Halifax Regional Municipality

Climate Adaptation Baseline Report

Completed in support of the HalifACT 2050 Community Energy and Climate Action Plan

Completed by:

Sustainability Solutions Group

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Climate Adaptation

Introduction

The study of climate change adaptation borrowed from the area of disaster risk reduction at its inception and applied risk management approaches. Climate-related hazards create risks to someone or something, which then created the imperative for risk mitigation options. Climate change cannot solely be managed in relation to external climatic systems, but requires instead an understanding of the complex interaction among societies, ecosystems and hazards arising from climate change. This perspective stresses the importance of considering the concept of vulnerability.[1]

Figure 1 illustrates a schematic representation of the interaction among the physical climate system, exposure, and vulnerability, as defined in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) report.[2] Climate-related hazards interact with the exposure, sensitivity and adaptive capacity of human and ecological systems to determine changing levels of risk.

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[1] Oppenheimer, M. et al. 2014: Emergent risks and key vulnerabilities. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. ***O`qs A: Gkna`k `mc Rdbsnq`k Arodbsr. Cnmsqhatshnm~ ne Vnqjhmf Gqnto ξξ sn sgd Fhesg Arrdrr l dms Qdonqs ne sgd ξmsdqfnudqm l dms`k O`mdk nm Ckhl`sd~ Cg`mfd.***

[2] IPCC, 2014: Summary for policymakers. In: Climate Change 2014: Impacts,Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

[3] IPCC, 2014.

Terminology

Climate hazards refer to the potential occurrence of climate-related physical **events**, such as extreme weather (heat wave or flood), or climate change **trends**, such as increasing temperatures, that result in an impact for natural, built or human systems.

Risk results from the interaction of vulnerability, exposure, and hazard, and in this context, the term primarily refers to the risks of climate-change impacts. Risk is also referred to as the potential for consequences where something of value is at stake and where the outcome is uncertain; it is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. This mathematical approach, however, requires the consideration of vulnerability and exposure.

Impacts, also referred to as consequences or outcomes, refers to the effects on natural, built, and human systems of climate hazards; this includes the effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure. Impacts generally manifest in some form of damage, disruption, or complete (irretrievable) loss, and can be generally categorized as physical, social, or economic. Impacts result due to the interaction of climate events or trends (occurring within a specific time period) and the vulnerability of an exposed society or system. Additionally, impacts can be considered direct (damage to a building) or indirect (loss of a job or income as a result of damage to a building).

Exposure refers to the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected; for example, assets located in a flood plain, or people living in poor quality housing.

Vulnerability refers to the propensity or predisposition to be adversely affected, and refers to characteristics of human or social-ecological systems that are exposed to hazardous climatic events or trends; it is a function of sensitivity and adaptive capacity. **Sensitivity** or susceptibility to harm, refers to the degree to which a system or species is affected; while **adaptive capacity** refers to the ability to adjust or to respond to impacts. Ecosystems, geographic areas, assets or humans (amongst others) can be classified as vulnerable; this is of particular concern if vulnerability in one area (eg. humans) increases as a result of potential impairment or increased vulnerability in other areas (eg. assets).

Stressors refer to events and trends, which are often not climate-related, that have an important effect on the system exposed and can increase vulnerability to climate-related risk. For example, growing income inequality is a stressor that is pushing already low income families to their financial limits; this further increases these families' vulnerability, as they have less resources (and therefore decreased capacity) to respond to the impacts major climate event.

Adaptation refers to the process of adjustment in natural or human systems in response to actual or expected climatic change and its effects. The process of adaptation aims to moderate or avoid harm or exploit beneficial opportunities.[4]

Urban resilience refers to the **ability** of urban centers (populations, enterprises, and governments) and the systems on which they depend to anticipate, reduce, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner[5]; or the **capacity** of individuals, communities, institutions, businesses, and systems within a city to survive, adapt and grow no matter what kinds of chronic stresses or acute shocks they experience.[6] In this context, **climate resilience** is synonymous with the definitions above, but is more specific in that the hazardous events, shocks or stresses are those that are climate related. Climate resilience is often used interchangeably with adaptation, and can be viewed as a state, ability, or capacity, whereas adaptation is the process by which to accomplish this ideal. In other words, climate resilience can be achieved through the process of adaptation.

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[4] IPCC, 2014.

[5] IPCC, 2014.

[6] 100 Resilient Cities.

Context

Changing climate

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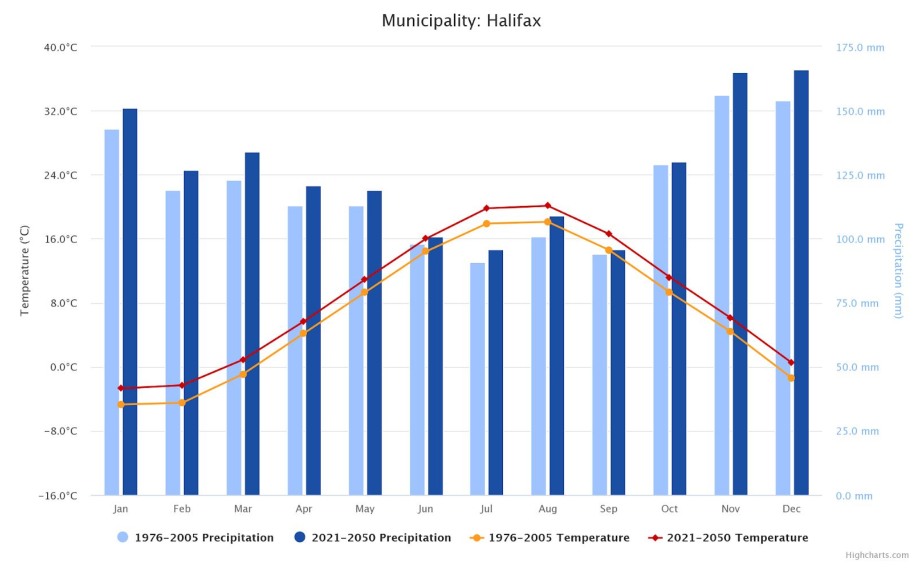
Halifax has experienced a number of climate hazards with major impacts over the last decade, including the Sackville River floods in December 2014 and April 2015; a record heat in summer 2018; and, more recently from Hurricane Dorian in September 2019; a storm that caused significant damage to public and private property from high winds and heavy rain, uprooted hundreds of trees, caused a large crane to topple over onto neighbouring buildings downtown, and resulted in 75% of the provinces electrical customers losing power, many for several days.[7]

Many of these climate hazards are projected to increase in variability, frequency, and intensity as a result of projected changes in climate. In general, Halifax can expect to see, amongst other changes, higher average annual and maximum temperatures, more heat waves, higher annual precipitation, increases in extreme precipitation, and increases in the intensity and frequency of some extreme events, including storms, flooding and wildfires.

Further detail on climate projections for Halifax is included in the ***Ckh l `sd- Oqnidbshnmr.*** section.

These events have significant impacts for people, infrastructure, natural systems and economies, including health impacts, damage to property, disruption in critical infrastructure systems, business and service interruptions, and inhibiting mobility and access to services. This is discussed in more detail in the ***H`y`qcr, Qhrj `mc {l o`bsr.*** section.

[7]Crane Toppled, Trees Uprooted As Dorian Hammers Nova Scotia | Cbc News https://www.cbc.ca/news/canada/nova-scotia/hurricane-dorian-nova-scotia-destruction-1.5274887



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Growing and aging region

While the climate is changing, the Halifax region is also growing. Currently home to just over 441,400 people, the region is projected to grow to approximately 572,600 people by 2050; a total growth of 30% over that period. In the context of climate change, this presents both new challenges and opportunities.

This growth will increase demand on existing infrastructure; infrastructure that in many cases is already at or over capacity, is aging rapidly, and is currently experiencing impacts of extreme climate events. It will also require significant investments in new infrastructure. As climate events become more extreme and occur more frequently, increases in disruption and damage to infrastructure, and the subsequent costs to repair or replace it will increase. Additionally, it is anticipated that the state of good repair (SOGR) backlog will increase exponentially, as already aging infrastructure that is subjected to these climate changes and extremes will age even faster and reach its lifetime more quickly than anticipated. In the absence of significant action and investment, the risk to existing and future infrastructure will exponentially increase.

This growth is also likely to result in urbanization, which is associated with elevated surface and air temperatures due to the presence of heat absorbing materials, reduced evaporative cooling caused by lack of vegetation, and production of waste heat, as well as increased flooding as a result of the increase in impervious surfaces and decrease in vegetation. Combined with projected increases in temperature and changing precipitation patterns, urbanization and the loss of vegetation and permeable surfaces in built up areas is likely to exacerbate these issues.

While the population of Halifax is growing, it is also aging. The number of seniors, a group that is more vulnerable to the impacts of climate change, is increasing in the region. The Canadian Institute for Health Information (CIHI) indicates that, as a cohort, seniors (65+ years) are growing rapidly in Nova Scotia, and more significantly, this is being outpaced by those aged 75+ years.[8] CIHI projects that seniors 75+ years will more than double in Nova Scotia by 2037.[9]

Inequality

Not all people will be affected equally by climate change. Certain groups, communities, or populations, referred to as climate vulnerable populations, will be disproportionately affected due to their increased exposure and sensitivity to climate risks, or lack of adaptive capacity to deal with the impacts. The degree to which certain people are vulnerable to climate is driven by a variety of socio-economic characteristics or factors, including income, housing and living conditions, and ability to access services (including infrastructure and support services). Climate vulnerable populations are discussed in more detail ***Utkmdq`ahkhsx s***ection.

In the context of climate change, inequality is a major concern, as it exacerbates the vulnerability to climate of those who are already vulnerable.

While the Halifax region is generally prosperous and growing, this prosperity is not shared by all. Some areas enjoy higher incomes, better health, and better access to a mix of housing, transit, and public services. In other parts, poverty is more concentrated, health outcomes are poorer, services (like transit) are more sparsely located and people face barriers that prevent them from accessing services and employment.

Research from the Neighbourhood Change Research Project indicates that income inequality in Halifax Regional Municipality (CMA) (measured between 1970 and 2010) did not change significantly overall [in comparison with other cities such as Toronto and Vancouver where this has become a significant issue], but there was increasing income polarization in the Halifax Peninsula area.[10] There are currently areas of the city that are well below and well above the city average, and that while the between Halifax's lower and upper income earners is not as great as in some cities, Halifax is losing its middle earners.[11]

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[8] Seniors Population Growth. Canadian Institute for Health. Accessed at https://www.cihi.ca/en/seniors-in-transition/web-tools/population-growth

[9] Infographic: Canada's Seniors Population Outlook: Uncharted Territory. Canadian Institute for Health. Accessed at https://www.cihi.ca/en/infographic-canadas-seniors-population-outlook-uncharted-territory

[10] Victoria Prouse, Jill L Grant, Martha Radice, Howard Ramos, Paul Shakotko. 2014. Neighbourhood Change in Halifax Regional Municipality, 1970 to 2010: Applying the "Three Cities" Model.

[11] Planning and Theory in Practice. Dalhousie University. Neighbourhood Change in Halifax: A Community Update. 2016. [Meeting minutes] http://theoryandpractice.planning.dal.ca/neighbourhood/working-papers.html

Climate Projections

About the climate projections

Climate projections data and content of this section was drawn directly from the Climate Atlas of Canada[12] and Canada's Changing Climate Report.[13]

Localized downscaled climate projections for temperature and precipitation for Halifax were sourced from the Climate Atlas of Canada. The Climate Atlas' primary source of climate model data is the Pacific Climate Impacts Consortium's (PCIC) statistically downscaled data derived from 24 CMIP5 global climate models, for two emissions scenarios (RCP4.5 and RCP8.5). The RCP4.5 and RCP8.5 are referred to as the "Low Carbon" and "High Carbon" scenarios, respectively.[14]

The temperature and precipitation projections data for Halifax that follows in this report is associated with the RCP8.5 scenario, or the "High Carbon" scenario. This scenario reflects a "business-as-usual" scenario that assumes global greenhouse gas emissions continue to increase at current rates through the end of the century. At present, based on the best available science, global emissions are on track to follow the High Carbon scenario.

The data displays information for three time periods, the ***Qdbdms O`rs~*** (1976-2005), the ***ξI IdcH`sd Ftstqd,*** (2021-2050) and the ***Md`q Ftstqd*** (2051-2080).

Information and projections for extreme events were sourced from Canada's Changing Climate Report. Where applicable, data and information related to a high emissions scenario (RCP8.5), considered to reflect a "business-as-usual" scenario, is presented.

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[12] Climate Atlas of Canada, version 2 (July 10, 2019), using BCCAQv2 climate model data. Accessed at https://climateatlas.ca/
[13] Bush, E. and Lemmen, D.S., editors (2019): Canada's Changing Climate Report; Government of Canada, Ottawa, ON.
[14] For further details on data and methods used by the Climate Atlas, refer to https://climateatlas.ca/data-sources-and-methods.

Temperature

Heat

	1976-2005	2021-2050	2051-2080
Average annual temperature	6.8	8.6	10.6
# summer days (+25)	18	39	66
# very hot days (+30)	1	3	12
# tropical nights (+20)	0	1	10
Typical hottest summer day	29.6	31.5	33.6
Hot season (# days from first to last +30 day)	6	22	50

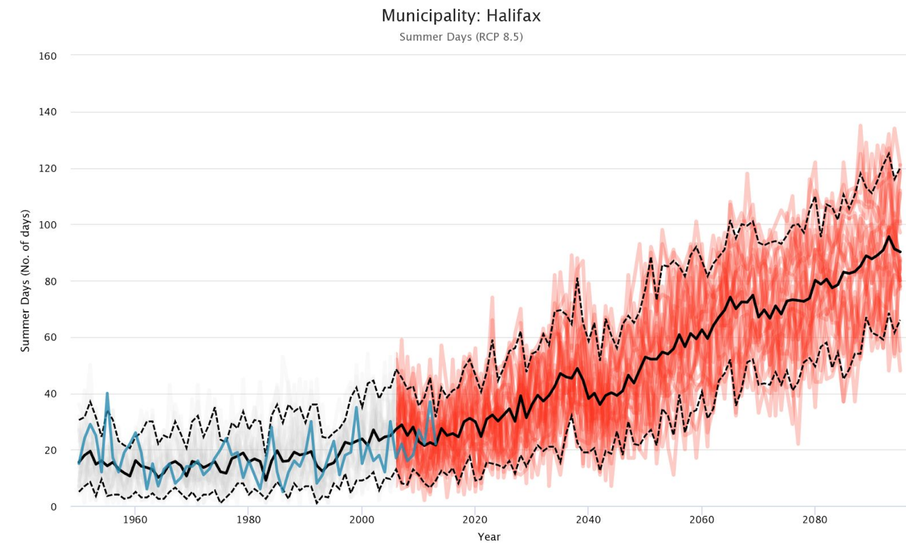
High temperatures are important. They determine if plants and animals can thrive, they limit or enable outdoor activities, define how buildings are designed, and shape transportation and energy use. It is useful, for example, to know how high summer temperatures are likely to become in the future, to ensure cooling and air-conditioning systems can reliably deal with these extremes.

When temperatures are very hot, people - especially the elderly - are much more likely to suffer from heat exhaustion and heat stroke. Many outdoor activities become dangerous or impossible in very high temperatures. In general, Canadians are not used to extremely hot summers, and further warming will bring new and unusual risks as well as a very different experience of the summer season.

High, persistent temperatures increase the risk of drought, which can severely impact food production and increases the risk of wildfire. High temperatures can also lead to more thunderstorms, which means increased risks of flash flooding, lightning, hail and perhaps even tornadoes.

Hot summer days are physiologically stressful, especially if overnight temperatures do not provide cooling relief. For Halifax, hot “summer days” (+25 ∊) are projected to more than double from an average of 18 days in the period 1976-2005, to 39 days in 2021-2050; and up to 66 days in 2051-2080 (Figure 3).

Many people are at risk from suffering heat exhaustion or heat stroke when nighttime temperatures fail to drop below 20 °C. Elderly people, the homeless, and those who live in houses or apartments without air conditioning are especially vulnerable during these heat events, particularly if they last for more than a few days. For Halifax, hot “tropical nights” (+20 ∊) are projected to increase from an average of 0 days in the period 1976-2005, to 10 days in 2051-2080 (Figure 4).



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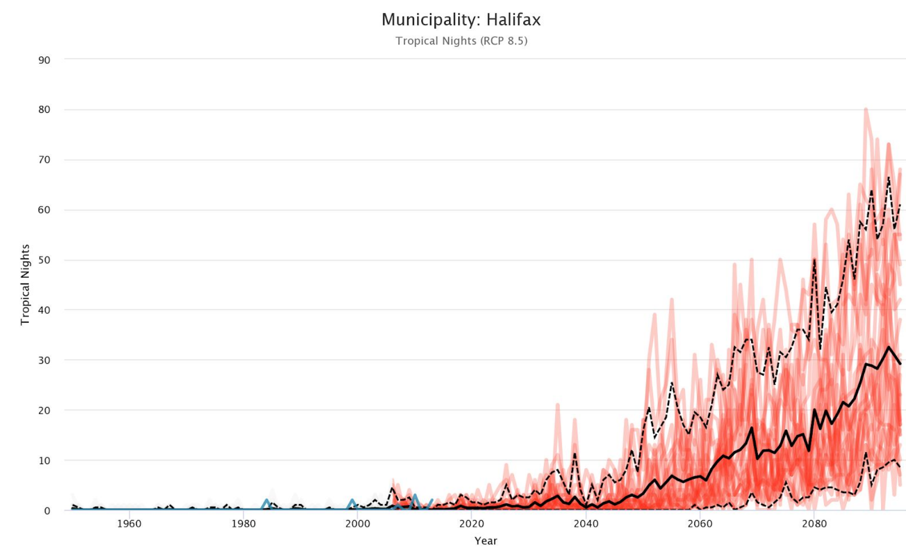

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Cold

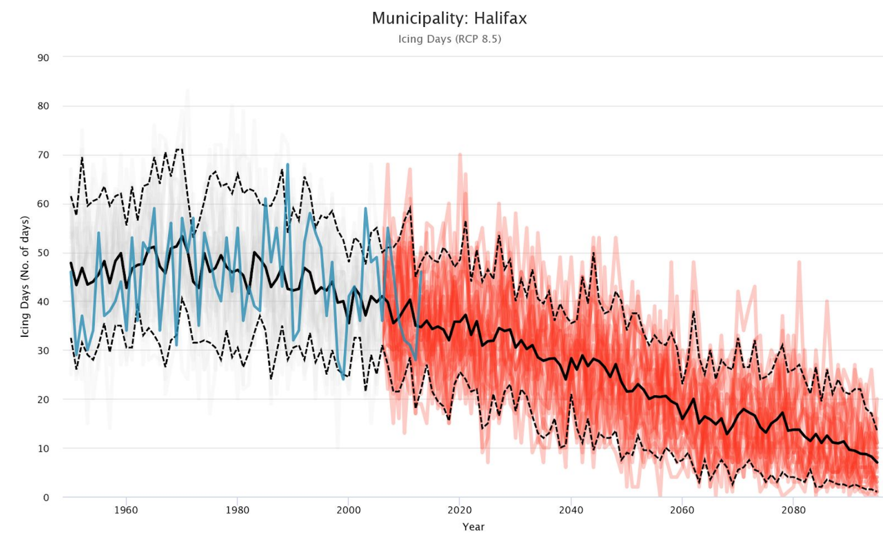
	1976-2005	2021-2050	2051-2080
Average winter temp	-3.5	-1.5	0.6
# mild winter days (-5)	77	59	41
# cold winter days (-15)	13	6	1
# icing days (# days air temp does not go above freezing/ 0 °C)	44	29	17

Cold weather is an important aspect of life in Canada, and many places are well adapted to very cold winters. Amongst others, cold weather plays a role in human health and safety, determines what plants and animals can live in the area, and limits or enables outdoor activities, as well as shapes our energy use, specifically for heating.

Halifax's winters are projected to get significantly warmer, with the average winter temperature increasing from -3.5 ∊ in the recent past, to -1.5 ∊ in the 2021-2050 period, and up to 0.6 ∊ in 2051-2080. Along with a decrease in heating degree days (HDD)[15], this has positive impacts for energy consumption, as less energy will need to be consumed for space heating

The number of mild winter days (-5 ∊) and cold winter days (-15 ∊) is also decreasing, along with the number of icing days (the number of days on which the air temperature does not rise above freezing) (Figure 5), and freezing degree days (FDD)[16]. These all indicate a decrease of the length and severity of winters into the future as temperatures increase, and have impacts for snow and ice accumulation.

Lower or decreasing FDD imply less or decreasing snow and ice accumulation, which is an important consideration for winter activities such as skiing, the building of winter roads, municipal and rural snow clearance, and many other aspects of winter life. Alongside increasing temperatures and changing precipitation patterns, decreased snow and ice accumulation is likely to impact groundwater recharge, runoff timing and stream flow.



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[15] Heating Degree Days (HDD) are equal to the annual sum of the number of degrees Celsius a given day's mean temperature is below 18 °C. For example, if the daily mean temperature is 12 °C, the HDD value for that day is equal to 6 °C. If the daily mean temperature is above 18 °C, the HDD value for that day is set to zero.

[16] Freezing degree days (FDD) are equal to the annual sum of the number of degrees Celsius that each day's mean temperature is below 0 °C. FDDs begin to accumulate when the daily mean temperature drops below freezing: if a day's mean temperature is -21 °C, for example, it increases the annual FDD value by 21. Days when the mean temperature is 0 °C or warmer do not contribute to the annual sum.

Growing season

	1976-2005	2021-2050	2051-2080
Frost free season (#days)	170	194	217
Date of last spring frost	May 2	Apr 21	Apr 9
Date of first fall frost	Oct 22	Nov 4	Nov 16
Frost days (# days <0)	145	118	92

A longer Frost-Free Season means plants and crops have a longer window to grow and mature. If projections show an increase in the length of the Frost-Free Season, then the annual growing season will be longer, and the period of cold weather correspondingly shorter.

The growth of most plants and crops is limited by the temperature of the air and soil; emergence and growth in the spring is limited by freezing temperatures.

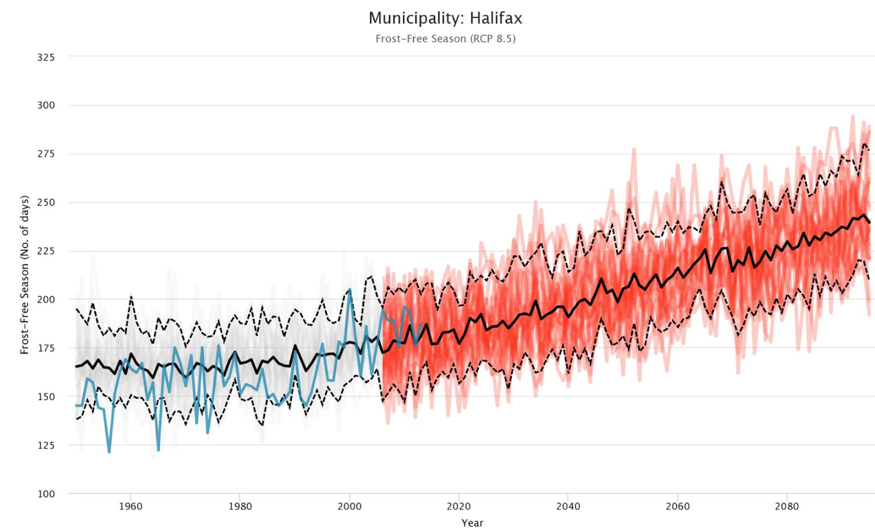
As crops and plants need time to mature, the earlier in the spring they start to grow without the occurrence of frost, and the later in the fall they experience freezing temperatures, the more likely it is that they will be able to mature to their full potential. This time available for growth, maturity and productivity (determined by the Date of Last Spring Frost and the Date of First Fall Frost), determines the overall length of the frost-free season.

As a result of increasing average annual and seasonal temperatures, the length of the frost-free season is projected to increase in Halifax from an average of 170 days in the period 1976-2005, to 194 days in 2021-2050; and up to 217 days in 2051-2080 (Figure 6). This is to be accompanied by a projected decrease in annual frost days, and an increase in growing degree days (GDD).

Growing Degree Days (GDDs) are often used to determine whether a climate is warm enough to support plants and insects with temperature-dependent growth rates.

GDDs accumulate whenever the annual sum of the number of degrees Celsius that each day's mean temperature is above a specified base temperature (Tbase). Generally, 5°C GDDs are used for assessing the growth of canola and forage crops; 10°C GDDs are more appropriate for assessing the growth of corn and beans; and 15°C GDDs are used to assess the growth and development of insects and pests.

Compared to the average Growing Degree Days (Base 15°C) during the 1976-2005 period, GDD (Base 15°C) is projected to increase by 70% during the 2021-2050, and more than double by 2051-2080.



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Precipitation

	1976-2005	2021-2050	2051-2080
Precipitation - annual (mm)	1440	1519	1571
Precipitation - spring (mm)	353	379	394
Precipitation - summer (mm)	291	306	310
Precipitation - fall (mm)	379	390	399
Precipitation - winter (mm)	416	445	468
Max 1-day precipitation (mm)	67	74	79

Precipitation patterns are critical for many important issues, including water availability, crop production, wildfire suppression, snow accumulation, seasonal and flash-flooding, and short- and long-term drought risk.

Very high precipitation totals and/or very high precipitation rates create many challenges. In cities and towns, high precipitation rates overwhelm storm drains and cause flash flooding. They can also cause problems in rural areas by drowning crops, eroding topsoil, and damaging roads. Heavy snowfall events can disrupt ground transportation, and very heavy snowfall events can cause damage to buildings if their roofs become overburdened.

Total annual precipitation and seasonal precipitation is projected to increase in Halifax out to 2050 and 2080, with the largest increases occurring during the spring and winter. Alongside increasing temperatures, specifically during the winter and spring, it is anticipated that more precipitation will fall as rain, not snow, compared to the most recent past, and contribute to earlier or more variable spring runoff.

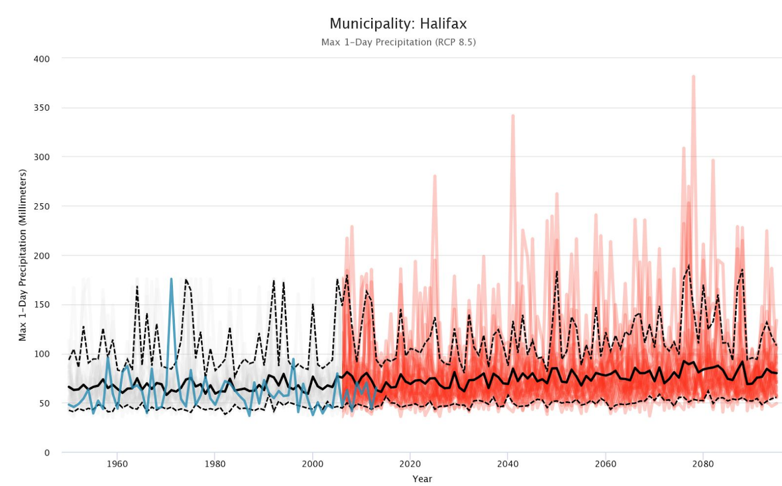
While annual and seasonal precipitation is projected to increase, increasing temperatures in the summer (especially heat waves), along with more variable spring runoff and groundwater recharge patterns are likely to have implications for both the water availability and water demand.

Extended hot periods, combined with extended periods of dry days during the summer increases the likelihood of drought risk. These dry and hot periods are also likely to increase demand for water, putting further strain on water availability.

Additionally, increasing temperatures are likely to increase biological activity in surface waters and decrease available dissolved oxygen in lakes and deeper water; affecting both drinking water quality (and potentially water treatment processes), and overall ecosystem health.

Maximum 1-day precipitation indicates the most precipitation that falls in a single day, and is sometimes also called the "wettest day of the year". This amount could be the result of a short but intense precipitation event such as a storm or because a moderate amount of snow/rain falls continuously all day, rather than all at once.

For Halifax, the average maximum 1-day precipitation is projected to increase by 5mm and 12mm for the 2021-2050 and 2051-2080 periods respectively (Figure 7).



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Extreme events[17]

Climate change is projected to increase the likelihood of extreme events, including extreme heat and extreme precipitation, and other events such as wildfires, storms and flooding that are attributable to changes in the climate system.

Extreme temperature changes, both in observations and future projections, are consistent with warming. Extreme warm temperatures have become hotter, while extreme cold temperatures have become less cold. Such changes are projected to continue in the future, with the magnitude of change proportional to the magnitude of mean temperature change.

For Canada as a whole, observational evidence of changes in extreme precipitation amounts, accumulated over periods of a day or less, is lacking. However, there is high confidence that daily extreme precipitation is projected to increase. The lack of a detectable change in extreme precipitation is not necessarily evidence of a lack of change. On one hand, this is inconsistent with the observed increase in mean precipitation. As the variance of precipitation is proportional to the mean, and as there is a significant increase in mean precipitation, one would expect to see an increase in extreme precipitation. On the other hand, the expected change in response to warming may be small when compared with natural internal variability. Warming has resulted in an increase in atmospheric moisture, which is expected to lead to an increase in extreme precipitation if other conditions, such as atmospheric circulation, do not change.

On the global scale, observations indicate an increase in extreme precipitation associated with warming. The median increase in extreme precipitation is about 7% per 1ºC increase in global mean temperature, consistent with the increase in the water-holding capacity of the atmosphere due to warming.

[17] Bush, E. and Lemmen, D.S., editors (2019): Canada's Changing Climate Report; Government of Canada, Ottawa, ON. https://changingclimate.ca/site/assets/uploads/sites/2/2019/04/CCCR_FULLREPORT-EN-FINAL.pdf

For Canada, extreme precipitation is projected to increase in the future. On average, extreme precipitation with a return period of 20 years in the late century climate is projected to become a once in about 10-year event in 2031–2050 under a high emission scenario (RCP8.5), and an extreme event that currently occurs once in 20 years is projected to become about a once in five-year event by late century. In other words, extreme precipitation of a given magnitude is projected to become more frequent. Moreover, the relative change in event frequency is larger for more extreme and rarer events. For example, an event that currently occurs once in 50 years is projected to occur once in 10 years by late 21st century under a high emission scenario (RCP8.5).

The amount of precipitation with a certain recurrence interval is projected to increase. The amount of 24-hour extreme precipitation that occurs once in 20 years on average is projected to increase by 12% under by 2031–2050, and to increase as much as 25% by 2081–2100 under a high emission scenario (RCP8.5).

Changes in temperature and precipitation each have impacts across many sectors. However, combined changes in temperature and precipitation can have additional impacts, and some sectors rely on information regarding concurrent changes in these two variables. An example is fire weather. Changing precipitation and temperature (along with changing wind) alter the risk of extreme wildfires that can result from hot, dry, and windy conditions. Understanding changes in both temperature and precipitation lends insight into changes in wildfire risk and how it might evolve in the future.

The Canadian Forest Fire Weather Index (FWI) System is a collection of indices that use weather variables, including temperature and precipitation, to characterize fire risk. It includes an index, labelled FWI, that synthesizes information from the collection of indices to quantify day-to-day changes in the risk of a spreading fire. Projected higher temperatures in the future will contribute to increased values of the FWI indices and, therefore, increased fire risk. The increase in precipitation that would be required to offset warming for most of the FWI indices exceeds both projected and reasonable precipitation changes.

The Atlantic region is subject to impacts from a wide range of seasonal and interannual events, including winter cyclonic storms and tropical cyclones. There is evidence of recent trends toward greater extremes and higher frequencies of such events.[18]

The U.S. National Oceanic and Atmospheric Administration (NOAA) funded Geophysical Fluid Dynamics Laboratory (GFDL) at Princeton University indicates that:

- Tropical cyclone rainfall rates will likely increase in the future due to anthropogenic warming and accompanying increase in atmospheric moisture content. Modeling studies on average project an increase in the order of 10-15% for rainfall rates averaged within about 100 km of the storm for a 2 degree Celsius global warming scenario;
- Tropical cyclone intensities globally will likely increase on average (by 1 to 10% according to model projections for a 2 degree Celsius global warming). This change would imply an even larger percentage increase in the destructive potential per storm, assuming no reduction in storm size. Storm size responses to anthropogenic warming are uncertain;
- The global proportion of tropical cyclones that reach very intense (Category 4 and 5) levels will likely increase due to anthropogenic warming over the 21st century. There is less confidence in future projections of the global number of Category 4 and 5 storms, since most modeling studies project a decrease (or little change) in the global frequency of all tropical cyclones combined.[19]

A full list of climate variables and associated projections for Halifax can be found in Appendix A.

[18] Natural Resources Canada. Climate and Climate-related Trends and Projections. https://www.nrcan.gc.ca/environment/resources/publications/impacts-adaptation/reports/assessments/2008/10261

[19] Global Warming and Hurricanes. An Overview of Current Research Results. Summary Statement (2019). Geophysical Fluid Dynamics Laboratory. Princeton University. https://www.gfdl.noaa.gov/global-warming-and-hurricanes/

Hazards, Risk and Impact

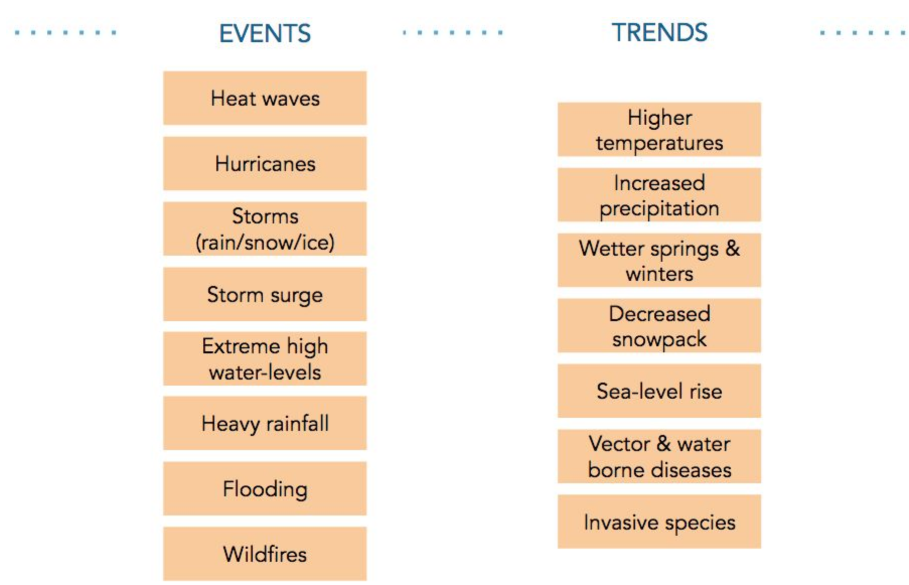
The risk of climate-related impacts results from the interaction of climate-related hazards with the vulnerability and exposure of human and natural systems (Figure 8). Changes in both the climate system (left) and socio-economic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability.

Fhftqd 8. Ckh I `sd Cg`mfd Qhrj `r ` Ftmbshnm ne Utkmdq`ahkhsx, Ewonrtqd, `mc- H`y`qc (ʗOCC).[20]

Hazards

Climate hazards arise from the climate system, and result from natural climate variability as well as change caused by human action. They refer to climate-related physical **events,** such as extreme weather (eg. heat wave or flood), or climate change **trends**, such as increasing temperatures, that result in an impact for natural, built or human systems.

As a result of changes in the climate system, Halifax faces an increase in both the intensity and frequency of several climate-related hazards (Figure 9). These include, amongst others, increased incidences of heatwaves, heavy precipitation events, rising sea levels, changing snow and ice conditions, and changes in streamflow.



Fhftqd 9. Ckh I `sd g`y`qc dudmsr `mc sqdmcr.-

[20] IPCC, 2014.

Relative sea level in different parts of Canada is projected to rise or fall, depending on local vertical land motion. Due to land subsidence, parts of Atlantic Canada are projected to experience relative sea-level change higher than the global average during the coming century.

Where relative sea level is projected to rise (most of the Atlantic and Pacific coasts and the Beaufort coast in the Arctic), the frequency and magnitude of extreme high water-level events will increase. This will result in increased flooding, which is expected to lead to infrastructure and ecosystem damage as well as coastline erosion, putting communities at risk.

Extreme high water-level events are expected to become larger and occur more often in areas where, and in seasons when, there is increased open water along Canada's Arctic and Atlantic coasts, as a result of declining sea ice cover, leading to increased wave action and larger storm surges.[21]

Risk and Impact

These hazards pose risks for people, infrastructure and the built environment, natural systems and resources, economies, livelihoods and safety; this includes health impacts, damage to property, disruption in critical infrastructure systems, business and service interruptions, increasing demand for health and emergency management services, inhibiting mobility and access to services, impacts on water quality and quantity, and impacts for food production and distribution.

The risks and impacts that Halifax faces from a changing climate are include:

- **Physical infrastructure** (buildings, transportation (roads, bridges, railways), energy supply, ICT, water & WW infrastructure etc.):
  - Damage from extreme weather events such as heavy precipitation, hurricanes/high winds, storms, and flooding;
  - Damage to coastal infrastructure & property from inundation, saltwater intrusion, and coastal erosion due to sea-level rise and storm surges;
  - Increased probability of power outages and grid failures;
  - Increasing risk of cascading infrastructure failures.
- **Water supply:**
  - Reduced water quality and quantity (declining or less regular water supply) due to changing precipitation patterns, diminishing snowpack, earlier or more variable spring runoff, increasing temperatures, inundation and saltwater intrusion from sea level rise and storm surge.
- **Food systems:**
  - Risks to agriculture and food systems, including adverse impacts on agricultural crops (decreased crop yield and decreased nutritional quality of crops grown), increased food prices, contaminated water and food supplies, increases in new and existing pests and diseases, and damage and disruption to food supply and distribution infrastructure from extreme events.
- **Ecosystems:**
  - Threats to biodiversity, ecosystem resilience, and the ability of ecosystems to provide a range of benefits to people (such as environmental regulation, provision of natural resources, habitat, and access to culturally important activities and resources).
- **Natural resources industries:**
  - Risks to fisheries and fish stocks, including declining fish stocks and less productive/resilient fisheries due to changing marine and freshwater conditions, ocean acidification, invasive species, and pests;
  - Risks to forestry, including declining forest health and lower production of timber and forest products due to

[21] Bush, E. and Lemmen, D.S., editors (2019): Canada's Changing Climate Report, Chapter 7 Changes in Oceans Surrounding Canada; Government of Canada, Ottawa, ON.

changing weather patterns, increasing frequency of extreme weather events, increasing range of invasive species and/or pests, and growing prevalence of wildfires.

- **Human health and wellbeing:**
  - Adverse impacts on physical and mental health due to hazards such as extreme weather events, heatwaves, lower ambient air quality, and increasing ranges of vector-borne pathogens.

- **Emergency services:**
  - Increased demands on emergency services (full-time and volunteer emergency service personnel and non-government organisations) from extreme weather events, along with decreased recovery times as events happen more frequently and or concurrently.

- **Economy and business:**
  - Risk of financial impacts to businesses and organizations from direct damage or interruptions to assets, operations, supply chain, transport needs, and employee safety;
  - Financial performance may also be affected by changes in water availability, sourcing and quality, and grid reliability.

- **Governance and capacity:**
  - Risks related to the capacity of government to effectively provide public services, manage and respond to climate risks, and maintain the public's trust, including new or increased obligations on government policies, programs, and budgets.

Vulnerability

Climate change will impact us all, but not all people will be affected equally. Certain groups, referred to as climate vulnerable populations, will be disproportionately affected due to their increased exposure and sensitivity to climate risks, or lack of adaptive capacity to deal with the impacts.

Communities that are highly exposed or sensitive to climate risks, or have less capacity to respond to these risks are often referred to as climate vulnerable populations. The table below includes (but is not limited to) those considered to be more vulnerable to climate change in the literature.

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Climate vulnerability as a function of >	**Exposure**	**Sensitivity**	**Adaptive Capacity**
	Ogxrhb`k / fdnfq`oghb~	***Ogxrhb`k / rnbh`k~***	***Rnbh`k / Ebnmn I hb~***
Climate vulnerable populations	- Location (eg. in a hazard area - Poor quality housing/living conditions - Homeless or under-housed - Outdoor occupation	- Elderly - Young children - Persons with pre-existing illnesses/bad health - Persons with disabilities - Pregnant women	- Low Income - Racialized groups - Immigrants & refugees - Person without access to insurance - Homeless or under-housed - Non-english speakers - Aboriginal peoples - Women - Single-headed households - Public housing residents - Undocumented individuals - Socially isolated persons - Residents in neighbourhood improvement areas

While illustrating the variables that contribute to climate vulnerability, the table does however present a static interpretation of these concepts and runs the risk of oversimplifying this complex issue. Exposure, sensitivity, and adaptive capacity are not static, and in many cases are inextricably linked. Income is closely tied with living conditions and occupation, while health is frequently tied to age. Both historic and growing social and economic inequalities, and continued systemic and institutional inequity, are linked to and exacerbate underlying drivers of vulnerability to climate change.

Physical, social and/or structural barriers in accessing services and social supports, and frequent discrimination, directly influences the ability of a person or groups of persons to seek and receive help, in addition to influencing health and income.[22] For example, for racialized groups, structural and institutional racism negatively influence income, living conditions and health, all of which increase vulnerability to climate change.[23]

Similarly, racialized and low income communities are frequently underfunded, which can result in inadequate green space or community resources, increasing exposure to climate impacts.[24]

The intent of this table and analysis is less about classifying these groups according to climate vulnerability, and more about demonstrating the link between climate vulnerability and social equity.

Many groups have both historically faced, and continue to face, barriers and/or discrimination that further influence income, health, living conditions and other factors that contribute to climate vulnerability, inherently increasing vulnerability.

It is also worth noting that across the spectrum of climate vulnerable populations, some will experience climate impacts disproportionately. Those who experience multiple, overlapping factors of vulnerability are more likely to experience disproportionate effects compared with those who may only experience one factor. For example a racialized, low income, non-english speaking, elderly person in bad health, will be significantly more affected compared with someone who is a non-english speaking person, but otherwise in good health and does not face other barriers.

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[22] Swanson, D., & Bhadwal, S. (Eds.), 2009. Creating adaptive policies: A guide for policymaking in an uncertain world. IDRC.

[23] USDN. (2017). Guide to equity, community driven climate preparedness planning. Retrieved from: https://www.usdn.org/uploads/cms/documents/usdn_guide_to_equitable_community-driven_climate_preparedness-_high_res.pdf

[24] Zupancic, T., Westmacott, C., Bulthuis, M. (2015). The impact of green space on heat and air pollution in urban communities: a meta-narrative systematic review. David Suzuki Foundation.

Appendix A: Climate variables and projections for Halifax