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Report

of the

SENATE COMMITTEE ON

GLOBAL WARMING AND CLIMATE CHANGE

entitled

NO TIME TO WASTE:

Our climate clock is ticking and our natural resources, public health and the future of our economy are at stake

February 13, 2015

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A Report of the
Senate Committee on Global Warming and Climate Change
February 2015

Massachusetts Senate
The Honorable Stanley C. Rosenberg
Senate President

Senate Committee on Global Warming and Climate Change
Senator Marc R. Pacheco, Chair
Senator James B. Eldridge, Vice-Chair
Senator Michael J. Barrett
Senator Benjamin B. Downing
Senator Thomas M. McGee
Senator Robert L. Hedlund

Senate Committee on Global Warming & Climate Change

Senator Marc R. Pacheco, Chairman

It shall be the duty of the Senate Committee on Global Warming and Climate Change to investigate the issues involving global warming and climate change, including but not limited to carbon emissions, greenhouse gas emissions and renewable energies. The committee will explore viable solutions and other innovations that stimulate our economy, promote jobs, and protect our security and environment. The Committee may hold hearings, as needed, to investigate and gather information. The committee shall report, from time to time, with recommendations for legislative action based on their review or on the findings of the investigations. The committee shall have the authority to develop and report legislative proposals pertaining to global warming and climate change, which shall be referred to the Senate Committee on Ways and Means.

This report was prepared by Committee staff, including **Kyle Murray,** Legislative Director and General Counsel, and **Maryalice Gill,** Communications Director.

The Committee would acknowledge the significant contributions from interns from Senator Pacheco's office, including Thomas Paine, University of Massachusetts School of Law– Dartmouth; Lindsay Webb, M.S., Tufts University, Food Policy & Applied Nutrition; and Harvard University's Kennedy School of Government Policy Group Program student research team: (Co-Chairs) Rajkumar S. Pammal and Cameron Thariani; (Group Members) Matt Deveney, Oliver Falvey, John Gabrieli, Priscilla Kim, Jacob Meisel, Kenneth Nanyumba, Michael Richard and Phonkrit Tanavisarut

Executive Summary

Massachusetts leads the nation when it comes to addressing climate change. It is committed to reducing emissions according to guidelines first established by the Intergovernmental Panel on Climate Change and has achieved some of the most dramatic reductions of any state in the United States. For all the progress Massachusetts has made, however, it is not currently on track to meet its 2020 greenhouse gas emission reduction goal set by the Global Warming Solutions Act; in fact, according to the Global Warming Solutions Project's "Massachusetts Clean Energy and Climate Scorecard," the state is only currently on track to achieve a 20 percent reduction in emissions below 1990 levels by 2020, whereas the Global Warming Solutions Act calls for emissions to be reduced by 25 percent below 1990 levels in that timeframe.[1] Nevertheless, Massachusetts is not far off from its goal and should be able to reach it with assertive action and many of the resources it already has on hand. This report will examine how climate change can affect the Commonwealth, the advancements the state has made so far to address this issue and a series of steps the executive branch should take, mostly within the scope of existing legislative authorization, to continue the progress Massachusetts has made to reduce our carbon footprint and to embrace a new, clean energy future.

When people talk about climate change, they usually only discuss potential damage to state infrastructure or the economy. However, many people do not realize climate change will impact nearly all sectors of life. This report explores some of these lesser discussed areas, specifically agriculture and public health. Massachusetts' significant agricultural output does not lead the nation when compared to states such as California or Florida, but its farming community is made up of centuries-old traditions and it remains strong today. That all could change as the

result of rising temperatures and increasing storms as the result of climate change, and cranberry production, one of Massachusetts' most vibrant farming communities, could be severely impacted. Additionally, rising ocean temperatures potentially could cause great damage to the Massachusetts seafood industry, which also comprises an important sector of the state economy. The Commonwealth's public health also faces threats from climate change. The increasing number of extreme heat days will endanger Massachusetts' most vulnerable populations, including the elderly, young, infirm and poor. Rising temperatures also could lead to an elevated insect population in the state, which will inevitably lead to more insect-borne illnesses. Furthermore, elevated levels of greenhouse gases jeopardize the lives of those with respiratory issues.

Massachusetts has made significant progress towards reducing greenhouse gas emissions and preparing for climate change. The Global Warming Solutions Act and Green Communities Act have provided the executive branch powerful tools to combat climate change. Fortunately, on one hand, the former Patrick administration took advantage of some of these tools. Apart from the Global Warming Solutions Act and Green Communities Act, Massachusetts utilizes a renewable portfolio standard, which requires increasing levels of energy coming from renewable sources and has helped Massachusetts dramatically increase its own renewable generation over time. On the other hand, the former Patrick administration unfortunately declined to promulgate as strong a set of declining annual aggregate emissions limits as possible or to pursue a carbon pricing mechanism. In fact, it has been argued by a number of environmental groups that they have not fulfilled their obligation to promulgate the aforementioned regulations. This lack of action has deprived Massachusetts of two extremely effective methods of reducing greenhouse gas emissions.

The new Baker administration will face myriad challenges from climate change. This report contains a number of recommendations to help ease that transition. The recommendations include:

- Adopt a clean fuel standard
- Enforce Global Warming Solutions Act regulations and implement carbon pricing
- Encourage more energy efficiency
- Incentivize smart meter use
- Embrace smart growth and target lifecycle costs
- Boost the Green Communities Designation and Grant Program
- Balance imported energy with renewables
- Promote clean energy and energy efficient transportation
- Strengthen the stretch code
- Adopt comprehensive adaptation management plan legislation and invest in resiliency statewide
- Modernize the grid

Contents

I. INTRODUCTION

Across the globe, climate change can generally be considered the defining issue of our age. Despite consensus around the reality of climate change, including its causes and threats, there still is a significant effort in the United States to stall federal action on this issue. In recent months there have been some positive signs of federal policy progress, including the Environmental Protection Agency's new rules for regulating carbon emitted from power plants, but much more is needed to be done. In the absence of cohesive federal leadership, many states have taken it upon themselves to reduce greenhouse gas emissions at the state level.

Climate change presents a number of challenges and opportunities for Massachusetts. Also known as "the Bay State," Massachusetts has large stretches of oceanfront communities and many productive seaports. In Massachusetts, many are familiar with the impending crisis of sea level rise and the numerous threats it poses to the state. This report will focus on some lesser discussed consequences of climate change that may have serious implications for Massachusetts' economy, including the potential threats to state agricultural production and public health concerns. Although Massachusetts does produce less agriculture than states such as California or Florida, the Commonwealth is home to a vibrant agriculture community that faces significant threats from a changing climate. Rising temperatures also pose direct health risks for Massachusetts residents. Between the state's aging population and infrastructure, an increase in high-temperature days in the Commonwealth will put at-risk communities in greater danger. Massachusetts also contains aging energy infrastructure and a lack of in-state consumable energy resources. Due to its dependence on imported natural gas and electricity, Massachusetts has a high exposure to volatile energy markets. The state will need to balance that exposure with competing needs to reduce greenhouse gas emissions.

Although climate change requires federal and global action, states and municipalities can and should execute solutions that mitigate the harms of climate change while upholding the health and vibrancy of their communities. Smaller governments at the state or local level are isolated from the pressures that drive federal decision-making. Cities and counties "appear to be more focused on demonstrable action instead of explicit quantification and cost-benefit analysis."[2] Furthermore, municipalities control many of the direct factors of greenhouse gas production. Massachusetts has been keen to support local initiatives through a host of legislative efforts in 2008 including the Green Communities Act, which gives incentives and guidelines for cities and towns to take action, the Global Warming Solutions Act, the Oceans Management Act, the Biofuels Act and the Green Jobs Act. Each act addresses a separate but related piece of the clean energy economy, and each has proven to be successful in strengthening that sector: according to the 2014 Massachusetts Clean Energy Industry report, Massachusetts is now home to nearly 6,000 clean energy firms and more than 88,000 clean energy workers. The clean energy sector now represents a $10 billion industry, which accounts for 2.5 percent of the Gross State Product in Massachusetts.[3] That growth is expected to continue.[4] This report aims to demonstrate that by taking action on climate change using the legislative tools Massachusetts already has enacted and some legislative tools the legislature should enact, the state can protect itself from the most extreme climate threats while promoting a strong clean energy economy in the process.

II. THE HEIGHTENED RISK OF RISING SEA LEVELS IN MASSACHUSETTS

Sea level rise is one of the many well-documented threats that climate change poses to the people and property of Massachusetts. According to the U.S. Geological Survey, seas along the United States' Atlantic coast are rising three to four times faster than the global average.[5] According to the U.S. Census Bureau, as of 2008, 52.6 percent (approximately 3.4 million people) of Massachusetts' population lives in coastal counties, placing them at risk of rising sea levels.[6] Boston alone is home to nearly 10 percent of the state's population, as well as an estimated $460 billion in real estate assets along the water.[7] In addition to sea level rise, coastal communities face magnified risks from storm surges, as rising seas caused by the pressure of a storm come towards shore. Hurricane Sandy incited storm surges of almost 9.5 feet above high tide to parts of New York and New Jersey.[8] Altogether, Sandy caused the region extreme infrastructure and economic damage, including $50 billion in expenditures in New York.[9] Thus far, Massachusetts has been spared a storm as destructive as Hurricane Sandy, but rising seas, combined with more intense and frequent storms, make the possibility of a Sandy-like storm more likely to occur not as a 100-year storm, but as a 10- or 5-year storm.[10]

Unless Massachusetts implements solid resiliency measures, large storms and flooding could greatly impair state transportation and energy infrastructure. Boston Massachusetts Bay Transport Authority's subway systems are at considerable risk, according to a statement released by former Massachusetts Secretary of Transportation Richard Davey.[11] The subway system, which includes underground tracks and stations below sea level, accommodates about 59 percent of public transportation ridership in the greater Boston area, according to the MBTA's online scorecard.[12] Trains run along electric cables that could be incapacitated in the event of massive

flooding and water damage. Such devastation of the subway system could prevent nearly one million rides for MBTA commuters over the course of a week and slow the city to a standstill.[13] Storms similar to Sandy's size and force also could cause a ripple effect of power outages and the loss of utilities along the eastern region of the state. Massachusetts maintains 12 energy facilities on land less than 10 feet below local high-tide, including power plants and Liquid Natural Gas storage facilities, which leaves them highly vulnerable to storm surge flooding.[14] Flood damage to these facilities could cause power outages that could take weeks or months to repair.

Massachusetts electricity is generated from varying sources of varying age. Massachusetts generates a significant amount of its electricity from the Brayton Point coal-fired plant and the Pilgrim nuclear plant. Both power stations are more than 40 years old and are located on the shoreline.[15] Although Brayton Point is slated for a 2017 shutdown, the plant is still generating power today, and may remain open in the future. Its anticipated closure is largely attributed to the glut of natural gas driving up the relative cost of coal-derived power, but a shift in the fuel market could alter plant operation economics.[16] With the scheduled closing of Brayton Point, Massachusetts' already heavy reliance on imported energy is likely to increase. Imported energy is effective in reducing state emissions through the utilization of external zero-emissions sources, but the state also must ensure the infrastructure behind those imports is reliable. Because imports are beyond state jurisdiction, Massachusetts is limited in its ability to take actions that could strengthen the grid or put demands on generators as part of the state purchasing contract.

Over the next 35 years, projections for Massachusetts' sea level rise are increasingly bleak, including estimations that suggest Boston's sea level could rise anywhere from one to two

feet.[17] At these levels, a storm of Sandy's proportions could submerge most of the city, including highly populated neighborhoods such as the Back Bay, East Boston, the North End, and Dorchester, according to the Boston Harbor Association.[18] In an extensive report that evaluated rising sea levels, Ben Strauss, the Vice President for Climate Impacts and Director of the Program on Sea Level Rise at Climate Central, detailed that by 2100 more than 25 percent of Boston and 25 percent of a combined 55 additional surrounding communities would be submerged underwater.[19] The result could amount to billions of unrecoverable assets.

III. CLIMATE CHANGE AND AGRICULTURE IN MASSACHUSETTS

Massachusetts has a long and storied history involving agriculture. According to the most recent, reliable data, there are nearly 8,000 farms in Massachusetts covering more than 500,000 acres of land.[20] In 2012 alone, farms in Massachusetts, primarily operated by families, produced fruits, vegetables, livestock, greenhouse and nursery goods, and other agricultural products valued at nearly $500 million.[21] Though agriculture is not the largest sector of Massachusetts' economy, it makes important contributions. In 2012, Massachusetts housed 7,755 principal farm operators and 15,649 hired farm workers, which indicate agriculture has a direct economic impact on more than 20,000 people who make their living on the farm and their families.[22]

Massachusetts agriculture is diverse. In terms of value, primary crops include greenhouse and nursery, cranberries, milk, apples, and aquaculture, but products are as varied as pastured pork, butternut squash, winter greens and tomatoes.[23] The food produced on Massachusetts farms makes a difference in the lives of residents every day. Across the state, for example, children enjoy fresh fruits and vegetables in school lunches from Massachusetts farms through the Farm to School Program. In 2013, Massachusetts farmers supplied more than 35,000 pounds of fresh food to Boston Public Schools alone.[24] Customers of Massachusetts' 250 farmers'

markets enjoy fresh fruits, vegetables and meats from farmers and vendors they meet face-to-face. The USDA found that in 2012, direct sales from Massachusetts farmers to customers, whether at farmers' markets, roadside stands or community-supported agriculture totaled nearly $48 million.[25]

Unfortunately, global warming is likely to be felt acutely by food producers in Massachusetts, and some effects already are felt today. Rising temperatures are expected to affect crop yields, livestock production and the fishing industry. Increased precipitation presents a number of challenges to fruit and vegetable farmers, including topsoil loss from erosion, and flood damage that can harm crops and soil. Increased variability in weather conditions and a greater frequency of high-temperature days could spell hardship for an industry in which the effects of one ill-timed frost, storm or drought may be felt years after the fact. Just as Massachusetts farmers will bear the burden of these changes, climate change presents implications for food security and food safety as well. As a result, likely every resident of the Commonwealth will be affected by the impacts of climate change on agriculture.

EFFECTS OF CLIMATE CHANGE ON AGRICULTURE IN THE UNITED STATES

Agricultural activities and productivity depend greatly on weather conditions, which make climate change impacts considerably concerning for farmers. Overall warming temperatures in the northern hemisphere, for example, have increased the growing season on average by about 10 days since 1970, but a lengthened growing season means a contraction of the winter season, on which many perennial crops depend to grow.[26] The effects of these changes on the food system are complex, but according to a 2009 report from the International Food Policy Research Institute, they can be expected to impact human well-being worldwide in several important ways: 1) through the biological effects on crop yields, 2) resulting outcomes on

factors such as prices, production and consumption, and 3) impacts on per capita energy consumption and child malnutrition.[27] Lobell et al. estimated 3.8 percent and 5.5 percent declines in global corn and wheat production, respectively, due to weather trends between 1980 and 2008.[28]

According to the National Center for Science Education, trends in weather events, temperature and precipitation will not affect regions of the world uniformly, and effects on agriculture will be varied.[29] It is possible to expect positive effects due to a longer growing season in some areas, but the IPCC indicates with high confidence in its 2014 report that thus far the effects have been more negative than positive, based on a variety of studies on crop responses to climate change.[30] In the United States, climate change could necessitate changes in crops grown domestically, which would require alterations to markets as well as labor and farm practices.

The effects of climate change in one region are not necessarily limited to that region, given that agriculture systems in the U.S. often do not operate independently of one another. For the most part, livestock farmers in Massachusetts do not grow their own animal feed; they buy a significant amount of it from the Midwest. This means that a drought or storm in Iowa can have profound implications for livestock in Massachusetts, including higher prices for feed grain and increased risk for disease due to pathogens and mycotoxins, which are harmful toxins from fungi that grow more easily in moist conditions.[31]

CLIMATE CHANGE IN MASSACHUSETTS

Climate change will affect U.S. regions in different ways and Massachusetts farmers and residents have already been experiencing its impacts. Brown et al. in 2009 assessed Northeast climate data over a period of 135 years (1870 and 2005) and found strong warming with an

increase in warm nights and warm summer days and a decrease in cold events such as ice days and frost days.[32] Overall, the study found an increase in minimum temperature, an increase in maximum temperature and an increase in annual average precipitation.[33] The National Climate Assessment, released in May 2014, notes a 2009 study found a 70 percent increase in the amount of precipitation falling in very heavy rainfall events in the Northeastern United States.[34] The increase is almost double that of the region with the next highest increase, indicating the Northeast is experiencing by far the highest increase in precipitation falling in very heavy rainfall events.[35] These increases have implications for soil conservation, aquaculture viability and productivity of Massachusetts farms.

The trends can be expected to continue. The Massachusetts Climate Change Adaptation Committee reported on expected effects of climate change in Massachusetts up to the year 2100 based on a number of studies including the most recent report of the Intergovernmental Panel on Climate Change.[36] In the Northeast they include overall temperature increase resulting in warmer winters and warmer summers, a higher frequency of high temperature (100 degrees-plus Fahrenheit) days, more precipitation falling as rain instead of snow and longer droughts.[37] Such changes would require large investments in adaptation strategies and infrastructure in multiple sectors, including agriculture.

Certain producers may stand to benefit from milder effects: moderately warmer temperatures can increase productivity for some plants and a longer growing season may offer opportunities for new crops to grow in areas in which they were unable to grow before. Increased water temperatures could spur a northward shift of warmer water species of fish and shellfish, though it is not yet clear what their productivity would be like during such a transition.[38] There also may be opportunities for farmers with the capital to begin cultivating new crop varieties,

though many farmers in Massachusetts do not have access to the resources to capitalize on these changes.[39]

It may be argued climate change could potentially pose benefits for some northeast agricultural operations, but the overall situation looks worse in almost every sense. Massachusetts producers may face increased risk and decreased predictability in the coming decades.[40] A potentially longer growing season might offer opportunities for new crops and markets in the long term, but the short-term investments and market development necessary to capitalize on this change present significant challenges. Though the growing season may be longer, increased precipitation such as rain, higher variability in temperatures, a higher frequency of high temperature days and changes in water temperatures and sea level could prove problematic overall. Wolfe et al. investigated how several potential effects of climate change (such as longer growing season, higher frequency of high temperature days, inadequate winter chill period and increased pressure from weeds and pests) might impact several high-value farm products that are economically important to agriculture in the Northeast (including dairy milk, apples, maple syrup, and several others).[41] The study concluded many crops will have yield losses, weeds will benefit more than cash crops from higher atmospheric carbon dioxide, and high temperatures will have negative effects on milk production.[42]

IMPACTS OF A LONGER GROWING SEASON

The Northeast has been experiencing a lengthening of the growing season since last century.[43] Several studies have found earlier flowering dates for a number of different plants in the region. Wolfe et al. studied historical and current spring bloom data (1965-2001) for woody perennials in the Northeast including lilac, apple and grape. The study found advances in spring phenology (date of first leaf and date of first flower) of two to eight days, providing evidence

that warming temperatures in the Northeast during the past few decades have affected the lifecycles of these species, effectively allowing them to bloom earlier.[44] Research cited in the most recent National Climate Assessment found a 10-day increase in the frost-free period (which corresponds to a lengthened growing season) in the Northeast during the period of 1991-2012 relative to the period of 1906-1960.[45]

Already farmers have managed the effects of a longer growing season that has developed in Massachusetts over the past couple of decades. Several economically and culturally important crops stand to suffer from warming temperatures earlier in the year. Apples, for example, require a certain number of days with temperatures below a certain threshold, which is called its chilling requirement. While the variety of plants that can be grown in Massachusetts may increase, significant infrastructure improvements are required to handle such changes. Switching crops often presents a large investment for farmers, many of whom do not have the resources necessary for new equipment and farm inputs. Production changes can offer opportunities for farmers with substantial resources to take certain risks, but for farmers who lack these resources, making changes in the crops they grow and bringing those products to the market can involve significant economic costs and take years.[46]

A substantial concern for maple syrup, for example, is a temperature increase earlier in the year: if weather warms too quickly, trees could stop producing sap.[47] This could pose major challenges for maple syrup producers in Massachusetts as the suitable climate for maple syrup production moves northward and precludes maple syrup production here.[48] Apple viability could be negatively affected by a lengthened growing season in Massachusetts. Researchers in Japan found a statistically significant correlation between warming temperatures from 1977 to 2004 and an advance in budding and flowering times for apple trees. In their discussion, they

hypothesize in the absence of significant differences in phenology across the locations they sampled, "the growing season in a high latitude in the future can be represented by that in a low latitude area at present."[49] In other words, to extrapolate these results, an apple variety suitable for Massachusetts now may be more suitable for a climate north of the state in the future as temperatures warm and the growing season changes. If the growing season continues to shift, apple producers in Massachusetts may need to make changes to the varieties of apples they grow.

HIGHER FREQUENCY OF HIGH TEMPERATURE DAYS

One anticipated effect of climate change is an increase in the number of high temperature days during warmer months. In Boston, for example, from 1961 to 1990, the EPA reports the city experienced an average of one day per year reaching 100 degrees Fahrenheit; under the conditions of climate change, however, the EPA expects Boston should experience as many as 24 such days per year by 2100.[50] These types of conditions could have negative effects on agricultural crops and livestock in Massachusetts. Extreme temperatures during critical growing times can produce lower yields and lower quality crops.[51] Massachusetts farmers may see a decline in high-value, water-dependent fruits and vegetables, which constitute a large part of Massachusetts agricultural output, because of more frequent droughts caused by higher temperatures.[52]

As livestock feel extreme temperature increases acutely, farmers who raise livestock can expect a decrease in productivity. According to the U.S. Department of Agriculture, most animals maintain an optimum body temperature within two and three degrees Celsius.[53] If animals need to exert more energy to maintain body temperatures in the face of greater fluctuation, animal fertility as well as animal products such as meat and eggs may be affected.[54] Confined animals systems such as those used to raise large numbers of pigs and chickens can

help mitigate these effects, but very few farm operations in Massachusetts use such facilities. Dairy and beef cattle, which are generally not kept in such facilities, could stand to suffer greatly from the extreme temperatures expected in the next few decades. Sheltering animals to protect them from extreme heat will require investments in modifications of shelter as well as cooling systems, which will in turn increase energy costs on the farm.[55] Additionally, higher temperatures could mean increased water consumption among livestock (potentially 20-50 percent) which presents a challenge for farmers under hot, dry conditions.[56] Temperature variability also may lead to an increased incidence of livestock diseases such as pneumonia.[57]

INCREASING TEMPERATURES YEAR-ROUND

Climate science indicates temperatures have risen and may continue to rise in summer and winter months. In general, additional temperature increases could pose significant challenges due to changes in the conditions important for crop and livestock growth and productivity.

A number of perennials, especially tree fruits such as apples and peaches, have a chilling requirement that means they must spend a specified amount of time under a certain temperature to flower and produce fruit.[58] As winter temperatures warm, some crops will be in danger of failing to meet their chilling requirements, which can lead to significant yield losses. Perennials with chilling requirements below 1,000 cold hours may not suffer greatly, but those with chilling requirements of more than 1,000 cold hours may experience difficulties. Northeastern farmers, for example, may want to make changes to the varieties of apples they grow as a result.

Higher temperatures also create friendlier habitats for pests and weeds not previously seen in Massachusetts, or those not previously seen at problematic levels. As temperatures warm, some pests and weeds move northward. As warming temperatures cause the growing season to lengthen, farmers may see more pest lifecycles occur over the course of a season.[59] Pest species

that previously underwent only two life cycles are capable of going through three or more life cycles, meaning farmers must monitor those species for a whole growing season, not only after June.[60] Increased pest and weed pressures will affect organic farmers disproportionately as their options for weed and pest control are limited.

One example of a potentially problematic pest in Massachusetts is the brown marmorated stink bug (BMSB), which feeds on crops including apples and tree fruits, ornamental plants, and soybeans, among others.[61] The BMSB wreaked havoc on apple crops in Maryland in 2010 and has become "a pest of almost unprecedented importance to agriculture," having moved steadily northward since its accidental introduction in Pennsylvania.[62] Though some pesticides have been able to control BMSB populations, their effectiveness is limited.[63] A 2012 study estimated the hospitable habitat for BMSB lies between the 30th and 50th latitudes.[64] Massachusetts inhabits the low 41st parallel to nearly the 43rd parallel, and BMSB have been seen in this state.[65]

Farmers can expect added weed pressure as temperatures increase. Though plants may benefit from added carbon dioxide in the air, certain types of weeds that compete with crop species for resources will thrive more quickly. Kudzu, for example, is a highly invasive plant that will pose a greater threat to crops in the Northeast in coming years. Farmers will need to adapt to new weed species as certain weed ranges move northward.

Temperature increases also result in more disease issues. According to Carrie Chickering-Sears of the University of Massachusetts' UMass Extension, veterinarians have seen diseases in the last 20 years they had never seen before.[66] Diseases with vectors such as mosquitos and ticks are more common now because they thrive in warmer environments. A number of studies also have found reason to believe illnesses due to certain types of salmonella bacteria will increase as temperature increases.[67]

IMPACTS OF CHANGES IN PRECIPITATION

Climate change may cause more precipitation to fall in the Northeast as rain instead of snow and cause more frequent, heavy rain events. Increased temperatures increase the ability of the atmosphere to hold moisture, which could result in more rain in certain parts of the world.[68] Projections related to precipitation per U.S. region, however, are less certain than projections related to temperature change. It may be difficult to predict the increase in the amount of precipitation and the frequency of the precipitation, but it is likely that more precipitation will fall as rain than as snow. Additional rain impacts flooding potential and water availability during the spring and summer from melting snowpack, which each have implications for agriculture.

Heavy rainfall, with its potential to disrupt and damage agriculture in Massachusetts, affects crops and aquaculture. It can cause erosion and topsoil loss, which are concerns in many areas of the United States. Soil erosion occurs when forces of water, wind, or gravity break down, detach, transport and redistribute soil particles.[69] These processes can prevent soil from supporting plant life that becomes food for humans and livestock animals. Erosion also is a significant source of water pollution as nutrients like phosphorus and nitrogen from agricultural fertilizer and manure move with runoff and sediment flows from cropland into waterways.[70] Heavy rainfall moves more soil off a field than mild rainfall because more water builds up, providing more energy to move particles down a slope. With heavy rainfall of 2-4 inches within 24 hours, even a small slope can generate erosion.[71]

Beyond jeopardizing soil productivity, heavy precipitation and runoff has detrimental effects on aquaculture on the Massachusetts coast.[72] Shellfish, the biggest aquaculture industry in Massachusetts, are sustainable because no inputs are added to the system.[73] Filter feeders such as clams and oysters take up algae already present in the water.[74] Large scale changes in

precipitation can have downstream effects on clams and oysters from inland runoff; as these organisms are indiscriminate feeders, they take up chemicals and other substances from the water around them.[75] Heavier rainfall poses greater challenges than milder, seasonal rains because of such pollutant buildup and washout.[76]

Heavy rainfall also threatens soil saturation. Extreme rainfall events can cause more water to sit on top of soil than the soil can reasonably absorb.[77] Standing water on soil for long periods of time can lead to the proliferation of soil-borne diseases as well as poor growth of crops.[78] Additionally, floodplain acreage becomes unavailable for livestock grazing, which is an important land use in Massachusetts.[79]

Farmers face difficult circumstances if heavy rainfall occurs before or early in the growing season. Such rainfall events before the growing season may demand a delay in planting, which affects growing and harvest time. If heavy rainfall occurs early in the growing season, some fresh market vegetable growers who make much of their profit based on early season production may be at a disadvantage. Thus, heavy rainfall can have substantially negative economic effects.

IMPACTS OF CHANGES IN WATER CONDITIONS

Global sea levels are expected to rise dramatically by the year 2100, anywhere from 1-4 feet.[80] Effects on the Northeast will vary due to terrain and sea level rise. The Boston metropolitan area, for example, should expect to incur up to $94 billion in the costs of damage due to sea level rise.[81] This rise poses an obvious threat to agriculture, particularly in low-lying areas where flooding can easily occur.

As water temperatures rise off the coast of Massachusetts, the fishing industry should expect changes as well. The suitable habitat for cod, for example, is expected to shift

northward.[82] Historically prolific fishing areas such as Georges Bank may become too warm to support the growth and survival of young cod, though they could support adult cod.[83] According to the Union of Concerned Scientists, waters south of Cape Cod will become entirely unsuitable for cod by late this century.[84] Lobster fisheries south of Cape Cod and the nearshore waters of Rhode Island and Long Island Sound should expect significant declines.[85] Cooler waters near Maine could offer a better habitat for lobster, but the waters also may be more hospitable to lobster shell disease.[86]

CRANBERRY PRODUCTION

Massachusetts growers have cultivated cranberries since the 19th century, though Native Americans and early settlers in the Northeast harvested them long before that.[87] In 2012, 43,918 acres of cranberries on 1,040 farms were harvested across the United States, concentrated primarily in Massachusetts (14,070 acres) and Wisconsin (20,641 acres).[88] In Massachusetts, cranberries make up the vast majority of the berry harvest, which generated more than $100 million in sales in 2012 in total.[89] Cranberry production should not be expected to end in Massachusetts due to climate change, but yields may suffer and producers may need to shoulder financial burdens in order to maintain their current level of production.

Like apples, cranberry vines grow according to a chilling requirement, meaning depending on variety, they must experience a specific number of days under a certain temperature threshold in order to produce fruit.[90] Earlier, warmer spring temperatures could prevent crops from achieving their chilling requirement.[91] What's more, even if spring temperatures arrive earlier, cranberry producers must be vigilant in terms of night time frosts that threaten cranberry vines. Producers do have methods at their disposal to avoid frost damage, but they may require a significant financial investment.[92]

Increasing temperatures in the summer months will have implications for cranberry growth and productivity. A 1996 study found early cranberry growth to be most rapid in areas with moderate temperatures between about 60 degrees Fahrenheit and 86 degrees Fahrenheit.[93] If there were more hot days in July or more cold days in August, the study found berries took longer to grow.[94] A 2013 study found flowering time changes for Massachusetts cranberries are related to changes in temperature, similar to other plants in the Northeast.[95] The study found on average, cranberry flowering occurs two days earlier for every 1 degree Celsius increase in May temperatures.[96] Though flowering times had not experienced statistically significant changes on average since the 1980s, the authors of the study note in years when flowering times occur earlier, workers need to be available earlier and harvesting and processing must happen earlier.[97] In those years, which may occur more frequently in coming decades, producers must compare the advantages and disadvantages of early harvests to late harvests.[98]

Though cranberry vines thrive in wetland conditions, increased precipitation could cause flooding that submerges vines for longer than they can stand, which impacts productivity.[99] Rising sea levels are concerning for similar reasons; ocean incursion may flood bogs at non-ideal stages of cranberry development and saltwater can have detrimental effects on the crop.

IV. CLIMATE CHANGE AND PUBLIC HEALTH IN MASSACHUSETTS

According to the most recent National Climate Assessment, climate change already poses a number of public health challenges and will continue to do so throughout the century.[100] Public health consequences, as with the consequences for agriculture, vary by region. As patterns of climate and vulnerability change, local and regional healthcare systems may need to adapt to a

higher numbers of patients and the increased prevalence of certain health conditions.[101] In Massachusetts specifically, any climate adaptation plan will need to address increasing public health concerns related to more hot weather days, decreased air quality, increased risks of diseases transmitted by insects and contaminated food.

EXTREME HEAT

Like sea level rise, extreme heat days are a substantial effect of climate change in Massachusetts. Already average temperatures in the Northeast are estimated to have increased by 2 degrees Fahrenheit since 1895.[102] As previously mentioned, the number of days per year in Boston with temperatures above 100 degrees Fahrenheit is expected to increase from an average of 1 day to as many as 24 days.[103]

Extreme heat can have serious consequences for the health and well-being of Massachusetts residents, including their increased exposure to heat exhaustion, heat cramps, heat stroke and death.[104] Heat exhaustion is the most common condition under high-temperature situations, but if the symptoms are not recognized and treated, it can progress to heat stroke, a condition in which core body temperature rises above 105 degrees Fahrenheit.[105] A person suffering from heat stroke may experience central nervous system abnormalities such as delirium, convulsions or coma.[106]

Citizens may expect an increased frequency of injury and premature death as a result of high temperature extremes, though children and older adults are most vulnerable to these changes.[107] Extreme heat events should be of major concern when considering the increasing population of older adults in the United States. Heat stroke affects adults more than 65 years of age at a much higher rate than those in other age groups; one study estimated that rate to be 12-23 times higher.[108] Heat stress can compound the effects of pre-existing conditions such as

asthma and other respiratory diseases and cardiovascular diseases, all of which are more prevalent in the elderly.[109] Very high temperatures also can cause dehydration and renal failure.[110] Additionally, extreme heat can exacerbate side effects of common medications, including medications to treat chronic obstructive pulmonary disease (COPD) and high blood pressure.[111]

Temperatures in larger cities tend to rise even higher than surrounding suburbs due to more concrete and asphalt and less vegetation, putting individuals living in urban areas at even greater risk.[112] Additionally, those living alone and those living without air conditioning also are at higher risk. A 2008 paper notes heat extremes have had the greatest negative impact in areas such as the Northeast and Midwest, where residents are less acclimated to high temperatures. This needs to be taken into account in any climate adaptation plan in Massachusetts.[113]

According to one study, the average per-summer mortality rate in Boston alone is approximately 100 people per year.[114] Taking expected extreme heat day increases into account, by the end of the century that number is expected to more than double to more than 200 deaths per summer. Further, by the end of the century, the study reports about 150,000 more deaths overall in the United States than there would be in the absence of extreme heat events caused by climate change.[115] Heat-related illness is more difficult to measure because their conditions are not always reported, but a study on Chicago's heat wave of 1995 concluded there were approximately 1,000 more hospital admissions than normal due to excessive heat during the heat wave.[116]

AIR QUALITY

Climate change is closely linked to negative impacts on air quality.[117] The same greenhouse gases and particle pollution that contribute to the warming of the planet also

contribute to air pollution that can affect the health and welfare of people around the world, especially in low-income countries. According to the American Lung Association, greenhouse gas pollution "threaten[s] the health and the lives of millions of Americans."[118] Weather patterns such as heat waves and droughts influence the effects of pollutants such as ozone and particle pollution on human populations.[119]

According to the World Health Organization, the health impacts of low air quality will be felt most acutely by those who already suffer from illnesses such as asthma and respiratory infections.[120] Eight groups of individuals are considered at-risk by the American Lung Association in Massachusetts: those under the age of 18 and over the age of 65, those suffering from pediatric asthma, adult asthma, chronic obstructive pulmonary disease, cardiovascular disease and diabetes, and those living in poverty.[121] Large portions of the Massachusetts population are included in these groups, including 11.5 percent who live in poverty and 10.7 percent who suffer from asthma.[122]

Exposure to ground-level ozone—a component of smog, the most common air pollutant—can pose significant health risks, especially for children whose lungs are still developing.[123] Breathing excessive levels of ozone can cause shortness of breath, increased risk for lung diseases and infection, increased frequency of asthma attacks and can aggravate existing lung diseases such as emphysema and chronic bronchitis.[124] According to the American Lung Association's report, State of the Air 2014, ozone levels in cities across the United States were worse in 2010-2012 than 2009-2011, likely because of higher temperatures, which are more favorable to forming ozone.[125] Currently, nearly half the American population lives in areas with unhealthy ozone levels.[126]

In the next century, as temperatures creep higher, the effects of ground-level ozone will likely become more widespread. In the coming years climate change can be expected to increase ground-level ozone levels, exacerbate ozone concentrations at times when weather is already conducive to high ozone concentrations, increase the ozone season and increase emissions of the precursors to ozone from natural sources.[127]

Particulate pollution, another common type of air pollution, is comprised of very small particles and liquid droplets. The particles are designated as "inhalable course particles" or "fine particles" based on size.[128] Inhalable course particles are common near roadways and dusty industries while fine particles are found in smoke and haze.[129] Inhalation of particle pollution can have severe health effects since fine particles and droplets can reach deep into the lungs. Inhalation of particle pollution has been linked to premature death in those with heart or lung disease, nonfatal heart attacks, aggravated asthma, decreased lung function and irritation of the lungs and airways.[130]

Climate change-related increases in particle pollution are more difficult to predict than those in ozone levels, but a 2010 assessment by the Environmental Protection Agency indicates the largest increases should be expected in the Midwest and Northeast regions of the United States.[131] Particulate pollution can be influenced by precipitation, clouds, and temperature, all of which will be affected by climate change in our region.

INSECT-BORNE ILLNESSES

As temperatures and precipitation increase, Massachusetts residents will likely experience a higher risk for food-and insect borne illness. Diarrheal disease as well as Lyme disease, Dengue fever, and deadly West Nile Virus and Eastern Equine Encephalitis (EEE) will become more prevalent and cause more individuals to be hospitalized, increasing healthcare

costs.[132] Higher temperatures also pose risks for food safety and storage, resulting in a potentially higher incidence of foodborne illnesses such as salmonella poisoning.

Warming temperatures in northern regions are causing ranges of certain mosquitoes and ticks to expand into areas where they were not prevalent before. The 2014 National Climate Assessment notes that even diseases not currently prevalent in the United States should be considered risks; trade with and travel to countries in which diseases such as Chagas disease and Rift Valley fever viruses are becoming more common can aid in spreading them.[133] The assessment indicates insect control measures and lifestyle choices such as spending more time indoors can lower the risks posed by the expansion of suitable conditions for disease-carrying insects such as mosquitoes and ticks.

Lyme disease is a bacterial disease caused by bites from black legged ticks. If untreated, Lyme disease can result in nerve problems, rashes, and muscle and joint pain.[134] Many cases of Lyme disease in the United States occur in the Northeast, and the rate of Lyme disease infection in Massachusetts is ranked one of the highest in the nation, with 57 new cases per 100,000 people reported in 2013.[135] Rising temperatures and a longer warm season increase the risk for contact with black legged ticks, posing risks for those who enjoy spending time outdoors and for those who have outdoor pets who may pick up ticks and transport them into homes. Currently, most of Massachusetts is considered tick habitat, but by the year 2080, tick habitat is expected to expand to all areas of the state, likely increasing the incidence of Lyme disease.[136]

Diseases transmitted by mosquitoes also should be considered a significant public health risk related to climate change. Mosquitoes thrive in wet areas and an increase in temperatures and precipitation falling as rain in Massachusetts can help create a larger hospitable environment for mosquitoes for a longer period during the year. This means increased risks for Massachusetts

residents and animals for mosquito-borne diseases such as Dengue fever, West Nile Virus and EEE, of which there already have been frightening instances in our state. West Nile Virus and EEE have relatively high mortality rates, as 33 percent of cases of EEE result in death.[137] Mosquitoes are tested every year in a number of states for the EEE virus and during the ten years between 2003 and 2012, Massachusetts saw positive results for all but three years.[138] Between 1964 and 2010, out of 270 cases of EEE reported, 37 cases (13 percent) were reported in Massachusetts, amounting to the second highest rate in the country next to Florida.[139] According to the Center for Disease Control and Prevention, residents and visitors are considered at-risk in areas where EEE activity has been identified and areas with a higher population of mosquitoes due to warmer temperatures and more rain.

V. THE GLOBAL WARMING SOLUTIONS ACT AND PROGRESS SO FAR

Massachusetts policies and laws relative to climate change are some of the most substantial in the country. At the forefront of those initiatives are the 2008 Global Warming Solutions Act (GWSA) and the Green Communities Act (GCA). These bills have brought impressive changes to the way the state gets its electricity and constructs its buildings and how its people move around. The GWSA is the cornerstone of the state's plan to address climate change. The law, as implemented by the Patrick administration, called upon the state to reduce its emissions 25 percent below 1990 levels by 2020, and 80 percent below 1990 levels by 2050.[140] The state already takes part in the Regional Greenhouse Gas Initiative (RGGI), a regionally designed cap-and-trade system that works to reduce emissions from power plants. While Massachusetts is a participating member of RGGI, the state sets a bar much higher than RGGI does; Massachusetts aims for 25 percent emissions reductions below 1990 levels by 2020

and targets emissions from all sources, not just power plants, whereas RGGI aims to reduce emissions 10 percent below 1990 levels by 2020 and focuses only on power plants.[141] Though RGGI provides an effective tool for market-based emissions reductions, for Massachusetts to fulfill its own obligations, it needs more effective tools.

Since the GWSA passed, Massachusetts has seen exceptional progress in renewable energy generation and energy efficiency. In fact, Massachusetts has been repeatedly ranked number one in the country for energy efficiency and was ranked number four for new solar generation in 2013.[142] Although fourth place might not appear impressive on its face, Massachusetts is the second smallest state on the "top ten" list as well as the state with the highest latitude, giving it the least amount of solar potential among the top ten.[143] Yet despite its small size and more limited sun exposure, Massachusetts still excels.[144] A major component of Massachusetts' outreach and education comes from the state's GCA, companion legislation to the GWSA that focuses on helping renewable energy, energy efficiency and other sustainable practices move forward at the municipal level. Rather than mandate green activities at the local level, the GCA offers incentives and rewards for cities and towns that enact certain climate-friendly guidelines, from high-efficiency vehicles to the stretch code for new buildings, by relying on local investment and leadership for its success.[145] Even without a mandate, the GCA has managed to enroll 136 of 351 municipalities in the state, covering about 50 percent of the population.[146]

RENEWABLE GENERATION

Massachusetts has ramped up renewable generation with considerable success. The state currently boasts 699 megawatts of total solar capacity and 107 megawatts of total wind

capacity.[147] Overall, according to estimates from the Massachusetts Clean Energy Center, Massachusetts maintains around 970 megawatts of total renewable installed capacity.[148]

Massachusetts has already outpaced its early solar energy targets, thanks to the Solar Carve-Out program. The standard put into place in 2008 sought to have 250 megawatts of solar power installed by 2017.[149] However, the 2017 target was met as of May 2013, leading the state to establish a new target of 1.6 gigawatts of solar installed by 2020.[150] To surpass this goal so quickly is excellent for the SREC program and the state, however, while 1.6GW may seem like a lot of energy, it only will make up a tiny fraction of the total energy produced and consumed in Massachusetts. The state has proactively expanded the SREC program and provided certainty to companies in the solar industry, but Massachusetts could do more. The SREC-II program (the portion of the program that comes after the initial 400 megawatt-target) has a long-term cap as well as caps for different sectors and for size of single projects.[151]

Several successful wind energy projects already cut carbon emissions in Massachusetts, but many more opportunities still exist and demand attention. Those opportunities, if implemented successfully, will help Massachusetts meet its goal of producing 2,000 megawatts of wind energy by 2020. To its credit, the Patrick administration took steps toward expanding Massachusetts' offshore wind infrastructure. In June 2014, former Governor Patrick joined Interior Secretary Sally Jewell to announce more than 742,000 acres off of Massachusetts' coast would go on sale for wind development, with an auction date set for January 29, 2015.[152] The result of this auction was the leasing of nearly 355,000 acres of offshore property by two companies, RES America Developments, Inc. and Offshore MW LLC.[153]

RENEWABLE PORTFOLIO STANDARDS

In addition to the Regional Greenhouse Gas Initiative, Massachusetts' portfolio of market-based policies to reduce greenhouse gas emissions includes the Renewable Energy Portfolio Standard (RPS).[154] A renewable energy portfolio is a law that requires electricity suppliers to obtain a given percentage of their electricity from renewable sources such as wind, solar and biomass generation. Under RPS, certified renewable energy generators receive renewable energy certificates (RECs) for every unit of energy they produce and they can sell these certificates along with their electricity to energy supply companies.[155] Electricity supply companies then use these certificates to demonstrate their compliance with the agreed-upon standard.[156] RPS is a market-based policy in that electricity supply companies are able to trade and in some instances bank and borrow RECs at market prices, allowing renewable energy targets to be met in the most cost-efficient manner.[157] RPS mechanisms or alternatives have been adopted in several countries, including Poland, Sweden, Belgium, Italy, and Britain, as well as in 38 of the 50 U.S. states, plus Washington D.C.[158]

RPS IN MASSACHUSETTS

Massachusetts' renewable energy portfolio standard (RPS) began with a renewable energy obligation of 1 percent of all energy supplied in 2003, and subsequently increased by 0.5 percent per year until it reached 4 percent in 2009.[159] As part of the GCA of 2008, RPS was then broken into RPS Class I and RPS Class II, with annual obligations set to increase by 1 percent annually starting in 2009.[160] Suppliers who are unable to meet renewable energy requirements are required to make "alternate compliance payments," which are set at a pre-determined price to ensure SRECs do not become too expensive and that available SRECs will be purchased so long as they don't cross the ACP rate.[161] The SRECs program also has a price floor established through the solar clearinghouse, which is a tool for the state to administer the sale of SRECs

directly and to ensure they don't sell below a minimum price.[162] Through a price floor and ceiling the RPS program provides stability to producers and consumers while still allowing for market flexibility.

The current requirement for Massachusetts utility suppliers is for 9 percent total renewable energy.[163] According to the U.S. Energy Information Administration (EIA), in 2013 the Commonwealth received 9.3 percent of its energy from renewable sources and is on track to continue meeting its 1 percent annual increase requirement.[164] The success of this program is commendable, but there is still more the state can do to increase the amount of renewable energy used and the emissions reduced.

CARBON PRICING

One of the most significant tools devised in the GWSA is the authorization for the state government to establish a price for carbon. Section 3(d) of the GWSA states, "The department shall promulgate regulations establishing a desired level of declining annual aggregate emission limits for sources or categories of sources that emit greenhouse gas emissions."[165] Thus far, the executive branch has declined to act as completely as possible on this tool. Though RGGI does establish a kind of price for carbon emissions, it is limited in scope and is controlled by the multi-state coalition. The legislation leaves the issue of deriving a carbon price up to the administration, but the state should move forward. Given Massachusetts is otherwise unlikely to meet its GWSA obligations by 2020, the state should use every tool available to achieve the most efficient reductions possible.

The two most common means for pricing carbon are through a market-based cap-and-trade system, such as that of the RGGI program, or through a carbon fee. The United States has seen some success with market-based trading programs, such as the program designed to limit

acid rain-causing emissions from power plants.[166] The U.S. also has had some success with cap-and-trade programs, but it has never attempted to use them on a scale as economy-wide as carbon emissions. Meanwhile, the European Union attempted to use a wide-scale cap-and-trade program for carbon and yielded mixed results, given the onset of the global economic downturn of 2008, a contracting economy and the glut of emissions permits initially issued.[167] This is not to say such a program could not work. One could argue the market would have been more sustainable by ratcheting emissions limits down quicker.

The alternative to a cap-and-trade program is a potential fixed carbon fee. Compared to a cap-and-trade program, a carbon fee program would provide a simpler solution: it avoids the bureaucratic infrastructure needed for managing a market, and with a future pricing schedule, a fixed carbon fee gives the business community means to anticipate future expenses and makes it less subject to unforeseen market instability. By establishing a commission of experts and stakeholders, the government could establish a price sufficient to drive down emissions, but low enough to prevent any major impact on the wider economy. In fact, some reports suggest such a carbon fee could yield added economic growth.[168] According to a study recently released by the former Patrick administration, a carbon fee has the potential to be more effective at cutting greenhouse gas emissions than any of the administration's other greenhouse gas reduction policies.[169] Furthermore, this reduction in greenhouse gases would be accompanied by a net positive impact on the economy, including the addition of 4,000 to 10,000 jobs by 2030.[170] In fact, a carbon fee plan put into place in British Columbia has been successful.[171] Since the program was implemented in 2008, British Columbia saw a 17.4 percent decrease in petroleum fuel sales as of 2012.[172] Meanwhile, the rest of Canada saw an increase in fuel consumption during that time period.[173] Nevertheless, the GDP of British Columbia kept pace with the rest of

Canada, and the pricing shift allowed British Columbia to have the lowest income tax rates in the country.[174]

A cap-and-trade program could be argued to be more efficient because it allows the market to determine the price of emissions and to find the cheapest means for emissions reductions. Yet a carbon fee still could provide much of these benefits if the program encourages the trading of emissions certificates. The market could be more efficient by allowing private enterprise to capture the value of emissions savings through methods such as renewable energy projects and forest preservation, and then selling those savings to emitting entities.

However Massachusetts chooses to move forward with carbon pricing, it will need to determine how to allocate the funds it raises. Regional Economic Models, Inc. (REMI) developed a report examining a potential carbon fee in the Commonwealth and found it could have a net positive effect on the state's economy if revenues are allocated properly.[175] If the state were to allocate its first $100 million in carbon fee revenue per year to research and infrastructure and use the remainder to lower taxes, the report found the state could achieve as much as a $10 billion increase in annual GDP.[176] The likelihood of such an outcome depends on many factors, but there is still evidence that a carbon fee could provide a net gain to the state economy and provide a significant tool for Massachusetts to continue reducing greenhouse gas emissions.

IMPLEMENTATION OF THE GREEN COMMUNITIES ACT

One potential target for carbon fee revenue is Massachusetts' GCA program. Increased funding from the cap-and trade program could increase town participation in the program. The Green Communities Act, as its title suggests, builds tight-knit communities of individuals who are dedicated to reducing energy usage. To designate a city or town as a Green Community, it

must meet five criteria: 1) sites for renewable energy facilities, 2) an expedited permitting process for renewable energy facilities, 3) the establishment of an energy baseline and a pledge to reduce energy consumption by 20 percent in five years 4) the purchasing of only fuel-efficient vehicles by the town and 5) set requirements to minimize the energy costs of new construction in the town.[177] When the state confirms a municipality as a Green Community, the town becomes eligible for funding that can be put toward renewable energy projects.[178] As of the publication of this paper, 136 of 351 Massachusetts municipalities have designated themselves as Green Communities, representing approximately 39 percent of the state's municipalities.[179] More than $30 million in funding has been allocated to these municipalities since 2010.[180]

On a local level, less than 40 percent participation among cities and towns is not nearly enough. The state also could consider lessening some of the stringent restrictions of the program and create a tiered system similar to the U.S. Green Building Council's Leadership in Energy and Environmental Design green building designation system, which progresses from "Certified" to "Platinum" designations. A town may not have the necessary buy-in to meet the as-of-right zoning criterion; a tiered approach could help attract more communities to the program, recognize the best performers, and encourage ongoing improvements by allowing towns to build upon their rating.

The Green Communities program has been funded annually by up to $10 million of carbon emissions auction revenues as part of the Regional Greenhouse Gas Initiative in Massachusetts.[181] Through carbon pricing that could reach broadly across the Massachusetts economy, additional revenues could help fund greater tax breaks for high-efficiency vehicles and expand energy efficiency measures and weatherization programs for low-income residents and

other groups of citizens. Funding also could be allocated to the Green Communities program, allowing the state to increase local aid to help cities and towns reduce energy-related expenses.

VI. RECOMMENDATIONS FOR MASSACHUSETTS

Massachusetts has made great progress on its commitment to reduce greenhouse gas (GHG) emissions as part of an ongoing effort to combat the effects of climate change. State collaboration with local organizations, businesses and constituents has helped Massachusetts decrease GHG levels, as public awareness about the threats of climate change has increased. As of 2011, the Commonwealth had reportedly lowered emissions from 1990 levels by 11 percent or 15 percent, depending on the source, but there is still much work to be done.[182] The state first approached its goals established in the GWSA with the easiest, impactful strategies to reduce GHG emissions. However, after grasping "low-hanging fruit," Massachusetts must make a greater effort to move forward with clean energy progress into the next administration and beyond. According to the Global Warming Solutions Project's "Massachusetts Clean Energy and Climate Scorecard," the state is currently on track to achieve a 20 percent reduction in emissions by 2020.[183] Though this reduction would be commendable, it's still short of the 25 percent reduction target set by the GWSA.[184] Massachusetts must continue to hold itself accountable to its people and the environment to protect them from the consequences of climate change. The following recommendations outline additional opportunities that would help the Commonwealth achieve its environmental targets, set in state statute, mostly without implementing additional legislation:

Strengthen the stretch code – The stretch code is a local option to build upon existing state building codes, both of which are based on the International Energy Conservation Code, which is

regularly updated.[185] While the state has updated "base" building codes, there have been no changes to the stretch code. By updating the base code and not the stretch code, the state has effectively destroyed the stretch code's significance, as the old stretch code will soon be the operable base code. This has limited the resources available for towns to access state guidance and to set themselves apart as committed to sustainability and the environment. Through the GCA, the stretch code helps cities and towns to increase residential and business energy efficiency and to showcase themselves as forward-thinking communities. By allowing the base code to advance without the stretch code, the state sacrifices an opportunity to further reduce emissions and limits the GCA program. Though Massachusetts once led the nation with a strong stretch code, it has since fallen to a second or third tier stretch code. The authority for the executive to update and strengthen the stretch code resides in the GCA of 2008.[186]

Enforce Global Warming Solutions Act regulations and implement carbon pricing - The GWSA states, "the department shall promulgate regulations establishing a desired level of declining annual aggregate emission limits for sources or categories of sources that emit greenhouse gas emissions," in reference to regulations required to be in place by January 1, 2012.[187] Now three years past the deadline, the Patrick administration never developed draft regulations. The former Patrick administration argued that Massachusetts' participation in RGGI fulfills the GWSA requirements. However, a number of environmental groups disagree and state that RGGI is not controlled by Massachusetts alone, and its emissions targets are markedly weaker than those set by Massachusetts. By declining to promulgate stronger regulations according to GWSA, the administration is depriving the state of a powerful tool to fight climate change.

Furthermore, the executive branch has failed to use all the options provided to it by the GWSA, including, according to a number of environmental organizations such as the Conservation Law Foundation, its ability to place a price on carbon. A value for carbon could have a dramatic impact on the state's ability to meet its 2020 and 2050 emission reduction goals. Once the state sets a carbon price, emitters could pay to pollute, reduce their emissions or offset their emissions.

The executive office has the authority to determine what sort of mechanism it might use to achieve the state's GWSA targets. By setting a price for carbon the state could determine a program pricing for energy efficiency, set emissions targets for businesses and households, set reductions targets in vehicle fuels, and help shift the entire state economy toward a greener future. There is some debate as to whether a carbon price should be revenue-neutral or revenue-positive. A revenue-positive approach with most of the funds being returned to the population would allow for public transportation upgrades with a good amount of direct benefit to the citizens of the Commonwealth. A revenue-neutral approach would provide the maximum amount of funds being directly returned to the people of Massachusetts. A revenue-neutral method is the preferred course of action. Whichever option is chosen, the state should act decisively and utilize all tools the GWSA has provided in state statute to finally phase-in a definitive and broad-based carbon pricing mechanism. If the executive branch continues to delay action, the legislature must modify the language of the GWSA so carbon pricing is mandatory, as the legislature originally intended.

The GWSA also requires the executive branch to take climate impacts into account for each significant decision they make. According to the GWSA, "[i]n considering and issuing permits, licenses and other administrative approvals and decisions, the respective agency,

department, board, commission or authority shall also consider reasonably foreseeable climate change impacts, including additional greenhouse gas emissions, and effects, such as predicted sea level rise."[188] Much of the former Patrick administration made admirable progress towards this end, and the Baker administration needs to adopt this mindset as well. The executive branch should hold a series of "boot camps" or regular training seminars with department heads and staff to reinforce the importance of prioritizing greenhouse gas emissions reduction and climate resilience.

In the event that the executive branch fails to act, the legislature has several bills that would mandate the implementation of carbon pricing. Senate docket 1815 and Senate docket 285 both are bills introduced which, if passed, would require the Baker administration to finally price carbon.

Adopt a clean fuel standard – According to the Renewable Fuel Standard created under the Energy Policy Act of 2005, the EPA requires gasoline and diesel refiners to blend renewable fuel into the final mix.[189] The GWSA included emissions reductions through the implementation of clean fuel standards. Since then, the EPA proposed loosening requirements for future clean fuel volumes, though it has delayed implementation of the rule.[190] New England leaders also are engaged in major discussions about the prospect of substantially increasing fuel imports from Canadian tar sands. The Congressional Research Service found these fuels represent a 14 percent increase in per BTU emissions than the average fuel in the U.S.[191] According to a report by the NRDC, without a clean fuel standard preventing further imports of Canadian tar sands fuel "as much as 18 percent of the [Northeast and Mid-Atlantic state's] petroleum-based transportation and heating fuel supply could be derived from the high-carbon feed stock."[192] As of 2012, the region derived about 1 percent of its fuel from high-carbon feed stock.[193] As tar sands fuel

threatens to grow in production and to make its way into New England, the Commonwealth should implement proactive, preventative measures and look into other opportunities to reduce emissions from vehicle fuels and transportation in general. A clean fuel standard also would help spur the development of newer, zero-carbon technologies, such as a hydrogen fuel cell. Without a clean fuel standard, or at the very least a mandate to prevent backsliding on transportation fuel carbon intensity, oil derived from tar sands in Canada could potentially completely erase much of Massachusetts' progress to cut emissions. As with pricing carbon, authority for a clean fuel standard has already been granted to the executive branch under the GWSA's allowance for "declining annual aggregate emission limits.[194]

Encourage more energy efficiency – Massachusetts bases its guidelines for rate-payer energy efficiency programs on cost effectiveness. When determining the upgrades for which a home is eligible, the cost of the given upgrade is weighed against its expected payback. Thus, whenever an energy audit occurs, whether it is a commercial or residential audit, each possible savings is measured with a return on investment (ROI). For example, the replacement of an incandescent bulb with a compact fluorescent bulb might have a six-month ROI, while filling the side walls of a home with cellulose insulation might have a four-year payback; these pieces are considered desirable ROI periods. On the other hand, measures such as new windows, which could have ROI periods of more than ten years, would not get approved.

The ROI calculation is an efficient means for making sure available funding is directed at the most significant building projects. It also affords flexibility to expand projects. More projects may become viable by changing the cost of energy or extending the ROI period. A cap increase or an extension of the ROI period would promote more comprehensive efficiency overhauls that achieve substantial energy savings. Energy efficiency measures offer great opportunities for

emissions reductions and employment, and through simple policy changes that loosen ROI restrictions, a good program could be made even better. The administration has broad authority to develop new energy efficiency measures under the powers granted from the GCA of 2008.[195]

Energy audits as part of the home inspection process would be an excellent way to encourage renewables. Many homeowners are not aware they have the ability to receive a no-cost energy audit of their homes. By making an energy audit part of the home inspection process, homeowners would receive information about energy loss that would encourage the greater use of energy efficiency measures in their homes. The executive branch has broad authority to promulgate regulations relative to home inspection.[196]

It also should be noted that a price on carbon could greatly enhance energy efficiency project benefits. By placing a value on carbon, individuals would better grasp the significant economic benefits of cutting carbon emissions.

Incentivize smart meter use – Electricity customers generally do not see the real cost of power, which limits price signals that could potentially change customer behaviors. Customers tend to have little information about the energy consumption of appliances, such as the added cost of a spare refrigerator, or the benefits of locating a refrigerator in a cool basement instead of a warm garage. They do not receive accurate signals about marginal costs of power, which can vary significantly throughout the course of a day. A widespread adoption of smart electric meters could begin to help consumers and utilities attain better pricing information.

Smart meters help utilities track consumer consumption with more accuracy and reward ratepayers who reduce consumption during peak demand periods, thereby reducing strain on the electric grid. Moreover, through their easily readable digital display, smart meters give ratepayers an opportunity to track their usage more closely than their monthly bill. The lack of

real-time pricing information hinders consumers from making smart energy choices. The administration should offer greater incentives to help promote the widespread adoption of smart meters. One incentive, for example, could grant the utilities savings if a certain number of their customers adopt smart meters. Alternatively, the administration could offer utility bill savings for customers who adopt smart meters. Whichever form the incentives take, the Baker administration must act swiftly to prioritize smart meters. Broad authority to provide incentives for smart meters can be found in the GCA of 2008.[197]

Target lifecycle costs – The state should look to update laws relative to public buildings to take all costs into account. Under current law, Massachusetts generally awards a construction contracts for public buildings to the lowest responsible bidder.[198] While this policy is generally sound, Massachusetts does not consider all costs associated with the building, including operational costs. Therefore, the state may lose money to construction with low upfront costs but high lifecycle costs. The state should modify the requirements of RFPs to embrace totally lifecycle costs. The legislature should alter the bidding law to include a reasonable estimate of all lifecycle costs of a building, including its operational costs, when awarding a contract to the lowest responsible bidder. Senate docket 1539 Senate docket 1083 would, if passed, require the state to factor in life cycle costs for any new public construction. Additionally, the state should look into the possibility of building all new public constructions as net-zero buildings to the extent possible, meaning they produce as more energy as they expend. This concept is realistic and functioning today, as the Executive Office of Energy and Environmental Affairs recently opened a 45,000-square-foot net zero office building in Westborough.[199] Senate docket 1804 is legislation which aims to help promote this concept. **Balance imported energy with renewables** – The state must encourage appropriately sized, cost-effective transmission lines to

bring additional power into Massachusetts. Clean energy imports could greatly reduce the state's reliance on dirty fuel sources and reduce emissions without significantly affecting grid energy prices; however, current infrastructure is insufficient to fully capitalize on this resource and additional transmission lines are needed.[200] The state therefore should move forward with planning, designing and supporting—considering much of the needed infrastructure is located outside Massachusetts—these grid upgrades to bring this energy to market in this state.

Canadian hydropower has increased to 8.5 percent of New England's electric consumption, but, according to the former Patrick administration, the transmission lines delivering this resource to southern New England are at full capacity and prevent additional Canadian hydro from entering the market, though this claim is disputed by some environmental groups.[201] Despite the disagreement, at some point the transmission lines will need to be upgraded. The Massachusetts Clean Energy Action Plan for 2020 argues that by incentivizing the reduction of fossil fuel plant operation, low-emissions electricity imports would help reduce criteria and hazardous pollutants in the air (such as mono-nitrogen oxides, sulfur dioxide, mercury and fine particulate matter) for public health and environmental benefits. In addition, added hydro imports will improve the region's fuel diversity, improving energy security and price stability.[202] However, the expansion of hydropower must be measured. Without foresight, hydropower projects may cause the release of methane, as large amounts of decaying vegetation may cause a burst of greenhouse gases.[203] Any new hydropower project must carefully account for potential greenhouse gas emissions and attempt to impact the environment as little as possible. The advancement of hydropower should be used to support, not replace, other renewables in Massachusetts, as part of a comprehensive strategy.

Though Massachusetts must increase its clean energy imports, the state must also continue to prioritize the development of renewables at home. While Massachusetts has moved aggressively to develop renewables so far, it is still not enough to reach its 2020 and 2050 emissions reductions goals set by the GWSA. The Renewable Portfolio Standard and Alternative Portfolio Standard both encourage greater renewable use in Massachusetts. One way to foster more renewables would be to boost the annual RPS goal from one percent to two percent. This boost in the RPS goal would require new legislative authorization by the House and Senate. Additionally, regulations that allow for thermal energy incentives would be an easy method to elevate renewable use as long as they include sustainability standards for thermal facilities operations.

Adopt comprehensive adaptation management plan legislation and invest in resiliency statewide – Massachusetts must develop a comprehensive adaptation management plan in order to help cities and towns work together to prepare for climate change. Senate docket 194, which was Senate bill 2028 last session, would require the administration to do just that.[204] The bill requires the administration to develop an adaptation action plan that includes a statement of Commonwealth goals and priorities, data on existing and projected climate change impacts, an assessment of the prepared and vulnerabilities in the commonwealth's emergency response and infrastructure resiliency and a commitment to the adherence of sound management practices.[205] Under this legislation, agencies also would be required to work together toward the common goal of combating climate change. The bill provides municipalities with tools to help on a local level and includes a coastal buyback program for those areas most at risk from sea level rise.[206] With the simple passage of this legislation, Massachusetts could add a powerful weapon to its arsenal to shore up resiliency against sea level rise and other climate threats.

Massachusetts already has a variety of options to enhance its resiliency to sea level rise, but the application of those options so far has been sparse. The state could reconstruct salt marshes and natural coastal environments. It could create floodable spaces through the conversion of waterfront to parkland with built-in storm runoff measures to help protect the coastline and minimize pollution. Swales also could be constructed on a commercial and residential scale to protect land, plants and soil during storm surges and to benefit the ecosystem. To design these systems, however, public think tank sessions should be held with local experts to keep costs low. Through local building codes and reclamation projects, municipalities can reduce exposure to future storms. State resources should be used to ensure local decision-makers have access to the most appropriate technical assistance and best practice strategies. Additionally, Massachusetts should consider investing in distributed renewable energy systems and community cooling centers that run on geothermal or solar energy solutions to confront the climate change. Funding for all such measures can be found in the most recent environmental bond bill.[207]

Even with innovative thinking, adequate preparation for sea level rise will require significant investment. Fortunately Massachusetts has invested in resiliency measures already. In the most recent environmental bond bill, the state established the Climate Change Adaptation Infrastructure Investment Fund with a $10 million investment.[208] The environmental bond bill also dedicates $5 million to develop resiliency efforts, $10 million for a Regional Comprehensive Climate Change Adaptation Management Plan grant program, and $20 million for the development of a statewide climate center.[209] These investments are a prudent start, but they pale in comparison to the funds truly needed to protect the state from the threats of sea level rise.

Modernize the grid – The state must encourage appropriately sized, cost-effective transmission lines to bring additional power into Massachusetts. Clean energy imports could greatly reduce the state's reliance on dirty fuel sources and reduce emissions without significantly affecting grid energy prices; however, current infrastructure is insufficient to fully capitalize on this resource and additional transmission lines are needed.[210] Massachusetts is home to some of the oldest energy infrastructure in the nation which is in great need of modernization and strengthening. Grid modernization can help reduce electricity costs by decreasing energy losses in the distribution system and increase customer service quality by rerouting connections when a transmission network is damaged, as often is the case in severe storms.[211] Modernization allows for better real-time tracking of grid status and for operators to quickly identify problems in the distribution network.[212] The state already is working with utility companies to develop 10 year grid modernization plans.[213] The progress so far is commendable, but the bulk of the work lies still ahead; the state must make every effort to ensure modernization plans become reality and that technology advancements and best practices are incorporated as the project moves forward. Additionally, the state must work with the utilities and private companies who generally own transmission lines to develop more lines. The authority for the executive branch to modernize the grid exists in multiple pieces of legislation, including the GCA of 2008, An Act Relative to Competitively Priced Electricity in the Commonwealth and An Act Relative to the Emergency Service Response of Public Utility Companies.[214]

The following recommendations include more general policy ideas which the new Baker administration should explore:

Embrace Smart Growth -- Smart growth is a school of thought that encourages the sustainable development of cities and towns. According to the EPA, this sustainable development includes concepts such as "mix[ing] land uses," "creat[ing] walkable neighborhoods," or "providing a variety of transportation choices."[215] Massachusetts already has a plan for smart growth advancement that promotes many of the same ideas as the EPA model but includes fostering clean energy and regional planning.[216] These goals are admirable, but the executive branch has not gone far enough to embrace them. Through concepts such as urban sprawl reduction and investment in Gateway Cities, Massachusetts can reduce the amount of miles traveled by vehicle and reduce greenhouse gases for health and economic benefits. The Baker administration should expand Massachusetts' smart growth policy to incorporate nature into new development as a simple and effective way to reduce carbon emissions.

Boost the Green Communities Designation and Grant Program – The Green Communities Designation and Grant program has successfully engaged communities and constituents in statewide energy efficiency efforts. However, untapped opportunities remain that would increase the Commonwealth's catchment and better recognize top Green Communities performers. Massachusetts could add resources to its Green Communities Designation and Grant program through funds that could come into the state from a carbon pricing mechanism. The state could revise the Green Communities standards to establish a tiered system recognizing the various resources available to different participating communities as well as a city or town's level of commitment to sustainability even if it can't meet all Green Communities Designation and Grant program benchmarks. The criteria for this new system could include an adoption of the stretch code or the use of by-right siting for renewables.

Promote clean energy and energy efficient transportation - The emissions potential of vehicle fuels poses its own set of challenges, but there are a number of other strategies Massachusetts can undertake to reduce transportation-related emissions according to its 80 percent emissions reductions goal.

- Encourage the adoption of more fuel-efficient vehicles among residents and businesses, specifically electric ones.
- Offer discounts off the purchase price of the fuel-efficient, electric or hybrid vehicle or relief on a consumer's annual tax bill.
- Encourage a wider dispersal of vehicle charging stations in Massachusetts and work with the automotive industry to standardize charging stations. Tesla, is the single largest manufacturer of electric-only vehicles, but it uses one standard for charging, while Nissan and BMW use other standards.[217] Although the industry appears to move towards better standardization, it is moving too slowly and the consumer is put at a disadvantage as a result.[218]
- Attempt to purchase all electric or hybrid vehicles for state operations through a state procurement process that could include a reverse auction bid.
- Collaborate with other RGGI states to purchase fuel-efficient, electric and/or hybrid vehicles for state operations for greater market power that could drive down purchasing costs.
- Offer more support for carpooling programs such as RideShare that attempt to reduce the number of miles citizens drive.[219]
- Work harder to encourage mode-switching, especially at the municipal level. While the MBTA serves more than 70 percent of the state's population, including

commuter rail service, it makes up more than 90 percent of the public transit rides served.[220][221] Regional transit authorities can do more to increase transportation access, but public transit is most efficient in highly populated areas. Regional transit will cost more per rider based on the distribution of the population served.

- Invest heavily in affordable public transportation, including an expansion of the MBTA and commuter rail systems. If implemented, South Coast Rail and North-South Rail are both projects which would serve large segments of the Commonwealth and would greatly decrease pollution from cars.
- Develop more programs to encourage driving less, including walkable communities or insurance discounts for those who do not drive as much.

VII. CONCLUSION

It is clear Massachusetts has already taken great strides to combat the impending threats of climate change under the former Patrick administration. However, the state's achievements, while admirable, do not go far enough for Massachusetts to reach its clean energy targets and to satisfy state statutes. A new administration in Massachusetts will offer new opportunities for the state to tackle clean energy and environment-related goals by using all available mechanisms already codified in state law, such as the sections of the GWSA that many environmental organizations argue allow Massachusetts to price carbon. By taking advantage of these tools, the Commonwealth will be better poised to clean up the environment and to strengthen its clean energy economy. As long as climate change remains one of the most pressing dangers our world faces, governments at the local, state, national and international level must innovate strategies to

achieve individual goals towards accomplishing our collective goal of protecting the only world we have. Climate change threatens not only our environment, but our public health, our national security and our global economy, among numerous other sectors of our daily life. Massachusetts has led the way in terms of focusing on some of the challenges that lie ahead. We have achieved much, but there is still so much more to do. The costs we face if we wait far outweigh any investments we make now.

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