Costs of Inaction:

Economic Analysis of Pincher Creek's Climate Risks

Summary Report

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HIGHLIGHTS

Information on the economic consequences of climate change is increasingly being demanded by decision-makers as they contemplate how to respond. A key piece of economic evidence used to make the business case for action are the costs that result from allowing climate change to continue unabated and without new adaptation. Both economists and adaptation practitioners often refer to these costs as the "costs of inaction". Estimates of the costs of climate change are being used by decision-makers to inform the overall scale of investment in adaptation, the prioritization of risks, and the selection, timing and sequencing of specific adaptation options, as well as the distribution of costs and adaptation benefits. The goal of this study is to estimate the "costs of inaction" for Pincher Creek (Town and M.D.) to inform and provide impetus to the climate adaptation planning process.

While climate change is anticipated to bring some benefits for Pincher Creek, the total economic impact is projected to be overwhelmingly negative. Under a high future climate scenario, direct economic losses attributable to further climate change are estimated at $18.3 million and $32.8 million (in 2020 dollars) per year, on average, by the 2050s and 2080s, respectively. The scale and direction of projected direct economic losses for Pincher Creek varies across climate-sensitive sectors:

Losses of $13.5 million (2050s) to $26.2 million (2080s) annually from public health impacts caused by higher temperatures and periods of poor air quality (e.g., from wildfire smoke).

Losses of $0.5 million (2050s) to $1.0 million (2080s) annually from reduced worker productivity due to higher temperatures.

Losses of $4.0 million (2050s) to $6.5 million (2080s) annually from damages to transportation infrastructure and associated delays in the movement of people and freight due to high temperatures and heavy precipitation events.

Losses of $1.6 million (2050s) to $2.7 million (2080s) annually from damages to electricity transmission and distribution infrastructure due to a range of climate-related hazards.

Losses of $0.7 million (2050s) to $1.9 million (2080s) annually from damages to water, wastewater and drainage infrastructure due to heavy precipitation events and drought conditions.

Losses of $0.8 million (2050s) to $1.4 million (2080s) annually from damages to building structures and contents resulting from river and stormwater flooding.

Losses of $2.5 million (2050s) to $3.6 million (2080s) annually from damages to building structures resulting from high winds, hail and freezing precipitation.

Savings of $0.4 million (2050s) to $0.2 million (2080s) annually from reduced building energy costs due to rising seasonal temperatures.

Increases in farmland values of $4.9 million (2050s) to $10.4 million (2080s) annually from rising agricultural productivity due to seasonal warming, a longer growing season and increases in total annual precipitation.

These direct economic losses will give rise to a range of secondary or indirect costs in the wider economy as spending by affected businesses and households in Pincher Creek is adversely impacted. The impacts of climate change on Pincher Creek are projected to reduce Gross Domestic Product in the region by $4.6 million and $6.8 million per year, on average, by the 2050s and 2080s, respectively.

The estimated costs of climate change for Pincher Creek are almost certainly larger than the losses presented above. There are several key gaps in our current state-of-knowledge, including failure to account for cascading and compounding impacts across interdependent infrastructure systems and climate hazards that occur simultaneously or in close sequence, the loss of key service flows provided by infrastructure (e.g., drinking water, power, etc.), and impacts to some key climate-sensitive sectors (e.g., natural landscapes, tourism).

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1 INTRODUCTION

Climate change is already causing impacts with economic consequences today and will do so increasingly in the future. These impacts affect different aspects of the built and natural environment, public health and safety, labour productivity, and the economy. Building resilience and adapting municipalities to unavoidable climate change has been conservatively estimated to require an annual investment of 0.26% of GDP[1], which equates to a total expenditure of about $13.6 million for the Town and Municipal District (M.D.) of Pincher Creek over the next 10 years. Given the potential magnitude of climate adaptation investment costs, there is a need to provide decision-makers—who must address competing priorities with limited human and financial resources—with defensible economic information on projected costs and associated benefits to support adaptation investment decisions. A key piece of economic information used to persuade senior leadership and elected officials of the need and urgency to allocate resources to adaptation planning is the future "cost of inaction"—i.e., the economic consequences that result from allowing climate change to continue unabated and without further planned adaptation (EEA, 2007; and Ackerman and Stanton, 2011)[2]. This information can be used to:

- Quantify the overall scale of the challenge presented by the physical risks of climate change and convey the urgency for action;
- Inform the distribution of economic impacts across population groups, assets, climate-sensitive sectors and areas;
- Support the prioritization of climate-related threats and opportunities;
- Support the selection, timing and sequencing of specific adaptation options; and
- Guide the required level of investment in adaptation.

Indeed, the first key message in the costs and benefits chapter of the National Issues 2021 volume of Canada in a Changing Climate states: "*Faced with limited resources and competing priorities, economic analysis can help decision-makers clarify trade-offs, and make the case for allocating resources to climate adaptation and specific actions, by providing information on the costs and benefits of different choices*."[3]

In accord with this key message, we performed an economic analysis of the physical risks of climate change for Pincher Creek (henceforth, "Pincher Creek" refers to both the Town and M.D.) to communicate the magnitude of the problem to senior leadership and the Council to support the business case for future investment in climate adaptation.

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[1] IBC and FCM, 2020, Investing in Canada's Future: The Cost of Climate Adaptation at the Local Level, Final Report, February 2020.

[2] EEA, 2007, Climate change: the cost of inaction and the cost of adaptation. EEA Technical Report | No 13/2007, European Environment Agency (EEA), Copenhagen, Denmark, 67 pp; and Ackerman, F. and Stanton, E., 2006, Climate Change – the costs of inaction. Report to Friends of the Earth England, Wales and Northern Ireland, Global Development and Environment Institute, Tufts University, Medford, Massachusetts, 38 pp.

[3] Boyd, R. and Markandya, A., 2021, Costs and benefits of climate change impacts and adaptation; Chapter 6 in Canada in a Changing Climate: National Issues Report, (Eds.) F.J. Warren and N. Lulham; Government of Canada, Ottawa, Ontario [https://changingclimate.ca/national-issues/chapter/6-0/]

2 APPROACH

There is a wide spectrum of terms used to characterise the economic consequences of climate change impacts and adaptation – e.g., direct costs, indirect costs, secondary costs, ripple-effects, macroeconomic impacts, private costs, social costs, externalities, side-effects, co-benefits, co-impacts, ancillary costs, market impacts, non-market impacts, tangible effects, intangible effects, net costs, and welfare costs. The range of terms, many of which overlap and are used interchangeably, can lead to confusion among practitioners and decision-makers. Additionally, quantifying the economic consequences of climate change across the range of potentially impacted human systems and the environment requires what are best described as multi-model, multi-sector approaches. Typically, modelling approaches vary across climate-sensitive sectors, but most analyses are performed within a common analytical framework that combines socioeconomic information with climate scenarios. For clarity when interpreting the results presented below, we first describe this common analytical framework before defining the scope of the analysis, including key cost terms.

2.1 Analytical framework for estimating economic impacts

The costs of inaction were estimated following best practice[4] in three steps.

1. The first step involves: estimating economic impacts today (for the purpose of this study, taken to be 2025), based on current exposures of human and natural systems in Pincher Creek, current vulnerabilities (the susceptibility of these systems to harm when exposed to different climate impact-drivers), and current climate conditions.
2. The second step involves: estimating economic impacts in the future (specifically, in 2055 and 2085) under current climate conditions, but accounting for projected socioeconomic change—i.e., growth in Pincher Creek's human and natural systems, growth in prices and wealth (e.g., higher property values and higher willingness-to-pay of individuals to avoid illness or risk of death), and anticipated changes in vulnerability (e.g., as shifts in the age distribution of the population affects baseline mortality rates). But, during this second step, the climate is held constant at baseline levels. In effect, current climate conditions are overlaid on a future society, such that the change in economic impact over time is driven solely by socioeconomic change.
3. The third step involves: overlaying projected future climate change on top of a projected future Pincher Creek. This generates an estimate of the overall scale of the challenge presented by the physical risks of climate change (in economic terms), which is also the pot of potential direct economic benefits from adaptation.

This approach enables isolation of the incremental impact of further climate change from the influence of anticipated growth and development of Pincher Creek. It also enables analyses of alternative climate futures (emissions pathways) beyond mid-century on economic risks for Pincher Creek.

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[4] Boyd, R. and Markandya, A., 2021, ibid; and Boyd, R., Gados, A. and Maynes, T., 2013, Economic Guidance for the Appraisal and Prioritization of Adaptation Actions, Technical Guidance Report prepared by C3 (Climate Change Central) for Natural Resources Canada, Ottawa, ON.

2.2 Scope: impacted systems and types of costs included

The human and natural systems included in the assessment are listed in Table 1. For each system, Table 1 shows the climate variable(s) driving the estimated impacts—the so-called “climate impact-drivers”. The corresponding economic consequences quantified in the study are also shown. Two broad types of economic consequences are assessed:

1. **Direct-tangible costs**. These costs arise from the direct biophysical impacts of climate impact-drivers, such as damage or disruption, to (**tangible**) goods and services that can be traded in a market and thus have an observed price as a basis for monetization (e.g., costs incurred to repair or replace damaged homes, the medical treatment costs for heat stress, etc.). This also includes business interruption costs, the costs of evacuation and temporary accommodation, etc. as a result of the direct damages caused by flooding[5]. Tangible costs are the familiar capital expenditures and “out-of-pocket” expenses.
2. **Direct-intangible costs**. These costs arise from direct biophysical impacts to (**intangible**) items not bought or sold in a traditional market and thus with no readily observable price as a basis for monetization (e.g., ecosystem services, stress or pain levels, travel delays, premature death). Economists have developed multiple techniques to ‘shadow price’ these intangible (or non-market) impacts (e.g., the Value of a Statistical Life used to price the risk of premature death in a population). Below, direct-intangible costs and welfare losses are used interchangeably—the latter term is more commonly used by economists.

Secondary-tangible costs were also estimated. These costs arise from the ripple effect of the direct **tangible** impacts on the wider economy as subsequent spending (both indirect and induced) is affected. Indirect impacts result from changes to upstream inter-industry purchases by the directly impacted economic sector(s) in Pincher Creek. Induced impacts result from changes in the production of goods and services in response to changes in consumer income and household expenditures driven by the direct and indirect impacts (originating in Pincher Creek) as they ripple through the economy. Below, the most commonly measured secondary-tangible costs are reductions in projected gross-domestic product (GDP).

Regarding the secondary-tangible costs, they are sometimes erroneously viewed as a net gain for society. While some sectors, like remediation services and construction, might benefit from increased demand for clean-up and restoration services following an extreme weather event, this benefit should be viewed more as a transfer of resources towards sectors responding to the event and away from those that suffer damages as a direct result of the event. The costs incurred to restore assets to their pre-event state thus represents an “opportunity cost”—the opportunity cost refers to the forgone benefits from transferring expenditures away from the activities that would have occurred in the absence of damage from the climate-induced event. In short, these expenditures would not have been incurred in the absence of climate change impacts.

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[5] The flood assessment literature refers to these latter costs as “indirect losses”. However, the economic literature tends to treat them as direct, tangible costs to distinguish them from wider indirect and induced (secondary or cascading) impacts on the economy.

Table 1: Exposed systems, climate impact-drivers and economic consequences included in study

Exposed human and natural systems	Climate impact-drivers	Economic consequences
Roads	High temperatures, heavy precipitation, freeze-thaw cycles	Damages
	High temperatures, heavy precipitation, freeze-thaw cycles	Delays (value of time)
Rails	High temperatures	Damages
Sidewalks - paths	High temperatures, drought, extreme cold, freeze-thaw cycles, pluvial flooding	Damages
Buildings	Fluvial and pluvial flooding	Damages
	Fluvial and pluvial flooding	Indirect losses
	Hail storm, high winds, freezing rain, freeze-thaw cycles, heavy snow	Damages
	Heating degree days, cooling degree days (residential)	Energy costs
	Heating degree days, cooling degree days (non-residential)	Energy costs
Electricity T&D (linear)	High temperatures, hail storm, high winds, freezing rain, heavy snow, pluvial flooding, wildland fire	Damages
Potable water (linear)	Cold temperatures, drought, freeze-thaw cycles	Damages
Wastewater (linear)	Freeze-thaw cycles, pluvial flooding	Damages
Drainage (linear)	Freeze-thaw cycles, pluvial flooding	Damages
Bridge culverts	Freeze-thaw cycles, pluvial flooding	Damages
Agriculture	Mean seasonal temperatures, mean annual precipitation, frost-free days, growing degree days	Farmland value
Labour	High temperatures	Lost output
Public health	Air quality (ground-level ozone) - mortality	Welfare losses
	Air quality (ground-level ozone) - mortality	Lost output
	Air quality (ground-level ozone) - morbidity	Welfare losses
	Air quality (smoke PM2.5) - mortality	Welfare losses
	Air quality (smoke PM2.5) - mortality	Lost output
	Air quality (smoke PM2.5) - morbidity	Welfare losses
	High temperatures - mortality	Welfare losses
	High temperatures - mortality	Lost output
	High temperatures - hospitalizations	Healthcare costs
	High temperatures - hospitalizations	Lost output
	Exacerbation of mental health disorders - multiple climate impact-drivers	Welfare losses
	Other public health and safety impacts - multiple climate impact-drivers	Welfare losses

2.3 Scope: climate scenarios and timeframes

The base year selected for quantifying economic impacts is 2025; this year provides a benchmark against which future impacts are compared. This year was chosen as it is the central year of the 30-year meteorological averaging period or “climate normal” (2011-2040) between: (a) the climate baseline used for the climate risk assessment (1976-2005); and (b) two future 30-year averaging periods encompassing remainder of the century—i.e., the 2050s (2041-2070) and the 2080s (2071-2100).

In addition to 2025, economic impacts are quantified for 2055 and 2085; the central years for the 2050s and 2080s time periods. For each of 2025, 2055 and 2085, economic impacts are calculated with respect to the projected changes in relevant climate variables under RCP (Representative Concentration Pathway) 8.5 relative to the 1976-2005 climate normal. Hence, estimated costs for 2025 are really the expected annual costs—for (say) roads—of climate change between 1976-2005 and 2011-2040. Likewise, estimated costs for 2055 represent the expected annual costs (for roads) of climate change between

1976-2005 and 2041-2070. Primary interest lies with the difference in estimated economic impacts between 2025 and 2055 and between 2025 and 2085; these differences represent the costs attributable to further climate change beyond what may be currently experienced in Pincher Creek.

When assessing climate-related economic risks it is prudent to consider the greatest plausible change scenario relative to the present, which in practice means working with the RCP 8.5 scenario (i.e., the most conservative of global "no climate policy" scenarios). The primary justification for using RCP 8.5 is that it means no economic risks are missed. Uncertainties relating to whether the future unfolds along RCP 8.5 or along a different, lower emission pathway, are managed when subjecting adaptation strategies and measures to economic analysis. Furthermore, as noted above, our analytical framework allows for consideration of alternative emission pathways beyond mid-century as a sensitivity test.

All estimated economic impacts are reported in constant 2020 dollars.

3 FINDINGS

3.1 Direct costs

Projected expected annual direct costs in 2025, 2055 and 2085 are presented in Table 2. By mid-century, total expected tangible costs (due to impacts on market goods and services) are estimated at $5.3M (2020 dollars) annually; roughly 1.2 times higher than expected costs in the immediate future ($4.6M per year by 2025). By the 2080s, total expected tangible costs are estimated to increase to $8M annually; roughly 1.7 times larger than expected annual costs for 2025. Looking at intangible costs (due to welfare losses from impacts to non-market goods and services), total expected costs by the 2050s are estimated at $13.9M annually, rising to $26.8M annually by the 2080s—4.6 times larger than expected losses for 2025 ($5.9M per year).

Total annual direct costs (i.e., tangible plus intangible costs) are expected to reach $18.3M and $32.8M by 2055 and 2085, respectively[6]. Put another way, in the 2050s and 2080s expected total annual direct costs from climate-related impacts are anticipated to amount to about $18.3M and $32.8M, respectively, in any given year. Compared with 2025 when total annual direct costs are estimated at $10.2M, projected costs in 2055 are 1.8 times higher and 3.2 times higher by 2085.

The breakdown of total annual direct costs by exposed system (such as people, buildings, infrastructure, etc.) for 2025, 2055 and 2085 is shown in Figure 1. When considering the figure, note that losses due to climate-related impacts are increasing in the following exposed systems over the course of the century, even though the percentage contribution of individual systems to total losses in ach time period is shown to decline: roads, rail and pavements; buildings-flooding; buildings-storms; linear electricity T&D infrastructure; water and drainage infrastructure; labour productivity; and all public health outcomes. With that caveat in mind, the largest source of loss for Pincher Creek in all three time periods is linked to

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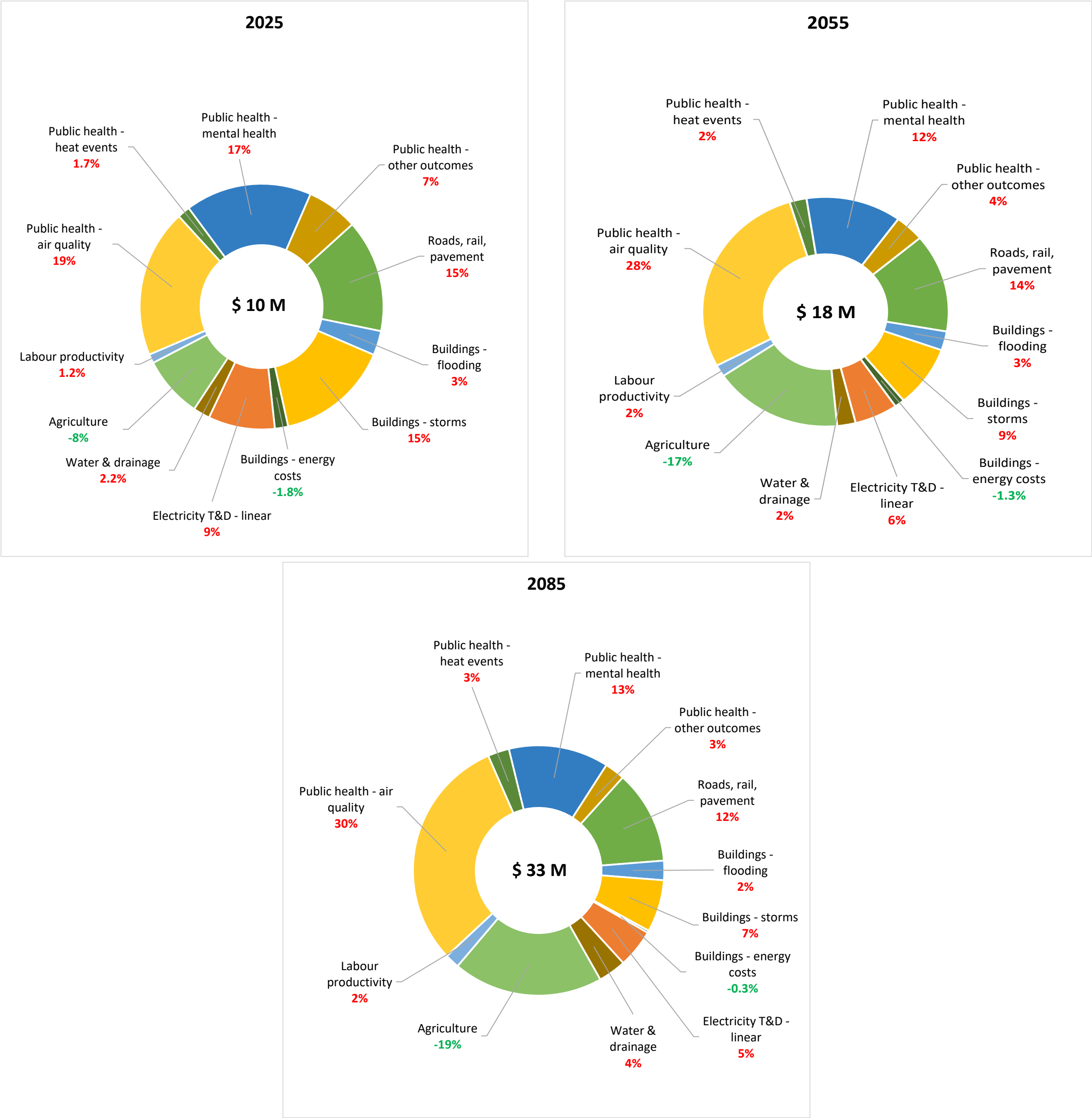
[6] Note that when calculating total costs, we do not include the lost output (human capital) costs associated with excess mortality as that would amount to double counting; the intangible costs (welfare losses) of public health impacts are valued using the Value of a Statistical Life, which will include an element of foregone output.

adverse public health impacts resulting from deteriorating air quality associated with—primarily—increased wildfire smoke (and exposure to particulate matter less than 2.5 microns in diameter). This is primarily due to excess deaths from chronic exposures of the population to smoke (see Figure 10 at Appendix 1). The exacerbation of mental health disorders due to climate-enhanced extreme weather events, like drought, wildfires and smoke, flooding, heatwaves, etc. is also a significant source of projected losses across all three time periods.

Figure 1: Projected *direct* economic impacts of climate change for Pincher Creel in 2025, 2055 and 2085, by exposed system



Note: Red font indicates projected losses due to climate change; green font indicates projected benefits.

Table 2: Projected *direct* economic impacts of climate change for Pincher Creek, by exposed system and future time period

Exposed human and natural systems	Climate impact-drivers	Economic consequences	2025	2055	2085	Change: 2025 to 2055	Change: 2025 to 2085
			($ 2020 M)	($ 2020 M)	($ 2020 M)	($ 2020 M)	($ 2020 M)
Roads	High temperatures, heavy precipitation, freeze-thaw cycles	Damages	1.4	3.3	5.3	1.8	3.8
	High temperatures, heavy precipitation, freeze-thaw cycles	Delays (value of time)	0.2	0.4	0.7	0.2	0.5
Rails	High temperatures	Damages	0.0	0.1	0.2	0.0	0.2
Sidewalks - paths	High temperatures, drought, extreme cold, freeze-thaw cycles, pluvial flooding	Damages	0.2	0.3	0.3	0.0	0.1
Buildings	Fluvial and pluvial flooding	Damages	0.4	0.7	1.2	0	1
	Fluvial and pluvial flooding	Indirect losses	0.1	0.1	0.2	0	0
	Hail storm, high winds, freezing rain, freeze-thaw cycles, heavy snow	Damages	1.9	2.5	3.6	0.6	1.7
	Heating degree days, cooling degree days (residential)	Energy costs	-0.3	-0.4	-0.4	-0.1	-0.2
	Heating degree days, cooling degree days (non-residential)	Energy costs	0.1	0.0	0.3	0.0	0.2
Electricity T&D (linear)	High temperatures, hail storm, high winds, freezing rain, heavy snow, pluvial flooding, wildland fire	Damages	1.1	1.6	2.7	0.5	1.5
Potable water (linear)	Cold temperatures, drought, freeze-thaw cycles	Damages	0.0	0.0	0.0	0.0	0.0
Wastewater (linear)	Freeze-thaw cycles, pluvial flooding	Damages	0.1	0.4	1.0	0.2	0.9
Drainage (linear)	Freeze-thaw cycles, pluvial flooding	Damages	0.1	0.2	0.4	0.1	0.4
Bridge culverts	Freeze-thaw cycles, pluvial flooding	Damages	0.1	0.2	0.5	0.1	0.4
Agriculture	Mean seasonal temperatures, mean annual precipitation, frost-free days, growing degree days	Farmland value	-1.0	-4.9	-10.4	-3.9	-9.4
Labour	High temperatures	Lost output	0.2	0.5	1.0	0.3	0.9
Public health	Air quality (ground-level ozone) - mortality	Welfare losses	1.5	2.9	5.1	1.4	3.6
	Air quality (ground-level ozone) - mortality	Lost output	0.2	0.3	0.6	0.2	0.5
	Air quality (ground-level ozone) - morbidity	Welfare losses	0.0	0.1	0.2	0.1	0.2
	Air quality (smoke PM2.5) - mortality	Welfare losses	0.9	5.0	10.9	4.1	9.9
	Air quality (smoke PM2.5) - mortality	Lost output	0.1	0.6	1.3	0.5	1.2
	Air quality (smoke PM2.5) - morbidity	Welfare losses	0.0	0.1	0.2	0.1	0.2
	High temperatures - mortality	Welfare losses	0.2	0.6	1.4	0.4	1.2
	High temperatures - mortality	Lost output	0.0	0.1	0.2	0.0	0.2
	High temperatures - hospitalizations	Healthcare costs	0.0	0.0	0.1	0.0	0.0
	High temperatures - hospitalizations	Lost output	0.0	0.0	0.0	0.0	0.0
	Exacerbation of mental health disorders - multiple climate impact-drivers	Welfare losses	2.1	3.6	6.9	1.5	4.8
	Other public health and safety impacts - multiple climate impact-drivers	Welfare losses	0.9	1.1	1.4	0.3	0.5
Sub-total		Tangible costs	4.6	5.3	8.0	0.7	3.4
		Intangible costs	5.9	13.9	26.8	8.0	21.0
Total			**10.2**	**18.3**	**32.8**	**8.1**	**22.6**

Climate-related impacts to road (and pavements) and rail networks likewise account for a consistently large share of total direct costs throughout the century. Damages to buildings from flooding and storms are currently significant, accounting for 18% of total losses in 2025, but account for only 9% by 2085. This is partly because two key climate drivers of impacts—specifically, freeze-thaw cycles and heavy snow—are projected to decrease as a result of climate change (see Figure 4 at Appendix 1). In general, the relative contribution of individual systems to total direct costs will increase over time for systems where:

a) The primary climate impact-drivers are temperature- as opposed to precipitation-related (projected changes in the former are larger than the latter);
b) Projected growth in the exposure system is relatively high compared with other systems;
c) Projected growth in the value of the exposed system is relatively high; or
d) Any combination of (a)-(c).

Two systems are anticipated to realize economic benefits from climate change. Net building energy costs are anticipated to fall as the climate warms. Though the estimated *net* saving masks a mixture of different underlying changes in natural gas and electricity consumption for space heating and space cooling demand across the residential and non-residential sector, as shown in Table 3.

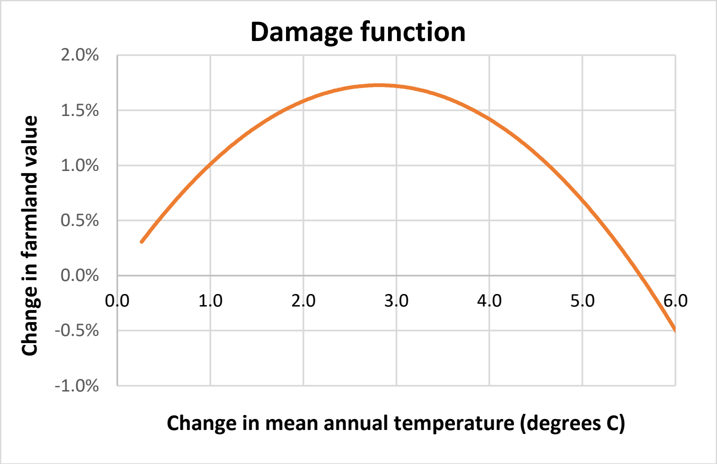
Table 3: Projected changes in energy costs to heat and cool buildings in Pincher Creek

Projected changes in baseline non-residential annual energy costs					
Year	Heating use Natural gas	Heating Use Electricity	Cooling Use Natural gas	Cooling Use Electricity	Total energy use
	$ 2020 M	$ 2020 M	$ 2020 M	$ 2020 M	$ 2020 M
2025	-0.14	-0.01	0.01	0.20	0.06
2055	-0.51	-0.02	0.07	0.50	0.05
2085	-0.83	-0.03	0.15	0.99	0.29
2025 to 2055	-0.37	-0.01	0.06	0.30	-0.01
2025 to 2085	-0.69	-0.02	0.14	0.80	0.23

Projected changes in baseline residential annual energy costs					
Year	Heating use Natural gas	Heating Use Electricity	Cooling Use Natural gas	Cooling Use Electricity	Total energy use
	$ 2020 M	$ 2020 M	$ 2020 M	$ 2020 M	$ 2020 M
2025	-0.28	-0.09	0.00	0.08	-0.28
2055	-0.91	-0.22	0.00	0.70	-0.43
2085	-1.74	-0.45	0.00	1.74	-0.45
2025 to 2055	-0.63	-0.14	0.00	0.62	-0.14
2025 to 2085	-1.46	-0.37	0.00	1.66	-0.16

The agricultural sector is anticipated to benefit from climate change—reflected by projected increases in farmland values due to net improvements in productivity across both crop and livestock farms. However, there are numerous reasons why these estimated benefits should be viewed as overly optimistic; indeed, the economic impact of climate change on agriculture in southern Alberta may well be negative. For a start, the estimated benefits in Table 2 are derived from what are known as Ricardian models of agricultural land values. When applying these models in a climate change context, it is assumed that the estimated statistical relationships embedded in the models are valid beyond the range of historical observations from which they were derived, which may not be the case, especially towards the end of the century. This is evident from the inverted U-shape at of the damage function at higher temperatures shown in Figure 2.The estimated relationships also capture historical autonomous adaptations by farmers. But farmers may face new barriers to autonomous adaptation in the future, reducing the efficacy of any actions they take. Most importantly, however, these Ricardian models and our analysis do not account for the expected impacts of climate and weather extreme events (like storms, flooding, drought, etc.) on agricultural output and land values, nor changes in pest/disease damage or the timing of precipitation.

Figure 2: Reduced form damage function for farmland values[7]



3.2 Secondary (macroeconomic) costs

The tangible costs shown in Table 2 were input to a macroeconomic model for Pincher Creek to gain some insights into the associated macroeconomic consequences of climate change arising from direct impacts in the Town and M.D. The results are shown in Table 4. The overall (direct, indirect and induced) impact of climate change for gross output by mid-century is estimated at $13M annually (an increased loss of $3M relative to 2025). By the 2080s, the overall opportunity cost of climate change for gross output is projected to amount to $30M (an increased loss of $9M relative to 2025). Looking at value-added, expected annual GDP losses due to climate-related impacts on Pincher Creek in 2055 and 2085 are estimated at $5M and $8M; representing increased losses of $1M and $3M, respectively, relative to

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[7] Reduced form damage function fitted to the farmland Ricardian models for the Prairies estimated by: Ayouqi, H. and Vercammen, J., 2014, Evaluating the impact of climate change on Canadian prairie agriculture, LEARN Linking Environment and Agriculture Research Network, Research Project PR-01-2014, University of British Columbia, Vancouver, 18 pp; and Amiraslany, A., 2010, The impact of climate change on Canadian agriculture: a Ricardian approach. Doctoral dissertation, Department of Bioresource Policy, Business and Economics, University of Saskatchewan, Saskatoon, SK, 169 pp.

2025. Table 4 also shows expected annual forgone municipal, provincial and federal tax revenues because of climate related-impacts on Pincher Creek. Note that the annual costs shown in Table 4 reflect secondary losses across the provincial economy resulting from direct annual costs incurred in Pincher Creek.

Table 4: Projected *direct*, *indirect* and *induced* tangible opportunity costs of climate change impacts on Pincher Creek, by time period

Macroeconomic indicators	2025	2055	2085
	($ 2020 M per year)		
Tax revenues	0.3	0.4	0.6
Labour income	2.4	3.3	5.4
Gross output	10.5	13.0	19.7
GDP	3.9	4.6	6.8

To illustrate the economic consequences for Pincher Creek from different levels of climate change relative to the 1976-2005 climate normal, the thermometer shown in Figure 3 was created from the results presented in Table 2. The expected direct annual tangible and intangible (welfare) costs associated with one degree Celsius increments in Pincher Creek's mean annual temperature relative to the climate normal are shown on the left-hand-side of the thermometer. For reference, the projected mean annual temperature for Pincher for the 2050s and 2080s under RCP 8.5 are shown on the right-hand-side of the thermometer. By way of example, if Pincher Creek develops as projected and the climate continues to change in accordance with the RCP 8.5 scenario, when the mean annual temperature change in Pincher Creek reaches 3°C above the climate normal of 5°C, total direct tangible plus intangible costs attributable to this level of warming are estimated at about $19M annually. Table 5 also shows projected total direct tangible, intangible and direct and indirect GDP costs for different amounts of future climate change for Pincher Creek.

4 SIMULATING THE COSTS AND BENEFITS OF ADAPTATION

Below, we illustrate how the results presented in Section 3.1 could be used to guide the required level of investment in adaptation in Pincher Creek. As noted in the Introduction, adapting municipalities for projected climate change has been conservatively estimated to require an annual investment equivalent to 0.26% of GDP[8]. Over the 10-year period 2025-2035 this equates to an annual average investment of about $1.36M[9] ($13.6M in total) for Pincher Creek. Per capita this level of investment amounts to about $194 per resident per year for 10-years or $1,935 per resident in total[10]. Fortunately, as per Boyd and

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[8] IBC and FCM, 2020, ibid.

[9] Note that this is the total level of investment irrespective of who pays; in practice, all three levels of government as well as private households and businesses will need to invest in adaptation actions.

[10] Based on the projected average annual population over this period.

Markandya (2021), “*the benefits of planned actions to adapt to climate change in Canada generally exceed the costs, sometimes significantly, providing a strong business case for proactive investment in adaptation*.” While some adaptation actions do not make economic sense, most investments in adaptation typically offer rates of return from $2 to over $10, with the majority providing $3-$5 in benefits for each dollar invested[11].

Figure 3: Projected aggregate economic impacts of different amounts of future climate change for Pincher Creek (direct tangible and intangible costs) (2020 million dollars annually)

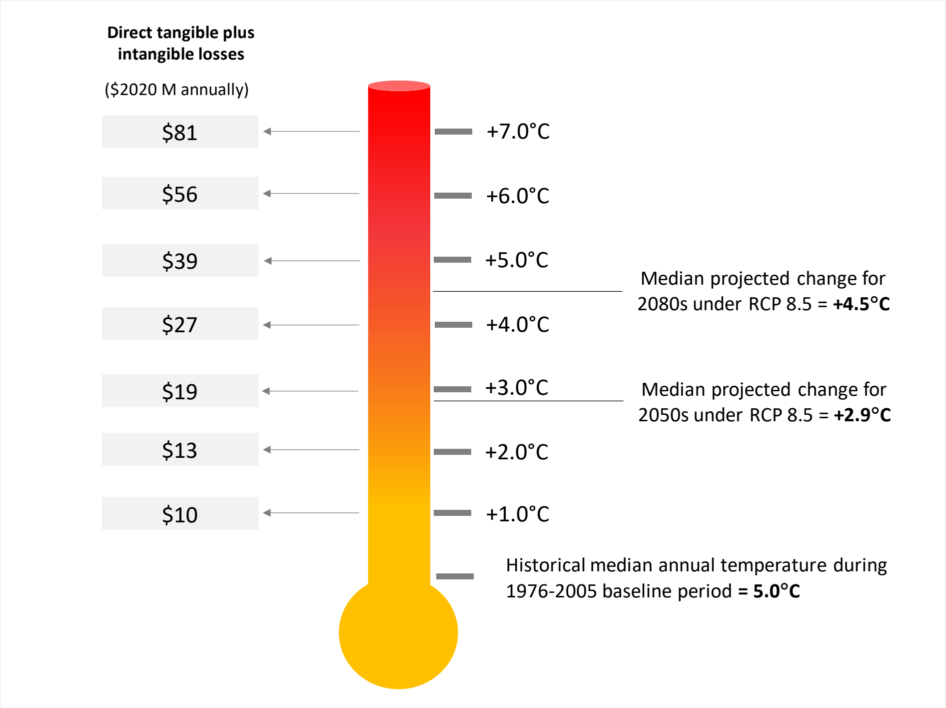

Table 5: Projected aggregate economic impacts of different amounts of future climate change for Pincher Creek (direct tangible, intangible and direct and indirect GDP costs) (2020 million dollars annually)

Change in mean annual temperature relative to 1976-2005 baseline period	Direct tangible costs	Direct intangible costs	Direct tangible and intangible costs	Direct and indirect GDP costs
+1°C	4.7	5.1	9.7	3.9
+2°C	4.7	9.0	13.7	4.0
+3°C	5.5	14.7	20.2	4.7
+4°C	7.0	22.3	29.3	5.9
+5°C	9.2	31.8	41.1	7.8
+6°C	12.2	43.1	55.4	10.2
+7°C	16.0	56.3	72.3	13.3

Note: The sum of columns 2 and 3 may not equal the value in column 4 due to rounding

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[11] Boyd and Markandya, 2021, ibid.

Table 6 show the estimated costs and benefits from investing $13.6M (i.e., 0.26% of projected GDP) in adaptation in Pincher Creek over the 10-year period 2025-2035, *assuming* the money is invested in actions offering typical rates of return found in other economic studies of between $3-$5. The corresponding benefits in present value terms (at a real annual discount rate of 3%) over the useful life of the implemented actions (assumed to be 35 years) are shown in the third column. For example, the present value benefits from a total 10-year investment of $13.6M in adaptation in Pincher Creek at an assumed $3 rate of return are estimated at $41M. The fourth column in Table 6 shows the percentage reduction in projected total direct costs under a baseline, no adaptation scenario (derived from the results presented in Table 2). The fifth column shows the percentage of projected baseline costs still being incurred in Pincher Creek even with a total 10-year investment of $13.6M in adaptation—i.e., the residual direct costs of climate change in present value terms. Continuing with the same example, an adaptation investment of $13.6M at the assumed $3 rate of return reduces projected direct costs over the lifetime of the adaptation actions by 21%, with 79% of projected costs still being incurred in Pincher Creek. It is evident from Table 6 that investing 0.26% of projected GDP in adaptation actions at typically rates of return from other economic studies ($3-$5) still leaves Pincher Creek exposed to significant residual losses.

But what if the investment in adaptation actions was roughly tripled, say, to 0.75% of projected GDP annually. This equates to a total investment of about $39.3M over 10-years or roughly $560 per person per year[12]. At the same typical rates of return found in other economic studies (i.e., $3-$5), it is now evident from Table 6 that this higher level of investment in adaptation can virtually eliminate the incurrence of residual direct costs—especially if adaptation projects return close to $5 per $1 invested.

Table 6: Simulated costs and benefits of 10-year adaptation investment strategy for Pincher Creek

Investment Strategy	**10-year adaptation investment plan (2025-2035)**	**Present value lifetime benefits of adaptation investment**	**Reduction in projected total direct costs (2025-2060)**	**Present value residual direct costs with adaptation (2025-2060)**
	($2022 M)	($2022 M)	(% of baseline costs)	(% of baseline costs)
Invest **0.26%** of projected GDP				
$1 returns **$3**	13.6 *$1,935 / person*	41	**21%**	**79%**
$1 returns **$4**		54	**27%**	**73%**
$1 returns **$5**		68	**34%**	**66%**
Invest **0.75%** of projected GDP				
$1 returns **$3**	39.3 *$5,585 / person*	118	**59%**	**41%**
$1 returns **$4**		157	**79%**	**21%**
$1 returns **$5**		196	**99%**	**1%**

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[12] Again, it must be stressed that adaptation investment expenditures will almost certainly be spread across multiple public and private sector actors.

5 KEY LIMITATIONS

This assessment of the economics consequences of climate change for Pincher Creek has several limitations that should be borne in mind when interpreting the results:

- The built environment systems included in the assessment produce service flows (e.g., drinking water, power) that residents and businesses in Pincher Creek value. With the exception of the time value of passenger and freight delays on the road network, the dollar value of loss or disruption to these services flows is not captured in the results.
- Economic impacts to several climate-sensitive systems were not captured in the study due to data and budgetary constraints, including impacts to forestry, water resources, tourism, and ecosystem services outside of the provisioning services provided by agriculture. In studies for the City of Edmonton and the City of Calgary, damages and loss of ecosystem services from impacts to the urban tree canopy and natural urban areas (shrublands, wetlands, grasslands, forests) accounted for 17-19% of total direct costs by mid-century, for example.
- For several exposed systems and climate impact-drivers, the analysis focused on a single event of defined intensity. For example, expected damages from the exposure of buildings to a hailstorm assumes the storm produces hail stones of "40 mm or greater in diameter". While the intensity levels of the events considered are towards the upper tail-end of the distribution of possible events, other events with lesser intensities (like hail stones with a 20 mm diameter), but a higher likelihood of occurring, may still collectively result in material damages.
- The analysis does not account for the potential of compounding and cascading effects. There are multiple ways that climate change can produce these effects. Compound effects occur, for example, when one set of climate impact-drivers result in multiple "impact chains" occurring simultaneously or in sequence, thus amplifying the overall consequences (e.g., the same climatic drivers that cause heat stress for workers and the general population can also cause drought and wildfire). When climate hazards occur in sequence (like the extreme heat and wildfires or the succession of "atmospheric rivers" that hit British Columbia in 2021) they act as a series of toppling dominos that accumulate and intensify, each becoming harder to manage as capacity to cope and recover becomes more strained, ultimately turning them into disasters. Cascading effects are indirect biophysical impacts of direct effects, such as when direct damages or losses to one system (like power outages from damage to electricity T&D infrastructure) from exposure to a climate hazard leads to spin-off impacts for other systems (like traffic signals, pumping stations, etc.). In this study, climate impact-drivers are assessed as discrete events occurring in isolation in any given year.
- The analysis does not account for feedback effects on projected growth. Simply put, the analysis measures the impacts of climate change on the level of output and not the growth rate. Climate change can cause lasting damage to natural, manufactured and human capital and productivity in most affected systems in Pincher Creek and is thus likely to impact long-term growth rates underpinning the projections of socioeconomic change. Studies that have investigated the impact of climate change on growth rates have found substantially larger losses than those that measured impacts on the annual level of output (as done in this study).

Collectively, these limitations suggest **the projected economic risks of climate change for Pincher Creek are almost certainly larger than the estimates presented** in this report.

6 APPENDIX 1: ADDITIONAL FIGURES

Figure 4: Projected direct annual damages to buildings by climate impact-driver

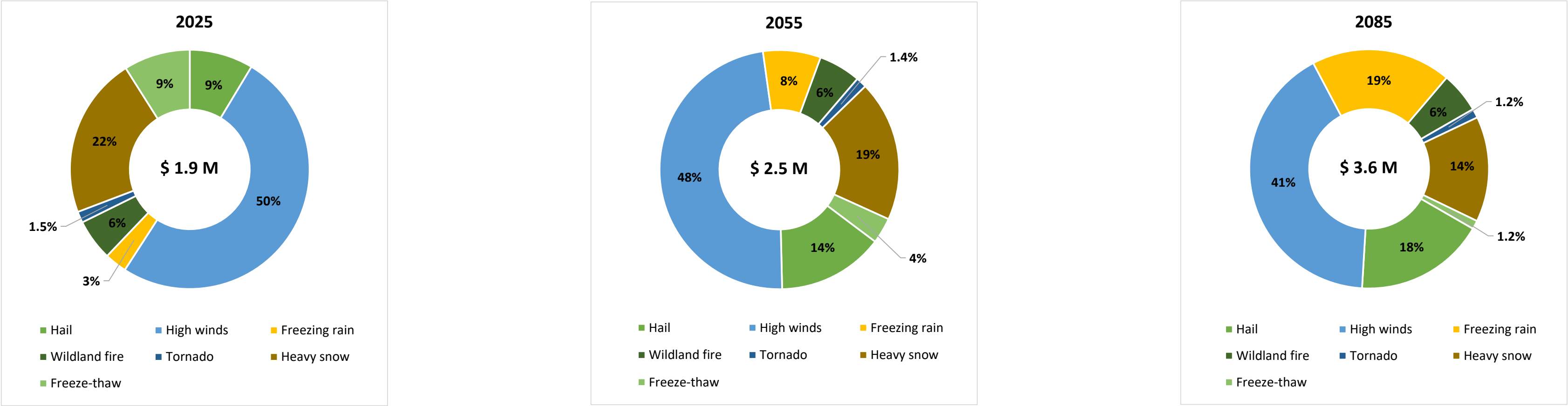


Figure 5: Projected direct annual damages to electricity T&D system by climate impact-driver

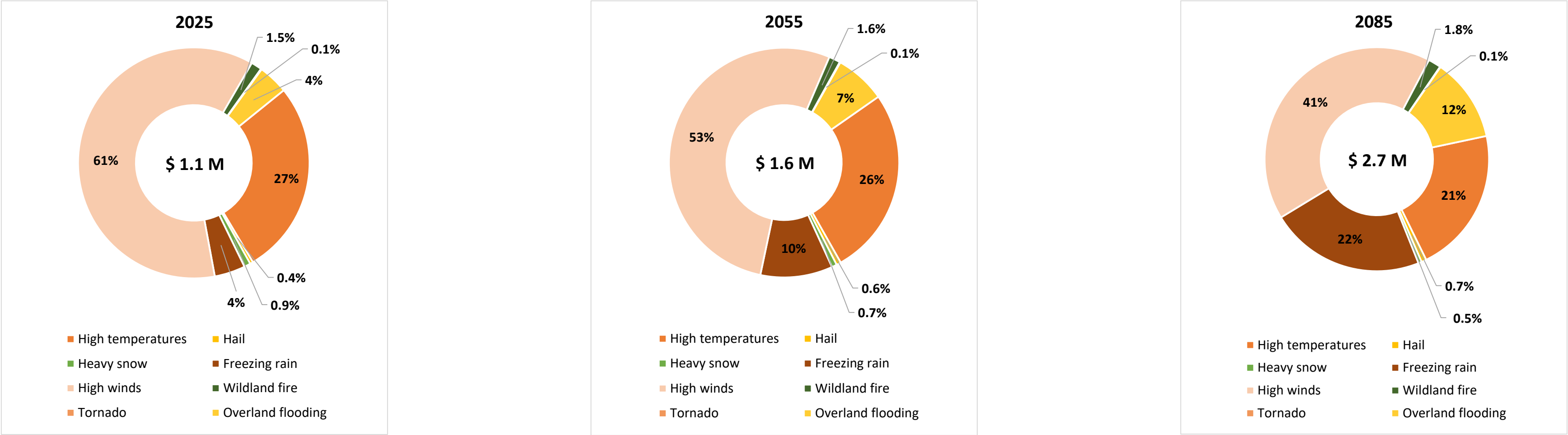


Figure 6: Projected direct annual damages to water infrastructure by asset

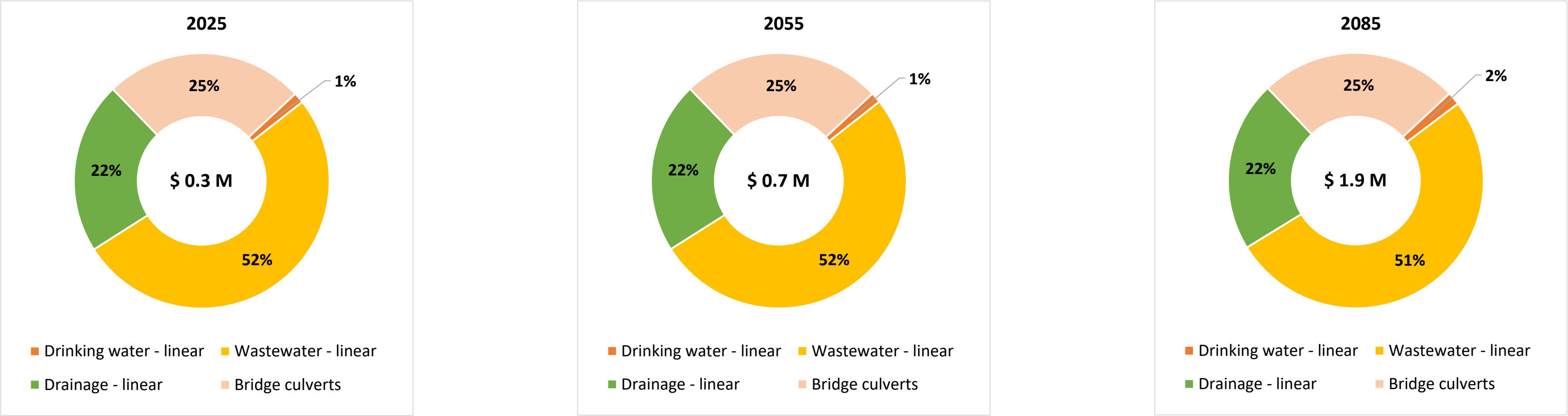


Figure 7: Projected direct annual damages to transportation system by asset and delays

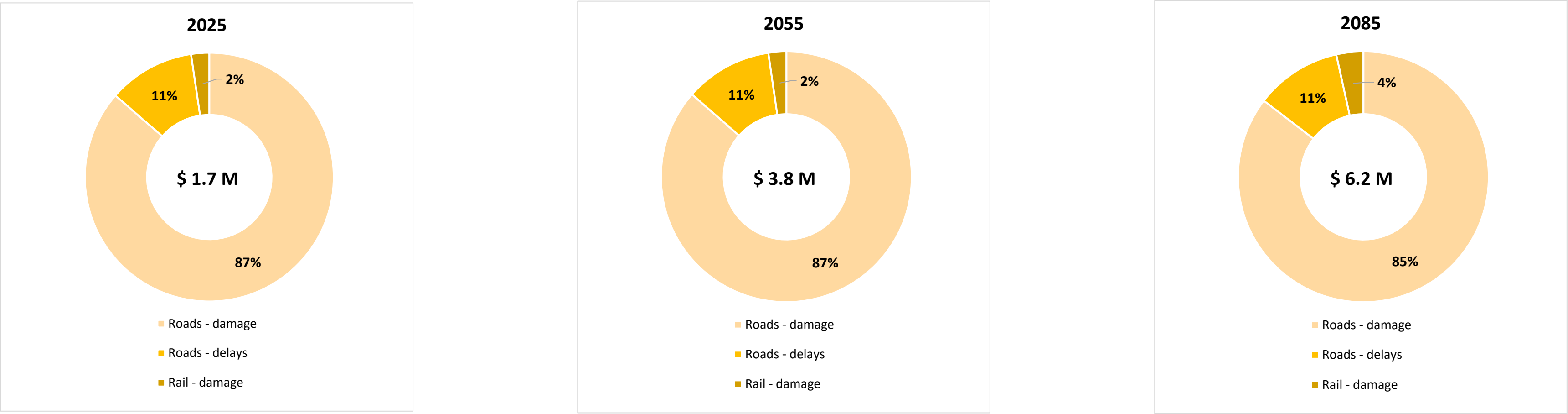


Figure 8: Projected direct annual labour income losses by “high-risk” industry

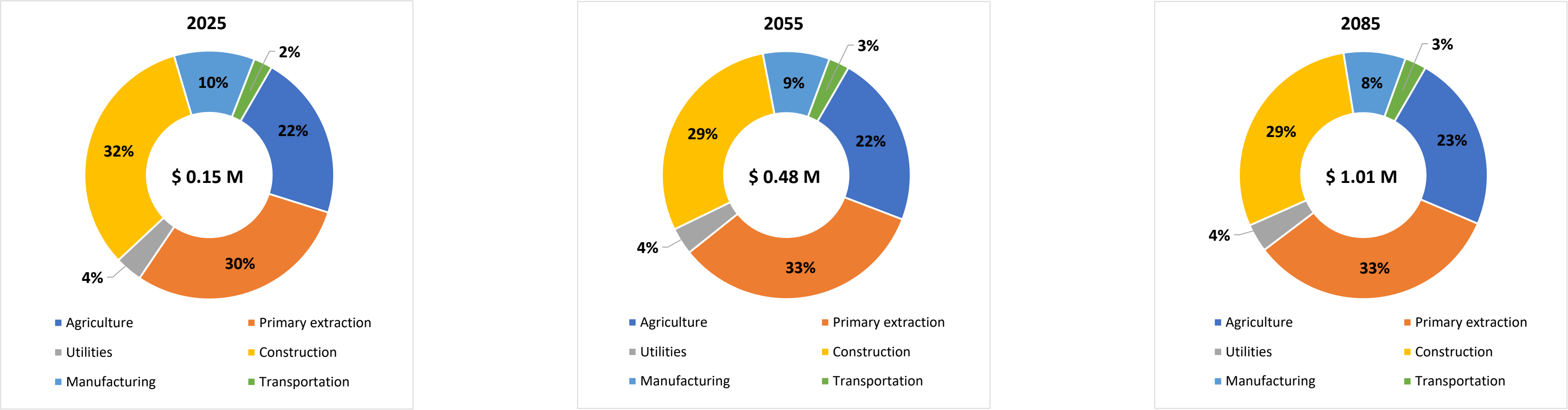


Figure 9: Projected direct annual labour productivity losses by “high-risk” industry

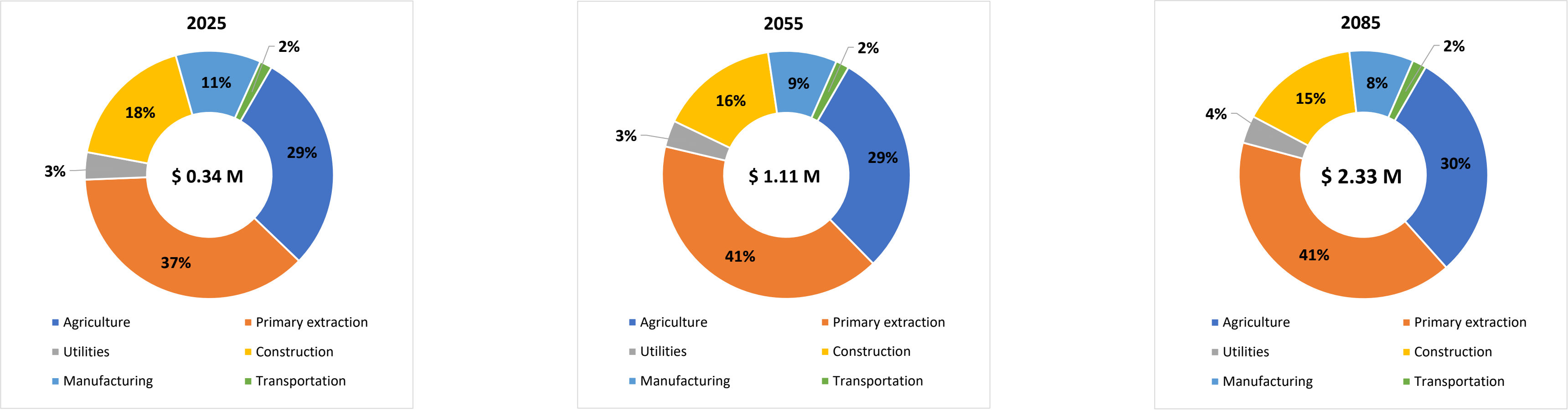
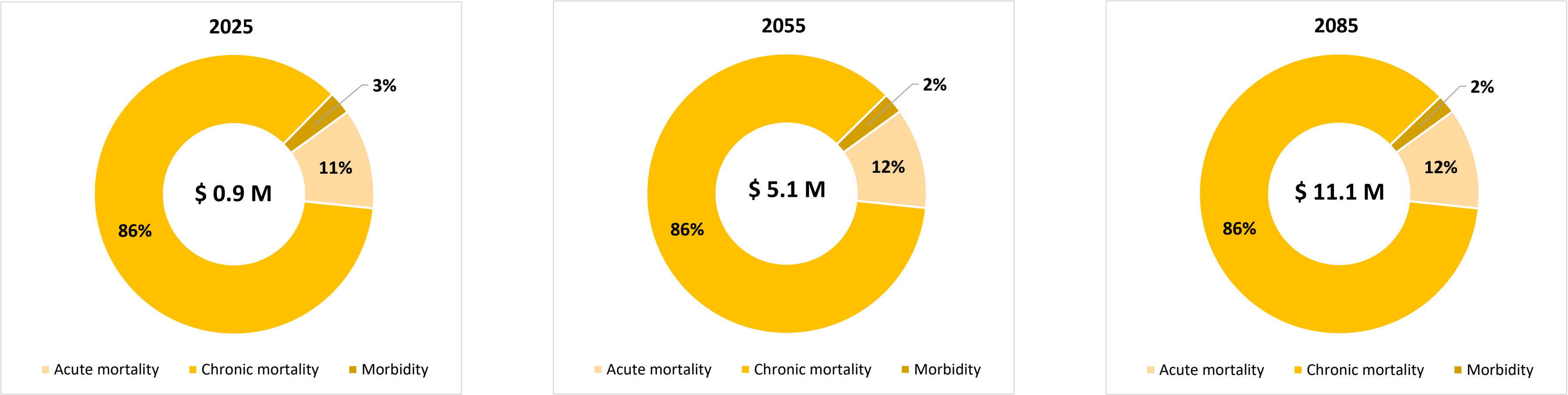


Figure 10: Projected direct annual intangible (welfare) losses from mortality and morbidity attributable to wildfire smoke exposure



All One Sky

FOUNDATION

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