Understanding Climate Change and Health Implications:

A Background Report to New Brunswick's Climate Change and Health Vulnerability & Adaptation Assessment Project

Department of Health
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EXECUTIVE SUMMARY

The purpose of this report is to use the evidence base to establish the link between climate change and health in developing the business case for undertaking Climate Change and Health Vulnerability and Adaptation Assessments in New Brunswick. New Brunswick specific tools will be developed to carry out the assessments. These will first be piloted in two communities of the province, one rural and the other urban, and hopefully eventually used in many more communities.

Health is not simply determined by health care and biological factors, but by a broad range of factors called determinants of health. Determinants of health include factors such as income, social supports, social and physical environments, working conditions, among others. Our health is also dependent on ecological determinants of health which implies healthy natural ecosystems and at the most basic level adequate oxygen, water and food. Therefore, climate change poses a serious public health challenge and is not simply an environmental problem. The COVID-19 pandemic has provided a glimpse of how the impending global climate crisis may play out by demonstrating how the environment and ecosystems effect and will continue to affect the health of the population. Most significantly, the collaborative response to COVID-19 has set a precedent for dealing with so-called "wicked problems" in the modern world.

A recent report on Canada's Top Climate Change Risks identified human health and wellness as one of the top six areas of climate change risk facing Canada. Impacts from climate change in Canada include increased severe weather events, higher average temperatures, and rising sea levels which in turn create environments where air and water quality are affected, and biodiversity is altered. These impacts can lead to a wide array of consequences for all populations ranging from injuries, heat-induced illnesses, vector-borne diseases, mental health issues such as anxiety and climate stress, other health problems and even death.

All Canadians are at risk of the health impacts of climate change, but some populations are at higher risk. Vulnerability to climate change is a function of exposure (e.g., heat wave), sensitivity (e.g., elderly person with respiratory conditions), and adaptive capacity (e.g., ability to get to a cooling centre).

In New Brunswick, the population suffers from higher rates of obesity, diabetes, cardiovascular disease, and living with a disability than many other parts of Canada. With 50% of the New Brunswick population living in dispersed rural areas, addressing the health care needs has its challenges, notwithstanding the exacerbating impacts of climate change. For instance, nearly 60% of the provincial population lives within 50 kilometres of the coast, making almost two thirds of the population particularly vulnerable to sea-level rise, one of the key impacts of climate change. The province's population will experience the impacts from climate change in different ways, based on geography (e.g., coastal or inland), urban or rural setting, and personal vulnerabilities to the range of anticipated climate impacts.

New Brunswick's response is to develop a New Brunswick-focused Climate Change and Health Vulnerability and Adaptation Assessment tool kit, which, used throughout the province can then lead to policy changes and program development to help mitigate and adapt to the most pressing health impacts.

Vulnerability and adaptation assessments can identify risk areas based on a wide range of indices to determine how they interact with climate to increase or decrease a community's risk. The ultimate purpose of any climate change and health vulnerability and adaptation assessment is to provide up-to-date information to support health policymakers to take action in order to reduce the

threat posed by climate change and to build climate resilience within communities including resilient health systems.

To determine the best approach for conducting Climate Change Health Vulnerability and Adaptation Assessments (CCHVAA), a scan of the literature was undertaken which concluded that there are many different approaches to determine population vulnerability to climate change used within Canada and around the world. In Canada, there are primarily four frameworks used that specifically focus on climate change vulnerability that includes a health lens. These frameworks include the World Health Organization's Health Impact Assessment (2013), the US-based Building Resilience Against Climate Effects (BRACE) (2014), and Health Canada's Guide to Climate Change and Health Vulnerability and Adaptation Assessments (2019). These frameworks generally followed a similar process that involved 1) framing the approach and establishing baseline health information; 2) establishing current health risks based on climate change projections; 3) identifying and prioritizing adaptation responses; 4) creating an adaptation plan; and 5) implementing the plan and monitoring progress. However, the approaches varied in their details, level of scientific expertise required, and the ease of adopting the tools in a local New Brunswick context. Based on an analysis of approaches and the literature, the following recommendations were made to help move forward on the project: Adapting to Climate Change in New Brunswick: Health Vulnerability and Adaptation Assessments with an Urban and Rural perspective.

Recommendation 1: Utilize the Health Canada Guide to CCHVAA as a starting point in developing the New Brunswick model. The model should also consider unique features of the Ontario Climate Change Health Tool Kit as the tools have been developed and tested in a Canadian rural and urban context.

Recommendation 2: Consider Section 3 of BRACE to establish the health indicators for an evidence-based approach to the study.

Recommendation 3: Work with provincial experts to identify climate change indicators of significance in the New Brunswick context, particularly for the pilot communities identified.

Recommendation 4: Research examples of vulnerability indicators in the literature and adapts them for the New Brunswick context.

Recommendation 5: Develop indicators are developed that can differentiate between urban and rural contexts.

Recommendation 6: Work with provincial and academic experts to identify data sources that are disaggregated to the lowest level possible to determine community-specific climate projections and/or health status for the pilot communities.

Recommendation 7: Consider both bottom-up and top-down methods for gathering data in the development of the New Brunswick vulnerability framework and associated tools.

Recommendation 8: Ensure that data collected reflects local realities within the context of climate change.

Recommendation 9: Develop public engagement and communication strategies with key stakeholders including Public Health, environment, local governments, public works, planning, agriculture, fisheries, local chambers of commerce, etc.

Recommendation 10: Establish selection criteria for the pilot communities based on the definition of vulnerability – including factors related to exposure, sensitivity, and adaptive capacity.

Recommendation 11: Identify gaps in current knowledge related to CCHVAAs and helps direct future research and data collection in the province.

GLOSSARY

Adaptation–The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harming or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects. (1)

Adaptive Capacity – The ability of communities, institutions or people to adjust to potential damage, to take advantage of opportunities, or to respond to consequences of climate change. (2)

Bottom-up approach –Bottom up approaches start with analysis of people affected (vulnerable populations) and work backwards to determine causes and develop strategies to address impacts.

Built environment– The human-made physical surroundings, features, amenities and spaces where we work, live, learn and play that together make and connect our communities.

Climate – The "average weather" in a particular place over a particular time period (typically 30 years). (3)

Climate Change – The average atmospheric conditions that occur over long periods of time. A changing climate refers to changes in long-term averages of daily weather (e.g. precipitation, temperature, humidity, sunshine, wind velocity and other measures of weather). (4)

Climate-sensitive health outcomes - Any health outcomes whose geographical range, incidence or intensity of transmission is directly or indirectly associated with weather or climate. (3)

Exposure – The contacts between a person and one or more biological, psychosocial, chemical, or physical stressors, including stressors affected by climate change. (2)

Health – Is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity. (3)

Impact – Is measured by exposure to hazards and the target's sensitivity to those hazards. In this report, the term is used to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. (1)

Mitigation – The human intervention to reduce the sources (or enhance the sinks) of greenhouse gases. (5)

Resilience – The capacity of social, economic, and environmental systems to cope with a hazardous event, trend, or disturbance, and respond or reorganize in ways that maintain their essential function, identity, and structure while also maintaining the capacity for adaptation, learning, and transformation. (1)

Risk –Risk is often represented as probability of hazardous events or trends to occur multiplied by the impacts if these events or trends. Risk results from the interaction of vulnerability, exposure, and hazard. (1)

Rural – Statistics Canada refers to rural areas having a population concentration of less than 1,000 and a population density of less than 400 per square kilometer based on the previous census. (6)

Sensitivity – The degree to which people or communities are affected, either adversely or beneficially, by climate variability or change. (2)

Social capital– The effective functioning of social groups through interpersonal relationships, a shared sense of identity, a shared understanding, shared norms, shared values, trust, cooperation, and reciprocity.

Top-down approach – [1] Top down approaches start with climate change and impacts and focus on the numbers – often they focus on creating simulation models to project future impacts. This approach is useful for biophysical effects of climate change that can be readily quantified. (7)

Urban – Statistics Canada refers to areas with a population concentration of 1,000 or more and a population density of 400 or more per square kilometer based on the previous census. (6)

Vulnerability – The degree to which a system is susceptible to injury, damage, or harm. Vulnerability is determined by exposure to climate risks, sensitivity to that exposure, and the adaptive capacity of the population to deal with the impacts experienced. (7)

ABBREVIATIONS

CCAP – Climate Change Action Plan
CCVAA – Climate Change Vulnerability and Adaptation Assessments (* does not use a *health lens*)
CCHVAA - Climate Change ***Health*** Vulnerability and Adaptation Assessments
CDC – Centers for Disease Control and Prevention (USA)
EPA – (US) Environmental Protection Agency
IPCC – International Panel on Climate Change
PHAC – Public Health Agency of Canada
UNEP – United Nations Environment Programme
WHO – World Health Organization
WMO – World Meteorological Organization

1.0. INTRODUCTION AND BACKGROUND

Until the current pandemic crisis, climate change was considered an environmental issue - the impacts have been described, analyzed and assessed with an ecological, civil engineering, and economic lens. As a result, damages to buildings, and cost of damage to roads and infrastructure, loss of private property and productivity have generally been the centre of discussion and reports. Using a "human health lens" to analyze the effects of climate change reveals very different impacts. Although it is difficult to determine the exact effects that climate change has had to the public, it is well known that climate change already is having negative effects on human health and well-being and has associated financial costs. Further, it is predicted that climate change will have ripple effects on countries' economies that will impact funding needed to support other governmental programs. Indeed, climate change is said to be one of the greatest threats to human health of the 21st century. (8) "Climate change risks are complex and interconnected, and impacts can propagate through natural and human systems in ways difficult to anticipate." (9)

In its recently released report on Canada's Top Climate Change Risks (2019), the Council of Canadian Academies identified human health and wellness as one of the top six areas of climate change risk facing Canada. "Risks to human health and wellness in Canada, include adverse impacts on physical and mental health due to hazards accompanying extreme weather events, heatwaves, lower ambient air quality, and increasing ranges of vector-borne pathogens." (9) Climate change has recognized implications for the entire world and is a growing concern of New Brunswickers. In New Brunswick, experienced and anticipated increased severe weather events, higher average temperatures, and rising sea levels create environments where air and water quality are affected, and invasive species can thrive. These impacts, in turn, can lead to a wide array of health consequences for all populations such as injuries, heat-induced illnesses, vector-borne diseases, food and water-borne illnesses, and mental health issues such as anxiety and climate stress. Climate change will increase the strain on the New Brunswick health care system, which has implications for its long-term sustainability.

Public Health New Brunswick has embarked on a multi-year initiative to assess health vulnerabilities related to climate change in New Brunswick. Using an evidence-based public health approach, the goal is to enable capacity building at all levels (local, regional and provincial) in New Brunswick to help communities identify, adapt, and respond to the impacts of climate change through the development and refinement of New Brunswick specific Climate Change, Health Vulnerability, and Adaptation Assessment (CCHVAA) tools. The project activities will eventually target the entire province (approximately 750,000 inhabitants) and will benefit from participation of an array of stakeholders including multiple government departments, non-profit entities from the health, emergency response, and environmental fields, as well as municipalities and regional service commissions.

Vulnerability is a significant concept that will be used throughout this report and refers to the degree to which an individual, a community or the health system is susceptible to injury, damage or harm. Vulnerability is determined by exposure to climate risks, sensitivity to that exposure, and the adaptive capacity of the population to deal with the impacts experienced. (7)

1.1. Outline of this Report

This report is intended as a white paper for a multi-year project to develop and test a climate change and health vulnerability and adaptation assessment tool kit in New Brunswick. The document is intended to provide municipalities and communities with information on how climate change affects health and how they can prepare to lessen the impacts. In the following section, evidence is provided to establish associations between

health issues, weather/climate change, province-specific climate change concerns, and the link between climate change impacts and health vulnerability. In the third section of this report, the New Brunswick context is described from both health and climate change perspectives. This then sets the stage for the fourth section, in which an overview of literature is presented regarding existing vulnerability assessment and adaptation approaches that could be used in New Brunswick. This review will include an evaluation of the existing frameworks and an assessment of their applicability to the New Brunswick health context. The final section of this report will provide recommendations for moving forward including which urban and rural areas will be used as pilot studies for the New Brunswick Climate Change and Health Vulnerability Adaptation Assessment tool. This evidence-base will help to inform the remainder of the project and can be used to help increase awareness and manage the impacts to human health and the health system. A separate report describes the criteria the project team developed to select the pilot communities.

2.0. HEALTH AND CLIMATE CHANGE

In past centuries, the dominant health challenge being faced by society was acute short-term illnesses (e.g., communicable or infectious diseases). Now, Canadians are living longer than before but are suffering from chronic longer-term illnesses. Approximately 1 in 5 Canadians live with a major chronic disease such as diabetes, heart disease, and chronic respiratory disease and in the past 10 years, cancer has surpassed heart disease as the leading cause of death. (10) More recently, some of the top health threats worldwide are climate-related adverse effects on health. (11)

As climate change impacts are introduced into the health equation, the entire population is at risk; however, not everyone will be impacted equally. For instance, in many developed regions of North America, the homeless and those who live in precarious housing conditions are amongst the most vulnerable groups associated with new and resurgent disease associated with climate change. (12) Many climatic effects on health can be more severe when sensitivities and vulnerabilities are present. The very young and the very old as well as those with underlying health conditions may experience greater climate-related health risks than the general population. (4) There is also significant evidence to demonstrate that biological and social differences between women and men contribute to differences in their health, as sex (biological attributes) and gender (sociocultural factors) influence our risk of developing certain diseases, how well we respond to medical treatments and how often we seek health care. (29)

2.1. The Determinants of Health

Health is often thought of as the absence of disease; however, the World Health Organization (WHO) defines Health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.” (13). Indeed, health is not simply determined by health care and biological factors, but by a broad range of both individual and collective factors, and their interactions; these factors are referred to as the ‘determinants of health’. The Public Health Agency of Canada has identified twelve key determinants of the health of a population: (14)

Determinants of Health

- Income and Social Status
- Social Support Networks
- Education and Literacy
- Employment / Working Conditions
- Social Environments
- Physical Environments
- Personal Health Practices and Coping Skills
- Healthy Child Development
- Biology and Genetic Endowment
- Health Services
- Gender
- Culture

Health services are but one of the determinants of health and studies have revealed that the influence (25%) they can have to ameliorate health is only one of the various elements relative to the influences of the physical (10%), social, and economic determinants (50%), and biological and genetic factors (15%). (15)

As noted above, the physical environment is one such determinant of health. The physical environment includes where people live (e.g., urban or rural) and the natural environment. Human health and continued existence on the planet are dependent on healthy natural ecosystems and, at the most basic level, adequate oxygen, water, and food. As such, additional determinants of health, known as the "ecological determinants" of health have also been established. (14) It has also become evident that our built environments have a large role to play in determining health outcomes, as they can negatively (or positively) impact/influence several of the ecological determinants. The built environment refers to what surrounds us that is human made - where people live, work, learn and play on a daily basis.

Ecological Determinants of Health

- Oxygen
- Water
- Food
- Fuel and Materials
- Protection from UV Radiation
- Waste Recycling and Detoxification
- Relatively Stable and Livable Climate

If a "relatively stable and livable climate" is one of the key precursors on health and wellbeing, then the impact of climate change will have a dramatic effect on the health of the population around the world. The WHO considers climate change as one of the many determinants of health, where weather conditions and social determinants create variable impacts on communities around the world. (16) Further, climate change can affect population health through climate-induced economic dislocation and environmental decline, and through development setbacks incurred by damage to critical public health infrastructure. (16) Indeed, research shows that "making the link between climate change and physical and mental health is important because…climate change affects the environmental and social determinants of health and can undermine provincial strategies to improve well-being." (17)

2.2. What Is Climate Change?

Climate change is now widely recognized to be anthropogenic (human-caused) as opposed to a normal process in the geological and biotic evolution of the Earth. (13). Global warming, attributed largely to increased levels of atmospheric carbon dioxide produced by humans' use of fossil fuels, causes changes in weather patterns. Over the long-term, these changes can affect the regional and global climate pattern. Since 1988, the Intergovernmental Panel on Climate Change (IPCC)[1] has been the key source of information on the science of climate change. Scientists who participate in the IPCC have published widely on the vulnerability to and effects of climate change, and the strategies to mitigate greenhouse gases and adapt to global warming. According to the findings of the IPCC's latest report[2] published in 2014:

- Warming of the climate system in unequivocal and unprecedented;
- Each of the last 3 decades has been successively warmer than any preceding decade since 1850;
- Ocean warming is happening, particularly in the upper ocean;
- Greenland and Antarctic ice sheets have been losing mass and shrinking at unprecedented rates;
- Mean sea-level rise has been increasing faster than any time in the previous 2000 years;
- Atmospheric concentrations of Carbon Dioxide (CO_2) are unprecedented in the last 800,000 years;
- Human influence on the climate system is clear. (18)

These changes to the climate have significant implications in Canada where warming is anticipated to occur twice as fast as the global average. (19) According to the 2019 Canadian Climate Change Report, the implications of climate change in Canada include:

- Oceans surrounding Canada have warmed, become more acidic, and are less oxygenated.
- Effects of widespread warming are evident and will continue, such as extreme heat, less extreme cold, longer growing seasons, shorter snow and ice cover seasons, earlier spring peak streamflow, thinning glaciers, thawing permafrost, and rising sea levels.
- Precipitation is projected to increase for most of Canada, on average, although summer rainfall may decrease in some areas.
- The seasonal availability of freshwater is changing, with an increased risk of water supply shortages in the summer.
- A warmer climate will intensify some weather extremes in the future (heat waves, rain fall, etc.).
- Canadian areas of the Arctic and Atlantic Oceans have experienced longer and more widespread sea-ice-free conditions.
- Coastal flooding is expected to increase in many areas of Canada due to local sea level rise.

[1] The Intergovernmental Panel on Climate Change is the United Nations scientific body for assessing the science related to climate change made up of approximately 195 climate scientists from around the world. https://www.ipcc.ch/

[2] The 5th report of the IPCC was published in 2014. The 6th report is due to be released in 2021.

Further, these impacts will not be felt even across the country, with more extremes being experienced in the far north, and coastal provinces experiencing variations of these impacts. (19)

2.3. Variation of Climate Change Exposure and Impacts

2.3.1. Temporal Variations

Climate change has been linked to the increasing concentration of greenhouse gasses such as carbon dioxide emissions in the atmosphere as a result of human activity. (20) The concentration of greenhouse gasses will largely determine the magnitude of the change over the next century. (19 p.79) The IPCC and the broader scientific community have created a range of models to predict global temperature increases and sea-level rise, based on scenarios of the future related to greenhouse emissions. These future scenarios are based on assumptions about human activities such as the use of fossil fuels and land use patterns. The models represent a range of scenarios from whether humans continue with the status quo (which is equivalent to an extremely high emissions model), or whether there will be aggressive reduction and /or elimination of greenhouse gas emissions (a low-emission model) in the future. These high emissions and low emissions scenarios are used to predict temperature increases around the planet, which in turn, create models for sea ice melt and sea-level rise, among other factors.

The rate and magnitude of climate change under high versus low emission scenarios project two very different futures for Canada. Scenarios with large and rapid warming illustrate profound effects on Canadian climate. Scenarios with limited warming will only occur if Canada and the rest of the world reduce carbon emissions to near zero early in the second half of the century and reduce emissions of other greenhouse gases substantially. Emission models or projections based on a range of emission scenarios are needed to inform impact assessment, climate risk management, and policy development. (19 p. iv)

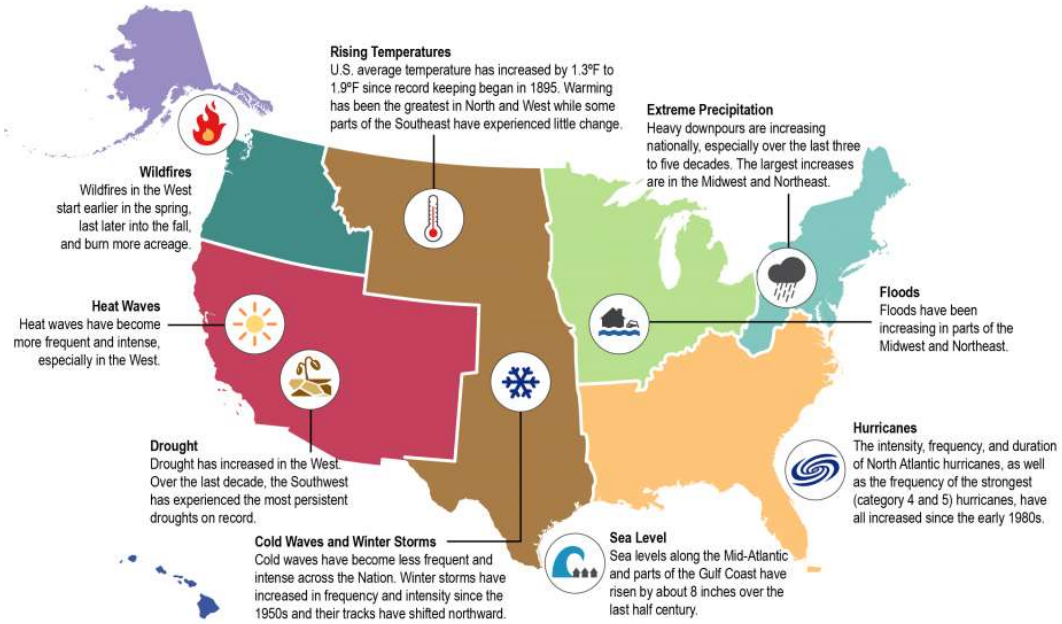
In different emissions models, the projections for temperature and precipitation change over time. In the short-term, impacts in some local communities such as flood events or extreme heat waves appear as anomalies which have rarely been experienced. Climate models illustrate how the frequency of these events will increase dramatically from the present to 2100. This concept will be explored more thoroughly in Section 3 when we consider the climate projections for New Brunswick-specific communities.

2.3.2. Geographic Variation

There is little dispute among scientists that climate change is a worldwide phenomenon. While increasing greenhouse gas emissions cause a rise in temperature, the effects of this temperature increase will have differing impacts on countries and communities depending on their location and other geographic factors (such as terrain, proximity to water bodies, etc.). Figure 1 shows the range of climate-related impacts based on general areas within the continental USA. Although the illustration is somewhat simplified, it illustrates how inland areas will experience higher temperatures and the possibility of heat waves; drought already being experienced in California is expected to increase in frequency; hurricanes on the east coast have already increased in magnitude and frequency; sea-level rise will affect all coastal areas; and heat waves and cold snaps will affect various parts

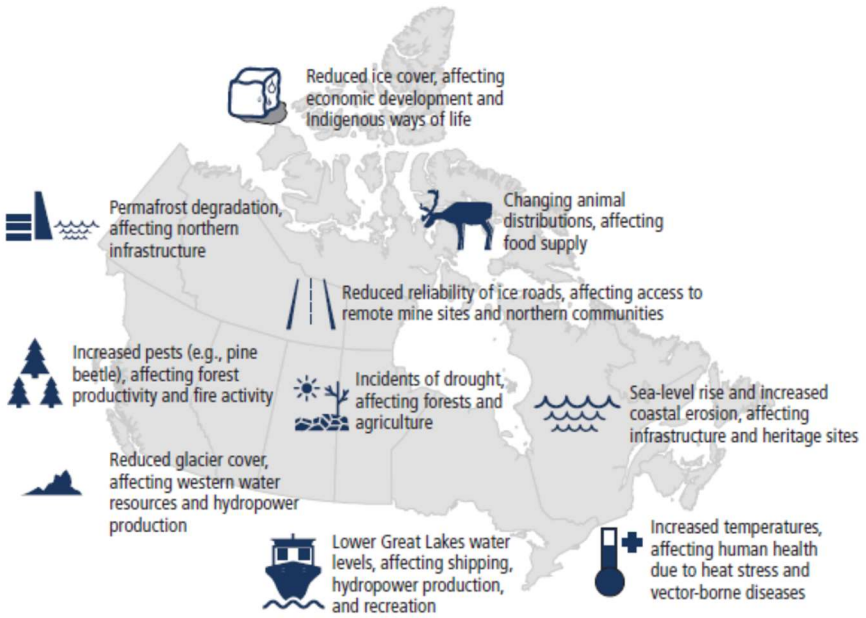
of the country. Importantly, this is not to say that these impacts will be limited to those regions identified above, but that they will be prevalent in those locations in the coming decades.

Figure 1: Major US national and regional climate trends (21)



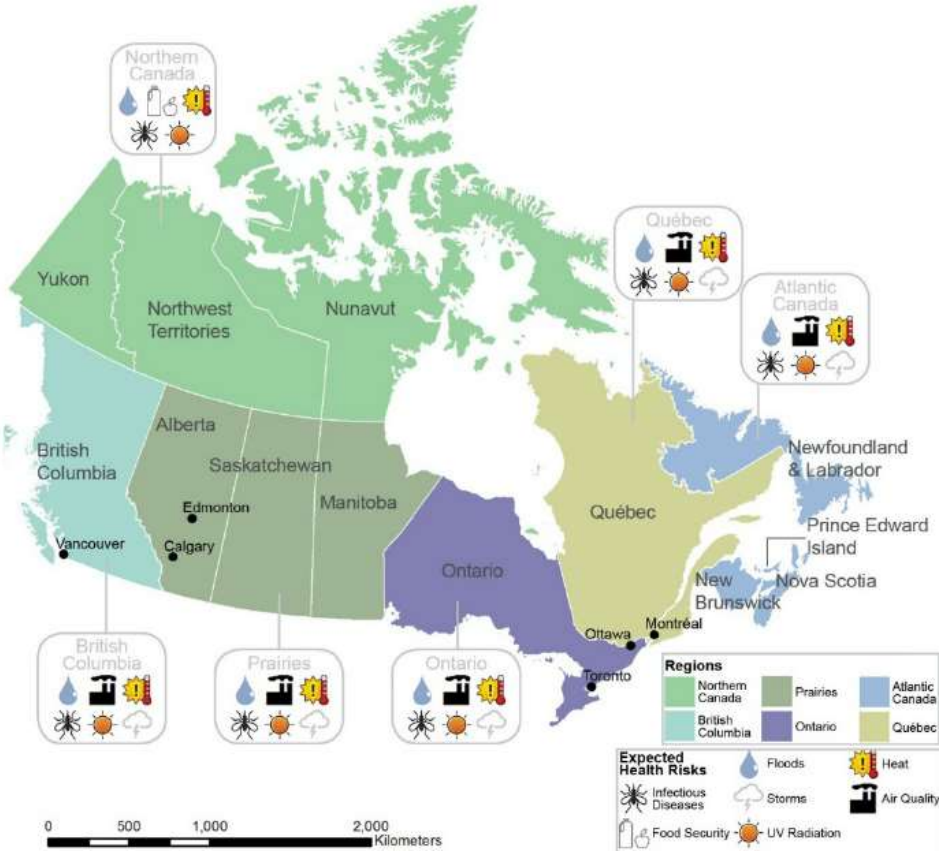
Canada will, generally, experience similar negative impacts to those described above as illustrated in Figure 2.

Figure 2: Negative climate change impacts and regional climate trends (Canada's Top climate Change Risks)



Changing precipitation patterns and increases in annual average surface temperatures over the country's land mass are already being experienced and will continue to change in coming decades. As illustrated in Figure 3, these impacts include flooding, infectious diseases, heat, air quality, UV radiation, and food security. (22) The increase in temperature in Canada – at almost twice the rate of the global average - has the added impact in the north of a loss of permafrost and sea ice which creates added complications for coastal and northern communities. (19)

Figure 3: Expected health risks posed by climate change by region in Canada (22)



2.3.3. Urban and Rural Differences

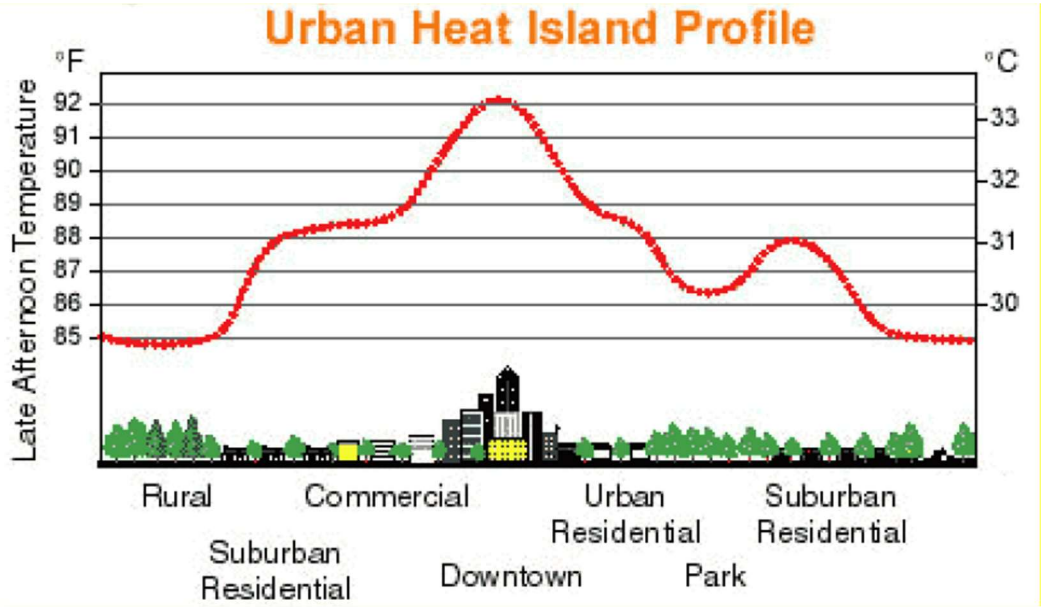
Climate impacts will also be experienced differently between urban and rural areas of the world.

Many of the sources of global problems such as climate change, pollution, crime, disease, and poverty originate from or are exacerbated by human activities concentrated within urban areas. (23) Research indicates that urbanization and climate change may increase disease burdens. For example, people living in high-density urban areas with poor housing are more susceptible to the increased frequency and intensity of climate-related hazards such as heat waves. This impact can further be exacerbated by the interaction between increasing heat and urban heat island effect. (3) The urban heat island effect happens when closely packed buildings and paved surfaces trap and intensify heat. In addition, cities also generate their own heat, which is released from sources such as furnaces, air conditioners,

and vehicles. (24) This is compared to natural ecosystems and rural areas, which are often shaded by trees and vegetation and cooled by evaporating moisture. Indeed, large cities can be as much as 12^{O}C warmer than their surrounding environments in the evening. (24)

Urban and suburban areas tend to have higher surface and near-surface air temperatures than surrounding rural areas, as shown in Figure 4. (25) The continued expansion of urban and suburban areas is resulting in more and larger areas with intense heat islands effects.

Figure 4: Urban Heat Island Profile (25)



Furthermore, flooding risk in urban centres is substantially increased because the increase intensity of storm events means that all that additional rainwater has nowhere to go because of the impervious surfaces (streets, buildings). This may result in stormwater backing up into sewer systems, covering streets, and filling basements. Air quality concerns could be exacerbated with climate change. Urban areas in general already have poorer air quality with only 12% of cities worldwide meeting the WHO air pollution guidelines. Many urban centres suffer from levels of pollutants as much as 10 times more damaging than recommended. (26)

This is contrasted with rural areas which have significantly fewer concerns with heat islands and stormwater run-off but may be more susceptible to other impacts including socio-economic implications of an unpredictable climate. Rural populations are generally located in areas that are highly vegetated and often near watercourses (river, streams, or coasts). As such, rural communities are more vulnerable to increased health risk from potential private well water contamination, vector-borne diseases, wildfires, and floods. Rural populations and regions may face changes in optimum crop-growing, decreased yields, reduced water resources, and loss of property and fields due to flooding, droughts and sea level rise. (3) Rural health is also at risk because of the manner in which climate change impacts the social determinants of health, such as access to services or basic necessities in times of a

storm event, access to public services, fewer options for employment, access to food, and dependence on resource-based economies that may be directly impacted by climate change.

Keeping in mind that some impacts, like for example suboptimum crop-growing, to rural areas will also affect, often indirectly, urban centres and vice versa it is difficult to anticipate the exact effects of climate change. Individual sensitivities to climate change may also diverge between urban and rural populations. On the other hand, protective factors may reduce vulnerabilities such as good social capital but these have not been studied as much yet. Table 1 below, summarizes some of the rural and urban characteristics that can exacerbate or attenuate climate change impacts on vulnerable populations.

Table 1: Urban and Rural Characteristics that Increase Vulnerability to Climate Change and Climate-Related Impacts (27)

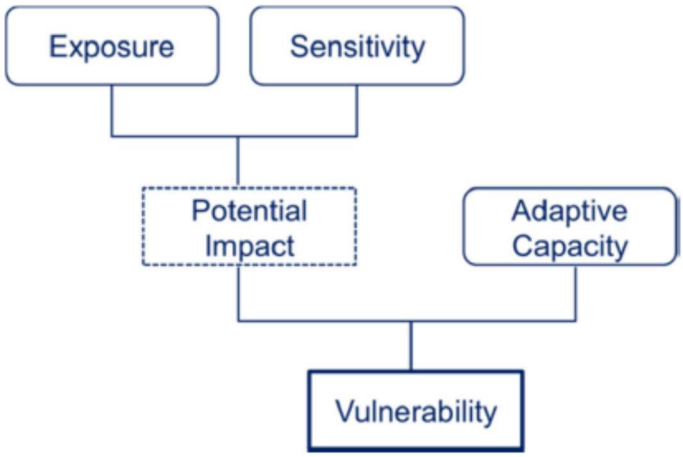
KEY VULNERABILITY FACTORS	EXAMPLES OF URBAN CHARACTERISTICS	EXAMPLES OF RURAL CHARACTERISTICS
Exposure • **Geography** • **Land use** • **Climate**	Complex infrastructure, high density buildings, and landscape dominated by impervious surfaces Higher population density Higher air pollution levels	Increase health risks from water contamination due to a high reliance on small drinking water systems More people employed in outdoor occupations Higher risk of exposure to land shifts, wildfires, vector-borne diseases, and floods
Individual sensitivity • **Age and gender** • **Health status**	Ageing population Cardiovascular and respiratory conditions in large urban centers from air pollution and extreme heat	High elderly population and high incidence of chronic illnesses, smoking, and obesity
Key adaptive capacity factors • **Socioeconomic status** • **Public services and risk communication programs** • **Employment**	Greater prevalence of high risk population groups, with limited adaptive capacity (e.g. low socioeconomic status) Higher prevalence of social isolation and limited access to services (e.g. immigrants, First Nations, homeless, or persons of low income or with mental illnesses) High reliance on critical infrastructure for health care and emergency service provision that are vulnerable to extreme weather	Limited access to services during extreme events (e.g. power, water, food, medical) Limited availability and accessibility of public services and programs and communication venues to deliver health and emergency messages High dependency on natural resources that are vulnerable to disruption from extreme weather Lower proportion of population highly educated Limited livelihood opportunities and economic diversification Limited resources and services to respond to extreme weather events and associated health burdens Limited service access to remote communities

2.3.4. Vulnerability to climate change

All Canadians are at risk of the health impacts of climate change; however, some populations are at higher risk. (27) As with temporal, geographic and rural/urban variations in climate-related impacts, some human populations and regions are more vulnerable to climatic exposures based on their social, economic, and environmental contexts. The most vulnerable populations to climate change include those who are elderly and very young; socially and economically disadvantaged; chronically ill; and socially Isolated.

Research on all the possible health consequences of climate change impacts is far-reaching and yet highly incomplete. A study in New York City focusing on heat-related illnesses considered individual factors such as gender, race/ethnicity and age as well as other factors such as built space, green space, public assistance, temperature, traffic density, and predominant language. The purpose of the study was to identify direct and indirect causes of unexpected deaths over a 10-year period. The study found that the most vulnerable were those who were considered socially isolated, living in a highly urbanized environment with few green spaces and trees, and in low socio-economic situations. (28) Another study conducted in the United States on maternal heat exposure during early pregnancy has been found to result in a higher rate of congenital heart defects of newborns. (29)

Figure 5: Establishing Vulnerability to Climate Change Effects (30)



Focusing specifically on the concept of vulnerability, Figure 5 illustrates how vulnerability is determined by exposure, sensitivity and adaptive capacity. Climate-related exposures include extreme temperatures (high or cold), extreme weather events (with various intensities and increasing frequency). Sensitivity includes both the individual susceptibility (intrinsic biological factors that can increase the health risk) as well as socio-environmental factors such as living conditions, poverty, and mental illness. (31) Adaptive capacity is the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences of climate change. (1)

The World Health Organization identified vulnerable populations based on factors like; demographic, health status, culture or life conditions; access to adequate resources, services or sociopolitical conditions, as illustrated in Table 2.

Table 2: World-wide categories of Vulnerability to Climate-sensitive Health Outcomes (3)

Vulnerability based on	Vulnerable population	Vulnerability based on	Factors affecting vulnerability
Demographic factors:	Proportion of children Proportion of women Proportion of elderly people Population density	limited access to adequate resources or services:	Unplanned urban housing Flood or drought risk zones Coastal storm and cyclone risk zones Water-stressed zones Food-insecure zones Urban-rural-remote areas
Health status:	Populations with HIV/AIDs and those who are immunocompromised Populations with tuberculosis Undernourished populations Populations with infectious disease burden Populations with chronic disease burden Mentally or physically disabled populations	limited access to adequate:	Health care Potable water Shelter Employment Education Economic Opportunities
Culture or life conditions:	Impoverished Nomadic or semi-nomadic Subsistence farmers and fisherfolk Displaced populations Ethnic minorities Indentured labourers	sociopolitical conditions:	Political stability Existence of complex emergencies or conflicts Freedom of speech and information Types of civil rights and civil society

Some populations are more susceptible to certain health conditions, as a result of differences in both exposures and sensitivity. Examples of the most important relationships are shown below in Table 3. (3)

Table 3: Vulnerability to climate-sensitive health outcomes by subpopulation (3)

Groups with increased vulnerability	Climate-related vulnerabilities
Infants and children	Heat stress, air pollution, waterborne/foodborne diseases, vector-borne diseases, malnutrition
Pregnant women	Heat stress, extreme weather events, waterborne/foodborne diseases, vector-borne diseases

Elderly people and people with chronic medical conditions	Heat stress, air pollution, extreme weather events, waterborne/foodborne diseases, vector-borne diseases
Impoverished/low socioeconomic status	Heat stress, air pollution, extreme weather events, waterborne/foodborne diseases, vector-borne diseases
Outdoor workers	Heat stress, air pollution, vector-borne diseases, ultraviolet light (UV) exposure

Similarly, Perrota (32) provided examples of climate-related inequity multipliers (i.e., those factors that exacerbate inequities or create unintended consequences related to different social determinants as illustrated in Table 4).

Table 4: Examples of how climate change may amplify existing health inequities and increase climate-related health risks for vulnerable populations (32 p.17)

Health inequity	**Examples of climate-related inequity multipliers**
Income and social status	• Increased risk from extreme heat, air pollution, UV exposure and extreme weather events • Limited financial resources/ability to take adequate protective action (e.g., seek shade, access cool spaces, afford air conditioning, make needed repairs to housing, and avoid sources of air pollution, such as high-traffic corridors.
Food security	• Increased risk of food insecurity due to extreme weather events such as droughts, heavy rainfall and flooding that damage or destroy food crops, leading to increased cost of healthy foods.
Employment and working conditions	• Increased exposure to extreme heat, air pollution, UV radiation and extreme weather events for outdoor workers (e.g., agriculture, forestry, landscaping/snow management, utility workers, construction, fire fighters and other first responders)
Housing and homelessness	• Increased risk from extreme heat and extreme cold for people who are homeless or living in housing with inadequate heating or cooling • Increased risk of damage from flooding and storms if living in home in need of major repair or living in flood-prone areas • Increased risk of poor indoor and outdoor air quality if living close to sources of air pollution
Children and persons with mental or physical challenges	• Higher sensitivity to extreme heat, air pollution • Increased risk from extreme weather events due to lower mobility and higher reliance on caregivers • Increased risk from mental health following disasters and extreme weather events
Indigenous people	• Exacerbated existing inequities (e.g., access to traditional cultural practices, access to safe water, access to health care) • Increased risk food insecurity due to general warming and lower availability/access to traditional food sources
Health status	• Increased risk from extreme heat, air pollution, infectious diseases, and extreme weather events for persons who are immunocompromised or living with chronic diseases or disabilities.
Access to health services	• Increased risk for northern, remote and low-income communities that currently experience inequities in terms of access to health care • Increased risk from extreme weather events as health, community and social supports may be disrupted by evacuations, population displacement and damage to critical infrastructure (e.g., hospitals, water, wastewater and transportation systems)

Health inequity	Examples of climate-related inequity multipliers
Social support networks	• Persons who are marginalized or socially isolated are more vulnerable to extreme heat and extreme weather events
Personal behaviours and coping skills	• Increased risk from extreme weather events, extreme heat and climate variability and change • While the general population is vulnerable to climate-related stress and distress, risks are amplified for persons with existing mental health conditions

As illustrated above, there are significant challenges to assessing the vulnerability of a population's health.

2.3.5. Combination of factors

Figure 6: Framework of the Risks of Climate Variability and Change (20)

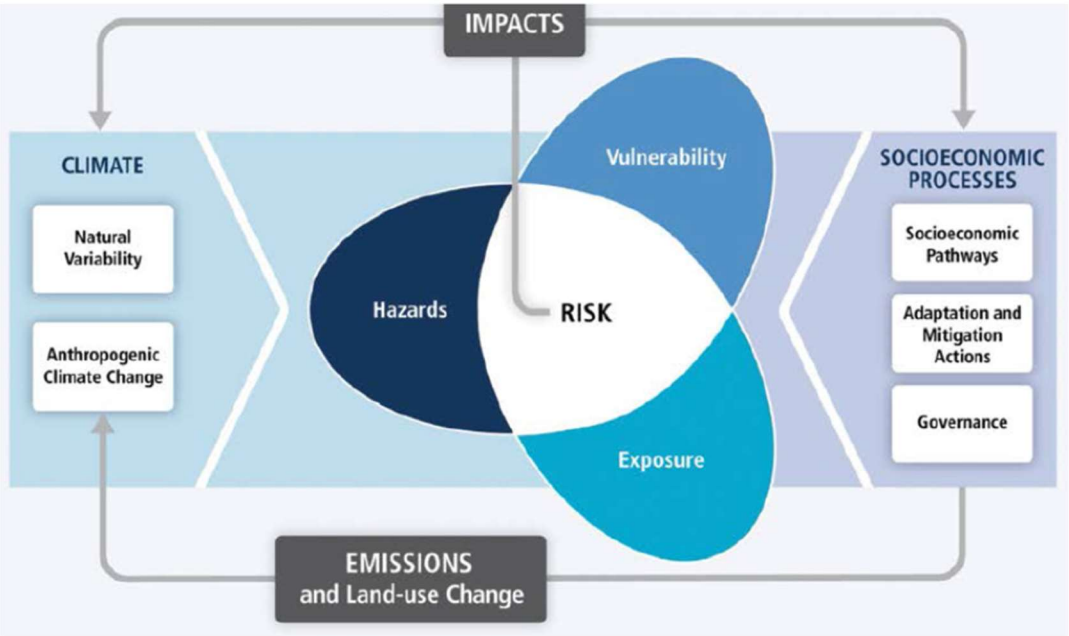


Figure 6 above, illustrates that climate change does not have linear implications and that the impacts are felt through a variety of processes – not just environmental. Risk to various climate change impacts is the result of a combination of factors including the actual hazard (e.g., a hurricane), the amount of exposure a population has (strength of the hurricane) and its overall sensitivity to that impact (e.g., community built in a flood-prone area). Socioeconomic pathways, governance policies and adaptation and mitigation actions all have an effect on emissions, the climate response and impacts faced by communities.

2.4. How Climate Change Affects Health

2.4.1. Introduction

A Task Group from IPCC published the first detailed assessment of climate change and human health in 1996. The report concluded that, "climate change, by altering local weather patterns and by disturbing life-supporting natural systems and processes, would affect the health of human populations. The range of health effects

would be diverse, often unpredictable in magnitude, and sometimes slow to emerge." (33) Even in this early report, climate change impact scenarios predicted:

- By 2050, major cities could experience up to several thousand extra heat-related deaths annually;
- By 2100, the proportion of the world's population living in potential malaria transmission zones would be increased substantially;
- Potential impacts on food productivity would be significant, with shifts in soil moisture, patterns of plants, pests and diseases, and ocean temperature impacts on aquatic productivity severely impacted;
- Health effects of extreme weather events (heat waves, floods, droughts, etc.) include event-related injuries, illness and mortality, but also increased the incidence of psychological and social disorders; and
- The potential health effects of increased exposure to ultraviolet radiation leads to increases in skin cancer, eye cataracts, and suppressed immune system functions.

Since that early publication in 1996, there have been a multitude of studies conducted to consider the possible long-term health impacts resulting from climate change. Generally, it is felt that most of the impacts of climate change will result from amplifying the existing health hazards already found in populations. (34) Indeed, the World Health Organization (WHO) has stated that "climate change is the greatest challenge of the 21st century, threatening all aspects of society in which we live." (35)

2.4.2. Physical and Mental Health Effects of Climate-Related Impacts

There are several health effects that can be attributable to climate change impacts. Health effects include such things as:

- Vector, water and food-borne diseases;
- Zoonotic diseases
- Illnesses related to extreme cold and heat events;
- Exacerbation of respiratory and cardiovascular illnesses;
- Neurological diseases and disorders from exposure to hazardous chemicals (air pollution and water contamination);
- Physical injuries directly related to a weather event;
- Heart attacks, strokes and cancer;
- Death

Existing health conditions can also be exacerbated by weather-related events in the short-term.

In addition, research suggests that mental health repercussions of climate change impacts add another layer of uncertainty in modelling future population health. Hayes and Poland described the situation as follows:

"Notable direct climate-related hazards that affect mental health include extreme heat, extreme weather events, and morbidity associated with vector-borne disease (VBD). Extreme heat has been shown to increase mood and behavioural disorders amongst people with pre-existing mental illness and the elderly who have poor thermoregulation. Extreme weather events, like flooding, hurricanes, and wildfires have been linked to depression, anxiety, post-traumatic stress disorder (PTSD),

suicidal ideation, substance abuse, vicarious trauma, loss of identity and a loss of a sense of place, relationship strain, and helplessness. Vector-borne diseases like West Nile Virus and Lyme disease may compound mental health issues for people with pre-existing mental health illness by contributing to cognitive, neurological, and mental health problems. At the community level, climate change-related drought and sea-level rise can threaten natural resources, placing strain on communities, resulting in displacement, violence, and crime. Further, a loss of land-based activities and occupations, due to a changing climate, can affect personal and community socioeconomic status leading to social and economic instability, loss of the community, and a disrupted sense of belonging. This is particularly evidenced in the north where climate changes are more pronounced, and their impacts felt more keenly by those living on the land." (36)

In fact, the research reviewed by Hayes and Poland indicates that mental health effects from any form of disaster far exceed the physical health implications. Further, the multicausal pathway linking climate change to mental health indicates that there are a number of direct (e.g., extreme weather), indirect (e.g., economic loss due to drought or displacement due to sea-level rise), and overarching (awareness of the climate change problem) pathways from which mental health may be affected by climate change, suggesting there are in fact numerous climate-related indicators affecting mental health. (36)

This complicated relationship is depicted below in Figure 6 which shows how climate change-related disasters often affect communities, physical health, and mental health via multiple channels. There are subsequent interactions among adverse impacts on communities, physical health, and mental health that can exacerbate these impacts.

Figure 7: Risks to Human Health and Wellness (9 p. 21)

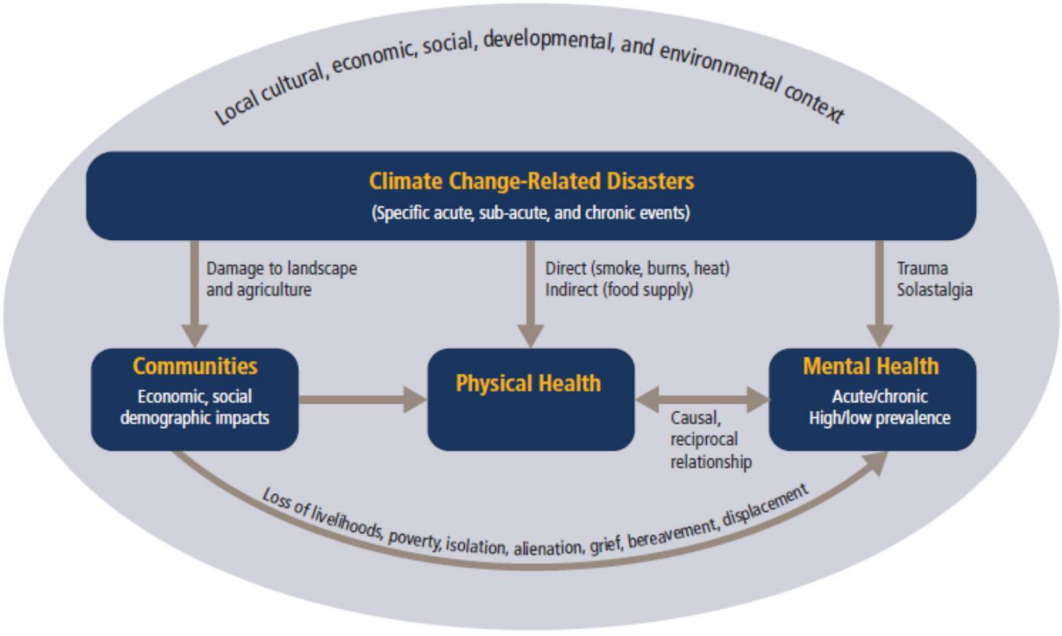
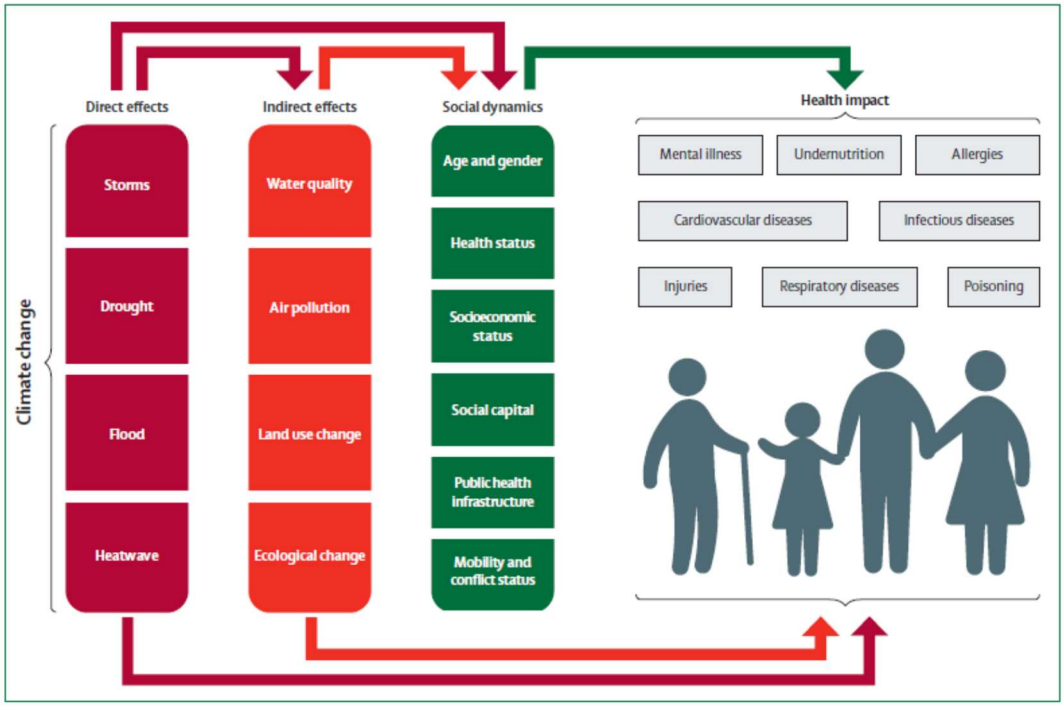


Figure 7 also introduces the concept of solastalgia, which “refers to any context where place identity is challenged by pervasive change to the existing order.” (37) For example, in the context of climate change, solastalgia is experienced by indigenous communities who, for generations have lived off land that is experiencing exceptional change in a short period of time. This is the case =for Indian Island First Nation in eastern New Brunswick, which has lost a significant amount of its land base through coastal erosion and sea level rise. Solastalgia, coined in 2007, is a new concept reflecting the recent trends in terms of physical upheaval around the world, often associated with climate change and global warming. New Brunswick is not immune to this concept or to the impacts of climate change.

2.4.3. The ″Climate Change, Environmental Effects and Health Impact″ Cascade

As shown in Figure 8 below, climate change has both indirect and direct effects that impact health and wellbeing. These risks can be modified by vulnerability factors as represented by the third pillar in the figure. There are complex interactions between both causes and effects. Ecological processes, such as impacts on biodiversity and changes in disease vectors, and social dynamics, can amplify these risks. (36)

Figure 8: The direct and indirect effects of climate change on health and wellbeing (38 p.1867)



More recently, Perrota (32) illustrated how various climate change drivers - such as rising temperatures, changes in precipitation, and extreme weather events – can create environmental effects such as the formation of air pollution, increased exposure to forest fires, and increased conditions to vector propagation. These environmental effects may lead to exposure to hazards such as extreme heat, UV radiation or infected mosquitos which then lead to twelve identifiable human health outcomes including cardiovascular disease, respiratory conditions, allergic reactions, and mental health stress and anxiety. Table 5 below summarizes the adverse health

outcomes that are associated with climate change and provide some examples of these causal pathways of relevance in Canada.

Table 5: Examples of climate-related health impacts and causal pathways of relevance in Canada. (32 p. 2)

←	←	←
HEALTH OUTCOME	**HAZARD/ EXPOSURE**	**ENVIRONMENTAL EFFECT**	**CLIMATE CHANGE DRIVER**
Cardiovascular Disease	Air pollutants	↑ formation of air pollutants ↑ forest fires ↑ droughts and dust storms	Rising temperatures Extreme weather events Changes in precipitation
	Extreme heat	↑ frequency and duration of heat waves	Rising temperatures Extreme weather events
Respiratory Conditions	Air pollutants	↑ formation of air pollutants ↑ forest fires ↑ droughts and dust storms	Rising temperatures Extreme weather events Changes in precipitation
	Extreme heat	Heat waves – hot days & warm nights	Rising temperatures Extreme weather events
Allergic Reactions	Pollen & spores	Longer growing season	Rising temperatures
	Mould	Heavy rainfall & flooding	Extreme weather events
Heat stroke/ exhaustion	Extreme heat	↑ frequency and duration of heat waves	Rising temperatures Extreme weather events
Cancer	Air pollutants	↑ formation of air pollutants	Rising temperatures
	UV radiation	Ozone layer depletion Longer summer season	Temp.-related changes Rising temperatures
Traumatic Injuries	Physical trauma, dangerous travel, drowning, violence	Floods, forest fires, tornadoes, hurricanes, storm surges, winter storms, melting permafrost	Extreme weather events Rising temperatures Sea level rise
Vector-borne Diseases	Infected mosquitoes, ticks and rodents	Expanding habitat conducive to disease vectors ↑ conditions for vector propagation	Rising temperatures Extreme weather events Changes in precipitation
Food-borne Illness	Food-borne pathogens/toxins	Contaminated food/flood waters ↑ conditions for bacterial growth	Extreme weather events Rising temperatures
Water-borne Illness	Water-borne pathogens/toxins	Contaminated water sources ↑ conditions for bacterial growth	Extreme weather events Changes in precipitation
Malnutrition	Food insecurity Water shortages	Drought, crop loss, biodiversity loss Floods	Rising temperatures Extreme weather events
Mental Health Stress & Anxiety	Population displacement Multiple stressors Climate-induced stress	Floods, forest fires, tornadoes, droughts, heat waves Prolonged and repeated climate-related events Catastrophic events	Rising temperatures Extreme weather events Sea level rise Changes in precipitation
Socio-economic impacts	Social disruptions Loss of incomes and culture ↓ quality of life	Floods, forest fires, tornadoes, droughts, heat waves Prolonged climate-related events Catastrophic events	Rising temperatures Extreme weather events

It has been reported that “these changes in climate create, and will continue to induce, a wide variety of environmental changes that can have consequences for human health. For example, higher atmospheric temperatures increase ground-level ozone, creating more smog and air pollution. Changes in rainfall and temperature can alter the distribution of disease-carrying vectors such as ticks and mosquitos.

Drought, extreme heat, wildfire, and severe precipitation events can damage crops and agricultural land leading to food insecurity and malnutrition. All of these changes have social, political, and economic implications, such as increases in food and water prices, increased medical costs, job loss, forced displacement and mass population migration." (17)

2.4.4. The COVID-19 Pandemic, A Current Example of the Effects of Climate Change On Population Health

While the focus of the NB HealthADAPT project and this report are on health impacts specifically related to climate change, significant knowledge has been gained regarding our response to and understanding of global health impacts related to COVID-19. Indeed, the parallels between the impacts of climate change and the global pandemic on vulnerable populations has been broadly recognized.

The pandemic has widely recognized economic impacts globally and locally, affecting New Brunswickers through changes in business practices, employment loss, and industry upheaval. Socially, people have been forced to change their routines and have been more isolated from the community than ever before. From an environmental standpoint, various ecological factors such as habitat destruction, biodiversity degradation, deforestation, intensive agriculture and overexploitation of resources have facilitated rapid transmission of the virus. (40)(39) A recent Canadian publication attests to the fact that the COVID-19 pandemic, in addition to creating additional vulnerabilities within communities, brings its own challenges in building capacity and resilience. (39) In order to cope with future crises, it will therefore be imperative to implement integrated strategies that include ecological, social, economic and health dimensions. (39) Researchers conclude that although the COVID-19 crisis differs in some respects from the climate crisis, notably in the speed at which it is developing, pandemic preparedness and climate adaptation have similarities in terms of community strengthening and community sustainability and resilience. (39) (41)

Finally, authors suggest that the experience gained so far in the global management of COVID-19 and the recommendations of international experts, such as the World Health Organization (WHO), provide substantial lessons on adaptive responses to climate from a public health perspective. (42) Five avenues for proactive action to protect the population emerge from these lessons: (42) (43) the first is to strengthen the governance model by clearly defining the responsibility between actors. The second is to rely on targeted information and communication strategies that are frequently updated on health and emerging practices. The third is to improve basic health services and include citizen volunteers to better prepare communities. Fourth, address broader determinants and the full concept of well-being: physical, mental, social, economic and financial. The fifth and final one is to develop the skills necessary for adaptability and leadership in public health.

Most significantly, the collaborative response to COVID-19 has set a precedent for dealing with so-called "wicked problems"[3] in the modern world. The global response

[3] "Wicked problems" are social, cultural or environmental problems that are difficult or impossible to solve because of incomplete, contradictory, and changing requirements as well as the economic burden and interconnected nature of these problems with other problems. Climate change is often described as one such "wicked problem."

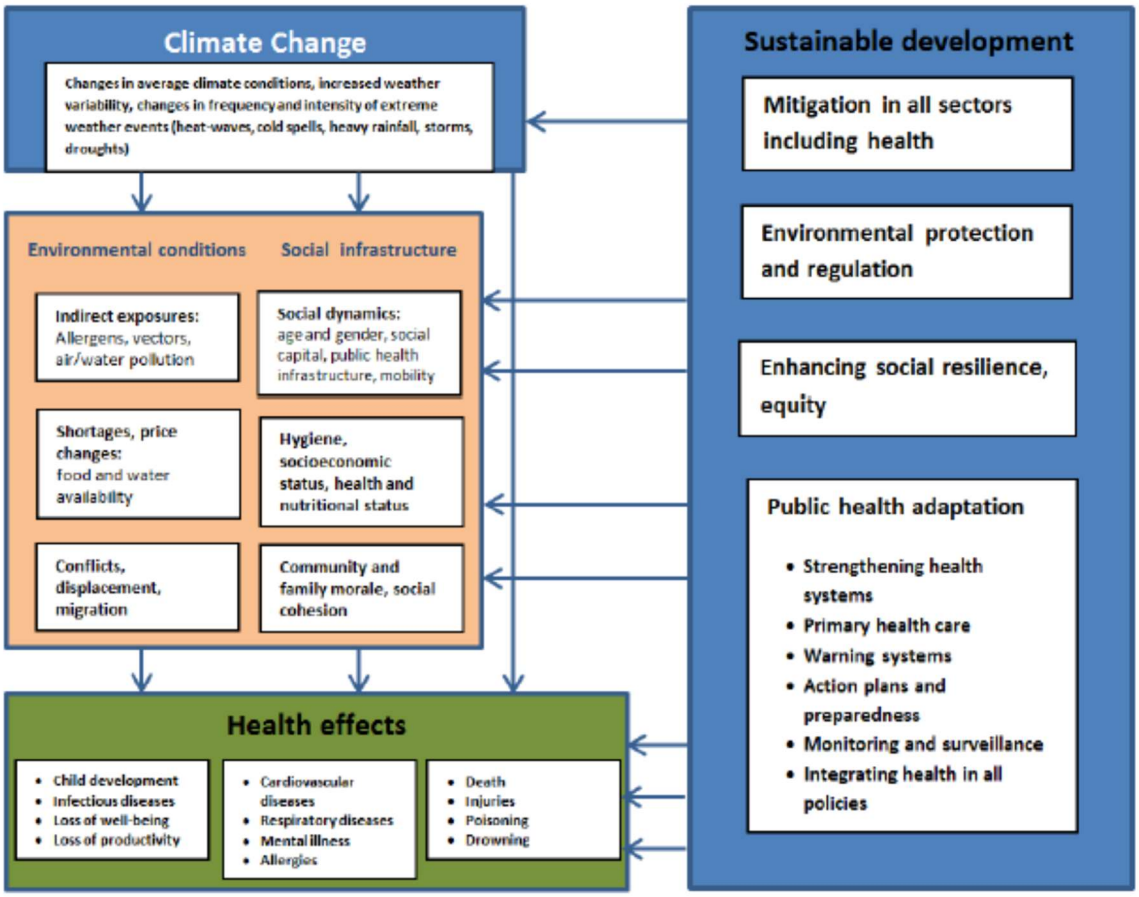
to the coronavirus pandemic has illustrated that collective action can drive innovation at all levels of society, decisions can be made outside of political ideologies, resulting in positive, tangible outcomes in the short-term.

2.4.5. How to Reduce Climate Change and Impacts on Health

The WHO's depiction of how climate change impacts affect environmental conditions and social infrastructure and impacts on health, whether through direct or indirect exposures is presented in Figure 9. This diagram also shows that sustainable development models need to take into account mitigation efforts to minimize climate change, as well as adaptation actions to reduce the impacts of climate change on health. One study undertaken by the WHO consisted of a quantitative risk assessment of climate change on selected causes of death with projections to 2030 and 2050. (44) The report found the strong effect of socioeconomic development on the projections of future risks and emphasized the need to ensure that policies and programs are targeted to the poorest and most vulnerable populations.

Mitigation and adaptation alter the human environment in order to address climate change and, in this way, alter human health outcomes. Susceptible populations exist for all climate-targeted health points, and the health systems play an integral role in addressing the health concerns driven by climate change. Importantly, research suggests that there is a need to consider synergistic effects of climate risks and how single risk factors may be underestimated because these interdependencies are not considered. The same is true for adaptation assessments, as such interconnections can hinder or enhance adaptation efforts by creating complementarities, synergies, and co-benefits, or even conflicts. (9) "Damage to physical infrastructure (buildings, roads, power grids) can also lead to lack of access to medical care, pharmacies, and social services putting people further at risk." (29 p.21)

Figure 9: Pathways of climate change, sustainable development and health (WHO) (45)



3.0. PUTTING IT IN A NEW BRUNSWICK CONTEXT

3.1. New Brunswick by the Numbers

New Brunswick is located on the east coast of Canada and borders the State of Maine, and the provinces of Quebec, Nova Scotia and Prince Edward Island (via the Confederation Bridge). In 2016, the population of New Brunswick was 747,101 and the density was 10.5 people per square kilometre. Atypical for Canada, only 53% of New Brunswickers lived in urban areas, while 47% lived in rural areas. (46) New Brunswick is the only bilingual province in Canada with approximately two thirds Anglophones, one third Francophones, and 2% First Nation. There are 107 municipalities which cover only 8.6% of the province's land mass but are home to 65.3% of its population. (47)

The province needs to be well prepared to face the impacts of climate change considering approximately half of the population is rural, where service provision is more expensive. The New Brunswick coastline is approximately 2250 kilometres in length. Significantly, nearly 60% of the population lives within 50 kilometres of the coast, making almost two thirds of the population vulnerable to sea-level rise, which is one of the key impacts of climate change. New Brunswick has the slowest performing economy of any Canadian province, and a per capita income of $28,000. Further, the province has the second-highest poverty rate in Canada for children making this population even more vulnerable to climate change. (48)

3.2. New Brunswick Health Status

New Brunswick is facing serious health challenges with an ageing population, physical inactivity, obesity and related chronic diseases such as heart disease, stroke, cancer, chronic respiratory diseases and diabetes. In fact, the province has the highest prevalence of chronic conditions in Canada and is among the unhealthiest in comparison to other provinces. (49) (50) Approximately 62% of New Brunswickers have at least one chronic condition (42% have one or two; 20% have three or more). The number of chronic conditions in seniors is more important than their age as a determinant of health care use. (51) Alarmingly, New Brunswickers are developing chronic conditions at an increased rate and at younger ages. (51)

New Brunswick, with 26.7% of its population aged 15 years or older living with a disability has one of the highest rates in Canada. Pain being the most common type, followed by flexibility, mobility, and mental/ psychological disabilities. (52) (53) According to Statistics Canada, the prevalence of disability increases with age. This is evident in New Brunswick where more than one-third (39.8%) of people in the province 65 years of age or older live with a disability. This is comparable across the country where the average percentage of this population living with a disability is 37.8% (with a high of 43.1% in Ontario and a low of 24.7% in Quebec. (53) Statistics Canada defined a disability as the result of the interaction between a person's functional limitations and barriers in the environment, including social and physical barriers that make it harder to function day-to-day. Thus, disability is a social disadvantage that an unsupportive environment imposes on top of an individual's impairment. (54) [4]

[4] Statistics Canada identifies ten different disability types, focusing on activity limitations related to hearing, vision, mobility, flexibility, dexterity, pain, learning, mental health, memory and developmental disabilities.

The province is also facing an obesity epidemic with 1 in every 3 New Brunswickers affected. In 2016, 38.8% of New Brunswick adults (18 years of age or older) were obese (the highest rate among provinces) and 32.7% were overweight. (55) During that same year, 31.0% of youth aged 12 to 17 were either overweight or obese, the fourth-highest rate in Canada. The rates of overweight and obesity among youth in New Brunswick have been increasing over the past three decades. Being obese as a child or youth increases the likelihood of being obese as an adult. This is a serious concern with obesity being an important risk factor for the development of chronic diseases and conditions such as diabetes, heart disease, cancer, high blood pressure and joint problems.

Heart disease is the result of complex interactions between genetic predisposition, lifestyle, mental health, pre-existing medical conditions, socioeconomic conditions and the environment. (56) Ischemic heart disease is the most common type of cardiovascular disease and the prevalence in New Brunswick has been increasing in recent years despite a decrease in the incidence, as more people are living longer with this condition. (53) From 2010/11 to 2013/14 for instance, prevalence increased by 4%. About one in every ten New Brunswickers aged 20 years or older is living with the disease. (57) Given the province's aging population and the fact that the occurrence of heart disease increases with age, the province's crude prevalence rate is expected to continue to increase. There are many risk factors for heart disease, such as physical inactivity, obesity and diabetes. In 2013, 1 in 10 New Brunswickers was living with diabetes. This represents a 25% increase in the numbers from five years earlier. One in four seniors has been diagnosed with the disease. (58)

Many of these conditions place enormous pressure on families, caregivers, public health and social service professionals as well as private and public sector productivity. In its report into the cost of chronic health care in the province, the New Brunswick Health Council identified New Brunswickers to be among the unhealthiest when compared to other provinces, experiencing more chronic health conditions at a younger age, and having a population that is aging faster than most other jurisdictions in Canada. (51) The report went on to suggest that with the costs of treatment rising, people living longer, and the shift to an older population there are concerns that climbing rates of chronic diseases threatens the sustainability of New Brunswick's health care system. As health care costs increase, the proportion of provincial funds available to dedicate to other priority areas, such as education, decreases. In 2014-2015 public spending on health services in New Brunswick was $3.46 billion, which was 39% of all provincial expenditures. This does not include private health expenditures including prescription medications, dental care and professional services, which account for 30% of total health expenditures. (51)

3.3. Anticipated Climate Change Impacts in New Brunswick

The effects of climate change are already evident in New Brunswick through changes in precipitation, severe weather events, changes in normal temperature ranges, and sea level rise. (59) According to the province's website, New Brunswick is already experiencing the following climate change impacts:

- The frequency of winter thaws and the intensity of precipitation events have increased.
- The accumulation of snow (snow pack) has decreased by 25% in the north and by 50% in the south.

- Sea-level rises are primarily the result of melting glaciers and subsidence of the land. The province expects that sea level will rise 50-60cm (+/- 35 cm) by 2100.[5] A rise of coastal water, along with an increase in storm surges, accelerates coastal erosion and results in the loss of built infrastructure (roads and bridges) and natural infrastructure (beaches and wetlands).

Further, the province has recognized the following anticipated changes (60) :

- A rise in coastal water levels and increased storm surges;
- Warmer weather in winter and summer,
- An increase in total precipitation, falling in fewer, but more intense events;
- More frequent winter thaws, and an increased risk of ice-jam flooding;
- Larger fluctuations in river runoff;
    - tree species will change, and the frequency of forest fires will increase in the province.
    - Over time, it is expected that agriculture, fisheries and aquaculture will experience impacts such as new diseases and pests.
    - Further, it is also anticipated that the quantity and quality of water supplies will also be affected
- More significant coastal erosion and flooding;
- More extreme and variable weather patterns; and
- Larger fluctuations in groundwater availability.

3.4. Geographic Variations in New Brunswick

Just as the global impacts of climate change will be experienced differently both around the world and within Canada, the impacts will be felt differently in various parts of New Brunswick. Coastal areas are expected to be impacted by accelerated sea-level rise, water temperature increases, storm intensification, changes in wave and storm-surge characteristics, altered precipitation and runoff, and ocean acidification. These impacts may affect populations through flooding and infrastructure damage, saltwater intrusion into freshwater resources, coastline damage and population displacement. [6] Further, it is anticipated that with climate change, sea water temperatures will rise. This could have an impact on water quality and therefore require additional food safety measures in order to protect human health as it relates to fish consumption.

Comeau and Nunes published climate projections for 16 New Brunswick communities based on data from the Canadian Climate Atlas. The projections include data for immediate to midterm (2020-2050) projections for average temperature (Table 6), hot days (Table 7), frost-free days (table 8) and precipitation (table 8). (17)

[5] These are numbers presented by the Province of New Brunswick based on work by Real Daigle. Other sources suggest sea-level change between 75-100 cm at the end of the century, based on high emission scenarios ("Canada's Changing Climate Report," prepared by Canada's Climate Change Adaptation Platform, Natural Resources Canada. Website accessed August 18, 2019 https://changingclimate.ca/CCCR2019/chapter/executive-summary/

[6] While there is an acknowledged link between water temperatures and fish/shellfish/mollusc health which has implications for food security, this study did not review those impacts as part of the human health review.

Table 6: Projected mean annual temperature (OC) (17 p. 14)

New Brunswick Community	Mean annual °C 1976 – 2005	Mean °C 2021 - 2050	Annual °C Increase	Annual % Increase
Edmundston area	3.1	5.2	2.1	68%
Campbellton area	3	5	2	67%
Dalhousie area	3.9	6	2.1	54%
Bathurst area	4.6	6.7	2	46%
Caraquet area	4.7	6.7	2	43%
Miramichi area	5	7	2	40%
Moncton	5.9	7.8	1.9	32%
Sackville area	6	7.9	1.9	32%
Sussex area	5.8	7.8	2	34%
Oromocto area	6	7.9	1.9	32%
Fredericton	5.6	7.6	2	36%
Minto area	5.6	7.5	1.9	34%
Woodstock area	4.3	6.3	2	37%
Grand Falls area	4	6.1	2.1	53%
St. Stephen area	6.1	8	2.1	31%
Saint John area	6	7.9	1.9	32%

Table 6 summarizes the annual temperature projections for 2020 and 2050 for various areas of the province. Findings suggest that average temperatures could rise 1.9 to 2.1°C, by 2050, with most of the warming in the winter and spring. These projected temperature increases are in addition to warming already experienced.

Table 7: Projected increase in the number of 30○C+ days 2021-2050 (17 p. 15)

New Brunswick Community	Mean # 30°C days 1976 - 2005	Mean # of 30°C+ days 2021 - 2050	% increase from 1976-2005 mean
Edmundston area	3	9	200%
Campbellton area	4	10	150%
Dalhousie area	4	11	175%
Bathurst area	6	14	133%
Caraquet area	3	9	200%
Miramichi area	9	20	122%
Moncton	6	16	167%
Sackville area	1	4	300%
Sussex area	4	12	200%
Oromocto area	9	21	133%
Fredericton	8	20	150%
Minto area	9	20	122%
Woodstock area	6	15	150%
Grand Falls area	5	13	160%
St. Stephen area	4	11	175%
Saint John area	1	3	200%

Source: Averaged for high-and-low-emissions scenarios by CCNB using Canadian Climate Atlas data.

Table 7 shows the increase in the number of days per year above 30^{O}C. The table illustrates that the number of hot days will more than double throughout the province with Sussex experiencing 12 hot days, three times the number of hot days by 2050 than it experienced annually (4 days) from 1975-2005.

Table 8: Projected average frost-free days 2021-2050 (17 p. 18)

New Brunswick Community	Mean 1976-2005 days per year	Projected frost-free season (days) 2021 - 2050	# of additional frost-free days	Frost-free season % increase
Edmundston area	125	147	22	18%
Campbellton area	115	137	22	19%
Dalhousie area	135	158	23	17%
Bathurst area	146	166	20	14%
Caraquet area	156	175	19	12%
Miramichi area	140	161	21	15%
Moncton	146	167	21	14%
Sackville area	154	175	21	13%
Sussex area	142	163	21	15%
Oromocto area	145	166	21	14%
Fredericton	141	161	20	14%
Minto area	139	159	20	14%
Woodstock area	126	147	21	17%
Grand Falls area	128	150	22	17%
St. Stephen area	150	172	22	15%
Saint John area	163	182	19	12%

Source: Averaged for high-and-low-emissions scenarios by CCNB using Canadian Climate Atlas data.

Frost-free days indicate higher average temperatures, particularly in the spring and winter months. As illustrated in Table 8, the province can expect 19-22 more frost-free days over the next 30 years, an increase of approximately 15%.

Table 9: Projected increase in precipitation 2021-2050 (17 p. 20)

New Brunswick Community	Mean mm 1976 - 2005	Mean mm 2021 - 2050	Annual mm Increase	Annual % Increase	Spring mm change (1976 – 2005 mean)	Winter mm change (1976 – 2005 mean)
Edmundston area	1021	1089	68	7%	247 (228)	257 (232)
Campbellton area	1070	1142	72	7%	260 (242)	277 (250)
Dalhousie area	991	1059	69	7%	238 (222)	257 (231)
Bathurst area	1026	1097	71	7%	265 (247)	285 (258)
Caraquet area	1028	1099	74	7%	259 (241)	292 (263)
Miramichi area	1052	1124	72	7%	276 (258)	293 (265)
Moncton	1117	1188	71	6%	300 (280)	327 (300)
Sackville area	1131	1198	67	6%	298 (276)	329 (303)
Sussex area	1163	1236	73	6%	301 (281)	345 (317)
Oromocto area	1103	1174	71	6%	284 (264)	314 (288)
Fredericton	1111	1182	71	6%	284 (265)	311 (285)
Minto area	1097	1168	73	6%	283 (264)	315 (288)
Woodstock area	1112	1185	73	7%	280 (261)	300 (273)
Grand Falls area	1048	1118	70	7%	250 (232)	271 (246)
St. Stephen area	1151	1218	67	6%	300 (281)	326 (302)
Saint John area	1243	1319	76	6%	322 (301)	372 (344)

Source: Averaged for high-and low-emissions scenarios by CCNB using Canadian Climate Atlas data.

Finally, Table 9 shows the average precipitation rates in the next 30 years, compared to the mean annual precipitation rates from 1975 to 2005. The annual increase is between 6-7% in the mid-term, but the seasonality of precipitation illustrates annual spring precipitation increasing 7-9%, and winter precipitation increasing 8-11%, and higher amounts expected in northern communities.

3.5. Vulnerable Populations in New Brunswick

Referring back to Table 2 which presented categories of population vulnerability from a global perspective, the following table outlines vulnerable populations who are likely to be disproportionately affected by climate change in New Brunswick:

Table 10: Categories of NB populations vulnerable to health impacts of climate change in an urban/rural context

Vulnerability factor	Population	Context
Demographic factors	Proportion of children	Urban/rural
	Proportion of women	Urban/rural
	Proportion of elderly people	Rural
	Population density	Urban
Health status	Undernourished populations	Urban/rural
	Populations with infectious disease burden	Urban
	Populations with chronic disease burden	Urban/rural
	Mentally or physically disabled populations	Urban/rural
Culture or life condition	Poverty	Urban/rural
	Subsistence farmers	Rural
	Fisherfolk	Rural
	Displaced populations	Rural (coastal)
	Ethnic minorities	Urban

Vulnerability factor	Population	Context
	Literacy levels Indigenous communities	Rural Rural
Life condition	*Climate risk or Resource*	*Context*
Limited access to adequate resources or services	Flood risk zones (formalized or not) Coastal storm and hurricane risk zones Water-stressed zones Food-insecure zones	Rural Urban/rural Urban/rural Rural
Limited access to adequate:	Health care Potable water Shelter (homeless issue) Employment	Urban/rural Rural Urban Urban/rural
Sociopolitical conditions	Political stability Existence of complex emergencies (e.g., flooding)	Urban/rural Urban/rural

3.6. Summary of Climate Change, Health and the New Brunswick Context

This section illustrated that the threat of climate change is very real, it has significant potential to severely impact population health, and health systems, and New Brunswick is not immune to these impacts. An ever-growing field of scientific research is establishing methodologies to test causal and associative impact paths, resulting in an evidence base linking changes in the climate to a myriad of impacts on human health at a global level. While direct causal links to climate change and human health impacts are difficult to prove with confidence, the precautionary principle would suggest that even in the absence of absolute certainty, action should be taken to reduce possible negative consequences. (61) In that vein, this project seeking to understand how climate change will impact our local communities from a health perspective - both urban and rural, coastal and inland and what intervention could be planned to lessen the impacts.

On October 4, 2019, the Canadian Public Health Association (CPHA) released its policy and position statement on Climate Change and Human Health. (62) CPHA called for action to be taken to integrate health-in-all-policy approach to climate policy, identifying health co-benefits associated with climate change policy, and integrating health equity impact assessments into ongoing policy decisions. Further, to protect the health of Canadians, the organization recommends undertaking local and regional climate change impact assessments, develop adaptation plans, undertake emergency response planning and training, prepare health equity impact assessments, develop and implement sustainable practices, and support best practice information-sharing among provinces, territories, municipalities, and Indigenous peoples. (62)

As part of its response, the province is developing a New Brunswick-focused Climate Change and Health Vulnerability and Adaptation Assessment tool kit, which, used throughout the province can then lead to policy changes and program development to help mitigate and adapt to the most pressing health impacts.

4.0. LITERATURE REVIEW OF HEALTH VULNERABILITY AND ADAPTATION ASSESSMENTS TO CLIMATE CHANGE

4.1. Introduction

Climate Change Health Vulnerability and Adaptation Assessments (CCHVAAs) are being conducted around the world to help inform public health practitioners about the risks,

impacts, and vulnerabilities associated with climate change and health. These assessments also help decision makers identify opportunities to build or enhance health adaptations to a changing climate. (36) This section of the report provides an overview of the methodology used to assess CCHVAAs elsewhere and then outlines key vulnerability and adaptation approaches relevant to the current project. These adaptation approaches have been employed by various jurisdictions across Canada, the United States and around the world, allowing a comparison to the New Brunswick context, particularly in relation to urban and rural settings.

4.2. Methodology

An overview of the literature on climate change and its relation to health impacts and vulnerability assessments was conducted from January to September 2019. Specifically, the review encompassed tools and frameworks published from 2000 to present and included approaches to undertaking Climate Change Vulnerability Assessments, Health Vulnerability Assessments, and more specifically, Climate Change and Health Vulnerability Adaptation Assessments. Peer-reviewed scientific publications and case studies were included, such as The Lancet and the International Journal of Environment and Public Health, although much information used was derived from various technical government reports. Additional grey literature included various provincial, regional and community-based assessment reports based on the subject matter. A scan of online literature and health-related data sources yielded six examples of various domestic and international frameworks on climate change vulnerability assessment and four frameworks that used a health lens to assess climate change vulnerability and adaptation. Further, a jurisdictional review yielded more than 22 CCHVAAs that made use of the approaches identified.

4.3. Climate Change and Health Vulnerability and Adaptation Assessment Frameworks

The review identified a wide range of vulnerability assessment tools, some of which were specific to Climate Change impacts, other specific to health. Only a limited number of tools were identified that combined the two criteria (health vulnerability related to climate change impacts). A scan of the literature revealed the key frameworks that were used in various vulnerability and adaptation assessments across Canada, the United States and around the world. The following section highlights the key vulnerability assessment frameworks that were identified as applicable to the present study.

4.3.1. Climate Change Vulnerability and Adaptation Assessment Frameworks

The IPCC outlined several frameworks with which to assess local climate change, including 1) impact-based approaches that are climate scenarios driven; 2) adaptation-based approaches that focus on the capacity of communities and natural systems to respond effectively to stress; 3) vulnerability-based approaches centred on the factors driving the susceptibility of individuals and groups to harm; 4), integrated approaches that include modelling and other procedures for investigating climate change across sectors; and 5) scales and risk management approach that focus directly on decision-making. (63) Most of these models were designed primarily for the environmental and economic sectors and do not necessarily account for consideration of health or social system impacts. (64) Despite this limitation is important to take a look at these approaches as they provide the basis for most of the climate change vulnerability assessments that have been developed to date. Some key examples of processes developed are outlined in Table 10, from which we can extract direction and considerations which will be helpful for developing a vulnerability assessment approach using a health lens in the New Brunswick context.

Table 11: Examples of Climate Change Vulnerability Assessments Frameworks

Framework	Focus	Steps Involved	Relevance for CCHVAAs
Preparing for Climate Change – a Guidebook for Local, Regional and State Governments[7] (2007)	Community/regional level framework American-based tool, easily adaptable to Canadian context Human-centred	1. Scope climate change impacts on major sectors in subject area 2. Build support for process (identify champion, understand audience, communication plan) 3. Build Climate Change Preparedness Team 4. Identify areas relevant to climate change 5. Conduct Vulnerability Assessment (review climate information, conduct climate sensitivity analysis, evaluate adaptive capacity of systems) 6. Conduct Climate Change Risk Assessment (determine risk exposure, risk tolerance, prioritization) 7. Preparedness Planning (establish vision, guiding principles, and goals; identify potential preparedness actions; select and prioritize actions) 8. Implement the plan 9. Measure progress and update plan	Design of guide is user-friendly and is meant to be conducted at a community level by non-scientific experts Answers many questions often faced at the local level Focus on adaptive capacity
Climate Change Adaptation Planning: A Handbook for Small	Small communities Municipal framework (Canadian)	1. Get Started (build public awareness, identify champion, create multi-departmental team,	Only framework to focus of "small" communities in a Canadian context.

[7] Developed by the Center for Science in the Earth System in association with ICLEI (Local Governments for Sustainability) (94)

Framework	Focus	Steps Involved	Relevance for CCHVAAs
Canadian Communities[8] (2011)		determine engagement process, identify stakeholders, get political commitment) 2. Analyze How Local Climate Will Change (gather scientific knowledge, gather local knowledge, build climate change scenarios) 3. Scope Potential Impacts (develop inventory of CC impacts, document possible consequences, review inventory with the community, revise as needed) 4. Assess Risks and Opportunities (risk and opportunity assessment, evaluate adaptive capacity, prioritize risks and opportunities) 5. Prepare Adaptation Plan (establish principles, policies and actions, prioritize actions, prepare program gap analysis, assign responsibility to act, draft CC Action plan) 6. Adopt, Implement, Monitor and Review (obtain political approval of CC Action plan, develop implementation strategy, incorporate actions into community policies and budgets, establish key indicators and milestones, review)	Recognition of political will as key to implementing change Recognition that there are budget implications to adaptation Identification of roles and responsibilities for adaptation Focus on built environment adaptation approaches

[8] Developed by the Canadian Institute of Planners (90)

Framework	Focus	Steps Involved	Relevance for CCHVAAs
7 Steps to Assess Climate Change Vulnerability in Your Community[9] (2013)	Small communities Municipal framework (Canadian)	1. Issues: Identify the types of climate and weather-related issues that have affected your community 2. Locations: Locate where these issues have occurred or could occur in your community; 3. Infrastructure: Assess what infrastructure has been or will be impacted 4. Society: Identify the residents who have been or will be most affected as well as those who can provide assistance in the community 5. Economy: Assess which economic sectors have been or will be most impacted by the issues 6. Environment: Identify how the natural environment has been or will be affected; and 7. Options: Determine the best ways to address the issues identified	One of the only bottom-up approaches that includes detailed worksheets on each step that can be easily implemented by local groups Case studies from Atlantic Canada
India's Framework for Climate Change Vulnerability Assessments[10] (2014)	Rural areas framework (India)	1. Defining the purpose of the vulnerability assessment 2. Planning the vulnerability assessment (focus on local context (compare urban or state levels to rural context) 3. Assessing current vulnerability (compare urban/state levels to rural context)	- Uses both top down (state-level data) and bottom-up (using community-based information) approaches - Analysis of a multitude of models using top-down and bottom-up approaches which can be used for comparison in developing the NB approach.

[9] Developed by Natural Resources Canada and the Government of Newfoundland and Labrador (92)

[10] Developed by the Ministry of Environment, Forests and Climate Change, Government of India (7)

Framework	Focus	Steps Involved	Relevance for CCHVAAs
		4. Assessing future vulnerability (state to rural)	- Identified several tools for gathering information using a bottom-up approach. - Rural comparisons to state-level data.
Framework for vulnerability assessments in Watersheds[11] (2015) *This framework was informed by a review of climate change adaptation, risk assessment, and vulnerability assessment framework literature from various sectors (e.g., watershed, regional, municipal and community, provincial and federal government, natural resources), as well as a jurisdictional survey of adaptation implementation frameworks in development or in use across Canada.*	Watershed and ecosystems (Canadian)	1. Initiate process (set context, build awareness, engage experts, develop record-keeping system) 2. Increase knowledge, collect data (gather historical data, develop baseline and indicators, obtain future climate projections, develop inventory of climate change impacts) 3. Assess current vulnerability (determine degree of sensitivity of context, determine adaptive capacity to address historic and current climate change impacts, assess vulnerability, review results and communicate findings) 4. Assess future risk (conduct risk analysis, conduct risk evaluation, communicate findings) 5. Generate adaptation solutions (establish goals and objectives, identify adaptation options, evaluate options, review and	Combines both top down and bottom-up approaches[12] Uses an "adaptive management" approach which allows decision makers to manage in the context of uncertainty (i.e., learning by doing) Can be either standalone, or have aspects mainstreamed into existing policies, procedures, or management functions Process is iterative and designed to be flexible in its implementation Highly technical approach (need significant expertise)

[11] Developed by the Canadian Council of Ministers of the Environment (89)

[12] Top down approaches start with climate change and impacts and focus on the numbers – often they focus on creating simulation models to project future impacts. This approach is useful for biophysical effects of climate change that can be readily quantified. (Project on Climate Change Adaptation in Rural Areas of India, September 2014) Bottom up approaches start with analysis of people affected (vulnerable populations) and work backwards to determine causes and develop strategies to address impact.

Framework	Focus	Steps Involved	Relevance for CCHVAAs
		communicate results) 6. Implement Adaptation Solutions 7. Monitor and Review	
Climate Adaptation Guidelines for NB Communities[13] (2018)	New Brunswick municipalities	1. Establish Scope and Organize – undertake initial inventory of what has been done locally; identify stakeholders and champions; outreach and education plan 2. NB's changing climate – historic and predicted climate conditions for the province, including predicted types of hazards and impacts 3. Assess Vulnerability – understand climate threats and potential impacts locally; identify vulnerable areas of the community (economic, environmental, infrastructure and social) 4. Identify adaptation priorities, options and actions – prioritize impacts; identify adaptation options for those priorities; create a plan of action based on those options 5. Develop Adaptation plans.	New Brunswick-specific data and scenarios Presents made-in-New Brunswick adaptation solutions to general vulnerability Framework tailored to NB communities (urban/rural, large/small, French/English, etc.)

While the above assessment frameworks are clearly focused on a generalized approach to climate change vulnerability and adaptation, each provides key lessons for the development of health-lens approach to vulnerability and adaptation assessment in the New Brunswick context.

[13] Developed by the Climate Change Secretariat, Government of New Brunswick (91)

There are four key takeaways from these non-health climate change vulnerability assessment approaches. First, a combination of top-down and bottom-up approach is desirable to fill in data gaps, particularly in the rural context. Second, political buy-in is needed to undertake the process and implement recommendations. Third, recognition of budgetary implications to adaptation must be balanced against the potential cost of future scenarios where no action is taken. Measuring adaptive capacity is key to determining community resilience. Fourth, a wide array of stakeholders (emergency measures, infrastructure, planning, etc.) need to be included with health to determine best adaptation responses to health vulnerabilities. Finally, it is recognized that many of these climate change vulnerability frameworks provide a host of tool options for data collection, community engagement, and processes within their approaches.

4.3.2. CCVAA Frameworks using a Health Lens

The scan of literature revealed four frameworks that have been specifically developed to assess health vulnerability to climate change impacts. The first was the World Health Organization's Health Impact Assessment, the second American Building Resilience Against Climate Effects (BRACE), the third and last was the most recent by Health Canada specifically geared towards CCHVAAs. Each of these models is discussed below and summarized in Table 12.

4.3.2.1. World Health Organization's Health Impact Assessment

In response to early IPCC findings, the World Health Organization, along with the World Meteorological Organization and the United Nations Environment Program established a working group in 1995 to assess risks to health from climate change, setting the stage for two decades of further climate change health vulnerability assessments. (65) These assessments are prepared using various methodologies, from state level to community levels. They can be impacting specific (i.e., focus on urban heat island impact), or broadly based, considering a range of impacts and their effects on health. The approaches used may use qualitative and quantitative data depending on the level and type of data available and knowledge that exists.

Reflective of the models noted in the previous section, the World Health Organization (3), identifies five key steps involved in its framework for Health Impact Assessment:

1. **Frame and Scope the Assessment** – this stage includes identifying the community of study, establishing the policy context, selecting the project team, identifying stakeholders, and developing a communications plan.

2. **Assess vulnerabilities of the population** – activities include establishing a baseline of population health (physical and mental), identifying vulnerable populations, and identifying existing climate risks that have health outcomes, describing the capacity of health and other sectors to address risks, all the while considering social and ecological determinants of health.

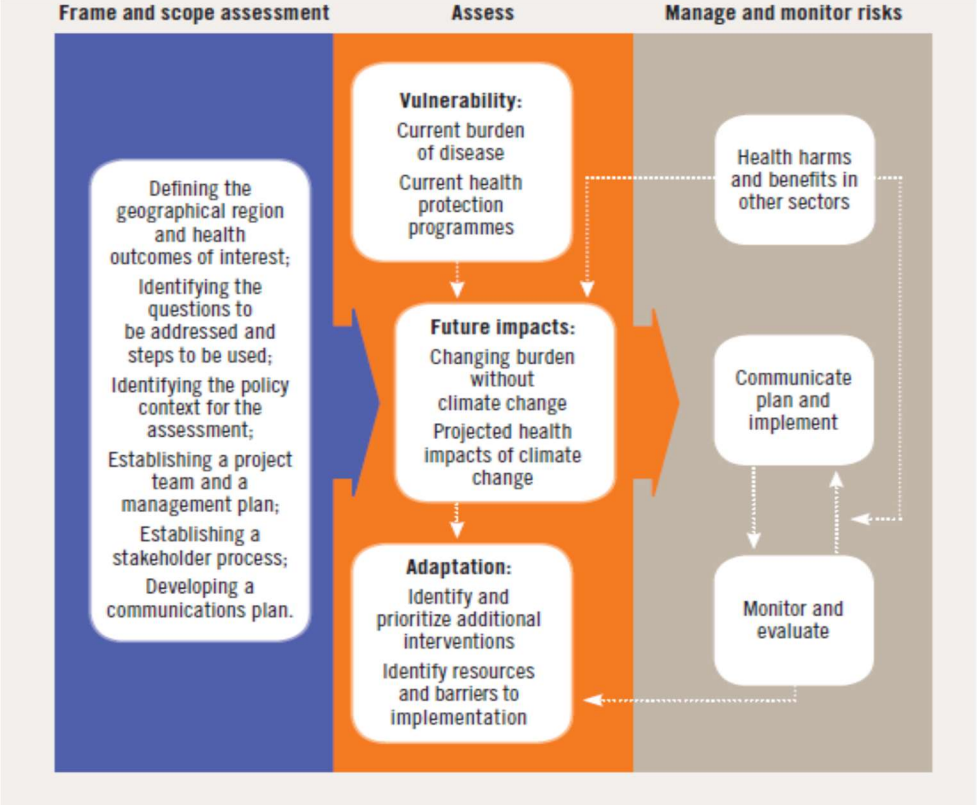
3. **Assess the future climate impacts** – the project team would then use scientific projections for climate risk assessment based on short, mid-term and long-term projections; estimate how the risks of climate-sensitive health outcomes may change over coming decades irrespective of climate change, estimate additional burden with climate change factored in; and assess possible future health burdens relative to climate impacts (physical and mental).

4. **Assess adaptation opportunities** – this stage includes identifying programs and opportunities that address climate health vulnerabilities and resiliency, short-term measures tied to emergency measures planning, long-term collaborations with range or sectors (land use, policy, food sector, etc.).

5. **Manage and Monitor Risks** – this stage is undertaken using an iterative process including evaluations of health harms in other sectors and constant reassessment of new health risks.

It is important to note that, similar to other vulnerability assessment approaches, the steps which are presented in a linear format (see Figure 10) are part of an iterative process that considers ongoing climate change and changes in vulnerability over time. (3)

Figure 10: WHO Vulnerability and Adaptation Assessment Framework (2013) (3)

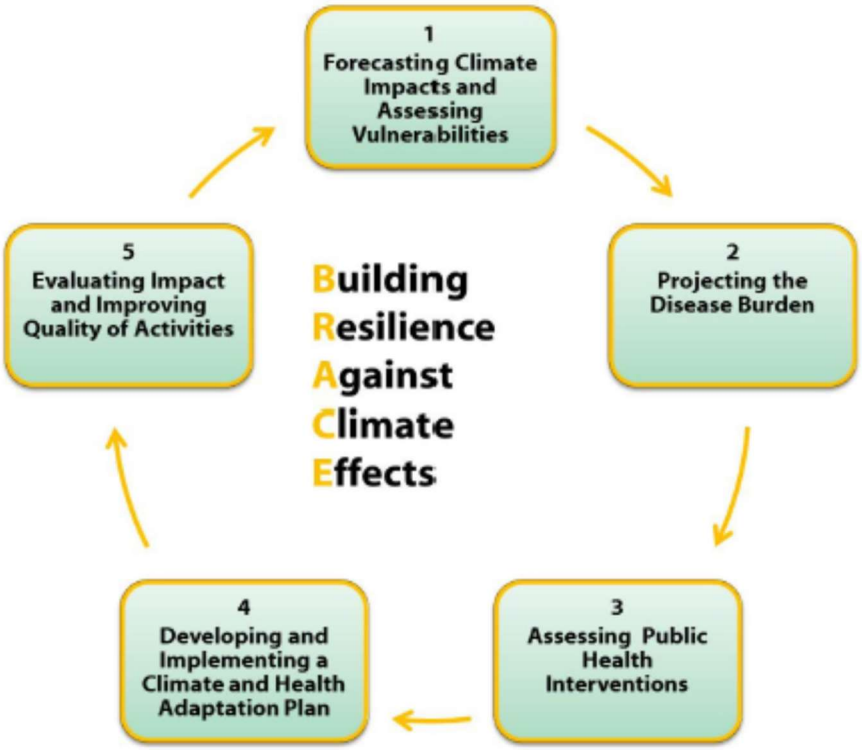


As the first approach developed to assess health vulnerability to climate change, the WHO process is reflective of the more generalized approaches to assessing climate change vulnerability. The focus of this framework is primarily on disease, health protection, and intervention considerations and has been used by many jurisdictions, among them Canada (66), Malta (67), Nepal (68) and Australia (69). This framework is developed for high-level assessment of the issues and programs available, often at a national level. One example of how it has been used was a process developed in 2010 to assess and manage changes in the risk of infectious disease transmission posed by climate change in European member states. (70) The handbook developed from that focused its scope on communicable diseases based on the WHO framework, supplemented by best practices from HVAs from other European countries as well as from Australia, Canada, New Zealand and the USA. The handbook is meant to provide guidance on how to organize, structure and manage a national vulnerability impact adaptation assessment.

4.3.2.2. The American Building Resilience Against Climate Effects (BRACE) Framework

In an effort to build climate change adaptation capacity in the public health community, the US Center for Disease Control and Prevention (CDC) devised a comprehensive framework for developing local climate change adaptation plans to use a health lens. (71) The Building Resilience Against Climate Effects (BRACE) framework is an iterative approach to managing the health impacts of climate change. This framework is based on concepts of Adaptive Management which is an iterative, learning-based approach to the design, implementation, and evaluation of interventions in complex, changing systems. (71) The BRACE model recognizes that the public health impacts of climate change are complex, involve many systems and are incompletely understood; it relies on modelling to project climate change health impacts, regular iterative reassessment of risks, and the integration of new knowledge about impacts and interventions; it requires vulnerability assessment and evidence-based evaluation of potential intervention options. BRACE measures exposure to risks against the population's sensitivity to those risks to determine the potential impact. Potential impact is measured against the population's adaptive capacity to determine its vulnerability. (30)

Figure 11: Building Resilience Against Climate Effects (BRACE) framework (2014) (30)



The five steps, as identified in Figure 11, are summarized below:

I. **Forecasting Climate Impacts and Assessing Vulnerabilities** – This stage includes defining the geographic area of the study, the time frame to consider future changes and potential health outcomes expected. The objective of this stage is to develop a profile of how the climate is changing, the likely effects on health, and the populations and systems most vulnerable to these changes by
   a) identifying climate-sensitive health outcomes (using weather and climate variability and change data sources), and
   b) identifying vulnerable populations (key concepts being exposure, sensitivity, and adaptive capacity)

II. **Projecting the Disease Burden** – This stage considers shifting disease burdens using a combination of qualitative and quantitative methods by:
   a) Identifying climate-sensitive diseases, indicators of exposures and outcomes, and dose-response relationships;
   b) Determining population exposure scenarios and relationships for pathways being assessed;
   c) Defining an approach to projecting outcomes; and
   d) Mapping projected disease burdens (and shifting demographics) in GIS

III. **Assessing Public Health Interventions** – The focus of this stage is identifying the most suitable interventions to adapt to climate change-related health threats.

IV. **Developing and Implementing a Climate and Health Adaptation Plan** – Here the goal is to synthesize the information generated thus far into an adaptation plan that complements and adds greater specificity to public health considerations and is also included across other jurisdictions in climate adaptation planning. (71)

V. **Evaluating Impact and Improving Quality of Activities** – Implementing BRACE is an iterative process that requires monitoring, evaluation, and revisiting key areas as new information is developed or climate forecasts change.

The BRACE framework was designed to specifically evaluate public health intervention programs at the state and county level. It has been widely used throughout the United States with examples in Georgia (30), Minnesota (72), Florida (73), Illinois (74), and Saint Paul-Ramsey County (75). In recognition of the evidence-based approach to public health, section 3 of the BRACE is of specific interest, as it evaluates standard public health interventions (specifically adaptative approaches) with respect to climate change impacts. This goes well beyond what other assessment tools have accomplished by providing a commentary and evaluation on adaptation approaches. This section of the BRACE framework will be key to moving forward with the New Brunswick CCHVAA tool.

4.3.2.3. Health Canada's CCHVAA: Workbook for the Canadian Health Sector

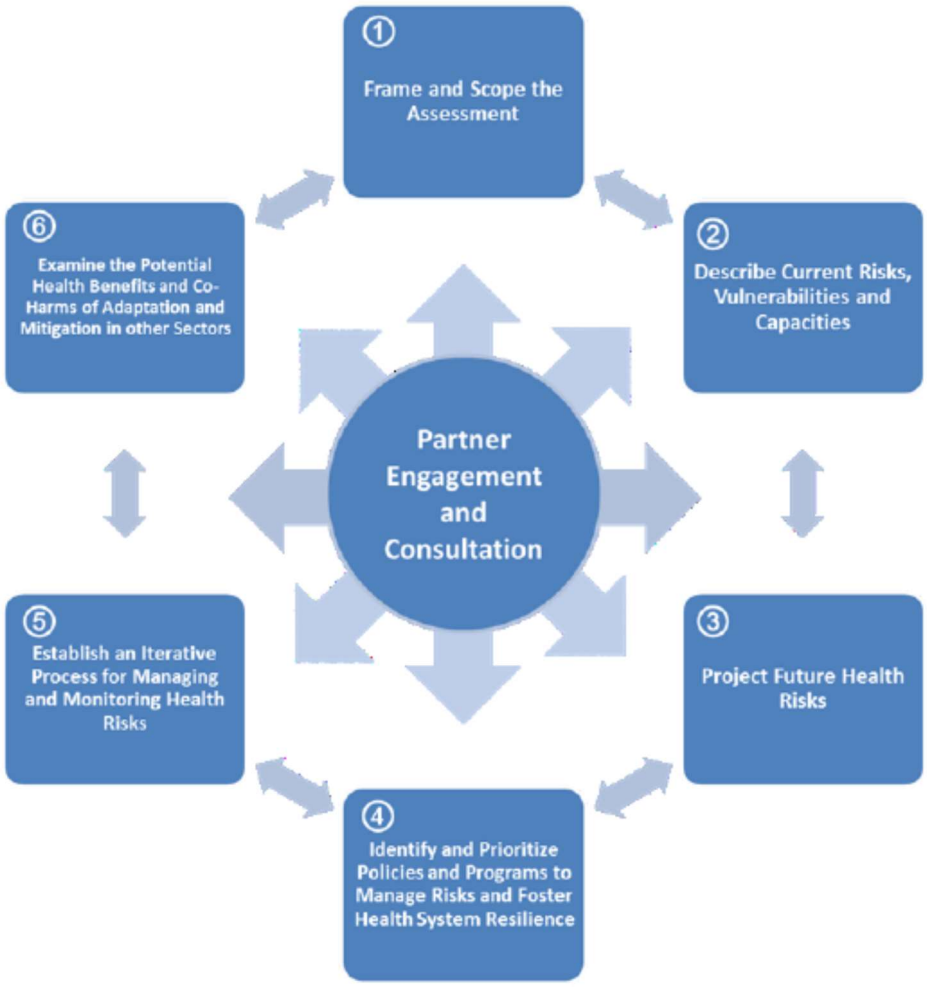
Most recently, Health Canada released its workbook for the Canadian Health Sector specifically related to climate change health vulnerability and adaptation assessments. (80) Largely based on the WHO approach and Ontario's Climate Change and Health Tool Kit (76), this workbook is designed primarily for use by health officials to develop CCHVAAs through participatory processes that engage partners from multiple sectors and organizations. This workbook includes step-by-step guidance, including worksheets and templates focusing on the six steps of its process, illustrated in Figure 12.

Step 1: Frame and Scope the Assessment – this stage includes establishing clear project management parameters (including timeframes and budgets), prioritizing health hazards and concerns, identifying project team and key stakeholders, establishing a project work plan, and developing a communications plan.

Step 2: Describe Current Risks Including Vulnerabilities and Capacities – review qualitative and quantitative information, estimate current relationships between weather patterns and climate-sensitive outcomes, describe historical trends in climate-related hazards of interest, characterize current vulnerability of individuals and communities, describe and assess the effectiveness of policies and programs to manage current vulnerabilities and health burdens.

Step 3: Project Future Health Risks – review qualitative and quantitative information and describe how current risks could change under different weather and development patterns.

Figure 2: Health Canada's Six Steps of a CCHVAA (2019) (80)



Step 4: Identify and Prioritize Policies and Programs to Increase Climate-Resilience of Health Systems – assess health system climate resilience; review data building on previous sections and presenting to stakeholder groups; inventory options to improve or implement policies and programs to manage the health risks of climate change; prioritize options and develop resources needs; assess possible constraints to implementing options and how to overcome them; and develop a CCHVA Plan of Action.

Step 5: ***Establish an Iterative Process for Managing and Monitoring Health Risks*** – develop a monitoring plan (what to monitor, how often, milestones and lead); develop indicators for success; and identify and share lessons learned and best practices.

Step 6: Examine the Potential Health Co-Benefits and Co-Harms of Adaptation and Greenhouse Gas Mitigation Options Implemented in

Other Sectors – review adaptation and mitigation options proposed or implemented in other sectors; and identify options to maximize synergies among adaptation and mitigation options.

While Health Canada's framework presented above is grounded in previously reviewed approaches, it contains some unique components. Specifically, those are the assessment of health system resilience, and the inclusion of the constant feedback loop with stakeholders and partners at all steps of the iterative process. The tools within this approach are meant to be used by non-experts and be completed by working with partners in various fields including health sector, engineering, emergency management, planning, and governance.

4.3.3. An Assessment of CCHVAA Frameworks

Findings from a 2018 review of CCHVAAs in European countries found that the studies (many of which used the WHO's approach) are effective in raising awareness of impacts on vulnerable populations, building capacity to prepare for impacts, and establishing the required knowledge base for climate change adaptation in the health sector. Overall, CCHVAAs have helped health authorities integrate the needs of the health sector into broader policy efforts for better decision-making on climate change responses. The research also found that the participatory approach used in CCHVAAs also facilitates climate change cooperation across sectors. (65)

The literature also highlighted some of the inherent limitations of CCHVAAs which include the current state of knowledge which can hinder the ability to assess the extent of health impacts related to climate change over time. Identifying gaps in current knowledge is key and can help direct future research and data collection. (35) Another limitation of the process is the reliance on historic weather data, and vector-borne disease surveillance, given that it is well recognized that this data can no longer be relied upon for anticipating future events. Recent demographic data can also be a limitation if there are anticipated shifts in demographics because of climate impacts (e.g.., migration, birth, or death rates). There may also be limited data availability and data accuracy depending on the subject community. A vulnerability assessment may not be able to capture the potential masking of disparities when data is aggregated or mapped. (47)

Finally, at the local level, it will be critical to mobilize communities and health authorities as key partners in taking action on climate-related health risks based upon CCHVAAs; this lack of uptake can be the result of limited funding, and/or political support. Health authorities, as well as Emergency Measures Organizations, municipalities, and higher order government agencies need to be able to translate the findings of the CCHVAA into adaptation practice to protect vulnerable populations and do so in a way that can build understanding and support at all levels. (65)

The literature scan identified a wide range of climate change vulnerability assessment frameworks – some that focused on environment, socio-economic, and infrastructure vulnerabilities. These frameworks provide some lessons moving forward in developing a model for health vulnerability assessments in New Brunswick. The literature also yielded four primary climate change and health vulnerability assessment frameworks, upon which much of the national and international assessment studies have been based. In reviewing the four primary

CCHVAA frameworks – the WHO's Health Impact Assessment, the CDC's BRACE program, Ontario's Climate Change and Health Assessment process, and Health Canada's new CCHVAA Workbook – it is useful to compare the strengths and limitations of each approach as is summarized in Table 12 below.

Table 12: Summary Comparison of CCHVAA Frameworks

	WHO – Health Impact Assessment[3] 2013	**CDC – BRACE[7] 2014**	**Health Canada's CCHVAA Guide[72] 2019**
Strengths of Model	• Standard, proven method of assessing health vulnerability • Focus on prevention and program intervention adaptations	• Developed for state and county-level interventions • Process steps detailed with supporting scientific examples of calculations (e.g., future forecasting of the disease burden)	• Newest tool based on the latest science and approaches • Is designed for implementation by regional health authorities • Iterative model with detailed fill-in worksheets specifically designed for non-technical project leads
Limitations of Model	• Very generalized and meant for higher-level assessments (national or provincial) • Does not have practical tools to directly use at the local level • Considers health impacts and projections in relative isolation from other sectors	• For the current study, the obvious weakness is that it is focused on the American/state model of public health delivery • Highly technical in some approaches and would require dedicated analysis to fully undertake in an NB context	• It is a very new product, so few jurisdictions have used all the tools in the guide to test if they are complete or limiting. • No specific tools included focusing on mental health and wellbeing
Unique Features of Model	• First model on which most others are based • Top-down approach	• Adaptive management model which is iterative and recognizes the inherent uncertainty of the process/end product • Assessment of intervention methodology is key (Section 3)	• Includes consideration of health system resiliency • Model requires regular and ongoing feedback with partners and stakeholders
Practical components	• None provided	• Step-by-step explanations with detailed mapping examples • Review of intervention approaches will be helpful in identifying and prioritizing options for NB case studies	• Fill-in templates and worksheets at every step of the process • Authors of guides are project sponsors and can provide further assistance if required.

	WHO – Health Impact Assessment[3] 2013	CDC – BRACE[7] 2014	Health Canada's CCHVAA Guide[72] 2019
Other comments	• This process is tried and tested at the higher level (i.e., national or even provincial), but it is not directly implementable at a local or municipal level.	• This process has also been well tested throughout the United States. • Aspects of this framework will be used to inform intervention options identified in the NB case studies.	• Iterative nature of the recommended process lends itself to flexibility in implementation.
Lessons Learned	• Data is more easily accessible at higher aggregations (national or state/provincial level) • May need to be creative with approach, particularly in small communities where data is limited or unreliable.	• Process needs to be flexible – use of an iterative approach allows changes to be made to accommodate gaps in data or new information	• New model is based on best practices and WHO and Ontario approaches.

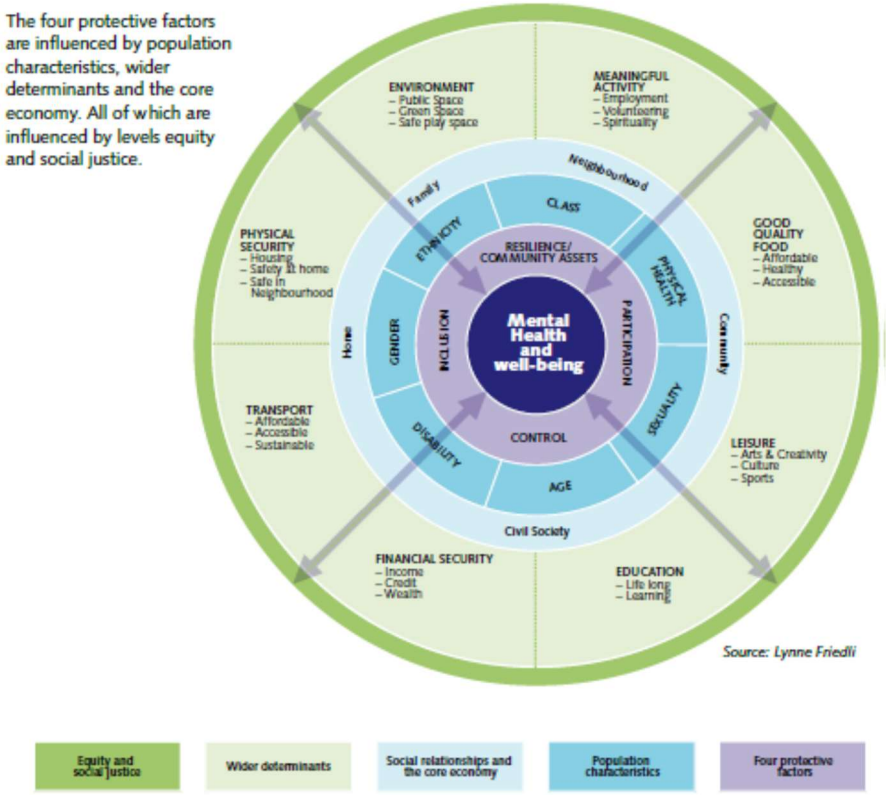
As indicated earlier in this report, common approaches to vulnerability assessments are either top-down or bottom-up. Top-down refers to approaches that start with analysis of climate change and its impacts where the main benefit lies in the direct cause and effect relationships of climate stimuli and their biophysical impacts and the ability to project a certain state far into the future. (81) This is the approach used in the WHO framework. There are two main weaknesses with the approach. The first is related to the uncertainties that are inherent in every modelling exercise (future development, economies, and climate system, and the environmental and human systems impacted). Second, these models generally only focus on the ecological components of communities or systems and do not necessarily consider the socio-economic impacts. Bottom-up approaches provide analysis of what causes people to be vulnerable to climate change hazards. These approaches are limited in scope and participatory in nature and conducted at local levels like households or rural communities, often in the developing world (or indigenous communities). The benefit of this type of approach is that results can identify which groups are particularly vulnerable to specific climate change hazards; however the drawbacks are that the results are very place-specific and difficult to generalize, and it is challenging to project future vulnerability based on this approach. (81) Given the population of New Brunswick and the geographical size of the province, it may be that a combined approach is the best option with which to approach CCHVAAs. Similar to that in the Indian example, (7) top-down data gathered at the state (or provincial) level on vulnerability projections can be compared to data gathered on the ground from local communities using a bottom-up approach. Using this methodology provides a consistent benchmark for communities, while acknowledging that New Brunswick communities, particularly rural ones, will not have the same level of measurable data at its disposal.

4.3.4. Mental Health and Social Wellbeing Considerations

Earlier in this report mental health and social wellbeing were identified as being indirectly affected by climate change impacts in many different ways. However, it is

acknowledged in the literature reviewed that mental health is rarely considered within the assessment study frameworks. (34) (17) (82) (36) The literature suggests adding a supplementary component to the larger CCHVAA processes to incorporate considerations for mental well-being. (83) Mental Well-being Impact Assessment (MWIA) frameworks have been developed, including one by the MWIA Collaborative in England (84) This process uses the evidence base for establishing influences of mental health and includes a complete MWIA including screening, scoping, appraisal, and formulating recommendations. The evidence base used in this approach includes: MWIA core protective factors (control, resilience/community assets, participation and inclusion); population characteristics (e.g., age, class ethnicity); social relationships and the core economy (friends, family neighbours and civil society); wider determinants (e.g., financial security, environment, transport, education); and core values (equity and social justice). (84) This is further illustrated in Figure 14 below.

Figure 12: A dynamic model of mental well-being for assessing mental well-being impact (84 p. 16)



Importantly to the current research, “The extent to which individuals and communities have control over their lives has a significant influence on their mental health and overall health.” (84) This process may be adaptable with a New Brunswick-based CCHVAA to include considerations beyond what is available in existing approaches. The pilot projects can include for example an assessment of whether physical isolation in rural areas and social isolation in either rural or urban areas plays a significant factor in determining vulnerability.

4.4. Summary of Literature

The overview of literature illustrated that there is a general set of principles and procedures to follow in conducting any type of climate change and health vulnerability assessment. Using an evidence-based approach to public health, the CCHVAAs have been conducted at national, provincial/state, and regional levels throughout Canada and around the world. Undertaking CCHVAAs at a small scale such as a rural community in New Brunswick will have its challenges in determining population specific health status indicators as well as climate change projections for small geographic areas. However, guidance from the non-health sector partners in methods for gathering data and information in a small or rural community setting, will help alleviate some of the challenges and provide for a more robust assessment by combining top down and bottom-up approaches to climate change and health vulnerability assessments in New Brunswick. This review provides the project team with a baseline of information from which to begin development of a New Brunswick-specific model. As the project progresses, it is anticipated that tools and approaches employed from communities, municipalities, regions, and states will continue to inform the tool kit as it is developed.

5.0. RECOMMENDATIONS FOR DEVELOPING A NEW BRUNSWICK-FOCUSED CLIMATE CHANGE AND HEALTH VULNERABILITY ADAPTATION ASSESSMENT FRAMEWORK

In this report we reviewed causes of climate change, health trends, and climate impacts specifically related to health. We then focused on the health and climate impact discussion specifically to New Brunswick. This provides the confirmation of the need to undertake a climate change, health vulnerability, and adaptation assessment using a New Brunswick approach that addresses both rural and urban populations. A range of assessment frameworks were reviewed and four specific frameworks using a health lens were evaluated based on transferability and practicality for the New Brunswick context. Based on this information, the following recommendations are presented for moving forward with the current project:

Recommendation 1: Utilize the Health Canada Guide to CCHVAA as a starting point in developing the New Brunswick model. The model should also consider unique features of the Ontario Climate Change Health Tool Kit as these tools have been developed and tested in a Canadian context and have been used in both rural and urban environments.

Recommendation 2: Use Section 3 of BRACE to establish the health indicators for an evidence-based approach to the study.

Recommendation 3: Work with provincial experts to identify climate change indicators of significance in the New Brunswick context, particularly for the pilot communities identified.

Recommendation 4: Researche examples (e.g., Quebec, Health Canada) and develop vulnerability indicators for the New Brunswick context.

Recommendation 5: Develop indicators that can differentiate between urban and rural contexts.

Recommendation 6: Work with provincial and academic experts to identify data sources that are disaggregated to the lowest level as much as possible to determine community-specific climate projections and/or health status for the pilot communities while maintaining the integrity of the data.

Recommendation 7: Consider both bottom-up and top-down methods for gathering data in the development of the New Brunswick framework and associated tools.

Recommendation 8: Ensure that data collected reflects local realities within the context of climate change.

Recommendation 9: Develop a process for public engagement and communication strategies with key stakeholders including those from a variety of sectors (public health, local government, public works, planning, agriculture, fisheries, chamber of commerce, etc.)

Recommendation 10: Establishselection criteria for the pilot communities based on the definition of vulnerability – including factors related to exposure, sensitivity, and adaptive capacity.

Recommendation 11: Identify gaps in current knowledge related to CCHVAAs and helps direct future research and data collection within the province.

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