4-5: Extreme Heat

Hazard Impacts	Probability	Potential Impact					Score:
		Infrastructure	Life	Economy	Environment	**Average:**	
Heat	3	1	3	2	2	2	6

Score = Probability x Average Potential Impact

This chapter aims to address the history, trends, vulnerability and mitigation efforts associated with extreme heat, prolonged hot weather and rising average annual temperatures. More information on increasing temperatures can be found in the Climate Change subsection of the Hazard Assessment and the Extreme Cold section.

Extreme hot temperatures can have significant effects on human health and commercial and agricultural businesses, as well as primary and secondary effects on infrastructure (e.g. damage to asphalt roadways from softening). What constitutes "extreme heat" can vary across different areas of the world based on what the population is accustomed to in their respective climates. An example of this difference in acclimatization can be understood when comparing analyses of excess mortality due to heat: in New York City, the data show that the heat index threshold needs to reach at least 95°F to measure a significant rise in heat-related mortality, whereas the threshold in Montreal, Canada, only 400 miles north, is 91°F and did not need to factor in heat index. Similar epidemiological analyses completed by the Vermont Department of Health suggest that the heat threshold in which hospitals in the State see a rise in heat-related emergency room visits is 87°F[1].

Temperature fluctuations are a result of several meteorological processes[2]. Due to the tilt of Earth's axis, regions of the globe receive varying levels of solar radiation. The delta between these levels produces circulation patterns at the global level, which drive air and storm system movement via air masses. Air masses, as defined by NOAA, are thousands of feet thick and extend across large areas of the earth. Air masses that form over tropical ocean regions will become exceptionally hot and humid, while those masses above high latitude continents will become cool and dry. When these air masses meet, a front is created; fronts can either be cold or warm. In addition to these air mass and front-related impacts humans feel at ground level, movement of narrow bands of strong wind high in the atmosphere, known as jet streams, maneuver weather systems below and transfer heat and moisture across the globe. The speed and intensity of the jet stream will affect the duration and temperature associated with a cold or warm front.

Extremely high temperatures can occur when a high-pressure system (under which air is descending toward the Earth's surface) develops and intensifies. Under such conditions, the potential for a heat wave exists. A heat wave is a period of three or more consecutive days during which the diurnal maximum temperature meets or exceeds 90°F.

In anticipation of extreme heat events, the National Weather Service (NWS) may issue the following advisories:

- **Excessive Heat Outlook:** A period of excessive heat is possible within the next 3 to 5 days
- **Heat Advisory – Take Action:** A period of excessive heat is expected. The combination of hot temperatures and high humidity will create a situation in which heat related illnesses are possible. Heat Advisories are issued when heat indices are expected to reach at least 95°F.

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1 http://www.healthvermont.gov/sites/default/files/documents/2017/01/CHPR_Sept7_2016.pdf
2 http://www.noaa.gov/resource-collections/weather-systems-patterns

- **Excessive Heat Watch:** A prolonged period of dangerous excessive heat is possible within about 48 hours
- **Excessive Heat Warning – Take Action:** A prolonged period of dangerous excessive heat is expected within about 24 hours. The combination of hot temperatures and high humidity will create a situation in which heat related illnesses are possible. Excessive Heat Warnings are issued when heat indices are expected to reach at least 105°F.

The Heat Index is a measure of how hot it really feels when relative humidity is factored in with the actual air temperature. As an example, if the air temperature is 90°F and the relative humidity is 65%, the heat index – how hot it feels – is 103°F. The red area without numbers indicates extreme danger. The National Weather Service will initiate alert procedures when the Heat Index is expected to exceed 105°F (depending on local climate) for any duration[3].

Extreme heat and prolonged periods of hot weather, as well as significant, projected increases in average annual temperature, also have direct and indirect effects on these other hazards, addressed throughout this Plan: Drought, Wildfire, Invasive Species, Infectious Disease.

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure and/or Strenuous Acitivity

Caution | Extreme Caution | Danger | Extreme Danger

Figure 47: Heat index
Source: NOAA

Extreme Heat History

Fortunately, Vermont has historically experienced a climate where extreme heat is less likely than other regions in the country. However, heat-related events do occur and are beginning to occur in much greater frequency (see Extreme Heat Trends & Vulnerability). In Burlington, the average number of days per year with above 90°F temperatures is nearly eight. In 1999, a drought year, this figure climbed to 19. Extreme maximum temperatures are often observed during drought years, and in many cases, the records that are broken were long-standing and set during previous droughts (see: Drought). It should be noted that a heat wave could be either a boon or a bane depending upon the time of year and the antecedent conditions. For example, the hot conditions of August 1996 followed a cool, wet summer, thereby providing an extra boost for plants.

3 http://www.nws.noaa.gov/om/heat/heat_index.shtml

In July of 1911, Northfield had a 12-day average of 90.75°F. The summer of 1949 was also very hot, with 25 days above 90°F. It is important to note here, however, that hot weather can have health impacts at even lower temperatures, with health risks increasing considerably when temperatures reach the mid-to-upper 80s[4]. Between 2000 and 2017, the number of recorded days per year with a daily temperature high greater than or equal 85°F peaked during the 2016 summer at 45 days, closely followed by the summer of 2015 at 41 days in Burlington.

March 8-9, 2000 is the only excessive heat event for Vermont on NOAA's records, impacting Windham and Bennington Counties. Temperatures climbed through the 60s to near 70°F on both afternoons. At the Albany International Airport, the high of 66°F on March 8 established a new record high, eclipsing the old record of 64°F set in 1942. On March 9, the temperature reached 68°F, replacing the old daily record high of 66°F set in 1977. Other heat events since 2000 include:

- **August 1-2, 2006:** a heat ridge moved into Vermont during the early morning August 1. Temperatures soared into the 90s but significantly more important were dewpoints that reached the middle to upper 70s to produce excessive heat index values of 100°F to 105°F some of the highest values in nearly a decade.
- **July 21, 2011:** temperatures across much of southern Vermont warmed into 90s with dew points in the 70s, combined with the hot temperatures and resulted in heat indices of 100°F to 104°F. This was the 2nd day of a 3 to 4-day heat wave across a large portion of Vermont with heat index values of 100°F to 108°F across the Champlain and Connecticut valleys as well as some interior valleys. One death is attributed to this event in Windsor County.
- **March 17, 2012:** winter of 2011-12 had temperatures that averaged 4-5°F above normal and snowfall 40-60% of normal. This combination accounted for snow pack across the region to be largely below normal or even non-existent by mid-March. In Vermont, temperatures climbed into the 70s March 18 and low-80s March 19-22. Record heat was recorded across all of Vermont with maximum temperatures 30-40°F above normal and some daily records being broken by 10°F or more. This event caused an estimated reduction of 30% of maple sugar production, resulting in an estimated impact of nearly $10 million. In addition, there was significant loss of ski industry revenue due to a 25-50% reduction in snow loading.

Extreme Heat Trends & Vulnerability

From 1895 to 2015, the average annual temperature in Vermont increased by 2.6°F (or 0.2°F per decade). Data from the National Oceanic and Atmospheric Administration (NOAA) further suggest that Vermont's average annual maximum and minimum temperatures increased by approximately 0.4°F and 0.6°F, respectively, per decade since 1960[5], representing an increasing trend in temperature increases within the State. This significant rise in average temperature is even more profound when comparing the differences between seasons: average maximum temperature in the summer (June-August) has risen 0.15°F per decade, while winter (December-February) has experienced a four-fold increase of 0.64°F per decade.

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4 http://www.healthvermont.gov/environment/climate
5 http://climatechange.vermont.gov/our-changing-climate/dashboard/increasing-max-min-temperature

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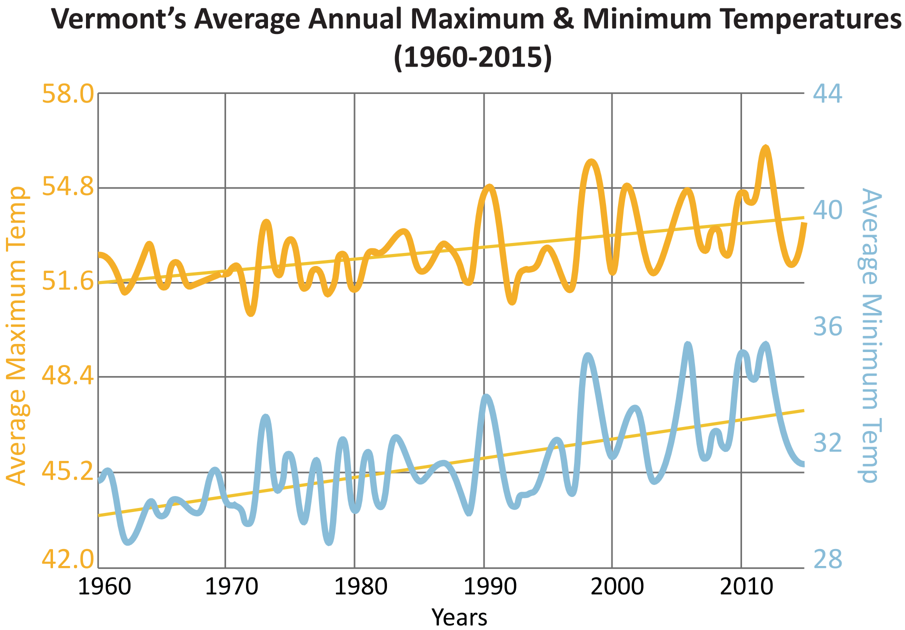

Figure 48: Vermont's average annual maximum & minimum temperatures (1960-2015)
Source: climatechange.vermont.gov

According to a recent published article[6], the northeast region of the country is the fastest-warming area of the contiguous United States and is warming at a rate 50% greater than the global average. Increases in ground surface temperatures will be further exacerbated by varying levels of greenhouse gases. Climatologists have modeled the projected increases in the number of days over 90°F for both reduced greenhouse gas emissions scenario (B1) and those increases in higher greenhouse gas emissions scenario (A2). This modeling suggests that increases in average temperature of 3°F to 6°F in the lower emissions scenario versus 4.5°F to 10°F under higher emissions conditions can be expected by the 2080s[7]. The most significant warming in this region will occur during the winter months, where average temperatures are projected to increase by 4°F, while the increase in summer months will be less severe, at 2°F, but still considered a significant rise.

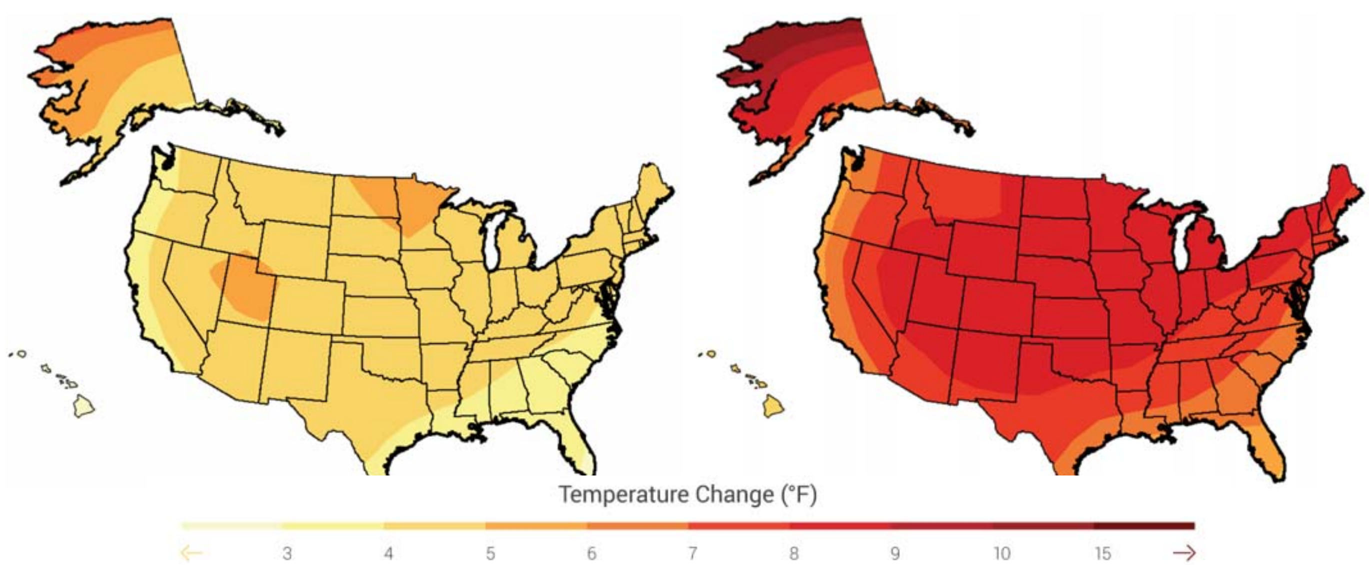

Figure 49: Projected temperature increase under lower emissions scenario, B1 (left) versus under higher emissions scenario, B2 (right)
Maps show projected change in average surface air temperature in the later part of this century (2071-2099) under a scenario that assumes substantial reductions in heat trapping gases (B1) and a higher emissions scenario that assumes continued increases in global emissions (A2) Source: https://nca2014.globalchange.gov/report

6 http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0168697
7 https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-northeast_.html#Reference%201 http://anr.vermont.gov/sites/anr/files/specialtopics/climate/documents/VTCCwhitepapers/VTCCAdaptAgriculture.pdf

More information for the compounding impacts of increasing gas emissions on increasing temperatures can be found in the 2014 National Climate Assessment[8].

The primary impact of extreme heat or prolonged periods of hot weather is to human life. Hot conditions, especially when combined with sun and high humidity, can limit the body's ability to thermoregulate properly. Prolonged exposure to hot conditions can lead to heat cramps, heat exhaustion, heat stroke, or exacerbate other pre-existing medical conditions. Some of these impacts require medical attention and can be fatal if left untreated.

The Heat Vulnerability in Vermont report[9] suggests that Vermonters are at a greater risk for serious, heat-related illness – potentially even death – when the statewide average temperature reaches or exceeds 87°F. The Health Department's Climate & Health Program has reviewed six heat vulnerability themes (population demographics of a town, socioeconomic status, health status of town residents, environmental characteristics, the ability of town residents to acclimate to hot temperatures and emergency room visits for heat illness) and determined a thematic vulnerability for each.

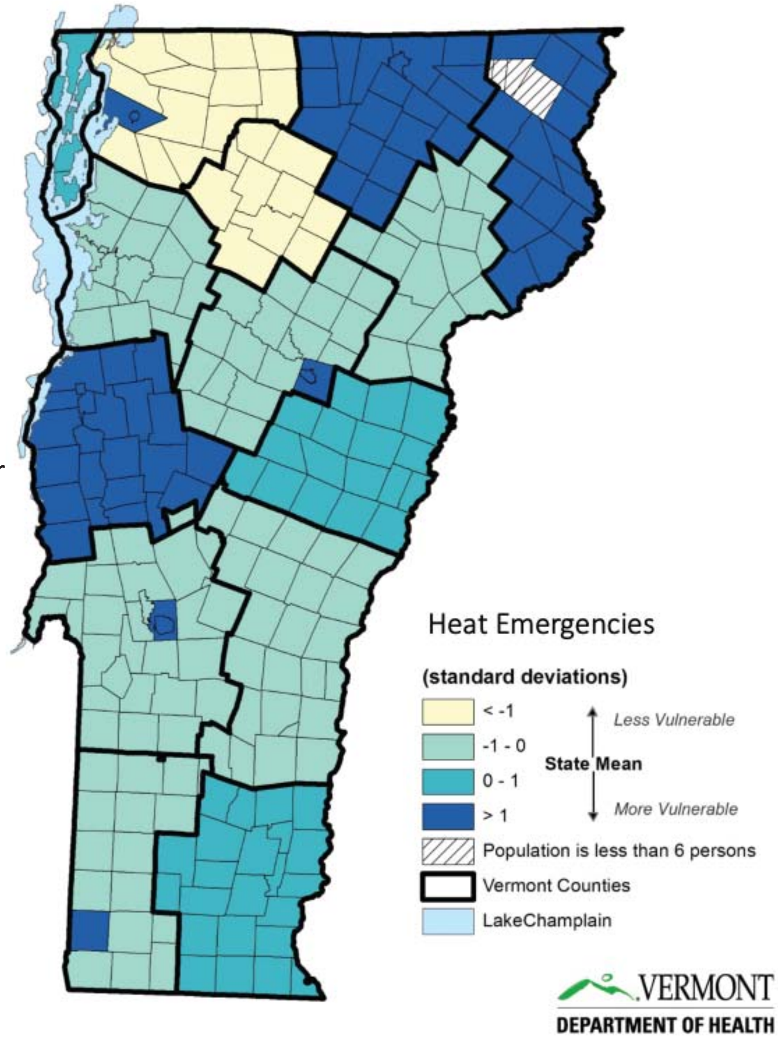

Figure 50: Vermont heat emergencies map by municipality
Source: Vermont Department of Health

In general, those at higher risk during hot weather include older adults and children, people with chronic medical conditions, people active outdoors, people without air conditioning, and people living in more urbanized parts of Vermont. The hot-weather vulnerability maps by theme, and more information regarding the health impacts of increasing temperatures and prolonged periods of hot weather are available at the Department of Health's Climate & Health website: www.healthvermont.gov/environment/climate.

Though higher temperatures are more likely in the southeast region of the state and in more urban areas, this does not translate to a linear relationship between temperature and vulnerability. Historically, relatively high rates of heat illnesses have been experienced in some of the cooler counties in Vermont, which may be a result of underlying population vulnerabilities (for example, an older population with more pre-existing health conditions), and a lack of acclimation to hotter conditions.

Further, higher concentrations of ground-level ozone are associated with hotter days in the northeast, which can exacerbate heat-related health impacts, particularly for older adults, children, and those with asthma or other respiratory conditions.

8 https://nca2014.globalchange.gov/report
9 http://www.healthvermont.gov/sites/default/files/documents/2016/12/ENV_EPHT_heat_vulnerability_in_VT_0.pdf

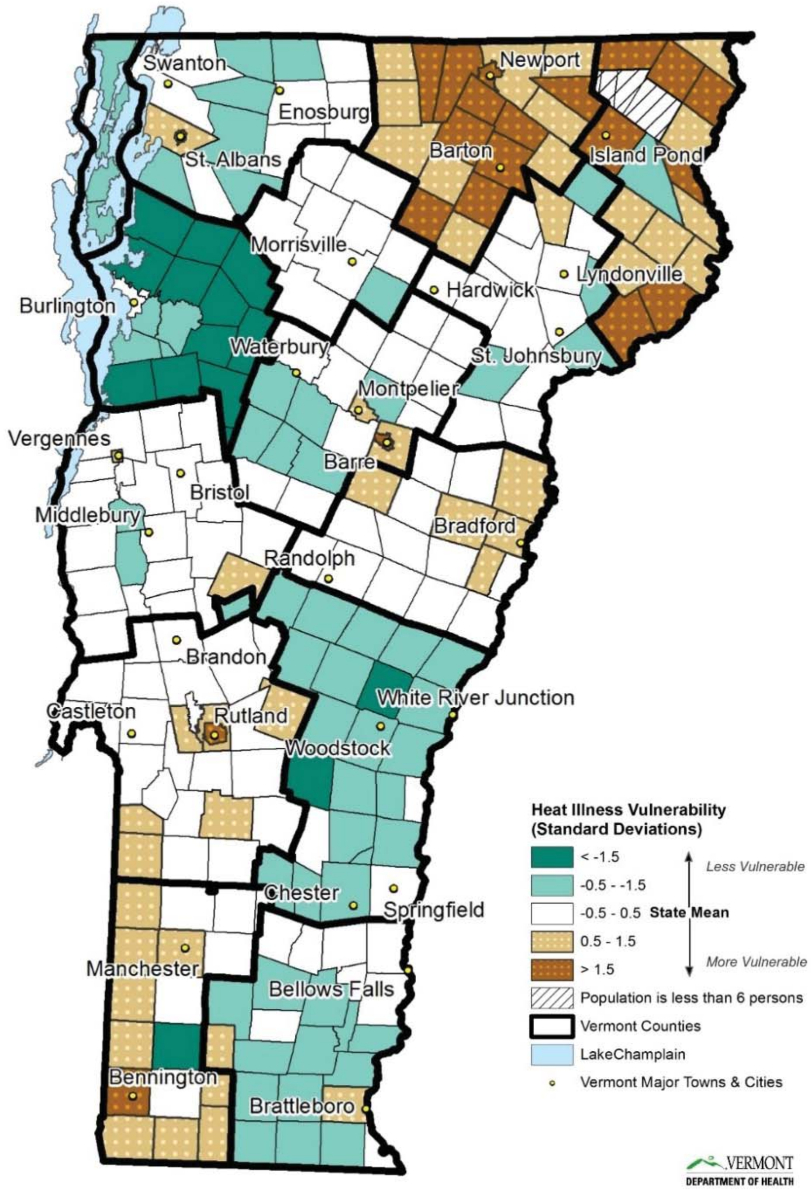

Figure 51: Vermont Heat Illness Vulnerability
Source: Vermont Department of Health

In addition to the direct health impacts associated with extreme heat, data suggest that health impacts are also associated with prolonged hot weather and increasing average temperatures. For example, increases in the incidence of vector-borne diseases (e.g. Lyme, West Nile and Eastern equine encephalitis) in Vermont and New England at-large have been observed and are attributed to warming conditions. The increase in average annual temperatures and shortened winters have allowed mosquitos and ticks to become more active earlier in the spring and remain active later in the fall. Because the incidence of Lyme disease in Vermont is higher than the national average at present, lengthening vector seasons is of great concern to the health community in Vermont (see: Infectious Disease). People working in the outdoors – loggers and farmers, for example – are most vulnerable to vector-borne illness.

Finally, hot weather can increase thermal stratification in water bodies, where shallow water layers are much warmer and do not readily mix with cooler, deeper water layers. Stratified water layers are most common in late summer and early fall, providing more favorable conditions for development of cyanobacteria blooms in Vermont's lakes and ponds. 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, stomach problems, or occasionally 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[10].

The rise in average annual temperature and increased occurrence of prolonged hot weather events will also have impacts on infrastructure, the environment and the economy in Vermont. These impacts are also not exclusive to the extreme heat hazard, but rather will affect many other hazards addressed within this plan. First, as temperatures continue to rise, there is likely to be a heightened consideration for water supplies, as many individuals in Vermont use private wells for water supplies. Higher temperatures will lead to increased evapotranspiration, soil drying rate and the frequency of short-term droughts, limiting water availability for tree growth (see: Drought).

10 http://www.healthvermont.gov/tracking/cyanobacteria-tracker

Native forests and ecosystems are projected to experience negative impacts of these warming trends, as well[11]. With 76% of the Vermont landscape covered by forest, and more than 50 tree species, increases in average annual temperatures will force these species to adapt. Northern hardwood species like maple, yellow birch and American beech are anticipated to be nearly eliminated in the State, replaced by those tree species that thrive in warmer, drier conditions, like oak and pine. Additionally, the changing climate will allow for greater survival and reproduction of forest pest species, as trees that are stressed due to lower water availability reduce their ability to maintain sufficient defense mechanisms, making them more vulnerable to pest invasion and disease (see: Invasive Species).

With a changing forest complexion and greater levels of evapotranspiration, extreme heat and prolonged hot weather could also lead to an increase in the occurrence of wildfires in Vermont (see: Wildfire).

Global warming projections also consider changes to crops and vegetation, which could drop by nearly 40 percent in some areas, causing great disruptions on the agricultural sector in Vermont. The Vermont Agency of Natural Resource's Climate Change Adaptation White Paper Series' Agricultural White Paper[12] identifies cold-weather crops, such as field corn, wheat and oats to be the most vulnerable to rising temperatures. The paper continues to note that many fruits grown in Vermont (e.g. blueberries and apples) require approximately 1,000 hours below 45°F to produce profitable yields, and with current climate projections, southern Vermont may not be able to meet these requirements. Maple sugaring, a $200 million industry in Vermont, will need to adapt to changing temperature patterns and adjust tapping schedules, as new estimates suggest that spring is arriving two weeks ahead of the average winter-spring transition. Vermont's dairy industry is responsible for 70-80% of the State's annual agricultural sales. Dairy farmers across the State will need to pay attention to increasing temperatures, as cows can experience heat stress at as low as 75°F, especially on humid days, which can reduce milk production by up to 20%.

Considering the already-observed increase in average annual temperature, the projected rise between 3°F and 10°F by the 2080s, and the impacts of extreme heat or prolonged hot weather, the Steering Committee considered the probability of a plausibly significant extreme heat or prolonged hot weather event to be Likely, with the most significant impacts felt by people, followed then by the direct and indirect impacts to the environment and the economy.

Extreme Heat Mitigation

As mentioned throughout the Extreme Heat hazard profile above, increases in annual average temperatures will have wide-reaching impacts to other hazards throughout this plan. Accordingly, many of the mitigation strategies and actions addressing the hazard impacts of Drought, Invasive Species, Wildfire and Infectious Disease can be both directly and indirectly tied to Extreme Heat (see: Mitigation Strategy).

The Vermont Urban & Community Forestry and Climate & Health Programs partnered with the Arbor Day Foundation in 2017 and 2018 to offer an Energy-Saving Trees Program to residents of urban communities in Vermont[13]. Communities were selected based on their relatively high risk for heat illnesses, according to the Vermont Heat Vulnerability Index, where one of their key risk factors was a lack of tree cover. Five hundred trees have been provided to residents in four different Vermont communities – Barre, Bennington, Newport, and Rutland.

11 http://climatechange.vermont.gov/sites/climate/files/documents/Data/VTCCAdaptForestry.pdf
12 http://anr.vermont.gov/sites/anr/files/specialtopics/climate/documents/VTCCwhitepapers/VTCCAdaptAgriculture.pdf
13 https://vtcommunityforestry.org/est

Other strategies that have been identified to address health risks of hot weather include general awareness raising and capacity building among the public, health and emergency service professionals, and home visiting staff and volunteers; building retrofits to help keep buildings cooler and better ventilated; designation of community cooling centers; adoption of workplace, school, and community policies to cancel or modify activities on hot days; and development of a state hot weather emergency communications and response plan.

The primary entity in Vermont devoted to extreme heat and prolonged hot weather mitigation and preparedness is the Vermont Department of Health Climate & Health Program[14]. Over the past several years, this team has developed a wide range of reports and resources used for hot weather planning, which aim to identify populations most vulnerable to heat-related health impacts while taking into consideration a warming climate[15].

14 http://www.healthvermont.gov/environment/climate
15 http://www.healthvermont.gov/sites/default/files/documents/pdf/ENV_CH_WhitePaper.pdf