Supplementary Materials

SP1 - IPCC AR6 Climate Projections

In the IPCC AR6 report, climate models participating in the latest Inter Comparison Project of Coupled Models (CMIP) – Phase 6 of the World Climate Research Program are evaluated. CMIP6 results include better representation of physical, chemical, and biological processes, and higher resolution compared to previous assessments. The scenarios created for the AR6 report are divided into five (5) Shared Social Pathways (SSPs) to illustrative emission scenarios based on a reference period (Baseline) 1850-1900. These pathways represent optimistic or pessimistic alternatives in GHG emissions. Emissions vary in scenarios depending on socioeconomic assumptions (e.g., development trajectories, technology, population), climate change mitigation levels, aerosols, non-precursors of methane and ozone, and pollution control.
The AR6 report scenarios are divided into short-2021-2040 (beginning), medium-2041-2060 (middle) and long-term-2081-2100 (end of the century):

1) High (SSP3-7.0) and Very High (SSP5-8.5) scenarios – double CO_2 emissions compared to baseline levels.
2) Intermediate (SSP2-4.5) scenario – same level from baseline to the middle of the century.
3) Low (SSP1-1.9) and Very Low (SSP1-2.6) scenarios – CO_2 emissions begin to decline reaching zero net emissions in 2050, varying to negative emission levels by the end of the century.

Regardless of the scenario, global surface temperature will continue to rise until at least mid-century. Future emissions add to the current warming of the planet, which is dominated by past and future emissions. The contribution of rising temperatures increases differently depending on emissions. The most pessimistic scenario raises almost 140 $GtCO_2$/year in emissions, and the scenario of strong mitigation shows negative balance of emissions from 2050 on. It is worth remembering that CO_2 emissions are dominant over other GHGs.

CMIP6 – North America
In CMIP6 Ensemble the Arctic region of North America has been divided into Arctic Northwest and Arctic Northeast. The resolution of these projections considers a grid of roughly 155 km x 155 km. The number of CMIP6 models used for each variable analyzed in these regions can vary from 33 to 26 models. Maps and data presented hereafter are the averages of these.
Below we describe CC mean model results for the CMIP6 Very High SSP5-8.5 warming scenario compared to the baseline and combined for the Arctic regions of North America. We include the following Climate and Physical variables in our analysis – **Figure 1**:

- Mean temperature (T) increase up to **+10.9°C**
- Minimum temperature (TN) increase up to **+12.2°C**
- Maximum temperature (TX) increase up to **+10.5°C**
- Mean Precipitation (PR) increase up to **+45.2%**
- Maximum one day (RX1-day) increase up to **+46%**
- Maximum five days (RX5-days) increase up to **+40.8%**
- Standardized Precipitation Index for six months (SPI-6[1]) increase change up to +**172.5%**
- Snowfall Precipitation (SF) decrease up to **-1.3%**
- Sea-ice Concentration (SIC) decrease of up to **-57%**

The uncertainty in the AR6 quantitive modeling results related to natural hazards for both regions is expressed in the following terms:

[1] Standardized Precipitation Index (SPI) is used index to characterize meteorological drought on a range of timescales. The SPI can be compared across regions with markedly different climates. It quantifies observed precipitation as a standardized departure from a selected probability distribution function that models the raw precipitation data. It does not include evapotranspiration data. The six months indicate that the index is calculated using a 6-month period (NCAR, 2021).

- High confidence increases in temperatures (mean, minimum and maximum), extreme heat, mean precipitation, river flood, heavy precipitation, sea level rise, coastal floods, marine heatwaves and ocean and lake acidity.
- Medium confidence increases for landslides, fire weather, coastal erosion, and coastal floods.
- High confidence decreases in frost, cold spells, aridity, snow, glaciers, ice sheets, permafrost, lake, river, and Sea-ice.
- Medium confidence decreases in Northeast North America for mean wind speed, relative sea level, snow, glaciers, and ice sheets.

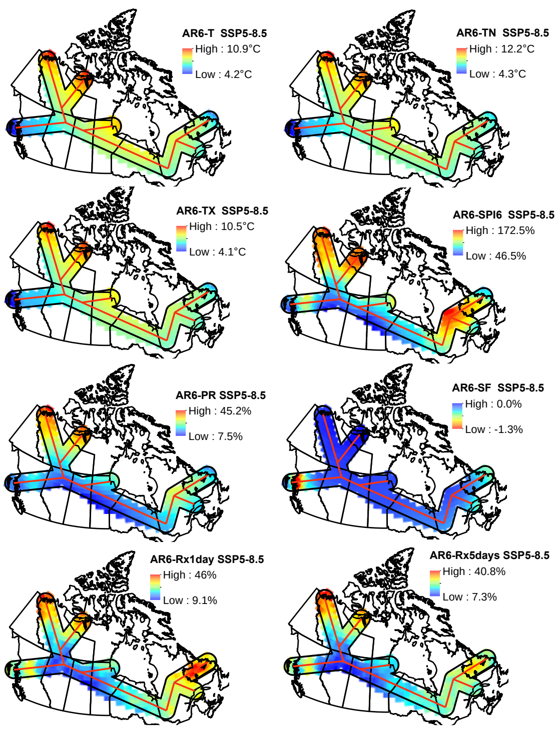

Figure 1 Annual warming map representation for CMIP6 SSP5-8.5 (rel. to baseline 1850-1900). Source: Adapted from CMIP6 Ensemble.

SP-2 AR5 Climate Projections

IPCC AR5

In the IPCC AR5 report the CMIP5 Ensemble projections are described as Representative Concentration Pathways (RCPs). These pathways represent GHGs mitigation scenarios associated with GHG concentrations in the atmosphere by the end of the century (2100). The RCP2.6 represents a low emission scenario with declining emissions trends; RCP4.5 represents a stabilizing scenario, and RCP8.5 represents a high emission scenario with no declining trends.

CMIP5 – Northern Canada

To explore CC data and projections specific for Northern Canada we downloaded climate variables in GeoTIFF format from the Canadian Center for Climate Services[2]. These datasets consist of statistically downscaled data derived from 24 climate models (CMIP5 Ensemble) using the RCP8.5 scenario. This scenario is representative of a high carbon pathway (IPCC AR5, 2014). The resolution of the Ensemble projections for the 1950-2100 period considers a grid of 10 km x 10 km for all of Canada. To acquire the Standardized Precipitation Evapotranspiration Index (SPEI)[3] we downloaded data for the landmass of Canada with a 1 km x 1 km degree grid resolution selecting the 12-month time scale. The SPEI results should be interpreted as a relative measure of surface water surplus or deficit with respect to hydroclimate conditions of the reference period 1950–2005 (Government of Canada, 2021). Maps and

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[2] Climate Data Extraction Tool.

[3] Standardized Precipitation Evapotranspiration Index data.

data presented hereafter are the averages of CMIP5 Ensemble for the RCP8.5 High Carbon Pathway during the 2081-2100 period. We consider the 50th percentile values (mean range). Values are representative of the proposed CNC and are described below –

Figure 2:

- Mean temperature (T) increase up to **+9.2°C**
- Minimum temperature (TN) increase up to **+9.8°C**
- Maximum temperature (TX) increase up to **+8.6°C**
- Mean Precipitation (PR) increase up to **+37%** increase
- Standardized Precipitation Evapotranspiration Index (SPEI) for twelve months (SPI-12) from **-0.8** to **+0.4** (SPEI[4] values)
- Surface Wind (SFC) from **-4.6%** to **+8.8%**
- Sea-ice Thickness (SIT) decrease up to **-100%**
- Snow Depth (SND) decrease up to **-96.9%**
- Sea-ice Concentration (SIC) decrease up to **-40.1%**

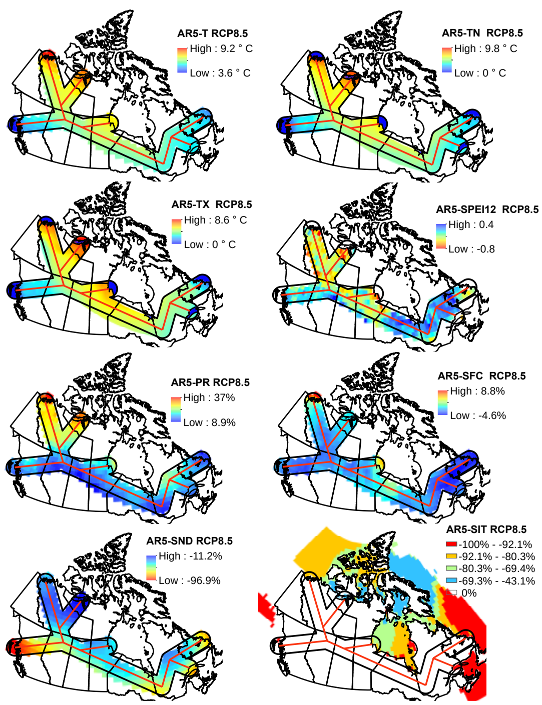

Figure 2 Climate Change mean values for selected variables CMIP5 RCP 8.5 2081-2100 scenario.
Source: Adapted from CMPI5-Ensemble.

SP-3 Codes and Standards

Since 2012 the SCC has formed a Northern Advisory Committee on adaptation codes and standards to help and guide the NISI on developing innovative solutions. This initiative addresses unique infrastructure vulnerability challenges from Northern regions. The committee is formed of representatives from the Northwest Territories, Nunavut, Yukon, and Nunavik. The committee decides which CC impacts and infrastructure need pressing attention. It also reviews and adapt new codes and standards to infrastructure projects and development plans (SCC, 2021[5]).

[4] The SPEI works like the SPI, the difference is that the SPEI considers the effect of Precipitation Evapotranspiration (PET) on drought severity is that its multi-scalar characteristics enable identification of different drought types and impacts in the context of global warming. The twelve months indicate that the index is calculated using a 12-month period (NCAR, 2021).

[5] SCC forms Northern Advisory Committee on Adaptation Codes and Standards.

SP-4 Approaches on CC Cost Calculation for various transportation infrastructures worldwide

Roads

Roads represent a support for economic and agricultural livelihood and indirect benefits, including access to healthcare, education, credit, and governance. Roads may be scarce through geographic regions, making each road critical, especially in Northern Canada. Extreme weather events increase hazard incidence on roads in terms of degradation, necessary maintenance, and potential decrease in lifecycle due to climate impacts. CC poses costly impacts in terms of maintenance, repairs, and lost connectivity, yet many of these impacts can be mitigated and avoided by proactive adaptation measures (Schweikert et al. 2014). In general studies look at the impact of temperature, rain, snow/ice, wind, fog, and coastal flooding on roads. Specific tools designed to analyze CC costs such as the CC Adaptation Tool for Transportation (CCATT) from Oswald et al. 2012 requires detailed input from local administrators which can be challenge when analyzing large geographical regions such as the CNC area.

CC and infrastructure impacts on roads were assessed by Schweikert et al. (2014) using opportunity cost[6]. These authors compared the CC impact on roads infrastructure in ten countries through 2100. They explore the allocation of roadstock inventory and the analysis of climate impact on the roadstock including temperature and precipitation data along with climate scenarios. Three different types of road inventory are included: paved, gravel and dirt, and impacts are determined per kilometer of road. Their analysis uses an Infrastructure Planning Support System (IPSS). This software tool combines engineering and materials-based stressor-response functions to determine the impact of climate on maintenance, repair, and construction costs. The tool quantifies the effects of both extreme events and incremental CC on road infrastructure. It identifies the financial cost yearly through 2100, allowing users to compare proactive[7] adaptation measures and reactive non-adaptation[8] measures. Impacts are determined based on civil engineering materials, field studies of tangible impacts on roads and buildings, and other data. Finally, it computes the cost of these impacts due to maintenance increases and/or construction costs. Reactive and proactive approach results provide fiscal costs, the opportunity cost, and a "regret"[9] metric results.

Results of this study shows that higher income countries have more significant dollar costs due to the extensive road networks and that proactive adaptation is less expensive than a reactive no adapt approach on a median and maximum scenario in 2050-2100. For i.e., in Italy the adapt regret for 2050 and 2100 is $1.5 billion while the no adapt regret is $9.6 billion and $58.2 billion for 2050 and 2100, respectively. For these authors CC poses long-term threat to viability and durability of roads incremental changes in surface condition and use and that adapting to climate impacts can reduce at a large-scale the lifecycle costs.

Energy Transmission and Telecommunications

Common costs associated with energy transmission and telecommunications grid can include interruptions, repair, replacement, operation, maintenance, and loss of capacity. CC cost studies on this infrastructure type were developed by Fant et al. (2020) at the US scale. This study uses a similar framework to Schweikert et al. (2014). In their analysis, physical infrastructure impacts are translated to economic impacts by estimating the costs associated with identified damages. The climate-driven stressors used in the study include temperature, precipitation, lightning, wildfires, and vegetation growth. Their methods included engineering cost analysis by calculating the net present value of repair or replacement costs to infrastructure, changes to the operation, maintenance costs and interruption costs. Moreover, it is important to capture key features of a changing grid to adequately estimate future CC impacts[10]. The Replacement costs used in this study are based on the cost of design and construction of new infrastructure, whereas the Interruption costs were

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[6] Metric which relates the cost of CC impacts to the country's existing road infrastructure.

[7] Incorporates measures to make the road infrastructure resilient to climate impacts by changing specific elements during the design and construction. The adapt strategy performs upgrades on the design standards of the roads to increase resilience to stressor impacts.

[8] Does not consider the future climate change impacts. Instead, any impact of climate change will be addressed by increasing the maintenance, often leading to a higher frequency of maintenance and repair works.

[9] Evaluates the risk of climate change in absolute value of money that could be lost. There are two components: "adapt regret" and "no adapt regret". The adapt regret value is the amount of money lost if a proactive adaptation policy is followed, but no climate change occurs. The no adapt regret metric evaluates a scenario where a reactive policy was taken, yet climate change occurred as predicted in the model.

[10] In some places, the transmission and distribution grid may contract in size due to the deployment of distributed energy resources (e.g., rooftop solar and batteries) (Fant et al. 2020).

estimated using the Interruption Cost Estimator (ICE) model. The ICE model is a tool commonly used by utilities and regulators to estimate the impacts of choke points on transmission flow.

According to the study, without CC, total annual expenditures for these infrastructure types would be around $95billion/year by 2090. Under the most extreme CC scenario emission scenario (RCP8.5), expenditures would roughly be double compared to a median level emission scenario (RCP4.5). At the US national level, reductions in the lifespan of substation transformers and increases in vegetation management expenditures represent the costliest impact categories (65%), but at the regional level, wildfire damage and impacts to substations due to sea-level rise and storm surge are more significant. The highest infrastructure impacts in 2090 (RCP8.5) indicate costs that are $11 billion/year higher than those associated with median impacts in 2090 (RCP4.5). With a Proactive Adaptation strategy, this high-median difference decreases to only $6 billion/year, highlighting the importance of timely adaptation for reducing the magnitude as well as the variability of infrastructure impacts. The net present value of total costs of CC impacts ranges from $120 to $380 billion through 2099 when using a discount rate[11] of 3%.

Railways

A study by Neumann et al. (2021) with an analogous framework from Fant el. (2020) and Schweikert et al. (2014) looks at the climate effects and costs on US infrastructure adaptation for rail, roads, and coastal development. The authors use median and high RCPs emission scenarios along with several climate models considering temperature, precipitation, sea-level-rise (SLR) and storm surge (SS) variables. Costs for these three infrastructure modals consider three policy options: business as usual, reactive, and proactive action for mitigation and adaptation. The authors also include indirect costs by utilizing user costs, adding an important dimension to evaluate adaptation options. The indirect costs have been identified as important omission for climate impact on rail and road systems studies (Wang et al. 2020). All analyses developed by these authors reflect adjustments over time for population and economic growth, including adjustments to traffic volume for rail and road sectors, and adjustments to property value for coastal properties.

To calculate rail costs under CC scenarios using inventories and climate variables Neumman et al. (2021) have considered the estimation of repair and delay costs in a business-as-usual scenario in which operators do not reduce speeds when temperatures increase, resulting in an increased risk of track buckling. There is also a potential for track buckling to cause train derailment, but recent literature suggests that less than four percent of derailments are caused by buckled track. In the case of reactive and proactive responses on costs the authors have estimated adaptation and mitigation costs by implementing “blanket” speed restrictions during periods of high temperature to avoid track buckling events, and track temperature sensors installation to optimize speed restrictions (Neumann et al. 2020; Chinowsky et al. 2017; Liu, Saat and Barkan, 2012). For i.e., costs of repairing damage associated with buckling events, includes (1) costs of replacing track to repair lateral alignment defects in the buckling zone and (2) costs of re- aligning rail in adjoining zones. To calculate passenger rail cost, Neumann’s et al. study assume that passengers would de-board trains that are stopped due to a buckling event and find an alternative mode of transportation to reach their destination, with an estimated total delay time of 8 h. To quantify the costs of passenger delay, they relied on the U.S. DOT’s 2016 guidance for the valuation of travel time in economic analysis. The calculation of these policy alternatives uses three functions that include railway inventory information and CC data.

Results from Neumann’s study shows that for three infrastructure modals under RCP8.5 scenario at a business-as-usual perspective, costs are projected to soar to $100 billions annually at the end of the century (2090-2100). With reactive response costs are reduced by a factor of 10, and with a proactive response total costs under the three sectors decrease to a the low $10billions annually. The railway sector sees a large increase in costs by the end of the century under the business-as-usual scenario with buckling events projected to increase leading to repair and delay costs. In the proactive scenario, the effectiveness of the risk-based speed orders dramatically reduces the delay cost compared to the Reactive Adaptation scenario blanket speed order. Costs in the Proactive Adaptation scenario are roughly an order of magnitude lower than costs in the Reactive and business as usual scenarios. In 2050, the Proactive Adaptation scenario has an average annual savings of $5.40 and $5.00 billion compared to the No Adaptation and Reactive Adaptation scenarios. By

[11] The discount interest rate is used in discounted cash flow (DCF) analysis to determine the present value of future cash flows.

2090, those savings increase to $7.80 and $5.90 billion annually. Proactive savings are driven by the large reduction in buckling events and a reduction in speed-order delay costs from a risk-based approach to speed orders. In addition, costs under RCP8.5 are five times higher than costs under RCP4.5 by the end of the century, and two to three times higher in the mid-century period (Neumann et al. 2021).

Ports/Coastal Infrastructure

Neumann's study on coastal infrastructure costs used 1-degree gridded SLR projections from Sweet et al. (2017) considering RCPs scenarios. To calculate SS[12], the authors used historical tide gauge measurements, which allow direct estimation of SS. They extracted the maximum daily water level from each record, and de-trended the resulting set of maximum gauge heights from each time series, then they calculated a distribution of SS heights by fitting a generalized extreme value distribution to the annual maximum time series from each gauge, providing an estimate of the surge heights associated with return intervals from 2 to 500 years. Tide gauges with less than 10 years of data were excluded. Tide gauge stations were matched to municipalities using proximity and topography (Neumann et al. 2021). In terms of cost calculation Neumann's study compared the cost of different adaptation options within each cell to the expected reduction in costs that would result from those adaption options. The method's decision rule is based on an estimate of the cost of expected annual damages (EAD) and expected annual benefits of adaptation (EAB). EAB is the avoided damage cost given the assumption that adaptation will prevent damage for events up to and including the current 100-year flood. In its simplest form, the decision rule implements the lowest cost adaptation option.

The coastal adaptation scenarios include:

a) No Adaptation scenario, where no protective measures are implemented to avoid the impacts of SLR and SS. If the costs of damage associated with SS exceed the value of the property, the authors assume that the property owner abandons the property. The costs include the property values of abandoned properties and the structure damage from SS flooding (calculated as a percentage of the property value).
b) Reactive Adaptation scenario, property owners do not implement protective measures to avoid SLR impacts. They assume that the property owner evaluates whether to elevate the property to avoid future damage. This is done by multiplying the damage in the current year by 10 to estimate the decadal cost of damage. If the projected decadal cost of damage is greater than the property value, the property is abandoned. If the projected cost of damage is less than the property value, and less than the costs of elevating, then the property incurs the cost of damage. If the projected cost of damage is less than the property value, but greater than the costs of elevation, then the property elevates.
c) Proactive Adaptation scenario, protective measures are implemented to avoid damage from both SLR and SS. These measures include beach nourishment, armoring, elevation, and abandonment. In this scenario, costs include the property values of abandoned properties and the costs of all forms of protection where it is warranted

The results indicate that property costs rise steeply from 2050 to 2090 for No Adaptation scenario; they are five times higher for RCP8.5. under a Proactive Adaptation scenario, the annual costs only rise about $1.5 to $1.9 billion (about 30% for both RCPs) between the two eras. Differences between the Proactive and Reactive Adaptation scenarios are negligible in 2050, but by 2090, savings are much more apparent between the two, more than $20 billion per year under RCP8.5.

Polar Regions

CC Infrastructure Costs Calculations in Canada and Polar regions

General Infrastructure in Canada

Our literature review captured studies conducted in Canada and other Polar regions worldwide. For example, Boyle et al (2013) developed a literature review on CC Adaptation and Canadian Infrastructure. The literature review focused on how CC and hazards affecting a diverse set of infrastructures in Canada including a) land transportation (roads, railways, airports, runaways, and bridges) b) building infrastructure (public and private buildings) c) water infrastructure (dams, reservoirs, aquifers, hydroelectric generators), d) marine infrastructure (port, canals, docks, wharves, piers, seawalls) e) wastewater infrastructure (treatment facilities,

[12] Rising sea levels will increase the severity of flooding by raising the baseline water level over which storms and other high water level events create a surge.

culverts, sewers, storm drains, pipes). The study describes the three main factors that influence the sensitivity of infrastructure to climate hazards, namely: age, composition, and design, and investigate a series of previous infrastructure plans, programs, and reports for Canadian regions, including the Arctic exploring codes, standards, and related instruments for infrastructure. The instruments mainly include the PIEVC protocol and the Standards Council of Canada (SCC) northern infrastructure standardization. Boyle et al study also explored markets, financial incentives, and liability rules and industry responses linking infrastructure damage and cascading effects into socioeconomics using vulnerability frameworks. These frameworks provided climate hazard description or weathering processes likely to be affected by CC (including potential infrastructure impacts). Finally, the study of Boyle et al (2013) proposes adaptation strategies linked to technical, policy/legal, financial, socioeconomic, and institutional aspects considering reliable information on past costs, however outdated since most values are before 2010 or until 2013.

The report Investing in Canada's Future: The Cost of Climate Adaptation at the Local Level developed by IBC/IBAC (2020) provides a series of costs and numbers for damage caused by CC and hazards in Canada with important information on financial assistance, average annual losses, insured and uninsured losses and cumulative losses. The report disserts about the benefits of CC adaptation in Canada considering grey and green infrastructure and provide examples at the province and local levels of adaptation strategies. Climate impacts to public infrastructure include analysis on land transportation, buildings, water infrastructure, marine infrastructure, wastewater infrastructure. Flood, erosion, and permafrost melt are associated with the highest cost as a percentage of GDP at 1.25%, 0.12% and 0.37%, respectively. When considering the infrastructure perspective, buildings, dikes, and roads require the greatest investment in adaptation; they are associated with the highest costs as a percentage of GDP at 2.01%, 1.18% and 0.47%, respectively. Grey infrastructure has the highest average cost at 0.75%, green infrastructure has an average cost of 0.05% and soft infrastructure (or administrative action) has an average cost of 0.03%. From a regional perspective, Canada's East, at 3.20%, and North, at 0.37%, have higher average costs. The report also provides and overview of approach for assessment of climate adaptation costs.

The methods developed by Green Analytics in the IBC/IBAC (2020) report collected adaptation cost estimates for a variety of communities across Canada and housed those estimates in an adaptation cost database. Estimates were based on vulnerability and risk assessments done at the local level, usually by a municipality. Adaptation cost estimates were adjusted to allow them to be compared between communities and added up at the national level. each adaptation cost estimate includes location, such as province or territory; infrastructure type, such as buildings, green infrastructure, roads, and water treatment; and climate risk, such as drought, erosion, flood, heat wave and wildfire. Additionally, the gross domestic product (GDP) values were obtained or established and added to the database. The cost of adapting to climate change was then determined relative to the size of the local economy, expressed as a percentage of local GDP. The adaptation cost as a percentage of local GDP collected for each community within a region of the country (West, Prairies, North, Central, East) was analyzed to determine the average percentage for that region. The five regional percentages were then weighted by the region's respective share of the national GDP. Combined, these regional results were added together to obtain a national estimate of the cost of adaptation as a percentage of national GDP.

The costs of CC for Canada's Infrastructure (CICC, 2021) are a complete report on the impacts of CC and extreme weather related to Canadian Infrastructure. The report uses a series of methods and frameworks including modeling tools incorporating climate scenarios, and economic modeling to assess different infrastructure impacts on homes and buildings, roads and railways and electricity systems. Their methods are mostly influenced by USA literature and are explained qualitatively only, though quantitative modeling has been used. The report includes an in-depth analysis of climate risks for each infrastructure type in Canada including description of known and unknown impacts. The models are used to assess costing climate related infrastructure damage and uses two types of inputs: infrastructure information and climate hazards data including climate models and scenarios. Each infrastructure type has its own specific model to calculate costs. Moreover, authors also developed a model to project the benefits of adaptation. They develop the idea of proactive investment in infrastructure adaptation as the most cost-effective way to protect services. They assume that not all impacts and costs of CC on infrastructure can be quantified – such as the loss of services and reliability. Finally, they suggest that poor or lack of climate information, transparency and regulation is leading to bad infrastructure decisions.

Polar regions worldwide

Coastal Erosion

In an international and polar perspective Min Liew et al. (2020) developed a study on the prevention and control of measures for coastal erosion in northern high-latitude communities: a systematic review based on Alaskan case studies. These authors describe general challenges of construction in northern latitudes grouped into three main categories: geographic challenges, engineering challenges, and socio-economic challenges. They describe how coastlines dynamics are affected by permafrost, erosion processes caused by ice features, extreme weather, and CC influences. They look at available techniques categories of erosion control status including techniques tested in the northern high-latitude regions using structural and non-structural erosion measures and explore structural erosion measures and erosion controls to detect failing or successful cases. Furthermore, the study compares types of materials to rates of erosion, the proportions of various types of measures and materials to detect which were most frequently employed and which measures and materials were mostly effective. To calculate CC costs Min Liew et al. (2020) use the life cycle cost analysis (LCCA), which is a quantitative approach that selects optimal measures based on their total costs over the life cycle. This technique has been the primary framework used by USACE and construction companies. The total cost in LCCA includes the initial construction costs, annual maintenance and repair costs, operating costs, and inspection costs. However, these authors indicate that analyses based on merely the total costs may not be adequate and the environmental impacts should also be considered. Recently, the life cycle assessment (LCA), which assesses environmental performance and impacts of a measure over its life cycle, including raw material extraction, manufacturing, use, disposal, and recycling, are of rising interest in civil engineering.

Permafrost

A study by Hjort et al. (2018) explores how degrading permafrost puts Arctic infrastructure at risk by the mid-century. These authors identify unprecedentedly high spatial resolution infrastructure hazard areas in the Northern Hemisphere's permafrost regions under projected CC and quantify fundamental engineering structures at risk by 2050. This is an in-depth study with important insights and vulnerability zoning for the CNC work where they consider that different stabilization scenarios of climate warming reveals that substantial cuts in global greenhouse gas (GHG) emissions now would not make a large difference for infrastructure risks in the highest hazard area by 2050. The authors mention that nearly the same number of buildings, roads, and other infrastructure would be jeopardized under moderate climate warming (RCP2.6) as compared to a pessimistic, business-as-usual scenario (RCP8.5). They also describe that damage to infrastructure can be caused by anthropogenic factors, such as human-induced disturbance of the ground thermal regime and poor maintenance. Although engineering solutions (e.g., adaptation strategies and structures such as insulation and thermosyphons that were not considered in the pan-Arctic study) can to some extent address both human-induced and naturally caused problems, their economic cost may be prohibitive at regional scales. The methods used in this study unfortunately did not include cost calculation. They included a) ground temperature and active layer data, b) geospatial environmental data, c) infrastructure, d) population and hydrocarbon extraction fields, e) statistical analysis, f) a geohazards indices including four indices (settlement index, risk zonation index, analytic hierarchy process (AHP) based index and a consensus of the former indices) depicting zones of hazard potential for infrastructure for periods 2041–2060 and 2061–2080 under three RCPs, and finally g) infrastructure and hazard computations.

Another study by Suter et al. (2019) asses the cost of CC impacts on critical infrastructure in the circumpolar Arctic including Canada. These authors study estimates the costs of fixed infrastructure affected by CC impacts in the Arctic region. Geotechnical models are forced by climate data from six CMIP5 models and used to evaluate CC changes between the decades of 2050–2059 and 2006–2015 under the RCP8.5 scenario. To model infrastructure costs and CC Suter et al (2019) included the value of roads, railroads, pipelines, (per km), ports, and airports (per unit) was obtained from Larsen et al. (2008) and adjusted for inflation to 2017 US dollars ($). The value of infrastructure was assumed to remain constant throughout the timespan of the study. Country- level variations in infrastructure value were accounted for using country-specific comparative price levels (OECD, 2018) as multiplication factors. The changing infrastructure lifecycle replacement costs from the present period to the future period were estimated following the approach of

Larsen et al. (2008). The baseline annual cost of replacing infrastructure was calculated by dividing each infrastructure type's cost per unit by each infrastructure type's designed useful lifespan. The adjusted annual cost was calculated using the same formula, but with each infrastructure's useful life adjusted for CC. The ratio used to calculate infrastructures adjusted useful life was based on relationships between permafrost extent and projected air temperature increases, established by Larsen et al. (2008).

Suter et al (2019) also used stressor-response models where each infrastructure type is associated with specific environmental hazards that impact it - in this case those hazards relevant to the Arctic context - and the cost of addressing their impacts. Damages, set equal to the replacement cost of infrastructure, were quantified using engineering & material science validated relationships between each infrastructure type, and the stressors associated with projected climate change, after given thresholds are crossed. The thresholds in this study were based off previously established research when available (Larsen et al., 2008; Melvin et al., 2017). Results indicate that buildings and structures account for 67% of the total value of infrastructure assets, while roads account for an additional 17%. Railroads and pipelines account for about 5% each, while airports and ports combine for another 5%. Buildings account for 41%, roads 37%, airports 36%, and ports 23% of infrastructure values in Canada. Baseline Lifecycle Replacement Costs by 2059 in Canada are estimated in $12,865.02 ($ Millions), with CC forcing increasing these values to $17,190.46. By 2059 Canada is projected to incur $4.33 billion, which represents a 33.6% increase from baseline lifecycle replacement costs and 28.0% of total increased costs. The Yukon and the Northwest Territories are projected to be the most affected. The ability of regional budgets to absorb these increased costs is tied to their economic prosperity, which is often measured in gross regional product (GRP). The mean annual costs to address increased lifecycle replacement costs and direct damages due to CC exceed 3.7% of annual GRP in Yukon. This figure lies at 1.5% and 1% of GRP for the North-west Territories and Nunavut. These ratios may seem low, but the sums become consequential when considered in relation to government spending, or the contribution of individual industries to GRP (Suter et al. 2019).

SP-5 Data Collection

Data Collection

We start by collecting data on the frequency of infrastructures available in the CNC area considering data from Statistics Canada available in points or lines format on a GIS environment (2018). We selected several infrastructure features that are pertinent for this study regarding transportation, energy transmission/communications and built infrastructure. Below **Table 1** shows the number of these infrastructures within the corridor area for each province. In general, the bulk of infrastructures in the CNC are mostly concentrated in Québec, British Columbia, Alberta, Ontario, and the Northwestern Territories respectively. We also divided the frequency analysis in lines and points information:

Point Information

- Airport Structure
- Antennas Frequencies
- Buildings
- Community Center Structures
- Fire Stations
- Food Court Structures
- Gas and Oil Structures
- Gas Stations
- Government Buildings
- Ground Satellite Structure
- Health Care Centers
- Health Emergency Centers
- Marina Structure
- Mining Areas
- Police Services
- Ports
- Power Plants
- Radio Stations
- Retail Stores
- Seaplane Base
- Towers
- Transformers Stations
- Transportation Stops
- Water Structures
- Water Transport Structures
- Weight Stations
- Wind Operated Stations

Lines Information

- Aerial Cables
- Ferry connections
- Major Roads
- Pipelines

- Rail Transit Structure
- Roads
- Runways
- Transmission Lines

Regarding the Lines information, the total frequency for these infrastructures is of **15,634** for the CNC area, and for the points information the total frequency for these infrastructures is of **4,608**. Frequency of lines is more important for Québec, Northwestern Territories, British Columbia, and Ontario respectively. For Points information the frequency is higher for British Columbia, Alberta, Quebec, and Ontario. The warm colours in the tables below indicate the highest numbers and the cold colours the lowest numbers.

LINES CNC 200km Buffer Area

Quebec	Northwest Territories	British Columbia	Ontario	Alberta	Manitoba	Saskatchewan	Newfoundland and Labrador	Yukon Territory	Nunavut	Total
3356	2897	2552	2455	1673	1499	709	429	33	31	15634

POINTS CNC 200km Buffer Area

British Columbia	Alberta	Quebec	Ontario	Northwest Territories	Manitoba	Saskatchewan	Newfoundland and Labrador	Nunavut	Yukon Territory	Total
956	825	808	496	385	296	147	129	22	4	4068

Table 1 Frequency of Infrastructure features in the CNC area for all provinces. Warm colours represent highest numbers, cold colours represent the lowest numbers.

CNC 200km Buffer Area

Infrastructure Feature	**AB**	**BC**	**MB**	**NL**	**NT**	**NU**	**ON**	**QC**	**SK**	**YT**
Air Transport Structure	77	58	41	12	50	4	49	45	25	2
Antennas Frequencies	25176	21392	2245	1916	3826	155	5594	11107	1080	6
Buildings	881	1554	319	304	171	4	2306	2516	74	2
Community Center Structure	96	189	8	11	33	0	73	124	2	0
Ferry Connections	2	28	300	25	64	0	157	19	5	0
Fire Stations	16	60	3	3	1	0	15	135	0	0
Food Court Structure	185	282	43	38	33	0	146	485	29	0
Gas and Oil Structures	45	87	0	1	1	0	9	0	0	0
Gas Stations	97	165	22	12	5	0	81	181	7	0
Government Buildings	187	384	114	111	719	12	173	293	40	2
Ground Satellite Structure	0	0	0	3	4	0	2	0	0	0
Health Care Centers	505	730	149	56	95	1	436	572	33	0
Health Emergency Centers	166	205	58	30	70	0	113	307	24	0
Major Roads	3745	4763	684	473	990	0	3098	5474	677	0
Marina Structure	4	12	1	0	0	0	2	6	0	0
Mining Areas	0	15	7	0	1	0	52	67	1	0

Pipelines	204	305	1	2	39	3	93	29	0	0
Police Services	20	38	17	7	41	0	11	88	6	0
Ports	0	4	0	0	0	0	0	1	0	0
Power Plants	13	24	9	3	28	2	12	29	2	0
Radio Station	41	33	15	6	11	1	32	42	3	0
Rail Transit Structure	333	1451	661	184	67	0	1136	1124	29	0
Retail	89	129	39	17	27	1	83	127	6	0
Roads	39591	52648	7374	4119	12574	272	42424	61676	4243	101
Runway	5	16	20	2	27	2	37	26	6	0
Seaplane Base	2	6	8	0	1	1	20	15	4	0
Towers	195	149	96	49	66	8	244	412	24	0
Transformer Stations	18	14	10	8	6	0	27	16	2	0
Transmission Lines	141	264	208	79	56	0	316	725	43	0
Transportation Stops	61	156	98	1	2	0	138	64	0	0
Water Structure	12	54	6	1	5	0	10	0	1	0
Water Transport Structure	27	190	191	70	53	1	59	306	109	0
Weight Stations	6	7	2	0	2	0	3	7	0	0
Wind Operated Structures	21	0	3	0	0	0	0	0	0	0
TOTAL	**71961**	**85412**	**12752**	**7543**	**19068**	**467**	**56951**	**86018**	**6475**	**113**

Infrastructure Cluster Analysis

To verify how these data infrastructures (points and lines) are distributed spatially throughout the region we performed three analyses under a GIS environment using three ArcGIS 10.7.1 tools:

(1) Multi-Distance Spatial Cluster Analysis (Ripleys K Function): Determines whether features, or the values associated with features, exhibit statistically significant clustering or dispersion over a range of distances. When the observed K value is larger than the expected K value for a particular distance, the distribution is more clustered than a random distribution at that distance (scale of analysis). When the observed K value is smaller than the expected K value, the distribution is more dispersed than a random distribution at that distance.

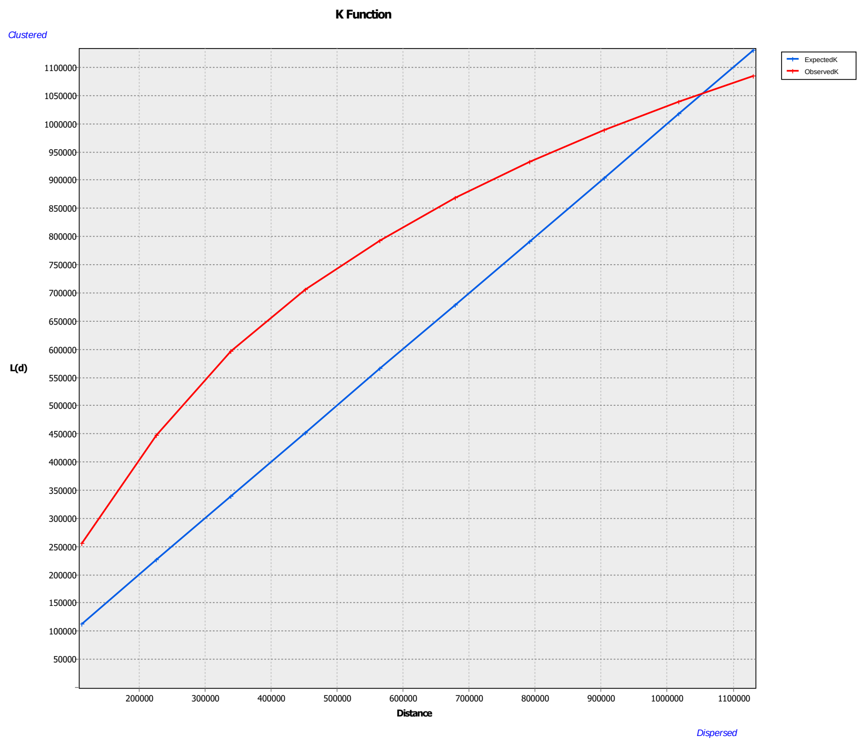

Figure-3 Multi-Distance Spatial Cluster Analysis (Ripleys K Function). Expected values are represented in blue and observed values are represented in red. The x-axis and y-axis represent the distance among the clustering points.

The results **Figure-3** and **Table 2** indicate that the distribution of points considering all the point infrastructures along the CNC area is more clustered than a random distribution at that distance (scale of analysis). This means that the clustering of infrastructures is higher than expected considering distances between 255-1,039km. After the 1,039km distance mark is reached, the clustering of infrastructures becomes more dispersed.

Table 2 Multi-Distance Spatial Cluster Analysis (Ripleys K Function) results throughout the CNC area including the expected, observed and the difference in the distances using the K function.

OBJECTID *	ExpectedK	ObservedK	DiffK
1	113	255	142
2	226	447	221
3	339	595	256
4	452	705	253
5	565	792	227
6	678	868	190
7	791	932	141
8	904	988	84
9	1,017	1,039	21
10	1,130	1,084	(46)

(2) Cluster and Outlier Analysis (Anselin Local Morans I): Given a set of weighted features, identifies statistically significant hot spots, cold spots, and spatial outliers using the Anselin Local Moran's I statistic. This tool identifies spatial clusters of features with high or low values. The tool also identifies spatial outliers. To do this, the tool calculates a local Moran's I value, a z-score, a pseudo p-value, and a code representing the cluster type for each statistically significant feature. The z-scores and pseudo p-values represent the statistical significance of the computed index values. A positive value for I indicates that a feature has neighboring features with similarly high or low attribute values; this feature is part of a cluster. A negative value for I indicates that a feature has neighboring features with dissimilar values; this feature is an outlier. In either instance, the p-value for the feature must be small enough for the cluster or outlier to be considered statistically significant.

(3) Hot Spot Analysis (Getis-Ord Gi*): Given a set of weighted features, identifies statistically significant hot spots and cold spots using the Getis-Ord Gi* statistic (**Figure 4**). This tool identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots). It creates a new Output Feature Class with a z-score, p-value, and confidence level bin (Gi_Bin) for each feature in the Input Feature Class (**Table 3**). The z-scores and p-values are measures of statistical significance which tell you whether to reject the null hypothesis, feature by feature. In effect, they indicate whether the observed spatial clustering of high or low values is more pronounced than one would expect in a random distribution of those same values. Features in the +/-3 bins reflect statistical significance with a 99 percent confidence level; features in the +/-2 bins reflect a 95 percent confidence level; features in the +/-1 bins reflect a 90 percent confidence level; and the clustering for features in bin 0 is not statistically significant.

The Getis-Ord local statistic is given as:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{S \sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j} \right)^2 \right]}{n-1}}} \quad (1)$$

where x_j is the attribute value for feature j, $w_{i,j}$ is the spatial weight between feature i and j, n is equal to the total number of features and:

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n} \quad (2)$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - \left(\bar{X}\right)^2} \quad (3)$$

The G_i^* statistic is a z-score so no further calculations are required.

Figure 4 Hot Spot Analysis (Getis-Ord Gi*) Equation. Source: https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/h-how-hot-spot-analysis-getis-ord-gi-spatial-stati.htm

Table 3 Hotspot Analysis thresholds for analysed variables. Values include low and high thresholds for ZScore and GiPValues.

Hot Spot Analysis Variable	GIZScore Low-Threshold	GIZScore High-Threshold	GiPValue Low-Treshold	GiPValue High-Threshold
Fires	-3.7	13.4	0	9.8
FP	-16.5	25.2	0	9.8
Rx1-day	-5.0	6.8	0	9.7
SCD	-17.3	3.9	0	9.9
Snowday	-14.8	4.45	0	0.9
TDD	-7.1	10.5	0	9.8

At **Figure 5** we illustrate the combination of lines and points infrastructures throughout the CNC area (top map). At the bottom right map, the cluster and outliers' analysis (2), and at the bottom left map, the hot spot analysis (3).

- The hot spot analysis results indicates that most important hot spots for lines and points infrastructures in the CNC area are concentrated in areas in southwestern Québec, central eastern Ontario, the Northwestern Territories (northeast and southwest), British Columbia, Saskatchewan, and the coast areas of Newfoundland Labrador.
- The cluster and outliers' results indicate that throughout the CNC area there are significant clusters of infrastructures in Québec, Ontario, British, Columbia, the Northwestern Territories and Saskatchewan. Low clustering in infrastructure is seen mostly in Alberta, Manitoba, western Ontario, and Eastern Québec. Outliers show how dissimilar these infrastructure types are. The outliers are most important in Alberta, Northeastern British Columbia, and Eastern Québec.

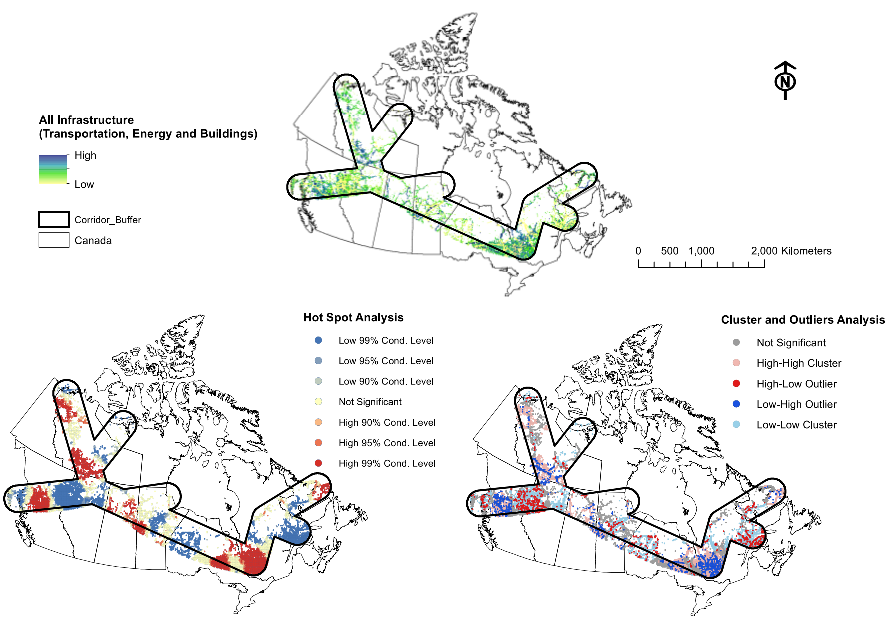

Figure 5 Top Map includes all lines and points infrastructure for the CNC area. Bottom map at the left includes the hot spot analysis results for the CNC area. The Bottom map at the right includes the cluster and outliers' results for the CNC area.

Population Data

We collected population data for the 200km buffer CNC area from the 2016 Population Census. According to this dataset there is a total of **726,140** people living within the buffer area in 2016. Higher Populations numbers are found in the districts of Wood Buffalo, Timmins, Sept-îles, Val-d'Or and Yellowknife respectively. Populations are mostly concentrated in the Québec southwestern and the Gaspé portions of the corridor, the Alberta southwestern area of the corridor, the central corridor areas of British Columbia, Southeastern areas of Ontario and mostly scattered in the other provinces and territories. The CNC buffer area population is considered relatively small considering that this corridor is expected to run through such extensive area and demand a high maintenance due to its northern location and climate related hazards**. Figure 6** indicates where these populations are concentrated within the CNC area.

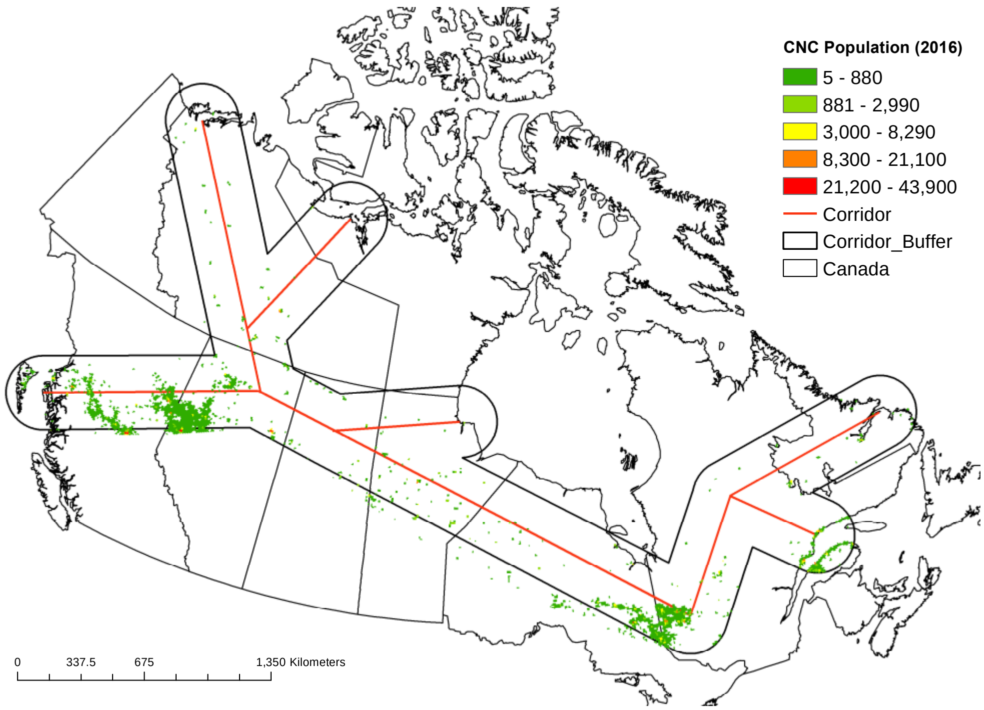

Figure 6 Total Population in the CNC 200km buffer area according to the 2016 Population Census. Source: StatCan Census, 2016.

Inventory Data on Infrastructures Cost

According to Statistics Canada (2020) capital expenditures on Canadian infrastructure totaled $93.3 billion in 2018. Over one-third of the total was attributable to transportation infrastructure ($33.1 billion) and Electric power infrastructure ($16.6 billion). Investment in electric power infrastructure was the largest contributor to infrastructure spending in Manitoba ($2.0 billion) and Newfoundland and Labrador ($1.4 billion). Of total capital spending on infrastructure, 77.0% was reported by public sector organizations. Private sector organizations accounted for more than 45.0% of infrastructure capital expenditures in Saskatchewan and Alberta, compared with an average of 16.8% in the rest of Canada. This was attributable to higher spending in these two provinces to support other transportation infrastructure (air, rail, water, and pipeline transportation).

To calculate CC Costs on infrastructure in the CNC area, we collected infrastructure data from several Canadian infrastructure cost inventories, focusing mostly on Statistics Canada sources. Unfortunately, a large part of the inventory data is at the national level, and it is not easy to find specific data at the local or regional/province level. Also, the data available has different dates depending on when the data surveys happened. For the most part, we collected costs data 2018 onward. These costs will be adjusted to inflation for 2021 during our final calculation steps and will include discount rates as necessary. To fulfill our methods requirements for different infrastructure types and the CC stress-response functions, we will perform adaptations and estimations from the scientific literature (whenever the Canadian inventory present gaps).

At the screening level we were able to identify two main infrastructure costs available for Canada in the Canadian Infrastructure Statistics Hub. We collected costs on investments[13] and stocks[14] (average age and remaining useful life ratio) for Alberta, British Columbia, Manitoba, and The Northwestern Territories. At **Table 4** a description of the data including the investment per sector (percentage - %), the average age remaining for each infrastructure segment, and the remaining useful life. Values from this inventory will be collected for calculations.

Table 4 Statistics Canada Inventory on investment costs and stocks per infrastructure sector

	Investment 2020 (%)			
	Alberta	British Columbia	Manitoba	Northwestern Territories
Commercial buildings	3	3.4	1.5	4.7
Institutional buildings	21.4	17.5	13.9	21.1
Marine engineering infrastructure	0.4	5.4	0.6	0.2
Transportation engineering infrastructure	32.7	23.9	33.1	51.3
Communications networks	3.6	4.5	4.4	0.5
Electric power infrastructure	17	27.5	34.4	14.1
Oil and gas engineering construction	11.9	9.1	0.3	0.2
Transportation machinery and equipment	1.4	2.1	1.7	0
Other machinery and equipment	1.8	0.5	1.5	0.9
	Average Age (years) 2020			
	Alberta	British Columbia	Manitoba	Northwestern Territories
Commercial buildings	10.5	11.1	13	13.7
Institutional buildings	14.9	15.8	16.3	16.9

[13] Investment means spending by businesses or governments during a given year for the purposes of construction of structures (airports, roads, etc.), purchases of equipment (locomotives, turbines, etc.) and improvements to existing facilities, all for future use in production during more than one year. In essence, investment is spending for the purposes of production in the future rather than for production today able 36-10-0608-01. Source: Infrastructure Economic Accounts, investment and net stock by asset, industry, and asset function (x 1,000,000 - https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610060801).

[14] The value of capital stock is estimated using the perpetual inventory method (PIM) whereby investment flows are accumulated and depreciated over time, giving rise to a stock of assets. In particular, the PIM uses a time series of investment flows, asset lives and prices, and assumptions regarding methods of depreciation and discard patterns when developing estimates of the capital stock. The value of infrastructure stock reflects the accumulation of investment over time minus retirements from the stock and the depreciation of that asset. The average age of the stock is compared to the average service life of that asset to determine the remaining useful life. Source: Infrastructure Economic Accounts, investment and net stock by asset, industry, and asset function (x 1,000,000 - https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610060801).

Marine engineering infrastructure	21.9	9.8	16.9	20.3
Transportation engineering infrastructure	8.7	11	9.9	9.3
Communications networks	10.4	9.4	8.3	7.7
Electric power infrastructure	14.7	14.8	13.5	17.8
Oil and gas engineering construction	12.1	10.1	12.2	24.9
Transportation machinery and equipment	10.3	10.5	10.6	14.7
Other machinery and equipment	9.4	9.3	7.6	7.1
	Remaining useful life 2020 (%)			
	Alberta	British Columbia	Manitoba	Northwestern Territories
Commercial buildings	61.3	59	51.9	49.2
Institutional buildings	60.1	57.5	55.9	54.7
Marine engineering infrastructure	22	64.8	39.5	27.3
Transportation engineering infrastructure	63.2	55.5	59.8	63.1
Communications networks	47.9	53	58.5	61.7
Electric power infrastructure	63.4	62.9	66.2	55.5
Oil and gas engineering construction	61	67.5	60.8	19.6
Transportation machinery and equipment	56.6	55	55.6	38.5
Other machinery and equipment	51.5	52.9	59.8	53.6

Drawing from these tables we can affirm that in 2020 **investments (%)** in infrastructure have been higher in British Columbia, followed by Alberta, The Northwestern Territories and Manitoba. Investments per sector were higher especially on,

a) transportation engineering infrastructure
   - British Columbia = $3,261M
   - Alberta = $3,968M
   - The Northwestern Territories = $244M
   - Manitoba = $1,082M

b) electric power infrastructure
   - British Columbia = $3,695M
   - Alberta = $2,063M
   - The Northwestern Territories = $67M
   - Manitoba = $1,126M

c) institutional buildings sectors
   - British Columbia = $2,383M
   - Alberta = $2,590M
   - The Northwestern Territories = $100M
   - Manitoba = $453M

In terms of the **remaining useful life of the infrastructures (%)** in 2020 British Columbia has the longest remaining useful life of infrastructures followed by Manitoba, Alberta, and The Northwestern Territories. The Remaining useful life is higher for,

a) electric power infrastructure

b) transportation engineering infrastructure
c) institutional buildings

The **oldest infrastructures (years)** in 2020 are in the Northwestern Territories followed by Alberta, Manitoba, and British Columbia. The oldest infrastructures include and are ranked by,
a) marine engineering infrastructure
b) institutional buildings
c) electric power infrastructure

A detailed description of the investments for each segment in $ millions in 2020 is available in **Table 5.** The warmer colours indicate where the investments have been the highest.

Table 5 Description of the investments for each infrastructure sector in $ millions in 2020. The warmer colours indicate where the investments have been the highest.

	2020 ($ millions)			
	Northwestern Territories	**British Columbia**	**Manitoba**	**Alberta**
COMMERCIAL BUILDINGS	**22**	**465**	**48**	**359**
Sports facilities with spectator capacity	4	47	19	259
Indoor recreational facilities	8	346	3	95
Student residences	0	1	0	0
Airports and other passenger terminals	7	69	26	3
Communications buildings	3	2	0	1
INSTITUTIONAL BUILDINGS	**100**	**2383**	**453**	**2590**
Schools, colleges, universities and other educational buildings	49	1305	204	1553
Hospitals	25	651	55	698
Nursing homes, homes for the aged	3	44	29	32
Religious centres and memorial sites	0	45	12	93
Museums	0	1	7	12
Historical sites	0	1	0	15
Libraries	0	8	0	4
Public security facilities	23	329	147	183
MARINE ENGINEERING INFRASTRUCTURE	**1**	**731**	**18**	**48**
Seaports	0	559	13	0
Marinas and harbours	0	143	3	18
Canals and waterways	1	8	2	28
Other marine infrastructure	0	21	0	2
TRANSPORTATION ENGINEERING INFRASTRUCTURE	**244**	**3261**	**1082**	**3968**
Highway and road structures and networks	191	2629	449	2045
Bridges	51	118	537	1479
Tunnels	0	0	0	4

Railway lines	0	498	71	433
Runways	3	15	24	7
COMMUNICATIONS NETWORKS	**3**	**608**	**145**	**435**
Cables and lines - coaxial, copper, aluminum, etc.	1	94	45	132
Optical fibre	1	183	58	169
Transmission support structures	0	59	25	104
Other communication construction	0	272	18	30
ELECTRIC POWER INFRASTRUCTURE	**67**	**3695**	**1126**	**2063**
Wind and solar power plants	0	27	0	183
Steam production plants	23	2	2	106
Nuclear production plants	0	0	0	0
Hydraulic production plants	23	2531	737	1
Power transmission networks	5	418	196	684
Power distribution networks	16	715	192	1076
Other electric power construction	0	2	0	14
OIL AND GAS ENGINEERING CONSTRUCTION	**1**	**1240**	**11**	**1446**
Pipelines	1	1240	11	1446
TRANSPORTATION MACHINERY AND EQUIPMENT	0	290	55	166
Buses	0	133	17	75
Locomotives, railway rolling stock, and rapid transit equipment	0	157	38	91
OTHER MACHINERY AND EQUIPMENT	**4**	**71**	**48**	**222**
Turbines, turbine generators, and turbine generator sets	0	34	0	37
Nuclear reactor steam supply systems	0	0	0	0
Water treatment equipment	3	21	18	122
Power and distribution transformers	1	16	30	63