Climate Change & Health in Vermont

October 2017

Prepared for the 2017
Agency of Natural Resources
White Paper Series on Climate Change

VERMONT
DEPARTMENT OF HEALTH

Contents

Executive Summary

Climate change in Vermont is resulting in hotter summers, shorter winters, and more frequent storms. The devastation from Tropical Storm Irene, the increasing occurrence of Lyme disease, and more frequent cyanobacteria blooms are just a few examples of how climate change can affect Vermonters' health. While everyone's health is affected by climate change, certain populations are more vulnerable than others. Taking action to minimize the impacts of climate change can improve the health of Vermonters today and in the future.

This Climate and Health white paper aims to:

- identify climate-related health risks in Vermont
- when possible, estimate the current and future health impacts of these risks
- identify populations and locations at greatest risk
- identify actions to prevent or minimize these risks

Climate change is already happening, and is expected to continue

Vermont's climate has been getting warmer and wetter in recent years:

- Air temperatures in Vermont have increased more than 4°F in winter and more than 2°F in summer over the past 50 years.
- Spring is arriving two weeks earlier and winter starting one week later, as compared to 1960.
- Lake Champlain temperatures increased 2°F to 7°F (varying by measurement location) from 1964 to 2009.
- Annual precipitation in Vermont has increased by almost seven inches over the past 50 years.

These trends are expected to continue or accelerate for the foreseeable future. Vermont is expected to continue warming in the future, leading to hotter summers, shorter and milder winters, stronger storms and more frequent droughts.

Climate change is increasing health risks in Vermont

Climate-related health risks in Vermont include:

- **Extreme heat**: Vermonters are eight times more likely to visit the emergency room for a heat-related complaint on days when temperatures reach or exceed 87°F. In Vermont, maximum temperatures reach 87°F about six times per year at present, but are predicted to reach 87°F between 20 and 34 times per year by end of century.
- **Extreme weather**: Vermont had 18 federally-declared disasters in the past 10 years (most notably, Tropical Storm Irene), an increase of 50% when compared to the previous decade. Precipitation events of three inches or more are expected to increase from less than once per decade now, to twice every three years by end of century.

- **Vectorborne diseases**: Warming conditions are one of several factors that have contributed to increased distribution and abundance of black-legged ticks that transmit the pathogens causing Lyme disease, anaplasmosis, babesiosis and other diseases. Climate change is expected to further expand the range of the black-legged tick and lengthen the tick activity season, increasing the risk of tickborne diseases in Vermont in the future. Warmer and wetter conditions in the state will also make conditions more favorable for the survival and reproduction of mosquitoes that can transmit West Nile Virus, Eastern Equine Encephalitis or other harmful pathogens.
- **Air quality**: A lengthening growing season, combined with increased plant growth due to higher levels of carbon dioxide in the air, will likely increase allergenic pollen in the air we breathe, potentially resulting in widespread respiratory impacts to Vermonters. Wildfire smoke and air pollution are also potential concerns.
- **Foodborne and waterborne pathogens**: Warmer temperatures and more frequent downpours are likely to increase risks for contamination of drinking, recreational and irrigation waters.
- **Cyanobacteria (blue-green algae)**: More intense rain events may increase nutrient runoff to surface waters and warmer water temperatures will create more favorable conditions for cyanobacteria blooms.

Everyone's health is threatened by climate change, and the threat is greater for some

Climate change will affect everyone, but certain people and certain places will be affected more than others. Outdoor workers and hobbyists, homeless people, those living in flood plains, or living on upper stories of buildings in urban areas (which can be especially hot in summer) are at higher risk for experiencing climate impacts. Others may be more prone to suffering climate-related health impacts due to age (older adults, infants and children), having a chronic or pre-existing medical condition, or taking certain medications.

Even those in good current health may suffer excessively from climate impacts if they lack the economic, social or political resources to reduce their risks, prevent impacts from occurring, and recover from impacts when they occur or re-occur. For example, a home-bound older adult living alone may be especially vulnerable during a heat wave or extreme weather event.

Responding to climate change can benefit health now and in the future

Actions taken to limit climate change can also provide immediate health, environmental, economic or other benefits – such as improving transportation and building efficiency, switching to cleaner energy sources, and increasing tree cover in urban areas.

The Vermont Department of Health can play a critical role by raising awareness about climate-related health impacts, monitoring and responding to climate-related health risks, providing guidance to individuals, communities, and service providers for reducing climate-related health risks, and working with partners to implement programs and policies that limit climate change while improving population health.

1. Introduction

Vermont's climate has been getting warmer and wetter in recent years. Figure 1 summarizes the changes over the past 50 years:

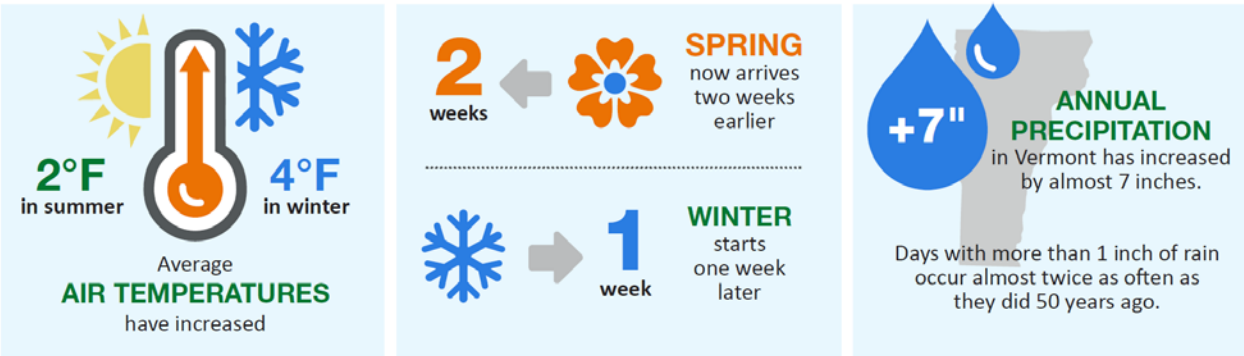


Figure 1. Summary of climate changes in Vermont over the past 50 years (Betts 2011, NOAA 2017)

Without a sharp reduction in greenhouse gas emissions, these trends are expected to continue or accelerate for the foreseeable future. Compared to average weather conditions from 1981 to 2010, by the end of the century the Vermont State Climate Office (2014) projects:

- an increase in average annual temperatures by 4°F to 7°F
- an increase in days per year reaching 87°F or hotter from an average of six to an average of 20 to 34
- an increase in the length of the frost-free season by two to six weeks
- an increase in total annual precipitation by three to 10 inches
- an increase in the frequency of the heaviest 0.1% of precipitation events (about three inches of rain) from once every seven years to once every two to three years

Based on a review of existing climate and health literature, this white paper identifies exposures of public health concern that may be exacerbated or initiated by the changing climate. The risk of each exposure is evaluated in the context of Vermont-specific climate projections and Vermont's particular vulnerabilities – and concludes with a discussion of actions that can be taken to decrease the risks posed by climate change (adaptation strategies) and a framework for considering the health impacts of actions taken to reduce greenhouse gas emissions (mitigation actions).

More detail can be found at the Health Department's website: healthvermont.gov/climate

2. Linking Climate and Health

The following highlights the connections between expected changes in Vermont's climate and current or potential impacts on public health. Each of the impacts is examined for its relevance to Vermont.

Extreme Heat Events

Climate change will increase the number of dangerously hot days. Figure 2 summarizes the results of a joint project of the Health Department and the Vermont State Climate Office of the University of Vermont, which showed that *Vermonters are at greater risk for serious heat-related illnesses—and even death—when the statewide average temperature reaches 87°F or hotter* (HEALTH, 2016).

Heat-related illnesses—such as heat exhaustion and heat stroke—occurred eight times more frequently on days when the statewide average temperature reached at least 87°F, and there was one additional death per day among individuals age 65 and older. Heart disease, stroke and neurological conditions were more common causes of death on these hot days.

From 1981 to 2000, Vermont had an average of six days per year when the temperature reached 87°F or hotter. Climate models from the Vermont State Climate Office predict an average of 15 to 20 days per year reaching 87°F by mid-century, and increasing to 20-34 days per year by the end of the century. In the absence of adaptation, as the climate warms and there are more hot days, more heat-related illnesses and deaths will occur.

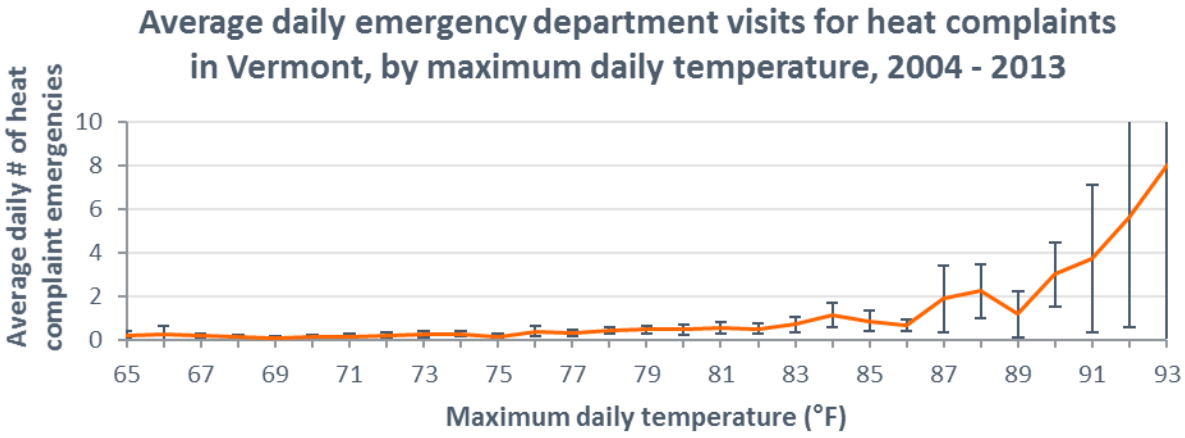


Figure 2: Emergency department visits by maximum temperature. (Data sources: temperature data - PRISM Climate Group, Oregon State University, in partnership with the Vermont State Climate Office and the National Oceanic and Atmospheric Administration's Postdocs Applying Climate Expertise Fellowship Program, University Corporation for Atmospheric Research; emergency department data - Early Aberration Reporting System (EARS)).

Vermonters may be more affected by heat for two reasons: our bodies are not adapted to hot temperatures, and many homes and businesses are not well designed to deal with summer heat. This may help explain why some of the highest rates of heat-related illnesses occur in cooler counties in Vermont. As shown in Figure 3, adults age 75 and older and people between the ages of 15 to 34 are more likely to experience a heat-related illness than the average Vermonter. Adults 65 and older are at higher risk for death on hot days.

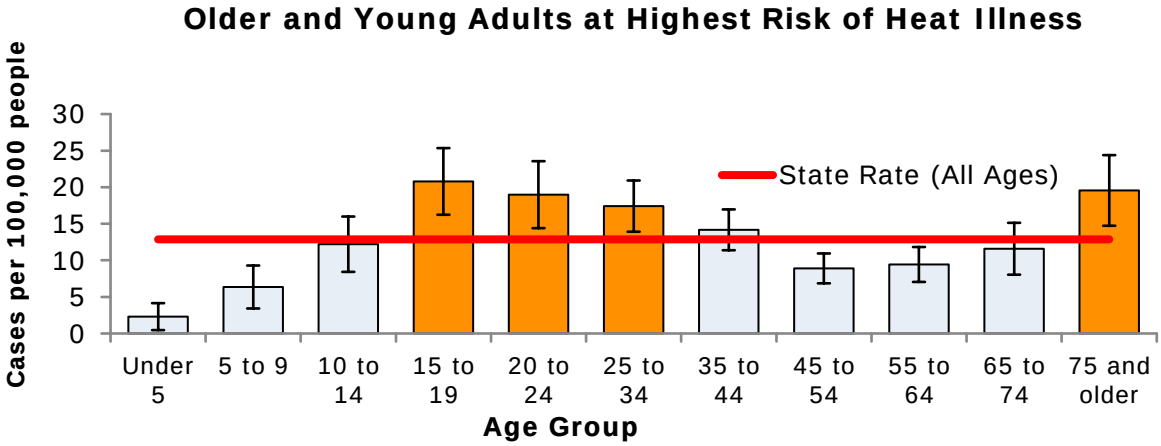


Figure 3: Annual Incidence of Heat Illness Emergency Department Visits in Vermont, by Age Group, 2003 – 2010 (Data source: Vermont Uniform Hospital Discharge Data Set)

In addition, people taking certain medications, and people with chronic health conditions may have problems regulating their body temperature. For people with pre-existing medical conditions, heat may put increased stress on already compromised systems. Young children can be particularly vulnerable to heat, and should never be left alone in a motor vehicle during warm weather. Older adults living alone, especially those with mobility difficulties or dependency on others for care, are also at an increased risk. As the climate warms and there are more hot days, it is important for people, communities and state agencies to take proactive steps to reduce heat-related health risks.

Extreme Weather Events

Climate change is already affecting weather patterns in Vermont. Since 1965, annual precipitation has increased by seven inches, and the number of days per year with precipitation of one inch or more has nearly doubled. These trends are expected to continue. Heavy rainfall events are expected to occur more often, which increases risk of flooding, damage to transportation infrastructure and buildings, water and crop contamination, wind damage and power outages.

Recent extreme weather events have had serious health consequences.

Vermont had 18 federally declared disasters from 2007 to 2016, almost twice as many as during the preceding 10 years. Most of these disasters were a result of severe storms and flooding. Tropical Storm Irene was the most notable of these, and was associated with:

- Six deaths
- Mold growth in water-logged buildings
- Extensive property and infrastructure damage, power outages, and other service disruptions
- Wellheads submerged and contaminated by floodwaters
- 30 public water systems issued Boil Water Notices
- 17 wastewater treatment facilities reported compromised operations
- Septic system failures, fuel spills, other hazardous contamination
- Over $10 million estimated damage to crops and farmlands

Health can be affected even after the storm is over. Ongoing risks include electric shock from downed power lines, managing hot and cold temperatures when the power is out, carbon monoxide poisoning from improper use of back-up electric generators, spoiled food and water contamination, mold growth in buildings, and post-traumatic stress disorder. As shown in Figure 4, a federally-declared "Major Disaster" happened roughly twice as often during the 2006 and 2015 period, as compared to the 1986 to 2005 period.

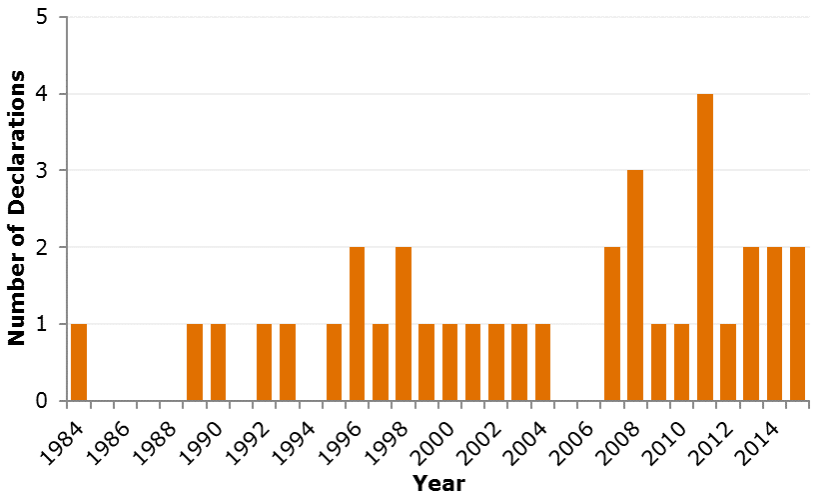


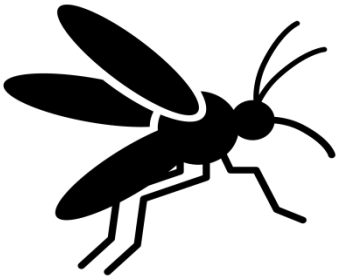
Figure 4: Disaster declarations in Vermont, 1984 to 2015 (data from FEMA 2016)

Vector-Borne and Other Infectious Diseases

Warming conditions are one of several factors that have contributed to an increased distribution and abundance of black-legged ticks in northern states that can transmit pathogens causing Lyme disease, anaplasmosis and other diseases. Climate change is expected to continue to contribute to the northward expansion of the range of the black-legged tick and lengthen the tick activity season, contributing to the increasing risk of tick-borne diseases in Vermont.

Warmer and wetter conditions will likely increase mosquito abundance and activity, and may facilitate the introduction of mosquitoes that can transmit pathogens not currently found in Vermont. The *Vermont Climate & Health Profile Report* provides additional details on which infectious diseases may become more common or spread to Vermont due to the impacts of climate change.

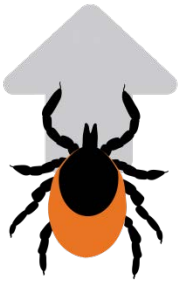
Mosquito-Borne Diseases



Mosquitoes can be a major annoyance during warmer months in Vermont and can occasionally transmit serious diseases. West Nile Virus (WNV) has been detected in the mosquito population in every county of Vermont and typically infects three or fewer Vermonters each year. Eastern Equine Encephalitis (EEE) has also been detected in mosquitoes in Vermont and caused two deaths in Rutland County in 2011.

Certain mosquito-borne diseases such as the Zika, dengue and chikungunya viruses are transmitted by mosquito species that are not currently established in Vermont. These diseases are traditionally associated with tropical and sub-tropical regions far to the south of the state. The mosquitoes that transmit these viruses (*Aedes aegypti* and *Aedes albopictus*) are not known to currently exist in Vermont, although *Aedes albopictus* is established in more southern areas of the Northeast. While climate change may influence the northern expansion of these mosquitoes, many other factors have prevented the spread of these tropical diseases in the U.S., including effective mosquito control.

Lyme and Other Tickborne Diseases



Nearly all tickborne infections in Vermont (99%) are caused by bites from black-legged ticks (*Ixodes scapularis,* also commonly known as deer ticks), the most commonly encountered ticks in the state. Currently, Lyme disease (*Borrelia burgdorferi*) and anaplasmosis (*Anaplasma phagocytophilum*) are the most common of these tickborne infections. As shown in Figures 5 and 6, the incidence of both diseases has been rising in recent years. In 2015, Vermont had the highest rate of reported Lyme disease cases in the U.S.

To survive and reproduce, black-legged ticks require forest cover and hosts to feed on, including mice and deer. Ticks also require a suitable climate. Black-legged ticks may be active anytime the temperature is above freezing (32°F). When active, warmer temperatures speed up the tick life cycle, which helps them to reproduce. But if it gets too hot and dry, ticks cannot survive. Warmer winter temperatures also make it easier for ticks and their hosts to survive.

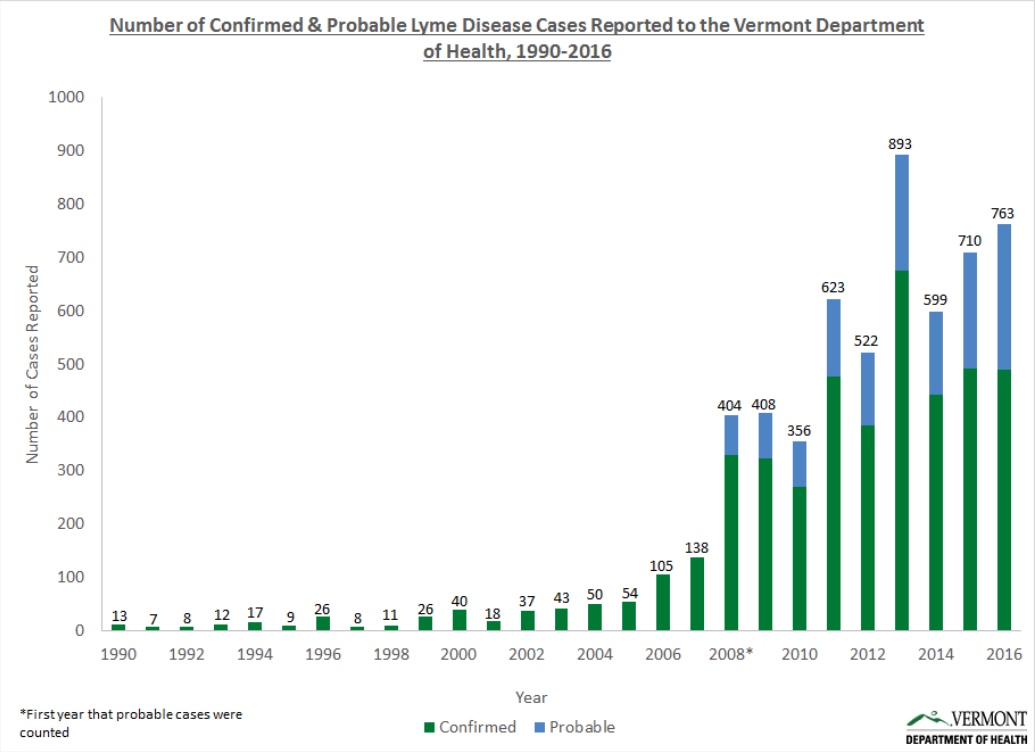


Figure 5: Number of confirmed and probable Lyme disease cases reported to Vermont Department of Health, 1990 to 2016

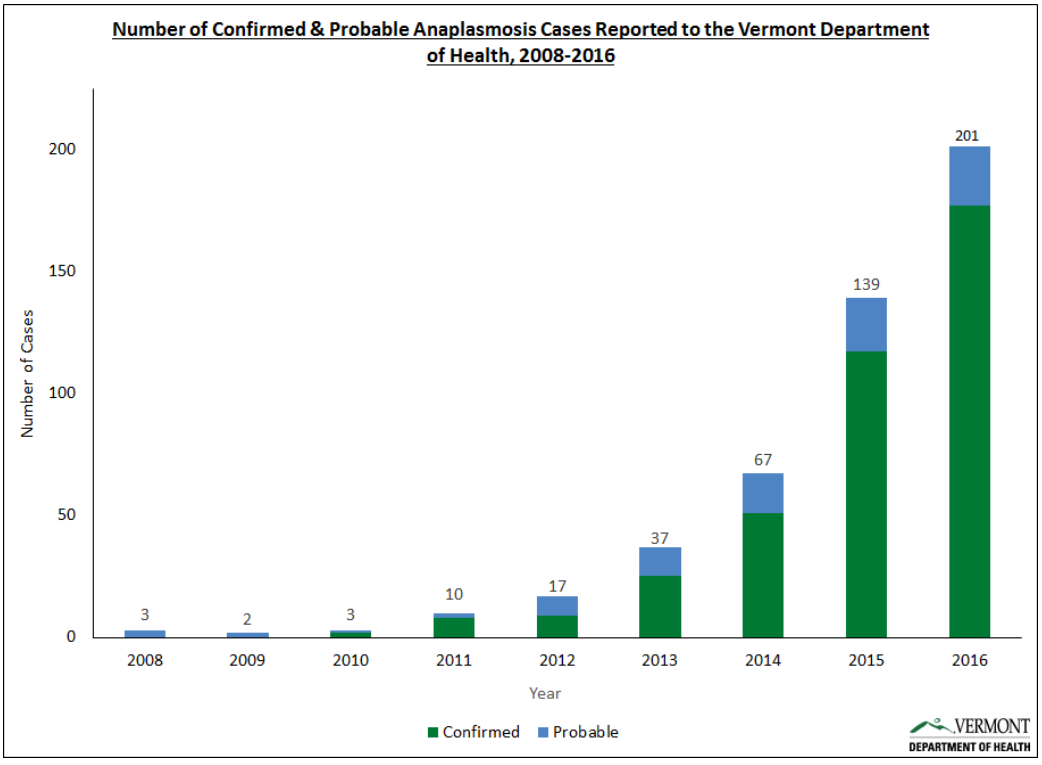


Figure 6: Confirmed & probable cases of anaplasmosis reported to Vermont Department of Health, 2008 to 2016

Climate change is one of several factors that have contributed to the spread of ticks in Vermont and the increase in tickborne diseases, providing warmer winters, a longer tick activity season, and greater likelihood of reproducing. Other factors have also contributed to an increase in tickborne diseases, such as better diagnosis and reporting by physicians, changes in forest cover, and changes in deer and small mammal populations that serve as hosts for tickborne diseases. With continued warming expected in Vermont, it is likely that tick populations and tickborne diseases will continue to increase and spread to more northern and higher elevation locations, and that ticks will have more days above freezing to reproduce and transmit diseases. Although there are currently very few cases per year, other tickborne diseases of concern in Vermont include babesiosis, erlichiosis, borrelia miyamotoi, and Powassan / deer-tick virus.

Foodborne and Waterborne Pathogens

Vermont averaged more than 500 cases of reported waterborne or foodborne illnesses per year from 2005 to 2014. Climate change is expected to exacerbate current levels of contamination and the incidence of food and waterborne illnesses in several ways:

- Warmer ambient air temperatures will help prolong survival and promote growth of pathogens. Warmer winter temperatures will reduce winter kill of pathogens.
- Warmer water temperatures will provide more favorable conditions for cyanobacteria development and growth of some pathogens such as legionella.
- More frequent heavy rains will increase the amount of runoff, the likelihood of flooding, the frequency of combined sewer overflows, and risk of contaminants splashing on field crops during heavy rains. Longer drought periods between heavy rains will exacerbate these impacts by making soil less absorbent.
- Periods of extended drought could result in drinking water shortages in some locations, and compromise water quality in drinking and recreational waters.
- Agricultural practices are likely to evolve in response to climate change. Changes in irrigation, manure and chemical applications, and crop and livestock management could have positive, negative, or neutral effects on crop and water contamination, depending on the practices used.

Vermont data from 2005 to 2014 demonstrate that heavy precipitation increased the risk of drinking and recreational water contamination (Figure 7). Assuming no other adaptations occur, expected climate changes will likely increase the occurrence of drinking water and recreational water contamination, lead to more frequent combined sewer overflows, and increase the number of reported cases of water and foodborne diseases.

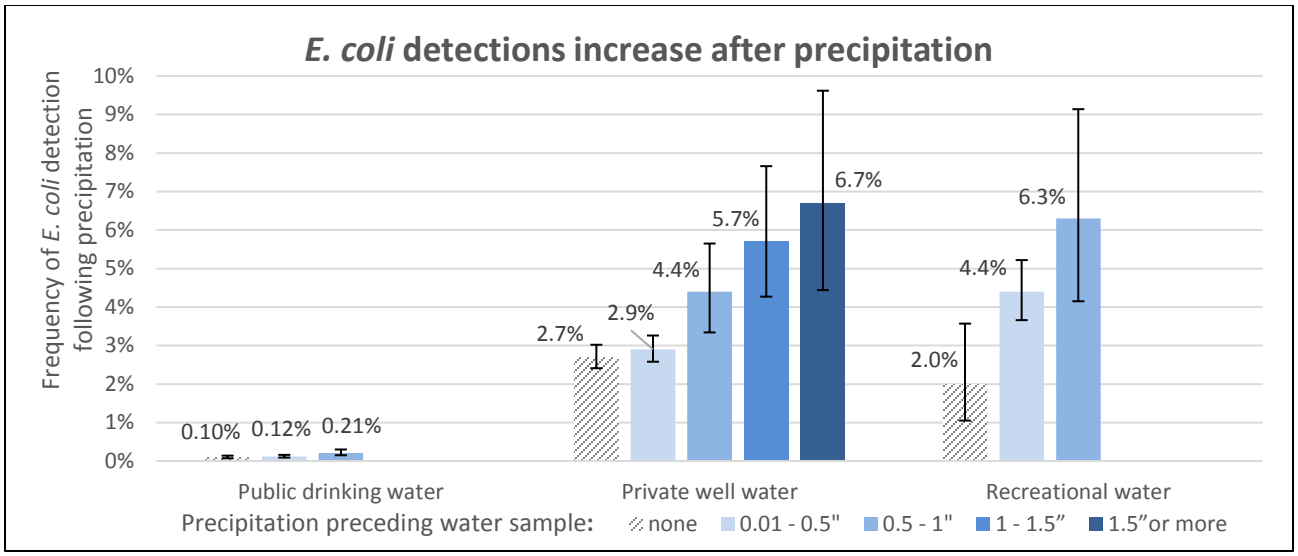


Figure 7: Percent of samples with *E.* coli detected in drinking water or *E.* coli above 235cfu/100 ml in recreational water following precipitation. *Few samples were available for public drinking water and recreational water for precipitation over 1 inch. These samples were combined with those from the 0.5 – 1” category.

Cyanobacteria Blooms

Cyanobacteria, also known as blue-green algae, are found in fresh water in Lake Champlain and other Vermont waters. Cyanobacteria can multiply quickly to form surface scums and dense populations known as blooms. Some types of cyanobacteria can release natural toxins or poisons (called cyanotoxins) into the water, especially when they die and break down. Swimming or wading in water with cyanobacteria may cause minor skin rashes, sore throats, diarrhea, vomiting, or more serious health problems. Children and pets are at higher risk of exposure because they are more likely to play near the shoreline and drink water while swimming.

Intense precipitation events can increase nutrient inputs into water bodies, which, combined with warmer temperatures, may result in more favorable conditions for cyanobacterial blooms in Vermont’s lakes. As temperatures in Lake Champlain and other fresh water bodies continue to warm due to climate change, and the frequency of heavy precipitation events increases, conditions will become more favorable for cyanobacteria blooms.

Changing climate contributes to more favorable conditions for cyanobacterial bloom formation by increasing water temperatures, which leads to greater thermal layer stratification and reduced vertical mixing (EPA, 2013). Also, cyanobacteria are better able to outcompete other aquatic organisms in a CO_2 rich environment (EPA, 2013). Finally, an increase in the frequency of intense rainfall events can lead to greater input of nutrients such as phosphorus and nitrogen into water bodies. Increased nutrient levels create more favorable conditions for cyanobacteria growth (EPA, 2013).

Looking forward, Zia et al. (2016) found that the negative impacts of climate change on water quality in the Missisquoi Bay may undermine some of the anticipated benefits of land use and land cover changes that reduce nutrient inputs into the lake.

Pollen, Mold and Air Quality

Climate change is expected to increase allergenic pollen in the air we breathe, increase mold growth in homes and businesses, and could increase air pollution from sources like wildfire smoke. The prevalence of asthma among Vermont adults increased by about 50% between 2000 and 2010. Adult asthma prevalence in Vermont has been significantly higher than the national rate since 2007, and was the fifth highest in the U.S. in 2014. About 67,000 adult Vermonters and 13,000 children report having asthma. Because pollen also affects many Vermonters who do not have asthma, further increases in allergy triggers could have widespread respiratory impacts to Vermonters.

Pollen and Allergies

Climate change is lengthening the growing season in Vermont, a change that may also extend the length of the pollen allergy season. Recent research from the Midwest reported that the ragweed pollen season has increased by over two weeks since 1995 in northern states (Ziska, 2013). The longer growing season, combined with increased plant growth due to higher levels of carbon dioxide in the air, is likely to increase the allergenic pollen in the air we breathe.

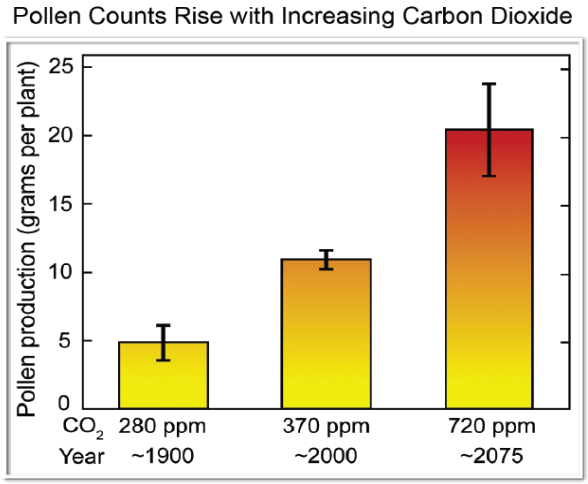


Figure 9: Pollen production in ragweed grown in chambers at carbon dioxide levels simulating past, current and projected atmospheric levels. (from Ziska and Caufield 2000, as cited in Luber et al. 2013).

Mold in Buildings

Increased humidity and occasional flooding will likely also lead to increased problems with mold growth in buildings. Damp and moldy conditions in buildings can trigger allergic reactions, asthma attacks, or other health problems.

Air Pollution and Wildfire Smoke

Climate change impacts on air pollution and wildfire smoke in Vermont are less certain. Air quality is generally expected to improve as more states replace fossil fuels with clean energy sources (wind, solar and hydro) and motor vehicles continue to get cleaner and more efficient. Air pollution may still be a problem at certain times of the year, or when winds blow in pollutants from nearby urban or industrial centers. For example, ozone formation is worst on the hottest days of the year, while fine particulate matter from wood burning is worst on the coldest days, especially in some mountain valleys. Both pollutants have impacts on respiratory

and cardiovascular health. Wildfire smoke could become worse if Vermont begins experiencing more droughts, which may contribute to more local wildfires, or if winds blow wildfire smoke from more fire-prone parts of the U.S. or Canada toward Vermont. Wildfire smoke can have impacts on respiratory and cardiovascular health.

Food Insecurity

Food insecurity, the lack of reliable access to affordable nutritious food, affects an estimated 69,724 Vermonters, including 17,091 children (Hunger Free Vermont, 2017). People who are food insecure often compromise quality for quantity, eating foods that cost less, but are nutrient-poor and calorie-rich. People who have experienced food insecurity may make permanent unhealthy changes to their diets to reduce the likelihood of experiencing food insecurity in the future (Pew Charitable Trusts, 2014). Increased atmospheric carbon dioxide levels can result in reduced protein and nutrient content in food staples, a process called carbon dioxide fertilization (USGCRP, 2016). Consumption of less nutritious foods (whether related to carbon dioxide fertilization or to dietary choices resulting from food insecurity) is expected to increase malnutrition, obesity, diet-sensitive chronic diseases, and susceptibility to infectious diseases (Seligman, 2010).

Climate change is also expected to threaten global food production and by extension raise food costs (Belanger et al. 2008, Frumkin et al. 2007, Luber et al. 2013). Crop yields are generally expected to decline due to shifting rainfall patterns, increases in extreme-weather events and increasing competition from weeds and pests (Luber et al. 2013). Globally, livestock and fish production are also expected to decrease (Luber et al. 2013).

Vermonters get much of their food from outside the state and are thus susceptible to the changes described above (Dunnington, 2010). However, Vermont has a strong and growing local food economy, ranking first in the country in the 2017 Locavore Index (Strolling of the Heifers, 2017). This active and diversified local agriculture system may help to buffer disruptions to the global food system, although local agriculture is also susceptible to climate change impacts.

Threats to Mental Health

Climate change is having widespread impacts on buildings and infrastructure, agriculture and other weather-dependent businesses, the quality of the environment, recreational opportunities, and physical health. Because all of these impacts affect individual and community quality of life, it should not be surprising that climate change is also resulting in stress, anxiety, depression, and other mental, emotional, and social impacts. Climate change can affect mental health in a number of ways:

Fear and Uncertainty About Climate Change: The current risks posed by climate change, along with the fear and uncertainty about what climate change may bring in the future, can lead to stress and anxiety. Climate change is already affecting businesses, communities and individuals,

and it is challenging to predict how these effects might change in the future. The scope of the problem can feel overwhelming, while the ability to individually influence it can feel daunting.

Distress Caused by Environmental Changes: Environmental degradation caused by climate change can result in a feeling of loss or grief, especially for people with strong emotional connections to their local environment. For example, a lack of snow and ice cover in winter, the presence of cyanobacteria on Lake Champlain or *didymo* algae (also known as rock snot) covering river and stream bottoms, can be distressing for people who remember more pristine versions of these environments.

Disruptions to Businesses and Hobbies: Tropical Storm Irene resulted in over $10 million in crop losses for Vermont farmers, while Vermont ski resorts suffered from an extremely warm winter in 2015-2016. These types of impacts affect not only personal finances, but also a way of life. In the same way, skiers, snowmobilers, hunters and fishermen, gardeners, hikers, swimmers and other outdoor recreationalists are being affected by changing weather patterns and new risks like disease-carrying ticks and mosquitoes. As the climate and vegetation of Vermont changes, some of the things that make Vermont quintessentially Vermont – such as maple sugaring, ice-fishing, snowy winters and fall colors – may be substantially altered.

Trauma Related to Flooding and Other Disasters: Those affected by disasters often experience traumatic stress during the event, post-traumatic stress following the event, and grief or depression over losses that occurred as a result of the disaster. These conditions were commonly reported around Vermont as a result of the loss of life, injuries, property and business damage, and environmental damage that occurred during Tropical Storm Irene.

Impacts Associated with Physical Health Problems: Climate change is increasing risks for heat stress, infectious diseases and seasonal allergic reactions. People affected by these conditions also often suffer from stress and depression related to feeling unwell, needing to undergo treatment, or having to reduce participation in typical daily activities.

Impact of Heat on Certain Mental Illnesses: Certain mental illnesses appear to be exacerbated by extreme heat. Several mental illnesses also reduce an individual's thermoregulatory capacity, either directly, as can be the case with schizophrenia, or through the side effects of certain medications used to treat mental illnesses, such as anticholinergic medications (Cusack et al. 2011).

Population Dislocation

Large migrations can have substantial health implications for both displaced and host populations. Population movements broadly fall into three categories: 1) forced displacement, 2) planned resettlement, and 3) migration (McMichael et al. 2012). Vermont may be impacted by all three forms of population dislocation. Vermont may experience forced displacement in river corridors during and after flooding events. For instance, more than 1,400 households were permanently or temporarily displaced after Tropical Storm Irene (ANR, 2011). Vermonters may

turn to planned resettlement as an adaption strategy in the face of flooding risk. Finally, Vermonters may migrate within or out of the state as economic opportunities become affected by climate change. For instance, a decline in the ski industry could lead to population shifts.

Also of concern to Vermont is the potential for an influx of environmental migrants from elsewhere. Environmental migrants could hail from more vulnerable regions within the United States as well as overseas. Vermont's inland and northern location provides a measure of adaptive advantage over many coastal or more arid areas, and this may make it a comparatively appealing destination. A recent assessment projected that over 4,000 Americans would migrate to Vermont from other states (predominantly to Chittenden County) due to displacement caused by sea-level rise (Hauer, 2017).

Ice Hazards

With warming winter temperatures, the strength of ice cover over water bodies is declining. A fall through ice can result in severe, or fatal, hypothermia or drowning. In Vermont, frozen lakes, ponds, and rivers are frequently used for transportation or for hunting. Given the popularity of ice fishing, snowmobiling, and other winter outdoor recreation in Vermont, and the clear warming trend in Vermont's winters, the threat of thinning ice is of concern.

While vital records show only two drownings and one hypothermia case related to a fall into water over the winters of 1999 to 2012, recent media reports have identified several deaths related to falls through the ice during the winters of 2015-2016 and 2016-2017 (Thurston, 2016; Frechette, 2017; Esch, 2017; Evans, 2017).

If the frequency of ice storms and freeze/thaw cycles increases in the future, the risk of ice-related falls or motor-vehicle injuries and fatalities may also increase. Unfortunately, climate projections do not allow us to predict icing or freeze/thaw frequency with sufficient confidence to make projections about this risk.

Sea-Level Rise

The latest Intergovernmental Panel on Climate Change assessment projects that by the end of the century, under the A2 scenario, mean sea level will rise by 1.5 to 2.7 feet above the 1985-2005 baseline (IPCC 2013). Vermont is a landlocked state, with a minimum elevation of 95 feet at Lake Champlain, so direct effects of sea level rise on human health in Vermont are not anticipated over this century. Vermont may experience indirect effects through migration and economic disruption.

3. Vulnerable Populations

Climate change affects everyone, but certain people and places are more affected than others:

- **Some people are more exposed to climate-related health impacts** such as extreme heat, flooding from extreme weather events, and tickborne diseases. Outdoor workers and hobbyists, homeless people, people living in flood plains, or living on upper stories of buildings in urban areas (which can be especially hot in summer) are groups that could be most exposed.
- **Others may have health vulnerabilities** due to age (older adults, babies and children), having a chronic or pre-existing medical condition, or being on certain medications.
- **Even people who are in good health but lack economic, social or political resources** may have less ability than others to reduce their risks, prevent impacts from occurring, and recover from impacts when they occur.

It is critical to identify individuals and communities that may be particularly vulnerable to climate-related health impacts, and to take actions to ensure that they do not suffer disproportionately from climate impacts.

Table 1 (next page) lists the populations and locations that have been identified as vulnerable to the six health impact areas that were identified in the *Vermont Climate Health Profile Report* as both most pressing and most readily addressed by adaptation actions.

The Vermont Heat Vulnerability Assessment (available at healthvermont.gov/climate) identifies and combines demographic and geographic vulnerabilities into a town-by-town vulnerability index specifically for heat-related morbidity and mortality.

The Vermont Social Vulnerability Index uses socioeconomic, demographic, housing and transportation data in a similar manner to evaluate the relative social vulnerability across the state.

Vulnerability Type		Health Impact Area					
		Extreme Heat	Extreme Weather	Water/ Foodborne Diseases	Vector-Borne Diseases	Cyano-bacteria	Asthma, Allergies & Air Quality
Target Populations	Older adults	X	X	X	X		X
	Children and teenagers	X	X	X	X	X	X
	People with chronic health conditions	X	X	X	X		X
	New Vermonters (refugee and other foreign-born)	X	X	X	X		X
	People with limited socioeconomic resources	X	X				X
	People living alone	X	X				
	People who are homeless or housing-insecure	X	X		X		X
	Users of private wells and small water systems			X			
	Outdoor workers	X	X		X		X
	Outdoor recreationalists	X		X	X	X	X
Target Locations	Mobile home communities	X	X	X			
	Urban areas (more impervious surfaces, less tree canopy)	X	X				
	Remote areas with long drive times to hospitals	X	X				
	Flood plains		X	X	X		
	Mountain valleys prone to temperature inversions						X
	Locations near recreational waters			X		X	
	Forest/field edges and trails where ticks thrive				X		
	Areas near stagnant water				X		

Table 1. People and places that are at elevated risk for particular climate hazards are indicated by an "X".

4. Taking Action

Reducing the risk of climate-related health impacts requires immediate action. The Health Department can play a critical role by raising awareness about climate-related health impacts, by monitoring and responding to climate-related health risks, providing guidance to individuals, communities and service providers for reducing climate-related health risks, and working with partners to implement programs that limit climate change while improving population health. Table 2 (next page) outlines the Health Department's strategic framework to address climate and health related risks.

Adaptation: Reducing Health Risks Associated with Climate Change

Even if all greenhouse gas emissions were to cease today, the earth would continue to warm an additional 2.3°F (Mauritsen et al. 2017). Therefore, action must be taken to minimize the public health risks of climate changes that have already occurred and that will inevitably continue to occur. The Health Department's website describes actions that individuals and communities can take to reduce health risks associated with:

- Hot weather
- Extreme weather events
- Tickborne diseases
- Mosquito-borne diseases
- Cyanobacteria blooms
- Waterborne and foodborne diseases
- Pollen, mold and air quality
- Mental health stressors

Mitigation: Reducing Emissions and Protecting Health

The more greenhouse gases emitted into the atmosphere, the more we can expect the planet to warm, resulting in increasingly more severe extreme weather and health impacts. Actions need to be taken now to reduce greenhouse gas emissions, remove greenhouse gases from the atmosphere, improve community resilience to climate impacts, and address vulnerabilities to health risks.

Climate action provides a health opportunity

Actions taken in Vermont to reduce greenhouse gas emissions can provide health, economic, environmental and other benefits for Vermonters today, while also reducing our state's contribution to climate change. Current land use, transportation, energy, economic and food systems policies and infrastructure can inadvertently increase the risk of chronic diseases like Type 2 diabetes, respiratory conditions, cardiovascular conditions and cancer. Not only do these chronic diseases have an impact on the quality of life for Vermonters, they also impose a substantial financial burden. The medical costs in Vermont related to these largely preventable chronic diseases were estimated to exceed two billion dollars in 2016 alone (HEALTH 2017a). A multidisciplinary panel recently concluded that "[t]ackling climate change could be the greatest global health opportunity of this century" (Watts et al. 2015).

Goals	Desired outcome	Strategies
Raise Climate & Health Awareness	Vermonters, agency partners, and state leaders are more aware of climate change impacts on health and the health impacts of climate actions	Communicate with the public, partners and leaders about climate-related health impacts
		Communicate with the public, partners and leaders about the health impacts of actions taken to help mitigate climate change
Support Healthy Climate Mitigation Actions	Vermonters and partners pursue climate change mitigation actions that provide health co-benefits	Encourage active lifestyles and reduced energy use through compact development, public transit, and by providing safe opportunities for walking and biking
		Improve the health of indoor environments and reduce energy bills through improved building weatherization and the use of advanced heating and ventilation technologies
		Improve outdoor air quality by reducing emissions from transportation, home and business heating and energy usage, and energy production
		Promote solutions that increase carbon storage and provide environmental health benefits and/or support local food production
		Assess the health impacts of climate actions to avoid or mitigate potential negative impacts, especially for the most vulnerable population groups
Strengthen Community Resilience	Vermont communities, organizations and businesses are better prepared to prevent climate-related health impacts	Increase capacity to identify vulnerabilities, prepare for emergencies, and address climate-related risks
		Build social connectedness and community wellness
		Increase access to health and emergency services that address climate-related health impacts
Build Health Department Capacity	The Health Department will be better prepared to prevent the health impacts of climate change	Enhance surveillance systems to improve real-time risk monitoring
		Routinely communicate with partners and the public about climate-related health risks
		Develop emergency plans and protocols to respond to climate-related health risks
		Work with other Health Department programs to increase awareness of climate-related health risks
		Conduct analyses to better understand climate-related health risks
Reduce Environmental Hazards	Natural and built environments in Vermont are more resilient to the impacts of climate change	Support activities that improve water quality, air quality, and the health of terrestrial ecosystems
		Support design of communities, buildings, infrastructure and landscapes to reduce environmental hazards
Strengthen Individual Resilience	Vermonters are better prepared to protect themselves from climate-related health impacts	Establish warning and outreach systems to alert Vermonters about climate-related health risks
		Provide health/safety guidance to Vermonters
		Reduce health, socioeconomic, or other factors that increase vulnerability to climate-related health risks

Table 2. Health Department framework to address climate and health related risks in Vermont.

Guiding principles for healthy climate action

The following guiding principles were developed for the 2016 Comprehensive Energy Plan to help prioritize climate actions that also provide health benefits, while avoiding actions that could negatively affect health or equity. Additional information related to each principle is provided in the call-out boxes.

1. Encourage active lifestyles and reduced energy use through compact development, and by providing safe opportunities for walking, biking and using public transit.

Compact community design, supported by safe and efficient pedestrian, biking, and transit networks, helps reduce the amount of energy used for transportation purposes, and enables more people to travel using active means. Healthy lifestyles can help reduce obesity, diabetes and cardiovascular disease. Measures such as education, enforcement and infrastructure strategies (e.g. Complete Streets and Safe Routes to Schools) help reduce traffic-related injuries and deaths and help address safety concerns that can prevent people from trying active transportation in the first place.

In 2016, 28% of Vermont adults were considered obese, up from 21% only 10 years prior (HEALTH, 2017a). A recent analysis found that the lifetime health and societal costs associated with obesity were $92,235 per individual (Kasman et al. 2015). Physical inactivity is a major contributing factor to obesity. In 2015, only 59% of Vermont adults met the national physical activity guideline of at least 150 minutes of moderate-intensity activity per week (HEALTH, 2017a). Using active transportation is one way to help reduce obesity rates and related costs (Mueller et al. 2015).

2. Improve outdoor air quality by reducing emissions from transportation, home and business heating and energy usage, and energy production.

Using cleaner energy sources (e.g. solar, wind and hydro), improving energy efficiency, using cleaner fuels, shifting to cleaner transportation technologies (e.g. electric/hybrid vehicles), and changing behaviors (e.g. reduced travel, transit/biking/pedestrian travel) will ease air pollution and improve overall air quality. Reducing energy-related air pollution can result in improved respiratory and cardiovascular health, and reduced risks of Type 2 diabetes and cancer.

There is no safe level of air pollution. Recent research found that even at PM2.5 and ozone levels below National Ambient Air Quality Standards, those exposed to relatively higher levels of PM2.5 and ozone experienced higher rates of hospitalization and mortality (Di et al. 2017; Makar et al. 2017). So even though the air quality in Vermont is generally good, making it even better can result in measurable health benefits. A recent assessment of the Regional Greenhouse Gas Initiative found that reductions in air pollution were associated with 30 to 68 million dollars in health-related benefits for Vermont from 2009-2014 (Abt Associates, 2017).

3. Improve the health of indoor environments and reduce energy bills through improved building weatherization and the use of advanced heating and ventilation technologies.

Improvements to home energy efficiency and heating systems can reduce energy usage, leading to cost savings, improved indoor air quality and greater indoor comfort, while yielding better respiratory, psychological and overall health. Using advanced wood-burning stoves and boilers improves home-heating efficiency and reduces the detrimental impacts of wood burning on indoor and outdoor air quality. Replacing old heating units with clean, advanced energy technologies, especially in areas of at-risk populations, reduces risk to vulnerable individuals.

A recent assessment in Massachusetts found that in addition to affordability benefits for occupants, each home weatherization project provided an average of over $1,300 in annual health benefits, primarily associated with reduced asthma symptoms, reduced thermal stress from both cold and heat, and fewer days of missed work (Hawkins et al. 2016). For every 1,000 units weatherized, 87 emergency department visits and 17 hospitalizations were avoided annually. The health benefits were largely attributable to air sealing, heating system improvements and insulation.

4. Reduce negative health impacts expected to occur as a result of climate change.

Climate change, which is affected by greenhouse gas emissions from energy production and usage, has been linked with health impacts related to heat illness, extreme weather events, degraded air and water quality, and vector-borne disease. A warming climate will likely increase demands for energy to cool homes, requiring thoughtful strategies to improve the efficiency of cooling systems and reduce the need for cooling with appropriate building, landscape and community design.

In 2017, the Vermont Climate & Health and Urban & Community Forestry Programs partnered to provide 200 trees to residents in urbanized areas of Bennington and Newport (FPR, 2017). These communities were selected based on their relatively high risk for heat illnesses, in part due to lack of tree cover. During the first 20 years, the trees are expected to save participating residents over $275 in energy savings, while reducing atmospheric carbon by over 200,000 pounds, removing nearly 600 pounds of air pollutants, and intercepting over 1.5 million gallons of storm water. The total estimated economic benefit for these household and ecosystem services is roughly $50,000.

5. Assess the health impacts of our energy system to avoid or mitigate potential negative impacts, especially for the most vulnerable population groups – such as older adults, low-income households, and those with chronic or pre-existing medical conditions.

Human health depends on the continuity of energy services – particularly space heating and cooling, food refrigeration and emergency services. At a minimum, we need to ensure that the most vulnerable populations are not further disadvantaged by the impacts of energy developments or strategies.

Health Impact Assessment (HIA) is a method used to evaluate the health impacts of plans, policies, or programs, and which could be applied to proposed climate actions in Vermont. To date, HIA has been used in Vermont to evaluate the health impacts of marijuana regulation, paid sick leave policies, and various land use and transportation plans (HEALTH, 2017b). Related to climate actions, HIAs have been conducted in other states on carbon pricing (Richardson, 2012), biomass combustion (Moshammer, 2009), and wind energy development (Oregon Health Authority, 2013).

References

Abt Associates. Analysis of the Public Health Impacts of the Regional Greenhouse Gas Initiative, 2009-2014. January 2017. Accessed at: http://abtassociates.com/AbtAssociates/files/7e/7e38e795-aba2-4756-ab72-ba7ae7f53f16.pdf

Agency of Natural Resources (ANR). Lessons from Irene: Building resiliency as we rebuild. 2012. Accessed Oct 2017 at: http://anr.vermont.gov/sites/anr/files/specialtopics/climate/documents/factsheets/Irene_Facts.pdf.

Betts AK. Vermont Climate Change Indicators. Weather, Climate and Society. 2011: 3(2); 106-115.

Cusack L, de Crespigny C, Athanasos P. Heatwaves and their impact on people with alcohol, drug and mental health conditions: a discussion paper on clinical practice considerations. J Adv Nurs. 2011 Apr;67(4):915-22. doi: 10.1111/j.1365-2648.2010.05551.x. Epub 2011 Jan 7. PubMed PMID: 21214621.

Di Q, Wang Y, Zanobetti A, et al. Air Pollution and Mortality in the Medicare Population. The New England Journal of Medicine. 2017:376;2513-2522. doi:10.1056/NEJMoa1702747

Dunnington G. The potential impacts of climate change on agriculture in Vermont. Climate change adaptation white paper series. 2010 Apr. 6 p.

Environmental Protection Agency (EPA). Impacts of Climate Change on the Occurrence of Harmful Algal Blooms. 2013 May. Accessed at: water.epa.gov

Esch M. Second VT snowmobiler's body found. Burlington Free Press. Feb 16, 2017. Accessed Oct 2017: http://www.burlingtonfreepress.com/story/news/2017/02/16/second-vt-snowmobilers-body-found/98004856/

Evans B. 93-year-old man dies trying to save dog from frozen pond. NBC 5. Apr 9, 2017. Accessed Oct 2017: http://www.mynbc5.com/article/93-year-old-man-dies-trying-to-save-dog-at-pond/9251320

Federal Emergency Management Agency (FEMA). Disaster Declarations for Vermont. Accessed 2016 Jan at: http://www.fema.gov/disasters/grid/state-tribal-government/35

Feeding America. Map the Meal Gap, Food Insecurity in your County. 2011. Accessed at: http://feedingamerica.org/hunger-in-america/hunger-studies/map-the-meal-gap.aspx

Frechette K. Vermont State Police: Man Dies After Falling Through Ice on Lake Willoughby. My Champlain Valley. Jan 26, 2017. Accessed Oct 2017: http://www.mychamplainvalley.com/news/vermont-state-police-man-dies-after-falling-through-ice-on-lake-willoughby/645907146

Frumkin H, Hess J, Luber G, et al. Climate change: the public health response. Am J Public Health. 2008;98:435–445. doi:10.2105/AJPH.2007.119362

Hauer M. Migration induced by sea-level rise could reshape the US population landscape. Nature Climate Change. 2017;7:321-325. doi:10.1038/nclimate3271

Hawkins B, Tonn BE, Rose E, et al. Massachusetts Special and Cross-Cutting Research Area: Low-Income Single-Family Health- and Safety-Related Non-Energy Impacts (NEIs) Study. Prepared for Massachusetts

Program Administrators. August 2016. Accessed at: http://ma-eeac.org/wordpress/wp-content/uploads/Low-Income-Single-Family-Health-and-Safety-Related-NonEnergy-Impacts-Study.pdf

Hunger Free Vermont. Hunger in Vermont. Accessed in October 2017 at: https://www.hungerfreevt.org/hungerinvermont/

IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Kasman M, Hammond RA, Werman A, et al. An In-Depth Look at the Lifetime Economic Cost of Obesity. Brookings Institute. 2015. Accessed 2017 October at: https://www.brookings.edu/wp-content/uploads/2015/05/0512-Obesity-Presentation-v6-RM.pdf

Luber G, Knowlton K, Balbus J, et al. Chapter 9: Human Health. Prepared for the Third National Climate Assessment. DRAFT. 2013 Jan. p 333-384.

Makar M, Antonelli J, Di Q, et al. Estimating the Causal Effect of Low Levels of Fine Particulate Matter on Hospitalization. Epidemiology. 2017:28(5);627-634. doi:10.1097/EDE.0000000000000690

Mauritsen T, Pincus R. Committed warming inferred from observations. Nature Climate Change. 2017 Jul 31;7(9):nclimate3357.

McMichael C, Barnett J, McMichael AJ. An ill wind ? Climate change, migration, and health. Environmental Health Perspectives. 2012 May;120(5):946-54

Moshammer H, Kaiser A, Flandorfer C, et al. Air Pollution due to Wood Burning for Heating: A Health Impact Assessment. Epidemiology. 2009:20(6);S99. doi:10.1097/01.ede.0000363010.29954.7f.

Mueller N, Rojas-Rueda D, Cole-Hunter T, et al. Health impact assessment of active transportation: A systematic review. Preventive Medicine. 2015:76;103-114. doi:10.1016/j.ypmed.2015.04.010

National Oceanic and Atmospheric Administration (NOAA 2017). Climate at a Glance. Accessed October 2017 at : http://www.ncdc.noaa.gov/cag/time-series/us

Oregon Health Authority. Strategic Health Impact Assessment on Wind Energy Development in Oregon. March 2013. Accessed at: http://www.oregon.gov/oha/ph/HealthyEnvironments/TrackingAssessment/HealthImpactAssessment/Documents/Wnd%20Energy%20HIA/Wind%20HIA_Final.pdf

Pew Charitable Trusts. 2014. Health Impact Assessment of Proposed Changes to the Supplemental Nutrition Assistance Program. Accessed October 2017 at: http://www.pewtrusts.org/en/research-and-analysis/white-papers/2014/11/health-impact-assessment-of-proposed-changes-to-the-supplemental-nutrition-assistance-program

Richardson MJ, English P, Rudolph L. A Health Impact Assessment of California's Proposed Cap-and-Trade Regulations. American Journal of Public Health. 2012:102(9);e52-e58. doi:10.2105/AJPH.2011.300527

Seligman H, Schillinger D. 2010. New England Journal of Medicine. Hunger and Socioeconomic Disparities in Chronic Disease. Vol 363: 6-9.

Strolling of the Heifers. 2017 Locavore Index. 2017. Accessed at: http://www.strollingoftheheifers.com/locavore-index-2013/

Thurston J. After Deaths and Close Call, Officials Urge People to Stay Off Ice. NECN. March 10, 2016. Accessed Oct 2017: https://www.necn.com/news/new-england/After-Deaths-and-Close-Call-Officials-Urge-People-to-Stay-Off-Ice-371747151.html

U.S. Census Bureau (USCB). 2012 American Community Survey: Table 1: 2012 State-to-State Migration. 2012 .

U.S. Census Bureau (USCB). Vermont Quick Facts. U.S. Department of Commerce. 2014 Jan. Accessed at: http://quickfacts.census.gov/qfd/states/50000.html

USGCRP, 2016: The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. Crimmins A, Balbus J, Gamble JL, Beard CB, et al. U.S. Global Change Research Program, Washington, DC, 312 pp. http://dx.doi.org/10.7930/J0R49NQX.

Vermont State Climate Office projections developed for the Vermont Department of Health (2014). As detailed in the Vermont Climate and Health Profile Report. Accessed October 2017 at: http://www.healthvermont.gov/sites/default/files/documents/2017/01/CHPR_Sept7_2016.pdf

Vermont Department of Forests, Parks, & Recreation (FPR 2017). Free Trees for Newport & Bennington Residents through the Energy Saving Trees Program. Accessed 2017 October at: http://vtcommunityforestry.org/news/free-trees-newport-bennington-residents-through-energy-saving-trees-program

Vermont Department of Health (HEALTH, 2017a). Chronic Disease in Vermont: Statewide Data Brief. Accessed 2017 October at: http://www.healthvermont.gov/sites/default/files/documents/pdf/hpdp_3-4-50_Statewide%20Data%20Brief%20072617.pdf

Vermont Department of Health (HEALTH, 2017b). Physical Activity, Nutrition, & Weight Scorecard. Accessed 2017 October at: http://www.healthvermont.gov/scorecard-nutrition-weight

Vermont Department of Health (HEALTH, 2017c). Health Impact Assessments. Accessed 2017 October at: http://www.healthvermont.gov/about/reports/health-impact-assessments

Vermont State Refugee Coordinator. Personal correspondence. 2014 Jan.

Watts N, Adger WN, Agnolucci P, et al. Health and climate change: policy responses to protect public health. The Lancet. 2015:386(10006);1861-1914. http://dx.doi.org/10.1016/S0140-6736(15)60854-6

Zia A, Bomblies A, Schroth AW, et al. Coupled impacts of climate and land use change across a river–lake continuum: insights from an integrated assessment model of Lake Champlain's Missisquoi Basin, 2000–2040. Environmental Research Letters. 2016 Nov 17;11(11):114026.

Ziska, Lewis, et al. 2011. Recent warming by latitude associated with increased length of ragweed pollen season in central North America. Proceedings of the National Academy of Sciences, 108: 4248-4251.