in aquatic habitats, tree species and forest composition, and temperature increases.

In general, the Connecticut River mainstem habitat, which covers most of the region, is not expected to experience any benefits to wildlife species diversity as a result of increased temperatures and precipitation (whereas southern central hardwood and salt march habitats may experience more species).

The Pioneer Valley Connecticut River Watershed Action Plan provides more detailed information in climate change impacts to fish and wildlife in the region. This section provides a summary.

7.8.1 VULNERABLE RESOURCES

The BioMap project estimates that 22 species of fish will be affected by changing stream flows in the region that will occur due to climate change. (Four of these species are already on the state protected species list.) In the late summer, evaporation, heat, and water demand peak at their highest levels and result in rivers and streams having their lowest flow periods of the year. If greenhouse gas emissions continue at current levels, the NECIA predicts that the flow of most streams in the Northeast will be reduced by 10% or more by the end of the century. The period of low flow will also begin earlier and continue later. Low-flow conditions create a threat to the region's fish that live in streams, as they are unable to survive very low water levels. Fish and other aquatic life require streams that are continuous in order to be able to reach proper temperature water at different times of the year, and low-levels in these streams makes this difficult.

American Shad, one of the 22 species of fish in the Pioneer Valley region that is especially vulnerable to climate change. *Source: U.S. Dept Interior <www.usbr.gov>*

As culverts erode, they create significant vertical gaps between streams and the culvert that are difficult or impossible for fish to travel through. According to the Connecticut Climate Adaptation Report, the spawning of alewife fish in the Connecticut River presently occurs 12 days earlier than in the 1970s. The composition of fish in the Connecticut River has also changed, with more sunfish now present. It is speculated that this migration is a result of increased water temperatures. Fish reproduction is tied to predictable flow and temperature conditions. For example, lake trout and whitefish is timed to ice cover, and stream fish lay eggs at a time when the newly hatched young fish can get around the peak flow of snowmelt that occurs in late winter.

As peak snowmelt occurs earlier due to warmer weather, fish reproduction cycles will be disrupted. Many of the region's fish, such as brook trout and lake trout, require year-round access to water temperatures below 70°F. Larger streams and other downstream areas will become less hospitable, as the largest temperature increases will be seen in these waterways. The effect that climate change will have on particular species of fish will depend on the ability of the species to access localized areas of cold water. Fish species living in shallow lakes will also be impacted greatly, while lakes that are deeper than 30 feet tend to stratify during the summer and maintain a cold-water layer near the bottom. These temperature impacts can already be seen in Connecticut, where fish stocks have shifted north to maintain their preferred temperature range (Nye et al., 2009).

Many common bird species in the Pioneer Valley are not projected to see a large impact due to climate change. Such species include the blue jay, American crow, starling, house sparrow, and American robin. However, the preferred habitats of many of these species, including the black-capped chickadee, may be diminished by climate change. For example, hemlock may be at risk due to temperature changes and pests, resulting in corresponding risks to species that rely on this plant, such as the Blackburnian warbler.

The black-capped chickadee, common in Massachusetts, may see its habitat diminished due to climate change.
Source: Massachusetts Audubon Society <www.massaudubon.org/Birds_and_Birding>

Bird species that migrate to the region from the south, such as the American goldfinch, song sparrow, cedar waxwing, and Baltimore oriole, may see a significant decline in their habitat and be more significantly affected.

Despite the potential risks that exist for these species of birds, there is the potential for more southern birds to expand into the region as temperatures increase. Because of this, the NECIA projects that while the composition of bird species in the region, as well as the number of birds within each species, will change, the number of total birds will likely remain the same.

7.8.2 THREATS

The Massachusetts Division of Fisheries and Wildlife report of April 2010 cites the Connecticut River mainstem habitat (spruce-fir forested area) as one of the 22 wildlife habitats in the state in need of conservation to protect wildlife species that are most vulnerable to climate change; the report categorizes the conservation need as "6-medium" on a 7-point scale. The report states: "Overall, it seems likely that a doubling or tripling of atmospheric CO_2 will result in major declines in many of the species that are currently listed as being in greatest need of conservation." Those species at greatest risk if GHG emissions double from 2010 levels by 2050 are: Sharp-shinned hawk, Blockpoll Warbler, White-throated Sparrow, Moose, and Bobcat. If GHG emissions triple by 2050 (the NECIA high-emissions scenario), then the following additional species are at greatest risk: Jefferson Salamader, Blue-spotted Salamander, Bog Turtle, Ruffed Grouse, Broad-winged Hawk, Canada Warbler, Rock Shrew, Indian Moytis, Eastern Small-footed Bat, and Southern Bog Lemming.

7.9 AGRICULTURE AND FORESTRY

Climate change will significantly alter the growing environment for agriculture and natural areas, such as forests. This is especially significant because of the carbon sequestration capabilities of vegetation.

Climate change impacts related to agriculture in the Pioneer Valley will be complex. Approximately one-third of Massachusetts' farmland is located in the region. Therefore, any change to agriculture production capabilities will have effects throughout the Northeast. NECIA projections for 2050 estimate that the growing season in Massachusetts will be 2 to 4 weeks longer that its current duration (mid-May to October), mostly because of warmer weather earlier in the spring. This may provide an opportunity for the growth of crops that require a longer growing season, including watermelons, tomatoes, peppers, peaches, and certain wine grape varieties. However, crops commonly grown in the Pioneer Valley, such as apples, potatoes, cabbage, and greens are adapted to cooler weather and will be adversely affected. Most of these crops require a certain number of cool days per year to properly yield, with an example being many varieties of apple (McIntosh, Empire, and Granny Smith), requiring at least 1,000 hours below 45°F to produce effectively. Others will go to seed early if too hot. The NECIA estimates that the Pioneer Valley will be at risk of no longer having enough cool days for these crops by late century.

"Concurrently, some species will likely increase substantially in habitat," according to Iverson, et. al (2008), in which the authors find "…these include several oaks (red, white, black, and chestnut), sweet birch, and silver maple. Increased habitat for oak could indicate an increased commercial and wildlife resource, but oaks are currently undergoing a regeneration crisis in the absence of fire or other agents that can partially open the canopy."

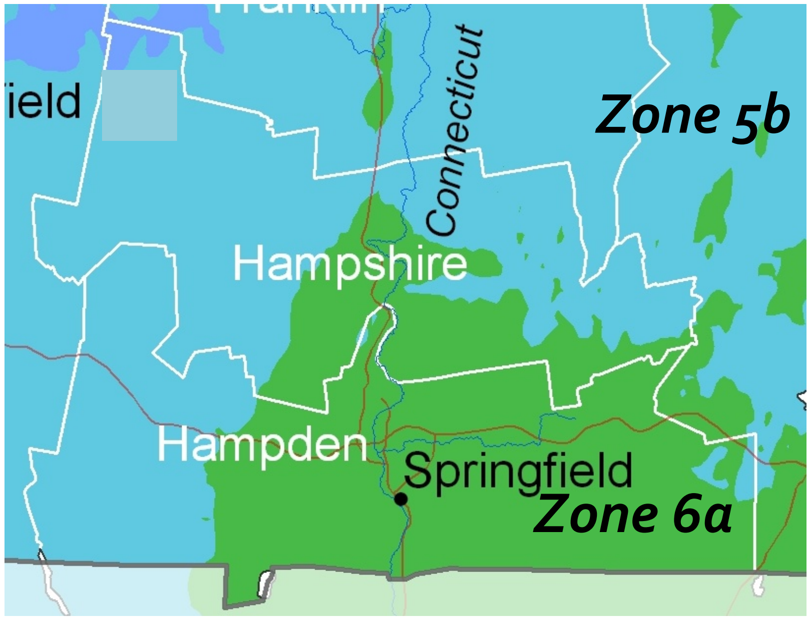
As the climate of the Northeast warms, it will also become more suitable for the Woolly Adelgid, a pest that feeds on the sap of hemlock, which will further endanger hemlock. The Massachusetts Adaptation Plan indicates that the future of other pests such as the emerald ash borer or the Asian Long-horned Beetle are still uncertain.

Table 7-12: Anticipated Changes to Number of Growing Days in the Northeast

	2035-2064		2070-2099	
	Lower Emissions	Higher Emissions	Lower Emissions	Higher Emissions
Onset of summer	-6	-11	-9	-21
End of summer	10	16	12	23
First frost (fall)	1	16	6	20
Last frost (spring)	-8	-14	-16	-23
Length of growing season	12	27	29	43
First leaf (spring)	-3	-5	-7	-15
First bloom (spring)	-4	-6	-6	-15

Source: NECIA 2007.

Figure 7-12: Plant Hardiness Zone Map for Massachusetts



Zone 5b: Average Annual Extreme Minimum Temperature: -15°F to -10°F

Zone 6a: Average Annual Extreme Minimum Temperature: -10°F to -5°F

The United States Department of Agriculture maintains a list of Hardiness Zones for the entire country. Based on the coldest temperatures recorded for a particular area, the zones are indicative of what plants are able to grow there. Prior to 2012, all of western Massachusetts was in zone 5, but using temperature data taken from 1976 to 2005, the USDA placed most of Hampden County into zone 6, meaning that it is capable of growing warmer weather plants. This change is telling of the climate changes that are occurring in the region. Source: USDA

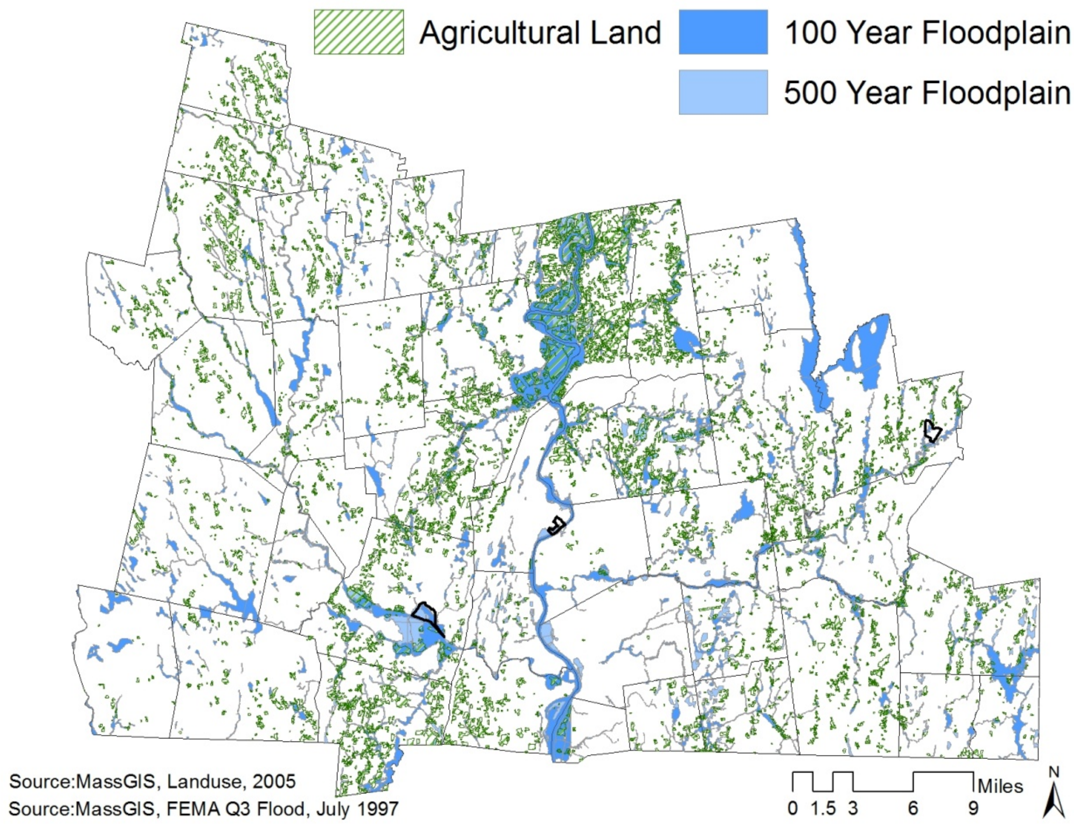
7.9.1 VULNERABLE RESOURCES

AGRICULTURE

Agriculture in the region includes the raising of crops and livestock, both of which will be affected by climate change. As of 2007, there were 1,960 farms in the Pioneer Valley using approximately 169,000 acres of land, or about 14% of the land area of the region. Total agricultural sales that year were $121 million, or about 7.4% of all local sales.

About one-third of all farmed land in the region (65,000 acres) is devoted to raising crops, which are sensitive to high temperature, drought and floods. The principal crops raised are hay, corn, and vegetables (potatoes, sweet potatoes, squashes). Also, fruit crops, such as apples, a regional favorite, require a certain number of chill days to properly mature. With the anticipated increase in the number and severity of heat waves, single-day record temperatures, and reduction in the number of chill days that will occur due to climate change, adaptation measures will be necessary for farmers of most types of crops. These measures may include planting hardier varieties of the crops that are currently being grown, or raising more of the types of crops that thrive in warmer climates (such as tobacco soybeans, and fruits). In addition, irrigation systems may be needed to help crops survive drought periods.

Figure 7-13: Regional Agricultural Lands



The Pioneer Valley is renown for its rich agricultural soil and local farms. There are approximately 53,088 total acres of agricultural land and nearly 2,000 active farms in the region.[i] This includes cropland, nurseries, orchards, and pasture lands. About 20% of farms are within 100 and 500 floodplains, which face flooding, erosion issues, and sediment discharge.

Crops will not only be affected by warmer temperatures but also variations in rainfall. Increased but more variable precipitation will cause more crop flooding and runoff, which removes nutrients from soil. In addition to the damaging effects of increased rainfall, increased periods of drought will be likely, which will require more irrigation of moisture-sensitive crops such as apples, potatoes, and tomatoes. Importantly, 20% of all agricultural lands in the Pioneer Valley are within the 100- or 500-year flood zones. This means they are at greater risk of flooding, which is expected to occur more often in coming years.

Crops will also face more potential susceptibility to weeds and pests, which may spread from the southern United States as temperatures warm. One example is witchweed, a major threat to soybeans, which has already made its way to Massachusetts and is likely to become more prevalent in coming years. A potential pest threat is the flea beetle, estimated by NECIA to be prominent in the region by the end of the century. Increased pests and weeds may require greater use of herbicides and pesticides by farmers, as well as more aggressive mechanical and hand weeding on organic farms – all of which will increase the costs farming operations. According to the Massachusetts Climate Adaptation Plan, climate change effects, will also likely adversely affect agritourism, a significant sector of the Western Massachusetts economy, as tourists and farmstand customers stay home to avoid increasingly inhospitable weather.

Dairy cattle and poultry are the principal livestock that are raised in the region. However, all livestock are sensitive to single days of extreme heat, as well as extended heat waves. In addition, flooding from heavy storms can be a problem for manure management. To adapt, farmers raising livestock will need to invest in structures to shade animals from direct sun, provide adequate ventilation and airflow, as well as misting, for sufficient cooling, as well as manure management.

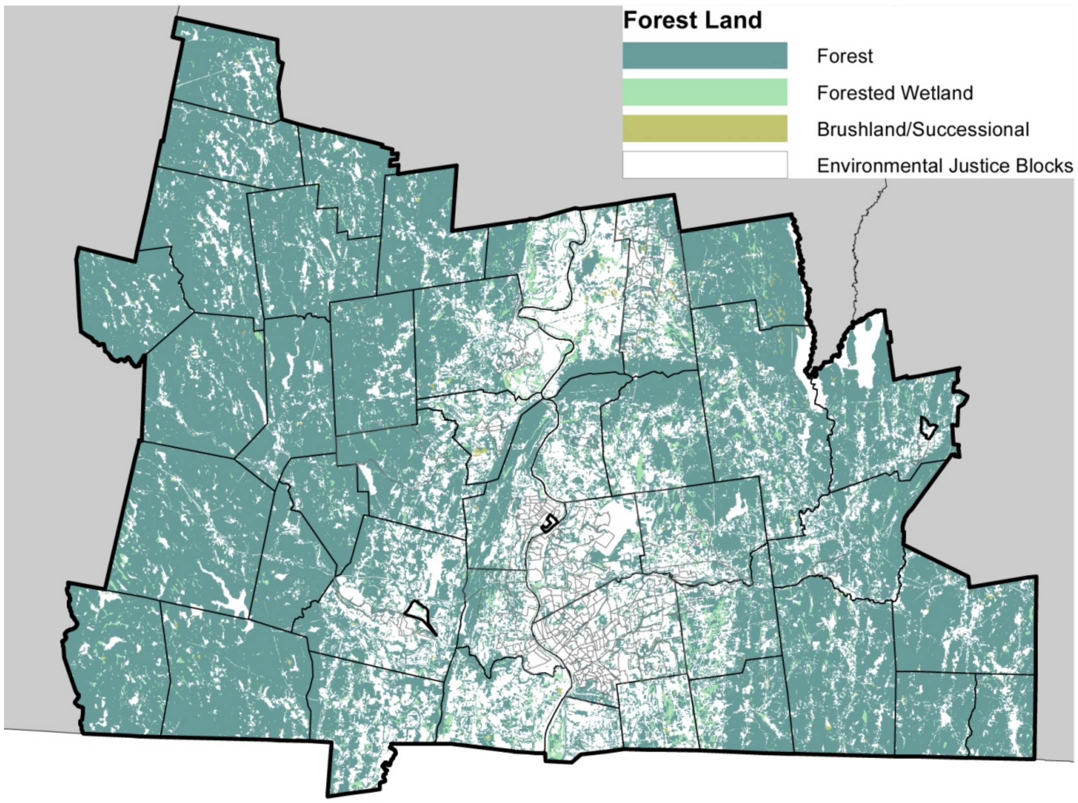
FORESTS

Forest management and conservation are essential adaptation activities, as well as GHG mitigation measures. As the Massachusetts Climate Change Adaptation report notes: "Intact forested watersheds, wetlands, and rivers support clean drinking water and help water suppliers avoid the need for billions of dollars of water purification infrastructure and operations."

Significantly, large areas buffering the Quabbin Reservoir in the eastern area of the Pioneer Valley are managed forests. Forest vegetation is also an important carbon sink that absorb green house gases.

The economic role of forests is critical. Statewide, forest harvesting directly supports 3,700 jobs for foresters, loggers, sawmill workers, and wood processing plant workers in Massachusetts; the wood products industry produces over $385 million of goods annually (Mass. Climate Change Adaption Report 2010).

Figure 7-14: Regional Forests



Most of the region's forest is composed of hardwood trees, such as maple, beech, and birch trees. There is over 520,000 acres of forestland in the region. Higher elevation areas are home to coniferous species and habitat. From this map, one can see that there is sparser forest cover in our more developed areas, a concern for climate risks such as the urban heat island effect.

Biodiversity of forested areas is critical to their ability to adapt to climate change. As the state Climate Change Adaption report states: "For a forest ecosystem to maintain its biodiversity, it should be able to absorb small perturbations, prevent them from amplifying into large disturbances (resistance), and return to the original level of productivity, function, structure and, in some cases, species composition following a disturbance (resilience). The resistance and resilience of ecosystems are dependent on their sizes, conditions and landscape contexts."

The most common tree species found in the Pioneer Valley include various types of pine, as well as maple, beech, and birch trees. Overall, the maple, beech, and birch trees are relatively robust and projections indicate they will be able to survive projected climate changes. However, the region's pine trees are more sensitive to climate change and their ability to overcome temperature increases is more questionable. Hemlock is a critical aspect of the region's forests that provides dense shade along stream banks and cools waterways. The habitat that is suitable for hemlock is projected by the NECIA to see a significant decline in the next 100 years.

7.9.2 THREATS

FORESTS

Forests in the Pioneer Valley will be adversely affected by climate change in several ways. The U.S. Department of Agriculture estimates that 63% of Massachusetts' total land area is forested; this proportion is significantly greater in the Pioneer Valley. Continued patterns of residential and commercial development will result in the loss of (Massachusetts Audubon Report "Losing Ground IV" 4th edition 2005 to 2009 <www.massaudubon.org/our-conservation-work/community-outreach/sustainable-planning-development/losing-ground>)

In the remaining forested areas, the composition of tree species will change. The Massachusetts Climate Adaptation Plan projects that the spruce-fir trees will likely disappear, while red spruce and balsam fir will likely be under increasing stress. Increased atmospheric CO2 and warmer weather may actually result in an overall increase in the growth of certain trees in the region. Most tree species currently in the Pioneer Valley are able to sustain variations in climate, though climate change will likely result in less than ideal conditions for them that will lead to increased stress on their growth. As climate change occurs, the likelihood that new species of trees being introduced into the region's forests increases as well.

7.9.3 ADAPTATION NEEDS

ACTION: PROMOTE ALTERED CROP VARIETIES

Consider assisting crop farmers in making changes to their crops varieties and rotation to those that may be more suitable for warmer weather and variations in precipitation.

7.10 REGIONAL ECONOMY

In addition to the economic impacts to other sectors mentioned in prior sections, the regional economy is geared to numerous recreational activities that are popular in the Pioneer Valley. These activities depend on specific weather conditions and will therefore be directly affected by climate change. These include:

- **Winter Recreation:** For traditional New England winter recreation, such as skiing, snow boarding, and snowmobiling, the number of days with snow is estimated to decrease. There are no major downhill skiing facilities in the region, but cross-country skiing, snow boarding, tobogganing and ice skating are popular at parks and conservation areas throughout Western Massachusetts. Higher temperatures will result in snow and ice conditions that are less desirable for these activities. The number of days with no snow on the ground is estimated to increase 4 to 15 days per year. Snowmobiling and cross-country skiing will be the most impacted since they cannot rely on man-made snow. The NECIA projects that the region will experience anywhere from a 50% to 80% decline in snowmobile season by mid-century (2035 to 2069).

- **Ice Fishing and Skating:** Rising temperatures in the winter and spring will result in the earlier thawing of surface ice. Since 1850 to present, the thawing of lakes has occurred nine days earlier in northern portion of New England. This thawing will reduce the potential for ice fishing, as well as skating on ponds and lakes.

- **Fishing and Boating:** Increased severe weather will result in erratic water levels, potentially making boat docks on streams and lakes unusable. In addition, adverse impacts to fish populations (Wildlife Section) will potentially reduce the opportunities for fishing.

- **Bird and Foliage Viewing:** Changes to the region's forests will create reduced habitat for birds and potentially lead to decreased numbers of certain species. Warmer weather later in the year will also lead to trees losing their leaves later in the year and hinder the viewing of leaf changing, a primary activity associated with the region's fall season and economy.

SOURCES

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FEMA: Flood Hazard Mapping. <http://www.fema.gov/plan/prevent/fhm/index.shtm#7>

EPA: Heat Island Effect. <http://www.epa.gov/heatisld/>

Urban Heat Island Mitigation Can Improve New York City's Environment: Research on the Impacts of Mitigation Strategies. <http://csud.ei.columbia.edu/sitefiles/file/SSBx_UHI_Mit_Can_Improve_NYC_Enviro%5B1%5D.pdf>

FEMA: Mapping Services Center. <http://www.msc.fema.gov/webapp/wcs/stores/servlet/FemaWelcomeView?storeId=10001&catalogId=10001&langId=-1>

[i] MassGIS, Landuse, 2005

8 RECOMMENDED STRATEGIES

Preventing more severe climate change, and mitigating the affects of the climate change that is already occurring, will require not just a plan, but significant changes in the way we live and manage our communities and businesses. We need clear and workable strategies to reduce our emissions of greenhouse gases (GHGs), to conserve energy and reduce our dependence on carbon-based fuels, to reduce auto travel, and to promote carbon sequestration in forests. At the same time, we need strategies to prepare for, and adapt to, our already changing climate.

This chapter provides a menu of strategies for reduction of greenhouse gas emissions or climate impacts, and for climate adaptation, which are designed specifically for municipalities, homeowners, businesses or regional entities. There are many complimentary climate actions which must be taken by state and federal government, but this plan focuses on local and regional actions.

There are two parts to our Climate Action Strategy: 1) **Mitigation** – to reduce GHG emissions and promote clean energy alternatives; and 2) **Adaptation** – to plan for and adapt to climate changes, including extreme weather events and flooding. The strategies in this chapter are further divided into several categories:

- **Mitigation Strategies for Land Use and Zoning** – to reduce GHGs by promoting more compact development, reducing auto trips, and planting and protecting trees;
- **Mitigation Strategies for Clean Energy and Energy Conservation** – to reduce GHGs by promoting energy conservation, production and use of renewable energy alternatives;
- **Mitigation Strategies to Reduce Transportation Emissions** – to reduce GHGs by cutting vehicle miles travelled and promoting alternatives to single driver vehicle trips;
- **Other Municipal Mitigation Strategies** – to promote community-wide planning and actions, including reducing landfilled waste and emissions
- **Regional Mitigation Strategies** – to coordinate intermunicipal cooperation and action on climate action, and to reduce the impacts of the transportation system and auto emissions
- **Mitigation Strategies for Individuals and Businesses** – to promote homeowner and business "best practices" for energy conservation, clean energy alternatives, tree planting, green vehicle purchases and composting
- **Adaptation Strategies** – to protect critical infrastructure, promote resilience to climate change and extreme weather events, prevent flooding and promote emergency preparedness
- **Bi-state Strategies** – these strategies can be most effective when cooperatively adopted by Knowledge Corridor communities in both Massachusetts and Connecticut
- **Implementation Projects** – these strategies are prioritized to be implemented in the initial "doing" phase of the Sustainable Knowledge Corridor project

Many of the strategies in this section are Cross-cutting Strategies. These strategies serve multiple goals, and cut across more than one of the Element Plans in the overall Sustainable Knowledge Corridor strategy. Cross-cutting strategies are indicated with icons in the table below.

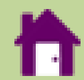
For more details about any of the strategies listed in this plan, please see the ***Climate Action Toolkit*** prepared by the Pioneer Valley Planning Commission. This Toolkit contains detailed fact sheets on many of the strategies listed below, plus model bylaws and policies.

MITIGATION STRATEGIES FOR LAND USE AND ZONING

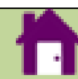
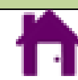
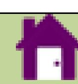
STRATEGY	DESCRIPTION	LEAD ROLE	CROSS CUTTING STRATEGIES
Transit Oriented Development (TOD) Zoning	Promote transit-oriented development by adopting new TOD zoning districts along high-speed rail lines and bus routes, near existing centers, reducing reliance on cars and vehicle miles traveled.	Planning Boards	
Protect and Manage Forests as Carbon Sinks	Conserve large forest blocks to serve as carbon sinks and to protect habitat areas for stressed wildlife. Pursue a goal of "no net loss of forests". Establish Urban Forest Overlay zoning districts. Manage forests to reduce methane releases from rotting wood.	Conservation Commissions, Planning Boards, land trusts, non-profit environmental groups	
Plant Trees	Undertake aggressive programs of community-sponsored urban tree planting to help sequester carbon emissions and reduce urban heat island effect. Adopt municipal zoning standards to require tree planting with all new developments.	Tree wardens, Planning Boards	
Zoning Tools for Carbon Offsets and GHG Impact Statements	Adopt zoning to reduce greenhouse gas emissions from large developments, including carbon offset requirements and greenhouse gas impact statements.	Planning Boards	
Green Development Performance Standards	Set zoning standards for new developments to limit site disturbance, preserve trees, protect farmland, promote pedestrian and bicycle access, reduce auto trips, and promote solar access, landscaping and tree planting.	Planning Boards	
Smart Growth Zoning Tools	Use tools such as Transfer of Development Rights, By-right Cluster Bylaws and Urban Growth Boundaries to promote more compact growth in and around town and city centers, and to protect forest blocks.	Planning Boards	

Bicycle and Pedestrian Access	Adopt zoning and subdivision requirements for sidewalks, bikeway connections and other bike-ped amenities to promote enhanced pedestrian access and safety in new developments.	Planning Boards	
Infill and Adaptive Use	Encourage property owners to bring underutilized or vacant parcels of land back into productive use or to discourage demolition or long-term vacancy of obsolete or underutilzed buildings, by amending zoning in these areas to allow a wider array of uses, densities, and dimensional requirements.	Planning Boards	
Trip Reduction	Require trip reduction plans for large-scale commercial or residential developments to reduce single-occupancy automobile travel through zoning regulations.	Planning Boards	
Track GHG Emissions Reductions	Reduce and track greenhouse gas emissions to meet regional targets.	PVPC	
Low Impact Development Regulations	Adopt low impact development (LID) regulations to reduce stormwater runoff to wastewater plants and waterways.	Planning Boards	
Protect Agricultural Land	Protection of farmland can provide additional carbon sequestration. Work in collaboration with land trusts and municipal Conservation Commissions to secure Agricultural Preservation Restrictions for prime farmlands.	Conservation Commissions, Planning Boards, land trusts, non-profit environmental groups	
Zoning for Climate Change Best Practices	Develop and adopt land use regulations to support climate action best practices, including reduction of impervious surfaces, on-site stormwater retention, tree protection and planting, parking, street configurations (i.e., Complete Streets), lot coverage and height restrictions, green roofs, and solar access. Undertake conformance reviews of existing municipal zoning and subdivision regulations to determine conformance with best practices for reducing GHG emissions.	Planning Boards	

STRATEGIES FOR CLEAN ENERGY and ENERGY CONSERVATION

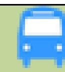
STRATEGY	DESCRIPTION	LEAD ROLE	CROSS CUTTING STRATEGIES
Generate More Clean Energy, Greener Power	Reduce the carbon intensity of our electricity supply. Invest in sustainable energy infrastructure, including solar, wind, hydro, biomass projects, to enhance energy resiliency and reduce emissions. Upgrade and improve the efficiency of power plants, and reduce leaks of fugitive sulfur hexafluoride in the electricity transmission system.	Utilities, municipalities	
Solar and Wind Zoning	Adopt local bylaws for solar and wind zoning to streamline permitting for renewable energy sources and promote passive solar access in siting of new buildings.	Planning Boards	
"Solarize" Neighborhood Programs	Develop neighborhood-based programs to assist homeowners in purchasing photovoltaic solar systems, by reducing costs through bulk purchasing and providing support with tax incentives and rebates.	Municipalities	  
Energy Efficient Building Requirements	Communities can ensure energy efficiency in new construction by adopting a super-efficient building code known as the "Stretch Code" in place of the State's existing "base" Building Code by decision of its governing body following a public hearing.	Municipalities	
Net Zero Energy Buildings	Communities can also provide information to home and business owners to encourage them to surpass energy code requirements and achieve net zero homes and businesses.	Municipalities	
Retrofit Municipal Buildings for Energy Efficiency	Upgrade energy efficiency in older leaky municipal buildings. A municipality can partner with an Energy Service Company (ESCO) or the local utility company to complete energy audits of buildings, then use energy savings from proposed improvements to finance the improvements without any out of pocket expenses for the municipality.	Municipalities	

Fuel Efficient Vehicle Programs	Local governments and private companies should adopt a policy that requires the purchasing of fuel efficient vehicles and/or vehicles that run on cleaner fuels like compressed natural gas, when new vehicles are needed.	Municipalities, businesses	
Regionalized Performance Contracting	Assist smaller communities through a regional energy performance contract. An ESCO will identify and evaluate energy-saving opportunities and recommend improvements, such as new lighting technologies, boilers and chillers, energy management controls, to be paid for through monthly energy savings over several years. The ESCO will guarantee that savings meet or exceed annual payments to cover all project costs.	Municipalities	
Energy Performance Scoring	Utilize energy performance (HERS) scores to gauge compliance with the state "Stretch" Building Code. These HERS scores are based on inspections from qualified professionals which test or audit the expected performance of a buildings' energy use. The score serves as a benchmark for home and building owners to compare how their property is performing, and how it could perform with improvements to the structure.	Municipalities	
Green Builder Programs	Communities can create voluntary builder certification programs offering incentives – such as priority plan review and guaranteed permitting timelines – to homebuilders who follow green building practices in new residential construction. Built Green Colorado in Denver and the Austin Energy Green Building Program in Texas are the largest and best established green building programs in the country. Built Green Colorado was established in 1995 and currently has 111 builders participating in the program. More than 9,000 homes have been completed to date in accordance to the program's guidelines. Participation in the Built Green Colorado program is voluntary. Builders receive marketing materials	Municipalities	

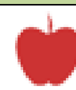
	and recognition in the market.		
Clean Energy Financing District (PACE)	Communities should establish clean energy financing (or PACE - Property Assessed Clean Energy) programs to set up a revolving loan fund that can pay for energy efficiency retrofits or renewable energy systems and receive payment from program participants over an extended period of time. Program costs may be partially repaid by utility subsidies, and often the program participant will see no increase in total monthly bill because the lower energy use will make up for the loan payment. In Massachusetts, state legislation is needed to facilitate PACE programs.	Municipalities	
Solar Gardens	Facilitate development, construction and operation of large-scale cooperatively owned and managed solar facilities for homeowners with properties that are not suitable for individual solar installations, consistent with Mass. DOER SunShot Roof Top Solar program.	Municipalities	
Convert to Natural Gas	Facilitate conversion of heating and hot water systems in public and privately owned buildings to natural gas.	Municipalities	
Energy Efficient Mortgages	Seek support from local lenders for Energy Efficient Mortgages. An Energy Efficient Mortgage (EEM) is a mortgage that credits a home's energy efficiency in the mortgage itself. EEMs give borrowers the opportunity to finance cost-effective, energy-saving measures as part of a single mortgage and stretch debt-to-income qualifying ratios on loans thereby allowing borrowers to qualify for a larger loan amount and a better, more energy-efficient home.	Municipalities	
Energy Efficiency Ratings for Apartments	Boulder, Colorado has adopted SmartRegs that require all rental housing to meet basic energy efficiency standards by 2019. Communities could also maintain energy efficiency ratings databases for use by renters of apartments.	Municipalities	
Energy Efficient Affordable Housing	Incorporate energy efficiency standards into public housing construction projects.	Housing Authorities	

MITIGATION STRATEGIES TO REDUCE TRANSPORTATION EMISSIONS

STRATEGY	DESCRIPTION	LEAD ROLE	CROSS CUTTING STRATEGIES
Sustainable Transportation	Provide more sustainable transportation options including rail, transit, and infrastructure for bicyclists and pedestrians.	Municipalities, MDOT, PVPC	
Safe Routes to School	Work with communities to adopt Safe Routes to School improvements, including continuous and wider sidewalks, improvements to inter-sections and traffic signals, pedestrian connections and snow clearing.	Municipalities	
Safe Biking	Establish safer bicycling routes, including bike lanes and off-road bikepaths.	Municipalities, MDOT, PVPC	
Complete Streets Policy	Adopt municipal complete streets policies. Complete streets are roadways designed and operated to enable safe, attractive and comfortable access and travel for all users, and include the following features: bike lanes; sidewalks; traffic calming devices; pedestrian crosswalks and features; street furniture; bus shelters; bike racks; trees; sidewalk pavers; interconnected streets.	Municipalities	
LED Traffic Signals and Street Lights	Install LED lights for traffic signals, municipal buildings, street lights, and decorative lighting community-wide. New LED traffic signals consume 80 to 90 percent less energy and last up to six to eight times longer than traditional incandescent signals.	Municipalities	
Idling Reduction Campaign	Local governments should implement anti-idling educational campaigns using parents of school-age children as a target population. Steps include: adopting a pledge to reduce unnecessary vehicle idling; and working with the school system to launch an anti-idling education campaign and distribute educational materials.	Municipalities	
Revise Parking Regulations	Revise parking requirements for multi-family and apartment residences to set maximum of 1 car per unit, and offer significant incentives for units with no parking.	Planning Boards	

Highway Tolls and Climate Revenues	Implement tolls on major highways, scaled to weight of vehicle and time of day. Heavier vehicles would pay higher tolls to account for greater carbon emissions; higher tolls during peak periods would reduce congestion and improve system efficiency. Revenues could be targeted to fund regional Livability or TOD Programs (described above).	MDOT, State Legislature	
Pre-paid Regional Bus Fares	Implement pre-paid free bus fare program, similar to that in use in the UMass/Amherst area, by replacing the current farebox share of the cost of PVTA service with employer contributions or local assessments, municipal assessments, state support, tolls on major thoroughfares, or a combination thereof.	PVTA	
Improved Regional Ride Sharing	Improve on regional ride-sharing programs using social media or web-based technologies and measures to increase user trust, such as institutional sponsorship, certification and user satisfaction reports.	PVPC	
Park and Ride Lots	Work with MassDOT to expand the availability of park and ride lots to promote ease of commuter ride sharing.	MDOT, PVPC	
Telecommuting Centers	Establish telecommuting centers, where workers can access computers and the internet, and reduce long commutes to employment centers.	MDOT, PVPC, businesses	

OTHER MUNICIPAL MITIGATION STRATEGIES

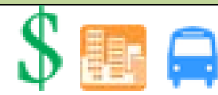
STRATEGY	DESCRIPTION	LEAD ROLE	CROSS CUTTING STRATEGIES
Municipal Climate Action Policy Statements	Adopt municipal policy statements in all 43 Pioneer Valley communities detailing steps each community will take to address GHG emissions and climate action.	Municipalities, PVPC	
Climate Action and Adaptation Plans	Communities should develop and adopt municipal Climate Action and Adaptation Plans to outline and track municipal goals to combat climate change within their own operation and throughout the community. Climate Action Plans often contain several key components: emissions inventories, mitigation strategies and adaptation strategies.	Municipalities	
Emissions Inventories and Tracking	Communities should create an emissions inventory, which is a vital part of Climate Action Plan, and a critical step in determining sources of pollutants and creating records of emission trends. The Mass Energy Insight website contains a free web-based tool to monitor and assess energy use and emissions.	Municipalities	
Reduce Landfilled Waste	Adopt municipal regulations to allow commercial composting and recycling of building materials to reduce landfilled waste. Making cuts in solid waste reduces methane emissions from landfills.	Municipalities	
Capture Methane from Landfills	Communities with landfills should install methane recovery systems, which can reduce the release of methane into the atmosphere from landfills by more than half. A series of vertical wells that are drilled down through layers of decaying matter, horizontal connectors, and a vacuum system can be used to collect and pipe the methane to a central location.	Municipalities	
Municipal Excise Tax Abatements for Zero-emissions Vehicles	Establish a program to eliminate or deeply discount municipal excise taxes on zero-emissions vehicles; municipality would be reimbursed for lost revenue from a source to be determined.	State Legislature, Municipalities	
Municipal Master Plans	Encourage all of the region's municipalities to include sections on climate action and resiliency in their municipal master plans.	Planning Boards	
Green Communities Designation	Encourage all of the region's municipalities to seek designation under	Municipalities, PVPC	

	the state Green Communities Act. The Act creates a program to provide up to $10 million/year (statewide) in technical and financial help to municipalities to promote energy efficiency and the financing, siting and construction of renewable and alternative energy facilities.		
Green Roofs	Promote and incentivize the installation of green roofs on new and existing buildings.	Municipalities	
Reduce Impervious Surfaces	Use green infrastructure to reduce impervious surfaces and capture and retain stormwater on site to reduce flooding and wastewater treatment needs.	Municipalities	
Green Public Projects	Establish municipal policies to incorporate green infrastructure into public building projects, such as schools, town/city halls, police and fire departments.	Municipalities	
Green Zoning Incentives	Create zoning incentives for building green roofs, permeable parking lots, and other green infrastructure.	Planning Boards	
Create Rain Gardens	Create rain gardens to store and infiltrate storm water, as part of public construction projects.	Municipalities	
Create Community and Backyard Gardens	Grow more food in cities, reducing transportation costs and emissions, by promoting community and backyard gardens and urban farms.	Municipalities	
Farm to School Food Programs	Promote programs for schools to buy food directly from local farms, reducing transportation costs and emissions, and providing fresh healthy food to students.	Municipalities	

REGIONAL MITIGATION STRATEGIES

STRATEGY	DESCRIPTION	LEAD ROLE	CROSS CUTTING STRATEGIES
Intergovernmental Compact on Climate Action	Develop an intergovernmental compact or MOU committing communities to specific actions to help regional GHG reduction targets. Seek approval of MOU from all 43 Pioneer Valley communities.	PVPC, Municipalities	
Livability Programs	Create a regional Livability program, using transportation funding streams that support community- and land use- oriented transportation projects, such as pedestrian, streetscape, mixed-use infill, transit-oriented development and transit improvement projects.	PVPC, Municipalities	
Sustainable Transportation Project Criteria	Work with MDOT and the Pioneer Valley Metropolitan Planning Organization to support adoption of sustainable project review criteria for review and ranking of transportation projects in the region.	MDOT, PVPC	
Regional Funding for TODs	Provide regional funding to support development of Transit Oriented Development (TOD) districts. Funds are provided for a variety of uses including TOD planning, site acquisition and clearance, and project development costs.	PVPC, MDOT	
Climate Action Goals in RTPs	Include strategies for reducing greenhouse gas emissions in the Regional Transportation Plan.	PVPC	
Transportation Funding Strategies	Utilize Congestion Mitigation Air Quality (CMAQ) to fund mitigation projects to reduce GHGs.	PVPC, MDOT	
Climate Action Leadership Program	Identify potential climate action "champions" or "ambassadors" with excellent communication and organizational skills to bridge disciplines and constituencies and facilitate progress on mitigation strategies at various levels (individual, business, non-profit, government).	PVPC	
Jobs-Housing Match	Promote a jobs-housing match, with new housing and jobs in central locations to reduce vehicle miles traveled.	Municipalities	

MITIGATION STRATEGIES FOR INDIVIDUALS AND BUSINESSES

STRATEGY	DESCRIPTION	LEAD ROLE	CROSS CUTTING STRATEGIES
Climate Pledge	Ask individuals and businesses to sign a Climate Pledge, to take steps to reduce their carbon footprints.	PVPC	
Promote Telecommuting	Identify job types and industries in the region for which increased telecommuting is viable; identify additional technologies and capacities necessary to support increased telecommuting in those industries; produce materials and conduct a business outreach initiative to employers to encourage their adoption of increased telecommuting.	Businesses, municipalities, PVPC	
Climate Education and Curriculum	Educate homeowners, businesses and residents about how they can reduce their carbon footprints, reduce energy consumption and increase home energy efficiency. Create a curriculum to provide interested individuals, businesses, non-profits and community groups (i.e., churches) with information to understand the likely regional impacts of climate change in various timeframes and the range of actions, programs and funding that are available for actions that can be taken.	Municipalities, Utilities, state and federal agencies, PVPC	
Best Homeowner and Business Practices to Reduce Energy Use	Encourage homeowners and businesses to: • Install Energy Efficient Lighting • Install Clean Energy Alternatives • Build commercial buildings to LEED Standards • Build homes to "Net Zero" energy use standards • Weatherize and Insulate Buildings • Recycle and Compost • Buy Energy Efficient Appliances • Plant Trees • Compost, Don't Burn, Leaves and Other Home Wastes • Purchase a Green Vehicle • Walk, bike or use transit whenever possible • Select LRR Tires • Conserve water, take shorter showers, install greywater systems for yard watering and toilets	Municipalities, Utilities, state and federal agencies, PVPC	

ADAPTATION STRATEGIES

STRATEGY	DESCRIPTION	LEAD ROLE	CROSS CUTTING STRATEGIES
Emergency Intermunicipal Water Connections	Identify options for creating emergency water supply inter-connections with neighboring communities, and seek formal agreements to purchase water in emergencies. Physical, piped emergency connections, and agreements to purchase water, should be put into place in advance of emergencies.	Municipalities	
Update Flood Maps	Work with FEMA to raise priority for update of flood insurance maps in the region, using LiDAR elevation surveys and climate models, and identify at-risk facilities.	PVPC, Municipalities	
Improve Flood Zoning	Adopt improved zoning to prevent new development in flood zones, increase flood resilience of buildings, and provide protection of basement and first floor levels.	Planning Boards	
Increase Flood Resilience	Promote restoration and protection of natural floodplains and flood forests as a natural defense against floodwaters rather than walls, dikes and hard barriers.	Municipalities, PVPC, non-profits	
Inventory, Update, Assess Vulnerability and Protect Critical Infrastructure	Inventory, update and conduct vulnerability assessments of critical infrastructure to flooding and other weather impacts, including energy generation, electrical transmission and distribution, communication networks, drinking and wastewater facilities, roads and highways, railways, dams and flood dikes and healthcare facilities. Take needed steps to improve resilience.	Municipalities	
Storm-proof Infrastructure	Increase resilience of water/ wastewater infrastructure, streets and roads, flood dikes, sewer and water lines, to severe storm events and flooding. Take action to harden and raise the level of infrastructure, as funds become available.	Municipalities	
Plan for Extreme Weather	Integrate climate change projections into hazard mitigation plans and emergency preparedness. Update "design storms' (i.e. what qualifies as	Municipalities, PVPC	

	100-year storm or 50-year storm) used for stormwater calculations, to reflect current and projected conditions.		
Extreme Weather Warnings	Consider establishing a public warning system for extreme weather events, to send emergency alerts to residents by email, text message, or telephone.	Municipalities, PVPC	
Upgrade Stream Crossings, Bridges and Culverts	Pro-actively replace underperforming culverts and bridges with larger structures designed to accommodate floods and promote wildlife passage. Identify and prioritize most important culverts for replacement. Establish pre-designed generic stream crossing designs for different types of sites to be prepared in advance for disaster replacements. Seek federal grants from agencies such as NOAA, USFWS and FEMA Hazard Mitigation grants.	Municipalities, MDOT	
Use Soft Streambanks	Increase use of bioengineering techniques for streambank stabilization, and prevent use of armored streambanks and riprap dumping.	Municipalities, MDOT, US Army Corps of Engineers	
Bury or Protect Powerlines	Investigate costs and feasibility of re-locating powerlines underground, on a long-term phased basis. Remove trees and branches near above-ground lines.	Utilities	
Reduce CSOs and Stormwater	Continue to work to reduce combined sewer overflows (CSOs) by reducing stormwater inputs to combined sewers and separating combined systems. Reduce stormwater by expanding use of low-impact development (LID) and stormwater BMPs.	Municipalities, DEP, EPA	
Adapt to Larger Stormwater Flows	Design stormwater management and treatment facilities and green stormwater infrastructure to have adequate capacity for increased, intensified storm flows resulting from climate change.	Municipalities, MDOT	
Plan for Preparedness	Seek funding for improved preparedness and response, including funding for dam inspection, maintenance and removal, and for acquisition of properties most vulnerable to climate change impacts. Work with FEMA to	Municipalities, MEMA, FEMA	

	increase the availability of hazard mitigation grant funds to smaller communities.		
Educate Town Officials on Storm Response	Educate Boards of Selectmen in smaller rural communities about the need to make environmentally sound, watershed-based decisions when addressing storm impacts to prevent post-storm man-made stream channelization and degradation, of the kind which impacted the Chickley River.	Watershed associations, non-profits, PVPC, DEP	
Climate Bond Bill	Seek Legislative support for a state Climate Action bond bill, similar to the Transportation Bond bill, which will help pay for infrastructure improvements to address climate/weather vulnerabilities.	State Legislature, climate advocacy groups	$
Assist Vulnerable Populations	Educate vulnerable populations about response to severe weather events, including floods, storms, heat waves. This could include support for a network of notification procedures for vulnerable populations, cooling centers (gathering places for people to get relief during heat waves) and "check your neighbor" programs.	Municipalities, PVPC	
Greenbelt and Land Protection	Protect greenbelts, parklands, floodplains and forested areas. Municipal Conservation Commissions should collaborate with non-profit environmental groups and land trusts to protect intact forest blocks, preserve natural flood storage areas and land important to watersheds.	Conservation Commissions, land trusts, non-profit environmental groups, state and federal agencies	
Protect Wildlife and Ecological Connectivity	Identify and protect wildlife migration corridors. Reduce fragmentation of wildlife habitat areas, protect large undeveloped habitat blocks, reduce barriers to fish and wildlife passage.	Conservation Commissions, land trusts, non-profit environmental groups, state and federal agencies	
Protect Water Resources	Provide greater protection to vulnerable water resources, such as coldwater fish habitat areas, intermittent streams, and wetlands, through local bylaws.	Conservation Commissions, municipal Water Departments	
Upgrade Aging Water/Wastewater Infrastructure	Protect and upgrade aging water and wastewater infrastructure, with particular attention to Greenfield type WWTP flood damages, and provide emergency backup equipment.	Municipal water and sewer departments, DPWs	

Green Stormwater Infrastructure	Incorporate green infrastructure into stormwater management, including green roofs, rain barrels, rain gardens, tree box filters and pervious pavement. Use municipal incentives to promote.	Conservation Commissions, Planning Boards, DPWs	
State Loans for Water and Wastewater Infrastructure	Support changes in the State Revolving Fund (SRF) Program, which provides $100 million in low-interest loans to water and wastewater projects, to address climate and weather vulnerabilities, and promote green infrastructure.	State Legislature, DEP, Municipalities	
Cooling Shelters	Seek funding for existing and new cooling shelters at municipal buildings and other appropriate private locations for residents without air conditioning during days of extreme heat.	Municipalities	
Assist in Municipal Climate Adaptation Plans	Assist communities to develop Climate Adaptation Plans to prepare for severe weather events and increase resiliency.	Municipalities, PVPC	
Prepare for Severe Droughts	Prepare municipal water supply systems for severe droughts, including repairing leaks, installing water efficient fixtures, and installing greywater re-use systems for lawns and gardens.	Municipal water departments	
Dam Inspection and Removal	Improve dam inspection and maintenance requirements and enforcement. Remove dams where practicable; where dams must be retained, ensure that high and moderate hazard dams are fully maintained.	Municipalities, state Office of Dam Safety	
Emergency Action Plans for High Hazard Dams	Prepare Emergency Action Plans for all dams with significant or high hazard ratings	Municipalities, emergency management directors, state agencies	
Continue to Improve Levees	Continue work to upgrade and increase resiliency of levees along the Connecticut River.	Municipalities, USACE	
State Funding for Dams	Seek approval for new state program to finance dam inspections, maintenance and remediation	State Legislature, municipalities	
Water Leak Detection	Encourage communities to undertake leak detection programs for water supply lines, to reduce waste of water and energy.	Municipal water departments	

Drinking Water Vulnerability Assessments	Conduct vulnerability assessments and increase resiliency of drinking water facilities. Assessments should look at projected climate impacts on water supplies, including droughts, severe weather events, flooding, changes in temperature, increased water demand due to heat waves and longer growing seasons, increased bacteria or nutrient loading, increased turbidity or eutrophication, dam or pipe failure, and reduced snowpack. Identify priority facilities for replacements and upgrades. Evaluate emergency backup water supplies.	Municipal water departments	
Promote Water Conservation	Promote use of landscaping with native plants, use of rain barrels for stormwater storage and watering, and water conserving plumbing fixtures.	Homeowners, businesses, municipalities	
Stormwater Utilities	Adopt municipal stormwater utility fees to increase incentives for on-site stormwater retention and to raise municipal revenues for stormwater facilities.	Municipalities	
Low Impact Development (LID) Regulations	Adopt LID standards in zoning and subdivision regulations to increase on-site stormwater infiltration.	Municipalities	

BI-STATE STRATEGIES

STRATEGY	DESCRIPTION
Sustainable Transportation	See above
Climate Pledge	See above
Intergovernmental Compact on Climate Action	See above
Livability Programs	See above
Sustainable Transportation Project Criteria	See above
Regional Funding for TODs	See above
Cut GHG Emissions	See above

The following section identifies projects that will be the priority for action in the implementation phase of the Pioneer Valley Planning Commission's efforts under the Sustainable Knowledge Corridor project, funded under the U.S. Housing and Urban Development Sustainable Communities grant.

IMPLEMENTATION PROJECTS

PROJECT NAME	LEAD ROLE
Municipal Climate Policy Statements Seek municipal adoption of policies to: establish municipal targets for tree planting; require LEED Silver ratings for all new municipal buildings and large developments; establish a target for percent of electricity to be purchased from renewable sources, undertake actions to promote climate adaptation and resiliency.	Municipalities
Regional Compact on Climate Change Seek municipal approval of an intergovernmental compact to cooperate in meeting regional GHG reduction targets.	Pioneer Valley Planning Commission, in collaboration with municipalities
Zoning Conformance Analysis and Technical Assistance Program for GHG Reduction Undertake conformance reviews of existing municipal zoning and subdivision regulations to determine conformance with best practices for reducing GHG emissions. Provide a technical assistance program to help communities adopt zoning for GHG reduction.	Pioneer Valley Planning Commission, in collaboration with municipalities
Solarize Neighborhood Programs Establish at least one model neighborhood "Solarize" program to assist homeowners in purchasing photovoltaic solar systems, by reducing costs through bulk purchasing and providing support with tax incentives and rebates.	Pioneer Valley Planning Commission, in collaboration with municipalities
Climate Pledge Create a model "Climate Pledge" for the region and ask individuals and businesses to sign it on the Sustainable Knowledge Corridor website. Monitor and update participation levels on the website.	Pioneer Valley Planning Commission, in collaboration with municipalities

Green Communities Assist 100% of all Pioneer Valley communities to become Green Communities under this state program.	Pioneer Valley Planning Commission, in collaboration with municipalities
Adaptation Plans Include climate adaptation strategies, inventories of vulnerable infrastructure and updated flood mapping in all Hazard Mitigation Plans as they are completed.	Pioneer Valley Planning Commission, in collaboration with municipalities

CROSS CUTTING STRATEGIES ICONS

The following icons are used in reference to issues and strategies also identified in the other nine Sustainable Knowledge Corridor Element Plans, called as "cross cutting strategies". To learn more about the cross cutting strategy as it may pertain to the topics and analysis in the cross cutting Element Plan, visit www.SustainableKnowledgeCorridor.org .

FOOD SECURITY	LAND USE	CLIMATE ACTION
GREEN INFRASTRUCTURE	TRANSPORTATION	ECONOMIC DEVELOPMENT
HOUSING	BROWNFIELDS	ENVIRONMENT

APPENDIX 1: GHG REGIONAL INVENTORY METHOD

GREENHOUSE GAS EMISSIONS CALCULATION METHOD

This appendix describes the methods and information used to develop the Chapter 3 Greenhouse Gas Inventory and Assessment summary presented in Chapter 3. These are three components to the inventory:

1. Regional GHG Inventory
2. Regional Carbon Sequestration estimates
3. Vulcan Project regional carbon emissions

For each of these components, the preparers of this plan made every attempt to obtain the most recent and most accurate data available. The assessment methods for each conform to current best practices for similar climate action planning efforts by state, national and international agencies.

It is important to note that there are several types of greenhouse gases, each with different atmospheric insulating properties that contribute to climate change. Consistent with the Massachusetts Clean Energy & Climate Plan for 2020 and supporting technical analyses, the metrics in the GHG estimates have been normalized by conversion to a unit of carbon dioxide equivalent impact on atmospheric warming, or "CO_{2e}" to provide uniform measures and estimates of GHG effects. In this method, 1 unit of carbon dioxide is equivalent to 1 unit of CO_{2e}. Methane, which has a greenhouse warming effect that is 25 times greater than carbon dioxide; therefore, 1 unit of methane is equivalent to 25 $CO_{2e.}$

A1. 1 REGIONAL GREENHOUSE GAS INVENTORY

The GHG Inventory was developed[i] to estimate and report GHG emissions generated in Pioneer Valley , specifically Hampshire and Hampden counties, and in other areas as a result of electrical demand in the region. This is different from the calculations made in the 2008 Pioneer Valley Clean Energy Plan, which also included Franklin County. This change is only a reflection of programmatic funding that has been limited to the former counties. PVPC is, however, providing support to the Franklin Regional Council of Government's (FRCOG) staff so that they can develop this type of accounting for Franklin County as well.

The protocol was also designed to be easily replicable. As with any data analysis, the inventory needs to be completed with limited staff resources. The method was designed to (a) Portray emissions as accurately as possible in order to provide a measurement tool that can indicate the direction in which the region is heading in response to local policy and programs; and (b) have local and regional policy implications, where actions can be measured using this protocol, over time.

The GHG Inventory is calculated using a mix of top-down and bottom-up methodologies. Top-down methods involve identifying the Pioneer Valley region's share of a state, national or other regional GHG emissions calculation. A simple example of this would be apportioning state GHG emissions by the Pioneer Valley's population share. Bottom-up methods add local data to form a total estimate for the region. An example of this bottom-up method would be adding up the electricity consumption readings for each of the 43 Hampden and Hampshire county municipalities to obtain the total regional consumption of electricity. While it is more accurate to have an inventory based on the bottoms-up method, most data required for the calculation is not available to have a complete census of GHG emissions. Where bottoms-up methods are not possible, the most accurate and useful top-down estimates are used.

The inventory consists of the following formula:

Total $MTCO_{2e}$ = Electricity + Heating + Transportation + Waste + Agriculture

where

- **Total $MTCO_{2e}$** = Total Metric Tons of CO_{2e} greenhouse gases
- **Electricity** = Indirect emissions from power generation to meet electricity use
- **Heating** = Direct emissions from heating with oil, natural gas, propane, and wood in buildings
- **Transportation** = Direct emissions from fuel combustion used in vehicles, trucking and public transit
- **Industry** = Direct emissions from industrial processes
- **Solid Waste** = Emissions related to active landfills and water treatment plants
- **Agriculture** = Methane emissions from livestock food digestion and manure management

Obviously, this inventory cannot provide a comprehensive total of all GHGs that are generated by every possible activity in the region. Activities for which there is insufficient information to produce useful estimates include the GHGs from product packaging, aviation, freight rail service, and passenger rail travel.

This inventory does provide a snapshot of the major emissions and their sources that can be affected by local and regional policy and programs.

A1.1.1 INDIRECT EMISSIONS FROM ELECTRICITY USE

GHG produced from electricity use can be calculated with a high degree of accuracy because the electric utility companies are able to provide consumption data at the municipal level. This electric consumption produces "indirect" emissions because the emissions are produced off-site at power plants that may or may not be in the region.

The electric consumption can then be estimated by using GHG conversion factors that consider the portfolio of power generation for the electric utilities in the region. An energy portfolio will consist of power sources that produce no GHG, such as hydro, solar, wind or nuclear power installations, while others use coal, natural gas and oil to power their turbines and emit GHG's in varying amounts. A GHG conversion factor approximates these indirect emissions by pooling electrical production data from the electric companies and assigning average emissions to the electricity produced in that portfolio.

For the electricity calculation the following parameters were obtained and used in a "bottom-up" approach:

Parameters	Units	Source(s)	Updates
Electricity consumed per municipality	Kilowatt Hours (kWh)	WMECo, National Grid and the Massachusetts Municipal Wholesale Electric Company	Every calendar year
GHG Factor	CO2e lbs / kWh	2005 EPA State Inventory	Every calendar year
Metric Tons factor	MT / lbs	http://www.epa.gov/cleanenergy/energy-resources/refs.html	N / A

These parameters are used to estimate the GHG emissions from electricity using the following formula:

Electricity $MTCO_{2e}$ = Total kWh/yr X GHG Factor X Metric Tons Factor

The first parameter, total kWH/yr is the electricity consumed per municipality in one calendar year. This parameter is considered relatively accurate, as it is obtained directly from electric utility distributor customer records. In the Pioneer Valley region, there are three main sources for this information: the Western Massachusetts Electric Company, and

National Grid, which are investor owned utilities that provide electricity to most areas; and the Municipal Wholesale Electric Company, which provided consumption information for all communities that receive electricity from municipally owned utilities[ii]. The breakdown of electricity consumed by residential, commercial and industrial sectors was provided for each of these. While this is useful information to analyze sector-specific impacts on the inventory, the breakdown is not required to have a total GHG emissions number.

The second parameter is a GHG Factor, a number that converts kWh consumed into CO_{2e} units emitted at power plants to create electricity. It is important to note that, because the energy grid continuously uses electricity from a different mix of fuel sources, this coefficient is an approximation based on regional averages and can change over time. Based on the electrical generation portfolio of the New England Grid, at least three GHG coefficients have been developed over the last decade to convert kWh to pounds of CO_{2e}. For this inventory, the GHG factor provided by the 2005 EPA State Inventory Tool was used because it incorporates emissions resulting from both power generation and the losses experienced during transmission.

The third parameter converts pounds of CO_{2e} to metric tons of CO_{2e}. Performing this conversion allows for easier comparison with other state, national and local GHG inventories, which uniformly use metric tons of CO_{2e} (MT CO_{2e}) as a common unit of measurement. One metric ton equals 2,205 lbs.

A1.1.2 DIRECT EMISSIONS FROM HEATING SOURCES

Direct emissions from heating come from the combustion of a variety of fuels, such as oil, natural gas, propane, wood, and coal. Unlike the indirect electric emissions where there are only a few electric utilities, these emissions are calculated using a top-down method since there are many fuel suppliers with less-sophisticated accounting systems and no obligation to reveal their market share of their fuel distribution business. Instead, data from the US Census Bureau and the US Energy Information Administration (EIA) was used to estimate the emissions from this sector coming from the Pioneer Valley. The following parameters were used:

Parameters	Units	Source(s)	Updates
Number of Households using each fuel type (state and 2-county region)	Housing Units that use each fuel type: Coal, Gas, Oil, etc.	2005 – 2010 American Community Survey	Every 5 years
Total State BTU	British Thermal Units (BTU)	Energy Information Administration (2009)	Every Calendar Year
Manufacturing employment (state and 2-county region)	Number of Employees	County Business Patterns (2009)	Every Calendar Year
GHG Factor for each fuel type	CO_{2e} kgs / Fuel Type Mbtu	U.S. EPA, Direct Emissions from Stationary Combustion Sources, Appendix B, May 2008	N / A
MT Factor	MT / kgs	Add source	N / A

These parameters are used to estimate the GHG emissions from non-electric energy using the following formula:

$$\textbf{Heating MTCO}_{2e} = [\,\textbf{ResGHG} + \textbf{ComGHG} + \textbf{IndGHG}\,] \times \textbf{MT Factor}$$

where ResBTU, ComBTU and IndBTU are defined as,

$$\textbf{ResGHG} = \sum [\textbf{Regional \% of State Residential fuel use} \times \textbf{State Residential fuel BTU total} \times \textbf{GHG Factor}]$$

$$ComGHG = \sum [\text{Regional \% of State Residential fuel use} \times \text{State Commercial fuel BTU total} \times \text{GHG Factor}]$$

$$IndGHG = \sum_{all\ fuels} [\text{Adjusted Regional \% of State Industrial fuel use} \times \text{State Industrial fuel BTUs} \times \text{GHG Factor}]$$

and the Adjusted Regional % of State Industrial fuel use is defined as:

$$\frac{\text{Regional \% of state manufacturing employment}}{\text{Regional \% of homes}} \times \text{Regional \% of state residential fuel use}$$

This method apportions the use of each heating fuel for Massachusetts to Hampden and Hampshire counties. It does so primarily by multiplying the amount of energy used at the state level (measured in BTU's), by the percent of households that use each fuel type in local counties. Then, the energy used for that fuel is converted to CO_{2e} units by using a GHG conversion factor.

Since high demand industrial users are more likely to cluster in a pattern that does not track population, industrial energy use was multiplied by an adjusted share of the state industrial fuel use. The adjustment consists of multiplying the county share of state residential fuel use by a location quotient for manufacturing employment.

This calculation assumes that on average, all homes across Massachusetts use fuel at the same average rate, failing to account for regional disparities in heating and cooling demands, degree days and energy efficiency of the housing stock or commercial and industrial operations. While this is a significant shortcoming in this methodology, a better estimate would require a more direct source of local consumption information, which is currently unavailable to PVPC.

A1.1.3 TRANSPORTATION

This section explains the method for estimating the direct GHG emissions in the region that are produced by combustion engines of vehicles, trucks and local public buses that burn fossil fuels such as gasoline, diesel and natural gas. While plug-in electric vehicles are now a reality, the indirect emissions associated with their electric consumption are not included in this section because the energy to charge them comes from the electric grid, so their emissions are already accounted for in the electricity. The transportation inventory method also does not include GHGs from intercity bus travel (i.e., Peter Pan buses), freight and passenger rail, and aviation.

Following are the parameters used to calculate the GHGs from transportation in the region:

Parameter	Units	Source(s)	Updates
Number of registered vehicles in Pioneer Valley	Vehicles by type	Mass. Dept. of Revenue, Municipal Databank/Local Aid Section	Every calendar year
MPG for type of registered vehicles	Miles per gallon, by vehicle type	FHWA Highway Statistics 2001	Every calendar year
Pioneer Valley annual Vehicle Miles Traveled (VMT) all private vehicles	Miles	2012 Regional Transportation Plan, PVPC	Every 4 years
Gallons of fuel used by PVTA fleet	Gallons of fuel	PVTA 2011 Records for SATCO, VATCO and UMass fleets	Every calendar year
MPG for PVTA vehicles	Miles per Gallon, by	PVTA 2011 Records for SATCO,	Every calendar

	vehicle type	VATCO and UMass fleets	year
BTU factor for each fuel type	Btu/gal for fuel type	1996 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 2 (Energy Section)	
GHG factor for each fuel	CO2e lbs / Btu of fuel type	U.S. EPA, Direct Emissions from Mobile Combustion Sources, Appendix B, May 2008	
MT GHG conversion	CO2e MT / lbs	Add source	

These parameters are used to estimate the GHG emissions from transportation from the following formula:

$$\textbf{Transportation } MTCO_{2e} = \sum [\text{Vehicle Fuel Used} \times \text{BTU Fuel Factor} \times \text{GHG Fuel Factor}]$$

When actual gallons were not known, the following formula was used for this variable,

$$\textbf{Vehicle Fuel Used} = \sum \frac{[\text{Vehicle type \% of all regional vehicles} \times \text{Regional annual VMT}]}{\text{Vehicle type MPG}}$$

This method estimates total emissions from roadway transportation by estimating the gallons of fuel used in the regional vehicle fleet. For public transit vehicles under the Pioneer Valley Transit Authority (PVTA), this calculation is relatively straight forward, as PVTA has a yearly accounting of the gallons of each fuel used. For other vehicles, the "Vehicle Fuel Used" is estimated by apportioning the total annual Vehicle Miles Travelled (VMT) for the region to each Vehicle Type (i.e. automobiles, light trucks, motorcycles, trailers or heavy trucks). That apportionment is then divided by the average vehicle type "Miles per Gallon" (MPG) which yields a total estimate of gallons used.

The precision of this method is limited by the nature of VMT itself. While VMT is a good indicator of traffic volumes for roadway and transportation planning, it does not necessarily reflect small movements towards sustainability; rather, it is focused on weekday commuting projections. Also, it is possible that vehicles with better fuel economy than the proscribed FHWA fleet mpg factors are being used more frequently due to social preferences or other characteristics of the population that are not reflected in the national average.

A1.1.4 INDUSTRY

Industrial activities such as manufacturing produces direct GHG emissions through chemical processes that are then released into the atmosphere. Starting in 2010, the US Environmental Protection Agency regulations started requiring large emitters throughout the United States to publicly disclose the level of those emissions for several industrial groups: mineral production; petroleum refineries; manufacturing of metals, chemicals, and pulp and paper; government and commercial facilities; and other industrial facilities.

Parameters	Units	Source(s)	Updates
Refinery emissions	MTCO2e	US EPA GHG Reporting Program: "Large GHG Emissions from Large Facilities" http://ghgdata.epa.gov	Every Calendar Year
Power Plants	MTCO2e	Same	Every Calendar Year
Chemical emissions	MTCO2e	Same	Every Calendar Year
Metals emissions	MTCO2e	Same	Every Calendar Year
Mineral emissions	MTCO2e	Same	Every Calendar Year
Pulp and Paper emissions	MTCO2e	Same	Every Calendar Year

As the EPA data has already aggregated and converted the reported emissions into $MTCO_{2e}$, calculating the industry inventory only requires adding these parameters:

Industry $MTCO_{2e}$ = Refinery + Power Plant + Chemical + Mentals + Mineral + Pulp and Paper + Gov and Com

While this is a bottom-up method, it currently only takes into consideration large emitters, and is therefore potentially undercounting the amount of emissions. There are also other industrial uses that are not accounted for in the initial data provided by EPA which will be included in following years. Starting in 2011, additional industrial uses will be included, such as: electronics manufacturing, production of magnesium and fluorinated gas, petroleum and natural gas systems, use of electric transmission and distribution equipment, underground coal mines, geologic sequestration of carbon dioxide, underground injection of carbon dioxide, and imports and exports of equipment pre-charged with fluorinated greenhouse gases or containing fluorinated greenhouse gases in closed-cell foams.

A1.1.5 SOLID WASTE

GHG emissions from solid waste occur as biodegradable materials in the disposed waste break down, the chemical reactions and microbes acting upon the waste create gases, primarily methane (CH_4) and nitrous oxide (N_2O). The main disposal items that contribute to landfill gas emissions are food discards, yard trimmings, paper, and wood. Landfill gas is made up of about 50% carbon dioxide (CO2), 50% methane, and trace amounts of other compounds. Municipal waste is the third-largest source of anthropogenic methane emissions in the U.S., accounting for approximately 17% in 2009.

There is only one parameter that is being used for the waste methodology, and no formula needs to be applied:

Parameter	Units	Source(s)	Updates
Landfill emissions	MTCO2e	Massachusetts DEP, Climate Change Registry	Every calendar year

The Pioneer Valley has five operating landfills, which are required by state and federal regulation to report their annual emissions to the same U.S. EPA GHG Reporting Program that is used in the inventory to account for Industrial emissions. While only landfill data is available for the first dataset iteration, the next update of the dataset will include emissions from industrial wastewater treatment and industrial waste landfills.

This parameter would also benefit from the future inclusion of emissions from inactive landfills, as well, which continue to generate GHGs after they are closed. This information could help local decision-makers in actions to recover usable biogas and methane from those sources. Unfortunately, there is currently very little data available about closed landfills in the region that is useful for estimating GHG emissions.

A1.1.6 AGRICULTURE

Agriculture plays an important part in the Pioneer Valley's economy and identity, where significant land is dedicated to small farm cultivation. While farming in the region is not generally practiced at the industrial scale as in the Midwest and other parts of the county, the energy use in the agricultural sector of this region is less than in those areas.

However, emissions from agriculture are included in the inventory because it is a standard practice across other state, local and international inventories. Agriculture is classified by the International Panel on Climate Change (IPCC) into the following categories: enteric fermentation, manure management, agricultural soils/crop management, rice cultivation, and the burning of agricultural residues. Due to the nature of the region's farms (i.e. lack of rice farming) and limitations on data for other categories, this inventory includes only enteric fermentation and manure management. Enteric fermentation refers to the process by which livestock digest food, which creates significant methane, a potent GHG (25 times the warming effect of carbon dioxide). Manure management refers to both dung and urine (i.e., solids and liquids) produced by livestock.

The following parameters were used to calculate the emissions from this sector:

Parameters	Units	Source(s)	Updates
Livestock population by species	Number of animals	US Agricultural Census (2007)	Every 5 years
Enteric Methane Factor	CH_4 / Livestock species	2006 IPCC Guidelines for National Greenhouse Gas Inventories: Chapter 10, Emissions from Livestock and Manure Management	-
Manure Methane Factor	CH_4 / Livestock species	2006 IPCC Guidelines for National Greenhouse Gas Inventories: Chapter 10, Emissions from Livestock and Manure Management	-
GHG Factor	CO_{2e} / CH_4	IPCC - Fourth Assessment Report on Climate Change (2007)	-

These parameters are used to estimate the GHG emissions from agriculture as follows:

$$\textbf{Agriculture MTCO}_{2e} = \textbf{Enteric Fermentation + Manure Management}$$

where,

$$\textbf{Enteric Fermentation} = \sum [\textbf{Livestock Population} \times \textbf{Enteric Methane Factor} \times \textbf{GHG Factor}]$$

and,

$$\textbf{Manure Management} = \sum [\textbf{Livestock Population} \times \textbf{Manure Methane Factor} \times \textbf{GHG Factor}]$$

This method follows the Tier 1 or 'default' method described by the IPCC, using readily accessible data from the U.S. Agricultural Census and multipliers that estimate how the quantity of GHGs emitted from livestock populations, published by the IPCC. This method assigns a unique amount of methane emissions for each type of livestock (i.e., dairy cattle, beef cattle, sheep, goats, and others), and then converts those estimates to CO_{2e} units.

A1.2 CARBON SEQUESTRATION

Carbon sequestration as defined by the U.S. EPA as the process through which agricultural and forestry practices remove carbon dioxide (CO_2) from the atmosphere. The term "sinks" is also used to describe agricultural and forestry lands that absorb CO_2, the most important global warming gas emitted by human activities. This effect occurs only with carbon dioxide; other greenhouse gases (i.e., methane, nitrous oxide, CFCs) cannot be absorbed in manner.

As of 2010, the U.S. EPA estimates that carbon sequestration from vegetation nationally offsets "approximately 12% of total U.S. CO2 emissions from the energy, transportation and industrial sectors."[iii] Accordingly, the capacity of regional natural resource areas to sequester and sink carbon emissions is taken into consideration in the inventory as an important tool with significant implications for local land use policies in the Pioneer Valley.

The estimate of the carbon sequestration capacity of the Pioneer Valley was made using the following information:

Parameters	Units	Source(s)	Updates
Pioneer Valley Land Cover Map	-	National Land Cover Database (2006)	Every 5 years
I-Tree Vue	-	United States Forrest Service, www.itreetools.org	-

The National Land Cover Database provides a map of the entire United States with information layers showing impervious surfaces, tree canopy, and land use. I-Tree Vue uses spatial tree cover maps developed by this database to apply average ecosystem service values per unit of canopy cover. These information layers were isolated for the Pioneer Valley region and feeding that information into the I-Tree software provides a direct calculation of CO_{2e} storage per year.

The following data comprehensively breaks down the several I-Tree analysis's that were run to depict the carbon sequestration within the Pioneer Valley:

Total Area Image Area-819,403.8 acres Impervious Cover-41,066.1 acres (5.2 %) Tree Canopy-564,067.3 acres (71.4 %) Carbon Sequestration: 754,873.6 short tons per year; $15,613,664.4 @ $20.68 per short tons per year CO2 Equivalent Sequestration: 2,767,366.7 short tons per year; $15,613,664.4 @ $5.64 per short tons per year"	**Total Wetlands Area (NCLD Data)** Wetlands, All-55,555.1 acres (6.8 %) Impervious Cover: 1.1 acres; or 0.0 % Tree Canopy: 45,775.9 acres; or (82.4 %) Carbon Sequestration: 61,260.4 short tons per year; $1,267,099.6 @ $20.68 per short tons per year CO2 Equivalent Sequestration: 224,580.8 short tons per year; $1,267,099.6 @ $5.64 per short tons per year
Developed Land (NCLD Data) Developed, all: 138,201.3 acres (16.9 %) Impervious Cover: 41,058.9 acres; or 29.7 % Tree Canopy: 41,046.7 acres; or 29.7 % Carbon Sequestration: 54,931.5 short tons per year; $1,136,193.4 @ $20.68 per short tons per year" CO2 Equivalent Sequestration: 201,379.0 short tons per year; $1,136,193.4 @ $5.64 per short tons per year	Woody Wetlands-53,321.6 acres (6.5 %) Impervious Cover: 1.0 acres; or 0.0 % Tree Canopy: 45,350.2 acres; or (85.1 %) Carbon Sequestration: 60,690.8 short tons per year; $1,255,317.2 @ $20.68 per short tons per year CO2 Equivalent Sequestration: 222,492.5 short tons per year; $1,255,317.2 @ $5.64 per short tons per year
Developed, Open Space-60,461.8 acres (7.4 %) Impervious Cover: 4,760.4 acres; (7.9 %) Tree Canopy: 32,819.4 acres; (54.3 %)	Emergent Herbaceous Wetlands-2,233.5 acres (0.3 %) Impervious Cover: 0.1 acres; or 0.0 % Tree Canopy: 425.7 acres; or (19.1 %)

Carbon Sequestration: 43,921.2 short tons per year; $908,457.9 @ $20.68 per short tons per year" CO_2 Equivalent Sequestration: 161,015.1 short tons per year; $908,457.9 @ $5.64 per short tons per year	Carbon Sequestration: 569.6 short tons per year; $11,782.3 @ $20.68 per short tons per year CO_2 Equivalent Sequestration: 2,088.3 short tons per year; $11,782.3 @ $5.64 per short tons per year
Developed, Low Intensity-45,858.3 acres (5.6 %) Impervious Cover: 15,252.3 acres; or 33.3% Tree Canopy: 7,361.4 acres; or 16.1 % Carbon Sequestration: 9,851.5 short tons per year; $203,766.7 @ $20.68 per short tons per year" CO_2 Equivalent Sequestration: 36,115.6 short tons per year; $203,766.7 @ $5.64 per short tons per year"	**Total Agricultural Area (NCLD Data)** Agriculture, All-62,153.1 acres (7.6 %) Impervious Cover: 1.4 acres; or 0.0 % Tree Canopy: 5,527.5 acres; or (8.9 %) Carbon Sequestration: 7,397.3 short tons per year; $4,641,108.1 @ $20.68 per short tons per year CO_2 Equivalent Sequestration: 27,118.4 short tons per year; $4,641,108.1 @ $5.64 per short tons per year
Developed, Medium Intensity-25,234.0 acres (3.1 %) Impervious Cover: 15,251.0 acres; or (60.4 %) Tree Canopy: 799.4 acres; or (3.2 %) Carbon Sequestration: 1,069.8 short tons per year; $22,127.2 @ $20.68 per short tons per year" CO_2 Equivalent Sequestration: 3,921.8 short tons per year; $22,127.2 @ $5.64 per short tons per year"	Cultivated Crops-17,095.0 acres (2.1 %) Impervious Cover: 0.8 acres; or 0.0 % Tree Canopy: 834.9 acres; or (4.9 %) Carbon Sequestration: 7,397.3 short tons per year; $4,641,108.1 @ $20.68 per short tons per year" CO_2 Equivalent Sequestration: 27,118.4 short tons per year; $4,641,108.1 @ $5.64 per short tons per year
Developed, High Intensity-6,647.2 acres (0.8 %) Impervious Cover: 5,795.2 acres; or (87.2 %) Tree Canopy: 66.5 acres; or (1.0 %) Carbon Sequestration: 89.0 short tons per year ; $1,841.7 @ $20.68 per short tons per year CO_2 Equivalent Sequestration: 326.4 short tons per year; $1,841.7 @ $5.64 per short tons per year	Pasture/Hay-45,058.1 acres (5.5 %) Impervious Cover: 0.6 acres; or 0.0 % Tree Canopy: 4,692.6 acres; or (10.4 %) Carbon Sequestration: 6,279.9 short tons per year; $3,940,086.3 @ $20.68 per short tons per year" CO_2 Equivalent Sequestration: 23,022.2 short tons per year; $3,940,086.3 @ $5.64 per short tons per year
Total Forest Area (NCLD Data) Forest, All-530,353.2 acres (64.7 %) Impervious Cover: 4.2 acres; or (0.0 %) Tree Canopy: 471,213.1 acres; or (88.8 %) Carbon Sequestration: 630,609.7 short tons per year; $13,043,412.0 @ $20.68 per short tons per year" CO_2 Equivalent Sequestration: 2,311,815.1 short tons per year; $13,043,412.0 @ $5.64 per short tons per year	**Miscellaneous (NCLD Data)** Miscellaneous, All-4,240.6 acres (0.5 %) Impervious Cover: 0.4 acres; or 0.0 % Tree Canopy: 504.2 acres; or (11.9 %) Carbon Sequestration: 674.7 short tons per year; $13,955.8 @ $20.68 per short tons per year CO_2 Equivalent Sequestration: 2,473.5 short tons per year; $13,955.8 @ $5.64 per short tons per year
Deciduous 365,766.3 acres (44.6 %) Impervious Cover: 3.1 acres; or (0.0 %) Tree Canopy: 324,144.6 acres; or (88.6 %) Carbon Sequestration: 433,792.6 short tons per year; $8,972,484.6 @ $20.68 per short tons per year CO_2 Equivalent Sequestration: 1,590,283.7 short tons per year; $8,972,484.6 @ $5.64 per short tons per year	Barren Land (Rock/Sand/Clay)-1,810.3 acres (0.2 %) Impervious Cover: 0.4 acres; or 0.0 % Tree Canopy: 109.4 acres; or (6.0 %) Carbon Sequestration: 146.4 short tons per year; $3,028.3 @ $20.68 per short tons per year CO_2 Equivalent Sequestration: 536.7 short tons per year; $3,028.3 @ $5.64 per short tons per yeay
Evergreen-71,732.3 acres (8.8 %) Impervious Cover: 0.5 acres; or (0.0%) Tree Canopy: 65,831.0 acres; or (91.8 %) Carbon Sequestration: 88,099.6 short tons per year; $1,822,234.7 @ $20.68 per short tons per year CO_2 Equivalent Sequestration: 322,973.0 short tons per year; $1,822,234.7 @ $5.64 per short tons per year	Grassland/Herbaceous-2,430.3 acres (0.3 %) Impervious Cover: 0.0 acres; or 0.0 % Tree Canopy: 394.8 acres; or 16.2 % Carbon Sequestration: 528.3 short tons per year; $10,927.5 @ $20.68 per short tons per year CO_2 Equivalent Sequestration: 1,936.8 short tons per year; $10,927.5 @ $5.64 per short tons per year
Mixed-82,432.0 acres (10.1 %) Impervious Cover: 0.4 acres; or 0.0 % Tree Canopy: 78,640.8 acres; or 95.4 % Carbon Sequestration: 105,242.5 short tons per year; $2,176,816.6 @ $20.68 per short tons per year" CO_2 Equivalent Sequestration: 385,819.1 short tons per year; $2,176,816.6 @ $5.64 per short tons per year	
Shrub/Scrub 10,422.5 acres (1.3 %) Impervious Cover: 0.2 acres; or (0.0 %) Tree Canopy: 2,596.6 acres; or (24.9%) Carbon Sequestration: 3,475.0 short tons per year; $71,876.1 @ $20.68 per short tons per year CO_2 Equivalent Sequestration: 12,739.3 short tons per year; $71,876.1 @ $5.64 per short tons per year"	

A1.3 VULCAN PROJECT REGIONAL CARBON EMISSIONS ESTIMATES

Reproduced from < http://vulcan.project.asu.edu>.

The Vulcan Project is a NASA/DOE funded effort under the North American Carbon Program (NACP) to quantify North American fossil fuel carbon dioxide (CO_2) emissions at space and time scales that are finer than has been achieved to date. The purposes are to aid in quantifying the North American carbon budget; support inverse estimation of carbon sources and sinks; and support the demands posed by higher resolution CO2 observations (in situ and remotely sensed). The detail and scope of Vulcan CO_2 inventory has also made it a valuable tool for policymakers, demographers, social scientists and the public at large (now on Google Earth).

The Vulcan Project has achieved the quantification of the 2002 U.S. fossil fuel CO_2 emissions at the scale of individual factories, powerplants, roadways and neighborhoods on an hourly basis. We have built the entire inventory on a common 10 km x 10 km grid to facilitate atmospheric modeling. In addition to improvement in space and time resolution, Vulcan is quantified at the level of fuel type, economic sub-sector, and county/state identification.

Vulcan uses the following sources of data:

- The point, non-point, and airport data files come from the EPAs National Emissions Inventory (NEI) for the year 2002, an inventory of all criteria and hazardous air pollutants across the US [*USEPA* 2005a];
- Continuous stack monitoring data provided by DOE's EIA and EPA Clean Air Market Division (CAMD) Emission Tracking System/Continuous Emissions Monitoring for electrical generating units are also utilized [*USEPA* 2004; *Petron et al.*, 2008];
- The onroad mobile emissions are based on a combination of county-level data from the National Mobile Inventory Model (NMIM) County Database (NCD) and standard internal combustion engine stochiometry from the Mobile6.2 combustion emissions model [*USEPA* 2005b; *USEPA* 2001; *Harrington* 1998];
- Emissions due to aircraft, beyond the takeoff/landing cycle, are taken directly from the Aero2K aircraft CO_2 emissions inventory, defined on a three-dimensional 1° x 1° degree grid [*Eyers et al.*, 2004];
- Nonroad emissions are structured similarly to the onroad mobile emissions data and consist of mobile sources that do not travel on designated roadways [*USEPA* 2005c; *USEPA* 2005d].

Full documentation is available here: <http://project.vulcan.asu.edu/research.html>

Work is underway to complete similar inventories for Canada and Mexico, to include CO and NOx emissions, quantification of all years from 1980 to the present, and incorporate biotic-based fuels (including ethanol).

Vulcan is led by Dr. Kevin Gurney and a team of researchers at Arizona State University. Key collaborators on the project include investigators at Colorado State University and Lawrence Berkeley National Laboratory.

Reference Citation: Gurney, K.R., D. Mendoza, Y. Zhou, B. Seib, M Fischer, S. de la Rue du Can, S. Geethakumar, C. Miller (2009) The Vulcan Project: High resolution fossil fuel combustion CO_2 emissions fluxes for the United States

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[i] This method was developed in conjunction with the University of Massachusetts-Amherst, Fall 2011 Regional Planning Graduate Studio led by Prof. Elisabeth Hamin, Ph.D.

[ii] While only the Municipal utilities are obligated to provide this information, WMECo and National Grid were gracious enough to provide this information in the spirit of cooperation towards better regional planning and sustainability.

[iii] http://www.epa.gov/sequestration/national_analysis.html

APPENDIX 2: BEST MANAGEMENT PRACTICES FOR STREAM CROSSING REPLACEMENT

INTRODUCTION

Recent storms have caused considerable damage to stream crossings throughout New England, including Hampden and Hampshire Counties in Western Massachusetts. Numerous stream crossings in both counties are in need of replacement and repair. As climate change effects become more pronounced, larger and more frequent storms are likely to increase damage to stream crossings in the future. In an effort to minimize impacts from these storms to surrounding wetland and riparian ecosystems, best management practices must be followed for stream crossing replacement.

In general, the design, replacement and new culverts should be based on updated estimated precipitation flows presented by the National Weather Service's Hydrometeorological Design Studies Center (www.nws.noaa.gov/oh/hdsc/), and updated design guidance offered by Massachusetts River and Stream Crossing Standards and the U.S. Department of Agriculture's Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings document (both available at (www.streamcontinuity.org).

General principles and approaches to stream crossing replacement should:

- Pro-actively replace underperforming culverts and stream crossings with appropriately designed culverts and bridge structures that will better accommodate floods, reconnect wildlife habitat areas and promote wildlife passage.
- Identify and prioritize most important culverts for replacement, based on culverts most at risk for failures and most adversely impacting wildlife passage.
- Adopt municipal policies for culvert replacement including best management practices.
- Establish pre-designed generic stream crossing designs for different types of sites in order to be prepared in advance for disaster replacements.
- Seek alternative funding sources, including federal grants from agencies such as NOAA and USFWS for wildlife-friendly culvert replacements, as well as FEMA Hazard Mitigation grants.

Listed below are best management practices for stream crossing replacement. These practices include design of initial construction and location identification to monitoring and evaluation of completed crossings. Also included are examples of replacement types that can be utilized for larger road-stream crossings. The following practices should be used as guidelines to prevent and minimize damage to ecosystems directly adjacent to stream crossings.

A2.1 ROAD AND CROSSING LOCATION

- Avoid sensitive areas such as rare species habitat and important habitat features (vertical sandy banks, underwater banks of fine silt or clay, deep pools, fish spawning habitat)
- Avoid unstable or high-hazard locations such as steep slopes, wet or unstable slopes, non-cohesive soils, and bordering vegetated wetlands. Alluvial reaches (where soils were deposited and are shaped by flowing water) are poor locations for road-stream crossings
- Where possible locate crossings on straight channel segments (avoid meanders)
- To the extent possible align crossings perpendicular to the stream channel

A2.2 DEWATERING

- Minimize the extent and duration of the hydrological disruption
- Consider the use of bypass channels to maintain some river and stream continuity during construction
- Use dams to prevent backwatering of construction areas
- Gradually dewater and re-water river and stream segments to avoid abrupt changes in flow
- Salvage aquatic organisms (fish, salamanders, crayfish, mussels) stranded during dewatering
- Segregate clean diversion water from sediment-laden runoff or seepage water
- Use anti-seep collars around diversion pipes
- Use upstream sumps to collect groundwater and prevent it from entering the construction site
- Collect construction drainage from groundwater, storms, and leaks and treat to remove sediment
- Use downstream sediment control sump to collect water that seeps out of the construction area
- Use fish screens around the intake of diversion pipes
- Use appropriate energy dissipates and erosion control at pipe outlets
- When using diversion pipes ensure adequate pumping capacity is available to handle storm flows
- After construction remove cofferdams downstream-to-upstream in a manner that minimizes introduction of sediment to the waterway

A2.3 STORMWATER MANAGEMENT, EROSION AND SEDIMENT CONTROL

Use of a downstream sediment retention pond is strongly recommended for all projects that involve work within the streambed.

- Minimize bare ground
- Minimize impact to riparian vegetation
- Prevent excavated material from running into water bodies and other sensitive areas
- Use appropriate sediment barriers (silt fence, hay bales, mats, Coir logs, mulch/compost filter tubes)
- Dewater prior to excavation
- Manage and treat surface and groundwater encountered during excavation with the following
    - sediment basins
    - fabric, biobag or hay bale corals

- irrigation sprinklers or drain pipes discharging into vegetated upland areas
- sand filter
- geotextile filter bags

- Turbidity of water 100-200 feet downstream of the site should not be visibly greater than turbidity upstream of the project site

A2.4 POLLUTION CONTROL

- Wash equipment prior to bringing to the work area to remove leaked petroleum products and avoid introduction of invasive plants
- To avoid leaks, repair equipment prior to construction
- Be prepared to use petroleum absorbing “diapers” if necessary
- Locate refueling areas and hazardous material containment areas away from streams and other sensitive areas
- Establish appropriate areas for washing concrete mixers; prevent concrete wash water from entering rivers and streams
- Take steps to prevent leakage of stockpiled materials into streams or other sensitive areas (locate away from water bodies and other sensitive areas, provide sediment barriers and traps, cover stockpiles during heavy rains)

A2.5 CONSTRUCTION OF STREAMBED AND BANKS WITHIN STRUCTURES

- Check construction surveys to ensure slopes and elevations meet design specifications
- Use appropriately graded material (according to design specifications) that has been properly mixed before placement inside the structure
- Avoid segregation of bed materials
- Compact bed material
- After the streambed has been constructed wash bed material to ensure that fine materials fill gaps and voids
- Construct an appropriate low-flow channel and thalweg
- Carefully construct bed forms to ensure functionality and stability
- Construct well-graded banks for roughness, passage by small wildlife, and in-stream bank-edge habitat
- Tie constructed banks into upstream and downstream banks. Banks within the structure should generally align with the profile and cross section of banks upstream and downstream of the structure, and should be installed so that the juncture between natural bank and constructed bank is stable. The banks should be designed and constructed so as not to hinder wildlife use of the streambed and banks for passage

A2.6 SOIL STABILIZATION AND RE-VEGETATION

- Surface should be rough to collect seeds and moisture
- Implement seeding and planting plan that addresses both short term stabilization and long term restoration of riparian vegetation
- Water vegetation to ensure adequate survival
- Use seed, mulch, and/or erosion control fabrics on steep slopes and other vulnerable areas
- Avoid netting and other erosion control materials that contain coarse mesh capable of trapping and killing fish and wildlife if it gets washed into streams or rivers
- Use native plants unless other non-native alternatives will yield significantly better results

A2.7 MONITORING

- Ensure that BMP's are being implemented
- Inspect for erosion
- Evaluate structure stability
- Inspect for evidence of stream instability

A2.8 TIMING OF CONSTRUCTION

- Construction should occur during periods of low flow, generally July 1 through September 30
- Ensure the lifestages of resident aquatic species are protected during times of construction
- Consider if construction should be limited during periods of high flows

A2.9 EXAMPLE STREAM CROSSING REPLACEMENT TYPES (LARGER ROAD-STREAM CROSSINGS)

One-piece corrugated metal pipe

One-piece corrugated metal pipe arch

One-piece open bottom arch

Multi-plate open-bottom pipe arch

Multi-plate open-bottom box

A2.10 REFERENCES

Massachusetts River and Stream Crossing Standards, developed by the River and Stream Continuity Project, UMass Amherst et al. pgs. 19-21. http://www.mass.gov/dfwele/der/pdf/mastreamcrossing_guidelines.pdf

Stream Simulation: An ecological approach to providing passage for aquatic organisms at road-stream crossings, U.S.D.A. pgs. 307-308, 310.

http://www.streamcontinuity.org/pdf_files/Stream%20Simulation.pdf

Table 1: Total Emissions

County	Total kWhs (2010)	GHG Factor	Emissions (lbs CO2e)	Emissions (MTC	Emissions (MMTCO2e	Population (2010)	Per Capita Emissions
Hampden	3,847,160,663	0.9099	3,500,456,392	1,587,780	1.59	463,490	3.43
Hampshire	1,050,570,677	1.0003	1,050,837,522	476,652	0.48	158,080	3.02
Pioneer Valley:	**4,897,731,340**	**0.9293**	**4,551,293,914**	**2,064,432**	**2.06**	**621,570**	**3.32**

Table 2: Emissions from Total Electrical Use for Pio

Town	County	Utility	Total kWhs (2010)	GHG Factor	Emissions (lbs CO2e)	Emissions (MTCO2	MMTCO2e	Population (2010)	Per Capita Emissions
Agawam	Hampden	WMECO	243,972,790	1.0003	244,034,759	110,692	0.111	28,438	3.89
Blandford	Hampden	WMECO	8,356,528	1.0003	8,358,651	3,791	0.004	1,233	3.07
Brimfield	Hampden	National Grid	19,800,894	1.0003	19,805,923	8,984	0.009	3,609	2.49
Chester	Hampden	WMECO/Municipal	6,147,137	1.0003	6,148,698	2,789	0.003	1,337	2.09
Chicopee	Hampden	WMECO/Municipal	488,824,433	1.0003	488,948,594	221,783	0.222	55,298	4.01
East Longmeadow	Hampden	NGRID/WMECO	211,504,760	1.0003	211,558,482	95,961	0.096	15,720	6.10
Granville	Hampden	WMECO	8,212,545	1.0003	8,214,631	3,726	0.004	1,566	2.38
Hampden	Hampden	National Grid	27,053,858	1.0003	27,060,730	12,275	0.012	5,139	2.39
Holland	Hampden	National Grid	12,399,319	1.0003	12,402,468	5,626	0.006	2,481	2.27
Holyoke	Hampden	Municipal	375,788,000	0.0750	28,202,000	12,792	0.013	39,880	0.32
Longmeadow	Hampden	WMECO	87,854,495	1.0003	87,876,810	39,860	0.040	15,784	2.53
Ludlow	Hampden	WMECO	134,638,266	1.0003	134,672,464	61,086	0.061	21,103	2.89
Monson	Hampden	National Grid	48,669,410	1.0003	48,681,772	22,082	0.022	8,560	2.58
Montgomery	Hampden	WMECO	3,439,631	1.0003	3,440,505	1,561	0.002	838	1.86
Palmer	Hampden	National Grid	96,770,704	1.0003	96,795,284	43,906	0.044	12,140	3.62
Russell	Hampden	WMECO/Municipal	12,239,760	1.0003	12,242,869	5,553	0.006	1,775	3.13
Southwick	Hampden	WMECO	68,664,662	1.0003	68,682,103	31,154	0.031	9,502	3.28
Springfield	Hampden	WMECO	1,223,869,593	1.0003	1,224,180,456	555,279	0.555	153,060	3.63
Tolland	Hampden	WMECO	3,552,507	1.0003	3,553,409	1,612	0.002	485	3.32
Wales	Hampden	National Grid	8,916,002	1.0003	8,918,267	4,045	0.004	1,838	2.20
West Springfield	Hampden	WMECO	258,385,525	1.0003	258,451,155	117,231	0.117	28,391	4.13
Westfield	Hampden	WMECO/Municipal	397,121,476	1.0003	397,222,345	180,177	0.180	41,094	4.38
Wilbraham	Hampden	NGRID/WMECO	100,978,368	1.0003	101,004,017	45,815	0.046	14,219	3.22
Amherst	Hampshire	WMECO	155,342,304	1.0003	155,381,761	70,480	0.070	37,819	1.86
Belchertown	Hampshire	National Grid	77,004,816	1.0003	77,024,375	34,938	0.035	14,649	2.38
Chesterfield	Hampshire	WMECO	5,559,805	1.0003	5,561,217	2,523	0.003	1,222	2.06
Cummington	Hampshire	WMECO	5,082,789	1.0003	5,084,080	2,306	0.002	872	2.64
Easthampton	Hampshire	WMECO	112,053,960	1.0003	112,082,422	50,840	0.051	16,053	3.17
Goshen	Hampshire	National Grid	4,258,371	1.0003	4,259,453	1,932	0.002	1,054	1.83
Granby	Hampshire	National Grid	29,864,774	1.0003	29,872,360	13,550	0.014	6,240	2.17
Hadley	Hampshire	WMECO	102,477,317	1.0003	102,503,346	46,495	0.046	5,250	8.86
Hatfield	Hampshire	WMECO	35,328,020	1.0003	35,336,993	16,029	0.016	3,279	4.89
Huntington	Hampshire	WMECO	11,065,316	1.0003	11,068,127	5,020	0.005	2,180	2.30
Middlefield	Hampshire	WMECO	2,220,252	1.0003	2,220,816	1,007	0.001	521	1.93
Northampton	Hampshire	National Grid	238,767,928	1.0003	238,828,575	108,331	0.108	28,549	3.79
Pelham	Hampshire	WMECO	6,388,206	1.0003	6,389,829	2,898	0.003	1,321	2.19
Plainfield	Hampshire	WMECO	3,390,117	1.0003	3,390,978	1,538	0.002	648	2.37
Southampton	Hampshire	WMECO	31,795,148	1.0003	31,803,224	14,426	0.014	5,792	2.49
South Hadley	Hampshire	Municipal	117,824,807	1.0003	117,854,735	53,458	0.053	17,514	3.05
Ware	Hampshire	National Grid	83,675,690	1.0003	83,696,944	37,964	0.038	9,872	3.85
Westhampton	Hampshire	WMECO	8,596,523	1.0003	8,598,707	3,900	0.004	1,607	2.43
Williamsburg	Hampshire	National Grid	14,591,539	1.0003	14,595,245	6,620	0.007	2,482	2.67
Worthington	Hampshire	WMECO	5,282,995	1.0003	5,284,337	2,397	0.002	1,156	2.07
Total			**4,897,731,340**	**0.9293**	**4,551,293,914**	**2,064,432**	**2.064**	**621,570**	**3.32**

Table 3: Emissions from Total Electrical Use for Fra

Town	County	Utility	Total kWhs (2010)	GHG Factor	Emissions (lbs CO2e)	Emissions (MTCO2	MMTCO2e	Population (2010)	Per Capita Emissions
Ashfield	Franklin	WMECO	7,593,051	1.0003	7,594,980	3,445	0.003	1,737	1.98
Bernardston	Franklin	WMECO	11,464,344	1.0003	11,467,256	5,201	0.005	2,129	2.44
Buckland	Franklin	WMECO	9,914,511	1.0003	9,917,029	4,498	0.004	1,902	2.37
Charlemont	Franklin	National Grid	8,157,628	1.0003	8,159,700	3,701	0.004	1,266	2.92
Colrain	Franklin	WMECO	15,715,452	1.0003	15,719,444	7,130	0.007	1,671	4.27
Conway	Franklin	WMECO	7,718,891	1.0003	7,720,852	3,502	0.004	1,897	1.85
Deerfield	Franklin	WMECO	69,170,103	1.0003	69,187,672	31,383	0.031	5,125	6.12
Erving	Franklin	NGRID/WMECO	54,357,916	1.0003	54,371,723	24,663	0.025	1,800	13.70
Gill	Franklin	WMECO	10,375,526	1.0003	10,378,161	4,707	0.005	1,500	3.14
Greenfield	Franklin	WMECO	142,944,241	1.0003	142,980,549	64,855	0.065	17,456	3.72
Hawley	Franklin	National Grid	1,431,104	1.0003	1,431,468	649	0.001	337	1.93
Heath	Franklin	National Grid	3,160,974	1.0003	3,161,777	1,434	0.001	706	2.03
Leverett	Franklin	WMECO	8,818,640	1.0003	8,820,880	4,001	0.004	1,851	2.16
Leyden	Franklin	WMECO	2,967,922	1.0003	2,968,676	1,347	0.001	711	1.89
Monroe	Franklin	National Grid	910,848	1.0003	911,079	413	0.000	121	3.42
Montague	Franklin	WMECO	61,234,388	1.0003	61,249,942	27,783	0.028	8,437	3.29
New Salem	Franklin	National Grid	4,358,961	1.0003	4,360,068	1,978	0.002	990	2.00
Northfield	Franklin	WMECO	20,493,609	1.0003	20,498,814	9,298	0.009	3,032	3.07
Orange	Franklin	National Grid	51,701,155	1.0003	51,714,287	23,457	0.023	7,839	2.99
Rowe	Franklin	National Grid	5,508,356	1.0003	5,509,755	2,499	0.002	393	6.36
Shelburne	Franklin	WMECO	11,383,038	1.0003	11,385,929	5,165	0.005	1,893	2.73
Shutesbury	Franklin	NGRID/WMECO	7,015,868	1.0003	7,017,650	3,183	0.003	1,771	1.80
Sunderland	Franklin	WMECO	19,520,189	1.0003	19,525,147	8,856	0.009	3,684	2.40
Warwick	Franklin	National Grid	2,921,026	1.0003	2,921,768	1,325	0.001	780	1.70
Wendell	Franklin	National Grid	3,484,035	1.0003	3,484,920	1,581	0.002	848	1.86
Whately	Franklin	WMECO	30,450,126	1.0003	30,457,860	13,815	0.014	1,496	9.23
Total			**572,771,902**		**572,917,386**	**259,871**	**0.26**	**71,372**	3.64

Table 4: Emissions from Residentia

Town	County	Utility	Total kWhs (2010)	GHG Factor	Emissions (lbs CO2e)	Emissions (MTCO2	Population (:	Per Capita Emissions
Brimfield	Hampden	National Grid	14,580,087	1.0003	14,583,790	6,615	3,609	1.83
East Longmeadow*	Hampden	National Grid	56,185,848	1.0003	56,200,119	25,492	15,720	1.62
Hampden	Hampden	National Grid	20,970,893	1.0003	20,976,220	9,515	5,139	1.85
Holland	Hampden	National Grid	11,516,489	1.0003	11,519,414	5,225	2,481	2.11
Monson	Hampden	National Grid	32,845,419	1.0003	32,853,762	14,902	8,560	1.74
Palmer	Hampden	National Grid	45,201,474	1.0003	45,212,955	20,508	12,140	1.69
Wales	Hampden	National Grid	7,614,330	1.0003	7,616,264	3,455	1,838	1.88
Wilbraham*	Hampden	National Grid	54,723,817	1.0003	54,737,717	24,829	14,219	1.75
Belchertown	Hampshire	National Grid	55,593,135	1.0003	55,607,256	25,223	14,649	1.72
Goshen	Hampshire	National Grid	3,646,778	1.0003	3,647,704	1,655	1,054	1.57
Granby	Hampshire	National Grid	24,206,915	1.0003	24,213,064	10,983	6,240	1.76
Northampton	Hampshire	National Grid	77,867,873	1.0003	77,887,651	35,329	28,549	1.24
Ware	Hampshire	National Grid	37,121,462	1.0003	37,130,891	16,842	9,872	1.71
Williamsburg	Hampshire	National Grid	8,865,422	1.0003	8,867,674	4,022	2,482	1.62
Charlemont	Franklin	National Grid	4,914,516	1.0003	4,915,764	2,230	1,266	1.76
Erving*	Franklin	National Grid	2,636,409	1.0003	2,637,079	1,196	1,800	0.66
Hawley	Franklin	National Grid	1,382,649	1.0003	1,383,000	627	337	1.86
Heath	Franklin	National Grid	2,863,964	1.0003	2,864,691	1,299	706	1.84
Monroe	Franklin	National Grid	341,720	1.0003	341,807	155	121	1.28
New Salem	Franklin	National Grid	3,812,900	1.0003	3,813,868	1,730	990	1.75
Orange	Franklin	National Grid	26,792,616	1.0003	26,799,421	12,156	7,839	1.55
Rowe	Franklin	National Grid	1,532,022	1.0003	1,532,411	695	393	1.77
Shutesbury*	Franklin	National Grid	5,940,760	1.0003	5,942,269	2,695	1,771	1.52
Warwick	Franklin	National Grid	2,623,097	1.0003	2,623,763	1,190	780	1.53

Wendell	Franklin	National Grid	2,795,271	1.0003	2,795,981	1,268	848	1.50
Total			**506,575,866**		**506,704,536**	**229,837**	**143,403**	**1.60**

**Only partial total - does not include additional WMECO supply*

Table 5: Emissions from Commerci

Town	County	Utility	Total kWhs (2010)	GHG Factor	Emissions (lbs CO2e)	Emissions (MTCO2	Population (	Per Capita Emissions
Brimfield	Hampden	National Grid	3,852,583	1.0003	3,853,562	1,748	3,609	0.48
East Longmeadow*	Hampden	National Grid	39,560,731	1.0003	39,570,779	17,949	15,720	1.14
Hampden	Hampden	National Grid	6,020,875	1.0003	6,022,404	2,732	5,139	0.53
Holland	Hampden	National Grid	833,755	1.0003	833,967	378	2,481	0.15
Monson	Hampden	National Grid	12,559,040	1.0003	12,562,230	5,698	8,560	0.67
Palmer	Hampden	National Grid	33,689,394	1.0003	33,697,951	15,285	12,140	1.26
Wales	Hampden	National Grid	1,241,173	1.0003	1,241,488	563	1,838	0.31
Wilbraham*	Hampden	National Grid	27,486,342	1.0003	27,493,324	12,471	14,219	0.88
Belchertown	Hampshire	National Grid	19,558,224	1.0003	19,563,192	8,874	14,649	0.61
Goshen	Hampshire	National Grid	495,040	1.0003	495,166	225	1,054	0.21
Granby	Hampshire	National Grid	5,193,289	1.0003	5,194,608	2,356	6,240	0.38
Northampton	Hampshire	National Grid	123,063,797	1.0003	123,095,055	55,835	28,549	1.96
Ware	Hampshire	National Grid	25,813,991	1.0003	25,820,548	11,712	9,872	1.19
Williamsburg	Hampshire	National Grid	5,223,500	1.0003	5,224,827	2,370	2,482	0.95
Charlemont	Franklin	National Grid	3,226,336	1.0003	3,227,155	1,464	1,266	1.16
Erving*	Franklin	National Grid	529,623	1.0003	529,758	240	1,800	0.13
Hawley	Franklin	National Grid	47,719	1.0003	47,731	22	337	0.06
Heath	Franklin	National Grid	286,112	1.0003	286,185	130	706	0.18
Monroe	Franklin	National Grid	560,459	1.0003	560,601	254	121	2.10
New Salem	Franklin	National Grid	519,889	1.0003	520,021	236	990	0.24
Orange	Franklin	National Grid	20,154,164	1.0003	20,159,283	9,144	7,839	1.17
Rowe	Franklin	National Grid	413,637	1.0003	413,742	188	393	0.48
Shutesbury*	Franklin	National Grid	584,637	1.0003	584,785	265	1,771	0.15
Warwick	Franklin	National Grid	291,042	1.0003	291,116	132	780	0.17
Wendell	Franklin	National Grid	680,982	1.0003	681,155	309	848	0.36
Total			**331,886,334**		**331,970,633**	**150,579**	**143,403**	**1.05**

**Only partial total - does not include additional WMECO supply*

Table 6: Emissions from Industrial I

Town	County	Utility	Total kWhs (2010)	GHG Factor	Emissions (lbs CO2e)	Emissions (MTCO2	Population (	Per Capita Emissions
Brimfield	Hampden	National Grid	1,325,736	1.0003	1,326,073	601	3,609	0.17
East Longmeadow*	Hampden	National Grid	115,260,947	1.0003	115,290,223	52,295	15,720	3.33
Hampden	Hampden	National Grid	1,708	1.0003	1,708	1	5,139	0.00
Holland	Hampden	National Grid	20,480	1.0003	20,485	9	2,481	0.00
Monson	Hampden	National Grid	3,151,945	1.0003	3,152,746	1,430	8,560	0.17
Palmer	Hampden	National Grid	17,483,082	1.0003	17,487,523	7,932	12,140	0.65
Wales	Hampden	National Grid	56,722	1.0003	56,736	26	1,838	0.01
Wilbraham*	Hampden	National Grid	501,448	1.0003	501,575	228	14,219	0.02
Belchertown	Hampshire	National Grid	1,690,320	1.0003	1,690,749	767	14,649	0.05
Goshen	Hampshire	National Grid	104,166	1.0003	104,192	47	1,054	0.04
Granby	Hampshire	National Grid	375,330	1.0003	375,425	170	6,240	0.03
Northampton	Hampshire	National Grid	36,598,684	1.0003	36,607,980	16,605	28,549	0.58
Ware	Hampshire	National Grid	20,472,277	1.0003	20,477,477	9,288	9,872	0.94
Williamsburg	Hampshire	National Grid	452,647	1.0003	452,762	205	2,482	0.08
Charlemont	Franklin	National Grid	2,667	1.0003	2,668	1	1,266	0.00
Erving*	Franklin	National Grid	46,555,663	1.0003	46,567,488	21,123	1,800	11.73
Hawley	Franklin	National Grid	-	1.0003	-	-	337	-
Heath	Franklin	National Grid	5,339	1.0003	5,340	2	706	0.00

Monroe	Franklin	National Grid	-	1.0003	-	-	121	-
New Salem	Franklin	National Grid	17,598	1.0003	17,602	8	990	0.01
Orange	Franklin	National Grid	4,601,607	1.0003	4,602,776	2,088	7,839	0.27
Rowe	Franklin	National Grid	3,548,614	1.0003	3,549,515	1,610	393	4.10
Shutesbury*	Franklin	National Grid	-	1.0003	-	-	1,771	-
Warwick	Franklin	National Grid	3	1.0003	3	0	780	0.00
Wendell	Franklin	National Grid	-	1.0003	-	-	848	-
Total			**252,226,983**		**252,291,049**	**114,437**	**143,403**	**0.80**

Only partial total - does not include additional WMECO supply

Table 7: Emissions from Streetlight

Town	County	Utility	Total kWhs (2010)	GHG Factor	Emissions (lbs CO2e)	Emissions (MTCO2	Population (	Per Capita Emissions
Brimfield	Hampden	National Grid	42,488	1.0003	42,499	19	3,609	0.01
East Longmeadow*	Hampden	National Grid	343,322	1.0003	343,409	156	15,720	0.01
Hampden	Hampden	National Grid	60,382	1.0003	60,397	27	5,139	0.01
Holland	Hampden	National Grid	28,595	1.0003	28,602	13	2,481	0.01
Monson	Hampden	National Grid	113,006	1.0003	113,035	51	8,560	0.01
Palmer	Hampden	National Grid	396,754	1.0003	396,855	180	12,140	0.01
Wales	Hampden	National Grid	3,777	1.0003	3,778	2	1,838	0.00
Wilbraham*	Hampden	National Grid	226,290	1.0003	226,347	103	14,219	0.01
Belchertown	Hampshire	National Grid	163,137	1.0003	163,178	74	14,649	0.01
Goshen	Hampshire	National Grid	12,387	1.0003	12,390	6	1,054	0.01
Granby	Hampshire	National Grid	89,240	1.0003	89,263	40	6,240	0.01
Northampton	Hampshire	National Grid	1,237,574	1.0003	1,237,888	561	28,549	0.02
Ware	Hampshire	National Grid	267,960	1.0003	268,028	122	9,872	0.01
Williamsburg	Hampshire	National Grid	49,970	1.0003	49,983	23	2,482	0.01
Charlemont	Franklin	National Grid	14,109	1.0003	14,113	6	1,266	0.01
Erving*	Franklin	National Grid	55,507	1.0003	55,521	25	1,800	0.01
Hawley	Franklin	National Grid	736	1.0003	736	0	337	0.00
Heath	Franklin	National Grid	5,559	1.0003	5,560	3	706	0.00
Monroe	Franklin	National Grid	8,669	1.0003	8,671	4	121	0.03
New Salem	Franklin	National Grid	8,574	1.0003	8,576	4	990	0.00
Orange	Franklin	National Grid	152,768	1.0003	152,807	69	7,839	0.01
Rowe	Franklin	National Grid	14,083	1.0003	14,087	6	393	0.02
Shutesbury*	Franklin	National Grid	8,255	1.0003	8,257	4	1,771	0.00
Warwick	Franklin	National Grid	6,884	1.0003	6,886	3	780	0.00
Wendell	Franklin	National Grid	7,782	1.0003	7,784	4	848	0.00
Total			**3,317,808**		**3,318,651**	**1,505**	**143,403**	**0.01**

Only partial total - does not include additional WMECO supply

Table 8: Sources

Data	Table	Source	Website Link
Total Electrical Sales - WMECO	Tables 1, 2	WMECO	
Total Electrical Sales - National	Tables 1 to 7	National Grid	
Total Electrical Sales - Municipa	Tables 1, 2	DPU, Individual Municipal Utilities	
GHG Factor - all except Holyoke	Tables 1 to 7	2005 EPA State Inventory Tool	
GHG Factor - Holyoke	Tables 1, 2	2008 Annual Report - Hol	http://www.hged.com/2008_Annual_Report_FINAL_WEB.pdf

Table 1: Pioneer Valley Emissions

County	Residential (MMTCO2e)	Commercial (MMTCO2e)	Industrial (MMTCO2e)	Total (MMTCO2e)	
Hampden	1.01	0.42	0.40	1.84	1,835,489.52
Hampshire	0.34	0.13	0.13	0.59	592,586.98
Total	**1.36**	**0.54**	**0.53**	**2.43**	2,428,076.50

Table 1: Franklin County Emissions

County	Residential (MMTCO2e)	Commercial (MMTCO2e)	Industrial (MMTCO2e)	Total (MMTCO2e)
Franklin	0.20	0.06	0.14	0.41
Total	**0.20**	**0.06**	**0.14**	**0.41**

Table 1: Emissions from Transportation

	Total Gallons	Fuel Type	BTU/unit	Total Btus	MMBTU
Automobiles	136,291,811	Gasoline	115,000	15,673,558,228,502	15,673,558
Light Trucks	103,062,447	Gasoline	115,000	11,852,181,404,337	11,852,181
Motor Cycles	5,388,109	Gasoline	115,000	619,632,554,829	619,633
Service Bus, Meet and Greet Vehicle, Special Transportation Vans	9,862	Gasoline	115,000	1,134,130,000	1,134
PVTA Vans	387,405	Gasoline	115,000	44,551,575,000	44,552
Trailers	64,068,683	Diesel	128,500	8,232,825,789,446	8,232,826
Heavy Trucks	15,927,692	Diesel	128,500	2,046,708,406,556	2,046,708
Other	-	Gasoline	115,000	-	-
UMASS Bus and Maintenance Trucks	199,050	Diesel	128,500	25,577,925,000	25,578
PVTA Buses	843,730	Diesel	128,500	108,419,305,000	108,419
Field Trip Bus	5,895	B20-Biodiesel	127,259	750,191,805	750
Total	**326,184,684**			**38,605,339,510,475**	**38,605,340**

Table 2: Total Gallons per year by Vehicle Type - Apportioned VMT Share by Vehicle Type

	Total Registered Vehicles by Vehicle Type	Share of Vehicles	Total VMT	Daily Total VMT	Yearly Total VMT
Automobiles	303,930	55%	15,132,000	8,252,189	3,012,049,016
Light Trucks	183,031	33%	15,132,000	4,969,586	1,813,899,067
Motor Cycles	19,029	3%	15,132,000	516,668	188,583,821
Trailers	38,789	7%	15,132,000	1,053,184	384,412,099
Heavy Trucks	12,536	2%	15,132,000	340,373	124,235,997
Other	11,514	0%	15,132,000	-	-
Total	**568,829**	**100%**		**15,132,000**	**5,523,180,000**

Table 3: Total Gallons per year - Average MPG

	Total Registered Vehicles by Vehicle Type	Share of Vehicles	Total VMT	Daily Total VMT	Yearly Total VMT
All	568,829		15,132,000	15,132,000	5,523,180,000

Table 4: Wells-to-Pump (Added emissions due to the oil extraction, refining, and distribution for Pioneer Valley's fuel needs)

	Total Gallons	Fuel Type	BTU/unit	W2P Emission Ratios	Gallons
Wells-to-Pump - Gasoline	245,139,634	Gasoline	115,000	0.27	66,187,701
Wells-to-Pump - Diesel	81,045,050	Diesel	128,500	0.21	17,019,461
Home Heating Fuel?					
Total	**326,184,684**				**83,207,162**

Table 4: Sources

Data	Tables	Sources
Total Registered Vehicles by Vehicle Type	Tables 2, 3	Massachusetts Department of Revenue, Division
Vehicles Miles Traveled	Tables 2, 3	Pioneer Valley Planning Commission
Miles Per Gallon	Tables 2, 3	FHA Highway Statistics 2001
GHG Factors	Table 1	Greenfield Energy Audit
W2P Emission Ratios	Table 4	Denver GHG Inventory

GHG Factor for Fuel Type	GHG Emissions (lbs CO2e)	Metric Tons of CO2e	Million Metric Tons CO2e
165	2,586,137,108	1,173,052	1.173 `
165	1,955,609,932	887,050	0.887
165	102,239,372	46,375	0.046
165	187,131	85	0.000
165	7,351,010	3,334	0.003
172	1,416,046,036	642,308	0.642
172	352,033,846	159,680	0.160
172	-	-	-
172	4,399,403	1,996	0.002
172	18,648,120	8,459	0.008
131	98,125	45	0.000
	6,442,750,083	**2,922,382**	**2.922**

Estimated MPG	Gallons per year
22.1	136,291,811
17.6	103,062,447
35.0	5,388,109
6.0	64,068,683
7.8	15,927,692
-	-
	296,180,237

Estimated MPG	Gallons per year
19.2	287,318,061

W2P Total Energy (Btus)	W2P Total Energy (Million Btus)	GHG Coefficient for Fuel Type	GHG Emissions (lbs CO2e)	Metric Tons of CO2e	Million Metric Tons CO2e
7,611,585,631,020	7,611,586	165	1,255,911,629	569,672	0.570
2,187,000,676,035	2,187,001	172	376,164,116	170,625	0.171
9,798,586,307,056	**9,798,586**		**1,632,075,745**	**740,297**	**0.74**

Table 1: Industrial Process Emissions for Pioneer Valley

Counties	Specific Process (MMTCO2e)	ODS (MMTCO2e)	Total Emissions (MMTCO2e)
Hampden	0.018	0.173	0.19
Hampshire	-	0.059	0.06
Total	**0.018**	**0.233**	**0.25**

Table 2: Industrial Process Emissions for Hampden County

Industries	NAICS Codes	Employees - County	Employees - Nation	County Share	2008 Emissions - Natic	Emissions - County
Cement Manufacturing	32731	-	15,558	-	40.5	-
Semiconductor Manufacturing	334413	-	108,050	-	5.2	-
Nitrogenous Fertilizer Manufacturing	325311	-	4,373	-	11.9	-
Petrochemical Manufacturing	325110	-	8,334	-	3.4	-
Ferrous Metal Foundries	33151	2.5	70,923	0.0000	64.3	0.002
Aluminum Foundries	331521, 331524	82.5	37,646	0.0022	7.1	0.016
Lime Manufacturing	32741	-	4,798	-	14.3	-
Total						**0.018**

Table 3: Industrial Process Emissions for Hampshire County

Industries	NAICS Codes	Employees - County	Employees - Nation	County Share	2008 Emissions - Nation (MMTCO2e)	Emissions - County (w/Fertilizer)	Emissions - County (wo/Fertilizer)
Cement Manufacturing	32731	-	15,558	-	40.5	-	-
Semiconductor Manufacturing	334413	-	108,050	-	5.2	-	-
Nitrogenous Fertilizer Manufacturing	325311	34.5	4,373	0.0079	11.9	0.094	-
Petrochemical Manufacturing	325110	-	8,334	-	3.4	-	-
Ferrous Foundries	33151	-	70,923	-	64.3	-	-
Aluminum Foundries	331521, 331524	-	37,646	-	7.1	-	-
Lime Manufacturing	32741	-	4,798	-	14.3	-	-
Total						**0.094**	**-**

Table 4: Emissions from the substitution of Ozone-Depleting Substances

County	National Emissions (MMTCO2e)	County Population (2010)	National Population (2010)	County Population Share	County Emissions (MMTCO2e)
Hampden	115.5	463,490	308,745,538	0.0015	0.173
Hampshire	115.5	158,080	308,745,538	0.0005	0.059
Total		**621,570**		**0.0020**	**0.233**

Table 5: Sources

Data	Tables	Source
Employment Totals	Tables 2, 3	2009 County Business Patterns - Census Bureau
Population Data	Table 4	2010 Census
National Emission Totals	Tables 2, 3, 4	Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 - 2009

Total	-

Table 1: Total Emissions for Waste Sector

	Emissions
Landfills	0.25
Wastewater	0.06
Total:	**0.31**

Table 2: Emissions from Landfills

Facility	Address	City	Contact	Owner	Total Direct Emissions	Total Biogenic Emissions	Total Facility Emissions
Chicopee Sanitary Landfill	161 New Lombard Rd	Chicopee	Thomas C. Murray	Connecticut Valley Sar	0.0018	0.0394	0.0652
Northampton Landfill	170 Glendale Rd	Northampton	David Veleta	City of Northampton	0.0068	0.0042	0.0110
Springfield Incinerator	Bondi's Island	Agawam	Will Campbell	Covanta Energy	0.0279	0.0778	0.1056
Granby Sanitary Landfill	11 New Ludlow Rd	Granby	Thomas C. Murray	Holyoke Sanitary Land	0.0003	0.0001	0.0122
South Hadley Landfill	12 Industrial Drive	South Hadley	Thomas Fields	South Hadley Landfill,	0.0005	0.0101	0.0287
Bondi's Island Landfill	Bondi's Island	Agawam	Scott Donelon	Springfield Departmer	0.0219	0.0019	0.0263
Total:					**0.06**	**0.13**	**0.25**

Table 3: Emissions from Wastewater

	Massachusetts			Pioneer Valley		
	2006	2007	2008	2006	2007	2008
Municipal CH4	0.43	0.44	0.44	0.041	0.042	0.042
Municipal N2O	0.19	0.19	0.19	0.018	0.018	0.018
Industrial CH4	0	0	0	0	0	0
Fruits & Vegetables	0	0	0	0	0	0
Red Meat	0	0	0	0	0	0
Poultry	0	0	0	0	0	0
Pulp & Paper	0	0	0	0	0	0
Total:	**0.62**	**0.63**	**0.63**	**0.06**	**0.06**	**0.06**

Table 4: Sources

Data	Tables	Source
Landfill Data	Table 2	Climate Change Registry
Wastewater Use	Table 3	Preliminary 2006-2008 Massachusetts Greenhouse Gas Emission Inventory, 2010 Census

Table 1: Emissions - Share of State Population

	State Emissions (MMTCO2e) - 2008	Region Emissions (MMTCO2e)
Pioneer Valley	**0.6**	**0.06**

Table 2: Emissions - Share of State Forests

	State Sequestration (MMTCO2e) - 2008	Region Sequestration (MMTCO2e)	Region Share of State Sequestration	State Emissions (MMTCO2e) - 2008	Region Emissions (MMTCO2e)
Pioneer Valley	**11**	**2.51**	**23%**	**0.6**	**0.14**

Table 3: Sources

Data	Tables	Source
State Emissions	Tables 1 & 2	Preliminary 2006-2008 Massachusetts Greenhouse Gas Emission Inventory, 2010 Census
Region Sequestration	Table 2	i-Tree Analysis - Kyle Boyd/UMASS-LARP
Population Estimates	Table 1	U.S. Census (2010)

Table 1: Pioneer Valley Fugitive Emissions

	MMCO2e
Transmission - Natural Gas	0.03
Distribution - Natural Gas	0.12
Total	**0.16**

Table 2: Transmission Emissions- Natural Gas

	MA Data 2005	Emission Factor	MA Emissions (CH4)	CH4 > CO2e	MA (MMCO2e)	MA > PV Factor	Pioneer Valley (MMCO2e)
Miles of gathering pipeline	-	0.4	-	25	-	0.0790	-
Number of gas processing plants	-	1,249.9	-	25	-	0.0790	-
Number of LNG storage compressor stations	6	1,185.0	7,110	25	0.178	0.0790	0.014
Miles of transmission pipeline	1,071	0.6	662	25	0.017	0.0790	0.001
Number of gas transmission compressor stations	6	983.7	5,902	25	0.148	0.0790	0.012
Number of gas storage compressor stations	2	964.1	1,928	25	0.048	0.0790	0.004
Total			**15,602**		**0**		**0.031**

Table 3: Distribution Emissions - Natural Gas

	PHMSA Data 2010	Emission Factor	Emissions (CH4)	CH4 > CO2e	Emissions (MMCO2e)
Miles of cast iron distribution pipeline	362	5.804	2,100	25	0.052
Miles of unprotected steel distribution pipeline	121	2.122	257	25	0.006
Miles of protected steel distribution pipeline	842	0.060	51	25	0.001
Miles of plastic distribution pipeline	666	0.372	248	25	0.006
Total number of services	98,409	0.015	1,502	25	0.038
Number of unprotected steel services	22,885	0.033	750	25	0.019
Number of protected steel services	18,750	0.003	64	25	0.002
Total			**4,971**		**0.124**

Table 4: Distribution Data- Natural Gas (PHMSA)

	Columbia Gas of MA Totals	% Columbia Gas in Pioneer Valley	Columbia Gas in Pioneer Valley	Berkshire Gas Totals	% Berkshire Gas in Pioneer Valley	Berkshire Gas in Pioneer Valley	Westfield Gas & Electric	Holyoke Gas & Electric	Total:
Miles of cast iron distribution pipeline	773	0.314	243	94	0.133	13	47	59	362
Miles of unprotected steel distribution pipeline	373	0.314	117	30	0.133	4	-	-	121
Miles of protected steel distribution pipeline	2,042	0.314	642	359	0.133	48	60	93	842
Miles of plastic distribution pipeline	1,637	0.314	514	227	0.133	30	100	21	666
Total number of services	251,349	0.314	78,969	30,558	0.133	4,078	7,809	7,553	98,409
Number of unprotected steel services	54,768	0.314	17,207	7,047	0.133	941	1,690	3,048	22,885
Number of protected steel services	50,015	0.314	15,714	6,387	0.133	852	352	1,832	18,750

Table 5: Sources

Data	Tables	Sources
MA Transmission Data	Table 2	2005 EPA State Inventory Tool
Emission Factors	Tables 2, 3	2005 EPA State Inventory Tool
CH4 to CO2e Conversion Factor	Tables 2, 3	IPCC - Fourth Assessment Report on Climate Change (2007)
Distribution Data	Tables 3, 4	Annual Gas Distribution Data from Pipeline and Hazardous Material Safety Administration

Table 1: Total Emissions From Agriculture

Type	CO2e (Metric Tons)	MMTCO2e
Enteric Fermentation	11,926	0.012
Manure Management	880	0.001
Total	**12,806**	**0.013**

Table 2: Emissions from Enteric Fermentation

Type	Population	GHG Factor	CH4 Emissions (Metric Tons)	CH4 > CO2e	CO2e (Metric Tons)
Cattle	7,603	53	403	25	10,074
Sheep	2,113	8	17	25	423
Goats	1,176	5	6	25	147
Horses	2,676	18	48	25	1,204
Swine	2,079	1.5	3	25	78
Total	**15,647**		**477**		**11,926**

Table 3: Emissions from Manure Management

Type	Population	GHG Factor	CH4 Emissions (Metric Tons)	CH4 > CO2e	CO2e (Metric Tons)
Cattle	7,603	1.00	7.6	25	190
Sheep	2,113	0.19	0.4	25	10
Goats	1,176	0.13	0.2	25	4
Horses	2,676	1.56	4.2	25	104
Swine	2,079	11.00	22.9	25	572
Total	**15,647**		**35**		**880**

Table 4: Sources

Data	Tables	Source
Livestock Population	Tables 2, 3	Agricultural Census (2007)
GHG Factors	Tables 2, 3	2006 IPCC Guidelines for National Greenhouse Gas Inventories: Chapter 10, Emissions from Livestock and Mar
CH4 to CO2e Conversion Factor	Tables 2, 3	IPCC - Fourth Assessment Report on Climate Change (2007)

Catalyst for Regional Progress
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