DAMAGE CONTROL

REDUCING THE COSTS OF CLIMATE IMPACTS IN CANADA

CANADIAN CLIMATE INSTITUTE
L'INSTITUT CLIMATIQUE DU CANADA

SEPTEMBER 2022

CONTENTS

FOREWORD

This ground-breaking report, *Damage Control: Reducing the costs of climate impacts in Canada*, is the culmination of the Costs of Climate Change series. Since December 2020, we have released four comprehensive reports—*Tip of the Iceberg*, *The Health Costs of Climate Change*, *Under Water* and *Due North*—analyzing the growing breadth and depth of climate change damages in Canada. In a first of its kind approach, *Damage Control* uses new data and research to apply a macroeconomic lens to the costs of climate change impacts.

The results are sobering. The mounting costs of climate change will cause severe damage to Canada's economy, with the worst costs being experienced directly by individual households. As climate change impacts intensify, life will become even less affordable as economic growth slows, governments will be forced to raise taxes or cut services to pay for climate disasters, job losses will be measured in the millions, and goods will become more costly as supply chains are disrupted.

This is not, however, our inevitable future. *Damage Control* demonstrates that if we invest in adaptation now, we can cut many of the costs of climate change in half. And, if adaptation is paired with Canadian and global success in reducing emissions in line with international commitments, these costs can be cut by three-quarters, helping to secure a more stable, affordable, and prosperous future for Canadians.

As the current and future costs of climate change become clearer, governments have a responsibility to implement effective policy solutions. The return on investment for adaptation is massive: as *Damage Control* shows, every dollar spent on some of the most important adaptation measures for Canada can save $13 to $15 in the long term.

So much of the climate change discussion is focused on the cost of taking action. What *Damage Control* demonstrates is that it is, in fact, the cost of inaction that is measurable and growing. The costs of climate change impacts are already a drag on Canada's economic growth—and that drag will only intensify. Investing in mitigation and adaptation measures, as quickly as possible, is the best way to secure Canada's future prosperity.

Rick Smith
President
Canadian Climate Institute

MAY 12, 2017: Volunteers fill sandbags at an emergency flooding station in Kelowna, British Columbia.

EXECUTIVE **SUMMARY**

Climate change is a serious and growing drag on Canada's economy and a major financial burden on households in Canada. Damage Control *quantifies these impacts, showing how climate change is already damaging infrastructure, destroying assets, and causing avoidable illness and death.*

We find that climate change results in cascading negative effects through Canada's economy, as climate damages slow the level of economic activity across sectors and regions, strain government budgets, lower household income, and erode competitiveness. Further, individual households end up paying the highest price for climate change, as slower growth, higher taxes, higher prices, and the costs of direct damages shrink income and wealth.

These impacts are already beginning to take hold and will compound quickly unless something changes. This future is not inevitable: There is a great deal that governments can do to reduce the economic risks and protect people in Canada from these impacts. Investment in proactive adaptation can substantially reduce overall economic damages, as will global success in reducing greenhouse gas emissions.

Damage Control is the culmination of the Canadian Climate Institute's Costs of Climate Change series, a multi-year modelling and research project that aims to better understand and quantify the potential costs of a changing climate in Canada. This report documents a first-of-its-kind study on the combined direct and indirect costs of climate change in Canada, integrating economy-wide macroeconomic analysis with bottom-up studies, including those from previous Costs of Climate Change reports.

Our approach to the macroeconomic analysis in *Damage Control* consisted of three steps:

- First, we identified 16 impact groups where climate change is likely to trigger major material economic consequences in Canada.
- Second, we estimated the direct economic cost and benefits for each impact group in a series of bottom-up analyses that examined impacts across 14 future climate scenarios, including a low- and high- emissions scenario and seven different climate models. We analyzed impacts at fine geographic scales and short time intervals.
- Third, we integrated these findings into a macroeconomic model of the Canadian economy, simulating economy-wide economic impacts across the 16 impact groups through to the end of the century, as well as the costs and benefits of proactive adaptation.

In total, accounting for each impact group, we assessed 84 scenarios: two global climate emissions scenarios, seven downscaled climate scenarios, three asset growth scenarios, and two adaptation scenarios. Yet despite the much more detailed picture that our analysis provides over previous studies, our results nonetheless remain the "tip of the iceberg" when it comes to the full range of effects to Canada's economy and society from a changing climate. There remain many below-the-waterline risks, where climate change will likely generate substantial impacts, but that have too much uncertainty and complexity to quantify at this stage.

August 29, 2021: Pedestrians in Penticton, British Columbia watch as a forest fire flares up in the hills above the city.

FINDINGS

Climate change is a macroeconomic risk that threatens to significantly undermine future prosperity

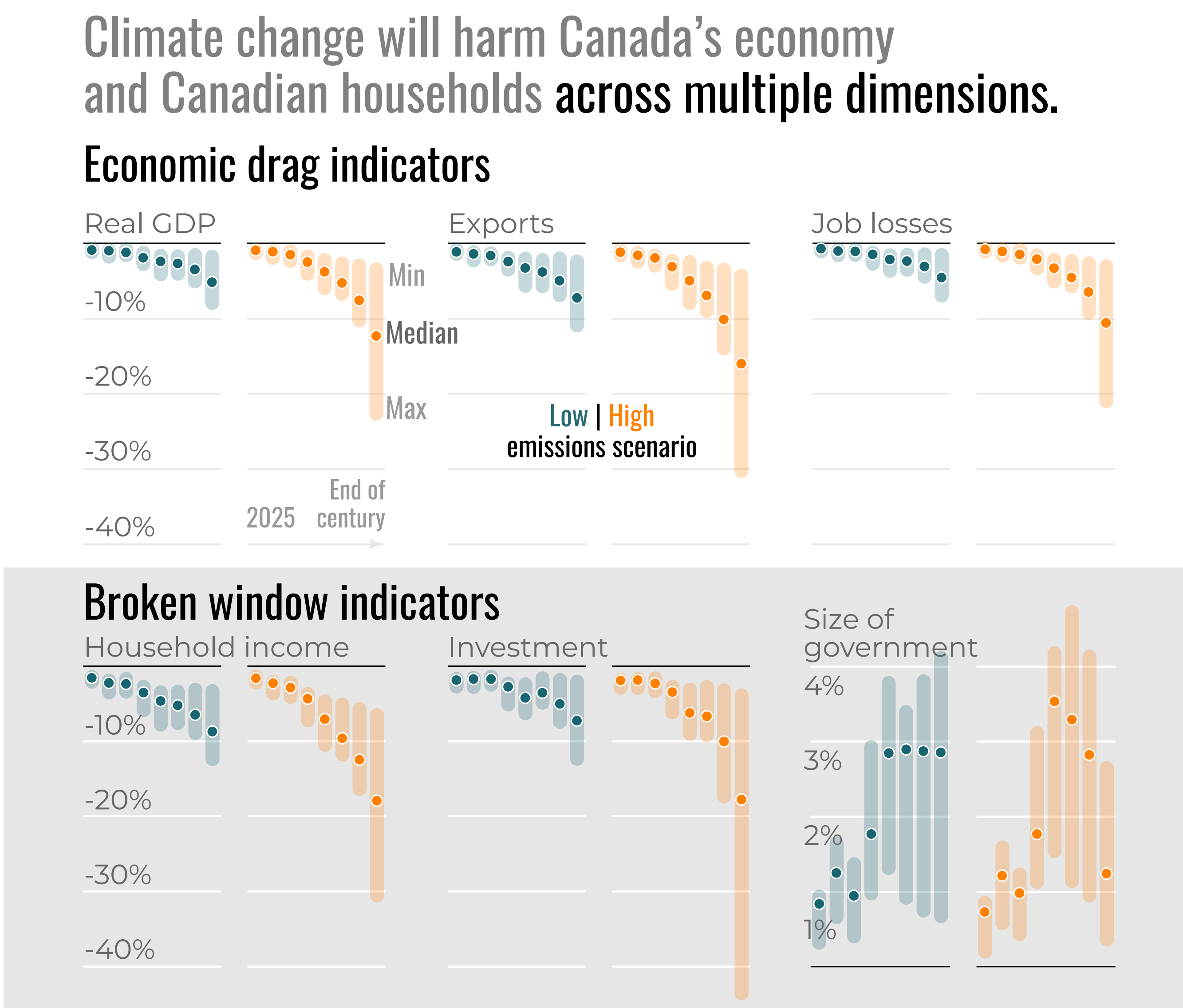
Absent aggressive policy to reduce and adapt to the impacts of a warming planet, climate change will drag down the rate of Canada's economic growth and result in a much smaller future economy. This macroeconomic damage will kill jobs, erode Canada's competitiveness, and drive greater government spending.

Climate damages are already resulting in large national income losses over the very short term. In 2025, Canada will experience $25 billion in losses relative to a stable-climate scenario, which is equal to 50 per cent of projected 2025 GDP growth. The mounting costs compound quickly over the years and decades ahead, rising to $78 and $101 billion annually by mid-century for a low and high emissions scenario respectively, and $391 and $865 billion respectively by end of century.

In addition to slowing GDP growth, climate impacts will cause large job losses, as heat-induced productivity losses and premature deaths shrink the workforce. Job losses could double to 500,000 by mid-century, and increase to 2.9 million by end of century. These impacts to labour will then ripple through the economy, reducing productivity and raising prices, and ultimately undermining the ability of the economy to support an affordable and secure future for people in Canada.

Export losses will grow over time as costs increase and competitiveness is reduced, and imports slow as output falls, reflecting a deepening economic weakness. By the end of the century, export losses in the low-emissions scenario will be $300 billion or seven per cent below a stable-climate scenario, and $600 billion or 16 per cent under a high-emissions scenario.

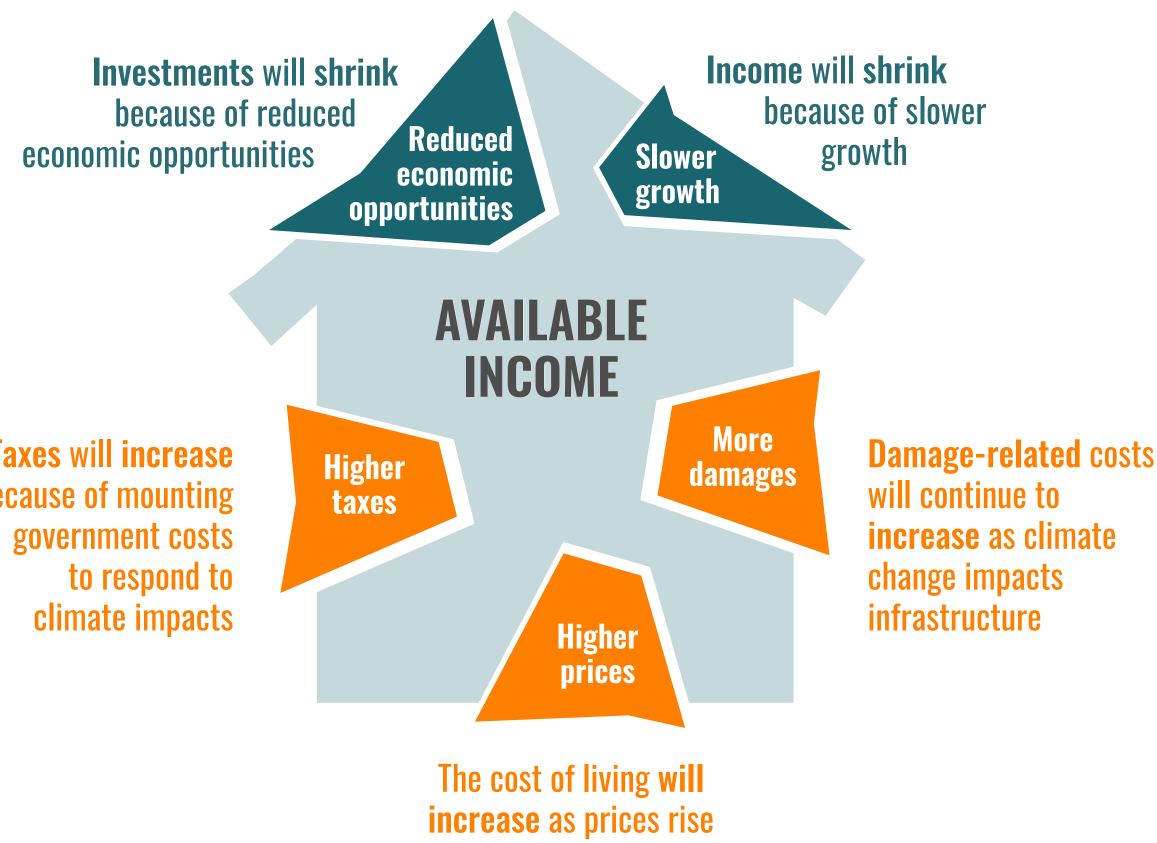
The losses in the global high-emissions scenario will be substantially higher than in the low-emissions scenario across all indicators, particularly after mid-century, driving home the imperative to reduce global greenhouse gas emissions in order to reduce costs.



The broken window fallacy

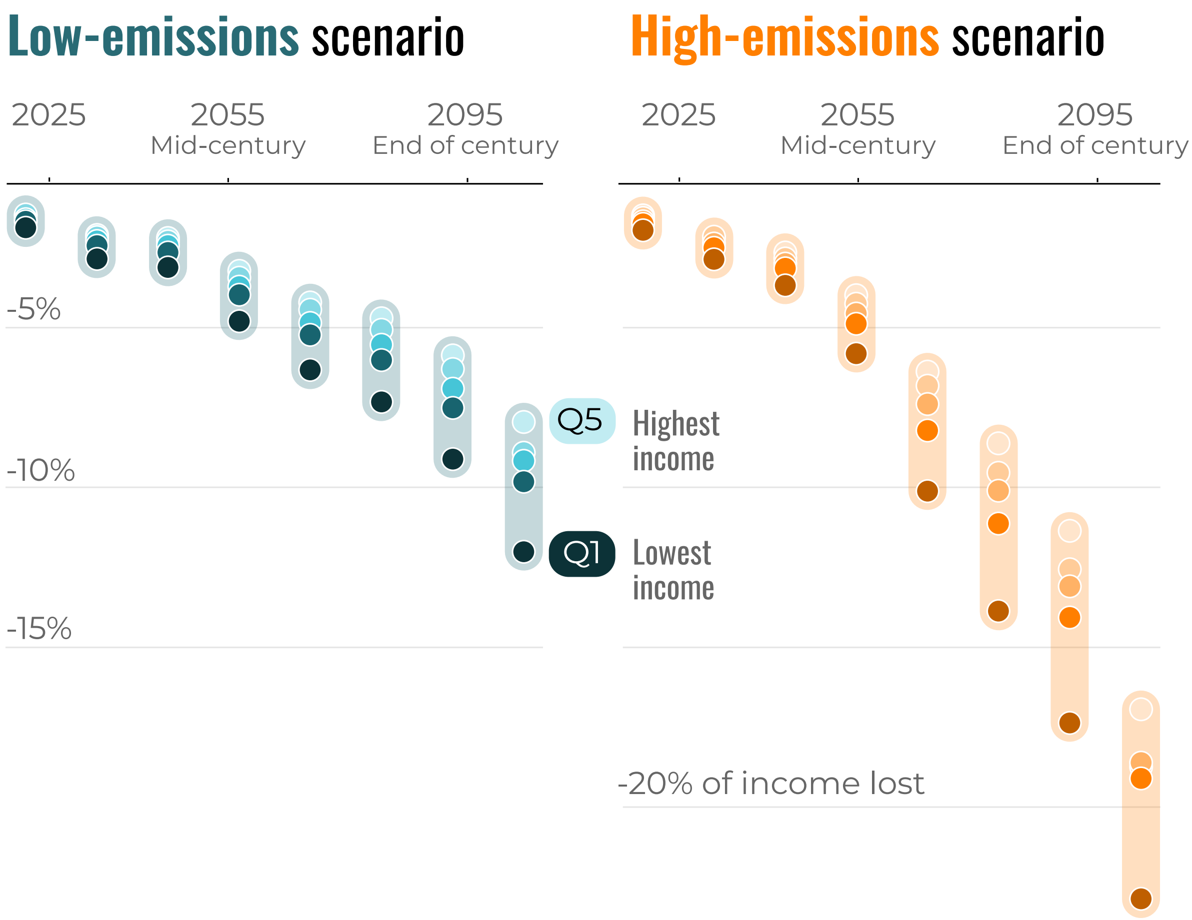
While the topline macroeconomic losses from climate impacts are concerning, actual costs for people in Canada are even more severe. These household impacts, obscured in the hit to national gross domestic product (GDP), are a classic case of the broken window fallacy, which describes the distorting effect that spending to repair destroyed assets can have on measures of the economic costs of climate damages. Such forced spending carries with it an opportunity cost, as significant expenditures are being directed merely towards fixing what has been broken, rather than towards new productive activities that create wealth, supporting the long-term well-being of people living in Canada.

Climate change will make life less affordable by reducing income and increasing expenses.



The impacts of climate change will inevitably lower individual wealth as income falls and is redirected to fix what gets prematurely broken. The full extent of the burden placed on individual households is partially obscured by looking only at topline macroeconomic indicators of economic drag. Spending to fix "broken windows" appears on the surface to stimulate some sectors of the economy, as the size of government grows and the construction sector receives a boost. However, there are opportunity costs to this forced spending to fix what climate change has damaged or destroyed, as resources are redirected away from productive new investments that otherwise would support output and wealth creation. These costs are reflected in falling household income, declining business investment, and increased taxation or a reduction in social services. So, while GDP may fall by 12 per cent in a median high-emissions scenario by end of century, prospects for households are even more dire, with income falling by 18 per cent.

All households will lose income, and low-income households will suffer the most.



FINDINGS

Climate change is an **affordability risk** for households in Canada, and **especially for vulnerable populations**

Climate change will hit households hard, making life even less affordable for people in Canada in the years and decades ahead. Affordability pressures will come from all directions.

Slowing economic growth will reduce economic opportunity and result in lower incomes at the same time as governments must raise taxes in order to maintain services and pay for the clean-up and repair from increased weather-related disasters. Job losses will accumulate, depriving people in Canada of a primary source of economic security, while prices for goods increase as costs multiply through supply chains.

As a result, households will be worse off across all climate scenarios. The loss of household income is already materializing, with a drop in income per capita of $720 in both emissions scenarios by 2025 compared to a stable-climate scenario, rising to $1,890 per capita by mid-century in a low-emissions scenario and almost $2,300 per capita in a high-emissions scenario. Real income losses will cut deep into household affordability after mid-century, and low-income households will be most affected, facing income cuts of 23 per cent in a high-emissions scenario by end of century, while the median income group faces cuts of 19 per cent.

The Canadian economy is highly climate-sensitive, posing a **major risk to businesses and investors**

The impacts of climate change are not confined to particular regions or sectors of the economy. Businesses and investors across the country and in virtually every sector are at risk.

Climate damages will make all regions worse off by the end of the century, with Northern Canada and Alberta bearing the most significant losses. Northern Canada will bear a disproportionate impact primarily due to infrastructure damage from the effects of permafrost thaw. Northern Canada could see GDP losses of $5,490 or $7,080per capita by mid-century in low- or high-emissions scenarios, respectively, rising to $11,820 and $26,060 by end of century. Alberta, the province most exposed to weather-related disasters, could experience median GDP losses at mid-century of $2,890 per capita in a low-emissions scenario or $3,920 per capita in a high-emissions scenario.

Most economic sectors will also be negatively impacted across all future climate scenarios. Manufacturing, the services sector, and transportation will be particularly hard hit by climate impacts. While the construction and agriculture sectors could see benefits, these sectors comprise just 8.5 per cent of Canada's economy and their gains are swamped by the losses experienced by all other sectors. Moreover, the boost to the construction sector is an example of the broken window fallacy, as sector growth is driven by spending to repair damaged infrastructure, which redirects resources away from more productive uses in the economy.

Finally, climate damages impair investments in future productivity. Investment will drop across all climate change scenarios relative to a stable-climate scenario, with the decline accelerating rapidly in the longer term, as costs accumulate and output shrinks.

Climate change is a fiscal risk that threatens to upend government spending

Climate change puts significant pressure on public finances. Slower economic growth throughout the economy will put downward pressure on government revenue.

This fiscal pressure will manifest at the same time as demands will increase on governments to respond to growing climate costs, such as backstopping weather-related disasters, upgrading and replacing infrastructure, and maintaining healthcare services amidst increased pressures on the health system.

The result will be a forced choice between raising taxes in order to maintain services, accruing additional public debt, or cutting services as climate damages consume a greater share of government budgets. By 2025, a 0.35 per cent increase in corporate and personal income taxes will be required to cover increased government spending of about $5 billion annually on climate damages, without eroding services. By mid-century this will rise to more than $17 billion annually, corresponding to a tax rate increase of approximately one per cent, and by end of century will increase to $24 billion or $55 billion annually with tax rate increases of 1.4 per cent and 2.7 per cent for low-emissions and high-emissions scenarios, respectively.

FINDINGS

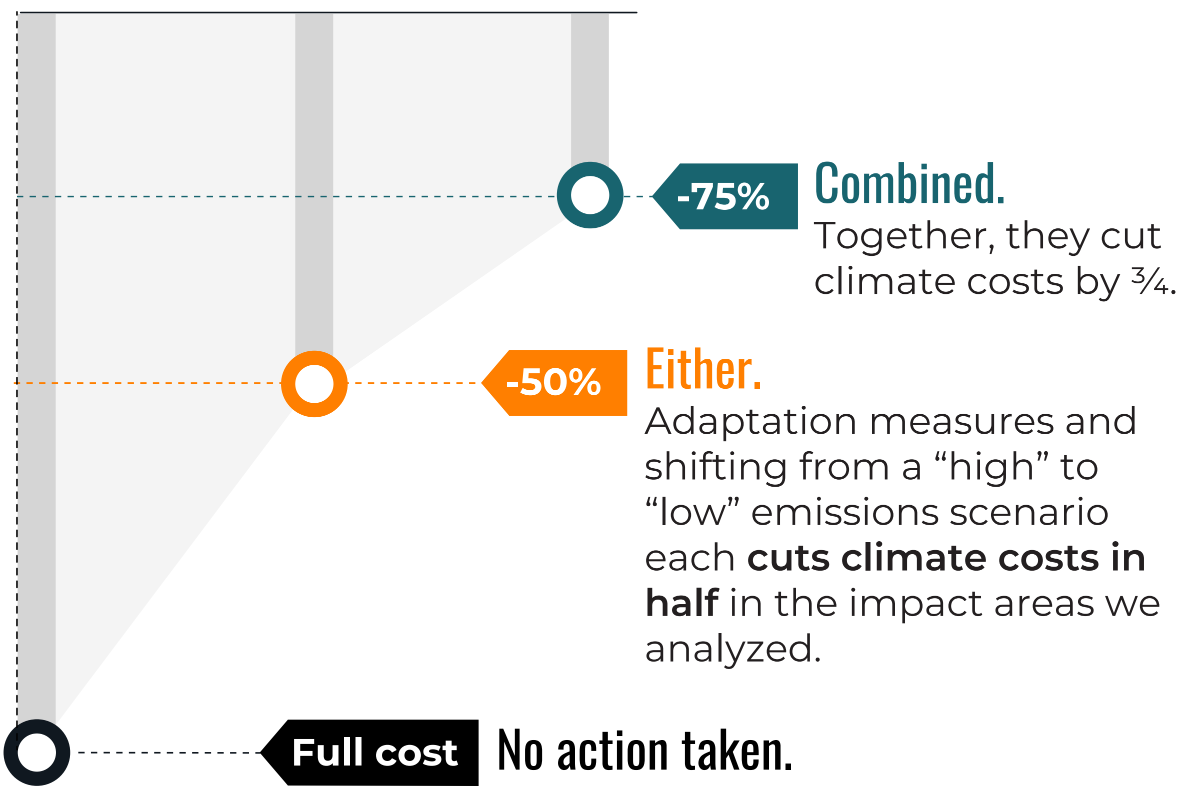
Emissions reductions and proactive adaptation measures, taken together, are the most effective means of reducing cost

Both global emissions reductions and proactive adaptation measures will substantially reduce the costs of climate change to Canada's economy.

Reducing emissions will result in major benefits after mid-century, with the reductions in the low-emissions scenario reducing damages by more than half compared to the high-emissions scenario. Proactive adaptation, meanwhile, will yield major benefits regardless of the emissions trajectory, and over a shorter time horizon. Taken together, a combination of proactive adaptation measures and global emissions reductions will be the most effective in mitigating damages, reducing Canada's total real GDP losses by 75 per cent.

Moreover, our macroeconomic analysis shows that spending on proactive adaptation has major economy-wide benefits. Our results indicate that for every $1 spent on the adaptation measures we modelled, $13-$15 in total benefits accrue. This includes $5-$6 of benefits for every adaptation dollar spent by avoiding direct damages such as premature infrastructure repair and replacement costs and $6-$10 of knock-on benefits that work their way through the economy. A macroeconomic frame reinforces the case that proactive adaptation is a smart investment, illustrating that it generates substantial direct and indirect societal returns.

Adaptation and global emissions reductions, taken together, can dramatically reduce costs.



Per cent reduction in GDP impacts

Proactive adaptation is a strong investment that **generates major economic returns.**

A dollar invested today will return $15 in a low-emissions scenario

Economy-wide benefits.

Knock-on benefits associated with avoided direct costs, such as avoided disruption of supply chains, avoided loss of labour productivity, and avoided loss of income as a result of road delay and damage.

Direct benefits.

Reduction of costs directly associated with the adaptation measure, such as reduction in cost of repair or replacement of lost or damaged infrastructure.

Recommendations

1. Governments should **build climate impacts** and **adaptation policies** into their own **economic decision making**.

Governments in Canada have failed to account for the economic threat posed by a warming and increasing volatile climate, leading to a collective underestimation of both the costs of inaction and the economic benefits of ambitious climate policies. Moving forward, governments should build the costs of climate change impacts, as well as the costs and benefits of adaptation and mitigation policies, into economic analysis and decision-making processes so that policy and spending decisions reflect the very real and significant costs of choosing not to invest in adaptation and emissions reductions.

2. Governments should **encourage**—and where appropriate, **mandate**—accounting for climate change risks **in private-sector decision making**.

As the frequency and severity of weather-related disasters continues to increase, the costs from physical climate damages are already beginning to accumulate both through direct impacts as well as through indirect costs that spread through the economy. The private sector must respond to this growing threat by integrating physical risk and risk-reduction measures into their risk management practices, a practice that governments and regulators should support through accelerating climate risk disclosure initiatives and generating climate information to support accurate and consistent disclosure nationwide.

3. Governments should **scale-up adaptation measures** to match the magnitude of the risk Canada faces.

Proactive adaptation can protect the health, security, and well-being of people in Canada and mitigate the impacts of climate change on Canada's economy, providing a return on investment of $13-$15 per dollar spent. Despite the clear benefits, Canada is behind on adaptation and governments need to urgently scale-up adaptation policy and investment to match the scale of our climate risk, starting with the forthcoming *National Adaptation Strategy*.

4. Governments should **double down on aggressive reductions in emissions** both at home and abroad.

Moving from a high to a low-emissions scenario results in significant reductions in climate damages. Without major emissions reductions, adaptation alone will be insufficient to address growing climate damages in Canada. All orders of government should continue to develop and implement ambitious policies to reduce Canadian emissions and meet our targets, while also supporting and encouraging global efforts to reduce emissions.

5. Governments should **invest in understanding and preparing** for the **economic risks** of climate change **that have not yet been modelled**.

While this report provides a more detailed picture of the economic risks facing Canada from a changing climate, these risks are just the tip of the iceberg and there are many others that we suspect may have major impacts but that we don't yet have the tools to understand. While governments should not hesitate to act immediately based on what we know today, they should also invest in further research to better understand and prepare for the full scope of climate impacts and economic risks that lie ahead.

Wind turbines dot the shoreline of West Pubnico, Nova Scotia.


April 30, 2019: The Gatineau River flooding the Boulevard de la Gappe in Gatineau, Quebec.

INTRODUCTION

The worsening impacts of climate change are a significant drag on Canada's economy and a major burden on households.

This report is the culmination of a multi-year investigation of the costs of climate change in Canada. The macroeconomic analysis presented here draws on a series of earlier reports from the Canadian Climate Institute on the economic implications of climate change and provides a top-down perspective on the overall macroeconomic drag that Canadians need to prepare for.

What we found is concerning. A warming and increasingly volatile climate is a drag on sustained economic growth that erodes Canadians' income and prosperity by accelerating infrastructure decay, destroying assets, and causing avoidable illness and death. While a few international studies to date have suggested that Canada could be a climate change winner, (Burke et al. 2015; Lafakis et al. 2019) our analysis shows that this is not the case: there are no scenarios we modelled under which climate change has a net positive impact on Canada's economy.

While the topline macroeconomic losses are concerning, actual impacts for Canadians are even more severe. These household impacts, obscured in the hit to national gross domestic product (GDP), are a classic case of the *broken window fallacy,* which describes the distorting effect that spending to repair destroyed assets can have on measures of the economic costs of climate damages. Such forced spending carries with it an opportunity cost, as significant expenditures are being directed merely towards fixing what has been broken, rather than towards new productive activities that create wealth, supporting the long-term well-being of people living in Canada.

Increased government expenditures required to clean up the damage caused by climate change are a good example of the cost illusion of national macroeconomic accounting. Government expenditures are the only component of national income, as measured by real gross domestic product (GDP), that increases in our scenarios because of increased spending to address climate damages—consumption, exports, imports, and investment all see relative declines because of these damages. But the increase in government spending masks real cost. Climate change lowers government revenue due to the economic hit. To preserve the fiscal balance, tax rates must necessarily rise, which brings about other economic costs that manifest in time, notably a loss in economic efficiency (Dalby and Ferede 2018).

Canadian households will pay the largest price for the many windows that climate change will break as slower economic growth, high unemployment, higher taxes, and direct climate damages come together to raise the cost of living and reduce economic opportunity. Moreover, not all households are impacted equally, with lower-income households countrywide and all households in the North and Alberta experiencing disproportionate income losses. And true to the broken window fallacy, some of these household costs, notably the increased risk of premature death or illness, are far more significant than the market-based costs that the macroeconomic analysis captures (Clark et al. 2021).

Business will also suffer significant investment losses under a changing climate. While construction and allied support sectors see net positive effects from climate change, all other sectors are negatively affected, with large drops in investment, labour demand, exports, and economic output.

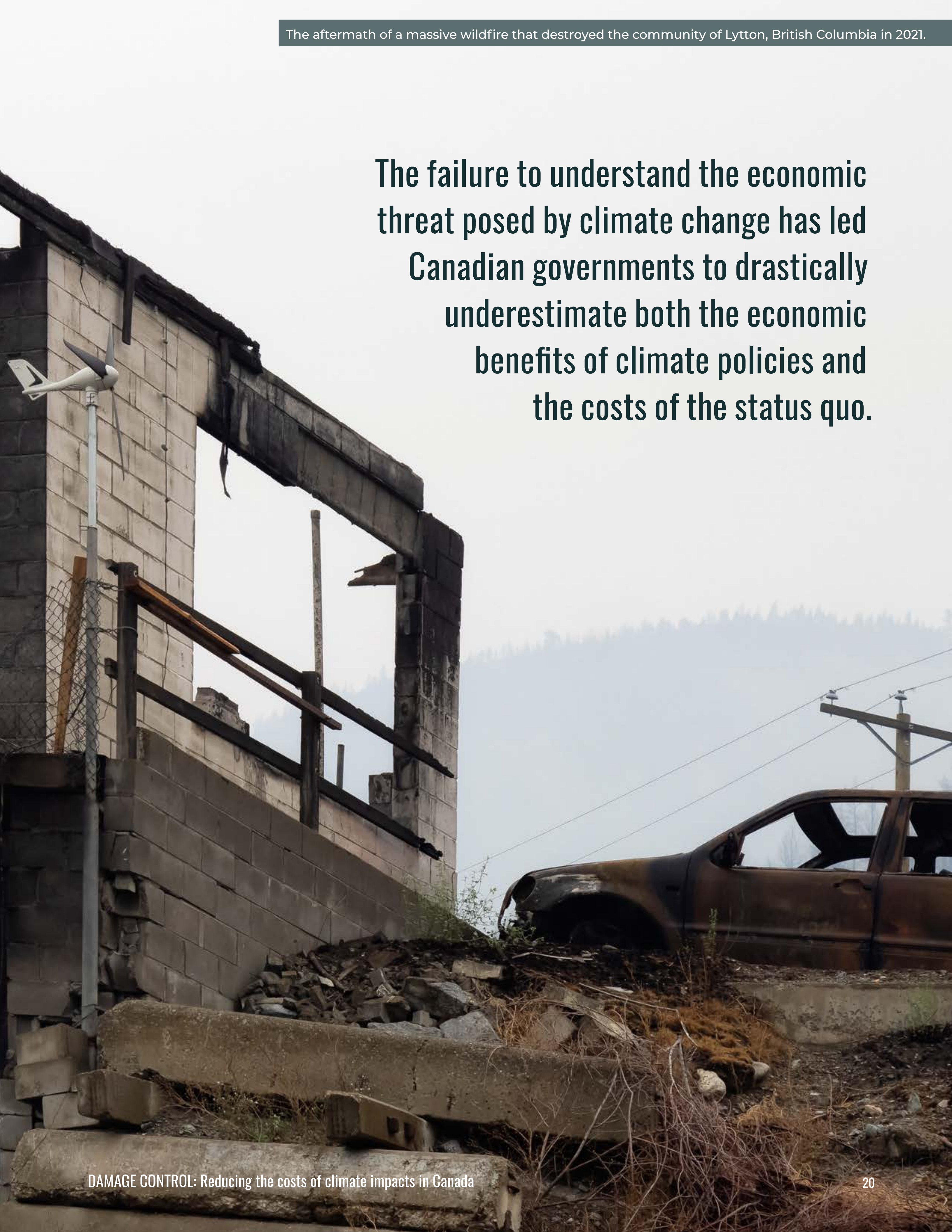
Our analysis finds that these economic damages from climate change are already occurring, that they will continue to worsen, and that they will accelerate rapidly after mid-century, meaning that future generations will bear the highest costs. But Canadians are not powerless in facing this threat. We find that both greenhouse gas emissions reductions globally and proactive adaptation here in Canada can cut future economic damages in half, and, in combination, can insulate Canada from the worst climate change damages, reducing losses in national income (as measured by real GDP) by 75 per cent in the impact areas we analyzed.

Moreover, the investment returns to society of proactive measures to prepare for worsening climate damages are multiples greater than the costs of such measures, with the adaptation measures we modelled providing a return on investment of $13-$15 for every one dollar spent. Notably, the economy-wide or general equilibrium impacts were a factor of two times greater than the direct costs of the adaptation measures we analyzed. This rate of return drives home the fact that investing in proactive adaptation is smart economic policy that pays substantial dividends. The benefits of mitigation and adaptation also occur at different time scales—adaption pays now while mitigation avoids future damages.

This report shows that governments and the private sector need to better bring into view the economic threat posed by a changing climate. The failure to do so thus far has led Canadian governments to drastically underestimate both the economic benefits of climate policies and the costs of the status quo.

The results of our analysis help lay the foundation for governments to set policy priorities, allocate programmatic and infrastructure spending, and better protect the health, well-being, and jobs of people in Canada. The results should also inform the federal government's forthcoming *National Adaptation Strategy* and its implementation. By quantifying where and how climate damages may create the biggest drag on Canada's economy, this analysis provides both a broader and a more detailed understanding of the largest climate risks that Canada's *National Adaptation Strategy* must guard against (Ness and Miller 2022).

The combination of top-down macroeconomic modelling and bottom-up analysis in this report



The aftermath of a massive wildfire that destroyed the community of Lytton, British Columbia in 2021.

The failure to understand the economic threat posed by climate change has led Canadian governments to drastically underestimate both the economic benefits of climate policies and the costs of the status quo.

paints a more comprehensive picture than earlier studies of how climate change will continue to affect people in Canada. However, we must emphasize that the economic drag and broken windows we modelled are only the tip of the iceberg, representing just a subset of the total impacts to be expected from a warming and increasingly dangerous climate. The true potential for macroeconomic damage is almost certainly far greater than the specific damages we have calculated.

As the threat of climate change comes increasingly into view, and as climate policy and the understanding of future climate conditions evolve, all orders of government should develop and maintain an up-to-date understanding of the economic risks we face, move quickly to address those risks, and ensure that the private sector follows suit.

The remainder of this report is organized as follows:

- **SECTION 2** describes the approach we followed to model 84 scenarios, including 16 impact groups and proactive adaptation responses, in a regionally disaggregated macroeconomic model of the Canadian economy.
- **SECTION 3** presents an overview of the macroeconomic impacts that a warmer and more volatile climate has on the economy over the next several decades. This section presents these impacts in terms of their overall drag on the economy and how continually fixing broken windows impairs wealth creation. It also shows how global effort to reduce greenhouse gas emissions can substantially reduce future economic risks here in Canada.
- **SECTION 4** highlights how a significant scale-up in proactive adaptation can cut the costs of climate damage in half.
- **SECTION 5** summarizes the key findings and **SECTION 6** provides a list of recommendations for policymakers.

Bottom-up analyses of the direct damages of climate change—like those in our earlier reports Tip of the Iceberg, The Health Costs of Climate Change, Under Water, and Due North—are important for understanding frontline costs, but do not capture the true scale of the economy-wide damages. As the case of the Fort McMurray fire illustrates, and as this report seeks to quantify, climate change will have economic consequences that far exceed the costs of the direct damage to homes, infrastructure, and people's health.

The top-down macroeconomic modelling study in this report seeks to fill in this picture, capturing not only the direct costs but also the indirect consequences of climate change, and showing how climate damages will reverberate through Canada's entire economy, impacting everyone and every sector. However, even this more comprehensive approach does not capture the full extent of the impacts a warming climate will have on our economy and society, as not all material economic damages are modelled, and there are significant risks that have too much uncertainty to include.

Finally, our findings unequivocally conclude that investments in proactive adaptive responses to climate change are an economic winner and should be scaled up aggressively.

May 2016: Cars lined up on Highway 63 south as the Fort McMurray fire burns.

BOX 1

The direct and indirect costs of the Fort McMurray wildfire

Recent years have seen an increase in climate change-fuelled, weather-related disasters with major economic consequences. A closer look at one of these recent events highlights the magnitude of the damages that will be experienced more frequently in a changing climate. It also shows the importance of looking not only at direct, immediate damages but also at how impacts reverberate throughout the Canadian economy.

The Fort McMurray wildfire of May 2016 was, at the time, the most expensive climate-related disaster in Canadian history. The fire caused approximately $4 billion in damage to homes and businesses (Alam et al. 2017). However, accounting for direct damages alone vastly undercounts the total costs. Economists estimate that, in addition to physical infrastructure damages, the fire caused an additional $7 billion in net additional and indirect costs, including over $3 billion in loss of production in the oil and gas industry and other economic sectors, over $3 billion in indirect environmental and resource impacts, $2 billion in government emergency response costs, and $200 million in lost provincial and municipal tax revenue, partially offset by gains from repair and reconstruction (Alam et al. 2017). In other words, when the total costs of the Fort McMurray wildfire are accounted for, the final bill balloons from $4 billion to $11 billion.

August 7, 2020: An EF-3 tornado touched down near the town of Scarth, Manitoba, killing two people.

2 OUR APPROACH

We developed a multi-step approach to estimate future economic damages of climate change for Canada, with and without adaptation. The approach began with bottom-up analysis of some of the most important costs (and, in some cases, benefits) of climate change for Canada using highly detailed models of climate change impacts on health, infrastructure, and climate-sensitive economic sectors. These costs and benefits were then fed into a top-down macroeconomic model to simulate repercussions to Canada's economy through the end of the century.

This report is the capstone of the Canadian Climate Institute's Costs of Climate Change series combining a top-down macroeconomic analysis with a series of bottom-up studies. Our approach included three discrete steps (Figure 1):

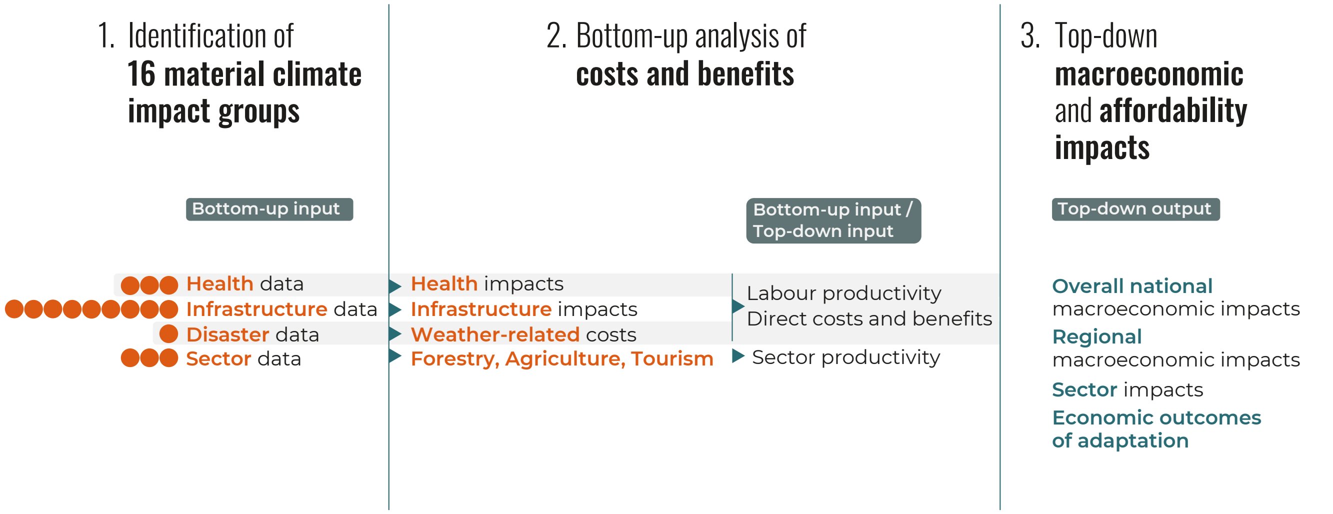
1. **We studied the literature and consulted with experts** to identify 16 impact groups where climate change is likely to result in material economic costs and benefits in Canada.

2. **We estimated direct economic costs and benefits** from climate change in a series of bottom-up analyses. For each of these 16 impact groups, we analyzed impacts for a total of 14 future climate scenarios—two global greenhouse gas emissions scenarios and seven downscaled global climate models. We then analyzed impacts to infrastructure, populations, and economic sectors across Canada from now to the end of the century at geographic resolutions as detailed as 10 by 10 kilometres and with timesteps as short as individual days. For many impact groups we also estimated the costs of investing in proactive climate change adaptation as well as the benefits to be gained in terms of avoided damages.

3. **We integrated the findings of the bottom-up analyses** into a top-down macroeconomic analysis using an advanced model of the Canadian economy.[1] We used the model to simulate economy-wide economic changes across all 16 impact groups until the end of the century, for the same 14 emissions and

[1] gTech is Navius Research's computable general equilibrium model of the Canadian and the United States economy.

Figure 1: Our approach to assessing the impacts of climate change in Canada



climate scenarios and three scenarios with different assumptions about growth in the value of assets at risk. We also examined the macroeconomic impacts of proactive adaptation as well as estimating the social return on investment within a cost-benefit analysis framework.

Bottom-up analyses of costs and adaptation benefits for health, on infrastructure, and on Northern infrastructure are documented in previous reports in the Institute's Costs of Climate Change series. To support a broader scope of macroeconomic modelling in this report, we also conducted additional bottom-up analyses of economic costs of climate change from weather-related disasters, and from effects on the agriculture, forestry, and tourism sectors specifically.

Our approach uses detailed bottom-up analyses to estimate costs and benefits across a wide range of impact groups, followed by integration into a macroeconomic model. This approach follows methods used successfully in other countries to assess national-scale economic impacts of climate change (Steininger et al. 2015; Szewczyk et al. 2018). Our results provide a more nuanced and granular picture of national-scale economic impacts of climate change in Canada than other solely top-down macroeconomic studies that rely on very broad and simplified assumptions about the effects of global temperature increases on Canada's economic performance without consideration of the actual processes through which specific climate and weather changes will affect different industries, regions, and demographics (Burke et al. 2015; Lafakis et al. 2019).

Table 1 summarizes the main climate change impact groups and their associated economic costs and benefits that we assessed in our research. For further information on how these costs and benefits were characterized in our economic impact modelling, consult the accompanying technical report (Navius Research and Canadian Climate Institute 2022).

Table 1. The economic costs and benefits of 16 climate impacts

Theme	Impact group	Description of economic cost or benefit
Infrastructure	Coastal and inland flooding	Damage to homes and buildings due to inland and coastal flooding*
	Road damage	Damage to roads resulting from increased heat, freeze-thaw, and precipitation impacts
	Rail damage	Track buckling caused by heat that exceeds design parameters
	Road delay	Lost productivity in the commercial transport sector from supply chain disruptions due to road damage
	Rail delay	Lost productivity in the rail sector resulting from supply chain disruptions due to rail damage
	Electricity infrastructure damage	Damage to electrical transmission and distribution infrastructure due to increased heat and changes in precipitation impacts
	Electricity demand	Increased costs for building cooling due to rising electricity demand driven by increased air temperatures
	Hydropower supply	Change in hydroelectricity generation due to changes in precipitation and snowmelt patterns
Northern infrastructure	Permafrost thaw	Damages to airports, roads, and buildings due to permafrost thaw
Health	Premature death	Reduction in labour supply due to premature death resulting from extreme heat and heat-induced increases in ground-level ozone levels
	Illness	Increased healthcare costs due to more Lyme disease, lower air quality, and extreme heat
	Labour productivity	Reduction in labour productivity due to extreme heat
Disasters	Weather-related disasters	Damage to homes, buildings, and infrastructure plus government response costs due to wildfires, ice storms, catastrophic floods and other extreme weather
Agriculture	Agriculture	Increased or decreased crop yields due to increased temperature and changes in precipitation
Forestry	Forestry	Reduction in timber harvest volumes due to increased temperature and changes in precipitation
Tourism	Tourism	Increased international tourism arrivals due to increased seasonal temperatures

*Damage to homes and buildings from coastal and inland flooding are net of catastrophic flood events, which are captured in weather-related disasters.

Identifying climate change impact groups

We identified 16 impact groups where climate change could trigger major economic costs and benefits for Canada. However, the costs and benefits on our list are ultimately just the tip of the iceberg—a warmer and more volatile climate will bring many more economic costs than the 16 we studied.

In our first report in the Costs of Climate Change series, *Tip of the Iceberg*, the Canadian Climate Institute reviewed current understanding of the potential scope and scale of the economic costs and benefits of climate change in Canada. The report highlighted that damages will cut across the Canadian economy, and without adaptation, these damages will compound over time (Sawyer et al. 2020).

We prioritized 16 impact groups as the focus for further analysis of economic costs and benefits from climate change that we ultimately integrated into a macroeconomic model of provincial and territorial economies in Canada (Table 1). These areas were selected to capture the largest estimated economic outcomes that are currently quantifiable using available data, methods, and models.

The impact groups we prioritized represent major economic risks for Canada, but are only the tip of the iceberg of the total economic outcomes to be expected (Figure 2). Other, hard-to-measure outcomes such as the impacts to productivity and healthcare costs of mental illness exacerbated by climate change could dwarf the anticipated costs of of other climate-induced illness (Clark et al. 2021).

Because of Canada's close integration into the global economy, climate change fallout at a global scale, including ecosystem collapse, war, famine, rising political extremism, and authoritarianism, could also have devastating impacts on Canada's economy and society. We need look no further than the COVID-19 crisis or climate-fuelled conflicts in Syria and Mali (Eyzaguirre et al. 2021) to appreciate the magnitude, complexity, and unpredictability of these risks.

July 2020: A homeless encampment in Vancouver's Strathcona Park.

Figure 2: The climate costs iceberg

Climate change is amplifying existing climate hazards and creating new ones, threatening Canadian prosperity and well-being. We can estimate some of these risks and their potential costs for households, businesses, communities, and the economy as a whole, but what we can measure so far is only the tip of the iceberg: many other risks loom under the surface. Governments need to address the risks we do understand while seeking to better understand and prepare for the many that we don't yet.

RISKS IN OUR PATH for which we can start to calculate the scale of impact and cost

Direct damage from increased heat, flooding, and permafrost thaw to vital infrastructure, including roads, railways, electricity systems, and buildings.

Costs of climate change-induced health hazards such as heat and declining air quality.

First-order costs of delays and outages to operators and primary users of critical infrastructure, such as transportation, energy, and communications systems.

Lower economic productivity due to more frequent weather-induced outages of critical infrastructure.

CLIMATE IMPACTS WE SUSPECT WILL AFFECT CANADA but whose scope and scale we don't yet have the tools to understand

Costs of conditions exacerbated by climate change in complex ways, such as mental illness.

Unpredictable changes to precipitation, wind, and cloud cover patterns that may affect renewable electricity generation.

Cascading impacts across multiple infrastructure and social systems, such as shutdown of healthcare systems during more frequent power outages, or inability of emergency responders to reach those in need after road network damage.

RISKS THAT MAY HAVE MAJOR IMPACTS through complex interactions and processes that are very challenging to predict

International conflict and migration exacerbated by climate change, leading to global geopolitical and economic instability.

Deterioration or collapse of ecosystems that provide vital ecological services and underpin Canada's economic activity.

International supply chain interruption impacts on food and water security and on business continuity for Canadian industry.

Tipping cascades of domino effect-changes that could fundamentally and irreversibly destabilize global ecosystems and institutions.

Quantifying the impacts of climate change and adaptation

We quantified potential economic costs and benefits across all 16 impact groups. We considered a range of possible future climate conditions, based on seven global climate models and two global emissions scenarios for a total of 14 scenarios. We also evaluated the effect of proactive adaptation for infrastructure and health in reducing economic damages.

Our analyses are based on two scenarios of potential future global greenhouse gas emissions. Our low-emissions scenario generally reflects the greenhouse gas emissions reduction policies that had been announced globally in 2020. This low-emissions scenario would result in approximately 2.5 degrees Celsius of global warming above pre-industrial levels (4.0 degrees of warming in Canada, which is warming faster than the global average) by the end of the century. Our high-emissions scenario reflects a future where 2020 rates of growth of global greenhouse gas emissions continue, causing about 4 degrees of warming globally and 7.5 degrees of warming in Canada by the end of the century (Box 2).

To understand what Canada's future climate might look like under these two global emissions scenarios, we chose an ensemble of seven different global climate models. Global climate models project future climate across the globe, and climate models from different research centres project different future climate conditions for the same emissions, all of which are plausible (Climate Data Canada n.d.). It is good practice in climate change impact assessment to use multiple climate models to capture this range of potential future plausible climates.

We obtained future projections of temperature and precipitation to 2095 for each of the seven global climate models. These projections, provided by the Canadian Centre for Climate Services, have been downscaled by the Pacific Climate Impacts Consortium to a grid of approximately ten kilometres by ten kilometres across all of Canada (PCIC 2019).

We used these high-resolution climate projections to estimate climate change impacts to infrastructure, populations, and economic activity across the country. For example, we were able to model the change in the number of freeze-thaw events for every segment of road and highway across the country, or the number of days per year that maximum daily temperatures crossed health danger thresholds for every major municipality in Canada.

A smoggy morning overlooking Hamilton, Ontario.

Nov. 17, 2021: A road in Abbotsford, British Columbia is flooded after heavy rains cause serious flooding of the Fraser Valley.

BOX 2

Projecting Canada's future climate in an uncertain world

While many countries, including Canada, have committed themselves in the Paris Agreement to limiting global temperature increases to "well below 2 degrees Celsius, while pursuing efforts to limit the temperature rise to 1.5 degrees," and to continuing to ratchet-up ambition to achieve this goal, the policies and actions set by governments around the world so far, as formalized through their nationally determined contributions as of December 2021, are estimated to result in warming of approximately 2.4 degrees (Climate Action Tracker 2021). Actual global emissions continue to trend upwards and remain on a trajectory towards warming of 4 degrees or higher.

In the analysis used for this report, the emissions scenarios reflect the above two future possibilities. Our emissions scenarios are based on the representative concentration pathway (RCP) scenarios used in the Intergovernmental Panel on Climate Change (IPCC)'s fifth Assessment Report: our low emissions scenario corresponds with RCP 4.5 and our high-emissions scenario corresponds with RCP 8.5, which result in projected warming of about 2.5 and 4.5 degrees respectively (Moss et al. 2010).

In recent months, governments have made further commitments to emissions reductions and corresponding actions that could restrict global warming to 2 degrees or less. At the time of our analysis being run, modelling that reflected the effects of such commitments (the IPCC 6th Assessment Report) was not yet available and has only been available in detailed form for Canada since December 2021. Nevertheless, the low-emissions scenario used throughout the Costs of Climate Change series reflects a highly plausible future to which Canada must be prepared to adapt, one in which countries meet but do not exceed or update their currently declared reduction targets. The high-emissions scenario serves to illustrate the dangerous consequences of continued growth in global emissions at current rates.

It remains imperative that Canada and the rest of the world do everything possible to deliver on the Paris Agreement. If this is achieved, the long-term economic impacts of climate change for Canada would be somewhat lower than our low-emissions estimates. However, our low-emissions results are still a useful guide to the types of impacts Canada will experience to the middle of the century, as changes to the climate over this period will be largely the result of emissions that have already happened, rather than emissions from this point forward.

Finally, while the IPCC scenarios also describe different global socio-economic development and demographic trajectories that would lead to the emissions associated with each representative concentration pathway, our modelling used more specific socio-economic scenarios based on projections of population and economic growth commonly used in Canada and three different assumptions about asset growth, as described below.

We developed detailed estimates of the potential costs in three categories—health, infrastructure, and Northern infrastructure—as the basis of the subsequent three reports in the Costs of Climate Change series:

- ***The Health Costs of Climate Change*** quantified the potential costs to the healthcare system and the costs of lost labour productivity from illness and premature death due to heat and declining urban air quality (Clark et al. 2021);
- ***Under Water: The costs of climate change for Canada's infrastructure*** analyzed the potential direct costs of property damage from increased flooding and infrastructure damage from rising global temperatures (Ness et al. 2021); and,
- ***Due North: Facing the costs of climate change for Northern infrastructure*** assessed the costs to governments and communities of permafrost thaw damage to roads, airports, homes, and buildings (Clark et al. 2022).

Each report contains a detailed description of our methods and results.

We conducted additional assessments to estimate the impacts of weather-related disasters on infrastructure, as well as of changing temperature and precipitation on agricultural productivity, forest timber harvest volumes, and tourist arrivals, for the sole purpose of developing inputs to the macroeconomic modelling that is the focus of this report:

- For weather-related disasters, we projected the potential future damage costs of weather-related disasters—which we defined as floods, wildfires, and storms identified as catastrophic losses reported by the Insurance Bureau of Canada—by extrapolating historic trends in the growth of disaster costs and by scaling future growth according to the severity of change projected by each climate model and emissions scenario. We allocated costs to each province and territory according to past regional distributions of disasters and removed flood costs that were already accounted for in the *Under Water* analysis to avoid double-counting.
- For agriculture, we obtained modelling estimates of the yield of spring wheat, canola, maize, and soy in Canada from Agriculture and Agri-Food Canada to project the future productivity of the agricultural sector in the macroeconomic model for each climate scenario (Jing et al. 2017; Qian et al. 2019).
- For forestry, we used estimates of the relationship between standing timber volumes and warming temperatures from Natural Resources Canada's Canadian Forest Service studies (Boucher et al. 2018) to estimate the future resource endowment of the forestry sector in the macroeconomic model for each climate scenario.

- Finally, for tourism, we applied the Hamburg Tourism model (Hamilton et al. 2005), an econometric model of the relationship between climate and international tourism flows. We used the model to estimate changes in foreign tourist arrivals to Canada based on projected future temperatures for each climate scenario, to modify tourism expenditures in the macroeconomic model.

To assess the likely net benefits of proactive adaptation, we examined the costs to adapt and the resulting benefits of certain proactive adaptation actions identified in the analyses for *The Health Costs of Climate Change*, *Under Water*, and *Due North*. There are numerous other adaptation actions that can be taken to reduce damages and costs across the 16 impact groups we analyzed, but the estimation of adaptation costs and benefits is challenging because of a lack of research and data on the effectiveness of adaptation measures. Therefore, we focussed on adaptation measures that have already been researched and that could be applied to reduce some of the largest impact groups we assessed.

Table 2 summarizes the findings of our bottom-up analyses, including adaptation scenarios.

Further detail on our bottom-up methods and results can be found in the accompanying technical report (Navius and Canadian Climate Institute 2022) and our previous reports in the Costs of Climate Change series.

Hay bales float in flood waters amidst rows of corn in Nova Scotia's Colchester County in 2014.

Table 2. Key findings from the bottom-up analysis

Impact group	Predicted costs and benefits (high emissions scenario)	Adaptation findings
Infrastructure		
Coastal and inland flooding	Coastal flood damage increases by as much as $1 billion annually and inland flood damage by as much as $13 billion per year.	Proactive coastal protection can reduce the net costs of coastal flooding by up to 90%. Large-scale inland flood adaptation benefits cannot be easily quantified.
Road damage	Additional damage to and degradation of roads costs up to $12 billion annually.	Proactive adaptation by choosing road materials suited to future climate conditions can eliminate costs or produce modest net benefits.
Road delay	Road delays for freight transport and passenger vehicles cost up to $2 billion annually.	Proactive adaptation can reduce delay costs from maintenance and repair by up to 92%.
Rail damage	Additional damage to rails costs up to $60 million annually.	Proactive adaptation with temperature sensors to isolate vulnerable track sections can reduce costs by up to 98%.
Rail delay	Delays to freight and passenger travel cost up to $4 billion annually.	Proactive adaptation with temperature sensors to target speed orders can reduce delay costs by up to 92%.
Electricity infrastructure damage	Damage to electrical infrastructure costs up to $4 billion annually.	Improving the resilience of electrical infrastructure can reduce costs by 77%.
Electricity demand	Net effect of reduced heating and increased cooling demand causes national electricity use to increase by up to 4% annually, requiring up to $5.3 billion per year in additional electricity system capital and operating expenditures.	N/A
Hydropower supply	Hydropower generation could decrease by up to 7% or increase by up to 35% annually in major hydro producing provinces.	N/A
Northern infrastructure		
Permafrost thaw	Road repair and replacement costs approach $200 million annually across the North. Damage to Northern airports in excess of $10 million annually. Building damages increase by $200 million annually.	Proactive adaptation can reduce net damage costs by up to 30% in some scenarios.

Impact group	Predicted costs and benefits (high emissions scenario)	Adaptation findings
Health		
Premature death	Up to 40,000 additional premature deaths could occur annually from elevated ground-level ozone. Up to 2,500 additional premature heat-related deaths annually.	N/A
Illness	Elevated ground-level ozone increases healthcare costs by up to $1.5 billion annually. Heat-related illness increases healthcare costs by up to $400 million annually. Increased incidence of Lyme disease increases healthcare costs by up to $270 million annually.	N/A
Labour productivity	Lost productivity caused by heat will cost up to $15 billion annually.	Installing shading technologies to cool 50% of manufacturing facilities would reduce total productivity losses by 12%.
Disasters		
Weather-related disasters	Continued increases in the frequency, magnitude and impact of weather-related disasters could increase annual damage and response costs by up to $54 billion annually.	N/A
Agriculture		
Agricultural yield	5-year average yields of key crops increase by up to 80% or decline by up to 30%, with high variability. Average yield generally increases with warming to the end of century.	N/A
Forestry		
Timber harvest volumes	Timber harvests decline by as much as 30% in major forest producing provinces.	N/A
Tourism		
Tourist arrivals	International tourism arrivals increase by up to 130%	N/A

Estimating macroeconomic impacts

We used economy-wide modelling to assess alternative macroeconomic futures under climate change, simulating changes to macroeconomic indicators such as real GDP and its key components—government spending, household consumption, exports and imports, and investment. We also assessed other macroeconomic outcomes including employment, regional and sectoral impacts, and impacts stratified by household income.

For this economy-wide analysis, we used a modified version of the Navius Research macroeconomic model, gTech, to simulate the economic impact of climate change on Canada's economy. gTech is a computable general equilibrium (CGE) model that simulates economic activity in all ten Canadian provinces, the territories, and the United States (Navius Research and Canadian Climate Institute 2022). We make some key modifications to gTech for this analysis, including extending its time scale to 2095.

We integrated the costs and benefits for the 16 impact groups into the gTech model. We carried forward bottom-up results for both emissions scenarios and all seven global climate models. For each of these 14 scenarios, we also simulated three asset growth scenarios to test the economy's sensitivity to different asset value assumptions to a changing climate. We then simulated scenarios with and without proactive adaptation across all combinations.

We thus assessed a total of 84 scenarios (two global climate emissions scenarios multiplied by seven downscaled climate scenarios, multiplied by three asset growth scenarios, multiplied by two adaptation scenarios) and compared each against a stable-climate reference case to identify the incremental impact of climate change.[2] This reference case is implicitly what typical long-term macroeconomic projections capture though simply extrapolating historical data other than population projections. As we will see below, this results in serious omissions and gaps, as the costs of climate change have material impacts on long-term macroeconomic projections.

The starting point of all scenarios, including the reference case, is the economic structure that existed in 2015 as reported by Statistics Canada. This analytical starting point assumes that economic relationships and structure in 2015 reflects the effects of climate change to that date. Starting simulations from the benchmark year of 2015, the macroeconomic model operates in 10-year increments to 2095 with the national economy growing in the reference case at an annual rate of about 1.7 per cent.[3] This starting point allowed us to capture in the scenario analysis the effects of the climate change of the recent past on the macroeconomy through the 2015-2025 results.

For the reference case, no further climate change was simulated beyond 2015. For some impact groups, notably for weather-related disasters, we netted-out current damages (to 2015) from a projection of future damages to isolate the incremental impacts of future damages above what exists today.

[2] Note that the asset growth scenarios are only used to scale the assets at risk in the with-climate-change scenarios. The asset growth assumptions don't impact the reference case in our analysis.

[3] Our macroeconomic growth assumptions are informed by Parliamentary Budget Office (2019). While we assumed a 1.7 per cent rate, the precise growth rate does not really matter. We are ultimately interested in the climate change impact relative to the reference case (that is, the climate change shock minus the reference case). Modellers developing long-term macroeconomic projections who assume alternative status quo growth rates such as 1.5 or 2 per cent can still use those growth rates and adjust them to reflect our study's findings.

In addition to modelling the economies of the provinces and the territories, the gTech model fully represents the United States (U.S.) economy, including bilateral trade. To reflect how trade with our largest trading partner and Canada's economic structure might evolve under a changing climate, we added to the model the macroeconomic impacts of climate change to the U.S economy. We adapted results from Hsiang et al. 2017, who evaluated the effects on U.S. GDP of a variety of climate change scenarios like the ones we considered for Canada. By including climate change impacts in the U.S., the analysis better reflects how price impacts from a changing climate would impact trade flows. Absent the adjustment, climate damages in Canada would be larger as trade moved in the U.S.'s favour. We did not model other global trade effects, as this would have required a separate global economic modelling exercise. However, we are confident that the most significant trade effects are captured given the primacy of Canada's trading relationship with the U.S.

The costs and benefits of the 16 impact groups were translated into the macroeconomic model as direct and indirect impacts.

DIRECT IMPACTS are mapped into the gTech model three ways:

1. **Changes to physical assets and factors of production alter productivity and output positively and negatively.** Productivity is negatively affected by climate impacts, as the costs of producing each additional unit of output increase. Climate impacts will trigger the premature retirement of productive capital or increase the operating costs of that capital as in the case of inland flooding. In either

case, the accelerated decay and higher costs reduce overall productivity. Impacted assets typically include residential and commercial buildings, and transportation and electricity infrastructure. Higher temperatures alter growing seasons and crop yields, changing the level of agricultural output.

2. **Changes in the stock of resources impairs the creation of value.** Climate change alters the quantity of resources available to support output, where a diminished endowment of resources means less production can occur and vice versa. Stock decreases from climate change include drops in available labour due to premature heat mortality and less timber for harvest.

3. **Supply and demand can increase or decrease.** Climate change may require more or less of a good or service to be demanded, as in the case of increased tourism arrivals, which are essentially an export. A net increase in electricity demand due to higher temperatures can also be expected as demand for more space cooling in summer outweighs drops in space heating in winter.

INDIRECT IMPACTS flow through the economy as direct impacts change market prices. Indirect market impacts affect supply chains as costs are passed on, alter income levels, disrupt investment patterns, and ultimately reduce demand for goods and services. Three indirect channels flow through the gTech model:

1. **Construction demand will grow alongside the need to rebuild and repair.** In the case of weather-related disasters, for example, households and businesses must use scarce resources to repair, rebuild, or more frequently maintain damaged infrastructure, which then increases demand for construction services, providing a positive boost to income and labour demand. But this spending comes at a cost to overall wealth and well-being as these forced expenditures only re-establish what was lost due to climate change. (See broken window fallacy, page 8).

2. **Supply chain costs will increase across the board.** Indirect costs manifest through supply chains, road and rail delays slow the movement of goods, and ultimately increase the costs of inputs for other business, which in turn experience a drop in productivity with higher costs.

3. **Taxes will increase to pay for damages while revenue will fall with a slowing economy.** On the government revenue side, economic growth will slow due to the damages of climate change, which lowers personal and corporate income tax receipts. On the expenditure side, there are increased demands due to rebuilding and repairing damaged infrastructure, backstopping damages for business and households through, for example, the Disaster Financial Assistance Arrangements (DFAA), and providing more healthcare services due to an increase in the prevalence of illness and hospitalizations. Governments must choose how to respond to a shrinking tax base and higher expenditures through some combination of service cuts, tax increases, or deficit spending. In our scenarios, we set gTech to endogenously increase tax rates to address fiscal gaps.

Table 3 provides an explanation of how the 16 impact groups were translated into the macroeconomic model.

Table 3. Modelling climate impacts and their translation into the macroeconomic model

Impact group	Translation into macroeconomic model
Infrastructure	
Inland and coastal flooding	Increased expenditures financed by households (consumption) and commercial sector (investment) to repair property and physical asset damage, treated as consumption of construction services.
Road damage	Increased government expenditure on construction services for roads, recovered through higher corporate and personal income taxes.
Road delay	Reduction in productivity in trucking, freight transportation, and other road transportation sectors.
Rail damage **Rail delay**	Reduction in productivity in the rail sector.
Electricity transmission & distribution	Reduction in productivity of the electricity sector.
Electricity demand	Changes in energy use intensities for heating and cooling in residential and commercial buildings.
Hydropower supply	Increased productivity of the electricity sector.
Northern infrastructure	
Permafrost thaw	Increased federal government expenditure on construction services, recovered through increased personal and corporate income taxes (damage to roads and airports). Increased expenditures by households and the commercial sector for repair of physical asset damage, treated as consumption of construction services (damage to buildings).
Health	
Premature death	Reductions in labour supply due to premature death, evenly distributed across skill levels. The difference between willingness-to-pay measures of avoided premature death risk are 10 times higher than the market-based capital approach that was necessarily adopted to remain consistent with national macroeconomic accounting.
Illness	Increased government healthcare spending funded by increases to personal and corporate income taxes.
Labour productivity	Reduction in productivity of sectors affected by extreme heat.

Impact group	Translation into macroeconomic model
Weather-related disasters	
Weather-related disasters	Increased expenditures by governments, households, and the commercial sector for repair of property and physical asset damage, treated as consumption of construction services. Government costs are recovered through increased personal and corporate income taxes.
Agriculture	
Agricultural yield	Increased (or decreased) productivity of key crops, modelled as reduced (or increased) economic input per unit of crop output.
Forestry	
Timber harvest volumes	Reduction in timber resource availability modelled as reduced shipment volumes and inventory.
Tourism	
International Tourism	Increased export demand in tourism services, including services, food, air travel, and vehicles.

Caveats

This analysis quantifies the macroeconomic impacts of key economic costs and benefits of climate change in Canada. As the most comprehensive study of its kind in Canada to date, it has required the development of new methodologies and approaches. While this analysis generates new insights, it also has limitations. As one overarching caveat, modelling is not a crystal ball exercise that accurately predicts the future. Instead, it is a tool that facilitates enhanced understanding of how climate change will affect the economy and a warning regarding the scale of potential impacts.

1. The impacts estimated are only the tip of the iceberg.

The analysis focuses on important climate risks and opportunities with material impact for Canada, but there are other material damagess, such as ecosystem damages, biodiversity loss, and mental health impacts not captured in our analysis. In addition, our analysis did not include risks that may have a major impact on Canada but that are beset by too much complexity and uncertainty to include in the model, such as geopolitical conflict or ecosystem collapse. As a result, readers should view our findings as merely the tip of the iceberg, understanding that the type and magnitude of impacts could far exceed our projections here. Much more research and data are still required to clarify the full scope of the types and scale of potential climate change impacts in Canada. This does not mean, however, that full clarity on these impacts should be seen as a prerequisite for working to mitigate them.

2. The analysis focuses on aggregate impacts.

While Section 3 explores some distributional implications, our analysis did not focus extensively on equity-deserving populations, whose social and economic vulnerabilities are exacerbated by a changing climate. Ultimately these distributional impacts could be some of the most important for governments to consider, especially when it comes to designing and implementing climate change adaptation and other social and economic policies that address systemic vulnerabilities.

3. The estimation of the benefits of adaptation is incomplete.

Adaptation measures were only modelled in a subset of the impact areas, meaning that the benefits of adaptation have only been compared across impact areas where adaptation measures were simulated. In other words, we have not quantified the benefits of adaptation across all assessed climate change impacts. More work is still required to understand the full range of adaptation benefits.

4. The analysis does not consider all interactions with the net zero transition.

This report isolates the macroeconomic impacts of physical climate change on Canada. In reality, the macroeconomic effects of climate change will be influenced by other dynamics in Canada's economy, including efforts to reduce or offset greenhouse gas emissions. While the macroeconomic modelling reference case does include the impact of currently legislated policies to reduce emissions in Canada, we do not explicitly consider interactions with other policy induced changes, such as:

a. **Deeper structural change driven in part by the net zero transition.** For instance, a more expansive electricity system in a net zero future may mean climate impacts on this sector are greater than the results of our analysis indicate.

b. **New net zero and clean growth policies.** Emissions reduction policies could interact positively or negatively with climate change damages. For instance, the potentially progressive impacts of Canada's carbon pricing approach and energy efficiency policies (specifically, their disproportionate benefit to low-income households) could help temper the regressive impacts of physical climate change on households.

Future work could explore these interactions between adaptation and mitigation more explicitly, particularly to identify policy options that simultaneously reduce emissions while increasing resilience.

5. **Uncertainty increases over time in our simulations.**

Modelling the macroeconomic effects of climate change impacts to 2095 comes with a range of uncertainties that accumulate and grow the farther out into the future we project. These uncertainties stem from assumptions that must be made in the macroeconomic model about future demographics, economic structure, growth rate of assets, and economic policies, assumptions that become harder and harder to make the further into the future we look. There are also significant uncertainties associated with global climate modelling—for instance, in projecting the type and extent of climate impacts associated with different atmospheric greenhouse gas emissions concentrations. The process of downscaling, or translating projected global climate patterns to regional and local effects, also introduces uncertainties. The choice of modelling tools, whether to model the physical impacts of a changing climate on infrastructure or an economic sector, or to conduct macroeconomic simulations, can influence results. We performed sensitivity analysis on key assumptions and relied on multiple global climate models, but uncertainty associated with long-term climate impact and economic projections remains inherent to this exercise.

Future work could explore a wider range of scenarios and could be updated over time to reflect new understanding of the science and economics of climate change as well as changes to global emissions policies and trajectories.

As a result of these limitations, the macroeconomic impacts of climate change in Canada may well manifest differently in reality than what our projections show.

June 21, 2013: Flooding in Calgary damaged major roadways, homes, and businesses when the Bow and Elbow Rivers hit record levels.

3 QUANTIFYING THE COSTS OF CLIMATE CHANGE

Climate change is projected to harm Canada's economy across multiple dimensions, slowing the generation of wealth and the level of economic activity at both the national and sector levels, straining government budgets, reducing household income and wealth, and eroding Canada's competitiveness. It is a drag on Canada's economy that will dramatically increase households' cost of living.

How big are the costs of climate change in Canada, and who will pay those costs? Our analysis highlights the scale of the damages that climate change will cause—both for the Canadian economy as a whole and for Canadian households specifically. The two concepts of *drag* and *broken windows* are key to understanding the results, as this section will detail.

By *drag* we mean that the physical impacts of climate change are having a material impact on the rate of economic growth and the ability of the economy to support the well-being of people in Canada. Drag implies that absent climate change, the economy would be growing at a faster rate, household income and consumption would be higher, investment levels would be greater, and Canada's exports would be stronger. The cumulative impact of the drag imposed by climate change is a much smaller future economy than would otherwise be the case.

Beyond the top-level macroeconomic impacts, the *broken window fallacy* in economics is instructive for understanding the costs of climate change. This parable teaches that an increase in economic activity to repair what is broken may look good from an economic perspective: money is spent, jobs are created, and output expands. But there is an opportunity cost to this spending on efforts to repair what was prematurely broken: it fails to contribute to beneficial outcomes such as productive output and wealth creation, and therefore represents a drag on growth and prosperity. Our analysis finds that Canadian households will disproportionately pay for the many broken windows that will result from a warming and increasingly volatile climate.

Slower growth coupled with higher costs, including increased taxation, has big implications for the prosperity of people in Canada. It means higher prices, fewer new jobs, lost savings, and higher costs to fix broken assets.

In other words, damage from climate change is shrinking the size of the economic pie for people in Canada and making life more unaffordable. The economy will adjust and respond to shocks over time, but Canadians' well-being and income see the largest drops of the climate impacts we assess. Low-income households and certain regions of the country will bear a disproportionate burden of those costs.

Damages are widespread and compounding

In this section, we provide a general overview of how each of the 16 impact groups influence macroeconomic effects. To understand these impacts, we ran the macroeconomic model for each impact group independently to isolate its contribution to macroeconomic change. The main results that follow this section capture the combined effects of all 16 impact groups across the total economy.

Projected improvements in agricultural productivity, foreign tourist arrivals, and increased hydroelectric generation will boost economic activity, with agricultural productivity driving the largest net gain. But this increased economic activity will be more than offset by weather-related disasters, illness and premature death, and coastal and inland flooding (Figure 3), which will drag down the economy and raise the cost of living.

More specifically:

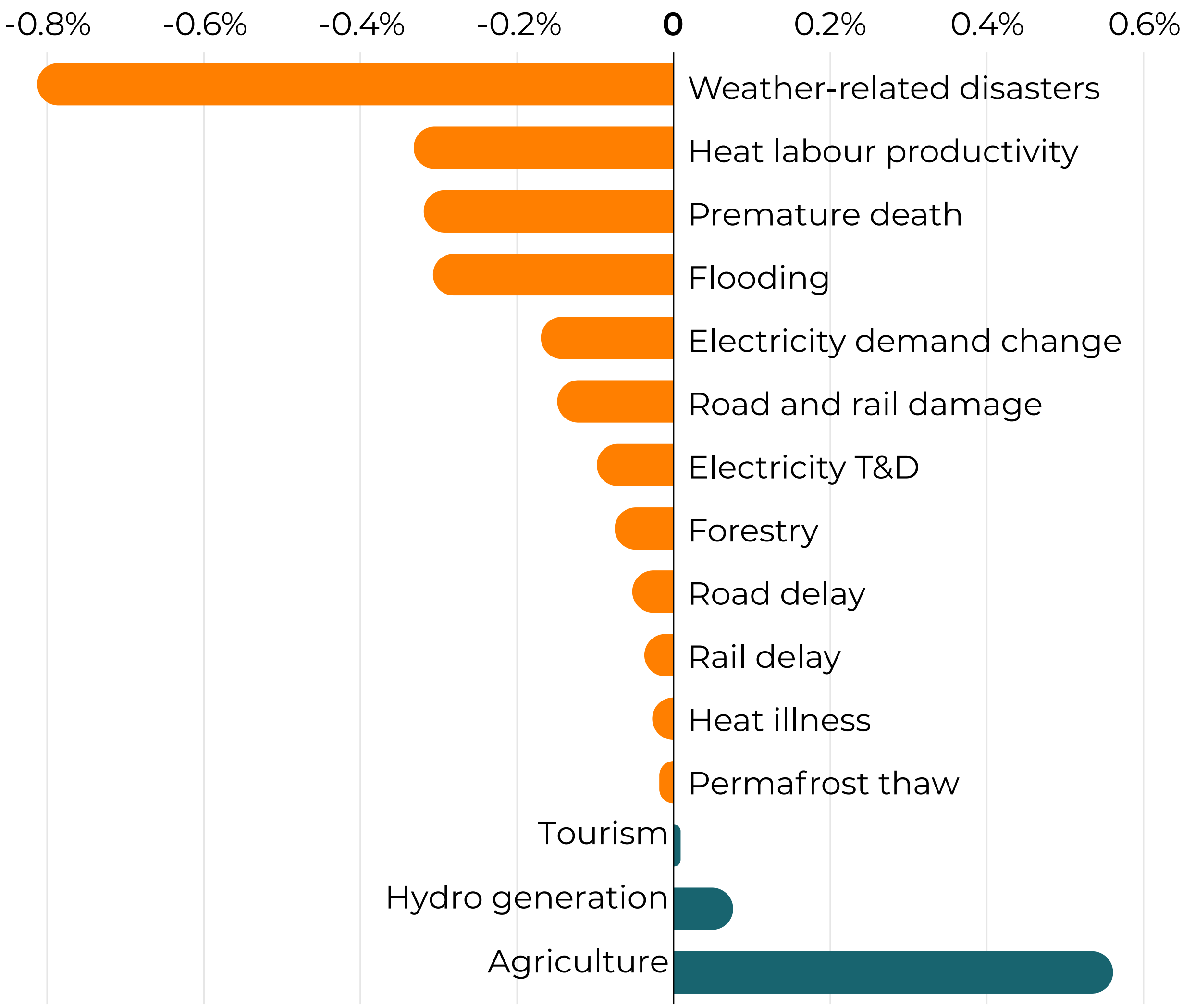
- **Weather-related disasters and flooding will continue to drive large damages.** Of all the climate impacts we assessed, weather-related disasters and coastal and inland flooding are the most front-of-mind for people in Canada. These impacts erode household wealth, take scarce government resources away from other social services, and reduce income benefits across many economic sectors. Disaster

April 27, 2019: Severe flooding on the Muskoka River running through Huntsville, Ontario.

Damage from climate change is shrinking the size of the economic pie and making life more unaffordable.

Figure 3: Compared to the stable-climate reference case, by the middle of the century, most impact groups will see a **loss in real GDP.**

Per cent change in GDP relative to a stable-climate reference case in a moderate low-emissions scenario



Note: This chart is based on one of the 42 no-proactive-adaption scenarios we simulated. It also represents a low-end estimate of the GDP changes as it was based on a moderate climate impact scenario. Still, the scenario provides a good illustration of the relative GDP changes across impact groups.

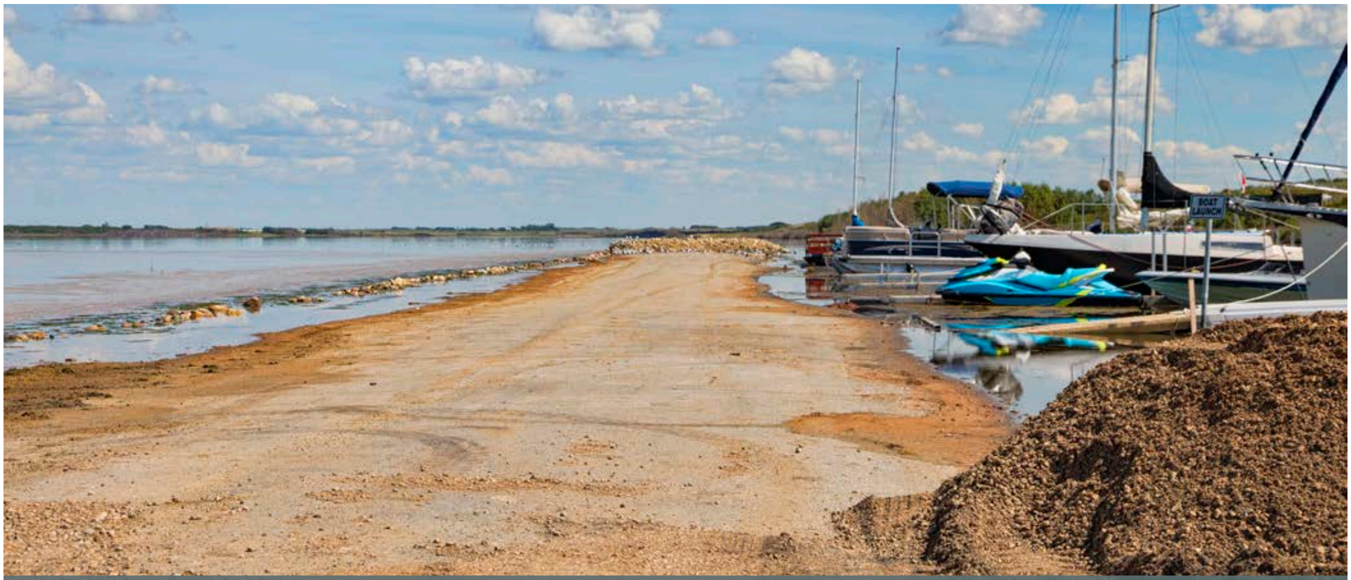
damages also erode natural capital and personal well-being (for instance, by increasing burdens on mental health), the assessment of which were beyond the scope of this study. These damages represent a major and growing drag on Canada's economy.

- **Impacts on labour productivity and premature deaths are a hidden yet significant source of economic drag.** Lost productivity reduces the competitiveness of the economy, reduces household income, and impairs our ability to earn and generate wealth. We find that extreme heat in climate-sensitive sectors will significantly reduce labour productivity. The increase in premature death will be significant enough to impact labour supply, a stark indication of the breadth of the impacts of climate change on human health.

- **Infrastructure damages are widely distributed across the economy and will cause large direct and indirect changes.** Infrastructure damages stem from an array of climate hazards such as permafrost thaw in the North, increased heat, changing rainfall patterns, and changing freeze-thaw cycles. These stressors cause direct infrastructure damage, but also create indirect losses—for instance, unprecedented floods in British Columbia washed out land access to the city of Vancouver for weeks, causing an estimated billion dollars in economic losses.

- **Natural resource sectors like agriculture and forestry will see significant impacts, in different directions.** The forestry sector will experience reductions in timber harvest, while agricultural productivity for key crops is expected to rise in most scenarios, but not all.

- **Climate change will also benefit international tourism.** Changes in seasonal temperatures will draw in more visitors from other countries, increasing domestic economic activity, but the benefits look small.



Manitou Beach, Saskatchewan, 2016: Due to flooding from the rising waters of Little Manitou Lake, the road was washed out and is now impassable.

Drag: The macroeconomic impacts of climate change

This section focuses on the drag that climate change represents on the Canadian economy, highlighting national, regional, and sectoral macroeconomic changes. We explore effects on national income (real GDP), trade, employment, regions, and sectors. The next section, Broken Windows, explores affordability issues focusing on the broken-window implications of climate change, including how government budgets, household income, and business investment can be expected to change as climate damages accumulate.

The macroeconomic impacts presented in this section, though calculated from a fine level of geographic resolution, are presented here as general trends at the national and provincial levels, and over long timescales. The magnitude and direction of some economic impacts may differ across regions and on shorter timescales. Furthermore, we acknowledge that the metrics we show in this report can each provide useful insights into economic well-being, but also have their limitations. We tackle the limitations of GDP in Box 3.

Climate damages are a drag on national income

Assessing the overall impacts of climate change over the coming decades, we find that damages are already showing up as large losses in national income today, as measured by real GDP. These losses are compounding fast, resulting in significant losses in national income over the medium and long term. Losses in national income in the low-emissions scenario after mid-century are less than half those of the high-emissions scenario, however, suggesting that a slowing of global emissions can avoid large costs.

Climate change is already costing Canadians billions of dollars. With simulations starting in 2015, we can assess the impact of near-term damages on the size of today's economy. In the simulations, climate impacts by 2025 result in a lower level of real GDP (in 2020 Canadian dollars)[4] by up to $25 billion relative to the stable-climate reference case, which equals up to $620 per person of lost national income (Table 4). To put this loss into context, the real GDP loss from climate change in 2025 is equal to half of the annual growth in national GDP in 2025. This shrinking in real GDP is equivalent to more than twice the cost of the November 2021 floods that ravaged British Columbia and 12 times larger than all insured losses from weather-related disasters in Canada in 2021, including the British Columbia November floods (IBC 2022).

Climate damages accumulate to lower the size of the economy and its rate of growth. To the end of the century, the median annual GDP growth rate under low-emissions slows 0.061 per cent, and 0.14 per cent under high-emissions (Table 4).[5] These annual drops in GDP growth might not seem a big deal, but they accumulate, reflecting a significant drop in investment, household income and consumption, trade, and employment.

The level of real GDP in 2025 is about 1 per cent smaller than the reference case, 2 to 2.6 per cent by mid-century under low- and high-emissions respectively, and 5 (low) to 12 (high) per cent smaller by the end of the century (Table 4). National income

[4] Measured as expenditure-based real GDP in 2020 Canadian dollars.
[5] All dollar values are reported as real 2020 Canadian dollars. Note that GDP per capita is not a measure of the impact on household income. We look at household income changes in Section 3.3.1 below.

BOX 3

Limits to ‘gross’: Why GDP is an imperfect measure of national wealth

Gross domestic product (GDP), the most commonly used indicator for tracking economic progress around the world, measures the total income that is generated from goods and services produced by an economy over a certain time period. While GDP can be a useful measure of economic performance, it has its limitations, particularly when seeking to understand the full extent of the macroeconomic impacts of climate change.

As a metric that captures flows rather than stocks, GDP fails to capture changes in natural capital, such as the depletion of fish, forest, and mineral stocks, and less tangible assets such as Indigenous cultural traditions. It also fails to fully capture impacts on people’s standard of living, cost of living, health, life expectancy, extremes of inequality, and many other deeply important indicators of progress. Lastly, as the broken window fallacy illustrates, an increase in economic activity to repair a broken window looks good for the economy, as money is spent on labour and a new window, but is a net loss since that money can’t be spent on new, productive goods and services that create new value.

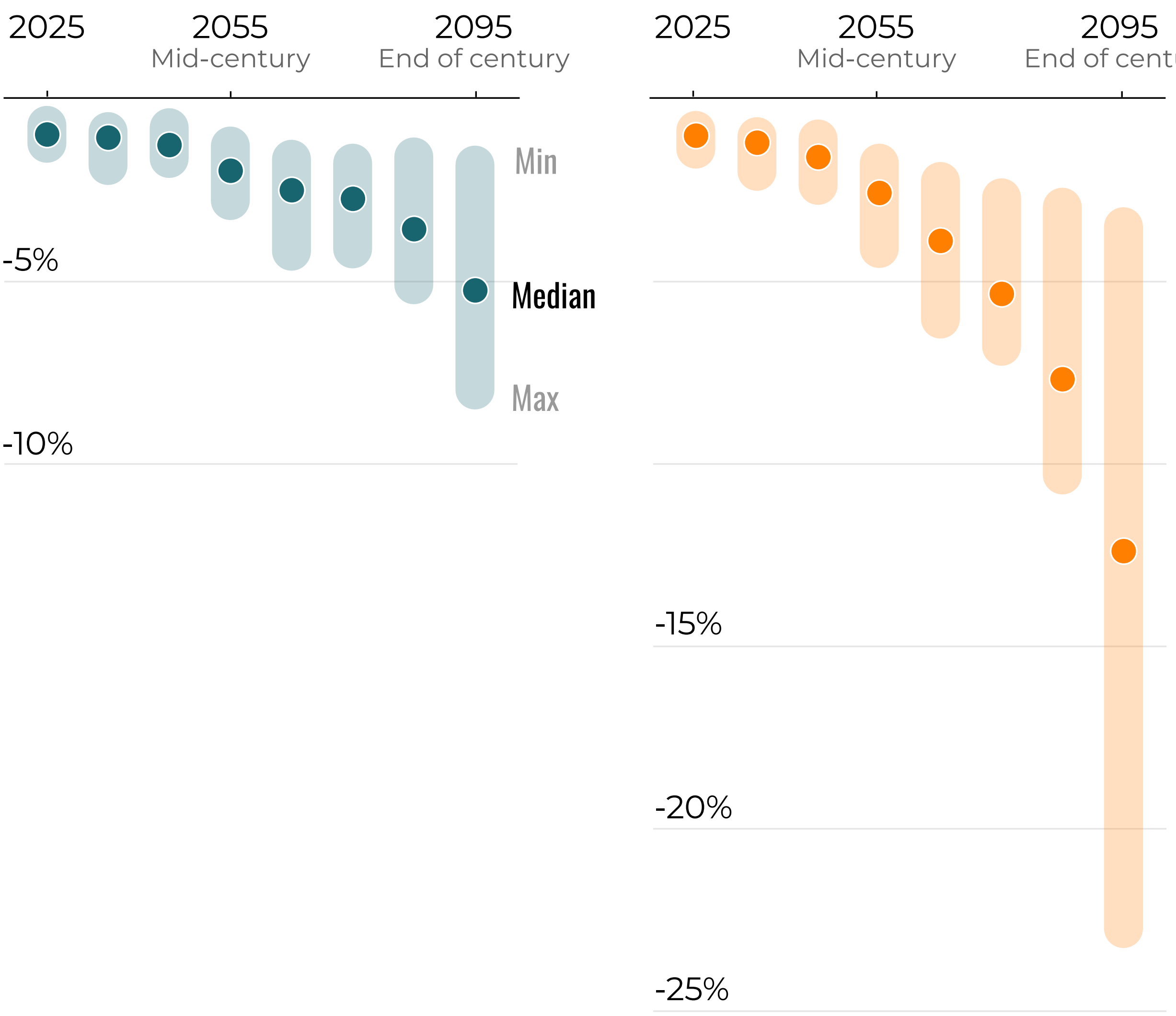
We still use GDP as one metric among several to communicate the findings of our analysis, as it does provide insights into the level of economic activity and remains a common metric understood and applied by economic decision makers. However, readers should understand that no single metric provides a complete picture of the well-being of the economy or individuals in it and should strive to recognize both the strengths and limitations of different metrics. Governments should consider applying additional metrics beyond GDP, such as household welfare, employment, and income inequality when assessing the economic impacts of climate change.

losses, or the level of real GDP, average about $25 billion in 2025, then rise to $78 (low) and $101 billion (high) by mid-century and to between $391 (low) and $865 billion (high) by the end of the century. Accounting for population growth, per capita national income losses by 2025 under both scenarios is $600.[6] By mid-century, per capita losses more than double under low-emissions and triple under high-emissions, but there is significant variation across the scenarios (Figure 4).

Reducing global emissions cuts climate impact costs in half. As climate impacts intensify in the high-emissions scenario, national income losses increase exponentially to average over $11,000 per capita. These losses are then halved in

Figure 4: Large GDP losses are already happening and will continue to grow in both low-emissions and high-emissions scenarios.

Per cent change in real GDP relative to a stable-climate reference case



[6] A median population forecast was developed from all eight Statistics Canada population projections to 2065 (Statistics Canada 2019). The annual growth for the last decade in the series was used to project 2065 to 2095.

Table 4. Real GDP will fall relative to a stable-climate reference case

	Emissions scenario	2025	Mid-century	End of century
Incremental loss in real GDP due to climate change				
What is the size of the loss? Dollar value (2020 $B)	**High**	-$24.6	-$101.2	-$865.0
	Low	-$23.9	-$77.9	-$391.0
How fast is the loss growing? Year-over-year change	**High**	-3.7%	-6.6%	-6.2%
	Low	-2.5%	-6.2%	-5.5%
What is the per capita loss? Per capita GDP loss	**High**	-$620	-$1,940	-$11,050
	Low	-$600	-$1,490	-$5,000
Change in size of real GDP				
How fast is real GDP growing? Year-over-year change	**Reference**	2.11%	1.65%	1.68%
	High	2.01%	1.56%	1.24%
	Low	2.01%	1.58%	1.51%
What is the loss? Loss in size of GDP relative to reference	**Reference**	100%	100%	100%
	High	-1.0%	-2.6%	-12.4%
	Low	-1.0%	-2.0%	-5.2%

the low-emissions scenario, indicating that global efforts to reduce emissions are in Canada's best interest.

National income losses add up to years of lost growth. We estimate the net present value of the stream of national income loss over the simulation period of 75 years. Monte Carlo analysis is used to account for uncertainty in the discount rate and across the 42 emissions and climate scenarios.[7]

We conducted a total of 5,000 simulations to estimate the probable range of the net present value.

In the high-emissions scenario, the present value of lost real GDP to the end of the century is about $8 trillion, equivalent to losing four years of 2025 GDP. The low-emissions scenario avoids GDP losses of about $3 trillion, mainly by moderating the severity of climate impacts after 2050.

The results also imply the risk of a higher-cost outcome is more probable than a lower-cost outcome since more of the possible cost outcomes sit above the average than below.

[7] Monte Carlo simulations are used to predict the probability of different outcomes given the existence of random variables—in this case, different discount rates. Monte Carlo simulations (n = 5,000) were run using real discount rates of 0.5, 1, and 2 per cent over the 75-year simulation period. The assumed real discount rates are 0.5, 1, and 2 per cent.

Climate damages are a drag on trade

Exports and imports are important components of GDP. The ability to compete in domestic and international markets is essential to a thriving economy, with a vibrant export sector creating value to support government services, consumption, and investment. Similarly, imports are needed to drive domestic production and to create value while supporting consumption and investment. As the climate warms, both imports and exports fall significantly relative to the reference case due to a loss in productivity as well as a contraction in domestic and foreign economies, constraining Canada's ability to compete.

Export losses will grow over time as costs rise and competitiveness is reduced. In the simulations, the level of exports is down $14 billion by 2025, or 1.2 per cent lower than the reference case (Table 5). Losses compound in both emissions scenarios to

Figure 5: Canadian exports will shrink over time in both low-emissions and high-emissions scenarios.

Per cent change in exports relative to a stable-climate reference case

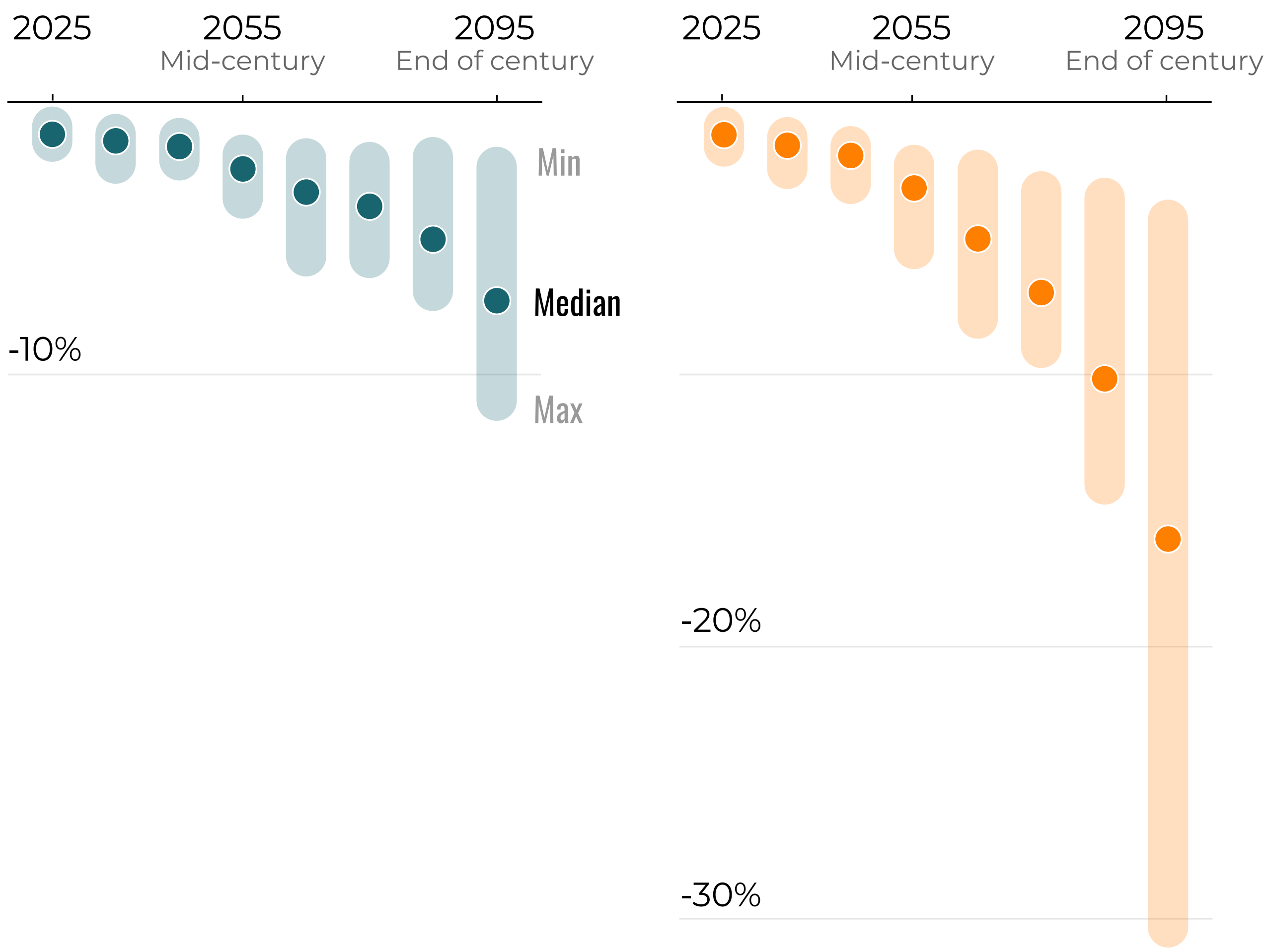


Table 5. Exports will fall relative to a stable-climate reference case

	Emissions scenario	2025	Mid-century	End of century
Incremental loss in exports due to climate change				
What is the size of the loss? Dollar value (2020 $B)	**High**	-$13.8	-$63.2	-$601.5
	Low	-$13.5	-$49.4	-$295.3
How fast is the loss growing? Year-over-year change	**High**	-5.4%	-6.8%	-6.1%
	Low	-4.2%	-6.1%	-5.5%
What is the per capita loss? Per capita export loss	**High**	-$350	-$1,210	-$7,680
	Low	-$340	-$950	-$3,770
Change in size of total exports				
How fast are exports growing? Year-over-year change	**Reference**	2.22%	1.97%	1.85%
	High	2.10%	1.86%	1.32%
	Low	2.10%	1.89%	1.63%
What is the loss? Loss in size of exports relative to reference	**Reference**	100%	100%	100%
	High	-1.2%	-3.1%	-16.0%
	Low	-1.2%	-2.4%	-7.3%

mid-century due to slowed export growth that slightly outpaces the drop in GDP growth. By the end of the century, export losses in the low-emissions scenario are $300 billion or seven per cent below reference, and $600 billion under high emissions, which is a 16 per cent drop in the level of exports below reference. In the high-emissions scenario, by the end of the century, losses in exports are significantly lower than the reference case, with Figure 5 highlighting the variability across scenarios. Note that climate impacts are affecting aggregate U.S. demand in the simulations, which has the effect of lowering Canadian exports and output.

Imports will slow as Canadian output falls, reflecting a deepening economic weakness due to climate change. The incremental fall in the level of imports is $17 billion by 2025, or 1.5 per cent of the reference case (Table 6). The growth in imports continues to slow at about the same rate as GDP to mid-century and beyond. By the end of the century, the impact of slowed import growth results in a reduction in the level of imports below the reference case by six per cent to 13 per cent, depending on the scenario (Figure 6). The decline in imports reflects a growing weakness in the economy as climate damages accumulate.

Figure 6: Canadian imports will slow over time in both low-emissions and high-emissions scenarios.

Per cent change in imports relative to a stable-climate reference case

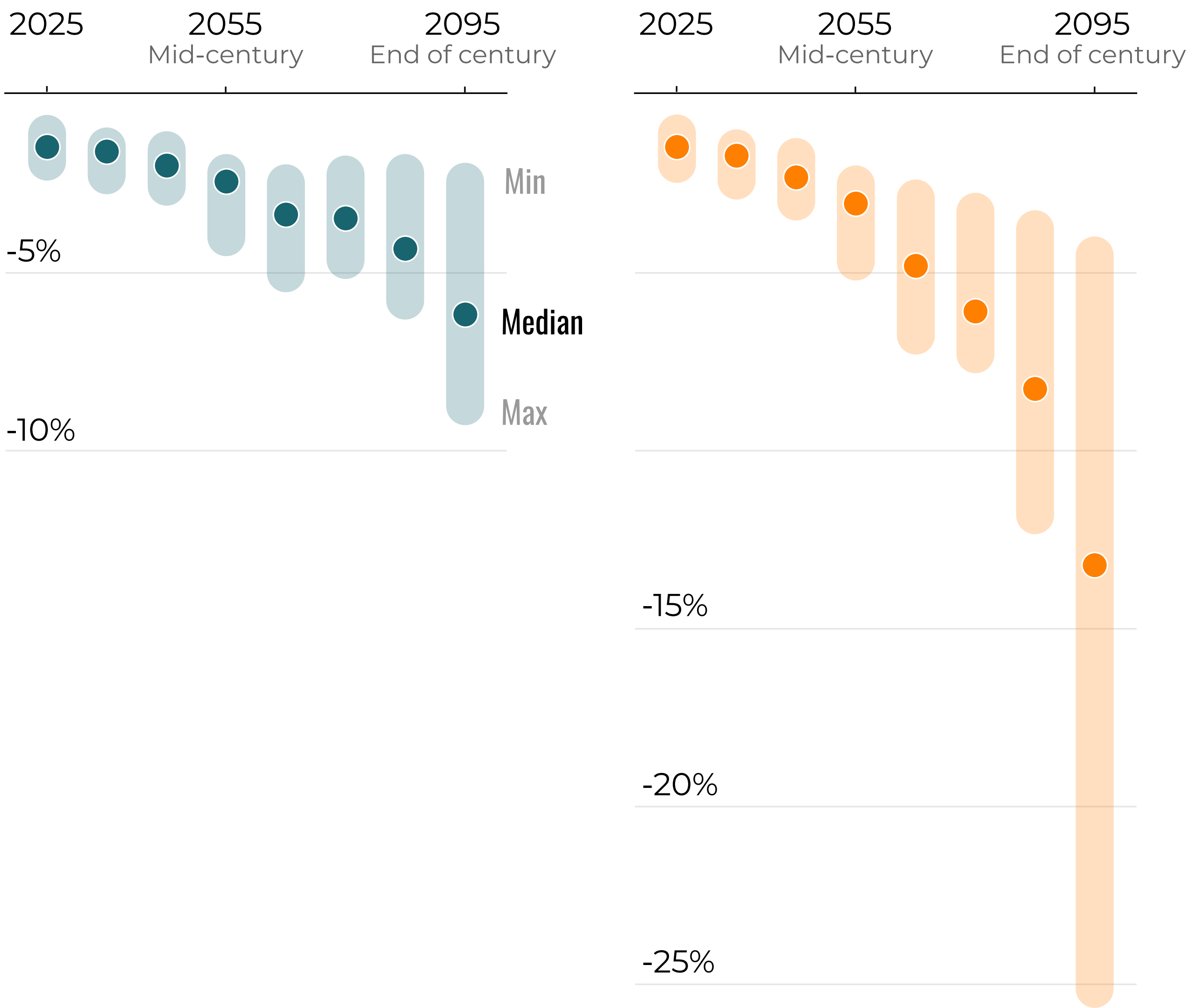


Table 6. Imports will fall relative to a stable-climate reference case

	Emissions scenario	2025	Mid-century	End of century
Incremental loss in imports due to climate change				
What is the size of the loss? Dollar value (2020 $B)	**High**	-$16.8	-$55.7	-$447.1
	Low	-$16.8	-$44.8	-$222.5
How fast is the loss growing? Year-over-year change	**High**	-3.1%	-4.6%	-6.2%
	Low	-2.3%	-3.9%	-5.3%
What is the per capita loss? Per capita import loss	**High**	-$420	-$1,070	-$5,710
	Low	-$420	-$860	-$2,840
Change in size of total imports				
How fast are imports growing? Year-over-year change	**Reference**	1.82%	1.85%	1.80%
	High	1.67%	1.77%	1.35%
	Low	1.67%	1.80%	1.62%
What is the loss? Loss in size of imports relative to reference	**Reference**	100%	100%	100%
	High	-1.5%	-3.0%	-13.2%
	Low	-1.5%	-2.4%	-6.2%

Climate damages kill jobs

The ability of an economy to generate and sustain jobs is central to securing an affordable future for people in Canada. With so many climate damages affecting labour, including heat-induced productivity losses and premature deaths shrinking the workforce, it is no surprise we see large employment reductions across all the simulations. These labour costs then ripple through the economy, reducing productivity and raising prices.

Expect significant job losses across all scenarios. In the high-emissions scenario by mid-century, job losses more than double 2025 levels, representing 500,000 lost jobs, which is about 1.5 per cent of all projected employment (Figure 7 and Table 7). By the end of the century, 2.87 million job losses are projected. In our simulations, these employment effects increase the unemployment rate to as high as 15 per cent, although it is likely that the unemployed would become discouraged and leave the labour force, which would likely curb this rise in the unemployment rate through a reduced labour participation rate. In addition to

Figure 7: Climate change will cause major job losses in both the **low-emissions** and **high-emissions** scenarios.

Change in employment relative to a stable-climate reference case (millions of jobs)

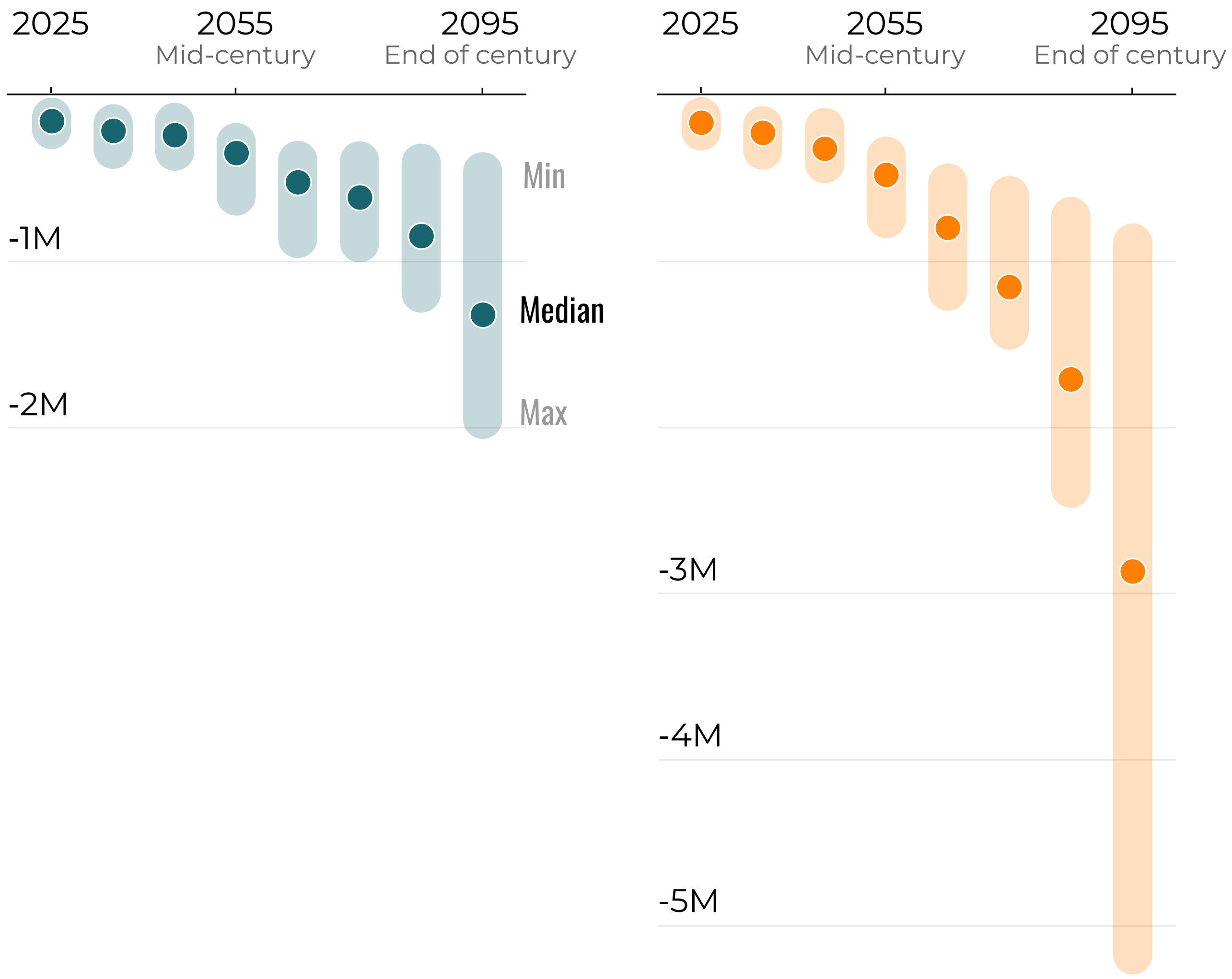


Table 7. Employment will fall relative to a stable-climate reference case

	Emissions scenario	2025	Mid-century	End of century
Incremental loss of jobs due to climate change				
What is the size of the loss? ‘000s jobs	High	-194	-478	-2,867
	Low	- 183	- 345	-1,320
How fast is the loss growing? Year-over-year change	High	-3.5%	-4.1%	-5.3%
	Low	-3.7%	-3.7%	-4.5%
Change in number of total jobs				
How fast are jobs growing? Year-over-year change	Reference	0.57%	0.65%	0.69%
	High	0.49%	0.59%	0.31%
	Low	0.49%	0.61%	0.54%
What is the loss? Change in employment level relative to reference	Reference	100%	100%	100%
	High	-1.0%	-2.7%	-9.6%
	Low	-0.9%	-1.8%	-4.4%

direct economic effects, this scale of job loss will create social costs related to mental health and other challenges.

Reducing global emissions will save jobs. Relative to the high-emissions scenario, lower global emissions avoid about 120,000 job losses by mid-century and halves the losses by the end of the century. Still, job losses in the low-emissions scenario add up to 345,000 by mid-century and 1.3 million by the end of the century.

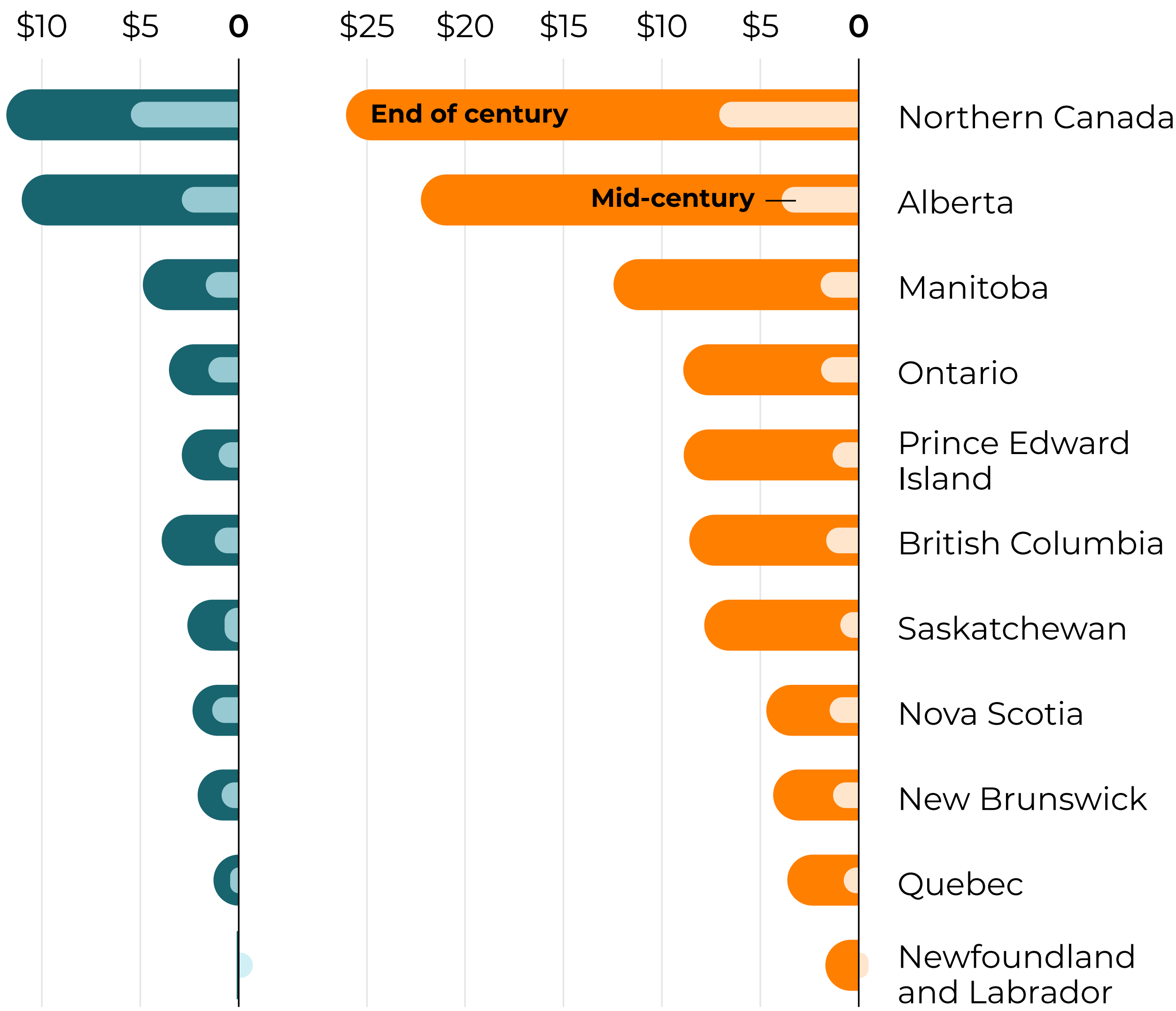
Climate damages drag down some regions more than others

By the end of the century, all Canadian regions are projected to be worse off economically than they would otherwise be due to worsening climate damages. The extent of these losses, however, varies across regions and time scales, with the North and Alberta being disproportionately impacted due to permafrost thaw in the North and a higher prevalence of weather-related disasters in Alberta.

The North will be hit particularly hard. Northern Canada is projected to experience the greatest proportional losses in GDP, with median GDP losses of $5,490 or $7,080 per capita by mid-century in low- or high-emissions scenarios respectively (Figure 8). By the end of the century, these losses are expected to increase to $11,820 and $26,060 per capita per year. GDP losses in the North are driven by changes in electricity demand, damage to buildings caused by permafrost thaw, and damage to infrastructure caused by weath-

Figure 8: No region is immune from the impacts of climate change, as losses take hold across the country, both in the **low-emissions** and **high-emissions** scenarios.

Median per capita GDP loss across ensemble of 24 scenarios (thousand $)



er-related disasters. These findings underscore the disproportionate impacts of climate change on Canada's North, as detailed in the Institute's report *Due North: Facing the costs of climate change for Northern infrastructure*.

Impacts are unevenly distributed across southern regions. Alberta is projected to experience particularly significant losses, resulting primarily from the impacts of weather-related disasters. Median GDP losses in Alberta are $2,890 or $3,920 per capita by 2055, in low- and high-emissions scenarios respectively. In some provinces, such as Saskatchewan and Prince Edward Island, net losses are tempered by some benefits resulting from improvements in agricultural productivity, although some of the scenarios show net losses in agriculture. Newfoundland and Labrador see muted losses and some gains, primarily due to improved hydroelectric supply, but these averages mask widespread damages in the other impact groups.

Climate damages drag down most sectors

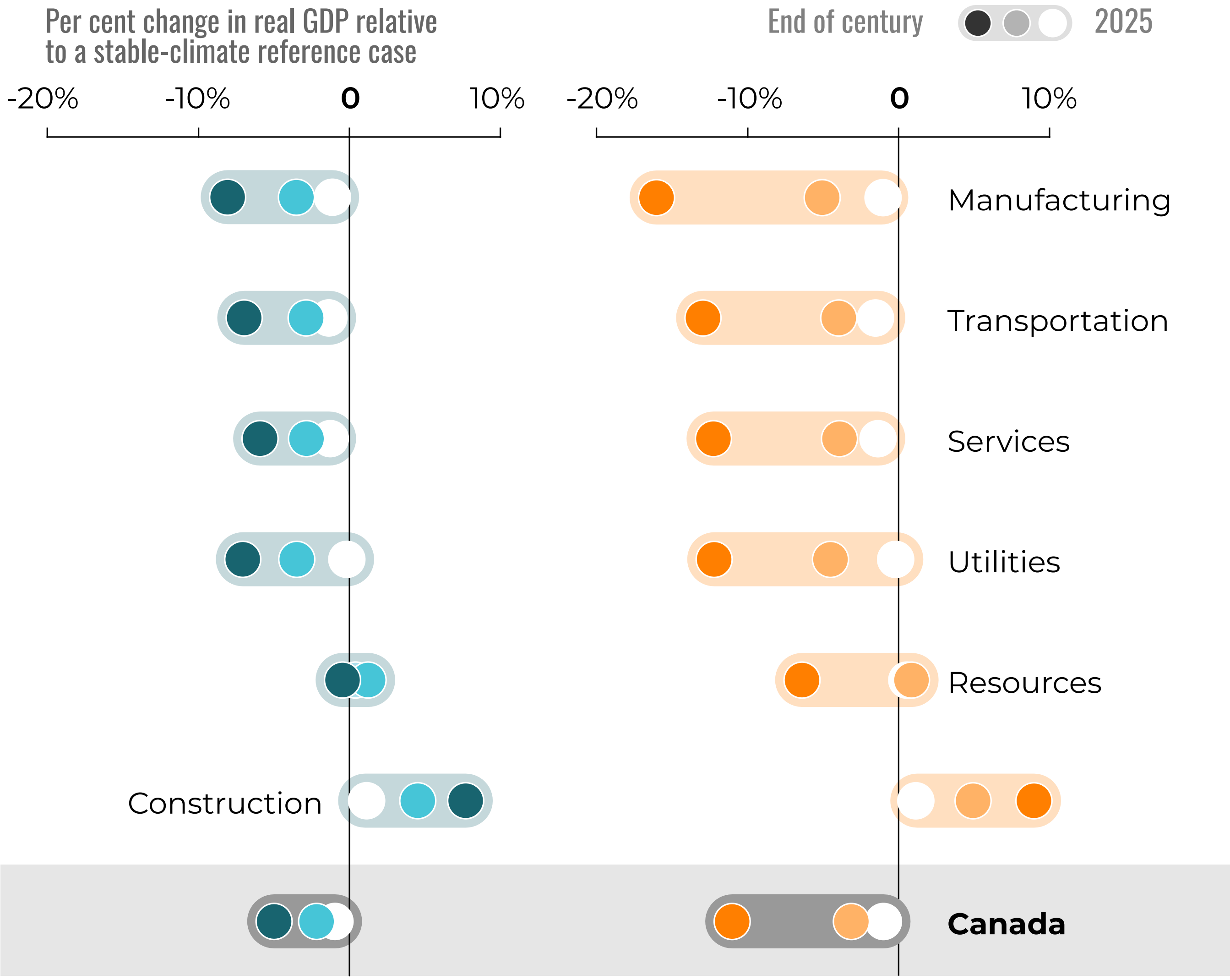
For most economic sectors, losses are experienced across all global emission and climate scenarios, as direct impacts raise costs, indirect supply chain costs impair productivity, and market effects reduce demand. There are very few economic sectors that are net winners under a changing climate, notably construction and agriculture, which comprise just 8.5 per cent of Canada's economy and whose gains are swamped by the GDP losses experienced by all other sectors.

The need to rebuild and repair will boost construction. Rebuilding damaged infrastructure boosts construction and allied industries such as cement and lime across all scenarios. The construction industry consistently increases its share of the total economy, albeit of a smaller total economy. In 2025, this sector looks to be in the order of 1.2 per cent larger than in the reference case and growing into the future through the simulations (Figure 9). However, the gains seen in the construction sector are not a good news story, instead highlighting the broken window fallacy: the growth in construction comes from repairing damaged infrastructure and carries significant income and wealth impacts to those who must pay for the repair and replacement. As the simulations suggest, there is an overall net cost to the economy.

Agriculture is a likely beneficiary of a warming climate. The resource sector benefits slightly in the short term, while across all scenarios agriculture expands relative to the reference case due to productivity increases from longer growing seasons. But as climate impacts intensify in the longer term, any gains from agriculture are wiped out as other resource sectors contract, including the forest products sector, which is particularly climate sensitive.

Manufacturing declines are widespread. Manufacturing will experience some of the largest declines as employment and labour supply impacts, including work stoppages from extreme heat, worsen, and as rising supply chain costs get passed on, for example, through increased shipping costs from road and rail delays. In 2025, the simulations suggest that climate change is already reducing the size of the sector by one per cent relative to the reference case. The sector continues to grow more slowly to mid-century under both scenarios, but in the high-emissions scenario the sector is ultimately down about 16 per cent compared to the reference case by the end of the century.

Figure 9: Most sectors of the economy are negatively impacted by climate change both in the low-emissions and high-emissions scenarios.



The service sector is vulnerable to direct and indirect impacts. The service sector is at the end of supply chains and is labour-intensive, and therefore can expect to be hit hard as costs get passed on through rising prices. Add flood and storm damages to commercial buildings and a slowing total economy, and the costs compound. In 2025, the sector is already 1.4 per cent smaller relative to the stable-climate reference case, and the damage only gets worse over time.

Transportation is highly climate-sensitive, raising the costs of moving goods and people. Transportation, comprising both road and rail transport, is the most climate-sensitive economic sector to mid-century. Specific drags on economic growth in the transportation sector include delays that raise costs and reduce demand, as well as premature failure of assets which must be replaced. Demand for transportation services also falls as the economy contracts, hitting this sector particularly hard. By 2025, the sector is 1.4 to 1.5 per cent lower in size relative to the reference case, indicating that even in the short-term the sector is highly sensitive to climate damages.

Electric utilities see short-term gain but long-term pain. Utilities fare relatively well in the short-term, but over the longer-term face a bigger contraction. Within the utilities sector, electricity transmission and distribution show a fairly high level of climate sensitivity, whereas generation is less impacted, particularly since more precipitation could support more hydro generation. A general contraction in the economy also drives a lower demand for energy services in the long run.

Broken windows: The affordability impacts of climate change

Our topline findings on the macroeconomic consequences of climate change—the drag it represents for overall growth—mask deeper affordability issues that will significantly raise the cost of living for households in Canada. Businesses are also picking up the tab to fix more and more broken windows as climate damages intensify. In fact, the largest impacts we saw were in areas associated with affordability—rising taxes as governments are forced to backstop climate disaster damages and devote a greater share of budgets to climate impacts, rising costs of basic goods due to supply chain disruptions, and falling business investment as spending on climate damages eclipses other priorities.

Climate damages hit households hardest

The consequences of climate change are not only impacting Canada's industries and infrastructure; they are also hurting people. Households are worse off across all scenarios we modelled. In the simulations, household income will be negatively impacted as labour income vanishes due to heat impacts and other illness, prices rise as costs mount in supply chains, and increased taxation is needed to pay for damages and maintain services.

Real income from employment, government transfers, and other sources is an important measure of economic well-being. We use real income measured in 2020 Canadian dollars as

May 21, 2022: Hydro crews work to restore power after rare derecho struck the city of Ottawa.

the indicator for household impact in this section.[8] Beyond the quantifiable costs to households reflected here through reduced household income, people will experience additional negative impacts that are not easily monetized, including significant mental health impacts, and the negative societal impacts of economic hardship. The fact that these below-the-waterline damages are not monetized and therefore cannot be included in the model is by no means an indication that they are not severe or worthy of significant government attention.

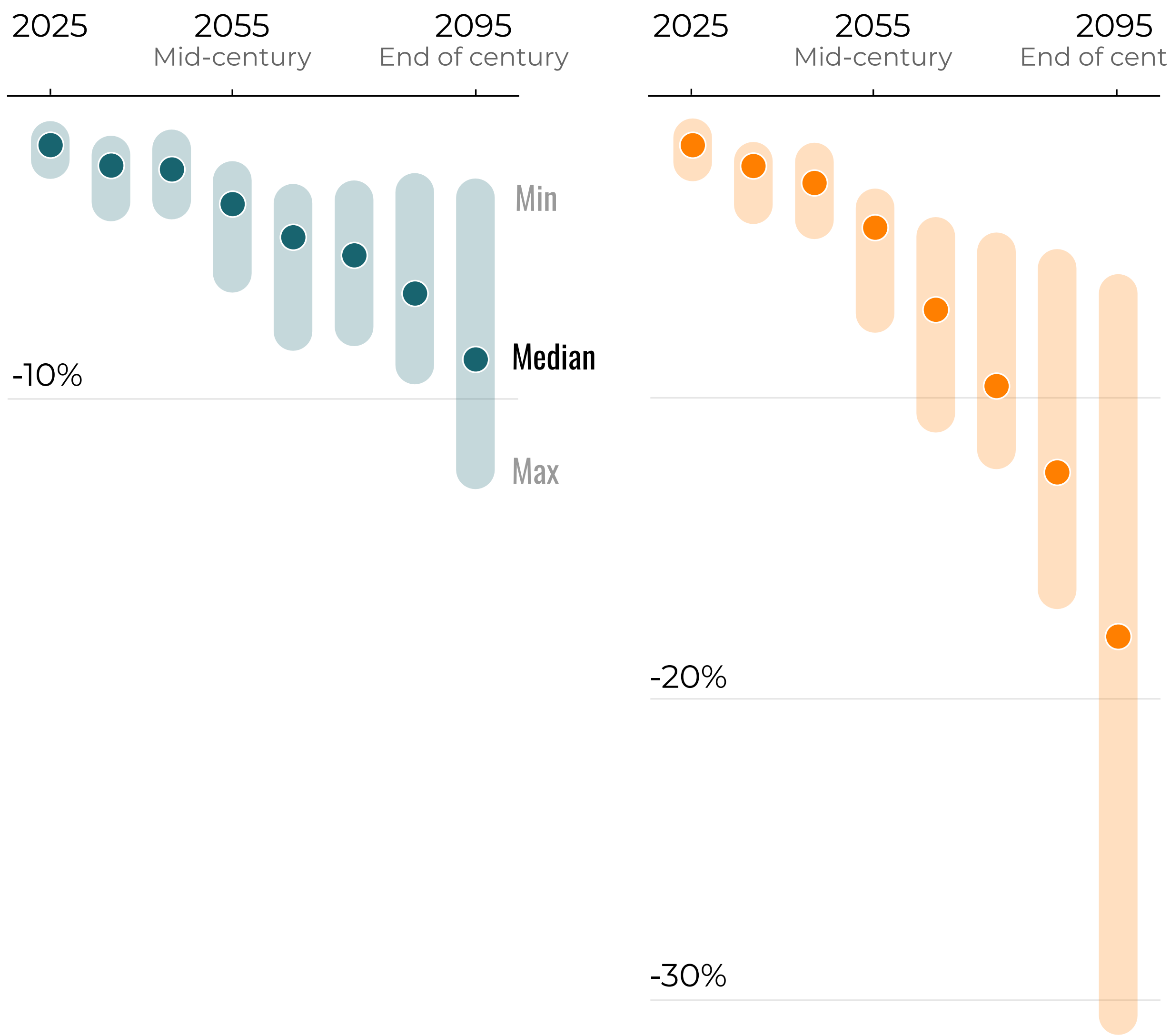
The loss of household income is large relative to other economic impacts. The growth in annual real income immediately slows in the simulations, outpacing the drop in GDP growth in the very near future. The impact of reduced income growth by 2025 is a drop in income per capita of $720 in both emissions scenarios. By mid-century in the low-emissions scenario, income losses are $1,890 per capita, which represents a 3.5 per cent drop in the level of income relative to the reference case. In the high-emissions scenario, per capita income losses are almost $2,300, representing a 4.5 per cent drop relative to the reference (Table 8 and Figure 10).

After mid-century, real income losses are a big threat to affordability. After mid-century when the high-emissions scenario inflicts greater damages, income losses on a per capita basis rise to $10,600 by 2095, with the low-emissions scenario about halving the level to $5,600 per capita. Across all high-emission scenarios by 2095, income levels are down 18 per cent below the reference case and in the worst-case scenario, 31 per cent lower (Figure 10).

[8] Changes in consumption or welfare would also provide similar insight on the household affordability impact.

Figure 10: Canadian households will pay a high price for climate damages in both the low-emissions and high-emissions scenarios.

Per cent change in per capita income relative to a stable-climate reference case



Low-income households will see the largest reductions in real household income. While high-income households lose more income in absolute terms, the share of real income lost by low-income households is higher. By mid-century, the lowest-income households are projected to face income losses, relative to the refence case, of 5.8 per cent under high-emissions and 4.8 per cent under the low-emissions scenario (Figure 11). This compares to losses of 4 per cent and 3.2 per cent for the highest-income households in the same period.

By the end of the century, the impacts on real household income cut deep into affordability. Low-income households face real income cuts on average of 23 per cent in the high-emissions scenario, and 12 per cent under low-emissions. Even the median group faces significant

Table 8. Household income will fall relative to a stable-climate reference case

	Emissions scenario	2025	Mid-century	End of century
Incremental loss of income due to climate change				
What is the size of the loss? Dollar value (2020 $B)	**High**	-$28.6	-$120.4	-$829.0
	Low	-$28.0	-$98.7	-$435.9
How fast is the loss growing? Year-over-year change	**High**	-5.8%	-5.7%	-4.8%
	Low	-5.8%	-5.5%	-4.4%
What is the per capita loss? Per capita income loss	**High**	-$720	-$2,300	-$10,590
	Low	-$700	-$1,890	-$5,570
Change in the total size in real income				
How fast is income growing? Year-over-year change	**Reference**	2.17%	1.51%	1.59%
	High	2.01%	1.36%	1.11%
	Low	2.01%	1.39%	1.38%
What is the change in the level of income? Income level relative to reference	**Reference**	-100%	-100%	-100%
	High	-1.6%	-4.3%	-17.9%
	Low	-1.6%	-3.5%	-8.7%

income losses of 9 to 19 per cent under low- and high-emissions scenarios, respectively.[9]

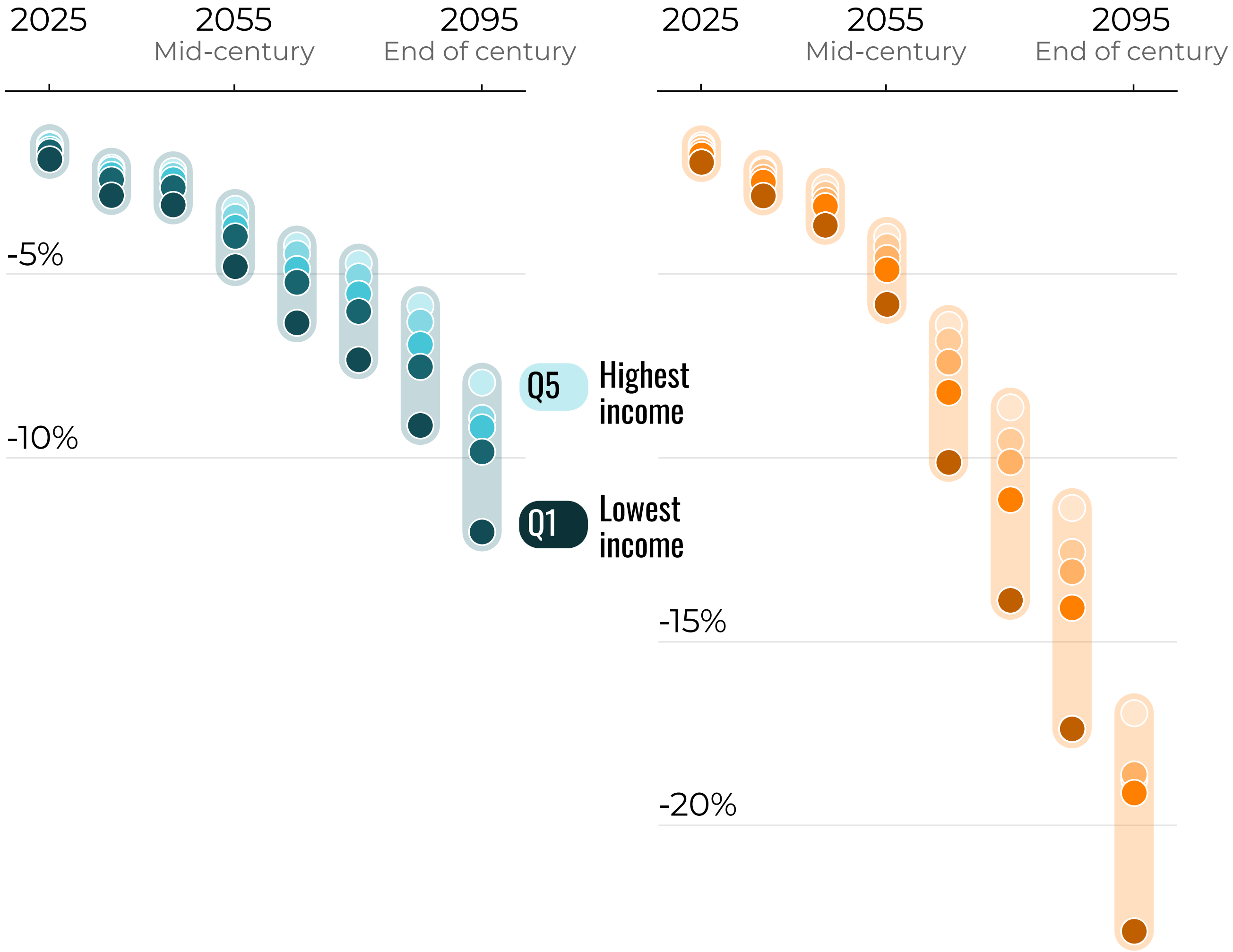
The disproportionate losses for low-income households are driven by lower baseline levels of income, resulting in the same dollar amount of lost income comprising a higher share of total income lost compared to high-income households. As well, there is a higher share of income coming from low-income employment in the service sector that is impacted heavily by damages to infrastructure and supply chain disruptions. Finally, the lower-income groups tend to spend more of their income on transportation services and housing, both of which are highly climate-sensitive.

Other equity-deserving groups, such as Indigenous people, racialized people, recent immigrants, and women, are disproportionately represented in low-income groups (Statistics Canada 2021; Statistics Canada 2022).[10] Therefore, climate change impacts risk exacerbating inequality across multiple dimensions.

[9] This value differs from Figure 11 as it is calculated just for the third quintile, median income group and not all income groups.
[10] Equity-deserving groups are those that continue to face significant, collective barriers to full participation in society, including racialized people, Indigenous people, women, recent immigrants and new Canadians, people with disabilities, and people who identify as LGBTQ2S+ (lesbian, gay, bisexual, transgender, queer or questioning, and two-spirit).

Figure 11: Low-income households have the most to lose from climate impacts both in the low-emissions and high-emissions scenarios.

Per cent change in household income relative to a stable climate reference case



Climate damages will lead to tax increases

Across all scenarios, climate impacts put stress on government budgets. A shrinking tax base reduces government revenue even as expenditure demands increase. Replacing and repairing damaged infrastructure, backstopping weather-related disaster costs, and funding increased healthcare needs all place greater demands on government budgets. To close this fiscal gap, taxes will need to rise to maintain services or costs will be transferred to future generations to service the debt, both of which add costs in the form of tax-induced inefficiencies.

More government revenue is needed to maintain infrastructure and services. Demands on governments increase with more expenditures needed to backstop the costs of weather-related disasters, to upgrade and replace infrastructure more frequently, and to pay for more healthcare. For governments to continue providing services while addressing climate damages, personal and corporate taxes must rise to offset the hit to output and the induced effect on tax bases, or services must decline—both of which leave households on the hook as the cost of living climbs. Alternately, borrowing will need to rise, which will transfer current costs to future generations through debt servicing. The indirect cost of increased taxation is to lower overall efficiency in the economy, where there is marginal cost to the economy of raising public funds.

Our modelling suggests that as early as 2025, governments at all levels will see increased expenditures of $4 billion annually to address climate damages. For governments to pay for these expenditures without eroding services relative to the reference case, corporate and personal income taxes will need to be on average 0.4 per cent higher (Table 9).[11]

Out to mid-century in both emissions scenarios, government's share of the total economy rises from 24 to 25 per cent. After mid-century in the low-emissions scenario, this trend continues at about the same pace, with government spending eventually making up an extra three per cent of the economy relative to the reference case. The incremental rise in per capita revenue is $700 per year (Figure 12), representing an increase in the average tax rate of 1.4 per cent (Table 9).

In the high-emissions scenario by the end of century, the size of government with climate impacts is still larger than the reference case, but the rate of government gain slows, as evidenced in the inverted U-shape in Figure 12. In this case, annual GDP growth falls fast and well below the reference case, which lowers government revenue. At the same time, damages are mounting and there is still a need to raise taxes 2.7 per cent to meet the increased spending by government, which triggers an indirect cost on the economy. The net effect by the end of the century is a small rise in the size of government, with a per capita gain of $300, down from a high of $730 (Figure 12).

[11] Measured as expenditure-based real Gross Domestic Product in 2020 dollars.

Figure 12: Governments will need to increase taxes to pay for climate damages both in the low-emissions and high-emissions scenarios.

Taxation on a per capita basis relative to a stable-climate reference case

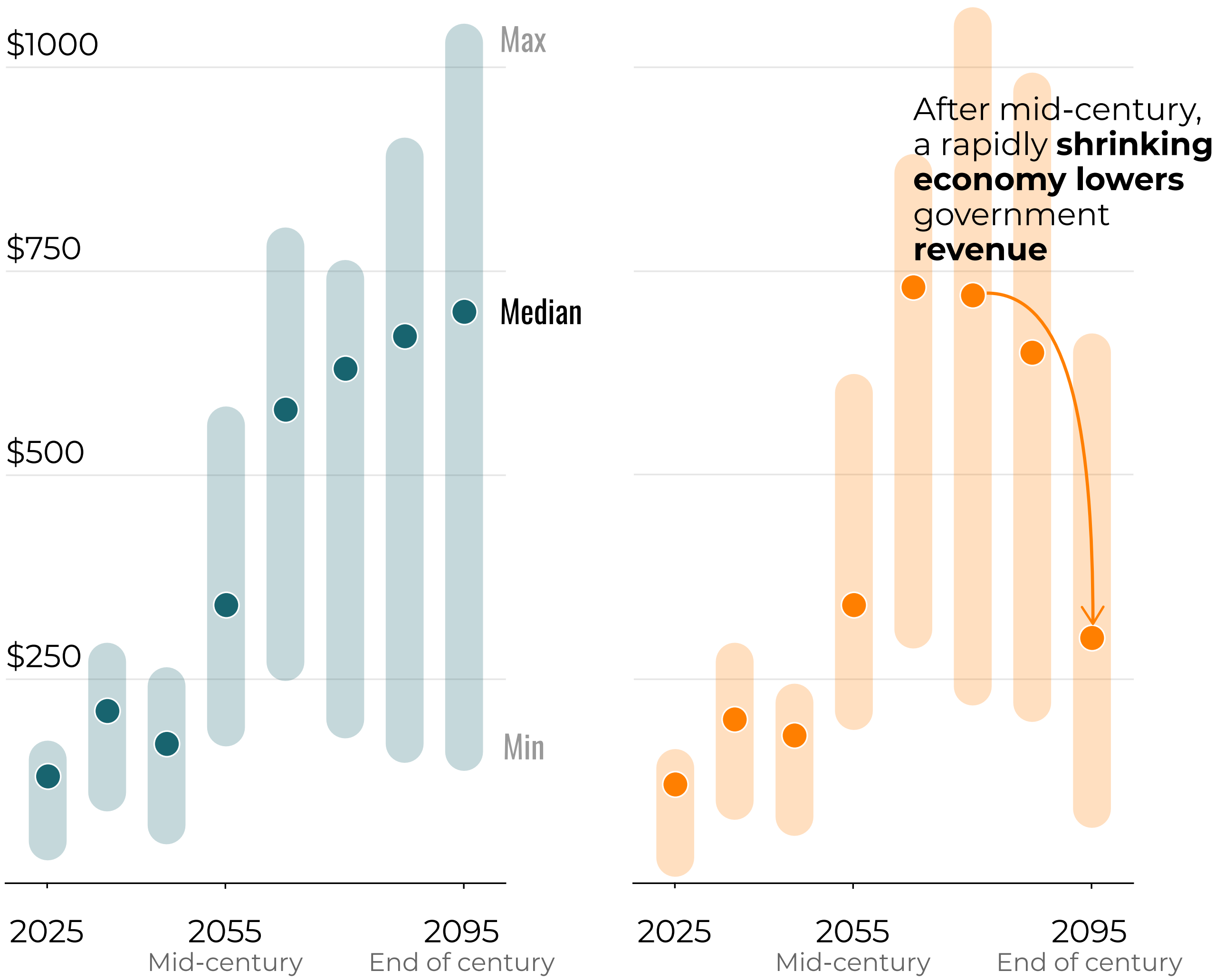


Table 9. Government spending will mostly increase relative to a stable-climate reference case

	Emissions scenario	2025	Mid-century	End of century
Incremental increase in size of government due to climate change				
What is the size of the increase? Dollar value (2020 $B)	**High**	$4.6	$17.6	$23.6
	Low	$5.3	$17.6	$55.1
How fast is the increase growing? Year-over-year change	**High**	7.9%	7.8%	-6.5%
	Low	6.3%	8.2%	1.6%
What is the per capita increase? Per capita change	**High**	$120	$340	$300
	Low	$130	$340	$700
Change in the total size of government				
How fast is government growing? Year-over-year change	**Reference**	1.71%	1.53%	1.69%
	High	1.79%	1.62%	1.52%
	Low	1.80%	1.62%	1.68%
What is the change in the size of government? GDP level relative to reference	**Reference**	100%	100%	100%
	High	0.7%	1.8%	1.3%
	Low	0.8%	1.8%	2.9%
Change in average corporate and personal tax rates				
	High	0.35%	1.1%	2.7%
	Low	0.35%	0.9%	1.4%

Climate damages impair investments in future productivity

A growing economy needs investment to generate income and build wealth. The slowdown in investment by Canadian businesses, households, and from foreign direct investment that our model predicts will hurt future productivity. Across all emissions and climate scenarios we see investment dropping relative to the reference case. Before mid-century, investment declines accelerate as businesses address damages to infrastructure and lower productivity. In the longer term, the decline in investment accelerates as costs accumulate and output shrinks.

Investment is already seeing declines in the short term, outpacing the drag on national income. In the simulations, the level of investment is down by about $7.5 billion by 2025, representing a drop in overall investment of about 2 per cent from the reference case, or twice the reduction in real GDP (Figure 13 and Table 10).[12] This drop comes from a variety of sources: reduced savings from households as their costs rise, lower economic activity, and higher business costs.

Investment declines accelerate in the medium term. Through 2055, in both emissions scenarios, the rate of investment falls faster than the rate of GDP decline, with the level of investment about 3 per cent lower across both scenarios. A large drop in investment is not a surprise given that business must continue to invest to address damages to infrastructure and declining labour productivity. Under high-emissions, the GDP drag starts to impact investment well in advance of the low-emissions scenario, indicating a longer-term trend of investment decline and adjustment leading to one of the highest drops of all the components of GDP.

Investment falls off a cliff around mid-century, reflecting a significant risk to long-term productivity and output. As climate damages mount, our modelling shows investment entering a precipitous decline. In the high-emissions scenarios, the size of the investment loss jumps from 3.5 per cent at mid-century to 18 per cent by the end of century (Figure 13). This is a huge impact on business. The low-emissions scenario more than halves the level of lost investment after mid-century.

[12] Measured as expenditure-based real GDP in 2020 dollars. The quantity of savings in the model is fixed relative to the quantity of labour assumed in the model, so the rate relative to income will vary if households consume more or less leisure.

Figure 13: Investment declines accelerate over the medium term, both in the low-emissions and high-emissions scenarios.

Per cent change in business investment relative to a stable-climate reference case

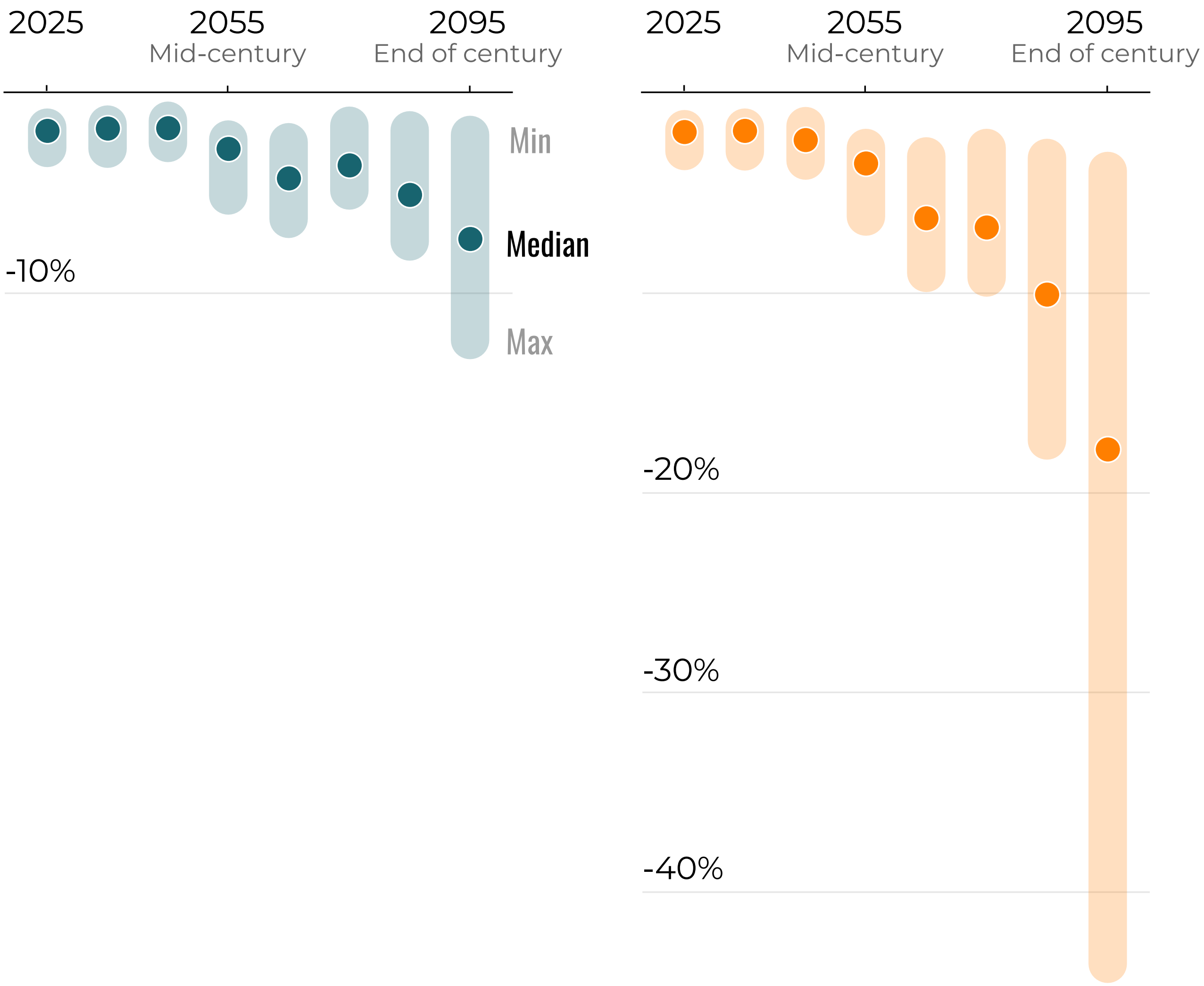


Table 10. Business investment will fall relative to a stable-climate reference case

	Emissions scenario	2025	Mid-century	End of century
Incremental investment loss due to climate change				
What is the size of the loss? Dollar value (2020 $B)	**High**	-$7.6	-$20.4	-$170.8
	Low	-$7.4	-$16.3	-$76.6
How fast is the loss growing? Year-over-year change	**High**	-0.5%	-6.0%	-6.9%
	Low	-0.2%	-6.7%	-5.2%
What is the per capita loss? Per capita investment loss	**High**	-$190	-$390	-$2,180
	Low	-$190	-$310	-$980
Change in the size of total investment				
How fast is investment growing? Year-over-year change	**Reference**	1.57%	1.89%	1.69%
	High	1.38%	1.77%	1.00%
	Low	1.38%	1.79%	1.48%
What is the cumulative loss in the size of investment? Investment level from reference	**Reference**	100%	100%	100%
	High	-1.9%	-3.5%	-17.8%
	Low	-1.9%	-2.8%	-7.3%

Blue Heron Pond in east Windsor, is a constructed storm water retention pond and recreation area/park.

4 THE BENEFITS OF ADAPTATION

While climate damages represent a significant threat to Canada's future well-being, proactive investments in adaptation accompanied by global emissions reductions in line with current commitments can cut those costs by a factor of four. In other words, protecting people in Canada from the costs of climate change requires both dramatic emissions reductions at home and abroad and a massive deployment of adaptation investment and policy across Canada.

Our analysis in the previous section shows that the costs of climate change increase with higher global emissions. Global efforts to reduce greenhouse gas emissions significantly reduce these costs. Alongside these efforts, proactive adaptation can also pay significant dividends.

Previous studies shed light on the benefits of adaptation. The earlier studies in the Costs of Climate Change series assessing the damages and costs to health, infrastructure, and Northern infrastructure each included analysis of the benefits of proactive adaptation measures (Table 2). In the case of health, we estimated the costs of implementing shading measures to mitigate summer overheating in manufacturing facilities and the associated benefits to labour productivity. For infrastructure and Northern infrastructure, we estimated the costs and benefits of installing adaptive infrastructure such as coastal protection measures to protect areas at risk of coastal flooding and incorporating resilient upgrades to infrastructure in planned maintenance and replacement cycles such as more temperature-resistant asphalt on roads and highways, or the excavation and replacement of Northern highway embankments in areas impacted by permafrost thaw.

In total, these previous Costs of Climate Change studies quantified the costs and benefits of adaptation interventions for eight of the 16 climate impact groups. To accurately compare the macroeconomic effects of adaptation against a scenario of continued inaction, for this report we developed a unique

A wind turbine and solar panels on a building in Halifax, Nova Scotia.

set of with- and without- adaptation scenarios. Practically, this means a separate and more limited set of scenarios was developed to compare macro-economic changes with and without adaptation.

Many adaptation measures that could be applied to the other eight impact areas that were not considered in this modelling have been shown to have significant positive returns on investment in other contexts. Therefore, we expect that more widespread implementation of adaptation across a variety of sectors and areas impacted by climate change will result in even greater net benefits and reductions in national economic losses.

We measured the societal benefits of adaptation in two ways: calculating the avoided lost national income with adaptation and calculating the net benefits of adaptation.

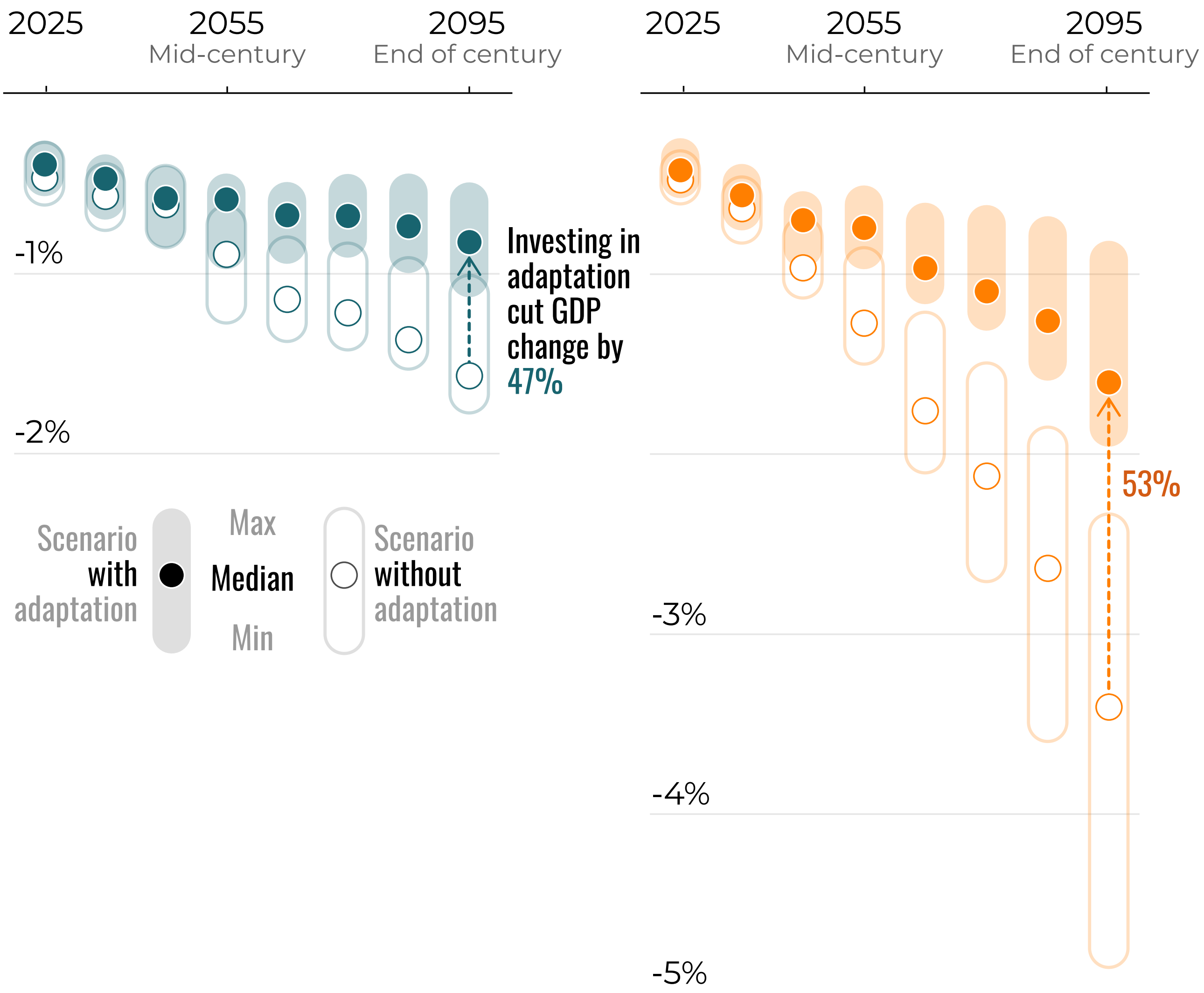
The avoided national income losses with adaptation are large

The first approach mirrors the previous analysis in this document, where we add the direct costs of adaptation and the associated damages into the macroeconomic model and track out the macro-economic changes. The indirect costs, those that manifest through supply chains and markets, are then tracked in the model alongside the direct benefits calculated from the bottom-up studies discussed in Section 2, Table 1 above.

Figure 14 shows the results of the modelling of these eight impact groups, with and without adaptation, for all seven climate models and each of the two emissions scenarios. The results show that investment in proactive adaptation results in a substantial reduction in overall economic damages from climate change impacts to those

Figure 14: Proactive adaptation cuts costs by half across both the low-emissions and high-emissions scenarios.

Per cent change in total economy (GDP) from a stable-climate reference case with and without adaptation



areas. In the low-emissions scenario, impacts are reduced by about 35 per cent by mid-century and 50 per cent by end of century, while in a high-emissions scenario impacts are reduced by approximately 50 per cent in both time frames. The combined effects of lower global emissions and proactive adaptation reduces total real GDP losses by the end of century by 75 per cent.

Adaptation investments pay big social dividends

We conduct a cost-benefit analysis using a welfare economic frame, which is the study of how the allocation of resources in an economy affects social welfare. This approach avoids the broken window fallacy by counting only those benefits that create value and those costs that expend real resources. The approach compares the stream of adaptation costs with the resulting direct and indirect benefits, discounting them back to today's dollars to reflect the time value of money. For a specific investment to pay a social dividend, the value of the social benefits of the adaption investments must be greater than the costs.

A few notes on the cost-benefit analysis:

- Costs and direct benefits of adaptation are estimated from the bottom-up Costs of Climate Change studies (see Table 2).
- Indirect benefits are estimated from the gTech model as a change in welfare. In the model, economic welfare is derived from the allocation of national income between private consumption and leisure. The welfare measure is the loss in economic value to households and is a measure of the social cost of the climate change damages we estimate.
- This is a partial cost-benefit analysis, meaning there are unquantified benefits of adaption that are not included. This implies the net benefit we estimate is likely lower than actual outcomes.
- We've used Monte Carlo analysis to vary the real discount rate and capture the significant variation in the emissions scenarios. We conducted a total of 5,000 simulations to determine the net present value of the net societal benefits of adaptation—in other words, whether the benefits of adaptive responses are greater than the costs.

Table 11 presents the results of the cost-benefit analysis. Across all the simulations, the net present value is positive and significant, indicating that a broad suite of adaptation investments is socially desirable. Indeed, adaptation investments pay large dividends with benefit-cost ratios in the order of 13 to 15, meaning every dollar invested in adaptation yields $13-$15 in benefits. The high benefit-cost ratio, or the multiple of benefits to

Table 11. Proactive adaptation generates major economic returns

	Costs	Direct benefits	Indirect benefits	Net benefit
Net present value ($B 2020) (discounted @ 0.5, 1 and 2% (real); 75 years)				
Low-emissions	$85	$411	$743	$,1069
High-emissions	$118	$696	$660	$1,237
Benefit cost ratio (b/c)				
Low-emissions	N/A	5.2	9.5	14.7
High-emissions		6.4	6.1	12.5

costs, highlights the importance of the indirect benefits of adaptation as climate damages work their way through the economy. Many costs occur in the short-term, but so do adaptive benefits, meaning that costs today do not necessarily mean a long delay in realizing societal benefits.

An important finding highlighted in Table 11 is that the indirect, economy-wide benefits of adaptive responses are a large multiple of the direct benefits. The economy-wide benefits in our analysis amplify the direct benefits that are typically calculated for adaptive responses by at least a factor of two.

August 2015: Burned out vehicles after a fire in Rock Creek, British Columbia.

5 KEY FINDINGS

Climate damage is a major and growing drag on Canada's prosperity that will disproportionately burden households with a higher cost of living. Our multi-year effort to quantify the economic impacts of a changing climate shows conclusively that Canada cannot afford to let that drag go unchecked.

Our modelling and analysis find that climate change is already causing widespread and costly economic losses with few economic benefits, and that these net damages are set to grow dramatically over time. While the infrastructure damages from weather-related disasters and floods are already evident to many Canadians, our analysis brings more opaque and more insidious losses into view, including those to labour productivity and employment, investment, and household income. The direct impacts of a changing climate, we show, are amplified in various indirect ways through supply chains and market interactions.

One of our most surprising findings was the scope and scale of damages in the very short term, up to 2025. Annual GDP losses rise by $25 billion between 2015 and 2025, equating to $620 per year for every Canadian.

Based on our study, we conclude that the climate threat to Canada's economy is marked by four major risks that must be addressed through policy changes if the damages are to be reduced:

1. **Climate change is a macroeconomic risk that threatens to significantly undermine future prosperity.** A warmer and more volatile climate is eroding the income and well-being of people in Canada by reducing productivity, accelerating infrastructure decay, destroying assets, and imperiling health. Macroeconomic indicators under all 84 climate change scenarios point to serious economic damages, including lower GDP relative to the reference case, higher government spending and taxation adding to direct climate costs, lost household income, higher unemployment, slowed business investment, and lost competitiveness. These impacts are distributed widely across regions and sectors. Actual damages are likely to be much higher, as we were unable to quantify or monetize a wide range of other impacts, and more

extreme but nonetheless plausible climate change scenarios may yet come to pass.

2. **Climate change is an affordability risk for households in Canada, and especially for vulnerable populations.** While climate damages will represent a significant drag on Canada's GDP, we find households will pay the highest price for climate impacts. All Canadian households will be worse off across all the scenarios we modelled, with low-income households being hardest hit. Households in Canada will experience the growing direct impacts of weather-related disasters and other climate impacts, such as loss and damage to homes and private assets. Meanwhile, wider macroeconomic risks also have material impacts. For instance, household taxation increases as government expenditures grow to cover climate damages, which erodes disposable income. Climate impacts lower labour productivity and increase unemployment, further eroding household income. Supply chain disruptions cause prices of consumer goods to rise. Moreover, climate change is colliding with existing socioeconomic vulnerabilities to amplify the risks to vulnerable populations. Low-income households, Alberta, and the North are disproportionately impacted by climate change. And despite current generations already feeling the heat, future generations will bear disproportionate costs as climate damages grow over time.

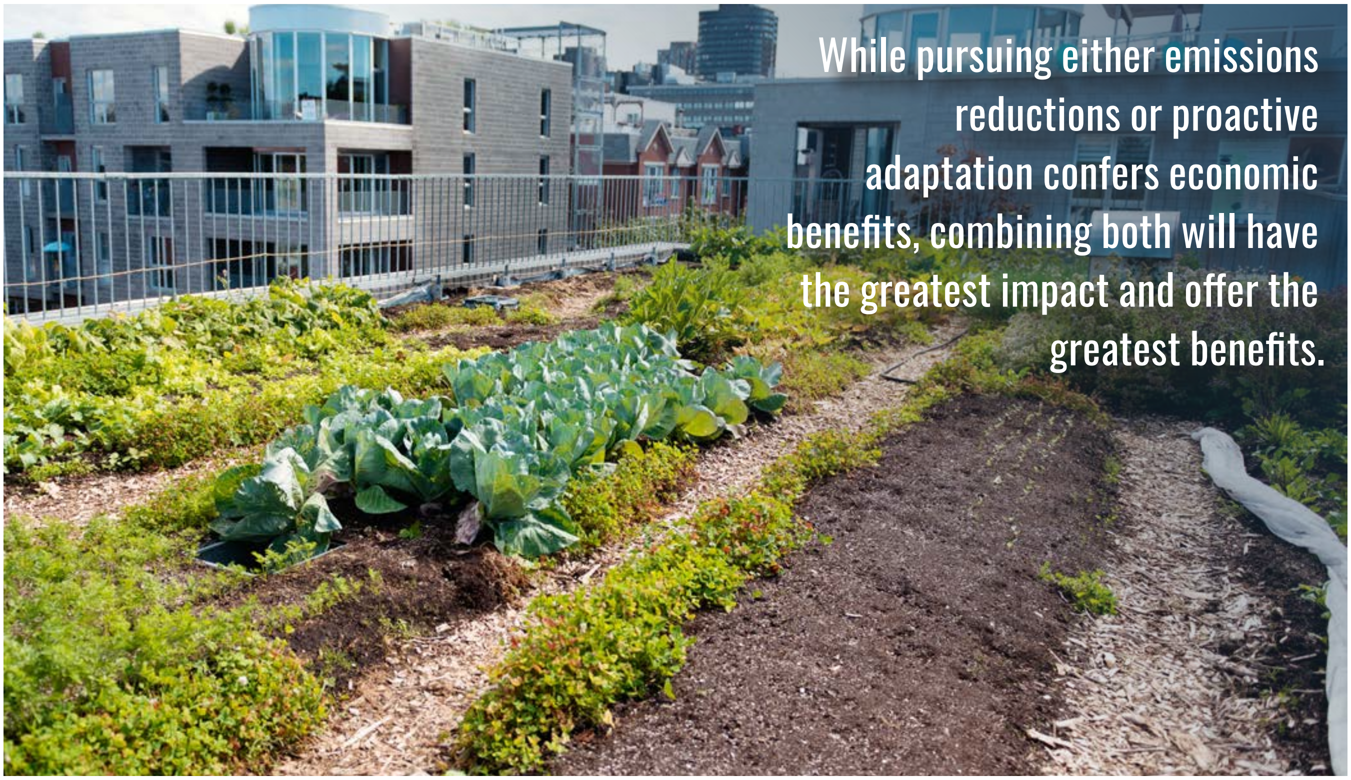
3. **The Canadian economy is highly climate-sensitive, posing a major risk to businesses and investors.** Virtually no economic sector is immune to climate change impacts. Climate damages will trigger net losses for most of Canada's economic sectors through lower productivity and output, lower returns on investment, and reduced employment. Even the case of construction—which appears on its surface to be a good news story—is indicative of the broken window fallacy. The growth is driven by public and private spending to repair climate damage, a reallocation of resources away from the production and purchase of new goods and services across the economy that will lower income and erode corporate and individual wealth. And investors—from pension funds to individuals—will see continually lower returns from investments in Canadian corporations, real estate, infrastructure, and other assets.

4. **Climate change is a fiscal risk that threatens to upend government spending.** Government revenues will be negatively impacted at the same time as expenditures must increase. Damages throughout the economy will lead to relatively lower revenue from corporate and personal income tax. An increased need to backstop weather-related disasters, to replace and repair damaged infrastructure, and to address health costs will require additional government spending. Moreover, these effects will interact: despite the increasing drag on projected economic growth, government expenditures will face pressure to grow to address the demands of a warming and increasingly volatile climate, adding a tax-induced cost to the economy. This pressure forces governments into a choice between raising taxes to maintain services, taking on additional public debt, or cutting services as climate damages consume a greater share of the total budget.

Emissions reductions and proactive adaptation measures, taken together, are the most effective means of reducing costs. While pursuing either emissions reductions or proactive adaptation confers economic benefits, combining both will have the greatest impact and offer the greatest benefits. Taken together, mitigation and adaptation lower the climate change impact on national income by 75 per cent in the impact groups we modelled. Substantial reductions in global greenhouse gas emissions will significantly reduce impacts to the economy, particularly after mid-century, when the low-emissions scenario more than halves the damages of the high-emissions scenario. Proactive adaptation that seeks to climate-proof infrastructure, businesses, and households, meanwhile, provides significant payback regardless of the future emissions trajectory. Investments in adaptation generate benefits almost immediately in all simulations, with the adaptation measures we modelled providing a $13-$15 return on investment for every one dollar spent. In the high-emissions scenario, GDP damages over the entire simulation period can be cut in half by pursuing proactive adaptation responses that build resiliency. In the low-emissions scenario, GDP losses are halved in the latter part of the century.

A final point that can't be emphasized enough is that the risks we have identified are just the tip of the iceberg. Climate change carries a wide range of economic risks, many of which are not yet able to be quantified or are yet unknown (Figure 2). While our assessment focused on the limited set of economic impacts that could be quantified at this stage, the analysis and modelling still show large economic damages.

It is abundantly clear that climate damage represents a substantial and growing drag on Canada's economy, that households in Canada will be bearing the burden of these costs, and that the two most effective measures that can be taken to significantly reduce these costs are emissions reductions and proactive adaptation.



LEED Gold-certified Purdy's Wharf in Halifax.

6 RECOMMENDATIONS

This report demonstrates the significant scale of climate impacts that Canada faces. Climate change is a major risk to Canada's economy and to the prosperity of all people in Canada, with adverse impacts cutting across how we work, play, and earn income.

Several high-level policy imperatives emerge from this analysis.

Overall, governments need to start accounting for the macroeconomic risks of climate change and the macroeconomic benefits of proactive policy. We recommend that, going forward, economic policy in Canada must consider the serious economic risks and impacts of a changing climate and the imperative to invest in adaptation, as follows:

1. Governments should build climate impacts and adaptation policies into their own economic decision making.

Specifically, governments at all levels should build climate damages and the costs and benefits of adaptation into economic analysis and decision making as common practice. This includes budget processes, short- and long-term economic projections, scenario analysis, and stress testing. Governments should also build climate change adaptation and resilience into programmatic spending by accounting for the potential costs of climate impacts and the benefits of increasing resilience in all program and infrastructure spending decisions. This also means factoring in the very real and significant costs of inaction when evaluating the economic impacts of climate change adaptation and mitigation policies.

2. Governments should encourage—and where appropriate, mandate—accounting for climate change risks in private-sector decision making.

The physical risks of a changing climate are a major direct and indirect threat to the sustainability and viability of Canada's economy. Business, industry, and capital markets need to do a much better job of building physical climate risk and measures to address it into risk management practices. Federal, provincial, and territorial governments and regulators should accelerate climate risk disclosure initiatives and develop the information and scenarios the private sector needs to analyze and disclose risk.

3. Governments should scale-up adaptation measures to match the magnitude of the risk Canada faces.

Our results show that climate change will have significant and wide-ranging impacts across the Canadian economy, with substantial economic benefits from adaptation in avoiding or mitigating these risks, regardless of the emissions scenario. Proactive adaptation is a sound investment that can pay returns of $13-$15 per dollar spent, under both lower- and higher-emissions scenarios. However, the gap between adaptation needs and adaptation action in Canada continues to grow. Governments should immediately scale-up adaptation policy and investment in proportion to the economic risk of climate impacts, beginning with the federal government committing to aggressive new policies, actions, and investments in the forthcoming *National Adaptation Strategy*.

4. Governments should double down on aggressive reductions in emissions both at home and abroad.

All orders of government in Canada should implement and strengthen policies to reduce emissions quickly, in line with climate science and net zero goals. For high-level recommendations on reducing emissions in Canada, see our report *Canada's Net Zero Future* (Dion et al. 2021). Furthermore, governments should also use their influence to encourage emissions reductions internationally, given the global nature of the emissions reduction challenge. Lowering global concentrations of greenhouse gases in the atmosphere means easing up on the gas pedal that drives climate change impacts. Without drastic emissions reductions, adaptation measures alone will be insufficient to address many growing climate damages in Canada.

5. Governments should invest in understanding and preparing for the economic risks of climate change that have not yet been modelled.

The tip-of-the-iceberg economic risks highlighted in this report should be more than enough to impel a dramatic acceleration of climate change adaptation and mitigation policies. However, there are many other risks below the waterline that may have profound effects on the Canadian economy, including supply chain disruptions, international trade disruptions, and ecosystem collapse. While governments must act immediately to adapt to and mitigate a changing climate with the imperfect information already at hand, they must also urgently seek to better understand the full scope of economic risks from climate change by investing in further research, data collection, scenario development, and economic impact analysis.

GLOSSARY

ADAPTATION Actions that reduce damage and loss from actual or expected climate change, while taking advantage of potential new opportunities.

ADAPTATION POLICY Policies that build adaptive capacity; legislation that builds strength, attributes, and resources that can be used to adapt to climate change.

ADAPTIVE CAPACITY The strengths, attributes, and resources available to an individual, community, society, or organization that can be used to adapt to climate change.

BROKEN WINDOW FALLACY A faulty economic concept that argues that repairing damage and destruction creates a net benefit for society and the economy. It is a fallacy because redirecting money towards repairing broken items, rather than towards new goods and services, may appear to boost one part of the economy but ultimately carries significant opportunity cost and results in net negative economic outcomes.

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 gases 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 CHANGE MITIGATION Making the impacts of climate change less severe by preventing or reducing the emission of greenhouse gases into the atmosphere, or sequestering them through nature-based or engineered approaches.

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 emissions or concentration of greenhouse gases 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.

CLIMATE-RELATED HAZARDS The potential occurrence of a climate-related physical event that may cause loss of life, injury, or damage and loss to property, infrastructure, service provision, and environmental resources. Due to climate change, frequencies of some hazards are expected to continue to increase.

CLIMATE RISK DISCLOSURE The practice by corporations and financial system entities of disclosing the risks they are facing from the physical impacts of climate change and the transition to a low-carbon economy, to encourage preparation for those risks and to help investors make more informed investment decisions.

COMPUTABLE GENERAL EQUILIBRIUM (CGE) MODEL A large numerical model that combines economic theory with real economic data to derive the impacts of policies or shocks in the economy. CGE models aim to capture how the structure of the economy changes due to policy-induced behavioural response of agents (firms, households, governments).

COSTS The amount that must be paid or spent to obtain something.

COST-BENEFIT ANALYSIS A systematic process that analyzes which decisions to make and which to forgo by summing the potential benefits expected from an action, and then subtracting the total costs associated from taking that action.

DAMAGES The size of the economic drag or loss due to climate change. This includes physical, social, or economic loss.

DISASTER Severe disruption of the normal functioning of a community or 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 and may require external support for recovery.

DISCOUNT RATE Refers to the rate used to reflect the time value of money to bring a future cash flow into today's dollars.

ECONOMIC DRAG A slowdown in economic activity.

ECONOMIC OUTPUT The total value of goods and services produced in a country or by an economic sector.

EXPOSURE The presence of people, livelihoods, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected by climate change.

EXTREME WEATHER The occurrence of a weather variable (such as temperature) that exceeds the upper or lower limit of observed values for that variable. These events are often short-lived and include heat waves, ice storms, heavy downpours, tornadoes, tropical cyclones, and floods.

FLOOD MAPS Maps that identify areas that are expected to experience periodic coastal or inland flooding. Flood maps or floodplain maps typically show ground elevation contours, the location of buildings and roads, and the horizontal extent of the high-water mark for one or more flood events, such as a hundred-year flood. In Canada, flood maps are typically developed by provincial or municipal governments.

GEOGRAPHIC RESOLUTION The spatial detail with which an analysis depicts the location and shape of geographic features.

GROSS DOMESTIC PRODUCT (GDP) OR NATIONAL INCOME Measures the value added, or national income created, through producing goods and services within a country's borders, inclusive of all private and public consumption, government outlays, investments, additions to private inventories, paid-in construction costs, and the foreign balance of trade. Exports are added to the overall GDP value, while imports are subtracted.

HOUSEHOLD INCOME Refers to the gross income of all members of a household above a specified age, including spouses and dependents. It is a useful indicator of the standard of living.

IMPACTS Effects on natural and human systems. In this report, the term impacts is used to refer to the effects on natural and human systems of physical events, disasters, and/or climate change.

INVESTMENT An asset or item acquired with the goal of generating income or appreciation. The intent is not to consume the good, but to create future wealth.

MACROECONOMIC IMPACT A change in the level of economic activity due to a policy or spending.

NET PRESENT VALUE The current value of a future cash flow. The present value of the cash flow depends on the time period between now and when the cash flow occurs, as well as the assumed discount rate.

PERMAFROST Ground that remains below zero degrees Celsius for at least two consecutive years.

PRODUCTIVITY Measures output per unit of input, such as labour, capital, or any other resource. It is often calculated for the economy as a ratio of the Gross Domestic Product to hours worked.

PROSPERITY The level of wealth of a country, including economic growth, economic security, and economic competitiveness.

RESILIENCE The ability of a physical, social, or ecological system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a disaster in a timely and efficient manner.

RISK The potential for consequences where something of value is at stake and where the outcome is uncertain. Risk is often represented as probability of the occurrence of hazardous events or trends, multiplied by the potential impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. In this report, the term risk is used primarily to refer to the risks of impacts related to climate change.

SENSITIVITY OR SUSCEPTIBILITY The degree to which an individual, asset, household, community, business, or ecosystem is affected, either adversely or beneficially, by climate change.

STABLE REFERENCE CASE The economic structure that existed in Canada in 2015, as reported by Statistics Canada. This starting point allows us to capture the effects of climate change of the recent past on the macroeconomy; The reference case shows no further climate change simulation after 2015. It is the basis from which the climate change scenarios are compared.

STRESS TESTING A computer simulation technique used to test the resilience of institutions and investment portfolios against future financial situations.

SUPPLY CHAIN The network of companies and people that are involved in the production and delivery of a product or service.

VULNERABILITY The degree to which a system is susceptible to, or unable to cope with, negative effects of climate change, including climate variability and extremes.

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ACKNOWLEDGMENTS

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Visualizations by **Voilà:** | *chezVoila.com*

Photography credits: cover © Nicolas Brulois on Unsplash

Design and layout: Laurie Barnett, Graphic Designer

Translation: Edgar Co-operative

Recommended citation:
Sawyer, Dave, Ryan Ness, Caroline Lee, and Sarah Miller. 2022. *Damage Control: Reducing the costs of climate impacts in Canada*. Canadian Climate Institute. https://climateinstitute.ca/reports/damage-control/