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THE CASE FOR ADAPTING TO EXTREME HEAT

Costs of the 2021 B.C. heat wave

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EXECUTIVE SUMMARY

British Columbia's June 2021 heat wave was the deadliest disaster in provincial history, and when the costs of the 619 lives lost from heat exposure are included, it was also one of the most costly. It reinforced the importance of being prepared for extreme heat events and the responsibility of all orders of government to urgently implement adaptation measures to protect people, communities, and the economy before the next major heat wave sweeps across the province.

Extreme heat is going to get worse. Climate models indicate that sustained temperatures similar to the 2021 heat wave have a 10 per cent chance of reoccurring in B.C. within the next two decades (Philip et al. 2022). By mid-century, B.C. could experience temperatures similar to the heat wave an average of three out of every ten years if global greenhouse gas emissions are not substantially reduced.

B.C. is not the only part of Canada that will experience more frequent extreme heat. Although reducing greenhouse gas emissions is critical to limiting future warming, locked-in warming from past emissions means that over the coming decades, many parts of the country will see a substantial increase in the number of days where heat can harm people, communities, and the economy. For example, under a medium-warming scenario, southern Ontario will see a near doubling in the number of days over 30° C per year by mid-century (Zhang et al. 2019). In Whitehorse the number of days over 30° C are projected to increase from one day every decade, to two days every year by mid-century—a 20-fold increase. All regions of Canada will need to adapt to these changes or risk repeating the deadly and costly outcomes of B.C.'s 2021 heat wave.

All orders of government are still figuring out how to deal with climate change impacts. While a future of more extreme heat is inevitable, disasters on the scale of the 2021 heat wave are not. **Although each region's experience with heat is different, the B.C. heat wave offers important lessons for governments across Canada on how to prevent future extreme heat events from becoming disasters, and how to limit the impacts on people, communities, and the economy.**

Over the past year, the Canadian Climate Institute has analyzed the costs and impacts of the 2021 heat wave, with the central goal of identifying actions that could reduce the risk of a similar disaster happening again. To do this, we looked at the four largest heat wave impacts and costs: workplace safety and productivity, human health

BOX 1

What are "heat waves" and "extreme heat"?

In Canada and in B.C., the terms "heat wave" and "extreme heat" are both used to describe periods where temperatures are unusually high. However, neither term has an official or consistent definition, often leading to confusion. For the purposes of this report, we use the term "heat wave" to describe extended periods of dangerous heat that trigger heat warnings. In B.C. and across most of Canada, warnings about dangerous heat—where hot weather could result in illness or death—are usually issued when forecasts call for two or more continuous days with unusually hot daytime and nighttime temperatures. Because climates and vulnerabilities across Canada and within provinces and territories differ, the thresholds for "unusually hot" vary. For example, the heat warning threshold for Kelowna is a daytime high temperature of 35° Celsius (C) and a nighttime temperature high of 18° C, while in Prince Rupert it is 28° C for daytime and 13° C for nighttime (ECCC 2020).

However, prolonged exposure to hot temperatures that last less than two days or that do not cross temperature thresholds can also have negative effects on people, communities, and the economy. Therefore, for the purposes of this report we use the term "extreme heat" to refer to any period of dangerous heat, including heat waves.

and health systems, electricity and transportation systems, and food systems. We also modelled potential impacts of future temperature rise and the effectiveness of different adaptation actions to reduce those impacts.

Overall, we find that there was a constellation of factors that led to the impacts and costs of the 2021 heat wave, which were extensive. While the most severe impacts were related to the deaths of hundreds of people, communities and businesses across the province were affected in many ways, highlighting vulnerabilities that should be addressed through adaptation.

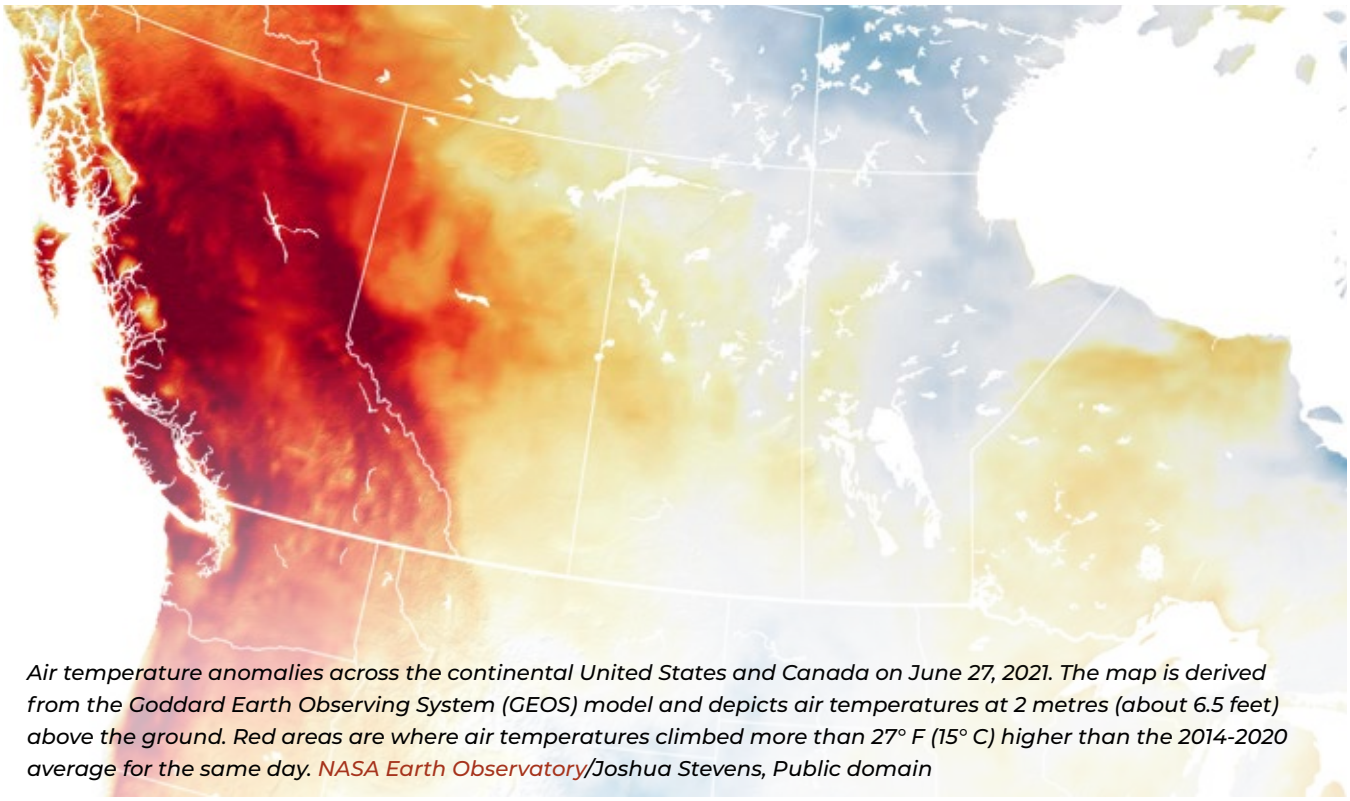
Our analysis and modelling led to **six key findings**:

1. **The 2021 heat wave was one of the costliest disasters in B.C. history when the cost of the lives lost is accounted for.** The most severe impacts of the 2021 heat wave were associated with the deaths of hundreds of people. We estimate that avoiding these deaths has an economic value of $5.5 billion dollars when based on the Value of a Statistical Life (See VSL Box, page 31). We also found that healthcare costs attributed to the heat wave amounted to $12 million.
2. **Broad uptake of mechanical cooling in homes and buildings, as well as urban planning, can save hundreds of lives in future extreme heat events and reduce healthcare costs.** The vast majority of people who died in the 2021 heat wave were exposed to extreme temperatures in homes without functional mechanical cooling. In addition, areas with a lot of asphalt and concrete surfaces and a lack of tree cover—often in socially and materially deprived neighbourhoods—experienced some of the hottest outdoor and indoor temperatures. Increasing mechanical cooling in homes and residential buildings, as well as urban greening efforts, can dramatically reduce heat-related deaths and deliver a substantial return on investment.
3. **Critical infrastructure, especially electricity infrastructure and health facilities, were pushed to the limit, highlighting the potential for future breakdowns.** During the heat wave, a number of hospitals became dangerously hot and had critical equipment outages. Further, while there were no widespread power outages, local heat-related electrical breakdowns suggest the potential for major system disruption. Not only will this have major economic implications for utilities and businesses, but it creates the risk that air conditioners, heat pumps, chillers, and fans will not have the power to run when people need them most.
4. **The impacts of the 2021 heat wave on B.C.'s economy were widespread but generally not as severe as other disasters, highlighting opportunities to proactively build resilience to a hotter climate.** The heat wave affected agricultural production, put workers at risk, and reduced economic productivity across many sectors. Further, agriculture producers alone lost at least $25 million in revenue from production declines. While not catastrophic, these impacts are significant and highlight the importance of protecting workers across all industries and, in particular, preparing B.C.'s agricultural sector for more frequent extreme heat.

5. **Institutional and policy gaps hindered B.C.'s response to the heat wave.** B.C. institutions and policies have not yet caught up to a changing climate and were not designed to effectively respond to a heat wave as long, severe, and widespread as the June 2021 event. As a result, communications and decision making did not provide rapid action, deployment of resources, and resolution of bottlenecks. These system-level challenges exacerbated capacity constraints and restricted the ability of individual agencies and actors to respond effectively.

6. **B.C.'s current approach to reviewing and understanding disasters like the 2021 heat wave is not optimized to support policy learnings and adaptive management.** While individual ministries, municipal governments, and health authorities have internally reviewed the events of the 2021 heat wave and have made recommendations for policy change, the relatively siloed nature of these reviews creates inefficiencies and undermines the ability of the Government of B.C. and other relevant actors to identify systemic issues and corresponding solutions.

Since the 2021 heat wave, various Government of B.C. departments and agencies made important changes to how disasters will be managed in the future. This includes starting to act on some of the recommendations from the BC Coroners Service. The Government of B.C. has taken important steps to improve emergency response to heat waves and public awareness, but many of the vulnerabilities we identified have not been fully addressed. The Institute's work indicates more needs to be done to protect people's health and reduce economic impacts of future extreme heat events.



Air temperature anomalies across the continental United States and Canada on June 27, 2021. The map is derived from the Goddard Earth Observing System (GEOS) model and depicts air temperatures at 2 metres (about 6.5 feet) above the ground. Red areas are where air temperatures climbed more than 27° F (15° C) higher than the 2014-2020 average for the same day. NASA Earth Observatory/Joshua Stevens, Public domain

Based on our findings, we identify six recommendations for what different orders of governments in B.C. and across Canada can do to reduce the impacts and costs of future extreme heat events. Although our recommendations are primarily intended for the Government of B.C., the lessons learned are relevant to communities and governments across Canada.

1. **The Government of B.C. and all health authorities should explicitly account for the human as well as financial costs of heat-related illness and death in policy cost-benefit analyses.** Extreme heat events are the deadliest form of climate-related disasters, but are often seen as lower priority by governments when they are considering adaptation investments, as they don't have the same tangible costs as other climate-driven events (i.e., flooding and wildfires). To capture the true costs of extreme heat events in order to make more informed policy decisions, the government should ensure that cost-benefit analyses include the human costs of illness and premature death using metrics such as Value of a Statistical Life (see VSL Box 3, page 31).
2. **Governments of all orders should urgently prioritize the targeted deployment of tools such as mechanical cooling and urban greening to help maintain safe indoor temperatures and protect lives.** To increase the use of mechanical cooling, governments should use tools such as building code updates, standards, and legislation to make homes and buildings safe for occupants during extreme heat events. To address equity-related issues and ensure that those who are most vulnerable to extreme heat are protected, those tools should apply to existing as well as new buildings, and policies should explicitly incentivise uptake for rental units. The Government of B.C. should also use mechanisms such as licensing and regulation to ensure that all government-run and licensed facilities do not exceed safe temperatures. Municipal governments should use mechanisms such as building permits to increase adoption of reflective roofing and green roofs, and invest in tree planting and enhancement of urban forest canopy.
3. **The Government of B.C. should build heat-related risk into critical infrastructure decision making and account for compounding hazards.** The government should prioritize adaptation investments that protect critical infrastructure from disruptions caused by extreme heat, such as building electricity systems that are resilient to rapidly rising demand, and incorporating climate-resilient road materials to reduce heat-induced rutting. The government should also update risk management processes and service capacity for critical infrastructure providers to ensure that services can continue when they are most needed.
4. **The Government of B.C. and provincial agencies should provide businesses and employers with the tools and information they need to protect themselves and their employees from extreme heat.** The government should update occupational standards to account for extreme heat while ensuring that there is adequate capacity to enforce these standards. In addition to updating these standards, the Government

of B.C. and WorkSafeBC should provide timely guidance to all industries about heat safety during extreme heat events to minimize workplace disruptions and harms to workers.

5. **Governments and public agencies should continue to address disaster response gaps and increase capacity to minimize impacts to people and the economy from extreme heat.** The Government of B.C. should collaborate with Meteorological Services Canada to increase investments in weather monitoring networks and deliver accurate public heat warnings three days in advance. The government and health authorities should also create a clear set of standards to guide activation of patient triaging and resource allocation if emergency medical demands exceed capacity. Health authorities should ensure that all staff are prepared to manage high patient inflows with tools such as upstaffing and pauses in outpatient procedures. The Government of B.C., health authorities, and municipalities should plan for multi-disasters—including combinations of climate-and non-climate related disasters. The Government of B.C. should proactively address institutional and policy gaps that restrict B.C.'s ability to respond effectively to disasters.
6. **The modernized Emergency Program Act should include requirements for independent and public reviews of disaster response and planning after major disasters to enhance accountability and support adaptive management.** The review should be automatically triggered based on clear thresholds such as number of deaths, displacements, or financial losses, and should give power to an independent body to access government records and conduct confidential interviews so that the strengths and challenges of disaster responses are thoroughly assessed.

1 INTRODUCTION

British Columbia's (B.C.) June 2021 heat wave drove home the human and economic stakes of being prepared for and able to adapt to extreme heat events. Between June 25 and June 30, sustained record temperatures across the province resulted in 619 people dying directly from heat. This heat wave was the deadliest disaster in provincial history and was also one of the most costly, when the economic value of lives lost is included.

This report builds on provincial, municipal, and health authority reviews of the 2021 heat wave. Through research and interviews with those directly involved in the response, we identify characteristics of the policies, institutional practices, and physical systems that made B.C. vulnerable and contributed to the human and financial costs that made this extreme heat event a disaster.

We began our review by assessing the actual impacts of the 2021 heat wave on people, communities, and the economy. We then modelled the potential future impacts of rising temperatures and more frequent extreme heat, as well as the effectiveness of different adaptation recommendations to reduce those impacts. Based on this analysis, we recommend six actions that would reduce the impacts and costs of future extreme heat events.

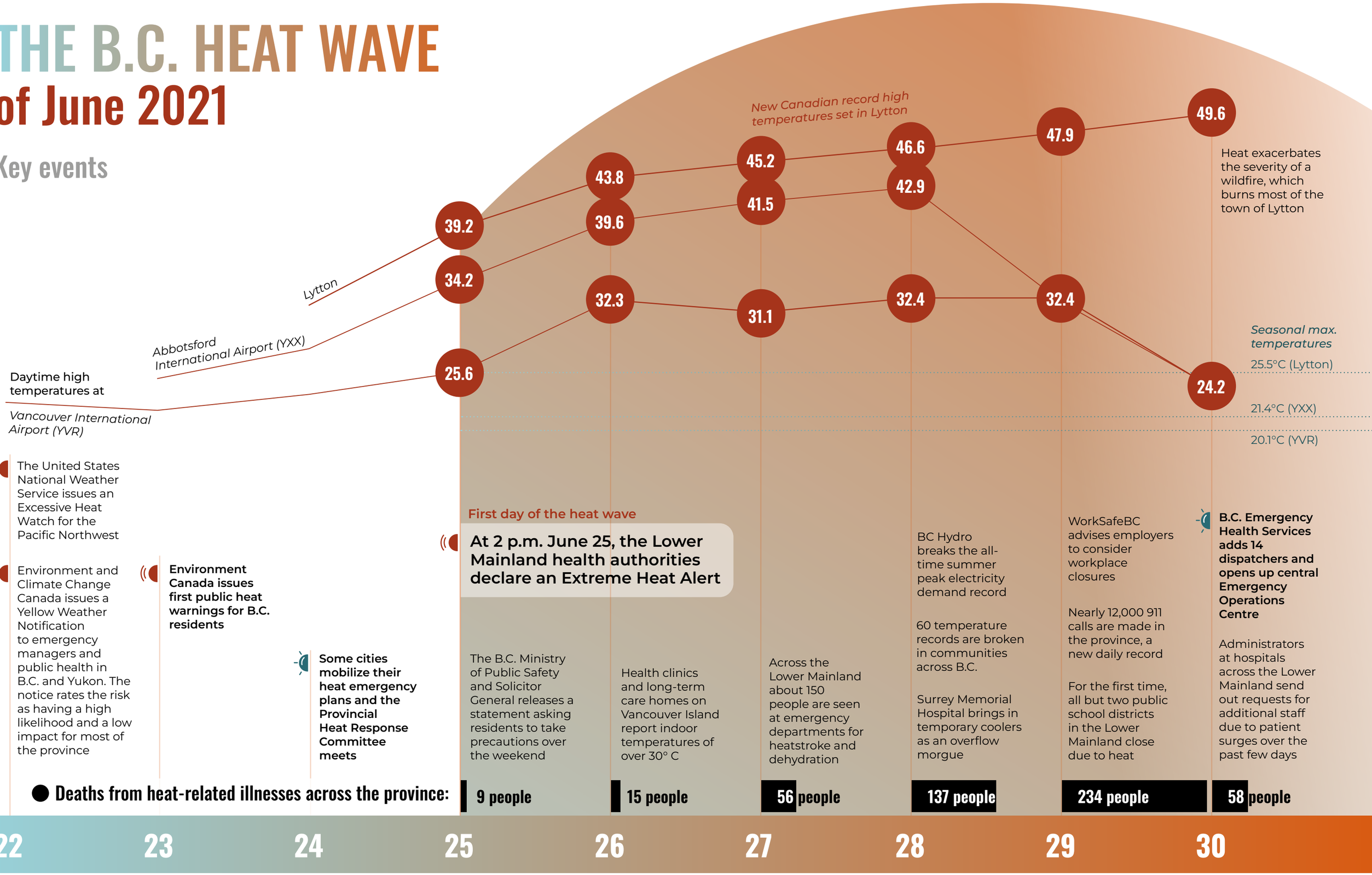
Although our recommendations are primarily intended for the Government of B.C., the lessons learned are relevant to communities and governments across Canada. Over the past 50 years, extreme heat events have been among the deadliest disasters across Canada (Vanderplanken et al. 2021) and they are growing in frequency and intensity.

After providing contextual information about heat waves in B.C., the remainder of this report is organized into the following sections:

- **SECTION 2** describes the approach we took to analyze impacts and costs of the heat wave.
- **SECTIONS 3 THROUGH 6** describe our findings on the impacts, costs, and potential of adaptation interventions for each of the following impact areas: workplace safety and productivity, human health and health systems, electricity and transportation systems, and food systems.
- **SECTION 7** summarizes our key findings and outlines recommendations to enhance resilience to future extreme heat events in B.C.

THE B.C. HEAT WAVE of June 2021

Key events



Heat waves in British Columbia

B.C.'s 2021 heat wave response was affected by multiple factors. These include a policy context that left people and systems vulnerable to extreme heat, and the co-occurrence of other events that put additional strain on the health and emergency response systems, including the COVID-19 pandemic and the 2021 wildfire season. In addition, the province's physical geography, history, and demographics influenced how the heat wave affected people and communities.

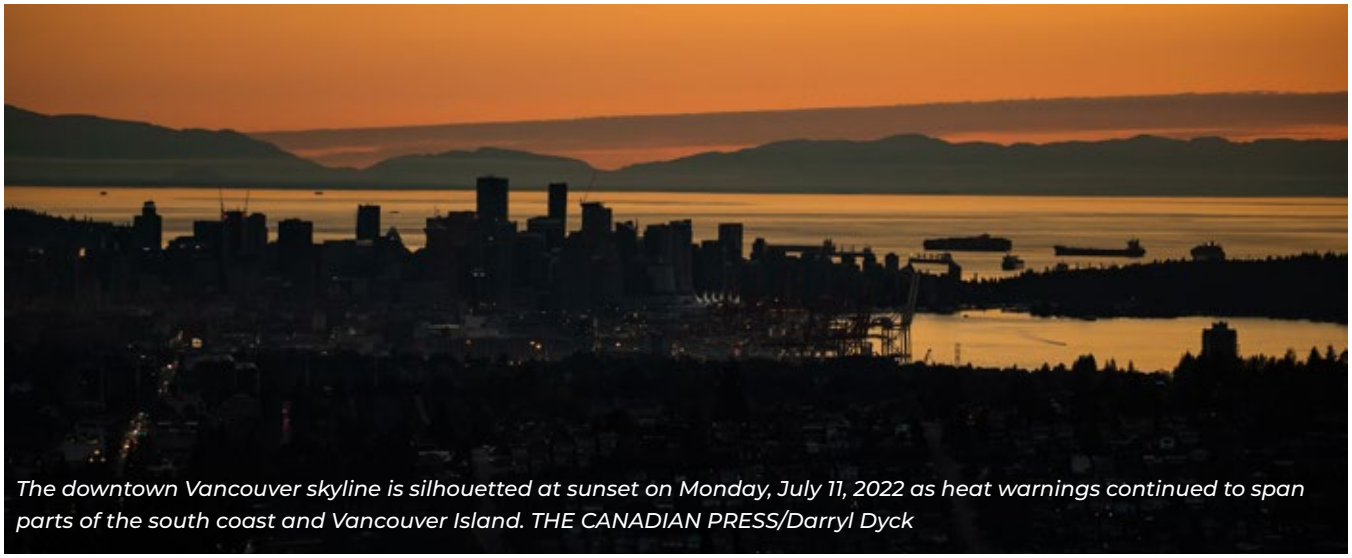
B.C.'s physical geography leads to different impacts across the province

B.C. is the third-largest province in Canada and has a diverse geography. The province is marked by vast mountain ranges, a variety of ecosystems, and 27,000 kilometres of coastline that results in significant climatic variations. For example, average daytime summer temperatures in coastal communities are approximately 20° C, whereas the interior and central regions often experience daytime highs of over 30° C in July (Government of British Columbia 2023a). B.C. also has some of Canada's wettest and driest climates (Government of British Columbia 2023a; Natural Resources Canada 2015). This geographic context means that communities across the province have diverse relationships to heat and are affected differently (Berry et al. 2015).

B.C.'s demographics highlight vulnerabilities to heat

Approximately 85 per cent of B.C.'s population lives in urban areas, with more than 60 per cent of people concentrated in the Lower Mainland (WorkBC 2022; Statistics Canada 2023a). A higher percentage of people live in cities and towns than in any other province in Canada (Statistics Canada 2022d). With 20 per cent of B.C.'s population over 65, the province also has the oldest population west of Quebec (Statistics Canada 2022c). Twelve per cent of all B.C. residents live alone, and nearly 11 per cent of B.C. residents live in low-income households (Statistics Canada 2023b). All of these factors are associated with increased vulnerability to extreme heat (BC HEAT Committee 2022).

Since time immemorial, Indigenous communities have lived across what is now known as B.C. There are 204 First Nations communities and 39 chartered Métis communities in B.C., though many communities travel and trade across the colonial border, which bisects some traditional territories (BC Assembly of First Nations 2023; MNBC 2023). The majority of Indigenous People in B.C. (78 per cent) live in urban and off-reserve areas (Government of British Columbia 2023b).



The downtown Vancouver skyline is silhouetted at sunset on Monday, July 11, 2022 as heat warnings continued to span parts of the south coast and Vancouver Island. THE CANADIAN PRESS/Darryl Dyck

Climate change, including extreme heat, has inequitable impacts on Indigenous communities and their traditional territories (Gifford et al. 2022; National Collaborating Centre for Indigenous Health 2022). For example, because of past and present policies, a disproportionate percentage of Indigenous People in B.C. (40 per cent) are unhoused or live in precarious housing conditions that are not conducive to protection from extreme weather (Homelessness Services Association of BC 2021). Indigenous People also experience higher rates of chronic diseases that increase vulnerability to heat (Indigenous Services Canada 2018). Extreme heat can also negatively affect the quality and availability of traditional foods (Section 6).

The future of extreme heat in B.C. will be very different than the past

Extreme heat is not new to B.C., but it is intensifying and becoming more frequent due to climate change (Gifford et al. 2022). Between 1911 and 2009, there were 13 documented events with maximum daily temperatures at least 10° C above seasonal averages in the Pacific Northwest (Bumbaco et al. 2013). In the last 10 years, B.C. has seen an additional three events that meet these criteria, in 2014, 2021, and 2022 (Government of British Columbia 2022a; The Canadian Press 2014; BC Coroners Service 2022). Further, the number of days per year with a maximum temperature over 30° C increased by an average of 3.3 days between 1948 and 2016 (Vincent et al. 2018).

Prior to 2021, the most damaging heat wave on record in B.C. occurred in 2009 where an estimated 114 people died from heat exposure across Metro Vancouver alone (Henderson et al. 2016). The heat wave's costs, including gross domestic product (GDP) losses, select health costs, and electricity-related impacts, amounted to approximately $155 million (2022 dollars) (Stewart et al. 2017). When the value of the lives lost is included (see VSL Box 3, page 31), the costs increase to more than $1.2 billion. The 2009 heat wave prompted some municipalities, health authorities, and the Government of B.C. to increase planning for extreme heat. For example, the BC Centre for Disease Control (BCCDC) and Environment and Climate Change Canada (ECCC) collaborated to develop heat alert thresholds for the Lower Mainland, above which public health measures are activated, such as opening cooling centres (McLean et al. 2018).

Despite a history of damaging extreme heat events in the province, heat has not widely been considered and prioritized as a major risk by governments across the province. In 2017, the BC Centre for Disease Control evaluated heat wave planning and readiness among the province's municipalities. Their report found that the risk of extreme heat was generally not considered a priority by most municipalities and health authorities (BCCDC 2017). This lack of prioritization is noteworthy given the Government of B.C.'s 2019 strategic climate risk assessment identified heat waves as the third highest climate risk to the province. (B.C. Ministry of Environment and Climate Change Strategy 2019).

While episodic heat waves and extreme heat are inherent to B.C.'s climate, temperatures during the 2021 heat wave had not been experienced in recorded history, and climate change made the 2021 heat wave at least 150 times more likely to occur (Philip et al. 2022). Daytime high temperatures in the province were 15° C to 25° C above the historic average for that time of year, and night temperatures did not fall below 20° C on some nights (ECCC 2021). The 2021 heat wave was at least five degrees hotter on average than the 2009 heat wave in most areas of the province (Government of British Columbia 2022b). Unlike other recent B.C. heat waves, the 2021 event occurred early in the summer, so people were less likely to be acclimatized to hotter summer weather that typically occurs later in the season, and were therefore less protected from its effects on health (ECCC 2021).

Debris-covered houses and businesses that were destroyed by the 2021 wildfire are seen in Lytton, B.C., on Wednesday, June 15, 2022. THE CANADIAN PRESS/Darryl Dyck

2 OUR APPROACH

Our objectives in undertaking an assessment of the B.C. heat wave were to both define the associated costs and impacts and articulate a baseline scenario for future costs if adaptation is not scaled up.

In this section we describe the steps we took to analyze the impacts of the heat wave and evaluate associated adaptation options for future extreme heat events. Our analysis included five steps:

1. **Identifying focal impact areas**
2. **Examining the impacts and costs of the 2021 heat wave**
3. **Connecting heat wave outcomes to the policy and institutional landscape**
4. **Estimating the potential costs of future extreme heat events for B.C.**
5. **Analyzing the costs and benefits of potential adaptation interventions**

STEP 1: Identifying focal impact areas

We used two criteria to select focal impact areas for our analysis: the economic magnitude of the impact and our ability to quantify impacts and costs across B.C. based on publicly available or accessible data.

For both Step 1 (identifying focal impact areas) and Step 2 (examining impacts and costs), we reviewed information from reports, academic articles, interviews, freedom of information disclosures, and data provided by the Government of B.C. Based on our review, we identified four focal areas where the heat wave had the most significant impacts:

- Workplace safety and productivity
- Human health and health systems
- Electricity and transportation systems
- Food systems

Due to a lack of available data, we excluded ecosystem impacts. We also excluded other focal impact areas for which there was insufficient evidence, including impacts of extreme heat on interpersonal and domestic violence, ports, and tourism. Further, to manage the scope of our work, we did not analyze non-heat hazards, such as wildfires and floods, though we highlight connections between these events where relevant.

STEP 2: Examining the impacts and costs of the 2021 heat wave

After selecting focal impact areas, we identified specific impacts within each area and calculated the costs of the heat wave based on the information and resources discussed in Step 1. Wherever possible, we also estimated the costs associated with these impacts, with all costs presented in 2022 Canadian dollars. We also characterize some impacts qualitatively, as it was not possible or appropriate to monetize all impacts. Specific costing methods are described in each section.

STEP 3: Connecting heat wave outcomes to the policy and institutional landscape

A central goal of the research was to understand the drivers behind the costs and impacts of the 2021 heat wave in order to improve future responses. The identification of principal contributing factors of a disaster is core to disaster risk reduction (UNDRR 2015).

We based our assessment on frameworks commonly used in post-disaster analysis (Burton 2010; Masys 2016; Mendoza et al. 2019; Oliver-Smith et al. 2016). Our approaches for the event reconstruction were also informed by procedures used for aviation crash investigations (ICAO 2011). We focused specifically on characteristics and vulnerabilities of physical systems and institutions because they frequently have a major influence on disaster outcomes and costs (Hewitt 1983; Cutter 2012; MacClune et al. 2014).

For each of the four focal impact areas, we identified how vulnerabilities affected the impacts and costs. To do this we reviewed provincial and regional emergency response plans, conducted in-depth interviews, and examined information obtained by various individuals and organizations under B.C.'s Freedom of Information and Protection of Privacy Act. We analyzed the data by asking the following questions (Table 1).

Table 1:

Questions used to analyze the data collected from our literature review and interviews

Physical Systems	Institutions
• How did the heat wave impact physical infrastructure? • Were there infrastructure failures or near-failures? • Were there redundancies if a failure happened? • Did physical infrastructure get adapted or end up serving a different purpose than intended? • If physical infrastructure failed, did it fail as expected? Did it fail safely? • How quickly were infrastructure disruptions restored? • Were risks and hazards anticipated when the infrastructure was built?	• What heat wave impacts were the most consequential to different organizations and why? • How did rules, laws, norms, and institutional structures affect the responses of different organizations and ultimate outcomes? • How effective was communication during the event? How would the impacts have changed if internal communications had been different? • Was upper management aware of operational realities? • Did the organization have difficulty in anticipating events? • Was there a conflict between informal norms (e.g., unwritten practices) and formal procedures? • Were groups of the population affected differently and, if so, why? • How did emergency responders, asset managers, and decision makers react to the heat wave? What actions were taken and when? • What long-term impacts, if any, did staff experience during or after responding to the event?

To identify important policy and institutional factors, we spoke to more than 50 individuals with expertise in extreme heat or our focal impact areas, some of whom were involved in the impact analysis (i.e., Step 2) (Table 2). We selected interviewees three ways: individuals listed as authors or contributors in publications we reviewed; a review of government organizational charts to identify relevant actors; and through recommendations from other interviewees.

STEP 4: Estimating the potential costs of future extreme heat events for B.C.

We modelled future impacts of extreme heat in three of the four focal impact areas, and estimated the cost of those impacts where there was sufficient quantitative evidence to calculate future costs. We synthesized existing evidence to analyze potential future impacts qualitatively in some focal impact areas (Table 3). Specific future costing methods are described in each respective section.[2]

Table 2:

Individuals interviewed for this report

Organization	Number of people interviewed
Government of B.C., including ministries, agencies, and Crown corporations[1]	21
Regional and provincial health authorities, First Nations Health Authority, and BC Emergency Health Services	12
Hospital staff, first responders, or physicians	5
Trade organization or unions	4
Federal, municipal, and Indigenous governments	3
Academic or private sector experts, and business owners	10
Total	**55**

July 29, 2021: people line up for Second Beach Pool in Stanley Park to try to keep cool during the heat wave.

[1] Government of B.C. interviewees were affiliated with a number of ministries, agencies, and corporations (Ministry of Health, Ministry of Public Safety and Solicitor General, Ministry of Agriculture and Food, Ministry of Water, Land and Resource Stewardship, WorkSafeBC, BC Hydro, and others)

[2] For further details, see technical report.

Focal impact areas

Table 3:

Summary of our focal impact areas, impacts, methods for future estimates, and future costs

Focus area	Impacts[3]	Method for future estimates	Future costs
Workplace safety and productivity	• Workplace safety issues • Labour supply and productivity losses	• Modelled labour supply and impacts	• Change in labour productivity and compensation
Human health and health systems	• Direct heat-related deaths • Emergency room visits and hospitalizations	• Modelled unexpected deaths and hospitalizations	• Welfare losses associated with heat-related deaths • Heat-related hospitalization costs
Electricity and transportation systems	• Damage to transformers and power lines • Higher electricity demand • Increased wear on roads • Flight disruptions	• Modelled impacts to electricity systems and electricity demand • Qualitative analysis of temperature impacts on flight disruptions	• Electricity system repair costs • Electricity system investments to meet new demand • Road repair costs • Rail transportation disruptions
Food systems	• Crop losses and livestock deaths • Impacts to marine life • Impacts to traditional foods	• Qualitative analysis of temperature impacts on agriculture	• Not enough quantitative evidence to calculate future costs

To model the future impacts of climate change in the four focal impact areas, we first needed to understand what Canada's future climate may look like. Studies of climate change impacts typically draw on global circulation models that project future climate conditions based on global greenhouse gas emissions. These models provide a range of possible future climates. This is because there are many ways to represent the complexity of the global climate system, as well as the uncertainty about societal and policy choices that determine future greenhouse gas emissions.

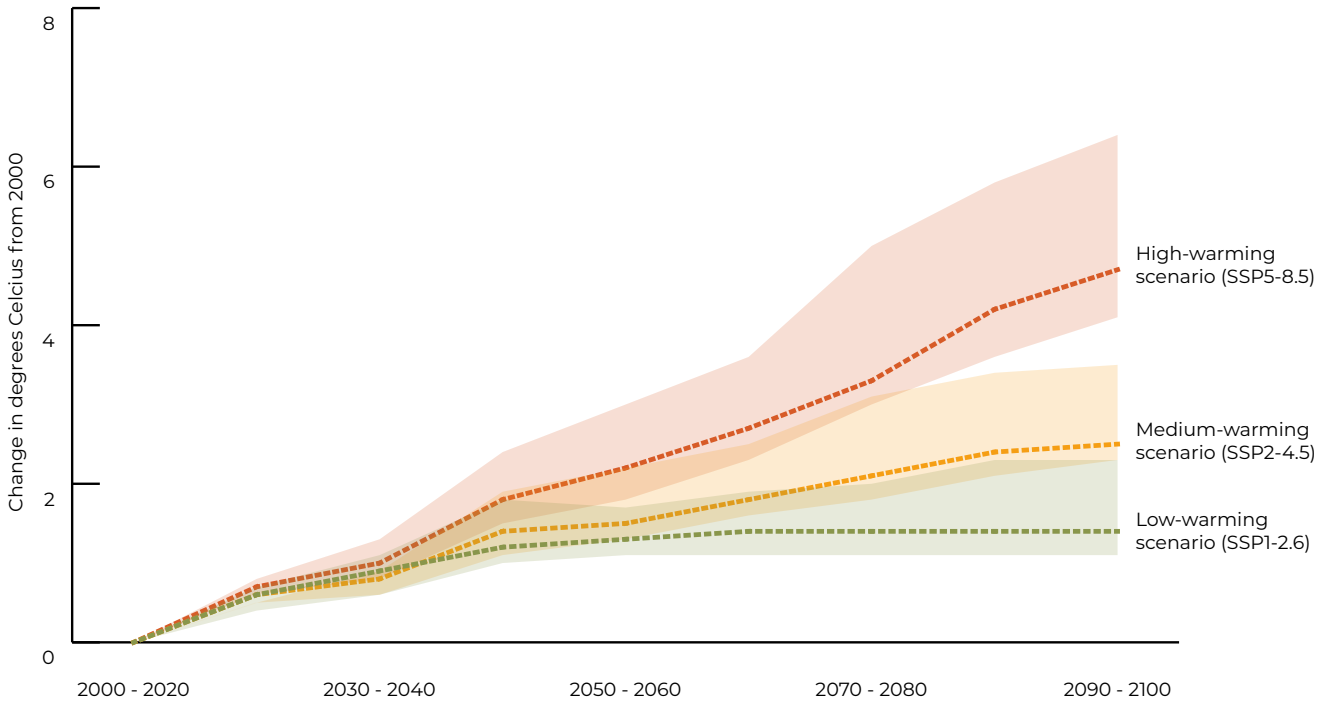
We used the data from five different global circulation models to capture a range of potential future climates in Canada[4] (Figure 1). We first assessed impacts and costs using daily temperature data from a "high-warming" scenario (SSP5-8.5) (IPCC 2021). Next, we evaluated impacts under a "medium-warming" scenario (based on the SSP2-4.5 scenario) by adjusting outcomes based on the projected temperature profile.[5] When we ran our analysis in late 2022, the greenhouse gas policies and actions that had been set by countries around the world were only likely to limit warming to around 2.7° C—moderately warmer than the medium-warming scenario (Climate Action Tracker 2022).

[3] The costs in Table 3 pertain only to direct heat impacts, not the costs of additional disasters to which heat contributes, such as droughts and wildfires.
[4] For further details, see technical report.
[5] We did not run the full models for a medium-warming scenario (i.e. SSP2-4.5) to reduce the required computing power. The practice of adjusting high-warming impacts down to other radiative-forcing scenarios is an increasingly common practice.

Figure 1:

Projected change in temperature in Vancouver based on warming scenarios

Projected changes in annual temperature (° C) for Vancouver using the five global circulation models and under the three warming scenarios referred to above.



For roads only, our modelling examined the impacts of changing precipitation and freeze-thaw cycles in addition to heat exposure.

STEP 5: Analyzing the costs and benefits of potential adaptation interventions

Finally, we assessed the costs and benefits of select adaptation interventions that governments can make to be better prepared for future events. Adaptation covers a broad suite of policy interventions and actions to reduce climate impacts on individuals, communities, and the economy. Adaptation actions can include local, community-driven actions, such as forming networks to check on elderly neighbours, to individual actions to improve resilience to extreme weather, such as installing a heat pump to keep one's home at a safe temperature. Our primary focus in this report is on specific adaptations that governments can facilitate through policy and governance interventions, such as increasing the uptake of mechanical cooling, reducing urban heat island effects, and improving disaster preparedness and response processes.

To analyze costs and benefits of select adaptation interventions, we first assessed policies and actions that are discussed in the heat wave literature and by international adaptation tracking assessments. Next, we examined which interventions would address the vulnerabilities we identified in Step 3. Finally, we narrowed our focus based on which policy outcomes had established quantitative relationships between heat exposure and health impacts. This was necessary for us to model the effectiveness of adaptation actions. To calculate the costs and benefits of each adaptation intervention, we re-ran our impact-cost models with a new set of exposure and temperature assumptions informed

by the estimated effectiveness of the intervention. We then calculated the benefits of each adaptation scenario—given by the difference in impacts and costs under the future high-warming scenario with and without the adaptation actions adopted. Finally, we calculated the return on investment for a few of the adaptation actions for which adaptation costs could be estimated using a standard discounted cash-flow analysis.

Scope and limitations

This report was commissioned by the Government of B.C. to define the impacts and economic costs of the 2021 heat wave, the factors that contributed to those impacts, and the costs and benefits of adaptation interventions that could reduce them in the future. Given this scope, our analysis focused on policy interventions where there is sufficient quantitative evidence to estimate effectiveness.

As quantitative analysis alone may not adequately capture details about context and individual experiences and decisions, we also used qualitative evidence from expert and government interviews to select focal impact areas, identify vulnerabilities, fill some evidence gaps, and provide additional context.

Our analysis relied on publicly available evidence from peer-reviewed studies, government reports and records, and online databases, as well as information provided directly by provincial government departments and agencies. There may be additional information about costs and impacts of the heat wave that we did not have access to.

Further, there are additional proactive or "upstream" interventions—such as improving access to mental health service or transforming agricultural practices—that were beyond the scope of this analysis but that may deliver substantial benefits. More primary research into how these types of interventions can reduce health or other risks is needed before their benefits can be quantified.

Quantitative climate change risk assessment, economic impact, cost-benefit, and policy analysis methods are useful to characterize many aggregate economy- or society-wide effects and outcomes. But these methods often do not capture important details about how different people experience impacts, how they are affected by policies, and why they behave and respond in certain ways. Quantitative analyses can also reinforce a focus on monetary, market-based valuation, which obscures

Thursday July 29, 2021: Wildfire smoke fills the air in Sicamous B.C. as people take part in outdoor activities, even though the air is 18 times above WHO exposure recommendations. THE CANADIAN PRESS/Jason Franson

different values, perspectives, and worldviews including those of marginalized and equity-deserving groups.

The story of what happened during the B.C. heat wave is ultimately a story about how people's lives were impacted. Therefore, in addition to quantifying impacts and their costs, we used qualitative research methods to gain insight into not just what happened, but why.

We interviewed individuals responsible for emergency and government response, such as healthcare workers and government officials, and those who observed impacts firsthand, such as affected business owners and agricultural producers. This qualitative data was critical for analyzing the different heat emergency impacts and why systems didn't always protect people, communities, and the economy.

We did not speak directly with people who were disproportionately impacted by the heat wave, such as elderly people who are isolated, people suffering from chronic health conditions and mental illness, and people living in public housing and institutions. Nor did we interview individuals whose health was seriously impacted or threatened during the disaster. More work is also required to understand the first-hand experience of community leaders, first responders, healthcare providers, and government officials who were working under extreme pressure and making life-and-death decisions. The perspectives of these groups need to be further documented to inform decisions on how to prevent the recurrence of a disaster at the same level of the 2021 B.C. heat wave.

Finally, while we discuss some non-economic impacts as well as justice and equity dimensions of extreme heat, a comprehensive engagement process with equity-deserving communities, especially Indigenous communities, was beyond the scope of this report. The focus of our analysis was on adaptation interventions relevant to the Government of B.C., regional health authorities, and municipalities. In implementing these or other adaptation actions, governments and agencies should engage with Indigenous leaders, rights holders and those most directly affected by extreme heat to ensure that their needs and perspectives are considered and that those actions do not create further harm or exacerbate systemic vulnerabilities.

A utility worker carries out repairs on a transformer connected to an 11,000 volt power line.

3 WORKPLACE SAFETY AND PRODUCTIVITY

In this section, we first describe the impacts of the 2021 heat wave on workers and then the potential impacts of future extreme heat events on labour productivity. We then describe vulnerabilities that influence how extreme heat affects workers and productivity. Finally, we analyze the costs and benefits of select adaptation actions.

Workplace safety and productivity impacts and costs

The 2021 heat wave imposed costs on workers and employers in several ways, including heat-related injuries and stress leading to lost income, closure of services leading to missed work, and lower labour productivity. The costs affected both employees and B.C.'s economy.

Workplace heat-related injuries and stress increased during the 2021 heat wave

Extreme heat is associated with increased injuries in the workplace (Adam-Poupart et al. 2021). Data from WorkSafeBC[6] shows that heat-related workplace injuries requiring compensation increased by 180 per cent during the heat wave when compared to the previous three-year average (WorkSafeBC 2022b). The average cost of heat-related workplace claims in the entire year of 2021 was $2,800 per worker—62 per cent of these claims were filed between June 25 and July 7 (WorkSafeBC 2023; WorkSafeBC 2022b).

Workers in outdoor industries typically have a higher risk of heat-related workplace illness because of longer exposure to heat, little control over workplace temperature, and the strenuous nature of the work (Gosselin et al. 2022; Weinberger et al. 2023). However on June 28, 2021, WorkSafeBC warned employers for the first time that "all workers are potentially at risk", reflecting an increasing concern about indoor industries (WorkSafeBC 2021). The data supports this: over a third of the heat stress claims in 2021 were from workers who primarily worked indoors (e.g., restaurant kitchens, warehouses), compared to approximately 20 per cent of indoor industry claims on average in previous years (Weinberger et al. 2023; WorkSafeBC 2022b).

[6] The Workers' Compensation Board of BC (WorkSafeBC) is the provincial agency that provides compensation for workers injured on the job and promotes the prevention of workplace injury, illness, and disease.

BOX 2

Migrant labourers are especially vulnerable to heat

Migrant workers in the agricultural sector are especially vulnerable to extreme heat due to the strenuous nature of their work, long hours, and crowded accommodations (Cohen 2019; Lee and Parfitt 2022; Employment and Social Development Canada 2022). The majority of temporary foreign workers in Canada's agricultural sector are in B.C. In 2021 there were over 10,000 migrant workers in the province (Statistics Canada 2022a). A 2021 survey of temporary foreign workers in the Canadian agricultural sector found that 43 per cent have no access to air conditioned or cooled accommodations (Employment and Social Development Canada 2022). The 2021 heat wave forced some produce farms to cancel work shifts, and tree fruit farms modified their harvesting time to after midnight to reduce heat stress on workers (B.C. Ministry of Agriculture and Food 2021b; 2021c). Media also reported potentially unsafe living conditions among migrant farm workers in the Okanagan region due to a lack of air conditioning and fans (Penticton Western News 2021).

Victoria B.C.: Migrant farm workers hoe weeds in a field of produce.

Workplaces and other facilities closed leading to potential lost income, reduced services, and diminished economic output

The 2021 heat wave led to temporary workplace, school, and childcare closures across B.C. Numerous restaurants, factories, breweries, retail outlets, offices, and recreational facilities voluntarily shut down or reduced work hours (Burchell 2021; Judd 2021a; CBC News 2021; McLean 2021; McIntyre 2021; Bethlehem 2021; Ghoussoub 2021). Most of these closures occurred in the Lower Mainland and on Vancouver Island in spaces without mechanical cooling or with ventilation and air conditioning systems that had malfunctioned because of overuse (Government of British Columbia 2022b). The B.C. Construction Safety Alliance also stated that on June 29 at least 30 construction contractors across B.C. slowed or stopped construction (McIntyre 2021).

Ten out of twelve public school districts in the Lower Mainland closed on June 28 (Holliday 2021)—the first time schools in the region closed due to extreme heat (Judd 2021b). Although we do not have data on the number of childcare facilities that closed, reports indicate that daycare and school closures impacted healthcare staffing (Government of British Columbia 2022b; Vancouver Coastal Health and Fraser Health 2022; FOI:VCH-2022-F-108).

Labour productivity decreased due to heat-related fatigue and the need for more breaks

High temperatures at workplaces are associated with productivity declines. Studies show that workers must take longer breaks, work fewer hours, and/or slow down to avoid fatigue in response to extreme heat (Varghese et al. 2018; Vanos et al. 2019; Kabore and Rivers 2023). This can have broad economic impacts. One study estimated that the GDP losses of the 2009 B.C.

heat wave were approximately $50 million (equivalent to $64 million in 2022 dollars) (Stewart et al. 2017). An analysis for the 2021 heat wave estimates that workers lost between $205 million and $328 million in income (based on an estimated 40 to 60 per cent reduction in hours worked during a four-day period) (Lee and Parfitt 2022).[7]

Heat impacts on productivity also affected critical services including healthcare and public safety services. The Vancouver Coastal Health and Fraser Health authorities documented several productivity impacts during the 2021 heat wave. For example, healthcare staff experienced heat stress while commuting and travelling on the job throughout Vancouver, particularly those relying on transit, walking, or biking (Vancouver Coastal Health and Fraser Health 2022). As a result, work efficiency declined due to fatigue causing delays for staff travelling to see clients, and staff required more time to care for patients (e.g., extra bathing tasks). The BC Wildfire Service also reduced work hours for frontline staff (Government of British Columbia 2022b).

Prolonged exposure to heat, including high overnight temperatures, exacerbates heat-related fatigue for workers (McInnes et al. 2017; Legault et al. 2017). Interviews with provincial agencies and employers confirmed that many workers had difficulty finding relief after work. This is partly because of high night temperatures, which did not fall below 20° C during part of the heat wave (ECCC 2021). Limited access to home mechanical cooling was also a factor; in 2021, 64 per cent of households in B.C. did not have air conditioning (Statistics Canada 2023d). This meant workers were exposed to heat for longer periods of time than in previous years, including at home, further decreasing labour productivity and compounding the dangers of heat exposure at work.

Workplace safety and productivity vulnerabilities

We documented several barriers to heat adaptation in the workplace related to physical systems and institutions (Table 4.)

Table 4:

Workplace safety and productivity vulnerabilities that contributed to 2021 heat wave impacts

Physical systems	Institutions
• Lack of workplace cooling infrastructure	• Limited institutional guidance on how to prevent heat stress among workers • Heat safety information was insufficient for employers and workers • Potential lack of capacity to enforce occupational standards

[7] The sectors included in this analysis were automotive repair and maintenance, food and drinking services, social services and childcare, manufacturing, construction, and agriculture.

Insufficient workplace cooling infrastructure exacerbated risk

Provincial regulations require employers to keep indoor temperatures and humidity levels within acceptable comfort ranges set by WorkSafeBC (WorkSafeBC 2005a). However, we found that numerous employers across the province did not maintain a safe temperature range during the 2021 heat wave, in part because of a lack of adequate workplace cooling infrastructure. As of 2019, 37 per cent of commercial and industrial BC Hydro accounts did not have air conditioning in at least some portion of their enclosed space (BC Hydro 2019).

WorkSafeBC also indicated that workers in buildings without adequate cooling and ventilation systems were at a higher risk of heat-related injuries during the 2021 heat wave (WorkSafeBC 2022b). Interviews with provincial agencies support this finding, highlighting that a lack of cooling infrastructure prevented some workplaces from operating safely.

Workers and employers had incomplete knowledge and awareness of heat risks

Interviews with government agencies and a Freedom of Information disclosure from WorkSafeBC show that employers and workers were uncertain about safe temperature rules, did not always know how to protect staff from heat, and were surprised by how heat affects worker safety and productivity (FOI:WCB-2022-1333). Between June 28 and June 30, WorkSafeBC received an average of 400 calls per day compared to an average of 100 calls in the same period in 2018 and 2019 (FOI:WCB-2022-1333). Seventy-nine per cent of these calls were questions from employers, workers, and customers—many were about what temperature threshold should trigger a workplace's closure, and how to keep workplaces safe without mechanical cooling. On June 28, WorkSafeBC advised employers to "consider workplace closures during the heat wave" (WorkSafeBC 2021). But workplace closures are not always an option—there were essential service workers that had to spend time outdoors, like paramedics and firefighters, who experienced health and productivity impacts during the heat wave.

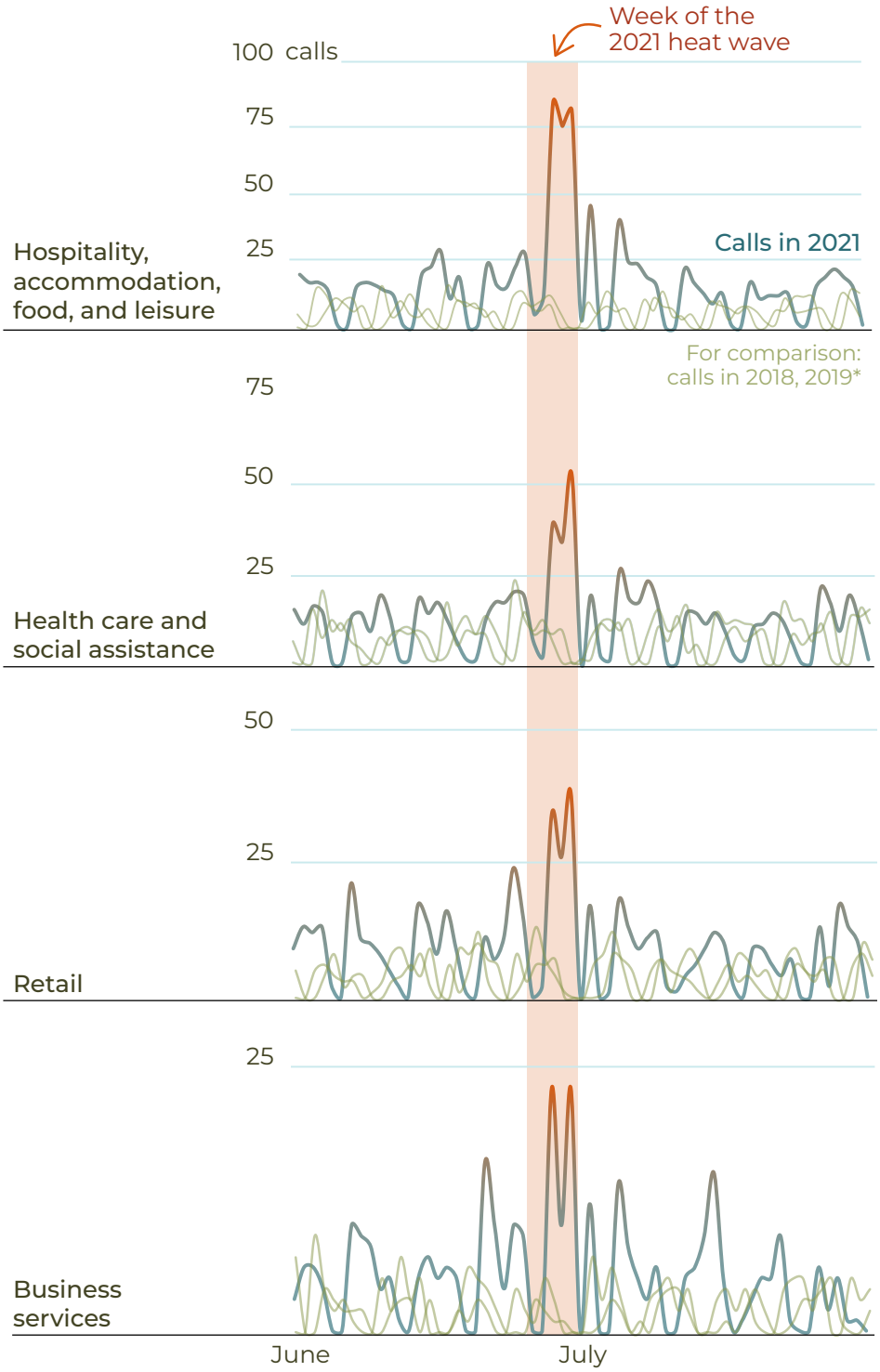
The average number of calls to WorkSafeBC was especially high for indoor workplaces. Calls from accommodation, food, and leisure services workplaces increased by approximately seven times during the 2021 heat wave compared to the same period in previous years, while calls from healthcare and social assistance workplaces increased by about five times (Figure 2). This points to knowledge gaps in occupational heat safety among industries that historically have little experience with extreme heat.

Workers in buildings without adequate cooling and ventilation systems were at a higher risk of heat-related injuries during the 2021 heat wave.

Figure 2

Calls to WorkSafeBC rose significantly during the heat wave.

Calls were high for indoor workplaces as they had little experience keeping employees safe in extreme heat



*Data from 2020 was not included because the COVID-19 pandemic dramatically affected WorkSafeBC call volumes, making it difficult to make comparisons.

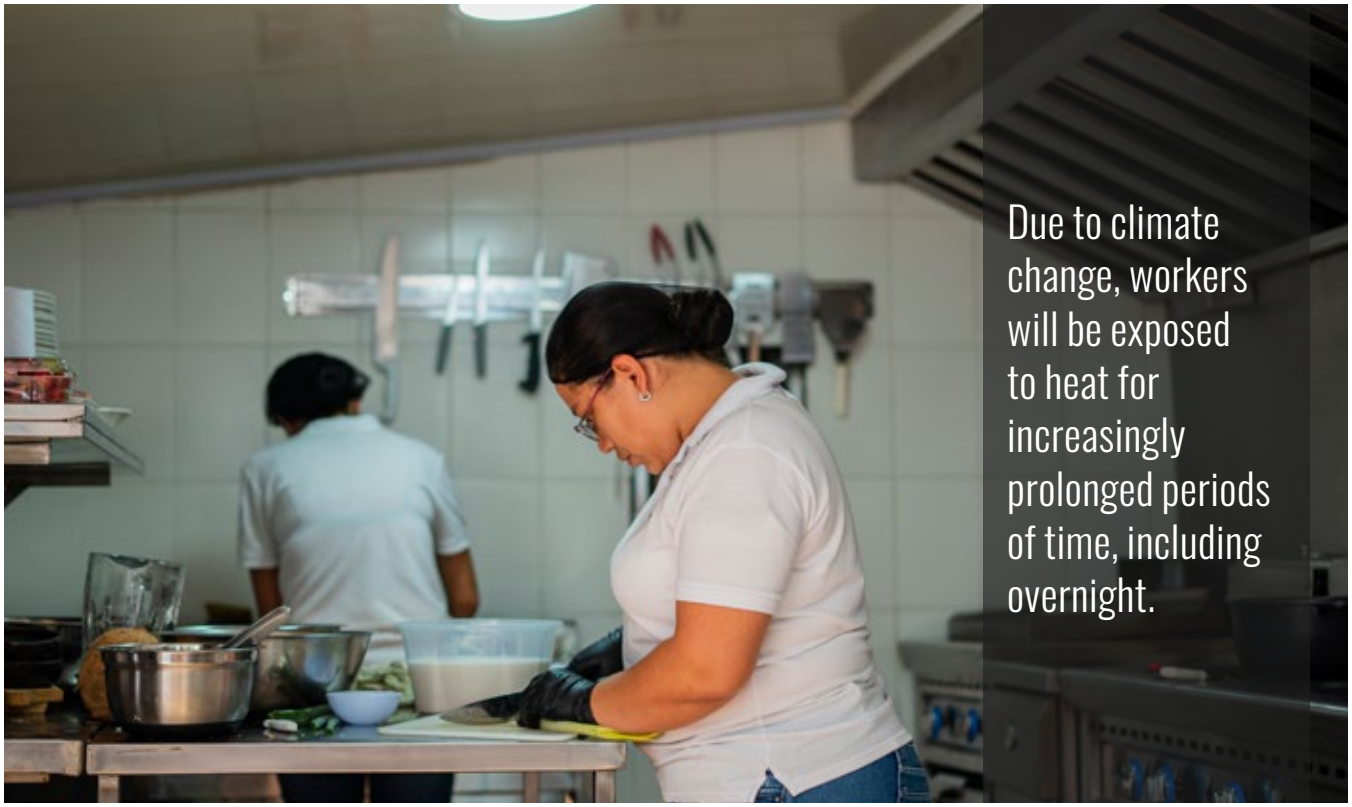
Source: WorkSafeBC 2022

Guidance and enforcement of workplace heat-response was inconsistent

Research has shown that workplace heat standards are more likely to be followed if they are simple, concise, and consistently communicated by employers (Vanos et al. 2019; McInnes et al. 2017; International Labour Organization 2019). However, many B.C. employers found occupational standards on preventing heat stress to be confusing and inconsistent. Interviews with government agencies and employers revealed that current institutional guidelines on extreme heat in B.C. are not easy to understand or apply. WorkSafeBC does not specify one safe indoor temperature threshold for workplaces. Instead, their guidelines refer to broad ranges of indoor temperatures and heat exposure limits that depend on workers' acclimatization levels, the physical intensity of the work, and how often workers can rest (WorkSafeBC 2005; ACGIH 2019).

Studies show that, due to climate change, workers will be exposed to heat for increasingly prolonged periods of time, including overnight (Legault et al. 2017; McInnes et al. 2017). However, current exposure limits assume workers' heat exposure lasts for only eight hours (i.e., the duration of a typical shift) (WorkSafeBC 2005; ACGIH 2019). While employers can partially adapt to these conditions by modifying shift times or decreasing workload, occupational standards alone will likely be insufficient to protect workers from extreme heat.

Capacity may also be a barrier for government agencies enforcing heat exposure standards, particularly as a larger number of workers will be impacted by heat waves in the future. If agencies such as WorkSafeBC have insufficient capacity to enforce and guide employers in all industries through occupational standards, more heat-related injuries could occur. The sudden spike in calls to WorkSafeBC during the 2021 heat wave shows the potential for increased capacity needs in the future.



Future labour impacts and costs

Heat-related impacts on labour productivity will increase in the coming decades without adaptation

We modelled future impacts of extreme heat on labour supply in B.C. in six high-risk industry groups: 1) agriculture, forestry, fishing, and hunting, 2) mining, quarrying, and oil and gas extraction, 3) utilities, 4) construction, 5) manufacturing, and 6) transportation and warehousing. While indoor industries other than manufacturing are an increasing concern, we selected these six industries because workers are primarily outdoors, in poorly cooled places, or working in close proximity to radiant heat. Combined, these industries comprise close to 20 per cent of B.C.'s labour force and make up almost 30 per cent of B.C.'s GDP (BC Statistics 2022). We used quantitative relationships which correlate heat exposure with labour supply to calculate the impacts of exposure to daily high temperatures for each high-risk industry (ESSA 2020). We analyzed labour supply impacts for each city and town in B.C. This localized approach allowed us to modify the labour-sector makeup for each city and town based on 2021 census data and growth projections.

We found that rising temperatures will have an increasingly negative impact on labour supply in B.C. over the coming decades. Our modelling shows that under a high-warming scenario, extreme heat will result in the loss of around 500,000 hours worked per year across the province in the 2030s which equates to the annual loss of about $22 million in wages and salaries—more than double the heat impacts on wages compared to the past 20 years. By mid-century there will be an annual loss of around one million hours worked. In a medium-warming scenario, our modelling suggests that there could be an annual loss of 850,000 hours worked per year by mid-century—this loss is approximately 27 per cent lower than the high-warming scenario losses.

By mid-century, we estimate that productivity impacts associated with reduced labour supply could range from one to nearly 5 per cent losses in projected GDP across the high-risk sectors modelled, totalling $122 million in GDP losses per year across all six industries. We estimate that the largest impact in terms of GDP loss will be in the manufacturing sector, which could see a 4.5 per cent loss due to heat impacts by mid-century. We found that impacts to the transportation and warehousing sector as well as the construction sector could amount to approximately 4 per cent losses in future GDP without adaptation interventions. The vast majority of this labour productivity decline will occur in the months of July and August. Among the sectors we modelled, we estimated that the lowest per cent GDP change would be to the mining, oil, and gas sector—likely because this sector has more employees working in less hot regions of the province.

Workplace adaptation interventions

Based on the vulnerabilities identified, we assessed the potential benefits of two sets of adaptation interventions that could reduce the impacts of extreme-heat workplace safety and productivity. The first adaptation focuses on shifting work schedules to cooler parts of the day and the second increases the amount of time outdoor workers spend in the shade. Our basic assumptions for each of these adaptation interventions are below and additional details can be found in the technical report. We analyzed the adaptation costs and benefits for the two largest cities in each region of B.C.—representing about 80 per cent of people living in the province.

Shift schedules:

- When a Heat Warning is forecast, employers re-schedule work to cooler times of day.
- We assume that work hours shift from 9 a.m. - 5 p.m. to 5 a.m. - 1 p.m.

We assume that this administrative workplace adaptation applies to all workers except those currently working regular evening or night shifts and for all six industry groups we modelled.

Increased shading for outdoor workers:

- When a Heat Warning is forecast, employers have outside workers spend half their shift working in some form of shade.
- We assume 65 per cent of all workers in all of the industry groups we modelled except manufacturing work outside.

Adapting workplace schedules could save millions of dollars

Changing the time of the day when people work can limit the productivity impacts and reduce health risks for workplaces exposed to heat. We estimate that in the 2030s, adapting work schedules would result in 9 per cent less GDP impacts from heat among high-risk industries. This is equivalent to an estimated $4 million less in heat-related GDP losses for the province per year. By mid-century, we estimate that adapting work schedules would reduce projected heat-related impacts on the GDP under a high-warming scenario by 24 per cent. We calculated that the return on investment would be between $7.30 and $1.20 for each one dollar invested in regions of the province with large outdoor sectors of the economy.

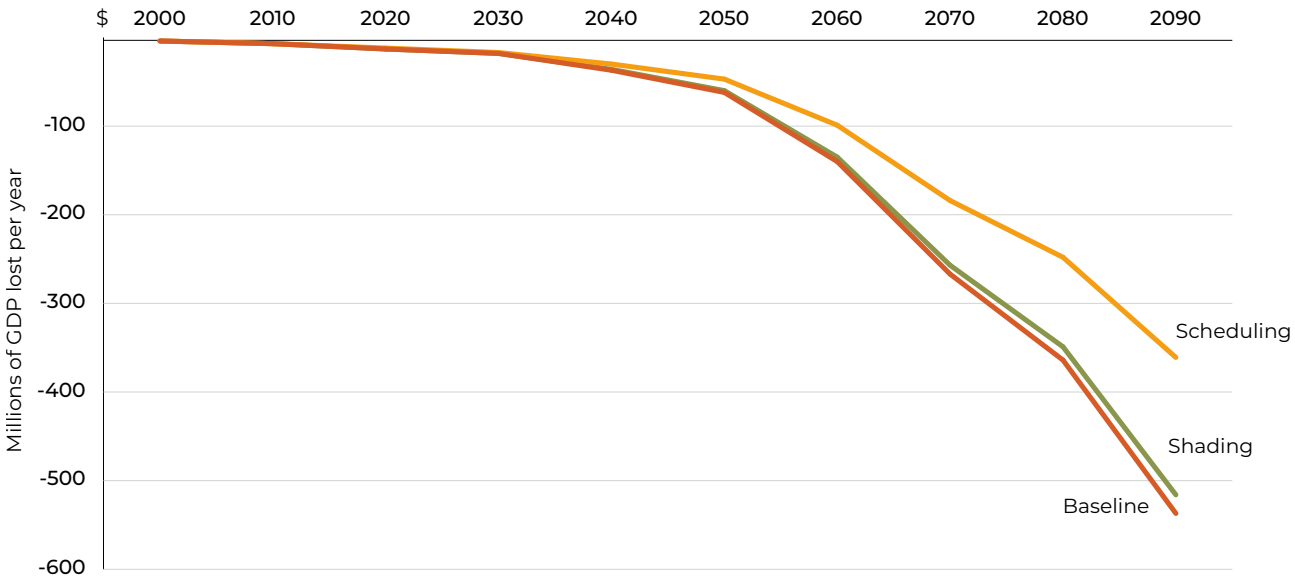
Increasing shading could marginally reduce impacts

Increasing the amount of time that workers are able to work in shade can reduce the temperatures outdoor workers are exposed to and mitigate some labour productivity impacts. We estimate that increasing shade for outdoor workers could result in a 1 per cent lower impact on GDP by the 2030s. This is equivalent to reducing heat-related GDP losses for the province by half a million dollars per year. By mid-century, we estimate that shading provisions for outdoor workers would result in a 3 per cent reduction in projected heat-related impacts on GDP under a high-warming scenario (Figure 3).

Figure 3:

Extreme heat will lower productivity and lead to GDP losses

Adaptation interventions like changing work schedules and increasing shading can reduce losses under a high-warming scenario.



4 HUMAN HEALTH AND HEALTH SYSTEMS

In this section, we assess the health costs and impacts associated with the 2021 heat wave and then examine how climate change could affect the impacts and associated costs of heat waves in the coming decades. Next, we describe key vulnerabilities that influenced the impacts and costs of extreme heat. Finally, we analyze the costs and benefits of new adaptation interventions.

The deadliest impacts and greatest economic costs of the 2021 heat wave were related to people's health. Therefore, as well as using the methods described in the Our Approach section (Page 13), we also analyzed impacts and related costs from a health-system perspective using medical records and health system data. We break down the human health and health systems costs and impacts into regions that align with the jurisdictional boundaries of B.C.'s five health authorities (Figure 4).

There are three general trajectories of heat-related health impacts (Health Canada 2011):

1. Minor illnesses which can resolve on their own, especially if individuals do not have underlying conditions and can cool down and rehydrate. These typically do not involve any healthcare costs or lasting impacts on health and well-being.
2. Severe complications which require medical care. These involve moderate to significant healthcare costs and in some cases long-term or lifelong illness.
3. Deadly outcomes which involve significant consequences, including mental health and well-being impacts on the loved ones of those who die, societal costs through VSL (see VSL Box 3, page 31), and can involve healthcare costs.

We used three primary data sources to estimate how many people fell into each of these categories during the 2021 heatwave and the respective impacts:

1. Data from the BC Coroners Service to determine how many individuals died due to heat-related illness.
2. Anonymized administrative data from the Ministry of Health to calculate heat-related emergency department visits and hospitalizations, as well as the composition of presenting illnesses.
3. Data from a patient chart review to validate resource usage for severe illnesses and patients that died.[8]

[8] For further details, see technical report.

Finally, we costed the impacts by estimating both direct resource costs and willingness to pay to avoid illness and death. Direct resource costs of healthcare services were based on illness profiles (length of time a patient stays in the hospital and diagnosis). Societal costs resulting from premature death were monetized using Value of a Statistical Life (VSL) (see VSL Box 3, page 31).

Figure 4

B.C.'s Health Authority regions

BOX 3

Value of a Statistical Life

The Value of a Statistical Life (VSL) estimates the dollar equivalent of the welfare benefit derived from preventing the loss of a life in a population. Although no one pays the VSL when someone dies, it is an estimate of society's collective willingness to pay to reduce the risk of someone dying (Chestnut et al. 2009). Economists calculate VSL based on people's everyday decisions about accepting risks, such as the amount of additional wages required for a riskier job. They also calculate the VSL by asking individuals directly about their willingness to pay to reduce their risk of death. Based on Government of Canada recommendations, we use a VSL of $8.89 million 2022 dollars per life lost (Government of Canada 2022). Governments frequently use VSL to inform cost-benefit analyses for public policy.

VSL can be a helpful tool in assessing the impacts of disasters, particularly for events such as extreme heat, which may not result in high direct damage costs but have extremely high human impacts. By monetizing the societal costs of unexpected deaths, decision makers can consider the potential benefits of preventing deaths in the same units as the costs to prevent those deaths, and allocate resources accordingly. However, VSL is not intended to reduce the value of human life to purely monetary terms. Some limitations associated with use of the VSL modelling include the homogenization of the population, as well as the reflection of private willingness to pay for a small risk reduction, and does not capture the value of a person's life to the rest of society (Colmer 2020).

Health costs and impacts during the 2021 heat wave

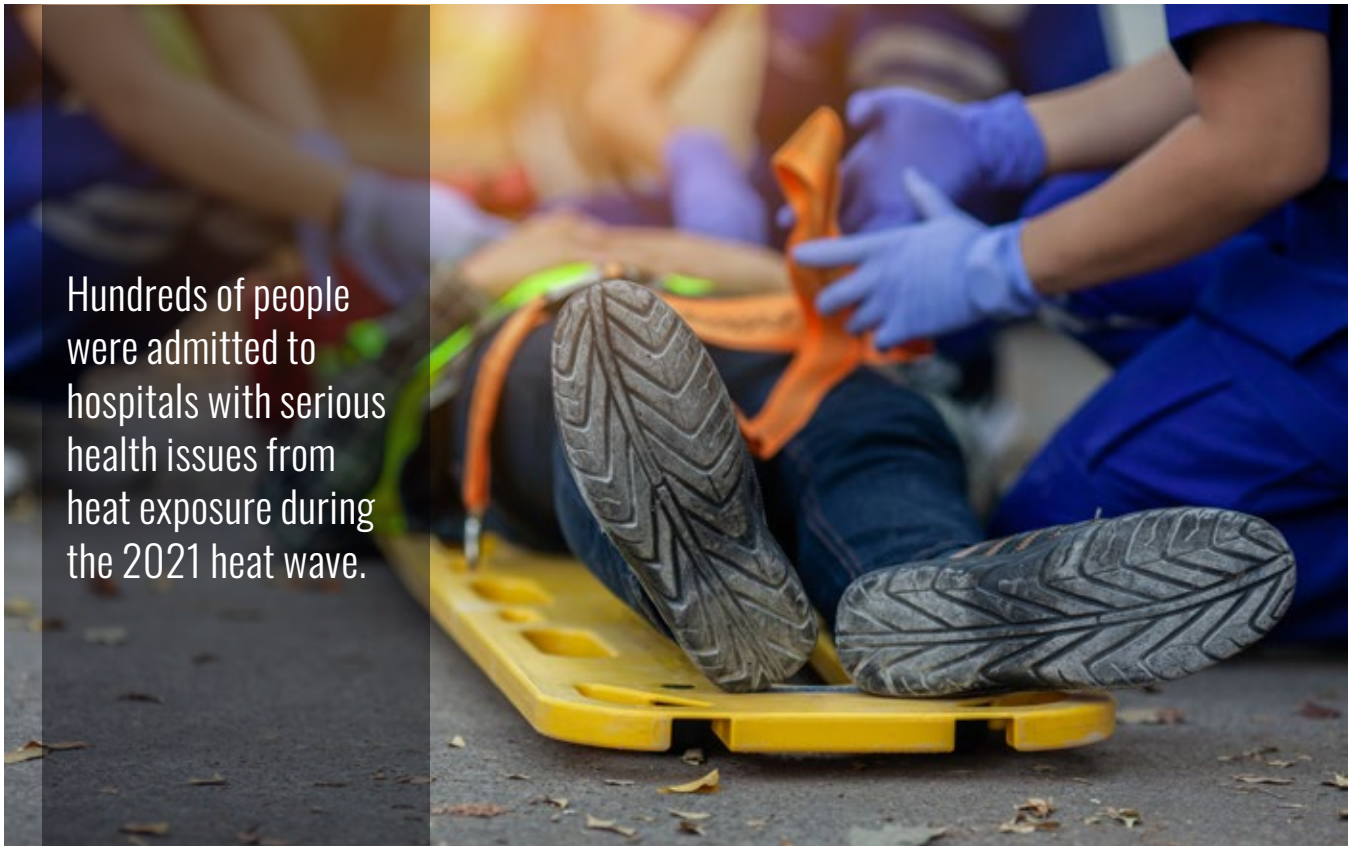
The heat wave affected people's health in different ways—these impacts also had economic implications and costs.

There was a surge in the number of people needing advanced medical care

Our analysis shows that during the heat wave there were significant increases in the number of people who needed advanced medical care. In our analysis of emergency department visit data across the Lower Mainland, we identified 1,300 excess emergency department visits across the Lower Mainland alone—a 6 per cent increase above what would be expected for that time of year (Clark, Forthcoming). The number of patients triaged as being at "imminent risk of death" (Canadian Triage and Acuity Scale of I) increased by about 170 per cent.[9] Further, the number of critically ill patients was also reflected in the record breaking number of calls for ambulances during the heat wave (BC Coroners Service 2022; FOI: HTH-2021-13060).

Hundreds of people were admitted to hospitals with serious health issues from heat exposure. There were 530 excess hospitalizations across the province during the week of the heat wave. The largest increase was in the Fraser region, where on June 29 alone there were 525 patients admitted to hospitals—more than double pre-pandemic levels or three times more than 2020 hospitalization rates (FOI:FH-2022-0483).

We also found that at the time of the heat wave, there were no clear clinical procedures or guides for healthcare providers to reference. These tools and healthcare provider knowledge are a key component of health system adaptation (WHO 2015).



[9] For further details, see technical report.

Table 5:

Illnesses requiring hospitalization that increased during the heat wave[10]

Illness	Per cent change from baseline (number of excess hospitalizations for B.C.)	Average acute bed length of stay (days)	Average cost of hospitalization per patient
Dehydration	136% increase (88)	3.8	$4,892
Acute kidney failure	45% increase (147)	6.4	$9,183
Diabetic ketoacidosis with coma	285% increase (4)	5.3	$5,739
Neurocognitive disorders*[11]	33% increase (94)	12.7	$14,513
Pneumonia	25% increase (40)	6.0	$8,718
Hepatorenal syndrome	170% increase (5)	7.9	$10,458
Heatstroke	16,876% increase (511)	5.8	$10,317

Some interviewees noted that during the first few days of the heat wave, some emergency departments were advising people in waiting rooms not to drink water—this is a usual precaution until a physician assesses a patient and determines they will not need to go to surgery. Other healthcare professionals noted many staff were uncertain of how to best cool patients (FOI: VCH-2022-F-108; FH-22-0483). Since the heat wave, there have been efforts to improve healthcare provider knowledge.

Heat exposure led to increased hospitalization and medical care costs

There was a significant increase in key diseases during the heat wave (Table 5). We compared the number of diagnoses for 66 unique illnesses between June 25 and July 1, 2021 to the baseline number of diagnoses between June 1 to June 24, 2021 and July 14 to July 31, 2021 and found a statistically significant increase in nine illnesses during the heat wave.[12]

Based on the above increases, we estimate that heat-related hospitalizations resulted in about $8 million in healthcare expenditures in B.C. during the 2021 heat wave. This estimate is based on illness cost data and our estimated change in cases compared to the baseline period immediately preceding and proceeding the heat wave. These estimates are conservative as they do not include life-time medical expenses like long-term care, outpatient follow-ups, or rehabilitation services. Further, these estimates do not include the opportunity costs of output from lost working time or willingness to pay to avoid suffering.

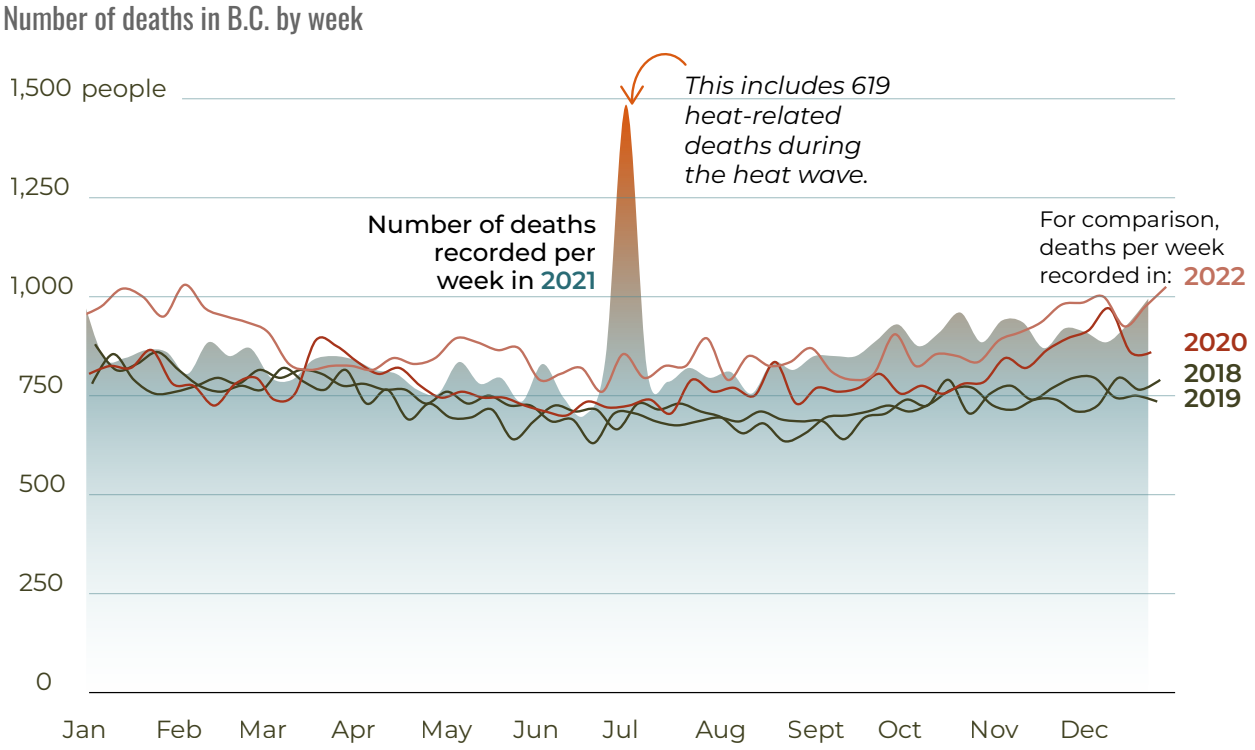
Heat-related deaths spiked between June 25 and July 2

A month after the 2021 heat wave, the BC Centre for Disease Control announced that they had identified 740 excess deaths above the historical average between June 25 and July 2 (Henderson et al. 2021; Vancouver Coastal Health and Fraser Health 2022). In their review, the BC Coroners Service linked 619 deaths directly to heat exposure—termed *heat-related deaths* (BC Coroners Service 2022) (Figure 5).

[10] Cost and length of stay data is based on Canadian Institute for Health Information cost estimates for each respective Case Mix Group among the 60 to 79 year old age group.
[11] Reduced brain function due to illnesses that are not psychiatric in nature.
[12] For further details, see technical report.

Figure 5

During the 2021 heat wave there was a large increase in the number of deaths.



Source: Statistics Canada 2023

Heat-related deaths were not distributed equally across the province during the heat wave (BC Coroners Service 2021). The BC Coroners Service reported the highest rate of death in the Fraser Health region (15.9 deaths per 100,000). The lowest rate was in the Island Health region (6.3 deaths per 100,000) and the average incidence rate across B.C. was 12.2 per 100,000. For context, in the state of Washington where the temperatures and duration of the heat wave were similar to those in B.C., excess mortality rates[13] are estimated to be between 1.3 and 2.1 people per 100,000 died (Washington State Department of Health 2021; Casey et al. 2023).

Even within each B.C. health region, heat-related deaths were not distributed equally. As highlighted by the BC Coroners Service and in analysis by the BC Centre for Disease Control, social, economic, and physiological factors all had a significant influence on risk of death (Lee et al. 2023; BC Coroners Service 2022). Some of the medical conditions associated with higher risk of heat-related death have also been linked to higher risk of hospitalization.[14]

Heat-related deaths were the single greatest cost of the 2021 heat wave

The largest single economic impact of the 2021 heat wave was the societal cost of the 619 lives lost directly from heat exposure (BC Coroners Service 2022). Based on the VSL (see VSL Box 3, page 31) the societal cost of 619 deaths attributable to extreme heat exposure during the heat wave is equal to $5.5 billion. Although the Government of B.C. did

[13] Excess mortality rates have a lower specificity compared to the coroner-based heat attribution that was done in B.C. This means that the Washington incidence rate of heat-related deaths would likely be lower.
[14] For further details, see technical report.

not actually spend this money, this value reflects how much the public would have been willing for the government to pay in order to prevent the 619 heat-related deaths.

In addition to the costs of lives lost, data shows that approximately 45 per cent of the individuals who died, had resuscitation attempts or interventions by paramedics or in emergency departments. We estimate that the average healthcare cost for individuals that died suddenly averaged $7,028 per person, for a total of approximately $4 million in direct healthcare costs (Fassbender et al. 2009). These costs represent actual expenditures paid by the Government of B.C. from taxpayer dollars.

The health system could not provide critical medical care to everyone

When health systems are not prepared to care for the influx of patients during a heat wave or any other mass casualty incident, then healthcare delays can lead to additional medical complications or death for other patients that need medical care. In other words, during a heat wave disaster, even patients not suffering from heat-related illnesses can have severe health outcomes or die.

Prehospital emergency medical services (Coroners service and ambulances) as well as emergency departments were significant bottlenecks during the heat wave (FOI:HTH-2021-13060; FH-22-0483; VCH-2022-F-108). These bottlenecks cascaded—in many cases ambulances waited hours with deceased patients for a coroner to come. Across B.C., ambulances also spent hundreds of hours waiting at emergency departments to off-load patients. And, emergency departments were not able to keep up with the number of critically ill patients.

The chances of survival for a patient who is not breathing or whose heart has stopped decreases with every additional second it takes an ambulance to arrive. Studies have demonstrated that 30-day survival decreases by about half if it takes seven minutes or more for a first responder to start CPR after cardiac arrest (Holmén et al. 2020).

Data from government emails suggests that compared to early June 2021, ambulance response time increased by 33 per cent for critical patients during the first few days of the heat wave due to call volume and the number of staff working[15] (FOI:HTH-2021-13060). Finally, the average amount of time that patients had to wait to be moved from the emergency department to an inpatient acute care bed increased by 16 per cent in the Lower Mainland during the heat wave. This means that on average patients spent an additional two and a half hours in the emergency department before being moved to an inpatient bed. Known as *boarding time,* these delays also increased by 18 per cent in Prince George, which serves as one

[15] BC Emergency Health Services did not respond to requests for more detailed data.

of the hubs of the Northern region of the province. At the peak of the heat wave, only 18 per cent of emergency department patients were admitted to Fraser Health hospitals within ten hours—the Health Authority's target is 65 per cent. These delays are correlated with longer hospital stays (Salehi et al. 2018).

Health professionals experienced trauma and burnout

Finally, health system issues affected healthcare providers' mental health and workplace retention. Based on interviews with nurses, paramedics, firefighters, and physicians, we found that there were substantial impacts on staff burnout and retention because of the moral distress experienced by many health professionals during the disaster. These findings echo trends identified in other research that have connected long wait times with healthcare-provider burnout and Post Traumatic Stress Disorder (Phillips et al. 2022).

We were not able to identify a precise number of staff that took medical leave or resigned specifically due to the stress of the heat wave, in part because of difficulties in distinguishing leaves associated with COVID-19 related burnout and responding to the ongoing opioid crisis. However, as of Fall 2022, approximately one out of three BC Emergency Health Service paramedics were seeking assistance related to psychological illness or injury according to union representatives (D.G. Clark, personal communication, October 26, 2022). In interviews multiple administrators underscored that some of these cases were a direct result of the stress on first responders during the heat wave response. These psychological impacts were also illustrated through comments paramedics wrote to managers during the heat wave. One paramedic wrote "[I] literally witnessed people today in our uniform dry heaving, sweating, close to tears." Another paramedic wrote "I booked off the last half of my shift. Mentally couldn't take it anymore. Worked another [cardiac] arrest for nearly an hour.... Sweat pooling in my boots; uniform and pants soaked... Yet another family who lost someone too soon; starts to hit close to home" (FOI:F22-1576).

Health and health system vulnerabilities

We identified a number of vulnerabilities that contributed to the health impacts and costs experienced during the 2021 heat wave (Table 6).

Table 6:

Human health and health system vulnerabilities that contributed to 2021 heat wave impacts

Physical systems	Institutions
• Critical healthcare equipment failed in some hospitals due to the heat • Many homes reached unsafe temperatures because of their design and a lack of mechanical cooling • Some government funded and run buildings became dangerously hot • Inequitable access to mental health services, green spaces, safe housing, and social supports resulted in unequal heat impacts • Early warning systems did not support adequate advance preparation	• The health system response was disjointed and uncoordinated • Some potentially useful disaster protocols and decision trees were not used • The ongoing COVID-19 pandemic affected public health and health system response • Current standards and regulations do not adequately consider heat for building occupants • There were very few critical incident debriefings for first responders or healthcare staff after the heat wave

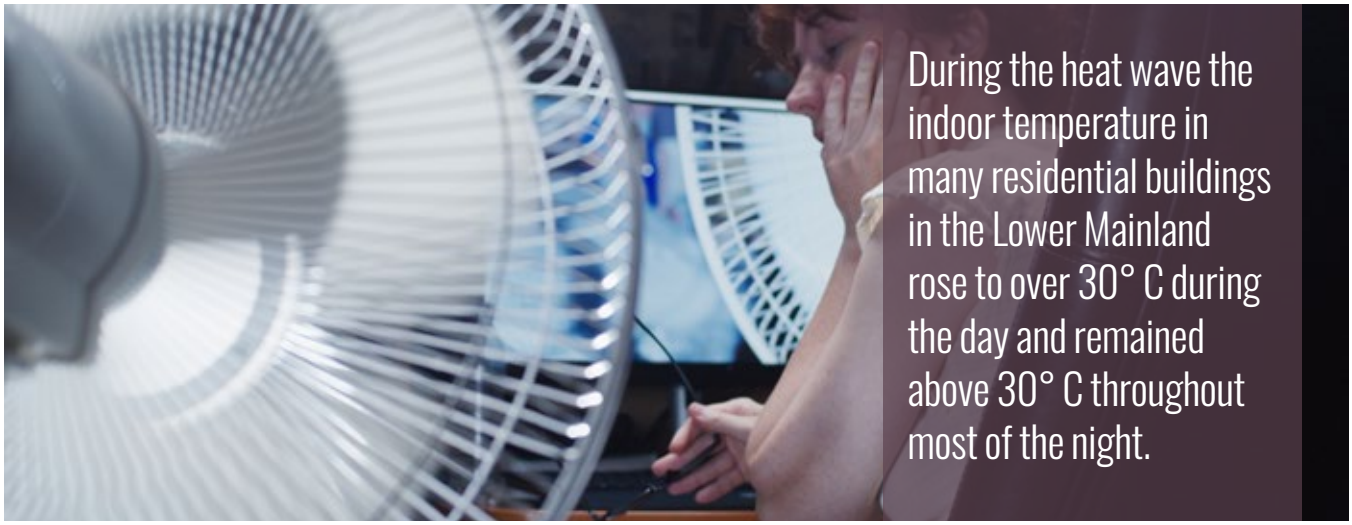
Critical healthcare equipment failed in some hospitals due to heat

There were cases where critical medical equipment failed during the heat wave. In particular, chillers for MRI and CT equipment were not able to provide sufficient cooling. At one point, both CT scanners at Lions Gate Hospital in North Vancouver and the CT scanner at Whistler Hospital were inoperable as a result (FOI: FHA-2022-0483; FOI:VCH-2022-F-108). Further, MRI scanners were also inoperable at Royal Columbia Hospital and Surrey Memorial Hospital. Although we were unable to identify how many patients were affected, the CT scanner outages would have severely limited the ability to diagnose and treat strokes, traumas, and emergencies like acute appendicitis. Finally, there were a number of ambulances across the province that did not have functioning air conditioning during the heat wave. This resulted in additional heat exposure for paramedics and patients (FOI:F22-1576).

Many homes reached unsafe temperatures because of their design and a lack of mechanical cooling

Poorly insulated buildings that lack mechanical cooling or external shading are more prone to overheating (BC Housing 2022). Because B.C. has a relatively moderate climate, most homes and buildings have been designed to retain heat, not keep people cool, and existing non-public sector buildings are presently not required to include active or passive cooling in their design. While provincial and federal guidelines recommend maximum indoor temperatures of 27° C to 28° C, they are currently not enforceable (BC Housing 2019; Laouadi et al. 2022). B.C. has a relatively low rate of air conditioning compared to other parts of Canada and the U.S. Only 36 per cent of homes in B.C. have air conditioning, compared to 84 per cent of homes in Ontario, 85 per cent of homes in Manitoba, and 53 per cent in Washington (Statistics Canada 2023d; U.S. Energy Information Administration 2022). Of the households in B.C. that do have air conditioning, most are in the Interior. For example, 84 per cent of households in Kelowna have air conditioning, compared to 19 per cent of households in Victoria and 26 per cent of households in Vancouver (Statistics Canada 2023d).[16]

During the heat wave the indoor temperature in many residential buildings in the Lower Mainland rose to over 30° C during the day and remained above 30° C throughout most of the night (BC Coroners Service 2022). In more extreme cases, indoor building temperatures rose to nearly 40° C



[16] While air conditioning units have traditionally been the primary source of mechanical cooling for homes and buildings in B.C. and elsewhere, heat pumps are increasingly being adopted to meet both heating and cooling needs. Heat pumps carry many benefits, including their ability to provide clean heat as well as cooling throughout the home.

in Abbotsford and remained hotter than outdoor temperatures throughout the night (Baze Baum and McClearn 2021; Henderson et al. 2022). This resulted in a multi-day period where many people were exposed to unsafe heat inside their homes—a major contributor to heat-related illness and death during the event. Analysis shows that 98 per cent of deaths and hospital visits during the heat wave were due to extreme temperature exposure inside buildings (BC Coroners Service 2022). Only 7.4 per cent of people who died from extreme heat exposure (46 people) had air conditioning in their homes, and of those, only 15 per cent (7 people) had it on at the time of death because it may have been malfunctioning, located in a different room, or was disabled by the building owners (BC Coroners Service 2022; Daflos 2022).

Some government-funded or licensed buildings became dangerously hot

An appreciable number of heat-related deaths during the 2021 heat wave occurred in government-funded or licensed buildings such as long-term care facilities. Of the total heat-wave-related deaths, 47 people died in community living, assisted living or long-term care facilities (BC Coroners Service 2022). This represents a higher incidence rate than average for people over 65 years old. Most deaths in long-term care facilities happened in the Fraser region. Further, 62 people died from heat exposure in social housing run or funded by the provincial government (BC Coroners Service 2022). Eight individuals who lived at Vancouver Mental Health and Substance use housing died (FOI: VCH-2021-F-108). Records show indoor air temperatures in some long-term care facilities rose to over 30° C during the heat wave (FOI:HTH-2021-13060; FOI: FHA-2022-0483). Some hospitals were also unable to keep temperatures in a comfortable range for patients and staff. At least two Lower Mainland and one Northern hospital recorded indoor temperatures of over 32° C in the emergency department, while an acute care floor at Lions Gate Hospital got as hot as 38° C (FOI: VCH-2021-F-108). Healthcare staff reported that these extreme temperatures made it more difficult to cool patients quickly and potentially led to worse patient outcomes.

A significant proportion of government-run and licensed facilities did not have air conditioning during the heat wave, particularly in patient rooms, where patients spend much of their time (Table 7).

Table 7:

Select estimated Government of B.C. run and licensed facilities with air conditioning[17]

Facility Type	Estimated per cent with air conditioning during 2021 heat wave
Patient rooms in hospitals	• < 25 %
Long-term care facility (licensed)	• 30 % fully air conditioned (96) • 34 % partially air conditioned (108) • 17 % no air conditioning (54) • 18 % unknown (54)
Inpatient substance use disorder treatment facilities and mental health facilities (non-hospital)	• < 25 %

[17] Because the Government of B.C. and health authorities do not have comprehensive data on facility cooling for the province, we estimated these values based on public documents and interviews. We did not include correctional facilities as we could not access reliable data on these institutions.

Correctional facilities in B.C. have different forms of cooling available in inmate living unit areas, but not within individual cells, and the type of cooling technology and level of air circulation varies greatly between facilities (FOI:PSS-2021-13054; FOI:PSS-2021-15530).[18] While the majority of provincial correctional centres are equipped with air handling units that can provide some cooling as well as heating, the level of cooling these provide into cells is unclear, and there were numerous reports of equipment being overwhelmed under the extreme heat conditions (FOI:PSS-2021-13054; FOI:PSS-2021-15530). On June 25, one inmate submitted a complaint that stated, "we are experiencing record breaking temperatures and the windows are sealed shut… Corrections should be required to provide us with portable fans" (FOI:PSS-2021-15530). Notably, Vancouver Island Regional Correctional Centre required inmates to pay for fans if they wanted one for their cell (FOI:PSS-2021-15530). There are no requirements for safe maximum temperatures in any of B.C.'s correctional facilities or federal prisons (Correctional Service Canada 2015).

Inequitable access to mental health services, green spaces, safe housing, and social supports resulted in unequal heat impacts

Neighbourhood material and social deprivation were strong predictors of 2021 heat wave deaths (Henderson et al. 2022). Twenty-eight per cent of the heat-related deaths during the heat wave occurred in neighbourhoods that had poorer quality housing, lower incomes, less green space, and less recreation opportunities[19] (BC Coroners Service 2022; Henderson et al. 2022). Furthering the risk, many of the chronic illnesses that increased susceptibility to heat hospitalizations and death are also linked to lower socioeconomic status (Henderson et al. 2022).

Lack of urban green space was also associated with higher death rates (Henderson et al. 2022), as urban green spaces and trees reduce the urban heat island effect. The urban heat island effect is an increase in temperatures caused by replacement of vegetation and land cover with infrastructure, buildings, and paved surfaces, combined

Over a quarter of all 2021 heat wave deaths occurred in neighbourhoods that had poorer quality housing, lower incomes, less green space, and less recreation opportunities.

[18] Further, the technical guidelines for federal correctional institutions specify that air conditioning is not to be provided in individual cells, unless an exception is granted on a case-by-case basis (Correctional Services Canada 2015).
[19] With an odds ratio of 2.88 (Henderson et al. 2022).

with increased urban traffic and exhaust heat from building ventilation systems (Rosenzweig et al. 2006; Santamouris 2014; Bowler et al. 2010). This effect can raise outdoor temperatures by as much as 12° C compared to surrounding areas (Schwaab et al. 2021).

Early warning systems did not support adequate advance preparation

Many decision makers in municipalities, health authorities, and Ministries did not receive or act on information about forthcoming health risks until the heat wave had already arrived. Based on our interviews and health authority after-action reports, we found that these late warnings and communication issues were one factor that contributed to delays in deploying public health actions, as well as emergency preparations (FOI: VCH-2021-F-108; BC Coroners Service 2022).

ECCC, which is responsible for weather forecasting and issuing heat warnings based on criteria established in collaboration with each province and territory, issued public heat warnings for B.C. on June 23, 2021 (Little 2021). Regional health authorities in the Lower Mainland escalated the heat warning, and issued a separate Extreme Heat Alert on June 25 in the afternoon, the first day of the heat wave, as forecasted heat posed a risk of significant human health impacts (Vancouver Coastal Health and Fraser Health 2021). Based on interviews, we found that during the 2021 heat wave many decision makers and organizations did not fully understand what each class of warning meant. Municipalities and health authorities echoed this finding in after-action reports, noting that both heat warnings and extreme heat alerts in 2021 were issued by separate agencies, sometimes at the same time, which created confusion (City of Vancouver 2022a; City of Burnaby 2021; FOI-VCH-2022-F-108).

As noted by the BC Coroners Service, "there was a lag between the heat alerts issued by ECCC and public agencies and the public response" (BC Coroners Service 2022). Internal reports sent by Emergency Management BC to other government ministries show that content on the 2021 heat wave risks was less detailed and signaled less urgency than other disasters occurring at the same time, such as the COVID-19 pandemic, wildfires, and floods (FOI-OOP-2021-13059). In some cases, key public and hospital officials with more background on heat response were out of the office during the first weekend of the heat wave, and weekend staff were not well versed in emergency plans, resulting in actions being delayed until staff returned on Monday—the fourth day of the heat wave (FOI: VCH-2021-F-108). After the 2021 heat wave, to address some of these issues, governments and agencies have taken steps to streamline and better communicate the warning process and criteria. For example, municipalities in the Lower Mainland renamed "extreme heat alerts" to "extreme health emergencies" to better reflect the public health risk associated with extreme heat, and ECCC took the lead in communicating both levels of heat alerts to the public (BC HEAT Committee 2022; City of Vancouver 2022a). However, we found that as of fall 2022, some emergency managers, healthcare staff, and policy analysts we interviewed remained unsure about what the different warning levels meant in practice. Further clarifying the appropriate responses to each type of warning level could improve preparedness and response to future heat events.

The ongoing COVID-19 pandemic affected public health and health system response

Because of the ongoing COVID-19 pandemic, public health measures that are commonly used during heat waves were more difficult to implement. Many people were apprehensive about going to public cooling centres and being in close proximity to others in an indoor space, while some non-profits that typically open these centres did not feel comfortable deploying due to COVID-19 risks (Yumagulova et al. 2022). Public health officials that we interviewed also reported that in

some cases wellness checks on neighbours did not occur as frequently because of hesitations around entering others' homes.

The effect of COVID-19 related hospitalizations in limiting health system capacity during the heat wave is unclear. Overall, hospital admissions in the province had been trending downwards for several months leading to lower bed occupancy rates that likely helped ease some pressure in emergency departments during the heat waves (FOI:HTH 2022-20789). However, occupancy rates at some hospitals remained high, including several in the heavily impacted Lower Mainland, which would have constrained their capacity to treat patients during the heat wave.

Disaster plans and response tools went unused

Because disasters often require quick reactions by decision makers who are under extreme stress, best practice is to use predetermined protocols, procedures, and decision trees to aid decision making. Further, disaster response plans and protocols are designed to be applicable to a broad range of disasters—being general enough that they can be adapted while still offering clear and tested procedures for specific scenarios. B.C.'s Emergency Program Act is the primary legislation that guides disaster response across the province (Government of British Columbia 2023d). B.C. also has a broad set of protocols and plans for various scenarios—at the time of the 2021 heat wave, the provincial response should have primarily been guided by the All Hazard Plan, since there were no heat-specific annexes to the All Hazard Plan (one was added in May 2022).

We found that many emergency planners did not utilize key tools and plans because, in part, the heat wave did not resemble the scenarios in training exercises (FOI:EMB-2021-13846; FOI: VCH-2022-F-108). It was not a discrete mass casualty incident like an airplane crash or explosion—instead, the heat gradually enveloped the province, lingering for nearly a week. In turn, officials struggled to respond because the heat wave did not look like a more commonly practiced disaster scenario (FOI:OCC-2021-13845).

Nonetheless, based on our interviews and a review of Freedom of Information disclosures, we determined that decision makers in health authorities, municipalities, and within the provincial government did not apply some existing procedures designed to guide decision making and communication during disasters in B.C. (see Table 8 for examples) (FOI:OOP-2021-13146; FOI:HTH-2021-13060; FOI: VCH-2021-F-108). Further, important tools that are part of the province's Comprehensive Emergency Management Plan, the Coroner Service Mass Fatality Response Plan, as well as local response plans were not used at all or were only triggered on the final days of the disaster (FOI:MMA-2021-13066). For example, only one hospital declared a mass casualty incident or a 'Code Orange' in response to the influx of patients in order to increase hospital capacity and shift resources to emergency departments (FOI:FHA-2022-0483; FOI:HTH-2021-13060). While in the final days of the heat wave various health authorities and BC Emergency Health Services took steps to redeploy staff and open up additional service space without activating Code Orange or other emergency response plans (FOI-HTH-2021-13060), some organizations and staff did not understand the urgency of the situation in the absence of Code Orange calls (FOI: F22-1576).

Based on interviews, we found that many people and organizations involved in the heat wave response did not understand the Government of B.C.'s disaster plans and their role within the structures. Work by the Government of B.C. to develop the Extreme Heat Preparedness for Ministries and Agencies, as well as the development of the provincial heat alert and response system have helped clarify roles since.

Table 8:

Key emergency response tools were not fully activated during the heat wave

Disaster response tool	Function	Criteria for activation	Use during heat wave
Provincial Emergency Coordination Centre (PECC)	The Provincial Emergency Coordination Centre is the central emergency operations centre responsible for the overall coordination of the integrated provincial response and implementation of the provincial priorities.	"If several ministries are involved in an integrated provincial response, Emergency Management BC will coordinate integrated provincial emergency management through the Provincial Regional Emergency Operations Centres and Provincial Emergency Coordination Centre" (All Hazard Plan).	Not activated—B.C. opened up regional emergency operation centres but did not activate a province-wide coordination centre with a PECC.
Central Coordinating Group (CCG) and Ministers-Deputies Emergency Council	The CCG is intended to provide strategic direction as well as oversight of provincial integrated emergency response and recovery activities. It is composed of Executive Director and ADM level staff. The Ministers-Deputies Emergency Committee is composed of ministers and deputies who provide direction for policy and strategic decisions to the CCG.	No specific activation criteria is outlined in public documents.	Neither the CCG nor the Ministers-Deputies Emergency Council were activated.
The BC Coroners Service Mass Fatality Response Plan (2011)	When a Mass Fatality Incident is declared, the Coroners Service has the ability to more effectively triage resources, call up volunteers through the Disaster Victim Identification B.C. Task Force, and assist with deploying temporary morgues.	Local resources can not manage a mass fatality.	Not activated.
Hospital mass-casualty response plans (Code Orange)	Hospital mass casualty response procedures include a broad toolbox of actions to increase capacity and triage care. Actions can include stopping all non-urgent work, activating departmental staff callbacks, bringing in staff from labour pools, and triaging patients.	A specific event stresses hospital operations so it is unable to provide normal service levels.	Numerous physicians requested activation in hospitals across the Lower Mainland, but the status was not approved by administrators for most hospitals. Lions Gate hospital declared a Code Orange (Stage I) on June 28 at 11:40 p.m. and cleared the code at 1:00 a.m. on June 29.
Mobile Medical Unit	The Provincial Health Authority can deploy a mobile 1,000 square foot 100-bed hospital to disasters and mass casualty incidents. The ward also has four critical care beds.	The Health Emergency Coordination Centre—run by the Ministry of Health—deploys the Mobile Medical Unit.	Not activated although documents show hospital leaders asked for its deployment.
Local emergency operations centres (EOCs)	The Local Authority Emergency Management Regulation requires that every local authority in B.C. establish an emergency management organization and develop and maintain a current local emergency plan. Local EOCs are a central tool for coordinating response and activating emergency plans.	Activation criteria is based on each local emergency plan.	Some municipalities, like Burnaby activated EOCs early, other cities like the City of Vancouver did not activate them at all.
Health authority emergency operations centres			Some health authorities, like Fraser Health, activated their EOCs quickly, substantially improving their coordination and response.

BOX 4

Individuals took initiative to try and fill in the gaps

During the heat wave, some individuals helped cool their workplaces when there were no provisions in place to protect people from extreme temperatures.

Hospital staff brought portable fans and air-conditioning units to emergency departments to help cool patient care areas and drove to grocery stores to buy ice when hospitals ran out. In a few cases fire departments flooded health clinic roofs with water to try to bring inside air temperatures down. Based on interviews, we found that others tried to cool down patient rooms and long-term care homes by lining windows with tin foil to deflect solar radiation.

Although we could not determine whether these actions had a net effect on heat exposure in those workplaces, individual initiative likely reduced overall costs and may have reduced heat illness and even saved lives.

The health system response was disjointed and uncoordinated

Standard emergency response to any disaster—including a health disaster—is for governments and agencies to use an incident command system to organize resources, tasks, and information. In essence, the system creates a transparent chain of command and ensures everyone has clearly articulated roles. As stated in a Government of B.C. document, "[the system], transforms the confusion of an emergency into a well-managed response. However, for the incident command system to work all responders must understand the system and their role in it" (Government of British Columbia 2002). B.C.'s emergency response plans all include an incident command system approach.

One of the major institutional problems we identified with respect to the health system response was that incident command systems were not activated and no single organization took charge of the response (FOI: VCH-2021-F-108). At a provincial level, we found that roles and responsibilities were unclear and that communication was inadequate among municipalities, health authorities, and ministries—including the Ministry of Health and Emergency Management BC, at the time under the Ministry of Public Safety and Solicitor General.[20]

[20] As discussed in Table 12, the province has since formed the Health Effects of Anomalous Temperatures (HEAT) Coordinating Committee to address issues of communication and coordination.

Because many decision makers inside hospitals, municipal governments, and ministries were not using an incident command structure, the quality and quantity of information moving between them would have constrained their ability to recognize the severity of events and to quickly respond to emerging issues. For example, briefing notes sent among health authorities and Ministries suggested much of the information being conveyed was outdated or contradicted information being circulated within hospitals (FOI:EMB-2021-13846; FOI-HTH-2021-13060 FOI:FHA-2022-0483)

There was also uncertainty around the division of roles and responsibilities between different actors in the provincial government, regional health authorities, and municipalities when it came to the heat wave health response. For example, B.C.'s Emergency Program Management Regulation places responsibility for coordinating a heat wave response with the B.C. Attorney General,[21] while in the All Hazard Plan, the Ministry of Transportation and Infrastructure is the technical lead for heat wave response (Government of British Columbia 2012)—yet we found no record that the Ministry of Transportation took an active role as a cross-ministry technical adviser during the heat wave response. Further, at the time of the heat wave, most health authorities' heat response plans noted that municipalities were in charge of setting up cooling centres, yet not all municipalities had cooling shelter plans as of 2017 (BCCDC 2017).

At a local level, there were communications challenges between doctors and nurses and their hospital administrators. Based on interviews, we found that there were numerous cases where hospital administrators did not know about their emergency department's state of crisis (FOI: VCH-2021-F-108). Some paramedics who were offering to work extra shifts were turned down due to management's scheduling rules (FOI:F22–1576). We also found that fire and police responders had difficulty coordinating with the BC Emergency Health Services—an issue that had hampered B.C.'s prehospital system prior to the 2021 heat wave (Feldman and Christenson 2019). For example, firefighters and police officers who were frequently waiting for multiple hours with patients had difficulty determining when an ambulance was coming or if one was coming at all (only ambulances are legally allowed to transport patients). Finally, there were communications challenges between the BC Coroners Service and first responder organizations. This was especially problematic since the Coroners Service was a key pinch point in the health response throughout the heat wave.[22]

Most healthcare staff did not have the opportunity to debrief

Critical incident debriefings are an international best practice after major disasters and mass casualty incidents. These debriefings are designed to help first responders and healthcare staff begin processing the emotional and moral distress that they experienced. Studies have shown that critical incident debriefings can reduce the use of negative coping mechanisms like alcohol abuse and may reduce incidence of PTSD (Tuckey and Scott 2014). In 2016, at the urging of healthcare staff unions, the B.C. Ministry of Health reviewed critical incident support practices in health authorities. The Ministry recommended increasing resources and training across the system so that staff and first responders have more timely access to debriefings after an event.

We found that the vast majority of nurses, physicians, paramedics, firefighters, and police who

[21] Although the regulation has not been updated, in practice central disaster coordination was through the Ministry of Public Safety and Solicitor General for 2021 and is now with the Ministry of Emergency Response and Climate Readiness.
[22] During the 2021 heat wave (when the cause of death was unknown) first responders were legally required to stay with bodies until the body was released to a coroner or police. This meant that paramedics, firefighters, and police spent large amounts of time waiting for a coroner and were unable to respond to new 911 calls. This legal requirement has since been changed.

cared for patients during the heat wave did not have critical incident debriefings in their workplaces. This may have been because the management and supervisors did not identify the heat wave as being a mass casualty incident and because the debriefings are generally designed around an event that takes place over a few hours rather than multiple days. Nonetheless, the absence of critical incident stress debriefings and mechanisms to support first responders to process the event may have worsened the incidence of PTSD and burnout.

Future health costs and impacts

Without investment in adaptation, future costs of climate-related heat impacts in B.C. are likely to increase.

Heat-related hospitalizations could double in the next decade

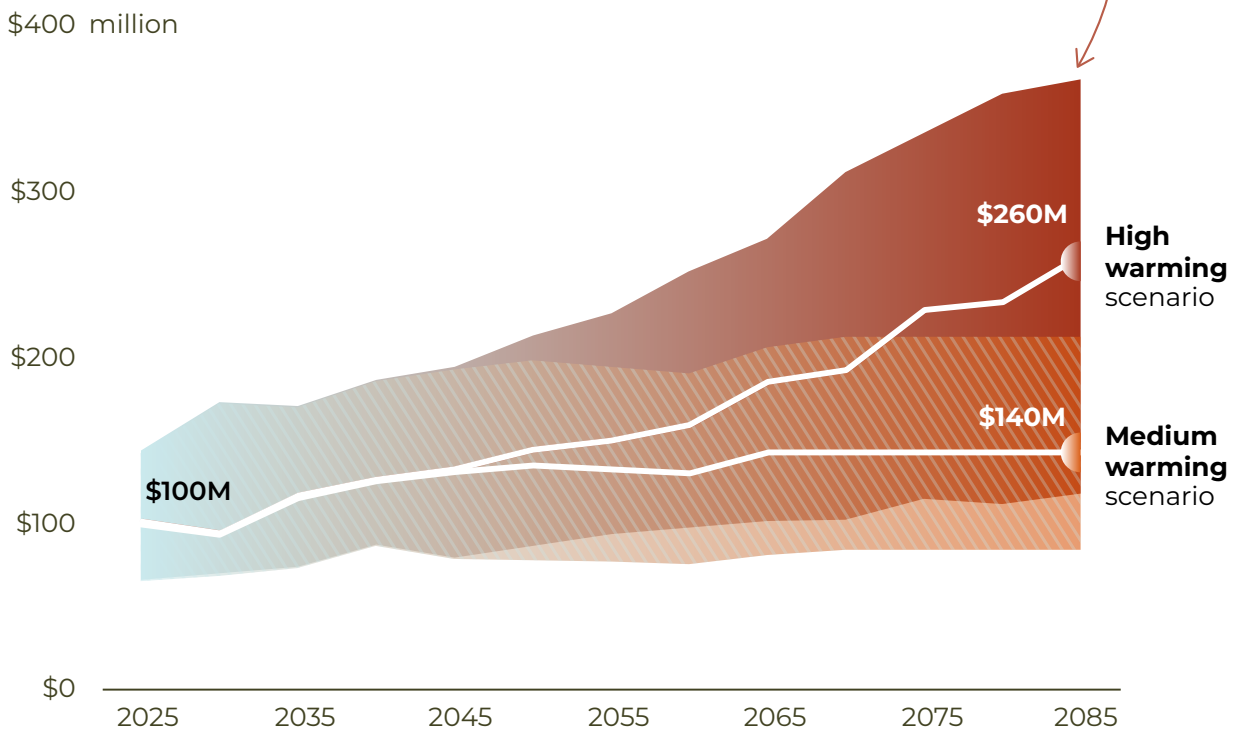
Our modelling suggests that without adaptation interventions, there could be nearly 6,000 heat-related hospitalizations per year by 2030 in B.C. (117 per 100,000). We estimate that these heat-related hospitalizations would cost at least $100 million per year by 2030—an increase of 140 per cent from average costs early in the century (Figure 6). Nearly all of these costs would be borne by the provincial government. Further, these costs do not include missed economic output from time away from work.

If global greenhouse gas emissions are rapidly reduced through additional global actions, then the rise in heat-related hospitalizations in B.C. would slow substantially by 2050 to approximately 8,000 hospitalizations per year (131 per 100,000).

Figure 6

In a high-warming scenario, costs due to heat-related hospitalizations will rise to over $250 million per year toward the end of the century.

Projected annual healthcare costs from hospitalizations due to extreme heat in B.C.

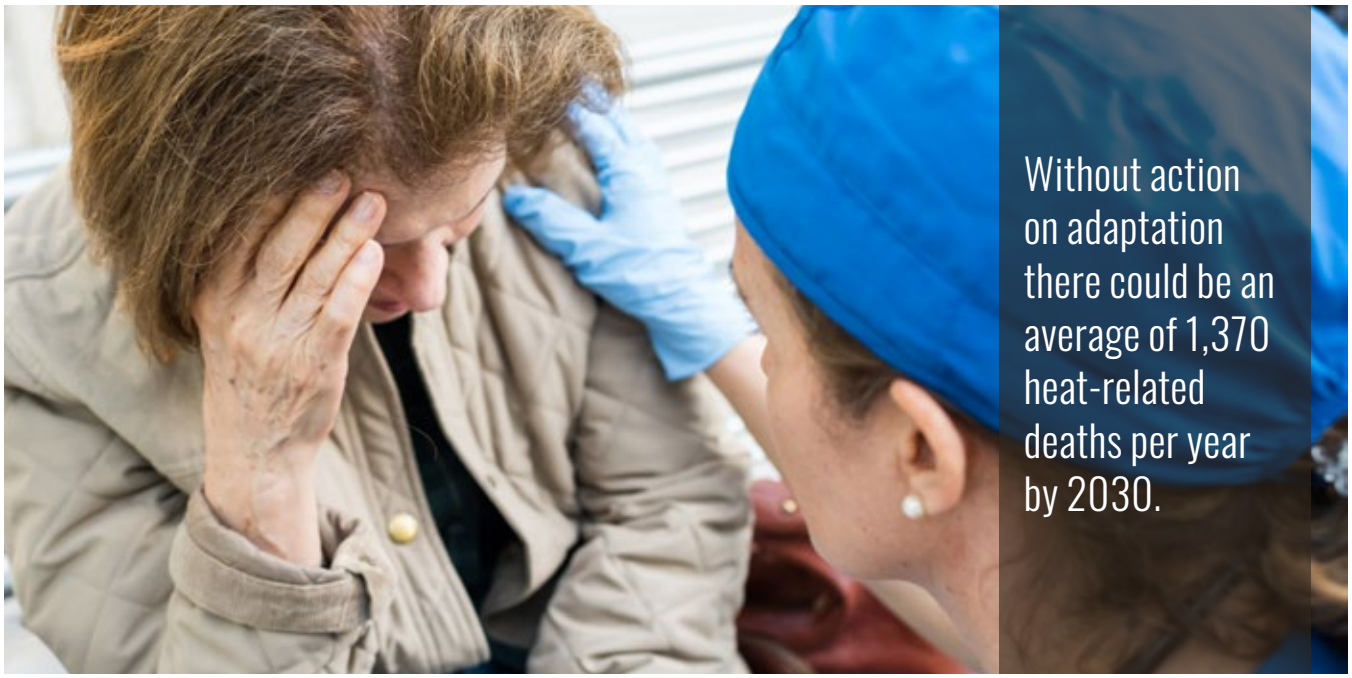


However, if global greenhouse gas emissions continue along a higher-warming pathway, then heat-related hospitalizations in B.C. could rise to more than 15,000 heat-related hospitalizations per year by the end of the century (318 per 100,000). We estimate that this would cost about $300 million per year in healthcare costs.

The number of heat-related deaths will continue to increase without adaptation interventions

Our modelling suggests that without action on adaptation there could be an average of 1,370 heat-related deaths per year by 2030 (30 per 100,000.) This represents a 58 per cent increase from modelled deaths over the past two decades with a societal cost of $12.2 billion per year based on the VSL plus an additional $11 million per year in healthcare costs.[23]

Because past greenhouse gas emissions have locked the world into a certain degree of warming, the number of people that will die from heat over the next several decades will not be reduced by global efforts to reduce greenhouse gas emissions (IPCC 2022). However, if global emissions are rapidly reduced, then the *rise* in heat-related deaths will slow by 2050 and eventually stabilize by 2070. For example, by the end of the century, our modelling shows that in a medium-warming scenario there will be 2,200 deaths per year (28 per 100,000) with an associated societal cost of $19.6 billion—nearly three times fewer deaths than in a high-warming scenario. This is equivalent to 40,880 fewer deaths per decade by 2090 and $363.4 billion less societal costs. The number of projected deaths is likely somewhat conservative (Figure 7).[24]

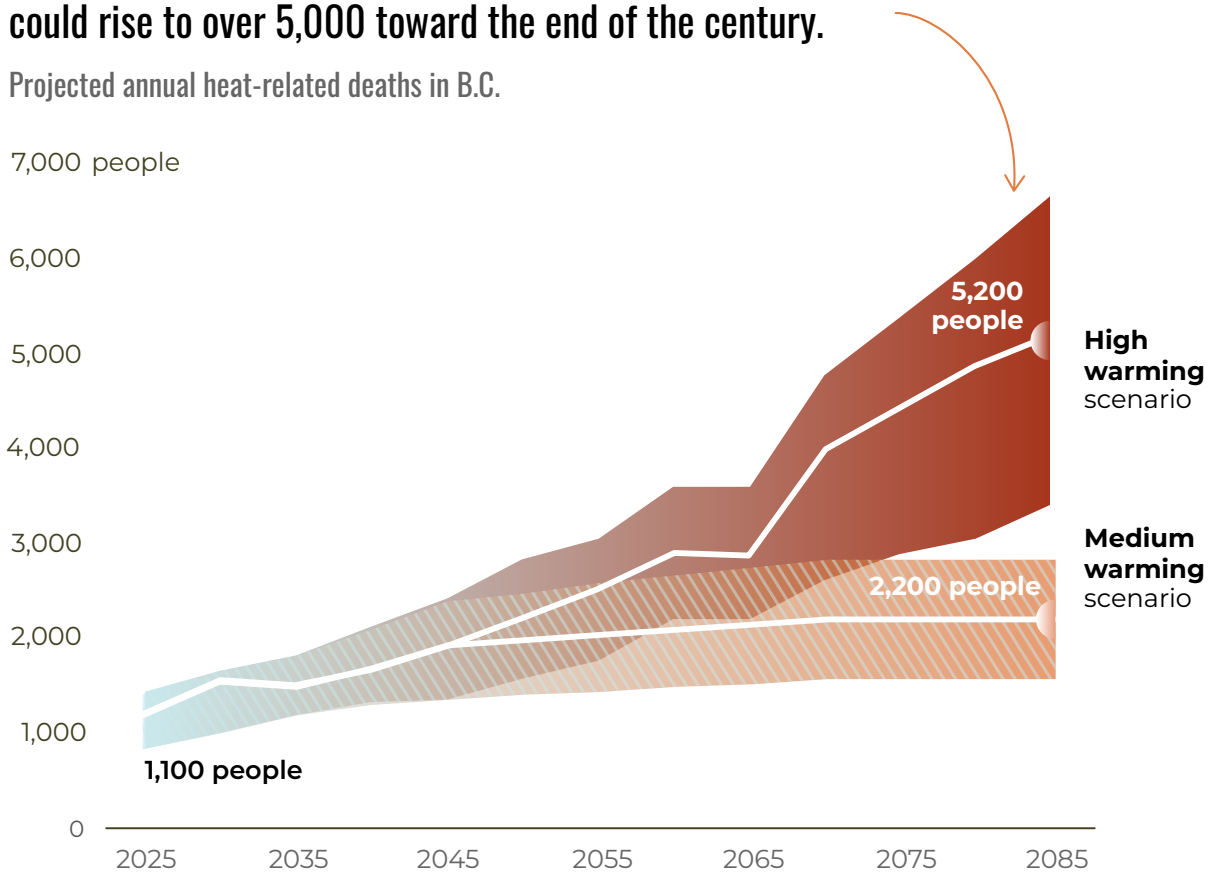


[23] For further details, see technical report.
[24] We have substantially improved the precision since the Institute's *Health Costs of Climate Change* was published by using functions that include observations from the 2021 heat wave and more local precision (Clark et al. 2021). This has resulted in values about 15 times higher than our previous estimates. Part of the challenge is that the relationship between heat exposure and deaths is exponential and rises sharply toward the upper end of the temperature distribution, and there are still relatively few observations of the health impacts of extreme temperatures in Canada with which to develop accurate models. Using 2021 heat wave data provided by the BC Centre for Disease Control we were able to update these functions to develop a more accurate model to capture the exponential shape of the relationship between daily mortality and extreme temperatures. See technical report for additional details on the methods used.

Figure 7

In a high-warming scenario, projected annual heat-related deaths could rise to over 5,000 toward the end of the century.

Projected annual heat-related deaths in B.C.



Health and health system adaptation interventions

Heat waves will continue to be one of Canada's most serious climate-related hazards, especially as the climate continues to warm, but a range of adaptation measures are available that can ensure heat waves are far less deadly and costly (WHO 2015). There are many ways that governments and communities in B.C. and across Canada can learn from the 2021 heat wave to adapt, protect people, improve response, and reduce costs. Potential adaptation interventions include upstream interventions that address root causes—like social isolation, inadequate or unsafe housing, access to mental health services, and management of chronic illnesses—as well as downstream interventions that help limit the severity of consequences if people are exposed to heat.

Building on our assessment of the heat wave and our modelling of potential future impacts, we assessed the costs and benefits of three types of adaptation actions that could reduce the effects of heat waves on health in the future.

1. **Installing mechanical cooling in homes and buildings**
2. **Increasing urban greening and cooling through urban planning interventions**
3. **Improving heat warning lead time and communications**

Increasing cooling in homes and buildings can save lives

Mechanical cooling—whether from traditional air conditioning or heat pumps—can protect people from extreme heat in their homes (Public Health Agency of Canada 2022; Health Canada 2011). However, nearly 64 per cent of B.C. households do not currently have air conditioning, and the vast majority of people who died during the 2021 heat wave died in their homes without access to adequate cooling (Statistics Canada 2023d; BC Coroners Service 2022).

We modelled the health benefits of increasing the uptake of mechanical cooling by two times the current projected rate of uptake for each region of the province.[25] This report does not recommend specific policies or technologies to achieve this increased uptake. Governments should consider affordability for consumers, equity considerations, and consistency with emissions reductions plans as they develop policies to protect people from future heat waves and more frequent extreme heat.

We found that if adaptation policy interventions resulted in a mechanical cooling uptake that is double its current rate, there would be a 12 per cent reduction in heat-related deaths by 2030 compared to the non-adaptation scenario. Between 2030 and 2040 we estimate an additional 18 per cent reduction in heat-related deaths. We also found there would be substantial reductions in hospitalizations if mechanical cooling uptake happened more quickly—reducing heat-related hospitalizations by about 40 per cent in the 2030s across the province and saving $20 million per year in healthcare costs from hospitalizations.

We calculated that the return on investment for doubling the rate of mechanical cooling uptake would be between $6.90 and $4.60 for one dollar invested. We did not account for co-benefits like potential to reduce wildfire smoke exposure, nor did we account for potential ancillary costs like impacts on greenhouse gas emissions or electricity system loads.[26]

Urban greening is an important adaptation tool for reducing impacts later in the century

Urban planning can be used to increase tree density, green roofs, and reflective surfaces in population centres in order to reduce the amount of heat that is absorbed in urban environments. We focused our analysis on the Lower Mainland, which likely has the highest return on investment for urban planning measures compared to less densely populated regions of the province. Similar to our mechanical cooling scenario, we focused on modelling the health benefits of a policy outcome and did not assess the best urban planning tools to achieve the outcome.

We used the following assumptions for our urban greening scenario:

- By 2050, 50 per cent of suitable impervious surfaces (e.g., roads, sidewalks, parking lots) are covered by a tree canopy, 50 per cent of impervious surfaces unsuitable for tree cover are made of light-reflecting surfaces, and 100 per cent of the surfaces are converted by the end of the century.
- By 2050, 25 per cent of roofs are converted to a living roof (vegetated) and 25 per cent of roofs are converted to light-reflecting surfaces. By end of century, half of the roofs are living and the other half are light-reflecting surfaces.
- By 2050, 50 per cent of suitable grasslands will be converted to tree canopy, with 100 per cent of tree potential of grassland reached by the end of century.

Based on these assumptions, we found that urban greening actions could reduce heat-related deaths across the Lower Mainland by 12 per cent in

[25] For further details, see technical report.
[26] For assumptions about the costs and benefits of increasing mechanical cooling, see technical report.

the 2030s compared to status quo policies. This is equivalent to a reduction in societal costs of about $1 billion per year. Further, we estimate a reduction of 7 per cent in heat-related hospitalizations, equivalent to savings of approximately $3 million in healthcare costs per year (Figure 8).

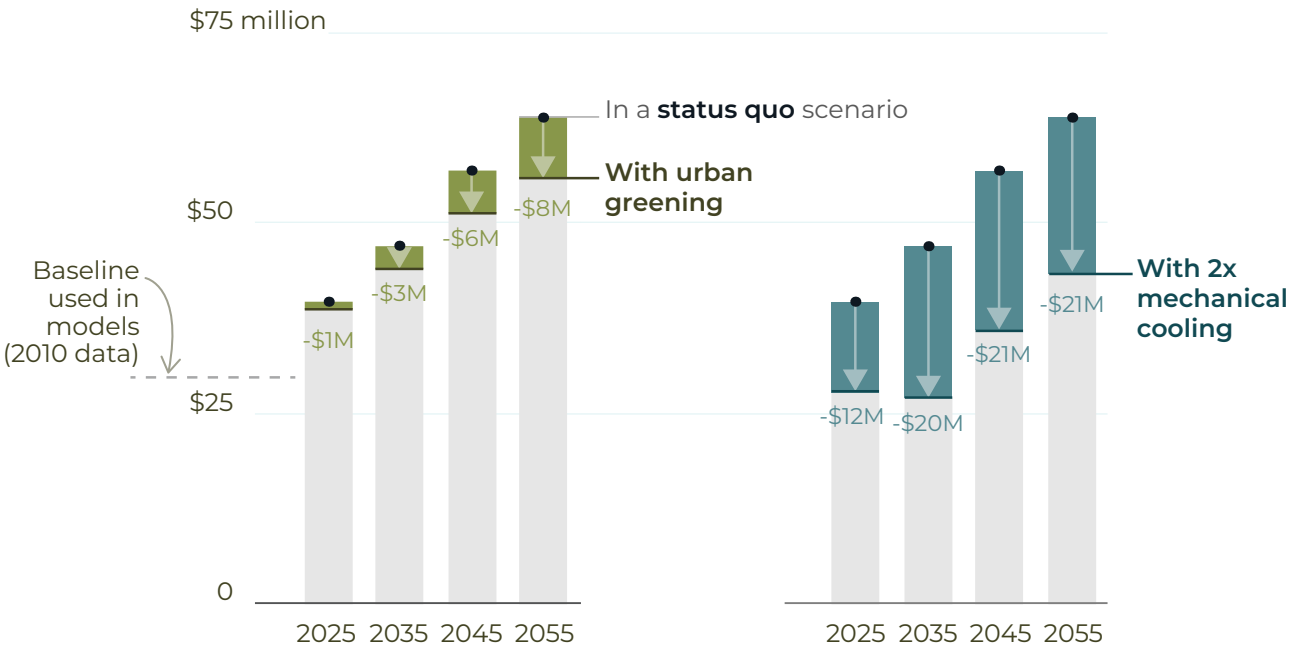
We found that compared to other adaptation options considered, urban greening measures did not have an immediate impact. In part, this is because it takes decades for trees to mature to a point where they make a substantial impact. Further, because it is often cost-prohibitive to retrofit roofing and pavement, we assume increasing reflectiveness takes time. However, urban greening measures show benefits over the long term; by the end of the century, under a high-warming scenario our modelling suggests that urban greening would result in fewer deaths and hospitalizations compared to mechanical cooling.

We calculated that the return on investment for the urban greening adaptation would be between $1.4 and $0.90 for every one dollar invested. We did not account for co-benefits, such as the potential to reduce local flood risk, nor did we account for potential tradeoffs and challenges in urban planning, such as the implications on housing affordability of urban greening and densification.[27]

Figure 8

Proactive adaptation interventions like urban greening and mechanical cooling can reduce the annual cost of heat-related hospitalizations by up to 30% by mid-century.

Projected annual costs of heat-related hospitalizations in the Lower Mainland



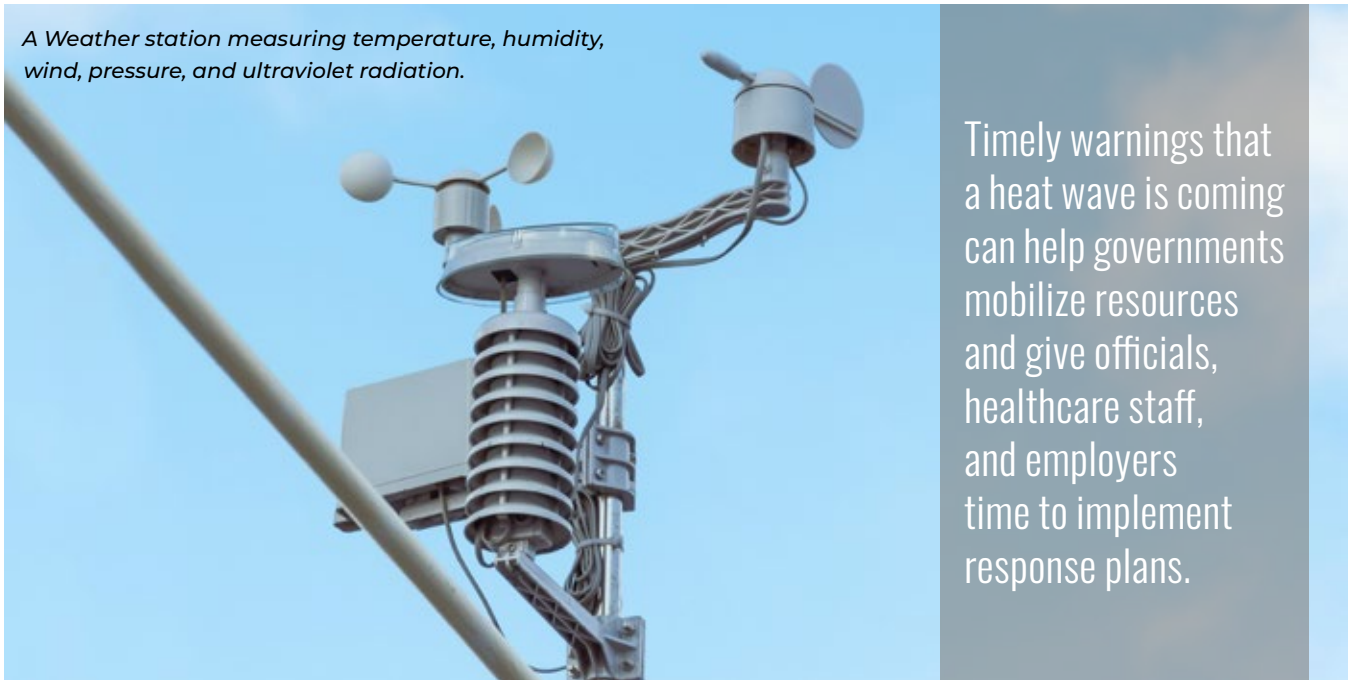
[27] Discussion of our assumptions about the costs and benefits of urban greening measures can be found in the accompanying technical report.

Weather forecasts are sufficiently accurate to increase lead times for public heat warnings in B.C.

Timely warning that a heat wave is coming can help governments mobilize resources and give officials, healthcare staff, and employers time to implement response plans. Public heat warnings in the United States, Europe, and Australia are issued several days in advance (National Weather Service 2023; Casanueva et al. 2019; Victoria Department of Health 2023). While ECCC shares information about potential heat waves with governments and the media prior to issuing official heat warnings, ECCC only issues public heat warnings one to two days prior to a heat wave (based on the weather forecast for the next two days) (ECCC 2020; McLean et al. 2018; BC Coroners Service 2022; City of Burnaby 2021). In 2021, ECCC issued a public heat warning at 5 p.m. on June 23, less than two days before the heat wave started (Little 2021). Some municipalities and other organizations relied on ECCC's public heat warning to trigger public health measures (City of Burnaby 2021). Other organizations waited until the Lower Mainland's Extreme Heat Alert was issued on the first day of the heat wave.

ECCC and the BC Centre for Disease Control cited weather forecasting accuracy as one potential limitation in developing heat alert thresholds for B.C. in an effort to minimize the number of false alarms and warning fatigue (McLean et al. 2018). Based on ECCC's heat-warning criteria (ECCC 2020), we examined if ECCC could issue public warnings multiple days in advance with a reasonable degree of accuracy. We did not quantify the benefits of increased lead times, but it can be reasonably assumed that greater lead times will improve emergency response, sometimes dramatically.

We used datasets from ForecastWatch to compare historic forecast data with historic weather observations and evaluated the accuracy of 16 weather station forecasts from the U.S. and Canada leading up to and during the 2021 heat wave (Figure 9). We found that temperature forecasts were generally accurate three days in advance. The most accurate stations three days out were Spokane, Omak, Kelowna, and Williams Lake. These stations had differences between forecasted temperatures and actual temperatures of about 1.5° C. The four least accurate stations were Lytton, Whitehorse, Vancouver, and Kamloops, where such differences averaged about 3.5° C.



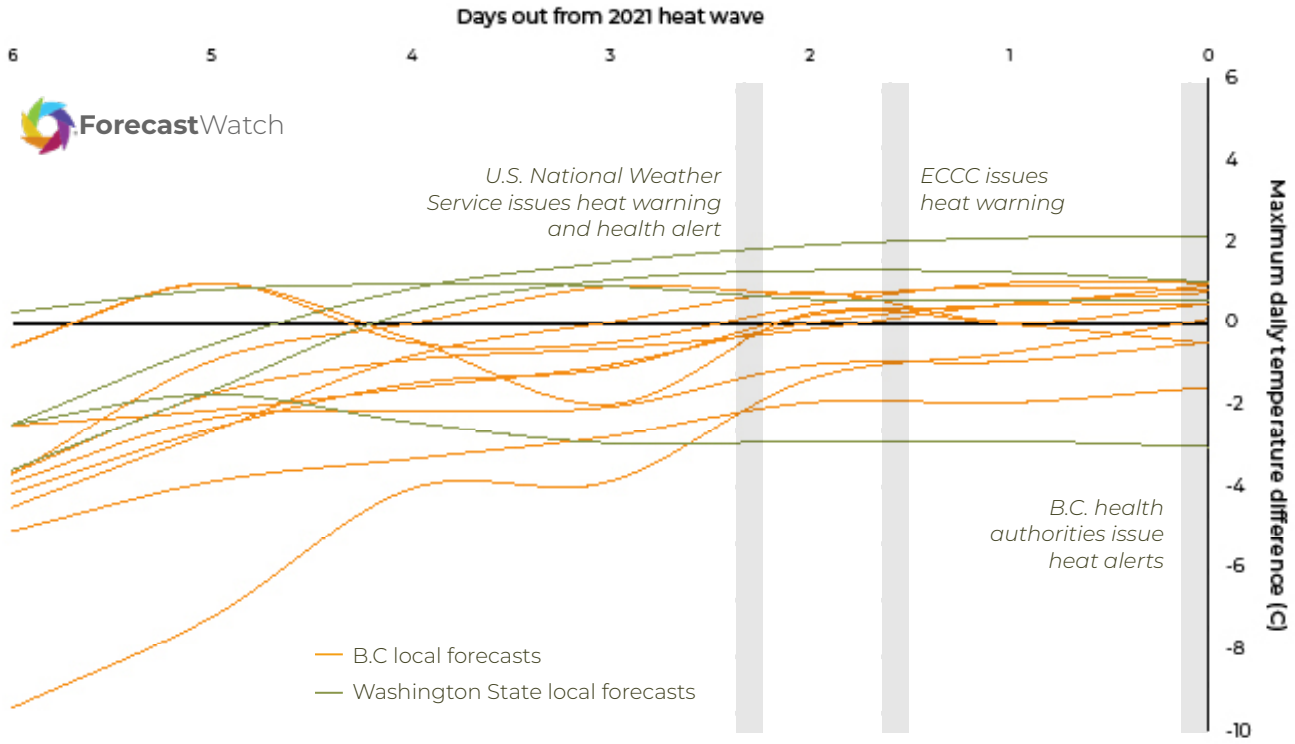
A Weather station measuring temperature, humidity, wind, pressure, and ultraviolet radiation.

Timely warnings that a heat wave is coming can help governments mobilize resources and give officials, healthcare staff, and employers time to implement response plans.

Figure 9:

Forecast accuracy was fairly consistent three days prior to the heat wave.

Forecasting accuracy in B.C. and Washington, June 25-29, 2021



We also evaluated how accuracy would change if ECCC transitioned from their usual approach of a one or two days notice for a public heat warning to a three-day notice. We found that warning accuracy and precision would decrease slightly—a 15 per cent increase in false alarms. However, this magnitude of error is less than ECCC average warning errors for all other types of extreme weather (ECCC 2022b). Our analysis suggests that weather forecasts are sufficiently accurate for ECCC to realistically issue public heat warnings three days in advance of heat waves.

Both upstream public health actions and downstream health system adaptation interventions are important

The healthcare system should be the last line of defence against heat wave deaths. Upstream adaptation interventions are critical to reducing demand on the healthcare system in the long term. However downstream interventions are also essential. And there is a substantial risk of downstream impacts across the health system if decision makers develop policies and public health initiatives in silos.

For example, an ambitious public communication initiative and increased wellness checks by neighbours or home care could help people recognize their symptoms earlier and get to a hospital before their condition becomes critical. However, the net lives saved could be substantially lessened because of added delays and deaths at hospitals. In other words, the issue could move downstream to another bottleneck unless policies are changed throughout the system. This aligned with our interviews with healthcare workers, many of whom suggested that the hospitals would have been in an even worse position if there had not been as many upstream issues with ambulances, as more people would have required triaging and care in emergency departments. This does not mean that upstream adaptation interventions are ineffective, but reinforces the importance of thinking about upstream and downstream adaptation interventions together.

5 ELECTRICITY AND TRANSPORTATION SYSTEMS

In this section, we describe how extreme heat can impact electricity and transportation systems, and the specific impacts the heat wave had on that infrastructure. We then identify key vulnerabilities that affected outcomes during the heat wave. Finally, we analyze the costs and benefits of adaptation interventions that could help address these vulnerabilities.

Extreme heat can affect the reliability of electricity systems by increasing electrical resistance within transmission and distribution lines and equipment, which reduces the efficiency of electricity transmission and increases the likelihood of equipment failures. Extreme heat can also cause outages if widespread use of air conditioners and other mechanical cooling equipment increases demand beyond a grid's capacity.

Heat waves also impact transportation systems. As temperatures rise, rail tracks can expand, which can cause them to warp (Industrial Economics 2021; Setsobhonkul et al. 2017; Ness et al. 2021), increasing the potential for derailments. Though less common in Canada, heat can also lead to asphalt rutting, resulting in higher maintenance costs (Barrow et al. 2020; Fletcher et al. 2016; Mills et al. 2007; Maadani et al. 2021). Temperature is especially important for paved infrastructure because these assets are designed for a specific temperature range, usually based on historical experience. If roads continue to be designed and maintained with pavement design criteria that do not account for a warmer future climate, more extreme heat is highly likely to lead to increased costs to governments for maintenance, repair, and replacement (Fletcher et al. 2016).

Electricity and transportation systems impacts and costs

All sectors and households depend on reliable electricity and transportation systems. When climate changes damage those systems, it can result in both human and economic costs. During the heat wave, there were no critical damage or outages in the B.C. electricity system that resulted in major costs, but there were signs the system would be at risk in a future of more frequent extreme heat.

The electricity system experienced record summer demand and numerous localized outages

To understand the impacts and costs on the provincial electricity system from the 2021 heat wave, we analyzed information from public reports, freedom-of-information disclosures, and interviews with government officials. Although we were unable to access detailed information from BC Hydro—the province's main power utility—to calculate specific costs of the 2021 heat wave, we describe the breadth of impacts.

During the summer of 2021, BC Hydro set 19 all-time summer daily peak electricity demand records, including an all-time summer peak hourly demand record on June 28 of 8,568 megawatts (BC Hydro 2022). This new record surpassed the previous one by 600 megawatts—the equivalent of turning on 600,000 portable air conditioners (BC Hydro 2022). The 2021 heat wave led to a number of localized power failures across B.C., resulting in outages for an estimated 40,000 customers (Colelli 2021; Nesbit 2021; BC Hydro 2021a). These outages affected the function of mechanical cooling systems in homes, businesses, and institutions in many parts of the province. For example, there was a heat-related power outage at the Vancouver Island Correctional Centre, which meant that fans and ventilation were inoperable for close to eight hours during the peak of the heat wave (FOI:PSS-2021-13054). Data was not available to assess the complete number and extent of cooling failures across the province during the 2021 heat wave.

Electricity and transportation system vulnerabilities

We identified four key factors that affected the function and safety of infrastructure during the 2021 heat wave (Table 9).

Table 9:

Electricity and transportation system vulnerabilities that contributed to 2021 heat wave impacts

Physical systems	Institutions
• The electricity system was resilient overall, but localized failures highlight heat wave vulnerabilities • Heat grounded critical helicopter fleets or limited their function	• Infrastructure codes and standards have been slow to reflect the changing climate-related risks • Utilities have few incentives to manage climate change and other longer-term risks

Electricity systems are not all designed for extreme heat

When electricity demand peaked during the 2021 heat wave, there were no wide-spread blackouts or system failures. However, there were specific elements of the electricity system that showed signs of weakness. For example, over 400 transformers failed due to the high power load (Government of British Columbia 2022b), and a power transmission cable that travels between mainland B.C. and Vancouver Island was damaged from heat exposure, leading BC Hydro to send out a notice warning large industrial customers on Vancouver Island of the potential need to reduce demand (BC Hydro 2021b).

These areas of vulnerability create significant risks. Reliable electricity is essential for critical services, including water treatment plants, grocery stores,

airports, and community centres (Clark and Kanduth 2022). The reliability of the electricity system will become increasingly important as more parts of the economy are electrified and people rely on electricity for even more aspects of daily life, in addition to the life-saving function of mechanical cooling during periods of extreme heat. Rural and remote Indigenous communities in particular may be at significant risk, as power outages sometimes last days or weeks before systems can be repaired (Unger 2021; Rezaei et al. 2016; Smart 2022).

Healthcare facilities are particularly vulnerable to power outages during extreme heat, as many do not have backup generators large enough to power air conditioning systems. Although hospitals and some long-term care facilities are required to have backup generators, they are only required to provide enough power for essential medical equipment and in many cases would not be able to power air conditioners during an electricity system failure.

Road infrastructure was damaged and air transportation disrupted

Interviewees from the B.C. Ministry of Transportation and Infrastructure indicated there were a number of instances where extreme temperatures damaged road networks. For example, busy roads developed deep ruts when extreme heat softened the asphalt, and bridges suffered joint damage due to thermal expansion (Government of British Columbia 2022d). The costs to the Government of B.C. of heat wave damage to road and bridge infrastructure was estimated to be in the tens of millions of dollars (B.C. Ministry of Transport and Infrastructure 2022). Data on the impacts of the heat wave on the province's railways was not available.

Air transportation was also disrupted. BC Ambulance Service helicopters were unable to land at main hospitals across the Lower Mainland, including at Royal Columbian Hospital, Vancouver General Hospital, and Whistler hospital because the hot air was too thin for them to safely hover and land (FOI: F22-1576). This meant that patients had to be transported by ground ambulances instead, potentially delaying time-sensitive treatment for conditions like stroke or traumatic injury. Further, based on interviews and performance data on the helicopters that BC Wildfire Service contracts, we found instances where wildfire management helicopters were likely unable to take off or where the service had to alter flight plans due to the heat (Sikorsky 2007).

BOX 5

Cascading hazards

The concept of cascading hazards refers to the creation of other hazardous events from the conditions created by an initial hazardous event. While our analysis is focused on the direct costs of the 2021 heat wave, factoring in the impacts of the cascading hazards resulting from the heat wave would have resulted in much higher overall costs. The heat wave was a major driver of the wildfires that followed, as it caused extreme dryness throughout the province, which raised fire danger levels to extreme conditions more normally seen towards the end of the summer (Government of British Columbia 2022b). Over the brief period of the heat wave, the number of active wildfires in B.C. rose from six, with 124 hectares burned, to 175 that consumed 78,939 hectares (White et al. 2023). The costs associated with heat wave-induced wildfires such as the costs of the damage and destruction to communities in affected areas, or the resources directed to firefighting, community evacuation efforts, or community recovery, are not included in our analysis. Complete assessment of the costs of the 2021 heat wave and of potential future heat waves, and preparation for future events, must incorporate the risks and costs of heat wave contributions to wildfire and other cascading hazards.

A motorist watches from a pullout on the Trans-Canada Highway as a wildfire burns on the side of a mountain in Lytton, B.C., Thursday, July 1, 2021. THE CANADIAN PRESS/Darryl Dyck

Future electricity and transportation costs

The costs of climate damage and destruction to infrastructure are likely to increase in the future, as more extreme weather, including extreme heat, place greater strain on critical infrastructure including electricity and transportation systems. Without proactive interventions, repairing and prematurely replacing climate-impacted infrastructure will carry a hefty price tag, and the human and economic costs of critical infrastructure disruptions will continue to increase.

Peak demand for electricity in B.C. could shift from winter to summer

In previous studies, the Canadian Climate Institute modelled future impacts and costs on the electricity system in B.C. due to climate-related equipment wear-and-tear and heat-induced electricity demand for air conditioning (Ness et al. 2021). While peak electricity system demand in B.C. has historically occurred in the winter, our analysis shows that increasing summer peak demand driven by increased mechanical cooling could overtake winter peak demand within a few decades. By the end of the century, average summer peak demands will match winter demand under a medium-warming scenario. Under a high-warming scenario, average summer peak demand will be higher than winter demand across B.C. (Ness et al. 2021).

Without new policies and adaptation of electrical transmission and distribution infrastructure, damage will continue to increase in the coming decades. We estimate that under a medium-warming scenario wear and tear due to heat and precipitation changes will cost B.C. electricity utilities $120 million annually and $140 million under a high-warming scenario (Ness et al. 2021).

Extreme heat could affect future railway reliability and operations

To estimate physical impacts and costs for B.C.'s railways, our earlier study examined the effects of warming summer temperatures directly on rail lines. Under extreme heat tracks become weaker and can deform, necessitating reduced train speeds and sometimes complete closure of track sections. We estimated that the cost of rail damage and delays in rail transportation in B.C. will grow by $19 million per year by 2030—with the majority of those costs being due to delays. We estimate costs could rise to between $27 and $62 million by mid-century for low- and high-warming scenarios respectively (Ness et al. 2021).

Extreme temperatures will increase wear-and-tear on B.C.'s roads

We estimate that wear and tear on B.C.'s roads from precipitation and temperature changes will cost the provincial and municipal governments an estimated additional $175 million per year by 2030 (Ness et al. 2021). By mid-century the additional annual costs for those governments will be between $346 and $483 million per year for a low- and high-warming scenario respectively. Heat impacts contribute roughly 75 per cent of these damages, with the remainder due to the impacts of more frequent and intense rainfall. Our findings indicate that a warming climate will reduce the costs of freeze-thaw damage to roads in some parts of B.C. but this reduction is far lower than the costs of damage from higher temperatures and increased precipitation (Ness et al. 2021).

Critical aviation services have not planned for more frequent and intense extreme heat

The main fleet of helicopters that is contracted by the BC Ambulance Service has reduced capabilities in high temperatures. For the current fleet to meet the hovering performance standards outlined in the Ambulance Service's procurement documents, temperatures need to be less than 15° C (Provincial Health Services Authority and BC Emergency Health Services 2021). Further, those helicopters have a stated maximum operating temperature of 45° C (Sikorsky 2007). This suggests that air ambulances may not be able to perform all of their necessary functions—such as landing on hospital helipads—in extreme heat, or may not be able to operate at all. By analyzing climate model projections for B.C., we found that by 2030, the helicopters currently contracted by the BC Ambulance Service and the BC Wildfire Service could be grounded in some regions for an average of one day every three years. By mid-century, we estimate that there would be at least two weeks each summer that some helicopters would be grounded due to extreme temperature. We were not able to estimate the potential costs of these impacts; however, it could impact medical care or wildfire suppression during times when they are most needed.

Electricity and transportation systems adaptation interventions

Proactive adaptation can lower these expected future costs. We modelled two sets of adaptation interventions based on the vulnerabilities we identified: replacing electricity system components with equipment that can withstand projected future heat, and upgrading road materials so that they are more resilient to future increases in precipitation and temperature.

Adjusting electricity system design could cut costs in half

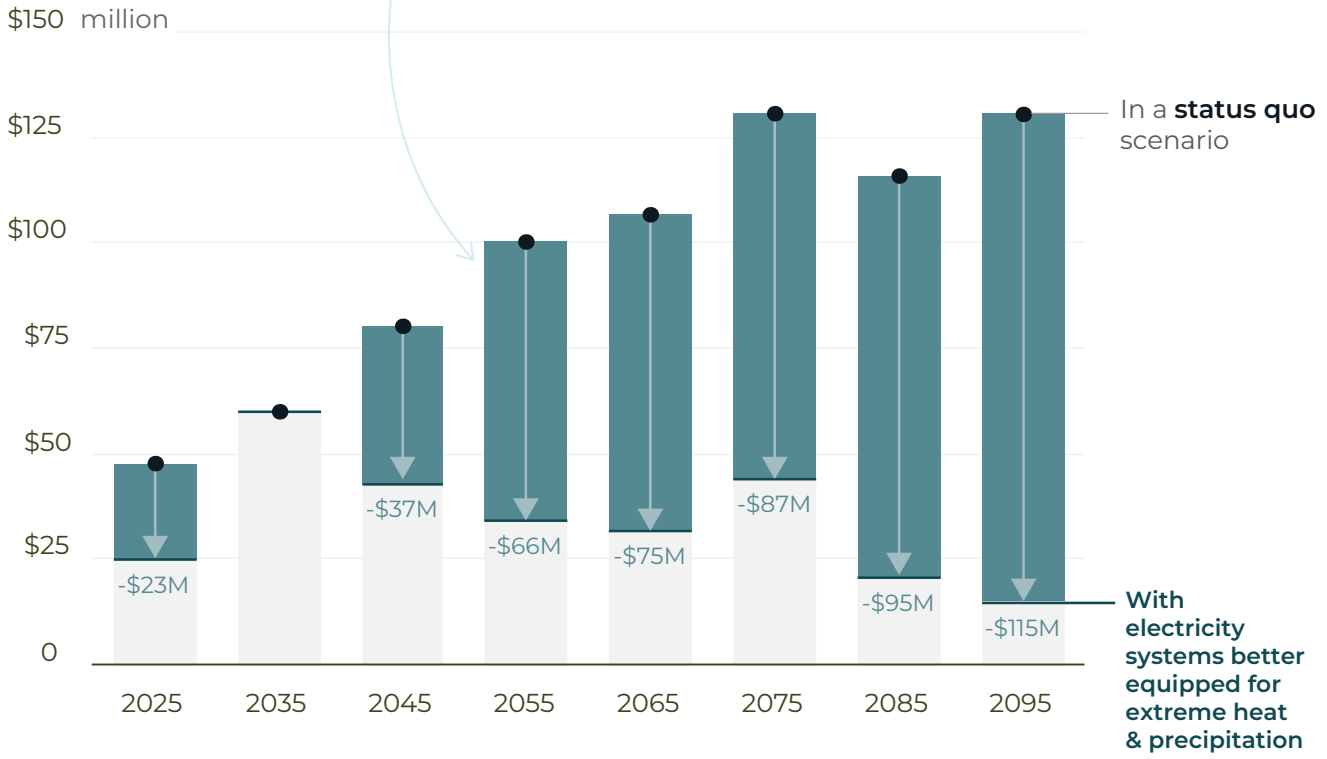
The Canadian Climate Institute previously analyzed the costs and benefits of proactively upgrading electrical transmission and distribution infrastructure in anticipation of future temperature and precipitation changes in all provinces and territories including B.C. (Ness et al. 2021). For the analysis, we assumed that utilities began replacing transmission and distribution equipment, such as transmission lines, transformers, and distribution poles, that is at the end of its life with materials and components that will be resilient to temperature and precipitation changes at least 30 years into the future.

We found that proactive adaptation can reduce climate-induced repair and replacement costs in B.C. by at least 50 per cent by 2040 compared to a baseline status-quo scenario (Figure 10). It was not possible to analyze the potential reduction in unplanned outages from designing and building electricity systems to operate in a hotter and more extreme environment. However, it is likely that adapting electricity systems to extreme heat would also reduce these risks (Canadian Electricity Association 2016).

Figure 10

Adapting electricity systems to operate in extreme environments can reduce repair and replacement costs by more than 50% by mid-century.

Projected annual electricity system repair costs for B.C. in a medium-warming scenario



Upgrading road materials will save costs and reduce disruptions

The Institute's previous analysis also modelled the benefits of upgrading to more heat resistant materials as roads are regularly maintained or replaced, including altering asphalt mixes with binder grades suitable for future summer temperature increases and modifying asphalt binders, surface sealants, and base layer material to better withstand future increases in precipitation. Our analysis found that, within a decade, climate-induced road damage costs could drop by 15 per cent in B.C. if these adaptation interventions are implemented. Further, returns will increase substantially thereafter as more roads are made resilient. Our findings suggest that with proactive adaptation interventions, by mid-century road damage costs from climate impacts could decrease by approximately 90 per cent. This is equivalent to about $300 million in savings per year for provincial and municipal governments. The B.C. Ministry of Transportation and Infrastructure has adopted new road design guidelines that have begun to drive this kind of adaptation (B.C. Ministry of Transport and Infrastructure 2019).

6 FOOD SYSTEMS

Extreme heat has negative physiological impacts for plants and animals that have implications for food systems (Thornton et al. 2021; B.C. Fruit Growers' Association 2018). In this section, we describe the impacts and costs of the 2021 heat wave on B.C.'s food systems with an emphasis on agricultural production. Next, we identify policy and institutional factors that played a role in heat wave impacts to those systems. Finally, we highlight adaptation interventions that could improve the resilience of the province's food systems.

Food system costs and impacts

The 2021 heat wave had a range of impacts on B.C.'s food systems. Livestock and shellfish fisheries were affected and production and quality of fruits and vegetables declined. These impacts led to costs for producers and increased insurance payouts, which are partially subsidized by governments and available for select crops to manage the risk of weather-related losses. There were also important impacts on traditional foods for Indigenous Peoples and communities.

Extreme heat stressed livestock and fisheries across B.C. impacting production and local economies

The 2021 heat wave affected the health of livestock and shellfish across the province. About 661,000 poultry died (Government of British Columbia 2021d), which represents more than $5 million in revenue losses (BC Chicken Marketing Board 2021; Lee and Parfitt 2022; B.C. Turkey Association and B.C. Turkey Marketing Board 2021). Egg and dairy production also declined (B.C. Ministry of Agriculture and Food 2021b; 2021c; FOI:AGR-2021-13065).

Shellfish harvesting and farming were significantly affected across B.C. One study estimated that one million wild mussels died in a 100-metre stretch of shoreline in the Salish Sea alone during the 2021 heat wave (White et al. 2023). Production of farmed mussels in 2021 decreased by 25 per cent compared to the previous two years (B.C. Ministry of Agriculture and Food 2022a). Media and government officials reported that up to 70 per cent of farmed shellfish died in some areas of the province (Dandekar 2021; CTV News 2022). The total revenue of commercial mussel farmers in B.C. declined by 40 per cent in 2021 compared to the previous five-year average, although the heat wave alone did not cause this decline (B.C. Ministry of Agriculture and Food 2022a). Impacts to individual operators were signif-

icant. For example, two oyster farmers reportedly incurred losses of $30,000 and $70,000 each after losing up to 80 per cent of their oysters (Dandekar 2021). No quantitative estimates of impacts to fish stocks were available, but anecdotal reports suggest the heat wave likely contributed to fish mortality (Government of British Columbia 2021d).

Fruit and vegetable production and quality declined in many regions

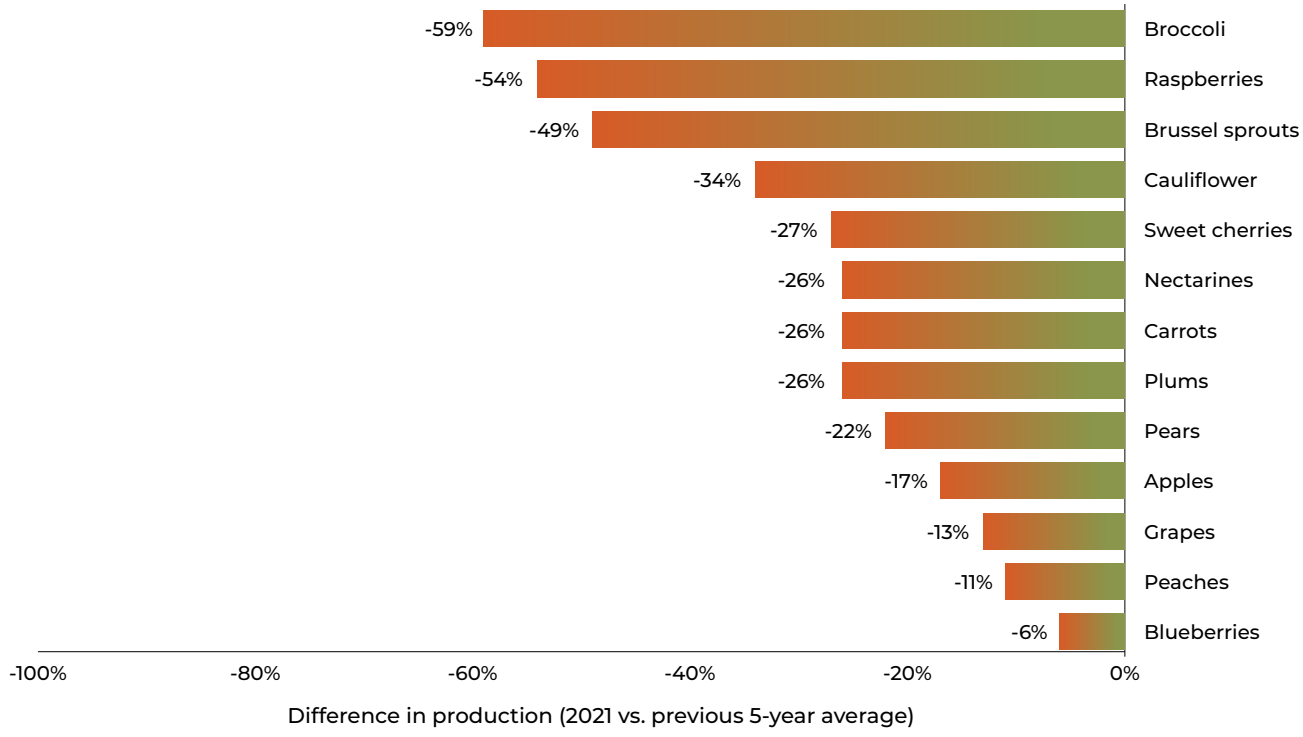
B.C. produces more fruit than any other province in Canada and the tree fruit industry alone contributed $162 million to the province's GDP in 2019 (AAFC 2021b; Deloitte 2021). The heat wave was especially costly for crops that were undergoing critical growth stages (White et al. 2023). For example, cherries and raspberries, which experienced some of the sharpest losses, are harvested in July and August, and are generally in a critical growth stage in late June (White et al. 2023). Other crops whose critical growth period did not coincide with the heat wave, like cranberries, were less impacted (White et al. 2023; B.C. Ministry of Agriculture and Food 2021b; 2021c).

It is challenging to isolate the impacts of the 2021 heat wave on annual crop production data, since B.C. faced multiple extreme weather events in 2021, including wildfires and floods. However, production data for crops that were impacted by the 2021 heat wave shows a considerable production decline in 2021 (B.C. Ministry of Agriculture and Food 2020; 2021c; 2021d; White et al. 2023) (Figure 11). In addition to production data, there are other metrics that can help paint a more comprehensive picture. Using satellite data, one study found a noticeable drop in live green vegetation—an indicator of plant health—in six out of the eight B.C. agricultural divisions between June 20 and July 3, 2021 (White et al. 2023). Some of the most pronounced declines in live green vegetation occurred in the most agriculturally productive regions of the province (White et al. 2023).

Figure 11:

B.C.'s crop production declined during the heat wave

It was especially costly for crops at a critical growth stage such as raspberries



Heat also leads to declines in fruit quality (Table 10). Heat stress can make fruits smaller and softer and cause skin damage, which can make them non-viable for sale (White et al. 2023; B.C. Fruit Growers' Association 2018). Raspberries and cherries, for example, which accounted for approximately $85 million of exported revenue in 2020, became smaller, discoloured, and shrivelled during the heat wave (B.C. Ministry of Agriculture and Food 2020; 2021c; 2021d).

The 2021 heat wave led to revenue losses for agricultural producers. The tree fruit industry lost over $17 million in revenue, which is 17 per cent of the industry's possible annual revenue (B.C. Fruit Growers Association 2021). Farm sales for raspberries in 2021 were over $6 million less than the previous five years' average—a 35 per cent decline.[28] Cherry sales were down by nearly $15 million—a 19 per cent decline (Statistics Canada 2023c).

Government-subsidized crop insurance payouts in 2021 for extreme heat amounted to nearly $12 million for tree fruits, which were the highest heat-related payouts of any recorded year according to interviewees from the B.C. Ministry of Agriculture (B.C. Ministry of Agriculture and Food 2022). The payouts were concentrated in the sweet cherry and apple sectors. In addition to revenue losses, producers incurred additional energy and irrigation costs (B.C. Ministry of Agriculture and Food 2021b; 2021c). B.C. farmers spent 17 per cent more on electricity in 2021 than the previous five-year average, although this increase cannot be attributed to the heat wave alone (Statistics Canada 2022b).

There were broad impacts to Indigenous food systems

Extreme heat poses distinct challenges to Indigenous communities (Gifford et al. 2022; National Collaborating Centre for Indigenous Health 2022). Warming temperatures over the past several decades have already affected the timing, availability, and abundance of traditional foods (Wale 2022; Turner et al. 2009). People who hunt, fish, and harvest traditional foods may have experienced additional impacts and short-term food shortages during the 2021 heat wave, likely contributing to food insecurity for Indigenous communities who rely on traditional food for their sustenance (Government of British Columbia 2022b; Yumagulova et al. 2022; BCAFN 2022).

[28] We use farm gate values to refer to producers' farm sales. Farm gate values only include payments to producers at the first point of transaction, and exclude subsequent delivery, storage, and marketing costs.

BOX 6

A first-person perspective on the impacts of the 2021 heat wave on Indigenous food sources

by Janna Wale

During the summer of 2021, I was in *Gitxsan* and *Secwépemc* territory gathering data for my master's thesis, which focused on climate resilience in Indigenous communities. I am a *Gitxsan* woman, and I was looking forward to being back in my community and participating in the harvesting activities that typically happen in late summer and early fall, like the salmon run and harvesting *Sima'aay* (Huckleberry). Through my research, talking to community members, and through my own experiences, I saw the significant impacts of the 2021 heat wave on our food systems.

During that summer, I interviewed eight individuals and surveyed 28 community members. Every one of them noticed the heat was impacting their territories. One participant commented on how dry the soil was, and how the heat was already altering flood and drought patterns in her territory. Another participant stated that it was almost like the plants were confused and were blooming at different times than normal. And someone told me about the poor condition of the fish coming up the rivers that year (Wale 2022).

When I went out to harvest huckleberry in August, I saw the extent of the impacts of the heat wave. Since huckleberry is one of the most harvested crops in our area, every family has their own favourite picking spots that have been providing for our families for generations. In 2021 we went to three locations before we were able to find berries in good enough condition to harvest. Once there, we had to hike to treeline to find berries that had survived—the lower elevations seemed to be hit harder than those up higher where it likely stayed cooler. Even still, the berries that survived the extreme heat at

higher elevations were showing evidence of heat stress: the leaves were withered, with visible damage along the leaf margins. The berries were smaller in size and were still quite bitter—almost as if they had ripened too quickly.

One of our teachings is that when you are picking, you must leave enough for animals, who also need the nutrients. While we were fortunate to get huckleberries that year, we had to work harder to get enough for everyone to have some to bring home while making sure we were not over-picking what little remained. As an Indigenous person living away from my community, being able to access traditional food like huckleberries throughout the year is a large part of my wellness—it creates continuity in my connection to community and allows me access to food as medicine. As climate change creates more frequent and more severe sudden onset events, coupled with continual slow onset warming, there will be more impacts to traditional food systems, like our huckleberry. These food systems impacts are far reaching: they impact our culture, identity, and health, because of the interconnected relationship they hold with the teachings, medicines, and practices that are threatened by climate change.

Wale is Gitxsan from Gitanmaax First Nation, as well as Cree-Métis on her mother's side. She holds two degrees from Western Institutions, and was harvesting huckleberry in her territory during the summer of 2021, the year of the B.C. heat wave.

Table 10:

Summary of the 2021 heat wave impacts on B.C.'s food industries.[29]

Industry	Regions affected	Impacts	2021 heat wave costs
Poultry	80% of poultry farms are in the Fraser Valley and Lower Mainland	• 661,000 poultry died, including 416,146 chickens and 60,000 turkeys raised for meat consumption • High temperatures in barns were unsafe; some birds had to be moved to cooler spots by hand • Some flocks produced at 70% below their egg-laying normal capacity	• $5 million in revenue losses for producers • No publicly available data for egg-laying poultry
Dairy	Most dairy farms are in the Lower Mainland, southeastern Vancouver Island, and north Okanagan-Shuswap area	• Milk production decreased by about 400,000 litres per day (17% decline) for five days • Half a million litres of milk were discarded because it was impossible to maintain it at cool temperatures	• Unspecified increase in costs for producers, including costs associated with supply chain disruptions
Shellfish	Most shellfish farms are on Vancouver Island and many Indigenous communities on the coast harvest shellfish	• Millions of marine species died, including commercially important ones (barnacles, mussels, oysters, clams, crabs) • Mussel harvesting declined by 9% in 2021 compared to the previous five-year average • Up to 70% of farmed shellfish died in some areas • Shellfish losses had food security and cultural impacts on Indigenous communities who harvest shellfish	• No information on total costs • Media reported that two oyster farmers incurred losses of $30,000 and $70,000 each after losing up to 80% of their oysters
Fish	Indigenous communities for whom salmon is nutritiously and culturally important were disproportionately affected	• Salmon mortality was likely higher given warmer waters and lower river and stream flows, which impairs salmon's ability to move and feed	• No publicly available data
Fruits	Fraser Valley and South Okanagan regions	• Decline in the production and quality of fruits, especially tree fruits (e.g., cherries) • Some cherry farms lost 70% of their fruit trees, and some berry farmers lost 10-60% of their crops • Lower sale revenues for fruit growers	• $12 million in crop insurance payouts due to heat damage to tree fruits • Industry estimates that the total loss of revenue from heat-damaged tree fruits is over $17 million
Vegetables	Field vegetables are primarily produced in the Lower Mainland, but also on Vancouver Island and B.C.'s southern Interior. Most greenhouse vegetables are produced in the Fraser Valley	• Decline in the production and quality of field vegetables (e.g., broccoli, cauliflower) and vegetables grown in greenhouses • Some crops could not be harvested from greenhouses because hot conditions were unsafe for workers • Increased energy and irrigation costs	• No publicly available data

[29] Sources: (B.C.CMB 2021; B.C.TA & B.C.TMB 2021; Lee and Parfitt 2022; White et al. 2023; Raymond et al. 2022; Dandekar 2021; B.C. Ministry of Agriculture and Food 2021d; Grant et al. 2019; B.C. Ministry of Agriculture and Food 2021b; Government of British Columbia 2022b; BC Dairy 2022; BC Fruit Growers Association 2021)

Food system vulnerabilities

We identified several vulnerabilities to heat for food systems in the province (Table 11).

Table 11:

Food system vulnerabilities that contributed to 2021 heat wave impacts

Physical systems	Institutions
• Inadequate cooling and refrigeration infrastructure	• Gaps in crop insurance policies and limited accessibility • Past and present colonial policies increase vulnerability of Indigenous food systems

Equipment and facilities were not able to keep food cool enough

Cooling, refrigeration, and ventilation infrastructure on farms was generally not designed to operate in the 2021 heat wave conditions making it more prone to malfunction and leading to crop and livestock losses (B.C. Ministry of Agriculture and Food 2021b; 2021c). For example, nearly half a million litres of milk had to be discarded during the heat wave because dairy processors overheated and shut down (B.C. Ministry of Agriculture and Food 2021b; FOI: AGR-2021-13065).

Crop insurance has limitations and is not accessible to many producers

Crop insurance regimes have gaps and limitations across the province. Crop insurance covers weather-related losses and is partially subsidized by the provincial and federal governments. However, not all crops are eligible for insurance in B.C., such as vegetables grown in greenhouses (Standing Committee on Agriculture and Agri-Food 2020). Shellfish and poultry producers also do not have access to subsidized insurance options available in other industries (Dandekar 2021; Standing Committee on Agriculture and Agri-Food 2020).

Even when insurance is available, participation rates in programs vary by crop. In 2021, 90 per cent of cherry hectares in B.C. were covered by production insurance, but only 35 per cent of blueberry and 40 per cent of broccoli, cauliflower, and brussel sprout crops were covered (B.C. Ministry of Agriculture and Food 2023). When extreme weather events occur and producers are not enrolled in crop insurance programs, they have few options to recover losses.

Crop insurance programs do not always meet farmers' needs. Insurance covers declines in crop abundance, but does not always pay out for heat-related declines in crop quality (B.C. Ministry of Agriculture and Food 2021d, 2021e). For example, cherry farmers can claim quality decline losses due to rain, hail, and wind, but not extreme heat (B.C. Ministry of Agriculture and Food 2021e). This limits crop insurance's applicability to situations where large declines in quality occur, rendering crops unmarketable.

Producers without access to crop production insurance can apply for income stabilization programs, such as AgriStability, which cover large declines in a producer's farm income relative to previous years. However, there are a number of barriers, including time-consuming application processes, producers' limited capacity to collect all the information required, payment delays, and low payouts (AAFC 2022a; Standing Committee on Agriculture and Agri-Food 2020; Peace River Regional District 2020; Crawford et al. 2013). Only half of fruit and vegetable farmers participate and

these barriers disproportionately affect smaller farms, women, young, and Indigenous farmers (AAFC 2017; AAFC 2022a; Crawford et al. 2013).

Disaster relief funds that the federal and provincial governments provided to producers after droughts, wildfires, and floods were not provided after the heat wave (AAFC 2021c; B.C. Ministry of Agriculture and Food 2021f, 2023d; B.C. Fruit Growers Association 2021). The B.C. Shellfish Growers Association also asked for access to insurance or disaster relief funds from the federal government (Dandekar 2021). To our knowledge, shellfish growers had not received financial assistance as of March 2023.

Past and present policies increase vulnerability of Indigenous food systems

The impacts of extreme heat on subsistence foods are amplified by the legacies of federal and provincial colonial policies and their impacts that continue today. Policies enacted by the Canadian government, including residential schools, the '60s Scoop, and the creation of the reserve systems, have impacted the relationship between Indigenous Peoples and their territories and have resulted in diminished access to traditional food and medicine, limited access to land, and theft of agency (Wale 2022; Gifford et al. 2022; Turner et al. 2009). In turn, this has impacted where and how Indigenous Peoples access food, contributing to food insecurity (Harper et al. 2022; Council of Canadian Academies, 2022). This legacy also affected Indigenous communities' trust in government emergency services during the heat wave (Yumagulova et al. 2022). A lack of autonomy afforded under current colonial policies to govern and make decisions regarding their own lands and territories is also a barrier to successful climate change adaptation efforts by Indigenous communities, including to extreme heat (Gifford et al. 2022).

Future impacts and costs

We have not projected future food system impacts because there were not clear quantitative relationships between heat exposure and yields that we could use to model impacts on many of the highest value crops grown in B.C. or the impacts on fish and aquaculture. However, existing evidence suggests that impacts of extreme heat will increase in the future. For example, agriculturally productive inland valleys and the central plateau of the province are projected to have more

People who hunt, fish, and harvest traditional foods may have experienced additional impacts and short-term food shortages during the 2021 heat wave, likely contributing to food insecurity for Indigenous communities.

than 15 days with temperatures above 32° C by mid-century (B.C. Ministry of Environment and Climate Change Strategy 2019). Heat-stressed plants, including fruit trees and blueberries, produce lower quality fruits above 30° C, and many fruit trees no longer grow above 35° C (BC Fruit Growers' Association 2018; Lobos et al. 2015). Heat stress among livestock is also projected to increase, and shellfish abundance in B.C. is projected to decline due to warming temperatures (Thornton et al. 2021; Marushka et al. 2019).

Food system adaptation interventions

We expect several key adaptation interventions to improve the resilience of B.C.'s food systems. Unlike the discussion of other impact areas, we do not quantify the benefits of these adaptation interventions, but we draw on research and experience in other jurisdictions to identify adaptation interventions that are likely to be effective in addressing the barriers and vulnerabilities described above. This is not a complete list of food adaptation measures, but rather illustrations drawn from studies and other jurisdictions.

Crop diversification can buffer against financial losses

Increasing crop diversity, including varieties with higher heat tolerance, can enhance the resilience of the agricultural sector to extreme heat. This is because farms and industries with diversified crops have more options if one crop variety fails due to heat-related stress, and diverse crop rotations produce more stable yields during extreme heat events (Council of Canadian Academies 2022; Standing Committee on Agriculture and Agri-Food 2018; Gaudin et al. 2015). Interviewees in B.C.'s Ministry of Agriculture mentioned that having more diverse crop varieties in the province could have lessened the damages caused by the 2021 heat wave, and producers in B.C. are already experimenting with different crops to reduce climate-related risks (B.C. Agriculture & Food Climate Action Initiative 2020). However, equipment and crop switching costs and economies of scale are often barriers to diversifying, especially for trees that take years to fruit (Wong et al. 2021; B.C. Agriculture & Food Climate Action Initiative 2014). Funding programs to incentivize climate-resilient agricultural practices, including diversification, can help farmers adapt to future extreme heat (Laforge et al. 2021; Thiessen Martens 2015; Abson 2013).

Increasing access to insurance could lessen financial impacts to farmers

Insurance regimes can reduce financial losses from extreme heat, but to be effective should be tailored to the needs and capacities of farmers. For example, crop insurance eligibility could be expanded to a wider range of crops and livestock as well as heat-related damages, farm types, and sizes (Standing Committee on Agriculture and Agri-Food 2020). In the case of aquaculture, interviewees in the B.C. Ministry of Water, Land and Resource Stewardship agreed that insurance programs similar to the ones available for other crops would benefit shellfish farms. Aquaculture insurance has also been shown in other countries to be an effective mechanism to help small-scale producers recover from large-scale losses (FAO 2022). Insurance programs will also be more effective if farmers have the information they need on the impacts of extreme heat to agriculture, and are aware of the programs available to help them make informed risk management decisions (Standing Committee on Agriculture and Agri-Food 2020; OECD 2020).

Cooling and irrigation infrastructure built for extreme heat can reduce impacts and costs

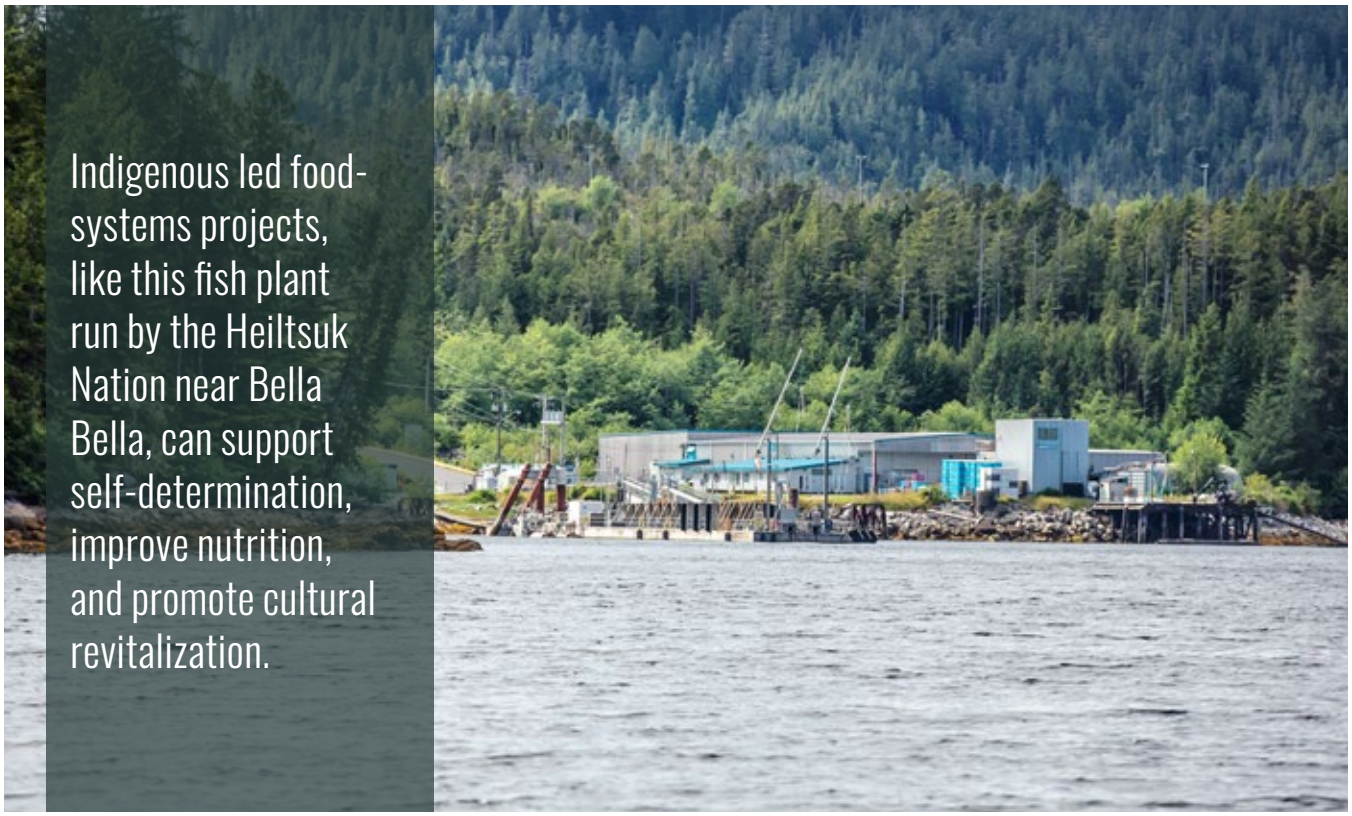
Improved cooling system infrastructure, like heat pumps or cross ventilation fans in barns, can help alleviate heat stress during heat waves by reduc-

ing internal temperatures to safe levels for livestock (B.C. Ministry of Agriculture and Food 2023b). Similarly, enhanced watering infrastructure (e.g., sprinkler systems in greenhouses), larger shade coverage from trees, and outdoor misters can help maintain safe temperatures for both crops and livestock and reduce losses (B.C. Ministry of Agriculture and Food 2023b; USDA 2016).

Addressing systemic vulnerabilities and improving food sovereignty could reduce impacts

Indigenous-led food sovereignty and food systems revitalization projects can help Indigenous communities adapt to extreme heat events. Reports and consultations with Indigenous communities conducted by Agriculture and Agri-Food Canada highlight the need to empower food sovereignty efforts to address food security challenges, including those exacerbated by climate change (Harper et al. 2022; AAFC 2021a). Indigenous-led food-systems projects can support self-determination efforts, address rural and remote diet deficiencies, and promote cultural revitalization (Harper et al. 2022; AAFC 2021a). These projects can also reduce dependency on food sources external to the community if an extreme weather event occurs (AAFC 2021a).

Two examples of Indigenous food sovereignty projects are the Tea Creek Farm located in Gitxsan territory and the Granny Gardens project in Haíłzaqv territory. Tea Creek Farm provides trades training for Indigenous people, while proactively growing and maintaining food crops that get distributed to the surrounding community (Fawcett-Atkinson 2020). Similarly, the Granny Gardens program coordinates seeds and soil delivered to community members who wish to grow their own food (Auger 2020). In addition, supporting aquaculture development, including training and infrastructure, would enable Indigenous communities to restore their traditional practices (e.g., clam gardening), and participate in the aquaculture industry (First Nations Fisheries Council 2016).



Indigenous led food-systems projects, like this fish plant run by the Heiltsuk Nation near Bella Bella, can support self-determination, improve nutrition, and promote cultural revitalization.

Don Glasgow, left, and Tricia Thorpe, whose home was destroyed by a wildfire in 2021, stand in front of their new home just north of Lytton, B.C., on Wednesday, June 15, 2022. THE CANADIAN PRESS/Darryl Dyck

7 FINDINGS AND RECOMMENDATIONS

This report surveys and assesses a large number of human and economic impacts from the 2021 heat wave in B.C., as well as potential future heat impacts due to a changing climate.

Our purpose, however, is not to simply articulate past issues, but rather to identify a path forward so that a disaster on par with the 2021 heat wave never happens again. Since the heat wave, various Government of B.C. departments and agencies have taken important actions to better manage and adapt to extreme heat (Table 12). What can B.C.—and other provinces and territories—take away from this report? And critically, what else can governments do to reduce these impacts in the future?

Table 12:

Actions provincial agencies have taken to address extreme heat since 2021

Actions include improved planning, increased investments, and policy changes

Type of Initiative	Specific actions [30]	Leading Ministry/agency
Creation of the BC Health Effects of Anomalous Temperatures (HEAT) Coordinating Committee	• Created BC's Heat Alert and Response System (HARS) to help ensure people, First Nations communities and local governments have the tools they need to stay safe during heat waves (May 2022) • Re-defined and established criteria for heat warnings and extreme heat emergencies, and streamlined activation processes • Recommended actions, standardized language, and key messaging to use in preparation for, and during extreme heat events • Established additional heat protocols in the event of an extreme heat emergency, including issuing public emergency alerts	BC HEAT Committee is led by the BC Centre for Disease Control, the B.C. Ministry of Health, and Health Emergency Management BC
Guidelines and communication tools	• Published a planning guide for provincial ministries and agencies on how the B.C. government will lead and coordinate activities in response to an extreme heat event based on the province's HARS (May 2022) • Published an *Extreme Heat Preparedness Guide* for individuals and communities on how to stay safe during extreme heat events (June 2022) • Developed communication tools for Health Authorities and healthcare provider guidance on heat-related illnesses • Co-developed extreme heat awareness resources for Indigenous audiences	B.C. Ministry of Health, B.C. Ministry of Emergency Management and Climate Readiness, PreparedBC, BC Centre for Disease Control, Health Authorities

[30] Strategies, plans, and objectives that have not yet resulted in material actions are not included in this table.

Type of Initiative	Specific actions [30]	Leading Ministry/agency
Infrastructure standards and incentives	• Established a climate resilience framework and heat-related standards for public sector buildings (2023) • Proposed changes to the BC Building Code that would establish design temperature requirements for a single living space within new dwelling units that must be maintainable through active and/or passive cooling measures, based on historical climate data (2023) • Funded infrastructure and equipment upgrades to adapt to extreme heat in livestock and horticultural operations through a pilot *Extreme Weather Preparedness for Agriculture Program* (Fall 2022) • Funding programs to incentivize cooling retrofits, like the *Better Homes and Home Renovation Rebate Program*	B.C.'s Climate Action Secretariat, B.C. Ministry of Agriculture and Food, B.C. Ministry of Energy, Mines and Low Carbon Innovation, B.C. Ministry of Housing
Emergency Health Services	• Created new Clinical Safety Plan to respond to B.C.'s ambulance system pressure and patient needs during extreme heat events, including increasing capacity and modifying triage protocols (June 2022) • Provided additional funding for BC Emergency Health Services to increase the number of paramedics and dispatchers, to increase the on-call rate for paramedics, and to increase the number of new ground and air ambulances • Initiated the transition of paramedics from an on-call workforce to a regularized workforce, both full and part-time • Introduced new low-acuity units to transport patients with non-urgent conditions to health care centres	B.C. Ministry of Health
Crop Insurance	• Expanded heat-related damage criteria for claiming crop insurance payments (Summer 2021)	B.C. Ministry of Agriculture and Food
Emergency preparedness and management	• Included funding for extreme heat risk mapping, assessment, and planning that First Nations and local governments can access via the *Community Emergency Preparedness Fund* (June 2022) • Made it easier to access emergency response funds during heat warnings and extreme heat emergencies	B.C. Ministry of Emergency Management and Climate Readiness
Engagement	• Developed an engagement plan for partners and the public on extreme heat-related activity and supports to date • Collaborated with federal partners and other ministries to share learnings and align knowledge and information • Engaged with equity-deserving communities to better understand diverse lived experiences of the heat wave and how these groups can be better supported (April 2022) • Consulted with local governments, the insurance and real estate industry, NGOs, utilities and regulators, and building owners on changing building codes in response to extreme heat (Fall 2021)	B.C.'s Climate Action Secretariat, B.C. Ministry of Housing
Public Housing	• Purchased and distributed air conditioners and fans • Developed heat adaptation plans for new buildings, as well as renovations and upgrades of existing buildings	BC Housing
Long-term care	• Funded new or upgraded HVAC systems in long-term care facilities through the Safe Long-Term Care	Government of Canada

Findings

Our assessment of the 2021 heat wave finds that impacts were extensive. The most severe direct impact—in both human and economic terms—was the premature death of hundreds of people. Food systems, workers, and electricity and transportation infrastructure were also significantly affected. Although the impacts to human health and the health system were by far the largest, impacts in other areas highlight important vulnerabilities that could lead to significant consequences in future heat waves.

Our modelling suggests that, without adaptation interventions, these impacts will reoccur and increase under B.C.'s future climate—even if global greenhouse gas emissions are reduced. The overall findings from our work can be summarized as follows:

1. **The 2021 heat wave was one of the costliest disasters in B.C. history when the cost of lost lives is accounted for.** The most severe impacts of the 2021 heat wave were associated with the deaths of hundreds of people. We estimate that avoiding these deaths has an economic value of $5.5 billion dollars when based on the Value of a Statistical Life (see VSL Box 3, page 31). We also found that healthcare costs attributed to the heat wave amounted to $12 million. The values of lost lives and premature deaths are often not adequately considered when weighing the costs and benefits of policy options and adaptation investments. Our analysis shows that the return on investment on adaptation interventions such as increasing access to mechanical cooling, and urban greening is substantial when the value of human life is accounted for.

2. **Broad uptake of mechanical cooling in homes and buildings, as well as urban planning, can save hundreds of lives in future extreme heat events and reduce healthcare costs.** The vast majority of people who died in the 2021 heat wave were exposed to extreme temperatures in homes without functional mechanical cooling. In addition, areas with a lot of asphalt and concrete surfaces and a lack of tree cover—often in socially and materially deprived neighbourhoods—experienced some of the hottest outdoor and indoor temperatures. Increasing mechanical cooling in homes and residential buildings, as well as urban greening efforts, can dramatically reduce heat-related deaths and deliver a substantial return on investment. These actions can also reduce risks for those most vulnerable to extreme heat, including the elderly and those with chronic illnesses, certain mental illnesses, and low incomes.

3. **Critical infrastructure, especially electricity infrastructure and health facilities, were pushed to the limit, highlighting the potential for future breakdowns.** During the heat wave, a number of hospitals became dangerously hot and had critical equipment outages. Further, while there were no widespread power outages, local heat-related electrical breakdowns suggest the potential for major system disruption in future heat waves. Not only will this have economic implications for utilities and businesses, but it creates the risk that air conditioners, heat pumps, chillers, and fans will not have the power to run when people need them most.

4. **The impacts of the 2021 heat wave on B.C.'s economy were widespread but generally not as severe as other disasters, highlighting opportunities to proactively build resilience to a future, hotter climate.** The heat wave affected agricultural production, put workers at risk, and reduced economic productivity across many sectors. Further, agriculture producers alone lost at least $25 million in revenue from production declines. While not catastrophic, these impacts are significant and highlight the importance of protecting workers across all industries and, in particular, preparing B.C.'s agricultural sector for more frequent extreme heat.

5. **Institutional and policy gaps hindered B.C.'s response to the heat wave.** B.C. institutions and policies have not caught up to a changing climate and were not designed to effectively respond to a heat wave as long, severe, and widespread as the June 2021 event. As a result, communications and decisionmaking did not provide rapid action, deployment of resources, and resolution of bottlenecks. These system-level challenges exacerbated capacity constraints and restricted the ability of individual agencies and actors to respond effectively. The impacts and costs were not the result of one single decision or issue, but a cascade of institutional challenges, including a lack of incident command, communications challenges, insufficient health system preparedness, and gaps in knowledge about heat's effects on people's health and well-being. Since 2021, governments across B.C. have taken significant steps to prepare for heat waves, but additional adaptation interventions are essential to better protect people, communities, and the economy.

6. **B.C.'s current approach to reviewing and understanding disasters like the 2021 heat wave is not optimized to support policy learnings and adaptive management.** While individual ministries, municipal governments, and health authorities have internally reviewed the events of the 2021 heat wave and have made internal recommendations for policy change, the relatively siloed nature of these reviews creates inefficiencies and undermines the ability of the Government of B.C. and other relevant actors to identify systemic issues and corresponding solutions. In addition, information related to the heat wave impacts and response has not always been easily accessible and not all reviews have been public, hindering the ability of other stakeholders to learn relevant lessons. To support adaptive management across the province and the country, all relevant information should be shared widely. The combination of existing reviews and this report create a reasonable understanding of the events of the 2021 heat wave, why it became a disaster, and policy changes that can improve outcomes in future heat waves. However, the review process should be improved to lay the foundation for policy learnings to prevent future disasters.

Recommendations

Our analysis shows that extreme heat events will occur more often in B.C. as climate change continues to worsen. Without adaptation interventions, more people will suffer and die from heat-related illnesses as B.C.'s health system will be repeatedly challenged. This places everyone in B.C. at greater risk, not only those particularly vulnerable to heat. In addition, the costs to governments, businesses, and taxpayers will increase—from emergency response, damage to infrastructure, and lost economic output.

However, B.C. is not bound to a future of heat disasters. Our analysis shows that key adaptation interventions—including policy and procedural changes—can significantly reduce the human and economic costs of extreme heat. Many of the interventions that can potentially deliver the greatest return on investment are changes to how the government and public institutions respond to disasters, such as improving execution of mass casualty response plans and incident command systems. Other adaptation interventions that prepare buildings, infrastructure, and workplaces can also dramatically reduce the toll of extreme heat. Neither will be easy to implement—the former requires changes to deeply embedded routines and the latter can entail significant investment. However, these investments more than pay for themselves when the value of the many lives lost is factored in. For example, increasing mechanical cooling returns between $6.90 and $4.60 for every dollar invested.

Since the 2021 heat wave, various Government of B.C. departments and agencies made important changes to how disasters will be managed in the future. This includes starting to act on some of the recommendations from the BC Coroners Service (Table 12). The Government of B.C. has also taken important steps to improve emergency response to heat waves and public awareness, but many of the vulnerabilities we identified have not been fully addressed. The Institute's work indicates more needs to be done to protect people's health and reduce economic impacts of future extreme heat events.

The following are recommendations for what different orders of governments in B.C. and across Canada can do to reduce the impacts and costs of future extreme heat events. Although our recommendations are primarily intended for the Government of B.C., the lessons learned are relevant to communities and governments across Canada.

1. **The Government of B.C. and all health authorities should explicitly account for the human as well as financial costs of heat-related illness and death in policy cost-benefit analyses.** Extreme heat events are the deadliest form of climate-related disasters, but are often seen as lower priority by governments when they are considering adaptation investments, as they don't have the same tangible costs as other climate-driven events (i.e., flooding and wildfires). To capture the true costs of extreme heat events when evaluating policy options, the government should ensure that cost-benefit analyses include the human costs of illness and premature death using metrics such as Value of a Statistical Life (see VSL Box 3, page 31). Although this metric is less tangible than the direct financial costs associated with other climate-related disasters, it represents how much government investment the public would support if it meant reducing the risk

of deaths. This provides important context for government decisionmaking—if the public supports substantial government investment to avoid premature deaths, higher priority might be given to extreme heat adaptation and emergency and health system response capacity for these events.

2. **Governments of all orders should urgently prioritize the targeted deployment of tools such as mechanical cooling and urban greening to help maintain safe indoor temperatures and protect lives.** To increase the use of mechanical cooling, governments should use tools such as building code updates, standards, and legislation to make homes and buildings safe for occupants during extreme heat events. To address equity-related issues and ensure that those who are most vulnerable to extreme heat are protected, those tools should apply to existing as well as new buildings, and policies should explicitly incentivise uptake for rental units. In addition, the Government of B.C. should use mechanisms such as health authority mandate letters, licensing, and regulation to ensure that all hospitals, correctional facilities, and inpatient mental health facilities do not exceed safe temperature limits. Municipal governments should use mechanisms such as building permits, zoning, and land leases to increase adoption of reflective roofing and green roofs, and should invest in tree planting and enhancement of urban forest canopy.

3. **The Government of B.C. should build heat-related risk into critical infrastructure decision making and account for compounding hazards.** The government should prioritize adaptation investments that protect critical infrastructure from disruptions caused by extreme heat, such as building electricity systems that are resilient to rapidly rising demand and a higher risk of transmission disruptions, and incorporating climate-resilient road materials to reduce heat-induced rutting. The government should also update risk management processes and service capacity for critical infrastructure providers—such as BC Hydro and hospitals—to ensure that services can continue when they are most needed. Increased service capacity would reduce direct risks to the infrastructure as well as limit the potential knock-on effects, such as power outages preventing the use of mechanical cooling during extreme heat events.

4. **The Government of B.C. and provincial agencies should provide businesses and employers with the tools and information they need to protect themselves and their employees from extreme heat.** The government should update occupational standards to account for extreme heat while ensuring that there is adequate capacity to enforce these standards. In addition to updating these standards, the Government of B.C. and WorkSafeBC should provide timely guidance to all industries, especially the agriculture, construction, and hospitality sectors, about heat safety during extreme heat events to minimize workplace disruptions and harms to workers. One tool that should be developed and implemented is shifting work hours to avoid the hottest periods of the day.

5. **Governments and public agencies should continue to address disaster response gaps and increase capacity to minimize impacts to people and the economy from extreme heat.** The Government of B.C. should collaborate with Meteorological Services Canada to increase investments in weather monitoring networks and deliver accurate public heat warnings three days in advance. The Government of B.C. and health authorities should also create a clear set of standards—such as a provincial mass casualty plan—for healthcare staff, first responders, and emergency managers to guide activation of patient triaging and resource allocation if emergency medical demands exceed capacity. Health authorities should ensure that all regional hospitals and trauma centres are prepared to manage high patient inflows. The Government of B.C., health authorities, and municipalities should increasingly practice and plan for multi-disasters—including combinations of climate-and non-climate related disasters, such as earthquakes and heat waves. The Minister of Emergency Management and Climate Readiness should be mandated to coordinate with the Ministry of Health and the Ministry of Public Safety and Solicitor General to proactively address institutional and policy gaps that are currently restricting B.C.'s ability to respond effectively to disasters.

6. **The modernized Emergency Program Act should include requirements for independent and public reviews of disaster response and planning after major disasters to enhance accountability and support adaptive management.** The review should be automatically triggered based on clear thresholds such as number of deaths, displacements, or financial losses, and should give power to an independent body to access government records and conduct confidential interviews so that the strengths and challenges of disaster responses are thoroughly assessed. Disasters are an indicator that there are significant system vulnerabilities, but they also provide an opportunity to identify the effectiveness of disaster resilience and adaptation investments taken to date and where gaps exist that require further action. An independent review is a critical component of a transparent and comprehensive learning process, which lays the ground for adaptive management to reduce vulnerabilities. Such a review process would be consistent with the principles of the UN Sendai Framework on Disaster Risk Reduction, which the Government of B.C. has committed to, and includes the importance of understanding why disasters happen.

GLOSSARY

2021 heat wave: In this report, the 2021 heat wave refers to the heat wave that occurred between June 25 and July 1, 2021 in British Columbia.

Adaptation: The ways in which human and natural systems adjust to reduce the harmful effects of climate-related changes.

Boarding time: The interval between when physicians decide a patient will be admitted to an inpatient ward and the time the patient is physically moved from the emergency department to the inpatient ward

Climate: The average weather in a place over a long period of time, typically 30 years or longer.

Climate change: Changes in the climate of the Earth, predominantly caused by the burning of fossil fuels, which add heat-trapping gasses to Earth's atmosphere. It manifests as overall global warming but also in sea level rise, melting of previously permanent snow and ice fields, and more extreme weather.

Climate model: A climate simulation based on well-documented physical processes. Global climate models, also known as general circulation models (GCMs), use mathematical equations to characterize how energy and matter interact in different parts of the ocean, atmosphere, and land.

Climate projections: A simulated response of the climate system to a scenario of future emission or concentration of greenhouse gasses and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission, concentration, or radiative forcing scenario used, which is in turn based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized.

Code Orange: An emergency response protocol implemented by a hospital in the event of a mass casualty incident or disaster. This protocol is typically activated when the hospital needs to rapidly respond to a large number of critically injured patients, such as those involved in a natural disaster, terrorist attack, or other catastrophic event.

Critically ill / critical patient: Patient with a life-threatening condition or a patient who is at risk of developing a life-threatening condition. For this paper we use the term to refer to patients that are triaged into Canada Triage and Acuity Score of a I or II.

Disaster: Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with conditions of social vulnerability, leading to widespread negative human, material, economic, or environmental effects that require an immediate emergency response to satisfy critical needs and may require external support for recovery. Disaster risk is the likelihood that a disaster will occur within a specified period.

Early warning system: An adaptive measure for climate change that uses integrated communication systems involving hazard monitoring, forecasting and prediction, disaster risk assessment, and communication and preparedness activities to help communities prepare for hazardous climate-related events.

Extreme heat: The definition varies based on geographic location and weather conditions such as temperature, humidity, cloud cover, and duration of event; extreme heat is when

temperatures are much hotter than average for a particular time and place.

Excess deaths: The number of excess deaths is the difference between the number of observed deaths and the number of expected deaths over a certain period of time based on historical trends.

Healthcare system: An organization of people, institutions, and resources that deliver health care services to meet the health needs of the community.

Heat-related illness: Health outcomes that are preventable and are primarily caused by over-exposure to extreme heat and/or overexertion for a person's age or physical condition.

Heat-related deaths: People that die due to heat exposure. In this report we use this term to refer to individuals that the Coroners Service specifically identified as dying from heat.

Heat wave: A period of temperatures higher than what is normally expected (based on historic climate averages). Heat waves may span several days to several weeks.

Lower Mainland: The Lower Mainland is located in the southwest corner of British Columbia, from Horseshoe Bay to Hope, and is home to 60 per cent of the province's population. While the Lower Mainland is not legally defined, it overlaps with Metro Vancouver and the Fraser Valley Regional District.

Mass Casualty Incident: These are events where the number and severity of casualties temporarily exceed the resources and capabilities of local emergency medical services.

Mass casualty triaging: The assignment of response priority based on the level of injury and available resources. Healthcare providers are trained to use universal triaging decision trees like Simple Triage and Rapid Treatment (START).

Mechanical cooling: Mechanical cooling refers to any method that uses energy to actively cool an area, such as air conditioning and heat pumps.

Moral distress: A psychological response to morally challenging situations such as those of moral constraint or moral conflict or both.

Pacific Northwest: The Pacific Northwest is a geographic region in western North America bounded by the Pacific Ocean and the Rocky Mountains. There is no official boundary, but it generally includes Oregon, Washington, Idaho, and British Columbia.

Tree fruit: Fruits that grow in trees for human consumption in B.C. include apples, pears, cherries, peaches, nectarines, apricots and plums. Other fruits, such as berries, typically grow in shrubs, so they are not considered tree fruits.

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, negative effects of climate change, including extreme heat. In climate science, vulnerability is a function of exposure to a hazard, susceptibility, and adaptive capacity.

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The researchers declare that Indigenous peoples have inherent cultural rights and ownership of all oral histories and cultural information respectively, as discussed within the context of this research, as well as further claiming first rights to any intellectual property arising from cultural knowledge derived from community members and Knowledge Holders.

REFERENCES

Abson, D. J., Fraser, E. D. G., and Benton, T. G. 2013. "Landscape Diversity and the Resilience of Agricultural Returns: A Portfolio Analysis of Land-Use Patterns and Economic Returns from Lowland Agriculture." *Agriculture and Food Security*, 2(2). https://doi.org/10.1186/2048-7010-2-2

Adam-Poupart, A. N. Nicolakakis, E. Anassour Laouan Sidi, P. Berry, C. Campagna, D. Chaumont, D. Hamel, F. Labrèche, M.-P. Sassine, A. Smargiassi, J. Zayed. 2021. *Climate Change and Heat Vulnerabilities of Canadian Workers: Focus on the Central and Western Provinces of Canada*. Institut national de santé publique du Québec. Quebec City, QC. https://www.inspq.qc.ca/sites/default/files/publications/2791-climat-echange-heat-vulnerabilities-canadian-workers.pdf

Agriculture and Agri-Food Canada (AAFC). 2017. *Evaluation of AgriStability, AgriInvest, AgriInsurance and the Wildlife Compensation Program*. Ottawa, ON. https://agriculture.canada.ca/en/department/transparency/evaluation-agristability-agriinvest-agriinsurance-and-wildlife-compensation-program

Agriculture and Agri-Food Canada (AAFC). 2020. *Climate Change Impacts on Agriculture*. https://agriculture.canada.ca/en/environment/climate-scenarios-agriculture

Agriculture and Agri-Food Canada (AAFC). 2021a. *Climate Adaptation and Food Security - Food Systems Summit 2021: Stage 2 Dialogue Report*. Ottawa, ON. https://agriculture.canada.ca/en/department/initiatives/food-policy/food-systems-summit/climate-adaptation

Agriculture and Agri-Food Canada (AAFC). 2021b. *Statistical Overview of the Canadian Fruit Industry*. Ottawa, ON. https://agriculture.canada.ca/en/sector/horticulture/reports/statistical-overview-canadian-fruit-industry-2021

Agriculture and Agri-Food Canada (AAFC). 2021c. "Government of Canada Increases Total AgriRecovery Funding to up to $500 Million to Support Farmers Facing Extreme Weather." https://www.canada.ca/en/agriculture-agri-food/news/2021/08/government-of-canada-increases-total-agrirecovery-funding-to-up-to-500-million-to-support-farmers-facing-extreme-weather.html

Agriculture and Agri-Food Canada (AAFC). 2022a. *Evaluation of AgriStability*. Ottawa, ON. https://agriculture.canada.ca/en/department/transparency/audits-evaluations/evaluation-agristability

Agriculture and Agri-Food Canada (AAFC). 2022b. *Statistical Overview of the Canadian Fruit Industry 2021*. Ottawa, ON. https://agriculture.canada.ca/en/sector/horticulture/reports/statistical-overview-canadian-fruit-industry-2021

American Conference of Governmental Industrial Hygienists (ACGIH). 2019. *TLVs® and BEIs® Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices*. Cincinnati, OH.

Auger, O. 2020. "How Gardening Is Helping Haíłzaqv (Heiltsuk) Nation Cope with COVID-19." *The Discourse*. https://thediscourse.ca/vancouver-island/how-gardening-is-helping-hai%C9%ABzaqv-heiltsuk-nation-cope-with-covid-19

Barrow, E., Bleau, N., Booker, J., Livingston, T., Matthews, L., O'Sullivan, S., Patt, A., and Tyler, K. 2020. *Pavement and Extreme Temperatures in the City of Toronto*. Climate Data Canada. Toronto, ON. https://climatedata.ca/case-study/pavement-and-extreme-temperatures-in-the-city-of-toronto/

Baze Baum, K., and M. McClearn. 2021. "Extreme, Deadly Heat in Canada Is Going to Come Back, Worse than Ever. Will We Be Ready?" *The Globe and Mail*. Toronto, ON and Vancouver, BC. https://www.theglobeandmail.com/canada/article-extreme-deadly-heat-in-canada-is-going-to-come-back-and-worse-will-we/ (June 26, 2022).

B.C. Agriculture & Food Climate Action Initiative. 2020. "Vancouver Island Adaptation Strategies." https://bcclimatechangeadaptation.ca/wp-content/uploads/2022/Resources/RegionalStrategies-VancouverIsland.pdf

B.C. Agriculture & Food Climate Action Initiative. 2014. "B.C. Farm Practices and Climate Change Adaptation: Summary Report and Additional Findings." https://bcclimatechange-adaptation.ca/app/uploads/FarmPractices-SummaryReport.pdf (April 13, 2023).

BC Assembly of First Nations (BCAFN). 2022. *Climate Strategy and Action Plan*. Vancouver, BC. https://www.B.C.afn.ca/sites/default/files/2022-04/B.C.FNCSAP%20Final%20Draft%20%2822April2022%29.pdf

BC Assembly of First Nations (BCAFN). 2023. "Vision & Mission." https://www.B.C.afn.ca/about-B.C.afn/vision-mission (April 13, 2023).

BC Centre for Disease Control (BCCDC). 2017. *Developing a Municipal Heat Response Plan: A Guide for Medium-Sized Municipalities*. Vancouver, BC. http://www.B.C.cdc.ca/resource-gallery/Documents/Guidelines%20and%20Forms/Guidelines%20and%20Manuals/Health-Environment/Developing%20a%20municipal%20heat%20response%20plan.pdf

BC Chicken Marketing Board. 2021. *2021 Annual Report*. Abbotsford, BC. https://B.C.chicken.ca/wp-content/uploads/2022/03/B.C.ChickenAnnualReport2021.pdf

BC Coroners Service. 2022. *Extreme Heat and Human Mortality: A Review of Heat-Related Deaths in B.C. in Summer 2021*. Burnaby, BC. https://www2.gov.B.C..ca/assets/gov/birth-adoption-death-marriage-and-divorce/deaths/coroners-service/death-review-panel/extreme_heat_death_review_panel_report.pdf

BC Dairy. 2022. "*2021-2022 Annual Report: Our Path to a Stronger B.C. Dairy*." Burnaby, BC. https://B.C.dairy.ca/dairy-farmers/annual-reports/

BC Fruit Growers' Association. 2018. *Climate Change and Tree Fruit Production in British Columbia: Presented to the Senate Committee on Agriculture and Forestry*. Kelowna, BC. https://www.B.C.fga.com/files/Senate%20Committee%20on%20Agriculture%20and%20Forestry%20-%20Climate%20Change%20in%20the%20Okanagan.pdf

BC Fruit Growers Association. 2021. *2022 Provincial B.C. Budget Submission for the B.C. Fruit Growers Association (BCFGA)*. Victoria, BC. https://www.bcfga.com/files/BC%20Fruit%20Growers%20-%20B_C_%20Budget%202022%20Submission(1).pdf

B.C. Health Effects of Anomalous Temperatures Coordinating Committee (BC HEAT Committee). 2022. *B.C. Provincial Heat Alert and Response System*. Victoria, BC. http://www.B.C.cdc.ca/resource-gallery/Documents/Guidelines%20and%20Forms/Guidelines%20and%20Manuals/Health-Environment/Provincial-Heat-Alerting-Response-System.pdf

BC Housing. 2019. *BC Energy Step Code: Design Guide Supplement S3 on Overheating and Air Quality*. Burnaby, BC. https://www.bchousing.org/publications/BC-Energy-Step-Code-Guide-Supplemental.pdf

BC Housing. 2022. *Extreme Heat and Buildings: An Analysis of the 2021 Heat Dome Related Deaths in Community Housing in British Columbia*. Burnaby, BC. https://www.B.C.housing.org/sites/default/files/media/documents/Extreme-Heat-Report%2B2022.pdf

BC Hydro. 2019. *Cold War: How Many B.C. Employees Are Losing the Battle over Office Air Conditioning*. Vancouver, BC. https://www.B.C.hydro.com/news/press_centre/news_releases/2019/report--b-c--employees-losing-the-cold-war-over-office-air-condi.html

BC Hydro. 2021a. "Operational Update: Extreme Heat Leads to Record-Breaking Electricity Demand for a Second Day in a Row." https://www.bchydro.com/news/press_centre/news_releases/2021/extreme-heat-leads-to-record-breaking-electricity-demand-for-a-second-day-in-a-row.html (April 24, 2023).

BC Hydro. 2021b. "Info bulletin: BC Hydro taking steps to ensure safe, reliable delivery of power to Vancouver Island." https://www.bchydro.com/news/press_centre/news_releases/2021/bc-hydro-taking-steps-to-ensure-safe-reliable-delivery-of-power-to-vancouver-island.html

BC Hydro. 2022. *2021: A Record-Breaking Year for Electricity Demand and Extreme Weather*. Vancouver, BC. https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/news-and-features/2021-demand-report.pdf

B.C. Ministry of Agriculture and Food. 2020. *British Columbia Agriculture, Seafood, Food and Beverage International Export: Highlights and Year in Review*. Victoria, BC. https://www2.gov.B.C..ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/statistics/market-analysis-and-trade-statistics/2020_B.C._agrifood_and_seafood_export_highlights.pdf

B.C. Ministry of Agriculture and Food. 2021a. *Crop Conditions Report - November 9, 2021*. Victoria, BC.

B.C. Ministry of Agriculture and Food. 2021b. *Situation Report: Extreme Heat Impacting Agricultural Operations (Province-Wide) - July 16, 2021*. Victoria, BC.

B.C. Ministry of Agriculture and Food. 2021c. *Situation Report: Extreme Heat Impacting Agricultural Operations (Province-Wide) - June 29, 2021*. Victoria, BC.

B.C. Ministry of Agriculture and Food. 2021d. *Berries: Policy Wording for The Continuous Specified Perils Production Insurance Contract*. Victoria, BC. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/programs/insurance-and-income-protection/pi-2022/berries/pi_berries_pw.pdf

B.C. Ministry of Agriculture and Food. 2021e. *Tree Fruit: Policy Wording for The Continuous Specified Perils Production Insurance Contract*. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/programs/insurance-and-income-protection/pi-2022/tree-fruit/pi_tf_pw.pdf

B.C. Ministry of Agriculture and Food. 2021f. "$20M to Help B.C. Ranchers, Farmers Recover from Drought, Wildfires." https://news.gov.bc.ca/releases/2021AFF0054-001739

B.C. Ministry of Agriculture and Food. 2021. "Briefing notes and situation reports regarding the record-breaking heat, its impacts across British Columbia and impacts on ministry and agency operations, for the period of June 24, 2021 to June 30, 2021." Victoria, BC. Released under the Freedom of Information Act. FOI: AGR-2021-13065. https://www2.gov.bc.ca/enSearch/detail?id=7AFDBC16F15F42E289E9F7DDB0F80C40&recorduid=AGR-2021-13065&keyword=AGR&keyword=13065

B.C. Ministry of Agriculture and Food. 2022a. *B.C. "Seafood Harvest, Landed Value, and Wholesale Value (2011-2021) - Wild Commercial Fisheries and Aquaculture*." Victoria, BC. https://www2.gov.B.C..ca/gov/content/industry/agriculture-seafood/statistics/agriculture-and-seafood-statistics-publications

B.C. Ministry of Agriculture and Food. 2022b. Email communication between the Canadian Climate Institute and the B.C. Ministry of Agriculture and Food in October 2022.

B.C. Ministry of Agriculture and Food. 2023a. Email communication between the Canadian Climate Institute and the B.C. Ministry of Agriculture and Food in November, 2022.

B.C. Ministry of Agriculture and Food. 2023b. "Adapting to Climate Change." https://www2.gov.B.C..ca/gov/content/industry/agriculture-seafood/agricultural-land-and-environment/climate-action/adapting-to-climate-change

B.C. Ministry of Agriculture and Food. 2023c. "Extreme Weather Preparedness for Agriculture Program." https://www2.gov.B.C..ca/gov/content/industry/agriculture-seafood/programs/extreme-weather-preparedness#3

B.C. Ministry of Agriculture and Food. 2023d. "2021 Flood Recovery Program for Food Security." https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/programs/agriculture-insurance-and-income-protection-programs/flood-recovery

B.C. Ministry of Environment and Climate Change Strategy. 2019. *Preliminary Strategic Climate Risk Assessment for British Columbia*. Victoria, BC. https://www2.gov.B.C..ca/gov/content/environment/climate-change/adaptation/risk-assessment

B.C. Ministry of Health. 2021. "Briefing Notes and Situation Notes Regarding Record-Breaking Heat." Victoria, B.C. Released under the Freedom of Information Act. FOI: HTH-2021-13060. https://www2.gov.bc.ca/enSearch/detail?id=7AFDBC16F15F42E289E9F7DDB0F80C40&recorduid=HTH-2021-13060&keyword=13060

B.C. Ministry of Health. 2021. "Yearly data of deaths caused by the following from 2016-2022: COVID-19, Influenza and Pneumonia, Chronic Obstructive Pulmonary Disease (COPD), All Respiratory Disease, Heart Disease, Stroke, Illicit Drug Toxicity, Opioid Drug Toxicity, Alzheimer's Disease and Dementia, Diabetes, Liver Disease, Parkinson's Disease, Kidney Disease, Hypertension, Pneumonitis due to Solids and Liquids, Obesity, Suicide; Specific data of hospitalizations and ICU admission in BC from 2016-2022, including: Total number of hospital beds in BC, Hospital bed capacity and use, Hospital ICU bed capacity and use." Victoria, BC. Released under the Freedom of Information Act. FOI:HTH-2022-20789. https://www2.gov.bc.ca/enSearch/detail?id=7AFDBC16F15F42E289E9F7DDB0F80C40&recorduid=HTH-2022-20789&keyword=HTH&keyword=20789

B.C. Ministry of Housing. 2021. *Existing Buildings Renewal Strategy: Engagement Summary*. Victoria, BC. https://www2.gov.B.C..ca/gov/content/industry/construction-industry/building-codes-standards/existing-buildings

B.C. Ministry of Transport and Infrastructure. 2019. *Resilient Infrastructure Engineering Design - Adaptation to the Impacts of Climate Change and Weather Extremes*. Victoria, BC. https://www2.gov.bc.ca/assets/gov/driving-and-transportation/transportation-infrastructure/engineering-standards-and-guidelines/technical-circulars/2019/t04-19.pdf

B.C. Ministry of Public Safety and Solicitor General. "Reports, plans, briefing notes, and memorandums regarding planning for or responses to heat wave conditions in the institution." Victoria, BC. Released under the Freedom of Information Act. FOI:PSS-2021-13054. https://www2.gov.bc.ca/enSearch/detail?id=7AFDBC16F15F42E289E9F7DDB0F-80C40&recorduid=PSS-2021-13054&keyword=PSS

B.C. Ministry of Public Safety and Solicitor General. "In regard to the extreme heat across British Columbia this summer 2021, Any and all correspondence or emails sent or received by the Wardens and HQ staff in relation to preparing for the extreme heat and impacts to infrastructure; Purchasing records of equipment to reduce impact of heat wave, i.e. air conditioners and/or fans purchases; All complaints by staff and individuals in custody (or by the public on behalf of individuals in custody) related to the extreme heat; Any documentation of protests, riots, strikes, or acts of defiance. This request is limited to centres without built-in air conditioning systems. Exclude portions of records not related to request as non responsive (NR)." Victoria, BC. Released under the Freedom of Information Act. FOI:PSS-2021-15530. https://www2.gov.bc.ca/enSearch/detail?id=7AFDBC16F15F42E289E9F7DDB0F80C40&recorduid=PSS-2021-15530&keyword=PSS&keyword=15530

B.C. Ministry of Transport and Infrastructure. 2022. Email communication between the Canadian Climate Institute and the B.C. Ministry of Transport and Infrastructure in October 2022.

BC Stats. 2022. *Employment and Unemployment Rate by Detailed Industry, 15 Years and Over, Annual (Employment in Thousands of Persons)*. https://www2.gov.B.C..ca/gov/content/data/statistics/employment-labour/labour-market-statistics

B.C. Turkey Association and B.C. Turkey Marketing Board. 2021. *2021 Annual Report*. Abbotsford, BC. http://www.B.C.turkey.com/resources/documents/2021AGMREPORT.pdf

BC Wildfire Service. 2019. *Request for Proposal: Medium Lift Helicopter Services (RFP #10193)*. Victoria, BC.

Berry, Peter, Anna Yusa, Toni Morris-Oswald, and Anastasia Rogaeva. 2015. "Heat Alert and Response Systems in Urban and Rural Communities in Canada." *Change and Adaptation in Socio-Ecological Systems* 1 (May): 84–97. https://doi.org/10.2478/cass-2014-0009

Bethlehem, M. 2021. "B.C. Heatwave Forces Some Restaurants and Breweries to Close." *CityNews*. Vancouver, BC. https://vancouver.citynews.ca/2021/06/27/B.C.-heatwave-restaurants-close/

Bowler, D. E., L. Buyung-Ali, T. M. Knight, and A. S. Pullin. 2010. "Urban Greening to Cool Towns and Cities: A Systematic Review of Empirical Evidence." *Landscape and Urban Planning* 97(3): 147–55.

Bumbaco, K. A., K. D. Dello, and N. A. Bond. 2013. "History of Pacific Northwest Heat Waves: Synoptic Pattern and Trends." *Journal of Applied Meteorology and Climatology* 52(7): 1618–31.

Burchell, M. 2021. "Heat Wave Forces Many Vancouver Island Businesses to Temporarily Close Today." *Victoria Buzz*: Victoria, BC. https://www.victoriabuzz.com/2021/06/heat-wave-forces-many-vancouver-island-businesses-to-temporarily-close-today/

Burton, I. 2010. "Investigations in Depth: Forensic Disaster Investigations in Depth: A New Case Study Model" *Environment* 52(5). https://doi.org/10.1080/00139157.2010.507144

CBC News. 2021. "Extreme Heat Prompts Closures, Cancellations Throughout B.C." https://www.cB.C..ca/news/canada/british-columbia/B.C.-businesses-close-1.6082448

Canadian Electricity Association. 2016. "Forced Outage Performance of Transmission Equipment." Equipment Reliability Information Systems. https://www.electricity.ca/wp-content/uploads/2017/09/2016-All-Canada-ERIS-Report.pdf.

Casanueva, A., Burgstall, A., Kotlarski, S., Messeri, A., Morabito, M., Flouris, A. D., Nybo, L., Spirig, C., & Schwierz, C. 2019. "Overview of Existing Heat-Health Warning Systems in Europe." In *International Journal of Environmental Research and Public Health* (Vol. 16, p. 2657). MDPI AG. https://doi.org/10.3390/ijerph16152657

Casey, J. A., Parks, R. M., Bruckner, T. A., Gemmill, A., and Catalano, R. 2023. Excess Injury Mortality in Washington State During the 2021 Heat Wave. *American Journal of Public Health*, e1–e4. Advance online publication. https://doi.org/10.2105/AJPH.2023.307269

Chestnut, L. G., and P. De Civita. 2009. "Economic Valuation of Mortality Risk Reduction: Review and Recommendations for Policy and Regulatory Analysis." Government of Canada. Ottawa, ON. https://publications.gc.ca/collection_2009/policyresearch/PH4-51-2009E.pdf

City of Burnaby. 2021. *2021 Heat Events: Extreme Heat Initial Response Guideline Activations.* Burnaby, B.C. https://pub-burnaby.escribemeetings.com/filestream.ashx?DocumentId=55734

City of Vancouver. 2022a. *Updates to Extreme Heat Response Plans for 2022*. Vancouver, BC. https://vancouver.ca/files/cov/2022-06-15-updates-to-extreme-heat-response-plans-for-2022.pdf

Clark, Dylan G., Ryan Ness, Dena Coffman, and Dale Beugin. 2021. *The Health Costs of Climate Change: How Canada Can Adapt, Prepare, and Save Lives*. Canadian Climate Institute. https://climateinstitute.ca/reports/%20the-health-costs-of-climate-change/

Clark, Dylan G., and Anna Kanduth. 2022. *Enhancing the Resilience of Canadian Electricity Systems for a Net Zero Future.* https://climateinstitute.ca/wp-content/uploads/2022/02/Resiliency-scoping-paper-ENGLISH-Final.pdf

Clark, Dylan G. (Forthcoming). The health toll of extreme heat: examining emergency department visits and hospital admissions during the 2021 BC Heat Wave. Manuscript submitted for publication.

Climate Action Tracker. 2022. "Climate Action Tracker." https://climateactiontracker.org/ (March 13, 2023).

Cohen, A. 2019. "'Slavery Hasn't Ended, It Has Just Become Modernized:' Border Imperialism and the Lived Realities of Migrant Farmworkers in British Columbia, Canada." *ACME: An International Journal for Critical Geographies* 18 (1): 130–148. https://acme-journal.org/index.php/acme/article/view/1430

Colelli, F. 2021. "2021 Heatwave in Canada: Record-Breaking Electricity Demand and Power Outages." EnergyA. http://www.energy-a.eu/2021-heatwave-canada-record-breaking-ouFtages/?cn-reloaded=1

Colmer, J. 2020. "What is the Meaning of (Statistical) Life? Benefit–Cost Analysis in the Time of COVID-19." Oxford Review of Economic Policy. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7499700/

Coroners Service of BC. 2021. "All communications to and from Premier John Horgan, Minister of Public Safety and Solicitor General Mike Farnworth, Health Minister Adrian Dix, Provincial Health Officer Bonnie Henry, Chief Coroner Lisa Lapointe, BC Wildfire Service Director of Provincial Operations Cliff Chapman, and Emergency Management BC executive director of regional operations Pader Brach that contain any reference, directly or indirectly to the B.C. heat wave. This includes but is not limited to email correspondence, text messages and briefing notes that reference the heat wave, preparation plans, discussion, outcomes, etc." Victoria, BC. Released under the Freedom of Information Act. FOI:OCC-2021-13845. https://www2.gov.bc.ca/enSearch/detail?id=7AFDBC16F15F42E289E9F7DDB0F80C40&recorduid=OCC-2021-13845&keyword=13845

Correctional Service Canada. 2015. *Technical Criteria for Correctional Institutions*. Ottawa, ON.

Council of Canadian Academies. 2022. *Cultivating Diversity: The Expert Panel on Plant Health Risks in Canada*. Ottawa, ON. https://cca-reports.ca/reports/plant-health-risks/

Crawford, E., and R. Beveridge. 2013. *Strengthening BC's Agriculture Sector in the Face of Climate Change*. The Pacific Institute for Climate Solutions. Victoria, BC. https://pics.uvic.ca/sites/default/files/uploads/publications/Strengthening%20BC%27s%20Agriculture%20Sector_0.pdf

CTV News. 2022. "Vancouver Island Researchers Look into Oyster Breeds as Temperatures Rise B.C." *CTV News Vancouver Island*. Victoria, BC. https://vancouverisland.ctvnews.ca/vancouver-island-researchers-look-into-oyster-breeds-as-temperatures-rise-b-c-1.5882095

Cutter, S. 2012. *Hazards, Vulnerability, and Environmental Justice*. Routledge. New York City, NY.

Daflos, P. 2022. "BC Housing Disabled Cooling Devices at Some Sites Over Costs." *CTV News*. Vancouver, BC. https://bc.ctvnews.ca/bc-housing-disabled-cooling-devices-at-some-sites-over-costs-1.5997284 (April 13, 2023).

Dandekar, V. 2021. "B.C. 's Shellfish Farmers Struggle After Heat Wave Decimates Oysters." The Tyee. https://thetyee.ca/News/2021/08/05/B.C.-Shellfish-Farmers-Struggle-After-Heat-Wave-Decimates-Oysters/

Deloitte. 2021. *Economic Contribution Study of British Columbia's Tree Fruit Sector: Prepared for the Ministry of Agriculture, Food and Fisheries of British Columbia*. Vancouver, BC.

Emergency Management BC. 2021. "All communications to and from Premier John Horgan, Minister of Public Safety and Solicitor General Mike Farnworth, Health Minister Adrian Dix, Provincial Health Officer Bonnie Henry, Chief Coroner Lisa Lapointe, BC Wildfire Service Director of Provincial Operations Cliff Chapman, and Emergency Management BC executive director of regional operations Pader Brach that contain any reference, directly or indirectly to the B.C. heat wave. This includes but is not limited to email correspondence, text messages and briefing notes that reference the heat wave, preparation plans, discussion, outcomes, etc." Victoria, BC. Released under the Freedom of Information Act. FOI:EMB-2021-13846. https://www2.gov.bc.ca/enSearch/detail?id=7AFDBC16F15F42E289E9F7DDB0F80C40&recorduid=EMB-2021-13846&keyword=EMB&keyword=13846

Employment and Social Development Canada. 2022. *What We Heard: Consultations on Accommodations for Temporary Foreign Workers*. Ottawa, ON. https://www.canada.ca/content/dam/esdc-edsc/images/services/foreign-workers/reports/what_we_heard_report.pdf

Environment and Climate Change Canada (ECCC). 2020. "Criteria for Public Weather Alerts." https://www.canada.ca/en/environment-climate-change/services/types-weather-forecasts-use/public/criteria-alerts.html#heat (April 13, 2023).

Environment and Climate Change Canada (ECCC). 2021. "Canada's Top 10 Weather Stories of 2021." https://www.canada.ca/en/environment-climate-change/services/top-ten-weather-stories/2021.html (April 13, 2023).

Environment and Climate Change Canada (ECCC). 2022a. "Temperature Change in Canada." https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/temperature-change.html (February 12, 2023).

Environment and Climate Change Canada (ECCC). 2022b. *Evaluation of the Weather Observations, Forecasts and Warnings Program*. Gatineau, QC. https://publications.gc.ca/collections/collection_2022/eccc/En4-459-2022-eng.pdf

ESSA. 2020. *Costing Climate Change Impacts on Human Health across Canada: Final Report*. Prepared for the Canadian Institute for Climate Choices. Ottawa, ON. https://climateinstitute.ca/reports/the-health-costs-of-climate-change/technical-report/

Fassbender, K., Fainsinger, R. L., Carson, M., and Finegan, B. A. 2009. "Cost Trajectories at the End of Life: The Canadian Experience." *Journal of Pain and Symptom Management*, *38*(1), 75–80. https://doi.org/10.1016/j.jpainsymman.2009.04.007

Fawcett-Atkinson, M. 2020. "How One Indigenous Farmer in the North Is Improving Food Security in His Community." *National Observer*. https://www.thestar.com/news/canada/2020/11/16/how-one-indigenous-farmer-in-the-north-is-improving-food-security-in-his-community.html

Feldman, M., and Christenson, J. 2019. *External Review of a Death during Prehospital Care, November 2018*. Government of British Columbia. https://www2.gov.bc.ca/assets/gov/health/conducting-health-research/bcehs-case-review.pdf

First Nations Fisheries Council. 2016. *First Nations Traditions and Aquaculture*. Vancouver, BC. https://www.fnfisheriescouncil.ca/wp-content/uploads/2021/11/First-Nations-and-Aquaculture-in-British-Columbia-Cultivating-Change-to-Preserve-Tradition-Brochure.-2016.pdf (April 13, 2023).

Fletcher, C., L. Matthews, J., Andrey, and A. Saunders. 2016. "Projected Changes in Mid-Twenty-First-Century Extreme Maximum Pavement Temperature in Canada." *Journal of Applied Meteorology and Climatology*, 55(4), 961-974. https://doi.org/10.1175/JAMC-D-15-0232.1

Food and Agriculture Organization of the United Nations (FAO). 2022. *Aquaculture Insurance for Small-Scale Producers*. Rome, Italy. https://www.fao.org/3/ca8663en/CA8663EN.pdf

Fraser Health. 2022. "Updates from Executive Team #148." Victoria, BC. Released under the Freedom of Information Act. FOI: FHA-2022-0483.

Gaudin, A. C.M., T. N. Tolhurst, A. P. Ker, K. Janovicek, C. Tortora, R. C. Martin, and W. Deen. 2015. "Increasing Crop Diversity Mitigates Weather Variations and Improves Yield Stability." *PLoS ONE* 10 (2). https://doi.org/10.1371/journal.pone.0113261

Ghoussoub, M. 2021. "Workers Swelter in B.C.'s Hottest Jobs As Heat Dome Blasts Province." *CBC News*. Vancouver, BC. https://www.cB.C..ca/news/canada/british-columbia/B.C.-hottest-jobs-heat-wave-heat-dome-1.6084703

Gifford, R., C. Brown, C. Baron, D. Clement, N. Melnychuk, H. Nelson, L. Sales, and D. Spittlehouse. 2022. "British Columbia Chapter." In *Canada in a Changing Climate: Regional Perspectives Report*, edited by F.J. Warren, N. Lulham, and D.S. Lemmen. Government of Canada. Ottawa, ON.

Gosselin, P., C. Campagna, D. Demers-Bouffard, S. Qutob, and M. Flannigan. 2022. "Natural Hazards." In , *Health of Canadians in a Changing Climate: Advancing Our Knowledge for Action*, edited by P. Berry and R. Schnitter. Government of Canada. Ottawa, ON. https://changingclimate.ca/health-in-a-changing-climate/

Government of British Columbia. 2002. *Introduction to the Incident Command System*. Victoria, BC. https://www2.gov.bc.ca/assets/gov/environment/air-land-water/spills-and-environmental-emergencies/docs/intro-ics.pdf

Government of British Columbia. 2012. *The All Hazards Plan*. Victoria, BC. https://www2.gov.bc.ca/assets/gov/public-safety-and-emergency-services/emergency-preparedness-response-recovery/provincial-emergency-planning/embc-all-hazard-plan.pdf

Government of British Columbia. 2022a. "B.C. Expecting First Hot Stretch of Summer." https://news.gov.B.C..ca/releases/2022PSSG0041-000997

Government of British Columbia. 2022b. *Extreme Heat: Preparedness for Ministries and Agencies*. Victoria, BC. https://www2.gov.B.C..ca/assets/gov/public-safety-and-emergency-services/emergency-preparedness-response-recovery/provincial-emergency-planning/extreme_heat_preparedness_for_ministries_and_agencies.pdf

Government of British Columbia. 2023a. "Climate of B.C." https://www.welcomebc.ca/Choose-B-C/Explore-British-Columbia/Climate-of-B-C (February 20, 2023).

Government of British Columbia. 2023b. "Urban & Off-Reserve Aboriginal People." https://www2.gov.B.C..ca/gov/content/governments/indigenous-people/supporting-communities/urban-off-reserve-aboriginal-people (February 20, 2023).

Government of British Columbia. 2023c. *Community Care and Assisted Living Act: Residential Care Regulation - B.C. Reg. 96/2009*. Victoria, BC. https://www.B.C.laws.gov.B.C..ca/civix/document/id/complete/statreg/96_2009

Government of British Columbia. 2023d. *Emergency Program Act [RSBC 1996]*. Victoria, BC. https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/00_96111_01

Government of British Columbia. 2023e. *Mental Health Act [RSBC 1996]*. Victoria, BC. https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/00_96288_01

Government of Canada. 2022. "Policy on Cost-Benefit Analysis" https://www.canada.ca/en/government/system/laws/developing-improving-federal-regulations/requirements-developing-managing-reviewing-regulations/guidelines-tools/policy-cost-benefit-analysis.html (March 7, 2023).

Grant, S.C.H., B.L. MacDonald, and M.L. Winston. 2019. *State of Canadian Pacific Salmon: Responses to Changing Climate and Habitats*. Fisheries and Oceans Canada. Nanaimo, BC. https://salmonwatersheds.ca/libraryfiles/lib_467.pdf

Harper, S. L., R. Schnitter, A. Fazil, M. Fleury, J. Ford, N. King, A. Lesnikowski, et al. 2022. "Food Security and Food Safety." In

Health of Canadians in a Changing Climate: Advancing Our Knowledge for Action, edited by R. Berry and R. Schnitter. Government of Canada. Ottawa, ON.

Health Canada. 2011. *Extreme Heat Events Guidelines: Technical Guide for Health Care Workers*. Ottawa, ON. https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/ewh-semt/alt_formats/pdf/pubs/climat/workers-guide-travailleurs/extreme-heat-chaleur-accablante-eng.pdf

Henderson, S. B., J. S. Gauld, S. A. Rauch, K. E. McLean, N. Krstic, D. M. Hondula, and T. Kosatsky. 2016. "A Proposed Case-Control Framework to Probabilistically Classify Individual Deaths as Expected or Excess during Extreme Hot Weather Events." *Environmental Health* 15 (109): 1–10. https://doi.org/10.1186/s12940-016-0195-z

Henderson, S. B., McLean, K. E., Lee, M., and Kosatsky, T. 2021. "Extreme heat events are public health emergencies | British Columbia Medical Journal." *B.C. Medical Journal*, 63(9), 336–367. https://B.C.mj.org/B.C.cdc/extreme-heat-events-are-public-health-emergencies

Henderson, S. B., McLean, K. E., Lee, M. J., and Kosatsky, T. 2022. "Analysis of Community Deaths During the Catastrophic 2021 Heat Dome." *Environmental Epidemiology*, 6(1), E189. https://doi.org/10.1097/EE9.0000000000000189

Hewitt, K. 1983. *Interpretations of Calamity from the Viewpoint of Human Ecology*. Routledge. London, United Kingdom.

Holliday, I. 2021. "Schools Across the Lower Mainland Closed Monday Due to Extreme Heat." *CTV News*. Vancouver, BC. https://B.C..ctvnews.ca/schools-across-the-lower-mainland-closed-monday-due-to-extreme-heat-1.5488000

Holmén, J., Herlitz, J., Ricksten, S. E., Strömsöe, A., Hagberg, E., Axelsson, C., & Rawshani, A. 2020. Shortening ambulance response time increases survival in out-of-hospital cardiac arrest. Journal of the American Heart Association, 9(21). https://doi.org/10.1161/JAHA.120.017048

Homelessness Services Association of BC. 2021. *2020/21 Report on Homeless Counts in B.C. - Prepared for B.C. Housing*. Burnaby, BC. https://www.B.C.housing.org/publications/2020-21-B.C.-Homeless-Counts.pdf

Indigenous Services Canada (ISC). 2018. "Preventing and Managing Chronic Disease in First Nations Communities: A Guidance Framework." https://publications.gc.ca/collections/collection_2018/aanc-inac/H34-313-1-2017-eng.pdf

Industrial Economics. 2020. *Costing Climate Change Impacts on Canada's Infrastructure: Results for "Deep Dive" Statistical and Process-Based Models*. Canadian Climate Institute. Cambridge, MA. https://climateinstitute.ca/wp-content/uploads/2022/06/Deep-Dive-Report.pdf

International Labour Organization. 2019. *Working on a Warming Planet: The Impact of Heat Stress on Labour Productivity and Decent Work*. Geneva, Switzerland. https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_711919.pdf

Intergovernmental Panel on Climate Change (IPCC). 2021. Summary for Policymakers. In: *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds). Cambridge University Press. Cambridge, United Kingdom and New York City, NY. https://doi.org/10.1017/9781009157896.001

Intergovernmental Panel on Climate Change (IPCC). 2022. *Climate Change 2022: Impacts, Adaptation, and Vulnerability: Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. https://report.ipcc.ch/ar6/wg2/IPCC_AR6_WGII_FullReport.pdf (March 7, 2023).

International Civil Aviation Organization (ICAO). 2011. *Manual of Aircraft Accident and Incident Investigation: Part III — Investigation*. Montreal, QC. https://store.icao.int/en/manual-of-aircraft-accident-and-incident-investigation-part-iii-investigation-doc-9756-part-3

Judd, A. 2021a. "B.C. Businesses Close Their Doors Due to Extreme Heat." *Global News*. Vancouver, BC. https://globalnews.ca/news/7986877/B.C.-businesses-closing-monday-extreme-heat/

Judd, A. 2021b. "For The First Time Ever, Dozens of B.C. Schools Had to Close Due to Extreme Heat Wave." *Global News*. Vancouver, BC. https://globalnews.ca/news/7987756/first-time-ever-B.C.-schools-close-extreme-heat/

Kabore, P. and N. Rivers. 2023. "Manufacturing Output and Extreme Temperature: Evidence from Canada." *Canadian Journal of Economics/Revue canadienne d'économique*, 56: 191-224. https://doi.org/10.1111/caje.12633

Laforge, J., V. Corkal, and A. Cosbey. 2021. *Farming the Future: Agriculture and Climate Change on the Canadian Prairies*. International Institute for Sustainable Development: Winnipeg, MB. https://www.iisd.org/publications/report/farming-future-agriculture-and-climate-change-canadian-prairies

Laouadi, A., M. Bartko, A. Gaur, and M.A. Lacasse. 2022. *Climate Resilience Buildings: Guideline for Management of Overheating Risk in Residential Buildings*. National Research Council of Canada: Ottawa, ON. https://nrc-publications.canada.ca/eng/view/object/?id=9c60dc19-ca18-4f4c-871f-2633f002b95c

Lee, M., and B. Parfitt. 2022. *A Climate Reckoning: The Economic Costs of B.C.'s Extreme Weather in 2021*. Canadian Centre for Policy Alternatives. Vancouver, BC. https://policyalternatives.ca/climate-reckoning

Lee, M. J., McLean, K. E., Kuo, M., Richardson, G. R., and Henderson, S. B. 2023. "Chronic Diseases Associated with Mortality in British Columbia, Canada During the 2021 Western North America Extreme Heat Event." *GeoHealth*, 7(3), e2022GH000729. https://doi.org/10.1029/2022GH000729

Legault, G., A. Clement, G. P. Kenny, S. Hardcastle, and N. Keller. 2017. "Cognitive Consequences of Sleep Deprivation, Shiftwork, and Heat Exposure for Underground Miners." *Applied Ergonomics* 58 (January): 144–150. https://doi.org/10.1016/j.apergo.2016.06.007

Lemmen, D., C. Lafleur, D. Chabot, J. Hewitt, M. Braun, B. Bussière, I. Kulcsar, D. Scott, and J. Thistlethwaite. 2021. "Sector Impacts and Adaptation; Chapter 7." In *Canada in a Changing Climate: National Issues Report*, edited by F.J. Warren and N. Lulham. Government of Canada. Ottawa, ON.

Little, S. 2021. "'Heat dome': Warnings Issued as Potentially Record-Breaking Temperatures Forecast in B.C." *Global News*. Vancouver, BC. https://globalnews.ca/news/7975968/heat-dome-warnings-record-breaking-temperatures-forecast-bc/

Lobos, G. A., and Hancock, J. F. 2015. "Breeding Blueberries for a Changing Global Environment: A Review." *Frontiers in Plant Science*, 6, 782. https://doi.org/10.3389/fpls.2015.00782

Maadani, O., Shafiee, M., and Egorov, I. 2021. "Climate Change Challenges for Flexible Pavement in Canada: An Overview." *Journal of Cold Regions Engineering*, 35(4), 03121002. https://doi.org/10.1061/(ASCE)CR.1943-5495.0000262

MacClune, K., Allan, C., Venkateswaran, K., and Sabbag, L. 2014. *Floods in Boulder: A Study of Resilience | Adaptation Clearinghouse*. https://www.adaptationclearinghouse.org/resources/floods-in-boulder-a-study-of-resilience.html

Marushka, L., Kenny, T. A., Batal, M., Cheung, W. W., Fediuk, K., Golden, C. D., ... and Chan, H. M. 2019. "Potential Impacts of Climate-Related Decline of Seafood Harvest on Nutritional Status of Coastal First Nations in British Columbia", Canada. *PloS One*, 14(2), e0211473. https://doi.org/10.1371/journal.pone.0211473

Masys, A. J. 2016. *Disaster Forensics* (A. J. Masys, Ed.). Springer International Publishing. Cham, Switzerland. https://doi.org/10.1007/978-3-319-41849-0

McInnes, J. A., M. Akram, E. M. Macfarlane, T. Keegel, M. R. Sim, and P. Smith. 2017. "Association Between High Ambient Temperature and Acute Work-Related Injury: A Case-Crossover Analysis Using Workers' Compensation Claims Data." *Scandinavian Journal of Work, Environment and Health* 43 (1): 86–94. https://doi.org/10.5271/sjweh.3602

McInnes, J. A., E. M. MacFarlane, M. R. Sim, and P. Smith. 2017. "Working in Hot Weather: A Review of Policies and Guidelines to Minimise the Risk of Harm to Australian Workers." *Injury Prevention* 23(5), 334-339. https://doi.org/10.1136/injuryprev-2016-042204

McIntyre, G. 2021. "With Heat Warnings in Effect, B.C. Businesses Take Measures to Protect Employees and Customers." *Vancouver Sun*. Vancouver, BC. https://vancouversun.com/news/local-news/with-heat-warnings-in-effect-businesses-take-measures-to-protect-employees-and-customers

McLean, H. 2021. "B.C. Heat Wave Forces Restaurants to Temporarily Shut Down Across the Province." *The Daily Hive*. Vancouver, BC. https://dailyhive.com/vancouver/B.C.-heat-wave-restaurants-closed

McLean, K. E., R. Stranberg, M. Macdonald, G. R.A. Richardson, T. Kosatsky, and S. B. Henderson. 2018. "Establishing Heat Alert Thresholds for the Varied Climatic Regions of British Columbia, Canada." *International Journal of Environmental Research and Public Health* 15 (September): 2048. https://doi.org/10.3390/ijerph15092048

Mendoza, M. T., and R. Schwarze. 2019. "Sequential Disaster Forensics: A Case Study on Direct and Socio-Economic Impacts." *Sustainability 2019, Vol. 11, Page 5898*, *11*(21), 5898. https://doi.org/10.3390/SU11215898

Métis Nation B.C (MNBC). 2023. "About MNBC" https://www.mnB.C..ca/about-mnB.C. (February 12, 2023).

Mills, B., Tighe, S., Andrey, J., Smith, J., Parm, S. and Huen, K. 2007. *The Road Well Travelled: Implications of Climate Change for Pavement Infrastructure in Southern Canada*. http://www.bv.transports.gouv.qc.ca/mono/0970582.pdf

National Collaborating Centre for Indigenous Health (NCCIH). 2022. "Climate Change and Indigenous People's Health in Canada." In P. Berry and R. Schnitter (Eds.), *Health of Canadians in a Changing Climate: Advancing our Knowledge for Action*. Government of Canada: Ottawa, ON. https://changingclimate.ca/health-in-a-changing-climate/chapter/2-0/

National Weather Service. 2023. "Heat Watch vs. Warning." https://www.weather.gov/safety/heat-ww#:~:text=A%20Heat%20Advisory%20is%20issued,of%20extremely%20dangerous%20heat%20conditions. (April 25, 2023).

Natural Resources Canada. 2015. *Introduction - British Columbia*. Ottawa, ON. https://natural-resources.canada.ca/changements-climatiques/impacts-adaptation/introduction-british-columbia/10395

Nesbit, B. 2021. "Hundreds Without Power Across Lower Mainland as Heat Wave Wreaks Havoc." *CTV News*. Vancouver, BC. https://bc.ctvnews.ca/hundreds-without-power-across-lower-mainland-as-heat-wave-wreaks-havoc-1.5487948

Ness, Ryan, Dylan G. Clark, Julien Bourque, Dena Coffman, and Dale Beugin. 2021. *Under Water: The Costs of Climate Change for Canada's Infrastructure*. Canadian Institute for Climate Choices. Ottawa, ON. https://climateinstitute.ca/reports/under-water/

Office of the Premier. 2021. "Internal communications about deaths due to the heat wave in late June, 2021." Victoria, BC. Released under the Freedom of Information Act. FOI:OOP-2021-13146. https://www2.gov.bc.ca/enSearch/detail?id=7AFDBC16F15F42E289E9F7DDB0F80C40&recorduid=OOP-2021-13146&keyword=13146

Organisation for Economic Co-operation and Development (OECD). 2020. *Resilience to Natural Disasters in Canada*. In Strengthening Agricultural Resilience in the Face of Multiple Risks. OECD Publishing. Paris, France. https://www.oecd-ilibrary.org/sites/d1b84788-en/index.html?itemId=/content/component/d1b84788-en

Oliver-Smith, A., I. Alcántara-Ayala, I. Burton, and A. Lavell. 2016. *Forensic Investigations of Disasters (FORIN): A Conceptual Framework and Guide to Research*. Integrated Research on Disaster. Beijing, China. Risk https://www.preventionweb.net/publication/forensic-investigations-disasters-forin-conceptual-framework-and-guide-research#:~:text=The%20Forensic%20Investigations%20of%20Disasters,causes%20and%20consequences%20of%20disasters

Peace River Regional District. 2020. *Agriculture Challenges 2019 Survey Update*. Dawson Creek, BC. https://prrd.B.C..ca/

wp-content/uploads/engage/agriculture-challenges-2019/09-R-12-Ag-Challenge-Survey-results-final.pdf

Penticton Western News. 2021. "Heat Wave: Okanagan Group Concerned About 'Miserable' Conditions for Migrant Workers." Penticton, BC. https://www.pentictonwesternnews.com/news/heat-wave-okanagan-group-concerned-about-miserable-conditions-for-migrant-workers/

Philip, S. Y., Kew, S. F., Van Oldenborgh, G. J., Anslow, F. S., Seneviratne, S. I., Vautard, R., Coumou, D., Ebi, K. L., Arrighi, J., Singh, R., Van Aalst, M., Pereira Marghidan, C., Wehner, M., Yang, W., Li, S., Schumacher, D. L., Hauser, M., Bonnet, R., Luu, L. N., … Otto, F. E. L. 2022. "Rapid Attribution Analysis of the Extraordinary Heat Wave on the Pacific Coast of the US and Canada in June 2021." *Earth System Dynamics*, *13*, 1689–1713. https://doi.org/10.5194/esd-13-1689-2022

Phillips, W., B. Cocks, and C. Manthey. 2022. "Ambulance Ramping Predicts Poor Mental Health of Paramedics." *Psychological Trauma: Theory, Research, Practice*. https://doi.org/http://dx.doi.org/10.1037/tra0001241

Provincial Health Services Authority and BC Emergency Health Services. *2021. Request for Information - Rotary Wing Air Ambulance Services: RFI PHSA RWAA150221*. Vancouver, BC. https://bcbid.gov.bc.ca/page.aspx/en/bpm/process_manage_extranet/143992

Public Health Agency of Canada. 2022. *Mobilizing Public Health Action on Climate Change in Canada*. Ottawa, ON. https://www.canada.ca/content/dam/phac-aspc/documents/corporate/publications/chief-public-health-officer-reports-state-public-health-canada/state-public-health-canada-2022/report-rapport/report.pdf

Raymond, W. W., J. S. Barber, M. N. Dethier, H. A. Hayford, C. D.G. Harley, T. L. King, B. Paul, et al. 2022. "Assessment of the Impacts of an Unprecedented Heatwave on Intertidal Shellfish of the Salish Sea." *Ecology* 103 (October): e3798. https://doi.org/10.1002/ecy.3798

Rezaei, M., and H. Dowlatabadi. 2016. "Off-Grid: Community Energy and the Pursuit of Self-Sufficiency in British Columbia's Remote and First Nations Communities." *Local Environment*, 21(7), 789-807. https://doi.org/10.1080/13549839.2015.1031730

Rosenzweig, C., Solecki, W., Parshall, G., Gaffin, S., Lynn, B., Goldberg, R., Cox, J., and Hodges, S. 2006. *Mitigating New York City's Heat Island with Urban Forestry, Living Roofs, and Light Surfaces*. Retrieved March 15, 2023, from https://www.researchgate.net/publication/242139673_Mitigating_New_York_City's_heat_island_with_urban_forestry_living_roofs_and_light_surfaces

Salehi, L., Phalpher, P., Valani, R., Meaney, C., Amin, Q., Ferrari, K., and Mercuri, M. 2018. "Emergency Department Boarding: A Descriptive Analysis and Measurement of Impact on Outcomes." *Canadian Journal of Emergency Medicine*, *20*(6), 929–937. https://doi.org/10.1017/cem.2018.18

Santamouris, M. 2014. "Cooling the Cities - A Review of Reflective and Green Roof Mitigation Technologies to Fight Heat Island and Improve Comfort in Urban Environments." *Solar Energy* 103: 682–703. https://doi.org/10.1016/j.solener.2012.07.003

Schwaab, J., Meier, R., Mussetti, G., Seneviratne, S., Bürgi, C., and Davin, E. L. 2021. "The Role of Urban Trees in Reducing Land Surface Temperatures in European Cities." *Nature Communications 2021 12:1*, *12*(1), 1–11. https://doi.org/10.1038/s41467-021-26768-w

Setsobhonkul, S., Kaewunruen, S., and Sussman, J. M. 2017. "Life Cycle Assessments of Railway Bridge Transitions Exposed to Extreme Climate Events." *Frontiers in Built Environment*, *3*, 35. https://doi.org/10.3389/FBUIL.2017.00035/BIBTEX

Sikorsky. 2007. *Sikorsky S-76C++TM: Helicopter Executive Transport Mission*.

Smart, A. 2022. "Vancouver Island Villages Without Power for Days, Northern B.C. Under Weather Warning." *The Canadian Press*. Vancouver, BC. https://vancouverisland.ctvnews.ca/vancouver-island-villages-without-power-for-days-northern-b-c-under-weather-warning-1.5733000

Standing Committee on Agriculture and Agri-Food. 2018. *Toward a Resilient Canadian Agriculture and Agri-Food System: Adapting To Climate Change*. House of Commons Canada. Ottawa, ON. https://www.ourcommons.ca/Content/Committee/421/AGRI/Reports/RP9814809/agrirp11/agrirp11-e.pdf

Standing Committee on Agriculture and Agri-Food. 2020. *Facing the Unexpected: Enhancing Business Risk Management Programs for Agriculture and Agri-Food Businesses*. House of Commons Canada. Ottawa, ON. https://www.ourcommons.ca/Content/Committee/432/AGRI/Reports/RP10966646/agrirp01/agrirp01-e.pdf

Statistics Canada. 2016. "Table 15.7: Land and Freshwater Area, by Province and Territory." https://www150.statcan.gc.ca/n1/pub/11-402-x/2010000/chap/geo/tbl/tbl07-eng.htm

Statistics Canada. 2022a. "Agriculture and Agri-Food Labour Statistics." https://www150.statcan.gc.ca/n1/daily-quotidien/220613/dq220613d-eng.htm

Statistics Canada. 2022b. "Farm Operating Expenses and Depreciation Charges." https://doi.org/10.25318/3210004901-eng

Statistics Canada. 2022c. *In the Midst of High Job Vacancies and Historically Low Unemployment, Canada Faces Record Retirements from an Aging Labour Force: Number of Seniors Aged 65 and Older Grows Six Times Faster than Children 0-14*. Ottawa, ON. https://www150.statcan.gc.ca/n1/daily-quotidien/220427/dq220427a-eng.htm

Statistics Canada. 2022d. *Population Growth in Canada's Rural Areas, 2016 to 2021*. Ottawa, ON. https://www12.statcan.gc.ca/census-recensement/2021/as-sa/98-200-x/2021002/98-200-x2021002-eng.cfm

Statistics Canada. 2023a. "Census Profile, 2021 - Lower Mainland, British Columbia." https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/details/page.cfm?Lang=E&SearchText=Lower%20ainland%2D%2D-Southwest&DGUIDlist=2021S05005920&GENDERlist=1,2,3&STATISTIClist=1&HEADERlist=0

Statistics Canada. 2023b. "Census Profile, 2021 - Province of British Columbia." https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/details/page.cfm?Lang=E&SearchText=British%20columbia&D-

GUIDlist=2021A000259&GENDERlist=1,2,3&STATISTIClist=1&-HEADERlist=0

Statistics Canada. 2023c. "Table 32-10-0364-01: Area, Production and Farm Gate Value of Marketed Fruits." https://doi.org/10.25318/3210036401-eng

Statistics Canada. 2023d. "Air Conditioners." https://doi.org/10.25318/3810001901-eng (April 25, 2023).

Statistics Canada. 2023e. "Provisional Weekly Death Counts, by Age Group and Sex." https://doi.org/10.25318/1310076801-eng

Stewart, R. E., D. Betancourt, J. B. Davies, D. Harford, Y. Klein, R. Lannigan, L. Mortsch, E. O'Connell, K. Tang, and P. H. Whitfield. 2017. "A Multi-Perspective Examination of Heat Waves Affecting Metro Vancouver: Now into the Future." *Natural Hazards* 87 (June): 791–815. https://doi.org/10.1007/s11069-017-2793-7

The Canadian Press. 2014. "B.C. Heat Wave: 3 Hottest Spots and 20 Records Broken Sunday." *The Canadian Press*, July 13, 2014. https://www.cB.C..ca/news/canada/british-columbia/b-c-heat-wave-3-hottest-spots-and-20-records-broken-sunday-1.2705834

Thiessen Martens, J. R., Entz, M. H., and Wonneck, M. D. 2015. "Review: Redesigning Canadian Prairie Cropping Systems for Profitability, Sustainability, and Resilience." *Canadian Journal of Plant Science*, *95*, 1049–1072. https://doi.org/10.4141/CJPS-2014-173

Thornton, P. G. Nelson, D. Mayberry, and M. Herrero. 2021. "Increases in Extreme Heat Stress in Domesticated Livestock Species During the Twenty-First Century." *Global Change Biology*, 27(22), 5762-5772. https://doi.org/10.1111/gcb.15825

Tuckey, M. R., and Scott, J. E. 2014. "Group Critical Incident Stress Debriefing with Emergency Services Personnel: A Randomized Controlled Trial." *Anxiety, Stress, and Coping*, 27(1), 38–54. https://doi.org/10.1080/10615806.2013.809421

Turner, N.J., and H. Clifton. 2009. "'It's so Different Today': Climate Change and Indigenous Lifeways in British Columbia, Canada." *Global Environmental Change* 19 (2): 180–190. https://doi.org/10.1016/j.gloenvcha.2009.01.005

Unger, D. 2021. "First Nations May Be without Power for Three Months as Hydro Crews Work to Restore Power." CTV News. https://winnipeg.ctvnews.ca/first-nations-may-be-without-power-for-three-months-as-hydro-crews-work-to-restore-power-1.5543810

United Nations Office for Disaster Risk Reduction (UNDRR). 2015. *Sendai Framework for Disaster Risk Reduction 2015 - 2030*. Geneva, Switzerland. https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030

U.S. Department of Agriculture (USDA). 2016. *Adaptation Resources for Agriculture: Responding to Climate Variability and Change in the Midwest and Northeast*. Washington, DC. https://www.climatehubs.usda.gov/sites/default/files/AdaptationResourcesForAgriculture.pdf

U.S. Energy Information Administration. 2022. *Highlights For Air Conditioning in U.S. Homes by State, 2020*. Washington, DC. https://www.eia.gov/consumption/residential/data/2020/state/pdf/State%20Air%20Conditioning.pdf

Vancouver Coastal Health, and Fraser Health. 2022. *Climate Change Vulnerability and Capacity Assessment*. British Columbia, Canada. www.vch.ca/climatechange

Vancouver Coastal Health and Fraser Health. 2021. "As Heat Continues to Build in the Lower Mainland, the Heat Warning Issued by Environment Canada Has Now Been Escalated to an Extreme Heat Alert." https://www.fraserhealth.ca/news/2021/Jun/extreme-heat-alert#.ZECV4nbML3E

Vancouver Coastal Health. 2022. "Transporting in Heat." Victoria, BC. Released under the Freedom of Information Act. FOI: VCH-2022-F-108.

Vanderplanken, K., van den Hazel, P., Marx, M., Shams, A. Z., Guha-Sapir, D., and van Loenhout, J. A. F. 2021. "Governing Heatwaves in Europe: Comparing Health Policy and Practices to Better Understand Roles, Responsibilities and Collaboration." *Health Research Policy and Systems*, *19*(1). https://doi.org/10.1186/s12961-020-00645-2

Vanos, J, D. J. Vecellio, and T. Kjellstrom. 2019. "Workplace Heat Exposure, Health Protection, and Economic Impacts: A Case Study in Canada." *American Journal of Industrial Medicine* 62 (12): 1024–1037. https://doi.org/10.1002/ajim.22966

Varghese, B. M., A. Hansen, P. Bi, and D. Pisaniello. 2018. "Are Workers at Risk of Occupational Injuries Due to Heat Exposure? A Comprehensive Literature Review." *Safety Science* 110: 380-392. https://doi.org/10.1016/j.ssci.2018.04.027

Victoria Department of Health. 2023. "Heat Health Warning." Victoria State Government. Melbourne, Australia. https://www.health.vic.gov.au/environmental-health/heat-health-warning

Vincent, L. A. et al. 2018. "Changes in Canada's Climate: Trends in Indices Based on Daily Temperature and Precipitation Data." *Atmosphere - Ocean* 56(5): 332–49.

Vivid Economics. 2019. *Accelerated Electrification and the GB Electricity System.* Report prepared for the Committee on Climate Change. London, United Kingdom. https://www.theccc.org.uk/wp-content/uploads/2019/05/CCC-Accelerated-Electrification-Vivid-Economics-Imperial.pdf

Wale, J. D. 2022. "Climate Rez-Ilience: Building Transformative Climate Resilience in Indigenous Communities." Master's thesis submitted to the University of British Columbia. Kelowna, BC. https://doi.org/10.14288/1.0416163

Washington State Department of Health. 2021. "Heat Wave 2021." https://doh.wa.gov/emergencies/be-prepared-be-safe/severe-weather-and-natural-disasters/hot-weather-safety/heat-wave-2021 (March 26, 2023).

Weinberger, K. R., L. Tamburic, C. E. Peters, and C. B. McLeod. 2023. "Heat-Related Illness Among Workers in British Columbia, 2001-2020." *Journal of Occupational and Environmental Medicine* 65 (2): e88–e92. https://doi.org/10.1097/JOM.0000000000002761

White, R. H., S. Anderson, J. F. Booth, G. Braich, C. Draeger, C. Fei, C.D.G. Harley, et al. 2023. "The Unprecedented Pacific

Northwest Heatwave of June 2021." *Nature Communications* 14 (December): 727. https://doi.org/10.1038/s41467-023-36289-3

World Health Organization (WHO). 2015. *Operational Framework for Building Climate Resilient Health Systems*. Geneva, Switzerland. https://www.who.int/publications/i/item/9789241565073

WorkBC. 2021a. *Industry Profile: Construction*. https://www.workB.C..ca/industry-profile/construction

WorkBC. 2021b. *Industry Profile: Transportation and Warehousing*. https://www.workB.C..ca/industry-profile/transportation-and-warehousing

WorkBC. 2022. "Provincial Overview." https://www.workB.C..ca/region-profile/british-columbia

WorkBC. 2022. "Statistics to Assess the Impacts of the 2021 heat wave in BC.' Victoria, BC. Released under the Freedom of Information Act. FOI:WCB-2022-1333.

WorkSafeBC. 2005a. *Indoor Air Quality: A Guide for Building Owners, Managers, and Occupants*. Vancouver, BC.

WorkSafeBC. 2005b. *OHS Regulation Part 7: Noise, Vibration, Radiation and Temperature*. Vancouver, BC. https://www.WorkSafeBC.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-regulation/part-07-noise-vibration-radiation-and-temperature#SectionNumber:7.27

WorkSafeBC. 2007. *Preventing Heat Stress at Work*. Vancouver, BC. https://www.worksafebc.com/en/resources/health-safety/books-guides/preventing-heat-stress-at-work?lang=en

WorkSafeBC. 2021. "WorkSafeBC Advising Employers to Consider Workplace Closures During Heat Wave." https://www.WorkSafeBC.com/en/about-us/news-events/news-releases/2021/June/WorkSafeBC-advising-employers-to-consider-workplace-closures-during-heat-wave

WorkSafeBC. 2022a. "Provincial Overview - Industry Claim Analysis: Counts (2017 - 2021)." https://app.powerbi.com/view?r=eyJrIjoiNWM3ZmI0OTYtNzdmYi00ZjhjLThiNWYt-NTE3MjdkY2FlNjFhIiwidCI6IjA1YzVjOTYzLWM4MzktNG-M5ZS1iNWMxLWI1MWIzNzk5YWMzNyJ9

WorkSafeBC. 2022b. "WorkSafeBC Reminding Employers to Keep Both Indoor and Outdoor Workers Safe from Heat Stress." https://www.WorkSafeBC.com/en/about-us/news-events/news-releases/2022/July/WorkSafeBC-reminding-employers-to-keep-both-indoor-and-outdoor-workers-safe-from-heat-stress

WorkSafeBC. 2023. Email communication between the Canadian Climate Institute and WorkSafeBC in February 2023.

Yumagulova, LT. Okamoto, E. Crawford, and K. Klein. 2022. *Lived Experience of Extreme Heat in B.C.: Final Report to the Climate Action Secretariat*. Government of British Columbia. Victoria, BC. https://www2.gov.B.C..ca/assets/gov/environment/climate-change/adaptation/resources/lived_experience_of_extreme_heat_in_B.C._final_report.pdf

Zhang, X., Flato, G., Kirchmeier-Young, M., Vincent, L., Wan, H., Wang, X., Rong, R., Fyfe, J., Li, G., Kharin, V.V. (2019): *Changes in Temperature and Precipitation Across Canada*; Chapter 4 in Bush, E. and Lemmen, D.S. (Eds.) Canada's Changing Climate Report. Government of Canada, Ottawa, ON. https://changingclimate.ca/CCCR2019/chapter/4-0/