Technical Design Requirements Climate Resilience Study for Alberta Infrastructure

Final Report

Contract #033732

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Executive Summary

Mission Green Buildings has been commissioned to conduct the research and analysis presented in this report which assesses Alberta Infrastructure's Technical Design Requirements (TDR) and makes recommendations to improve the document's resilience to climate change. The aim is to help understand the TDR's relevance in the face of climate change and to assess the document's ability to contribute to Alberta Infrastructure's strategic climate leadership goals and initiatives.

To support the TDR recommendations, analysis of the energy and water use associated with typical buildings located in various locations in the province is conducted for two climate change scenarios. Results show that total energy use is decreasing for all buildings, in all locations as the temperature warms throughout the century. The reduction in heating degree days (HDD) associated with increasing temperatures is forecasted to result in a northward shift of climate zone boundaries, resulting in each of the studied locations crossing at least one zone boundary by the end of the century.

Even with energy reductions associated with the warming climate, the baseline archetypal buildings in the study are not capable of achieving net-zero energy status, since there is not enough roof area for PV to offset modeled energy loads. Even when basic building design parameters are optimized for energy efficiency in a parametric study, only the school building in Medicine Hat can achieve net zero energy. All other buildings must undergo further design alterations to improve the energy efficiency and/or increase the capacity of PV.

Analysis of future precipitation levels shows that, without taking storage limitations into account, there is sufficient volume of water to offset municipal sources for non-residential buildings if high efficiency fixtures are used. Although water consumption in residential buildings is too high to be supplied with captured precipitation, 65% of the wastewater stream is made up of greywater suitable for re-use once building codes allow for it.

Given these insights, and our knowledge of sustainable building practices, we make several recommendations to improve the TDR document to address resilience to climate change, net-zero energy targets, improved sustainability goals, water use reduction, and preparation for future retrofits. Overall, the TDR document is found to be written in language that lends itself to be adapted to account for changes in climatic conditions.

This final version of the report has incorporated extensive constructive feedback and comments from AI staff on the Draft report, for which MGB is most grateful.

Acronym	Full Text
CDD	Cooling Degree Days
CLP	Climate Leadership Plan
CMIP5	Climate Model Intercomparison Project #5
EUI	Energy Use Intensity
FTE	Full Time Equivalent
HDD	Heating Degree Days
HRV	Heat Recovery Ventilation
IPCC	Intergovernmental Panel on Climate Change
LEED	Leadership in Energy and Environmental Design
lpf	Litres per Flush
lpm	Litres per Minute
NZE	Net Zero Energy
PV	Photovoltaic
RCP	Representative Concentration Pathway
RCP4.5	RCP with Radiative Forcing Increase of 4.5 W/m2
RCP8.5	RCP with Radiative Forcing Increase of 8.5 W/m3
TDR	Technical Design Requirements
TEDI	Thermal Energy Demand Intensity
TMY	Typical Meteorological Year
UNFCC	United Nations Framework on Climate Change
USI	U-value, shown in SI units
WWR	Window to Wall Ratio

Contents

1.0 Introduction

As emission levels continue to rise, climate change is becoming a significant reality that countries and governments must actively prepare for. In Alberta, climate change has already started to create an impact on the province, with temperature profiles trending upwards and more frequent occurrences of unpredictable weather events. Federal, provincial, and municipal governments have adopted climate change strategies that require updates to building codes and technical design requirements. This report aims to provide evidence-based support for these updates.

Since the life span of buildings is often 50-100 years, it is not only important to evaluate their energy performance relative to the current weather, but also to investigate their performance throughout their life cycle with respect to the changing climate. Building design decisions also have an impact on performance, as they dictate the amount of energy that is required to maintain occupant comfort. The energy modeling portion of this study addresses the interrelated effects of building design and climate change for three Albertan cities.

Along with temperature, precipitation rates are also affected by climate change. To investigate the impacts of water restrictions in the future, this report examines the impact of fixture selection on the capability of buildings to be self-sufficient for water use in the context of climate change.

Mission Green Buildings is a sustainable building engineering consultancy with expertise in energy modeling and sustainable building certification. With this core competency, we provide building energy and water use modeling and analysis to inform a review of the Alberta Infrastructure Technical Design Requirements (TDR) document. The scope of the review is limited to the elements that are related to building energy and water consumption only. Cost analysis associated with the recommended changes is provided in a separate report.

The four specific aims of this study are:

1. An assessment of the adaptability of the Technical Design Requirements to Alberta's future climate,
2. An assessment of the readiness of the Technical Design Requirements to contribute to Alberta Infrastructure's strategic climate leadership goals and initiatives,
3. A prioritized list of recommended changes to the Technical Design Requirements to account for Alberta's future projected climate, and,
4. An assessment of the cost impact to capital projects for each recommended change to the Technical Design Requirements.

This report is organized into six main sections: literature review, methods, TDR recommendations, energy modeling results, water use and precipitation results, and conclusion.

2.0 Literature Review

This section provides contextual information about climate change in Alberta, definition of terms, a brief discussion of climate leadership efforts at the federal, provincial, and municipal levels, and context around building retrofit lifecycle analysis.

2.1 Climate Change

According to the Intergovernmental Panel on Climate Change (IPCC), climate change is defined as,

"A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use." (IPCC, 2012)

In contrast to this definition, the United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as,

"a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

The UNFCCC definition makes the distinction that the dominant cause of climate change is anthropogenic i.e. caused by human activity.

2.1.1 Alberta's Current and Projected Emission Levels

Figure 1 shows the distribution of emissions to several sectors of the economy. Emissions associated with buildings and houses is projected to increase by 35% between 2013 and 2030, from 21 Mt to 29 Mt. Improvements to building standards will contribute to reversing this trend of increasing emissions.

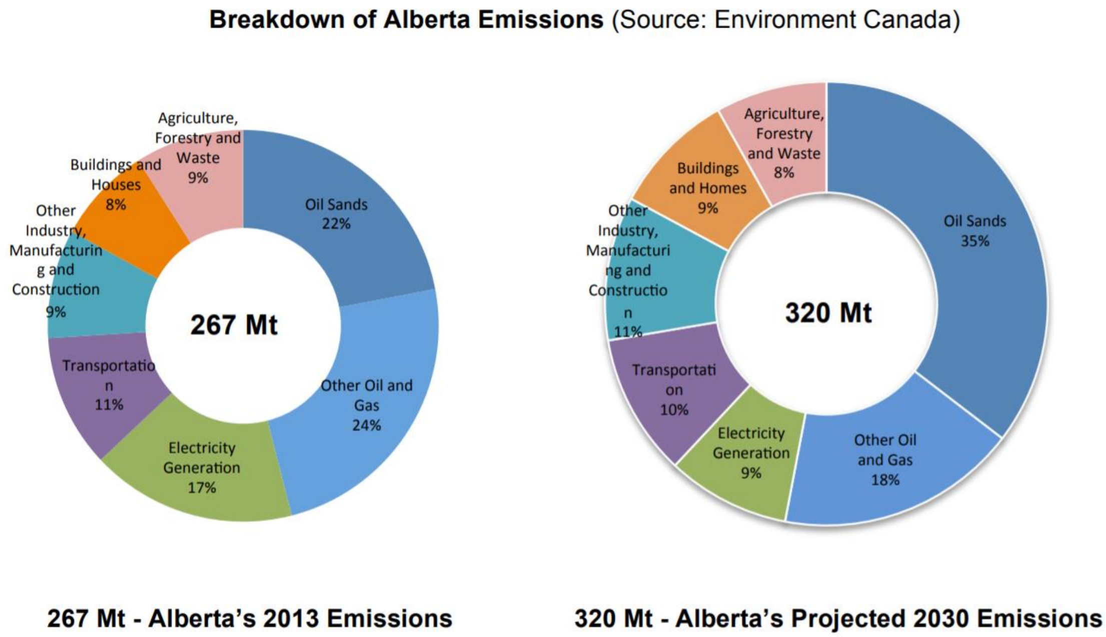

Figure 1 Alberta's current and future emissions (Government of Alberta, 2018a)

2.2 Definition of Resilience

According to the Resilient Design Institute, "Resilience is the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance. It is the capacity to bounce back after a disturbance or interruption" (Resilient Design Institute, 2013). In this study, we calculate the sensitivity of building energy and precipitation to climate change as a method to assess the resilience of the TDR document. By understanding the ability of buildings to withstand the effects of climate change, we are in turn also evaluating the document that informs their construction.

This study does not intend to measure the resiliency of buildings to catastrophic weather events caused by climate change.

2.3 Climate Leadership

One of the main goals of this study is to assess the readiness of the TDR to contribute to Alberta Infrastructure's strategic climate leadership goals and initiatives. The following sections provide a brief discussion on the various climate change targets that have been adopted for Canada, Alberta, Edmonton, and Calgary.

2.3.1 Federal Climate Change Leadership

The Government of Canada published the Pan-Canadian Framework on Clean Growth and Climate Change, which targets reducing emissions, growing the economy, and instilling resilience to climate change across all sectors (Government of Canada, 2016). The four main pillars of the framework include:

- Pricing carbon pollution;
- Complementary measures to further reduce emission across the economy;
- Measures to adapt to the impacts of climate change and build resilience;
- and actions to accelerate innovation, support clean technology, and create jobs.

Section 3.2 (page 15) in the Pan-Canadian Framework on Clean Growth and Climate Change addresses the built environment directly, stating that the approach to the built environment will include:

- Making new buildings more energy efficient;
- Retrofitting existing buildings, as well as fuel switching;
- Improving energy efficiency for appliances and equipment; and
- Supporting building codes and energy efficient housing in Indigenous communities.

The framework identifies the need to adopt increasingly stringent model building codes, starting in 2020, with the goal of reaching a "net-zero energy ready: model building code by 2030.

2.3.2 BC Step Code

The BC Step Code is a performance based standard created in April of 2017 that delineates the improvements in building energy performance that are required to achieve a net-zero energy ready building code by 2032 (Government of British Columbia, 2017). While not mandatory, compliance to this regulation requires that builders adhere to a set of metrics for building envelope, equipment and systems, and air tightness testing. Figure 2 shows the building performance requirements to achieve each incremental step.

STEP	AIRTIGHTNESS (AIR CHANGES PER HOUR AT 50 PA PRESSURE DIFFERENTIAL)	PERFORMANCE REQUIREMENT OF BUILDING EQUIPMENT AND SYSTEMS	PERFORMANCE REQUIREMENT OF BUILDING ENVELOPE
1	N/A	EnerGuide Rating % lower than EnerGuide Reference House: not less than 0% lower energy consumption or Conform to Subsection 9.36.5.	
2	≦ 3.0	EnerGuide Rating % lower than EnerGuide Reference House: not less than 10% lower energy consumption **or** mechanical energy use intensity ≦ 100 kWh/m².year	Thermal energy demand intensity ≦ 70 kWh/m².year **or** Peak thermal load ≦ 55 W/m²
3	≦ 2.5	EnerGuide Rating % lower than EnerGuide Reference House: not less than 20% lower energy consumption **or** mechanical energy use intensity ≦ 85 kWh/m².year	Thermal energy demand intensity ≦ 60 kWh/m².year **or** Peak thermal load ≦ 50 W/m²
4	≦ 1.5	EnerGuide Rating % lower than EnerGuide Reference House: not less than 40% lower energy consumption **or** mechanical energy use intensity ≦ 55 kWh/m².year	Thermal energy demand intensity ≦ 50 kWh/m².year **or** Peak thermal load ≦ 45 W/m²
5	≦ 1.0	Mechanical energy use intensity ≦ 25 kWh/m².year	Thermal energy demand intensity ≦ 15 kWh/m².year **or** Peak thermal load ≦ 10 W/m²

Figure 2 Performance thresholds for the BC Step Code (Government of British Columbia, 2017)

The BC Step Code presents a current regulatory framework that could be followed by other governmental bodies and provides a real guideline as to how provincial energy codes can be updated to meet net-zero energy going into the future.

2.3.3 Alberta Climate Leadership Plan

Alberta has put forward a Climate Leadership Plan (CLP) (Government of Alberta, 2015b), with the main goals to reduce carbon emissions in the province, while diversifying the economy, creating jobs and protecting health and the environment. To do this, the province introduced four key measures: (Government of Alberta, 2015b)

1. Implement greenhouse gas (carbon) pricing,
2. Phase out coal generated electricity production, and increase renewable electricity generation to 30% by 2030,
3. Introduce a cap on oil sands emissions at 100 Mt per year,
4. Reduce methane emissions from oil & gas production.

The leadership plan recommends strongly that the government roll out an aggressive regulatory agenda including the adoption of up-to-date energy codes for buildings and the labeling of building energy use so that residential buyers and renters and commercial lease holders can make more informed decisions with respect to energy (Government of Alberta, 2015a).

2.3.4 Calgary Climate Change Goals

The City of Calgary is in the process of developing a Climate Resilience Plan, which will outline measures around two key areas, adaptation and mitigation. This plan will be laid out in mid-2018, and the city has committed to reducing GHG emissions by 20% by 2020, and 80% by 2050, relative to 2005 levels. (World Energy Cities Partnership & The City of Calgary, 2009), (The City of Calgary, 2011). Calgary has already experienced climate change effects first-hand through the impacts of extreme weather events such as severe floods, and damaging hail storms. Most recently, in March of 2018, the City of Calgary held its first Climate Change Symposium which showcased the efforts of the city and was used as a platform to increase conversation around climate change issues.

2.3.5 Edmonton Climate Change Goals

The City of Edmonton is also in the process of developing a Climate Change Adaptation and Resilience Strategy, known as Resilient Edmonton (City of Edmonton, 2018b). This process was started in 2016 and will be presented in mid-2018. The city has also implemented a plan called Change for Climate, which calls for the city to reduce greenhouse gas emissions by 35% below 2005 levels by 2035 (City of Edmonton, 2018a).

2.4 Building Lifecycle

According to the Energy Policy Solutions tool developed by the Pembina Institute and Energy Innovation *(2018)*, building components are expected to be retrofitted on varying intervals, as shown in Figure 3. The dotted red lines show the time periods used in this report, if the building is completed in the current year (2018). Except for the building envelope, all building systems are assumed to be replaced before the first projected time period in the study; 2040.

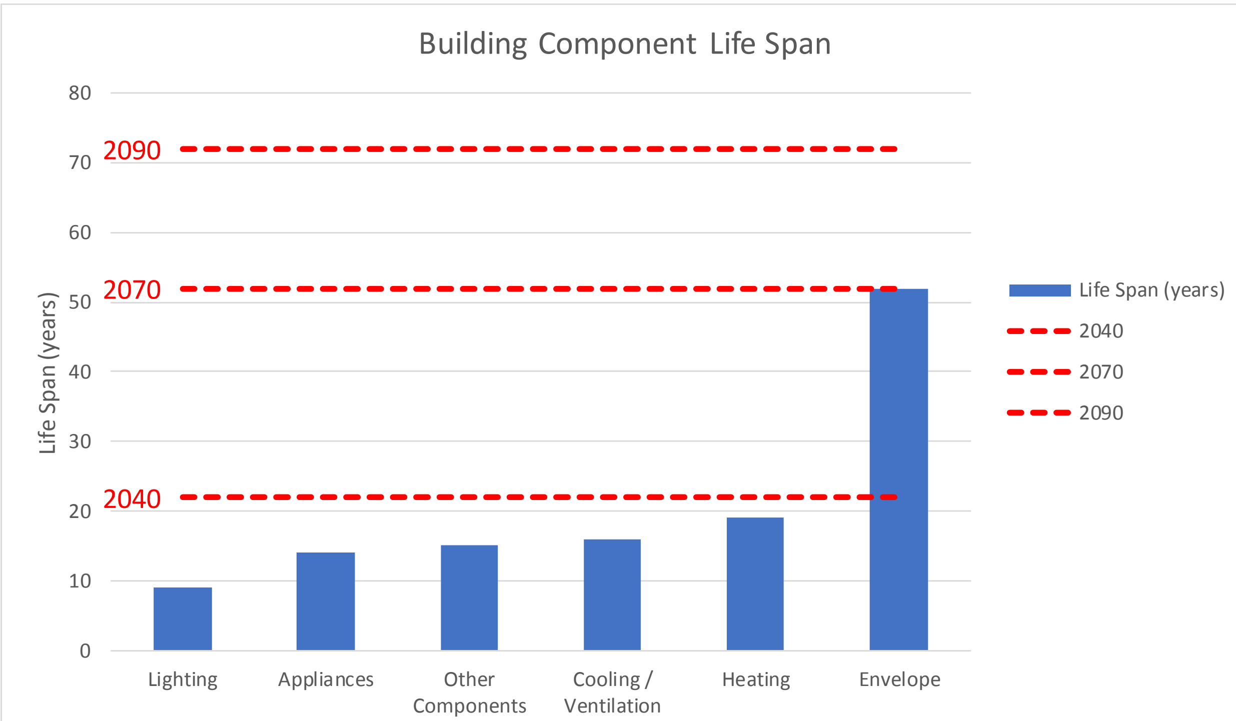

Figure 3 Building component life span (lifespan data from Pembina Institute & Energy Innovation, 2018)

Since the life span of the building envelope is significantly longer than the other building components, it is more vulnerable to changes in climate.

3.0 Methods

The following sections describe the methods used in this study. First, a review of the TDR document is conducted to identify sections that are related to energy and water consumption. Next, energy modeling simulations are calculated to investigate the effects of varying weather on building energy consumption. Then, a parametric study is completed to measure the effects of varying the design of various building components in relation to changes in weather.

3.1 TDR Standards Review

The TDR document is reviewed to identify the sections that are relevant to building energy modelling and water management. Each section of the TDR document is assessed to identify whether it has a:

1. Direct impact,
2. Indirect impact, or
3. May be related, and is open for discussion

A direct impact category is an area that would impact the energy use of a building directly. An example would be mechanical heating systems, as changing temperatures would have a direct effect on how much energy is needed to heat a building.

An indirect impact category is assigned if there is an effect on the building based on changing weather conditions, quantification of which is outside the scope of this study. An example of this would be building roof drainage standards, which could be impacted by an increase in the frequency of severe rainstorms.

If a section is deemed tangential to the topic of climate change, it is marked as, "may be related, and is open for discussion". These items are identified to bring awareness to them as having the potential to contribute positively or negatively to Alberta Infrastructure's climate change goals.

3.2 Energy Modelling

The following sections provide details about the methods used in the energy modeling portion of the study. First, a discussion is provided about climate projections, and how weather files are selected to represent climate change scenarios for building energy simulations. Next, three archetypal building models are chosen from projects recently completed by Mission Green Buildings to represent Alberta Infrastructure's building stock. Then, these models are simulated using various weather scenarios to evaluate the sensitivity of energy requirements to the changing climate. Finally, a parametric study is conducted to evaluate the sensitivity of altering building design elements for each of the studied weather scenarios. eQuest is chosen as the most appropriate energy modeling software for the scope. It is independent, widely used, robust and proven to be reliable.

3.2.1 Weather Files and Climate Projections

In this section, an explanation is provided for the selection of weather files used to simulate the various building energy model simulations in the study. First, a discussion is provided about the selection of geographic locations for the study. Next, various climate projections are introduced to show how future weather scenarios are predicted. Finally, details about the tools used to create the various weather files required for this study are provided.

3.2.1.1 Geographic Locations

Three geographic locations are selected for analysis in this study: Fort McMurray, Edmonton, and Medicine Hat. Please note that Calgary, which is not included in this study, is in the same climate zone as Edmonton. The three locations are selected to represent the range of weather for the province of Alberta, as shown in Figure 4. Medicine Hat, with 4540 heating degree days below 18°C (HDD), is representative of the warmer southern portion of the province, or Zone 6. Edmonton is representative of Zone 7A weather in the province, with 5120 HDD. Fort McMurray, in Zone 7B, is representative of the colder northern climate with 6250 HDD. As the climate changes throughout the 21st century, the boundaries between zones on the map will shift, perhaps causing a location to move from one zone category to another.

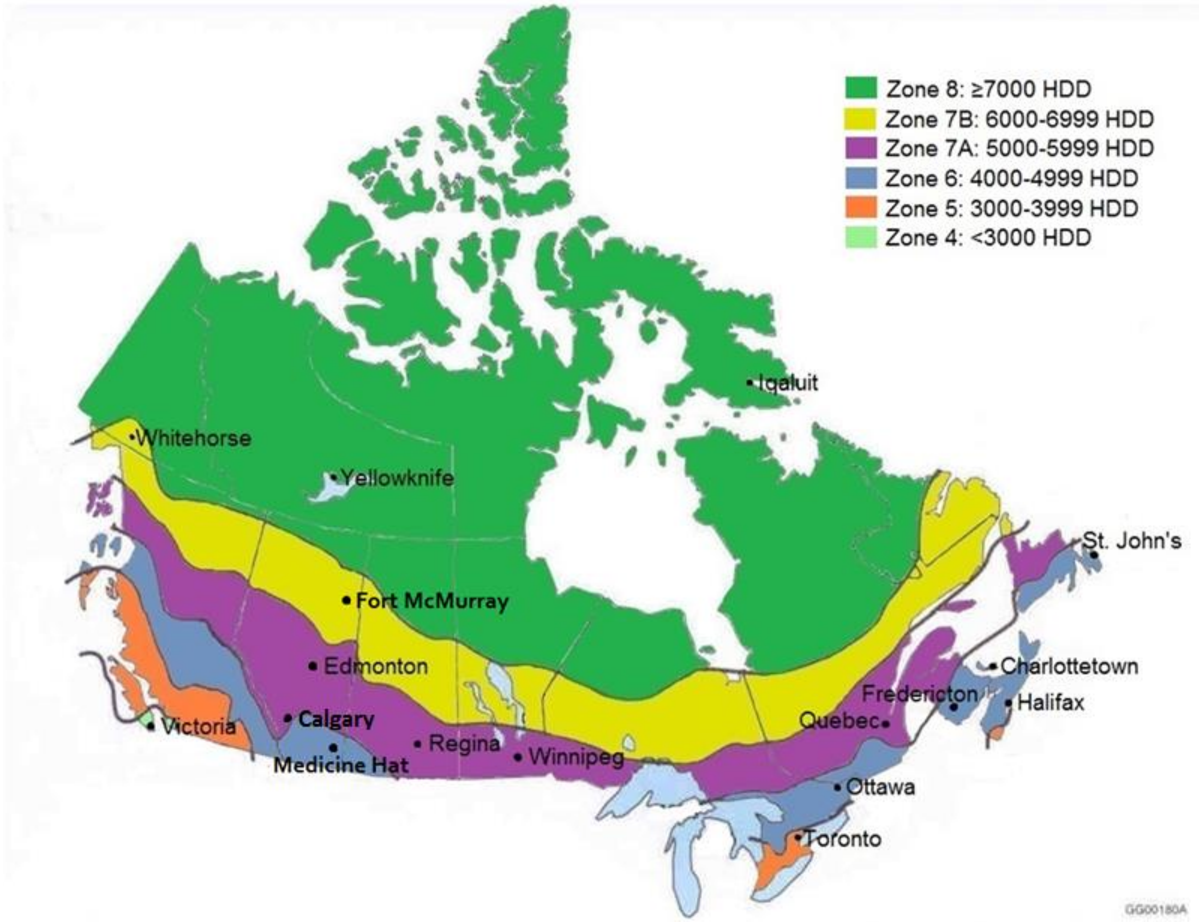

Figure 4 Canadian building code climate zone map (modified from NAIMA Canada, 2018)

Figure 5 shows the variation in dry bulb temperature between the three study locations, by month and day of the year. It is noted that Medicine Hat is warmer than the other two locations throughout the year, whereas Fort McMurray is slightly warmer than Edmonton during the summer, but colder during the winter.

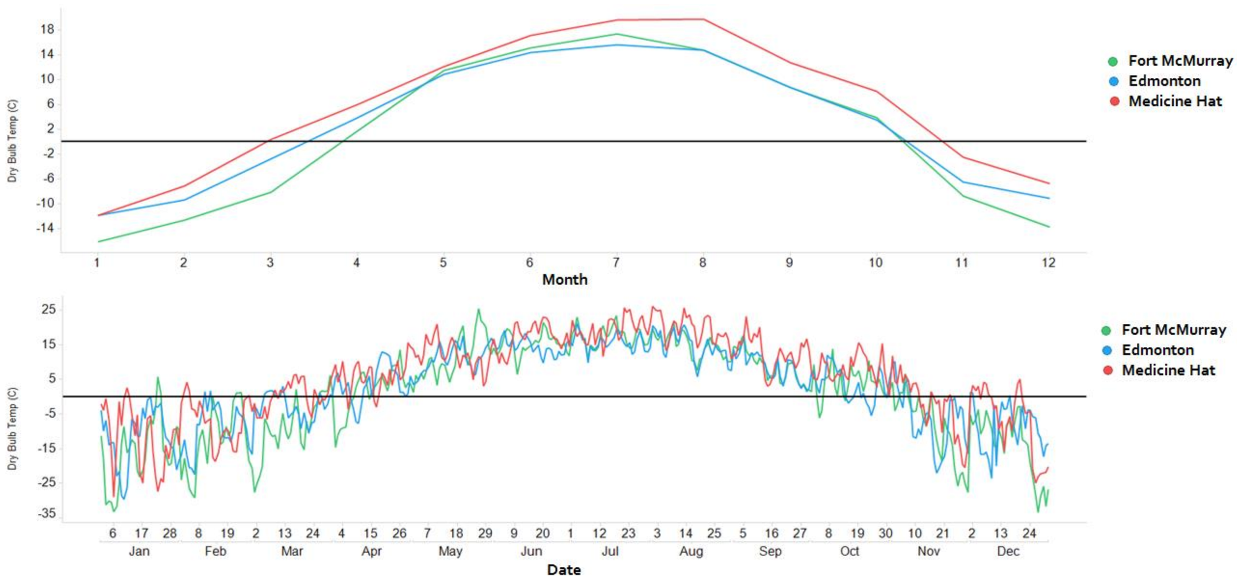

Figure 5 Dry bulb temperature for the three study locations by month (top), and by day (bottom)

3.2.1.2 Climate Projections

To study the effects of the changing climate over the 21st century on the energy use of the three archetypal buildings chosen for this study, two climate projections are selected from the fifth phase of the Climate Model Intercomparison Project (CMIP5) (Taylor, Stouffer, & Meehl, 2012). Four Representative Concentration Pathways (RCP) are provided by the CMIP5 project to delineate the range of possible outcomes for future climate. The RCPs are named after a possible range of predicted radiative forcing values for the year 2100; RCP2.6, RCP4.5, RCP6, and RCP8.5. Radiative forcing refers to the amount of sunlight energy, net of radiative energy losses, that is retained by the earth's atmosphere, in units of W/m^2. For example, the RCP4.5 climate projection is based on a scenario where the earth's atmosphere retains 4.5 W/m^2 of energy from the sun in the year 2100.

In the CMIP5 report, RCP2.6 represents a stringent mitigation scenario, RCP4.5 and RCP6.0 represent intermediate scenarios, and RCP8.5 represents very high GHG emissions (IPCC, 2014). In our study, the RCP4.5 and RCP8.5 projections are used to investigate the intermediate to high GHG emissions scenarios for Alberta. The global mean surface temperature changes associated with each projection are shown in Figure 6. The Paris Agreement and Pan-Canadian Framework on Clean Growth and Climate Change are targeting a 2°C increase scenario, as represented by the RCP4.5 projection (UNFCCC, 2016) (Government of Canada, 2016).

		2046–2065		2081–2100	
	Scenario	Mean	*Likely* range [c]	Mean	*Likely* range [c]
Global Mean Surface Temperature Change (°C) [a]	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
	Scenario	Mean	*Likely* range [d]	Mean	*Likely* range [d]
Global Mean Sea Level Rise (m) [b]	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

Figure 6 Projected change in global mean surface temperature and sea level rise (IPCC, 2014).

Since there are significant variations between the independent climate models that were assembled for the CMIP5 study, the authors created an ensemble climate projection to provide a probabilistic view of future climate trends. Using the ensemble data provides a robust approach that balances out the individual biases of the study researchers. For our study, the 50% probability curve is selected for each weather scenario. Figure 7 shows an example of the range of probabilities associated with the ensemble data of HDD for Fort McMurray under the RCP8.5 projection.

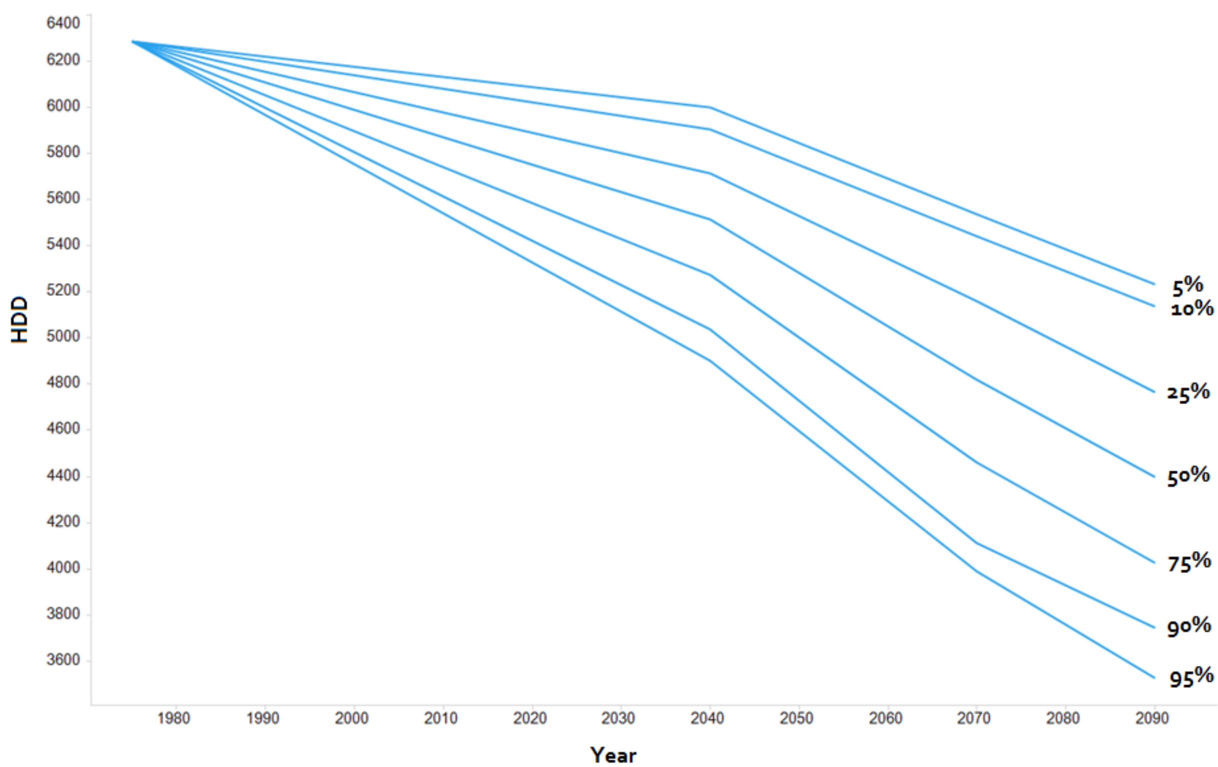

Figure 7 Probability of HDD for future years in Fort McMurray, according to the RCP8.5 projection

3.2.1.3 CWEC Weather Files

The CWEC weather files, published by the Government of Canada, are normally used for compliance building energy modeling. These typical meteorological year (TMY) weather scenarios are statistically calculated from 30 years of historical data, from 1958-1989, as shown by the dotted outline on the left of Figure 8, for a Toronto example. This example illustrates that the CWEC weather files are representative of past weather conditions and do not consider the effects of climate change. The dotted boxed in the centre of the figure, which shows a more recent window of historical weather data from 2000-2014, indicates that the city of Toronto has shifted from zone 6 to zone 5. The dotted box on the right shows a weather projection prepared by White Box Technologies to illustrate the effects of climate change predictions on Toronto's weather. By 2050, it is predicted that Toronto will have shifted into climate zone 4.

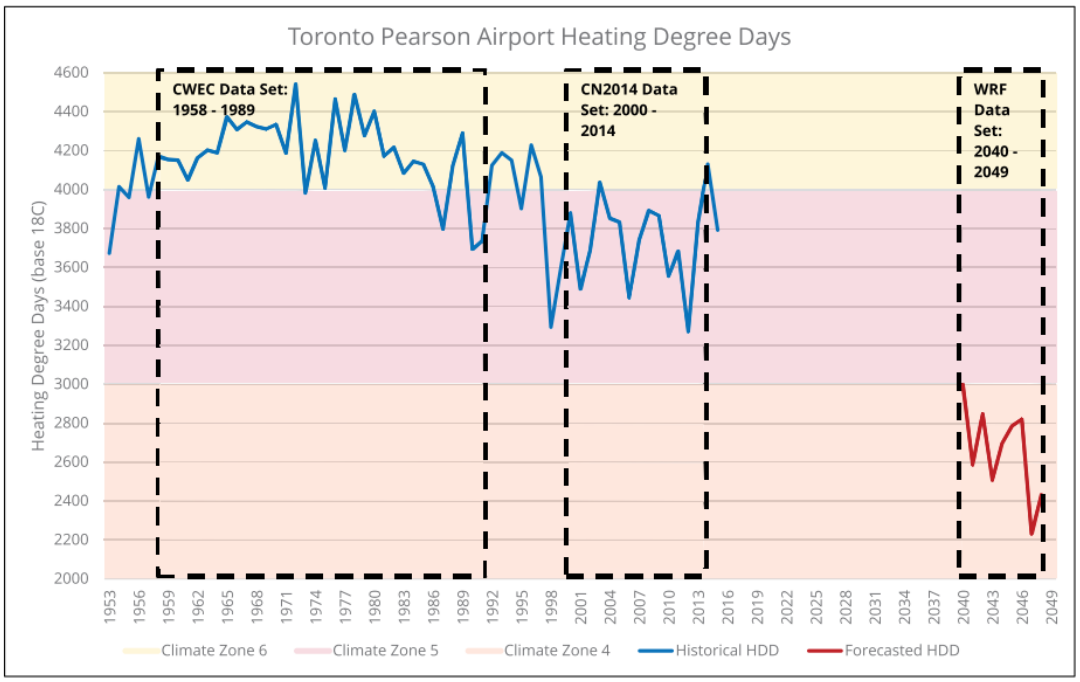

Figure 8 Example of HDD analysis for various climate scenarios for the Toronto area (White Box Technologies, 2018)

In section 5.1, a similar study of HDD is conducted for each of the geographic locations and future weather files selected for our study.

3.2.1.4 Weather File Tools

The online tool Weathershift (Arup North America Ltd, Argos Analytics LLC, & Slate Policy and Design, 2018) is used to modify the current weather files to align with the two selected weather projections. Figure 9 shows the online interactive tool that is available to modify existing weather files to represent the CMIP5 climate projection scenarios, based on the RCP and warming percentile.

Figure 9 Weathershift online tool (www.weathershift.com)

An additional step is required to convert the weather files output from Weathershift into the format that is used by eQuest software for this study. The software used to complete this conversion is provided by Hirsch (2006).

3.2.2 Archetypal Building Models

Three archetypal building models are selected to investigate their resiliency to future changes in climate; an elementary school, office building, and residential building. The residential building is included to represent seniors' accommodations and affordable housing. These models are based on actual projects that were recently completed by Mission Green Buildings and are not intended to be statistically representative of the inventory of Alberta Infrastructure building stock. The following sections provide details about these three models.

3.2.2.1 Elementary School

Figure 10 shows the 3-dimensional view of the western façade of the archetypal school building model.

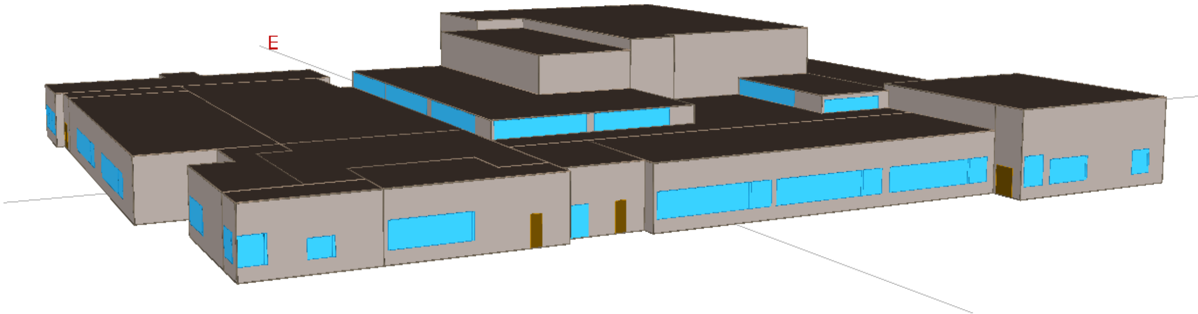

Figure 10 Archetypal school model

This single-story model has a floor area of 4,860 m², comprised of various classroom, gymnasium, administrative office, and modular classroom spaces. This model shows a 48% improvement in energy performance relative to the MNECB 1997 baseline, with an energy use intensity (EUI) of 197 eKWh/m². The main building is heated by a 94.6% efficient gas-fired boiler system employing perimeter radiant panels. Cooling is provided by direct expansion coils, and ventilation is supplied with a constant volume air handling unit. Each of the eight modular classrooms are heated by individual gas fired furnaces, cooled by a direct expansion cooling unit, and ventilated with heat recovery ventilators. The roof area of the school is 4,655 m².

3.2.2.2 Multipurpose Office

Figure 11 shows the eastern façade of the archetypal multipurpose office building model that is investigated in this study.

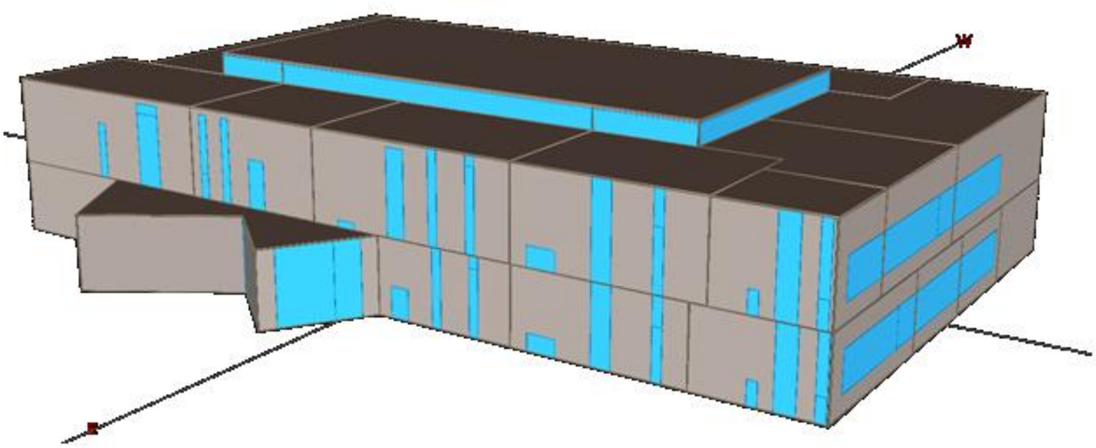

Figure 11 Archetypal office model

This two-story building has 2,668 m² of floor area, made up of meeting rooms, interpretive centre, and classroom spaces. The energy performance of this model is 44% better that the MNECB 1997 baseline, with an energy use intensity of 197 eKWh/m². Heating is provided by a 93.4% efficient boiler, supplying baseboard hydronic heaters. Cooling is provided by direct expansion coils, and ventilation is provided by an indirect gas-fired variable volume air handling unit. The roof area of the office is 1,396 m².

3.2.2.3 Residential Building

Figure 12 shows the southeast façade of the archetypal residential building used in this study.

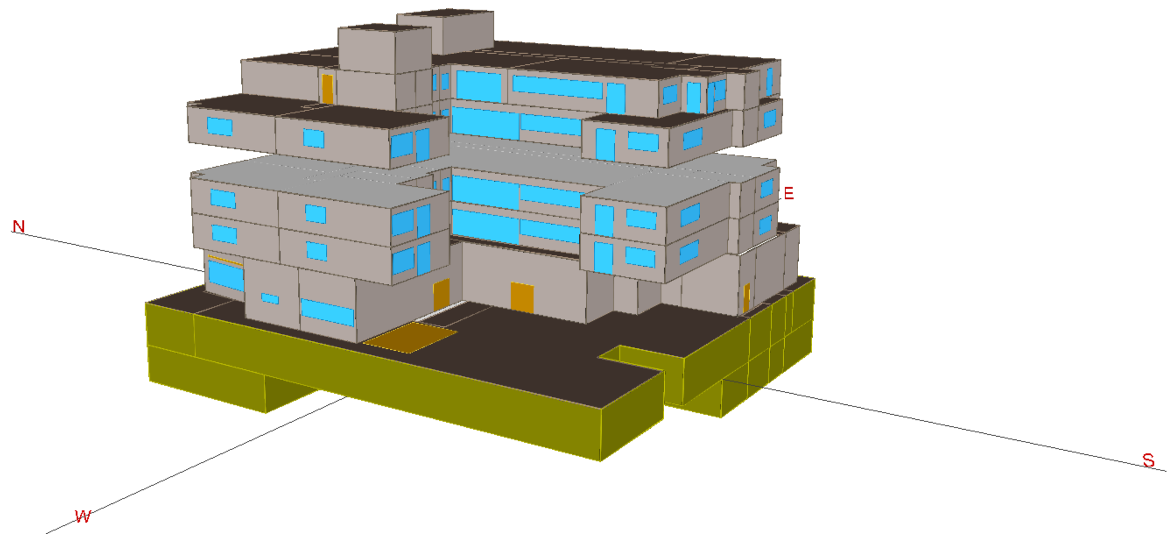

Figure 12 Archetypal residential model

This six-story building has 8,200 m² of floor space, made up commercial units on the main level and residential units on the upper floors. Energy performance is 23% better than the NECB 2011 baseline, with an energy use intensity of 224 eKWh/m². Ventilation air is heated by a combination of a 91% efficient direct-fired furnace and 96% efficient boilers. Heating and cooling in the residential and commercial suites is provided by a ground source heat pump. Heat recovery ventilation is included in the design. The roof area of the residential building is 1,700m².

3.2.3 Building Model Sensitivity to Climate Change

Since the life span of buildings is often 50-100 years, it is not only important to evaluate their energy performance relative to the current weather, but also to investigate their performance throughout their life cycle with respect to the changing climate. This is especially important for the elements of the building that are likely to remain unchanged for several decades, such as the building envelope. Although it is also important to consider the performance of HVAC equipment and lighting fixtures as the climate changes, the opportunity to upgrade or reconfigure this equipment comes several times during the life of the building.

In this study, the baseline simulations for each archetypal building are run with 21 weather scenario variations. Each weather file represents a combination of the geographic location, climate projection, and future time period. The changes in energy consumption between each of the weather scenarios illustrates the sensitivity of the building model to climate change for each location. For efficiency of labeling charts in the results section, the weather files are named according to the following structure:

- Geographic location
    - McM – Fort McMurray
    - Edm – Edmonton
    - Med – Medicine Hat
- Weather projection
    - Current - Existing CWEC weather files
    - RCP4.5 - Climate projection associated with a temperature increase of 2°C (radiative forcing value of 4.5 W/m^2)
    - RCP8.5 - Climate projection associated with a temperature increase of 4°C (radiative forcing value of 8.5 W/m^2)
- Time Period
    - Current – CWEC data files, based on 1958-1989 historical weather data
    - 2040 - TMY weather projected for the years 2031-2050
    - 2070 - TMY weather projected for the years 2061-2080
    - 2090 - TMY weather projected for the years 2081-2100

For example, the weather file for the Edmonton location, RCP4.5 projection, 2040 time period is written as Edm_RCP4.5_2040.

3.2.4 Parametric Study

The following sections describe the parametric study that is conducted to investigate the sensitivity of energy performance to various building design decisions, under various climate scenarios. First, a list of design parameters, and their discrete variations, are provided to show the scope of the study. Then, a discussion about the response variables that are calculated in the simulations to measure energy performance is provided.

3.2.4.1 Parametric Study Input Parameters

An evidence-based evaluation of energy performance for various design decisions is conducted using a parametric study, which is a systematic investigation of discrete changes in the building models. Table 1 shows the list of discrete design parameter alterations that are used to investigate the impact of building design decisions on energy performance.

Table 1 Parametric study input parameters

<table>
<tr><th>Parameter</th><th>Units</th><th colspan="8">Variations</th></tr>
<tr><td>Wall RSI (effective)</td><td>m²K/W</td><td colspan="3">3.5</td><td colspan="2">5.3</td><td colspan="3">7.0</td></tr>
<tr><td>Roof RSI (effective)</td><td>m²K/W</td><td colspan="3">5.3</td><td colspan="2">7.0</td><td colspan="3">8.8</td></tr>
<tr><td>Window USI-value</td><td>W/m²K</td><td>2.95</td><td colspan="2">1.65</td><td>1.59</td><td>1.53</td><td colspan="2">1.14</td><td>1.08</td></tr>
<tr><td>Window to Wall Ratio</td><td>percent</td><td colspan="3">25%</td><td colspan="2">50%</td><td colspan="3">75%</td></tr>
<tr><td>Infiltration Rate</td><td>L/s/m²</td><td colspan="3">0.25</td><td colspan="2">0.10</td><td colspan="3">0.05</td></tr>
<tr><td>Heat Recovery Vent.</td><td>percent</td><td colspan="3">0%</td><td colspan="2">65%</td><td colspan="3">85%</td></tr>
<tr><td>Heating Efficiency</td><td>efficiency</td><td colspan="3">80%</td><td colspan="2">85%</td><td colspan="3">95%</td></tr>
<tr><td>Cooling Efficiency</td><td>COP</td><td colspan="3">3.0</td><td colspan="2">4.0</td><td colspan="3">5.0</td></tr>
<tr><td>Lighting Power Density</td><td>W/m²</td><td colspan="3">NECB</td><td colspan="2">25% reduction</td><td colspan="3">35% reduction</td></tr>
<tr><td>Building Rotation</td><td>degrees</td><td colspan="2">0</td><td colspan="2">90</td><td colspan="2">180</td><td colspan="2">270</td></tr>
<tr><td>Overhang Length</td><td>meters</td><td colspan="3">0</td><td colspan="2">1</td><td colspan="3">2</td></tr>
</table>

The window parameters listed in Table 1 correspond to the glazing types listed in Table 2.

Table 2 Glazing types for climate zones 5-8 (Carmody & Haglund, 2012)

Glazing	Frame	USI-value	SHGC	VT
Double Clear	Nonmetal	2.95	0.57	0.59
Double, low-e, high SHGC, argon, improved	Nonmetal, improved	1.65	0.5	0.57
Double, low-e, medium SHGC, argon, improved	Nonmetal, improved	1.59	0.31	0.52
Double, low-e, low SHGC, argon, improved	Nonmetal, improved	1.53	0.2	0.46
Triple, low-e, high SHGC, argon, improved	Nonmetal, improved	1.14	0.41	0.5
Triple, low-e, medium SHGC, argon, improved	Nonmetal, improved	1.08	0.28	0.45

3.2.4.2 Parametric Study Response Variables

The main response variables that are calculated for the parametric study are electricity use, natural gas use, and total energy use. Energy use intensity (EUI) is calculated by dividing the total energy use by the floor area for each building.

3.2.4.3 PV Capacity Calculation

The potential to collect energy using photovoltaic (PV) modules on the roof is calculated for each building, in each location in the study based on the solar resource data by Natural Resources Canada (Natural Resources Canada, 2017). The PV system efficiency is assumed to be 12%, mounted horizontally, with 100% roof coverage. Although this amount of roof coverage is not likely achievable, it was used to show the maximum potential to collect solar energy.

3.2.4.4 Limitations

This section briefly discusses the limitations in the methods used in the energy modeling portion of this study.

Each of the building models was originally created for a specific geographic location. It was not within the scope of this high level study to optimize the parameters of each baseline model for each of the study locations.

The parametric study considers only one parameter alteration at a time. Although combining several beneficial design alterations will have a combined effect, the interrelated nature of some of the parameters will have a more complex effect. For example, if the window type and window size are both changed, the resulting change in energy use will not correspond to the sum of the change associate with each in isolation. A best-case scenario is simulated for the study, which selects an optimized option, from an energy perspective, for each design parameter. An option for future work is to investigate a broad range of parameter combinations to evaluate their energy performance.

The office building was not originally designed with heating recovery ventilation (HRV) equipment. The parametric study did not consider the optimization of the air economizer for the various weather scenarios.

3.3 Precipitation and Rainwater Collection

CMIP5 precipitation data for the study is downloaded from the Climate Change and Environment Canada website (Government of Canada, 2018) for the latitude and longitude coordinates closest to Fort McMurray, Edmonton, and Medicine Hat.

Rainwater collection volumes are calculated assuming that all rain that falls on the roof area of the building from March 1st to November 30th is retained and stored for future use. Future precipitation volumes are calculated by averaging a 20-year window around the study time periods: 2040, 2070, 2090.

4.0 Results: TDR Recommendations

Recommendations are made to improve Alberta Infrastructure's Technical Design Requirements based on our expertise in green building standards and building energy modeling. Each recommendation is prioritized on a scale of 1 to 3, with 1 being the highest priority, and 3 being the lowest. Effort to implement was also estimated for each recommendation, with high effort being the most amount of perceived work, and low being the least amount. Recommendations to address gaps in the TDR are also made, identified as "New Section". Recommendations are made to address resilience to climate change, net-zero energy targets, improved sustainability goals, water use reduction, and preparation for future retrofits.

The tables on the following pages provide details for each recommendation.

TDR Section Title	TDR Section Number	Description	Priority (1,2,3)	Effort to implement (H,M,L)	Relevance to AI Goals	Recommendations
Sustainability						
General LEED	1.2.2	All projects must meet LEED silver standards	1	Low	Resilience to climate change	• Introduce more stringent energy and sustainability requirements over time • E.g. 1. NECB 2. LEED 3. Step Code 4. Net Zero Energy
General NECB	1.2.5	NECB 2011 energy compliance	1	Low	Resilience to climate change	• Update NECB compliance to meet the most recent NECB standard
General Energy Modeling	1.2.6	Use an energy modeling consultant, and an updated weather file for energy modeling	1	High	Resilience to climate change	• Energy modeling to be conducted with a weather file that reflects the life span of the building
New Section	New	Alberta Step Code	2	Very High	Net zero energy target	• Create Alberta Step Code document to identify incremental performance targets to achieve net zero by 2030. • E.g. BC Step Code
New Section	New	Net Zero Energy	2	Medium	Net zero energy target	• Explain net zero and identify paths that can be taken to build towards net-zero ready buildings

TDR Section Title	TDR Section Number	Description	Priority (1,2,3)	Effort to implement (H,M,L)	Relevance to AI Goals	Recommendations
Sustainability	New	It is recommended that the Sustainability section be regularly reviewed to see how it can be improved in the face of climate change.	2	Low	Improved sustainability goals	• Monitor ongoing improvements in the sustainability and energy code sectors (Green rating system improvements, NECB standards, etc.) • Update sustainability section to reflect changes in certification programs.
Building Envelope						
New Section	New	Prioritize building envelope in energy modeling due to its long lifespan.	2	High	Net zero energy target	• Introduce a thermal energy demand intensity (TEDI) metric • E.g. BC Step Code
Structural						
New Section	New	Structural PV panel load optimization	2	Low	Net zero energy target	• Building roofs should be designed, optimized, and built to hold solar PV and/or thermal panels.
Mechanical						
Commissioning	5.1.7	Commissioning requirements prioritizing monitoring and envelope	2	Low	Resilience to climate change	• Consider requiring building envelope commissioning
Standard Design	5.1.11.1	Mechanical system design according to ASHRAE and NECB standards	1	Low	Energy Modeling	• Consolidate mechanical design standards

TDR Section Title	TDR Section Number	Description	Priority (1,2,3)	Effort to implement (H,M,L)	Relevance to AI Goals	Recommendations
Conservation Options	5.1.11.3	Energy conservation measures	2	Medium	Resilience to climate change	• Review and consolidate list of ECMs • Prioritize performance-based metrics over a list of specific technologies
Mechanical Design Criteria	5.2	Mechanical design requirements	2	Medium	Future retrofit	• Design mechanical systems and spaces for full electrification • e.g. electrical switch/breaker boxes in the mechanical rooms, designing for higher loads, backup power, etc.
New Section	New	Mechanical system location flexibility	1	Medium	Future retrofit	• Design mechanical systems to be located in a space that makes them simple to replace and accommodating to change. • e.g. During a retrofit, this gives much more flexibility to update system design.
HVAC Design Criteria	5.2.1	HVAC design requirements	2	High	Resilience to climate change	• Update design day heating and cooling temperatures for future climate projections. • E.g. Use climate projection RCP4.5 2040

TDR Section Title	TDR Section Number	Description	Priority (1,2,3)	Effort to implement (H,M,L)	Relevance to AI Goals	Recommendations
New Section	New	Ground Source Heat Pumps	3	High	Net zero energy target	• Add a section providing information and feasibility study for ground source heat pumps
New Section	New	Storm water collection	1	High	Reducing water usage	• Add standards for storm water collection systems to account for changing precipitation patterns • E.g. This would include cistern sizing, plumbing, pumps, and necessary filtering.
New Section	New	Grey water reuse	2	High	Reducing water usage	• Consider implementing grey water reuse standards when regulations allow it.
Domestic Hot Water System	5.5.3	Domestic hot water system requirements Solar thermal systems	1	Medium	Net zero energy target	• Add design guidelines for solar thermal equipment.
Electrical						
New Section	New	Solar PV	1	Medium	Net zero energy target	• Implement design requirements for potential solar PV systems
New Section	New	Full electrification	1	Medium	Future retrofit	• Electrical systems should be designed for full

TDR Section Title	TDR Section Number	Description	Priority (1,2,3)	Effort to implement (H,M,L)	Relevance to AI Goals	Recommendations
						electrification of equipment in the future
New Section	New	Electrical outlet placement	1	Medium	Resilience to climate change	• Consider raising electrical outlets higher off the ground, to protect from potential ground floor flooding.
Site Services						
Site Grading	9.6	Site grading minimum	1	Medium	Resilience to climate change	• Review the 2% gradient requirement due to increased precipitation
New Section	New	Site elevation	1	Low	Resilience to climate change	• Implement building elevation requirements above flood plain
Landscape Design						
Planting Design	10.2.4	Plant design layout that is tolerant of local conditions	2	Medium	Water use reduction	• Design using natural landscaping techniques • E.g. Xeriscaping • Reduce turf grass and high irrigation vegetation
New Section	New	Green roofs and vegetation	1	Medium	Resilience to climate change	• Implement guidelines for green roofs and vertical vegetation.

5.0 Results: Energy Modelling

In this section, simulation results are provided for the three archetypal building models and various climate scenarios. First, the climate trends at each of the three locations are presented. Next, a discussion of variability due to building type and geographic location are provided for the current weather file. Then, the investigation is broadened to include the various climate scenarios in the study. Finally, the results of the parametric study are presented for the various geographic locations, building types, and climate scenarios.

5.1 Climate Trends

Figure 13 shows the HDD and climate zones for the three study locations, for various time periods. The CWEC weather files are plotted at the mid-point of the historical date range (1975) used to generate the typical meteorological year (TMY). The climate projections for 2°C average global warming (RCP4.5) and 4°C average global warming (RCP8.5) are shown for the years 2040, 2070, and 2090. The dashed vertical line shows the year 2018.

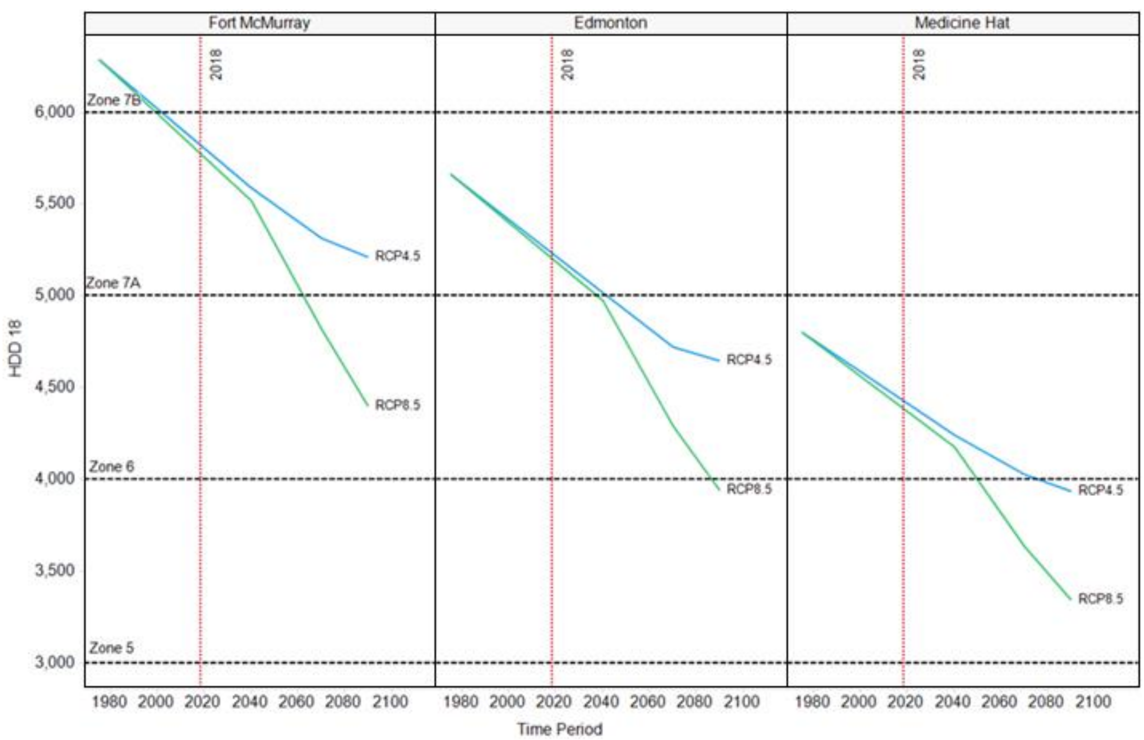

Figure 13 Changes in climate zone for the three study locations, for the RCP4.5 and RCP8.5 climate projections

For each location, the climatic warming trend leads to a shift to lower zone numbers over the 21st century. According to the climate projections, Fort McMurray has already passed from zone 7B to zone 7A and is projected to pass into zone 6 for the RCP8.5 projection just after mid-century. Edmonton will pass from zone 7A to zone 6 by approximately 2040 and will pass into zone 5 by the end of the century for the

RCP8.5 projection. Medicine Hat will pass from zone 6 to zone 5 sometime between 2050 (RCP8.5) and 2070 (RCP4.5).

Figure 14 shows the shift in cooling degree days (CDD) for the three locations and two weather projections. The CDD for Fort McMurray nearly doubles for RCP4.5 and increase by 231% for RCP8.5. Edmonton CDD values more than double for RCP4.5 and increase by 324% for RCP8.5. Medicine Hat CDD values increase by 75% and 176% for RCP4.5 and RCP8.5, respectively.

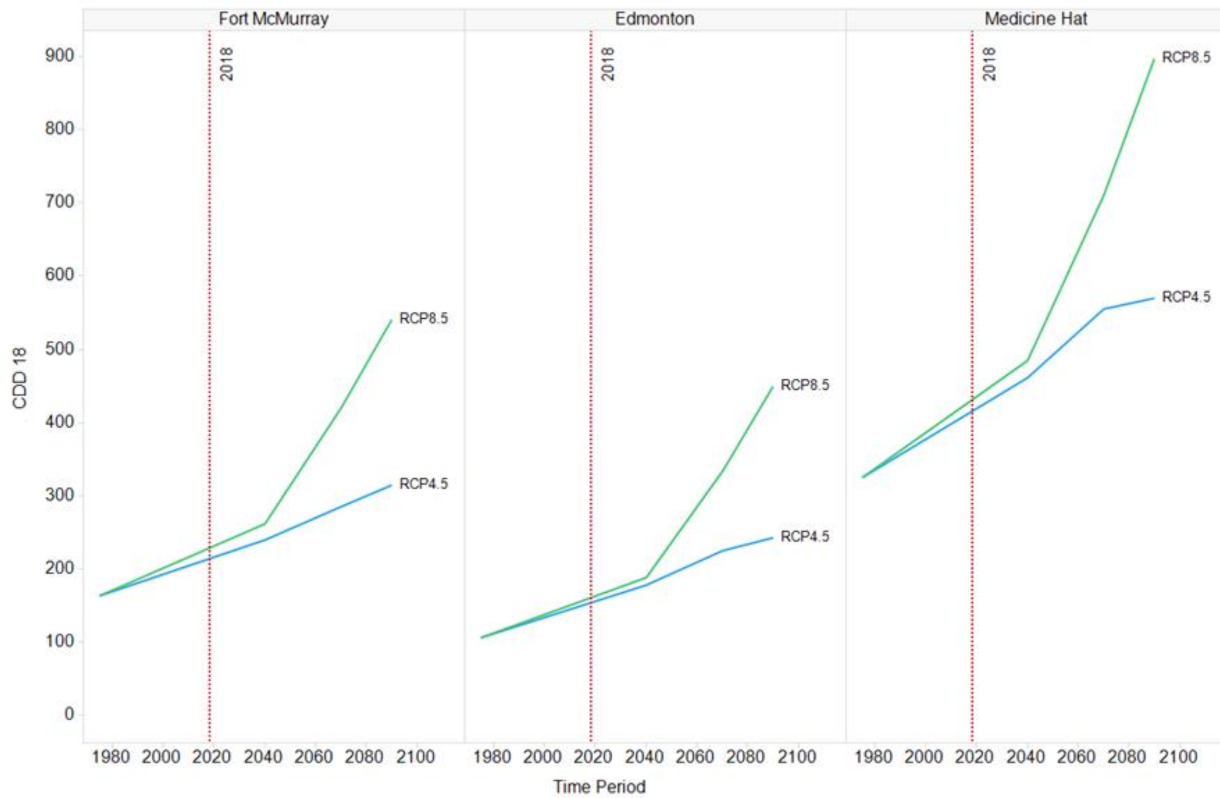

Figure 14 Changes in climate zone for the three study locations, for the RCP4.5 and RCP8.5 climate projections

5.2 Geographic Location and Building Type

Figure 15 shows the variation in energy use profiles for the three locations and three archetypal building models using the current weather file. The range of electricity use is within 3 to 9% for each of the building types as the geographic location is changed. Natural gas use, however, shows a higher variation with geographic location, with increases of 31%, 30%, and 35% from Medicine Hat to Fort McMurray for the office, school, and residential building respectively.

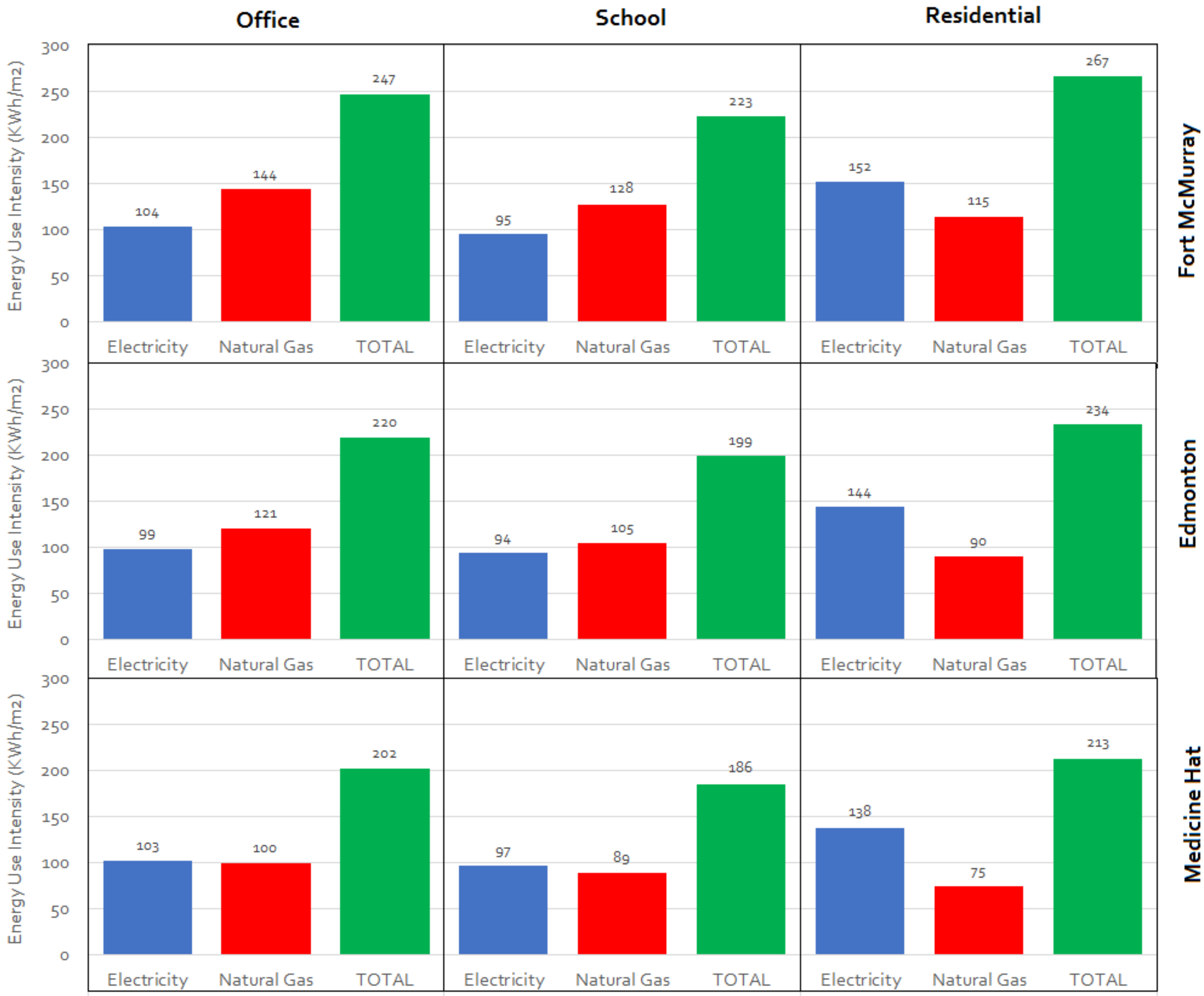

Figure 15 Energy use intensity for CWEC weather scenarios (current), geographic locations, and building types

5.3 Model Sensitivity to Climate Change

In this section, the data analysis is expanded to include the two future climate scenarios for each building type and location; RCP8.5 and RCP4.5. Figure 16 shows the natural gas, electricity, and total energy use for each of the building types and geographic locations for the RCP8.5 climate projection. Each of the scenarios show that natural gas for space and domestic hot water heating decreases in future years, while the electricity use, associated with cooling, lighting, fans, pumps and other electrical loads, is increasing slightly for the office and school, and decreasing slightly for the residential building. Since the residential building dwelling and commercial units are heated partly with electric heat pumps, the electrical energy demand is higher than for natural gas, and the trend in electricity use is reversed compared to the other two buildings that are heated exclusively by natural gas. The total energy use decreases with time for all scenarios.

Maximum PV capacity for a flat, 12% efficient system on 100% of the roof area is shown with the black line for each building and geographic location. It is noted that the only scenario where the building is close to net-zero energy ready is the school in Medicine Hat at the end the century for the RCP8.5 projection. The school has an advantage over the other two buildings for offsetting energy use with PV, since it has the highest roof area relative to floor area. The residential building, with six storeys, has the lowest roof area relative to floor area. The percentage improvement to the baseline building energy efficiency that is required to achieve net-zero ready status is shown in Figure 18 for the RCP8.5 projection.

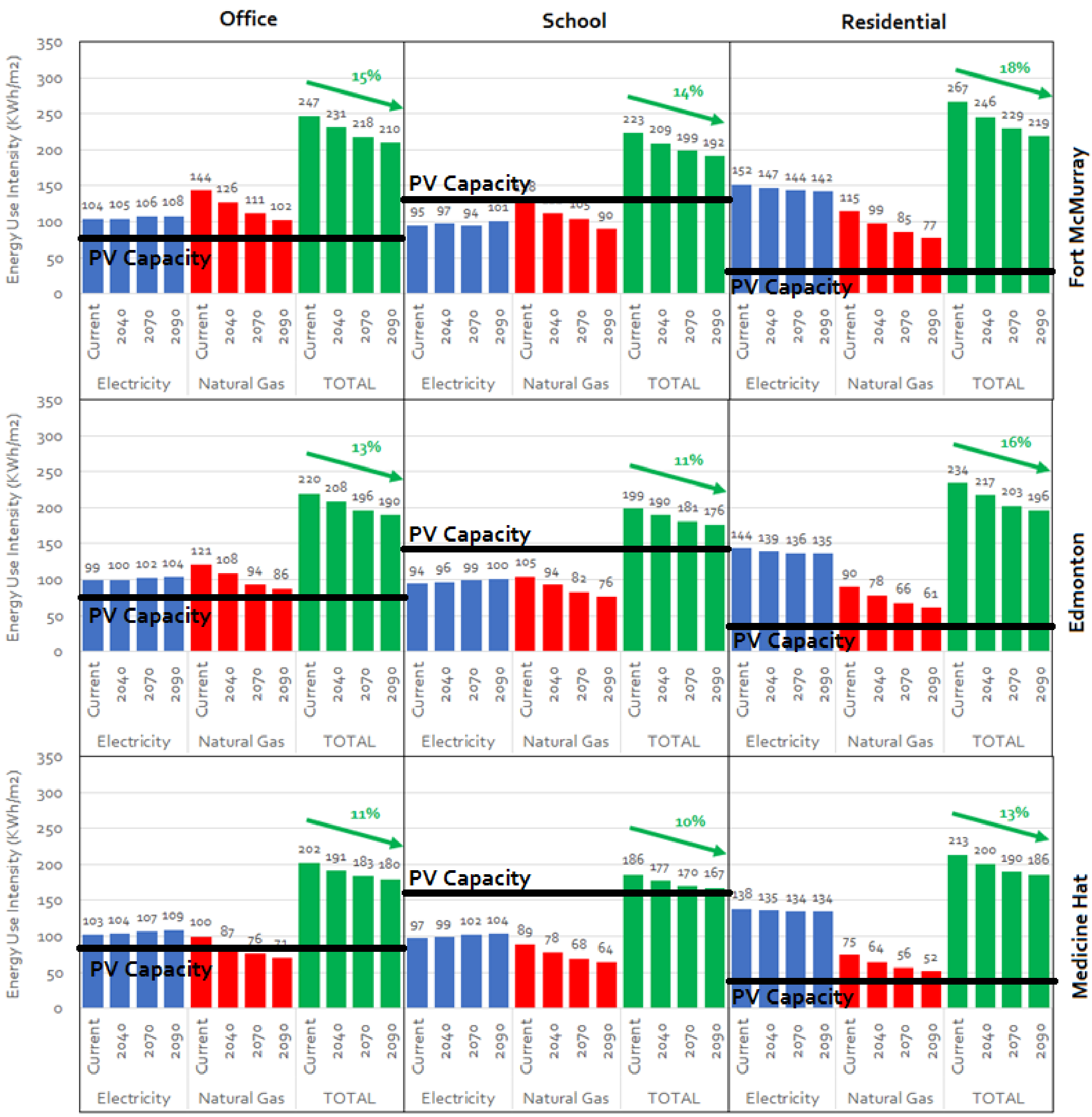

Figure 16 Energy use intensity trends for the RCP8.5 climate projection, geographic locations, and building types

Figure 17 shows the natural gas, electricity, and total energy use for each of the building types and geographic locations for the RCP4.5 climate projection. The trend directions are the same as the RCP8.5 projection, but with more gradual rates, as expected, since the RCP4.5 warming trend is more gradual. PV capacity, as calculated for the previous figure, is shown by the black line. There are no scenarios that achieve net-zero capability for the RCP4.5 projection. The percentage improvement to the baseline building energy efficiency that is required to achieve net-zero ready status is shown in Figure 19 for the RCP4.5 projection.

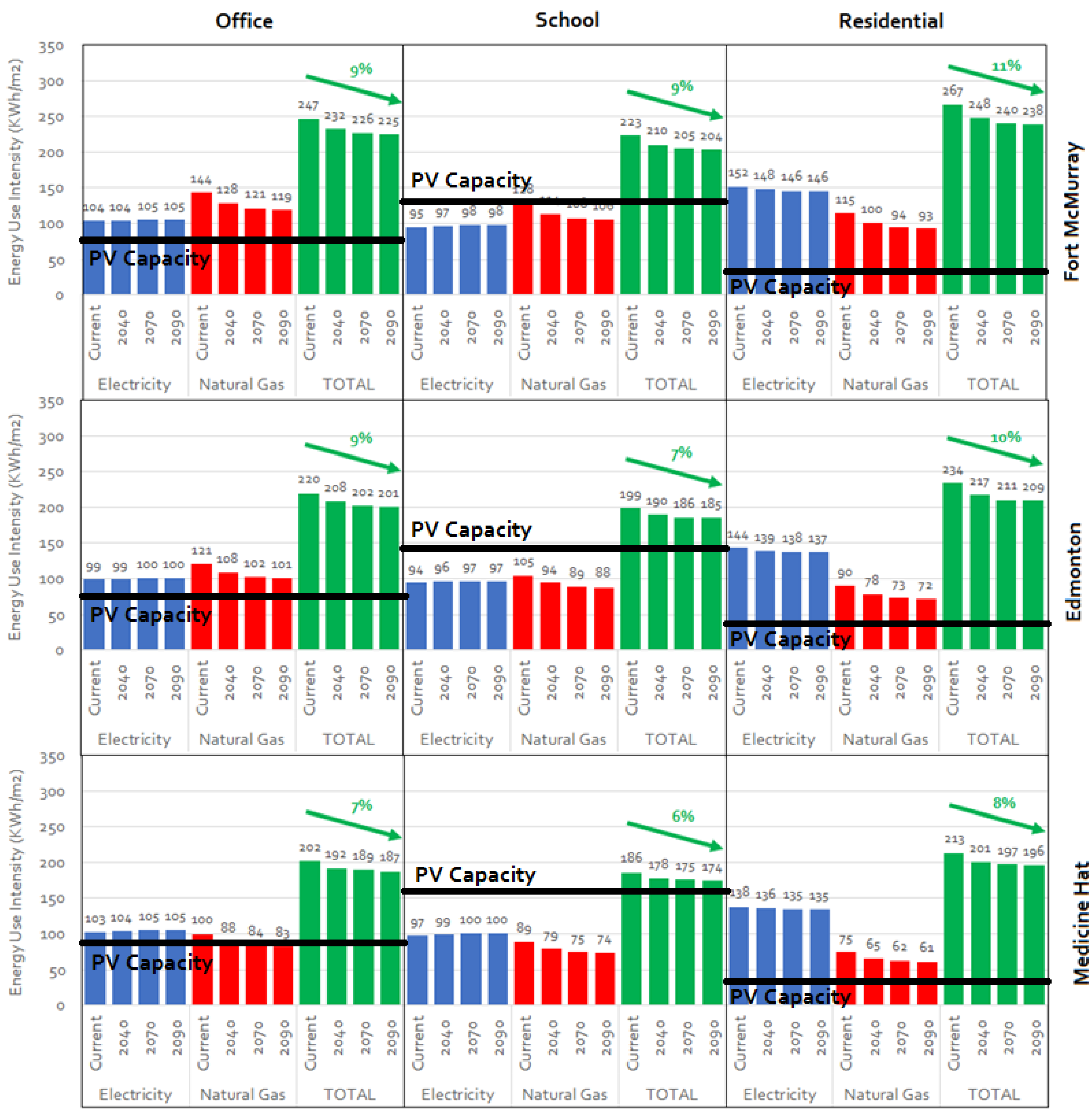

Figure 17 Energy use intensity trends for the RCP4.5 climate projection, geographic locations, and building types

Figure 18 Percentage energy savings from baseline required to reach net-zero ready for RCP8.5

Figure 19 Percentage energy savings from baseline required to reach net-zero ready for RCP4.5

5.4 Parametric Study Results

In this section, the data analysis is expanded to include building design variations investigated in the parametric study, as shown in Table 1. For each archetypal building, 756 simulations are completed to show the relative sensitivity of changes to the building design options and weather. Figure 20 shows an expanded illustration from the parametric study charts in Figure 21,22,23 to describe the format in detail. Each coloured line on the chart represents one of the 21 weather scenarios that are investigated in this study. The variations along each line shows the percentage change in total building energy associated with building parameter alterations relative to the baseline model.

The charts simultaneously show the sensitivity of energy use in each building to weather and building design variations. The point at which the 0% line intersects the current weather line indicates the design parameter that is included in the baseline building.

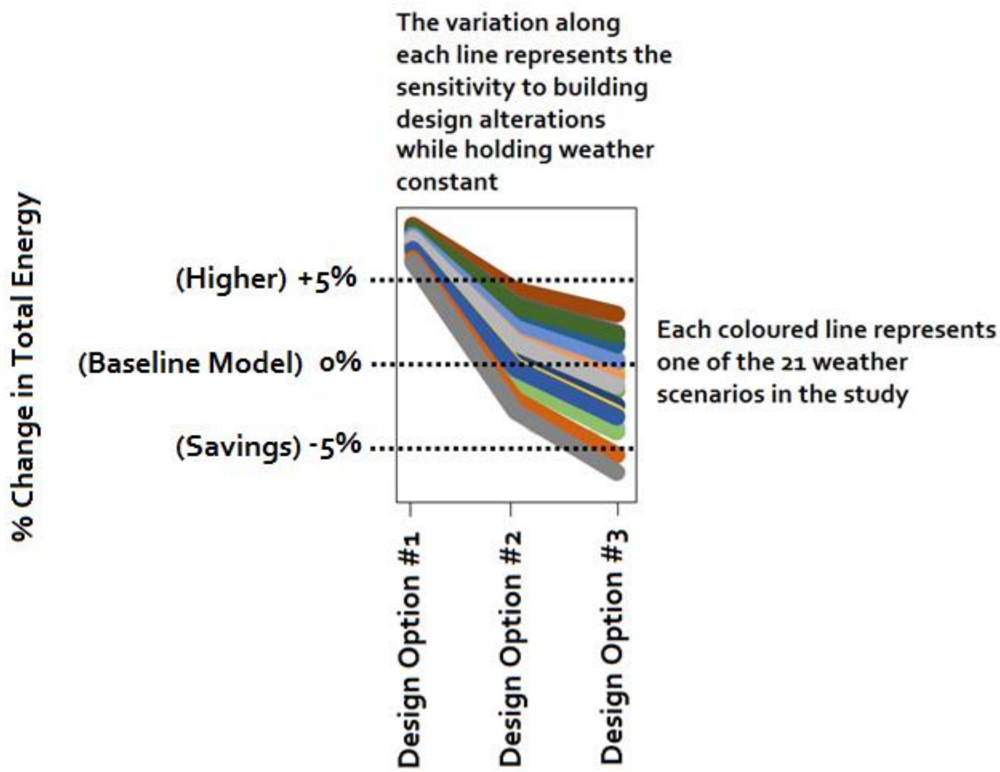

Figure 20 Chart legend for Figures 20, 21,22

Figure 21 shows the parametric study results for the office building. Values that fall below the 0% line indicate energy savings compared to the baseline building, whereas values that fall above 0% indicate energy use increases. The design parameters on the horizontal axis are broken into three groups: mechanical systems, lighting, and envelope parameters.

The results simultaneously show the sensitivity to weather and building design variation. For example, building orientation has a relatively small impact on total energy use, regardless of the weather scenario. The impact of heating recovery ventilation (HRV), on the other hand, is seen to be dependent on the weather scenario. In colder weather scenarios, energy use continuously improves with increasing HRV effectiveness, while the warmer weather scenarios show a reversal of the trend at the higher effectiveness values for some scenarios. When the best parameters are combined to create an optimized scenario, an average energy savings of 45% is observed for the office building for the three locations.

Figure 22 shows the percentage difference in total energy use for of each parametric variation for the school building. The trends for the school are similar to the office building, with the exception of HRV effectiveness, which has a higher magnitude of change relative to the base case. The school building is sensitive to HRV effectiveness regardless of the weather scenario. Parameters such as the wall and roof insulation levels are relatively insensitive to changes in weather, whereas changes to heating efficiency, infiltration rate, and window to wall ratio (WWR) show some sensitivity to weather. When the best parameters are combined for an optimized scenario, an average energy savings of 23% is observed for the school building for the three locations.

Figure 23 shows the percentage difference in total energy use for of each parametric variation for the residential building. The results for the residential building are similar to both the office and the school, with a large response to HRV effectiveness, infiltration, window type, and WWR. When the best parameters are combined to create an optimized case, an average energy savings of 35% is observed for the residential building for the three locations.

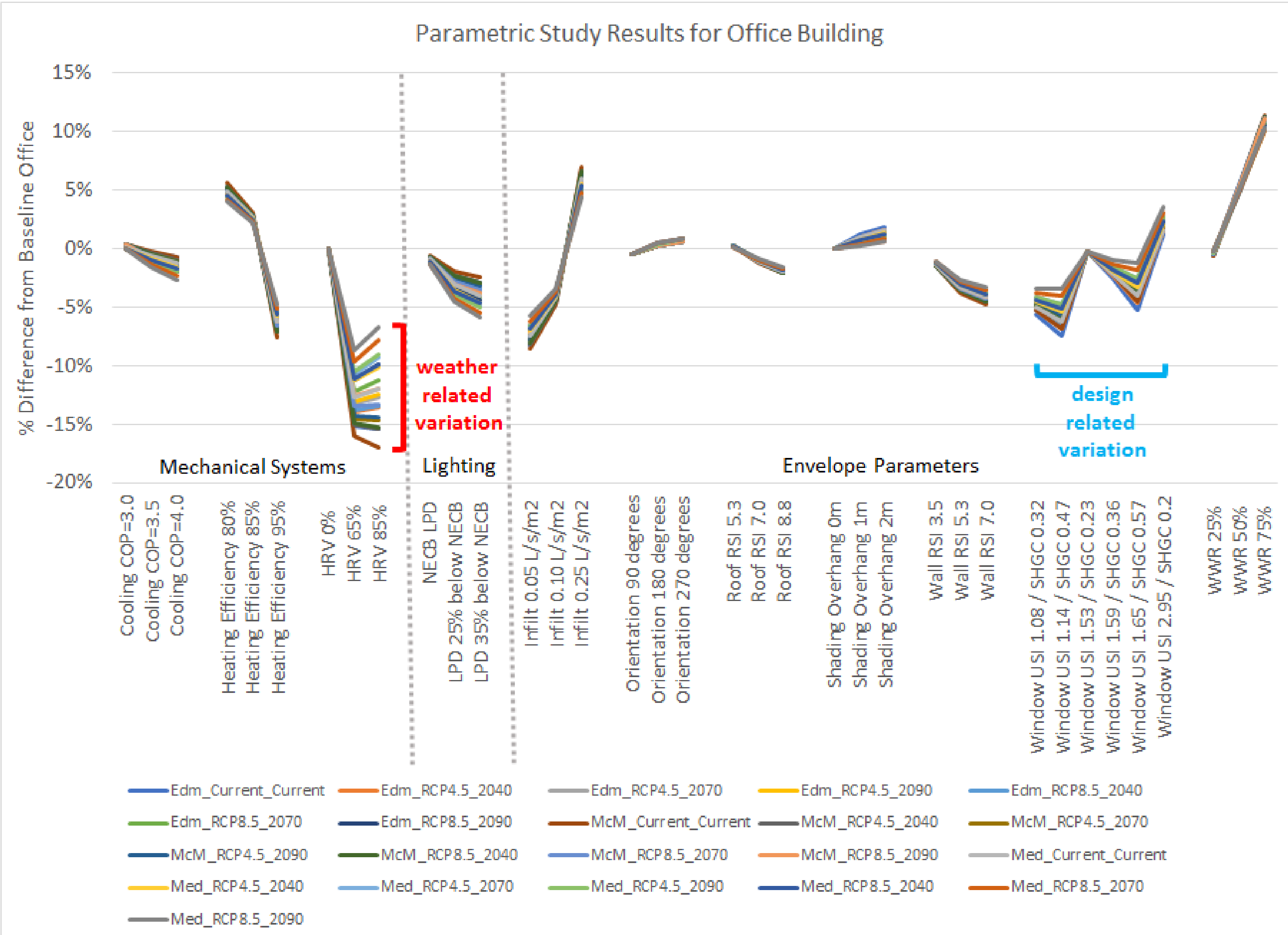

Figure 21 Parametric study results for the office building for all weather scenarios

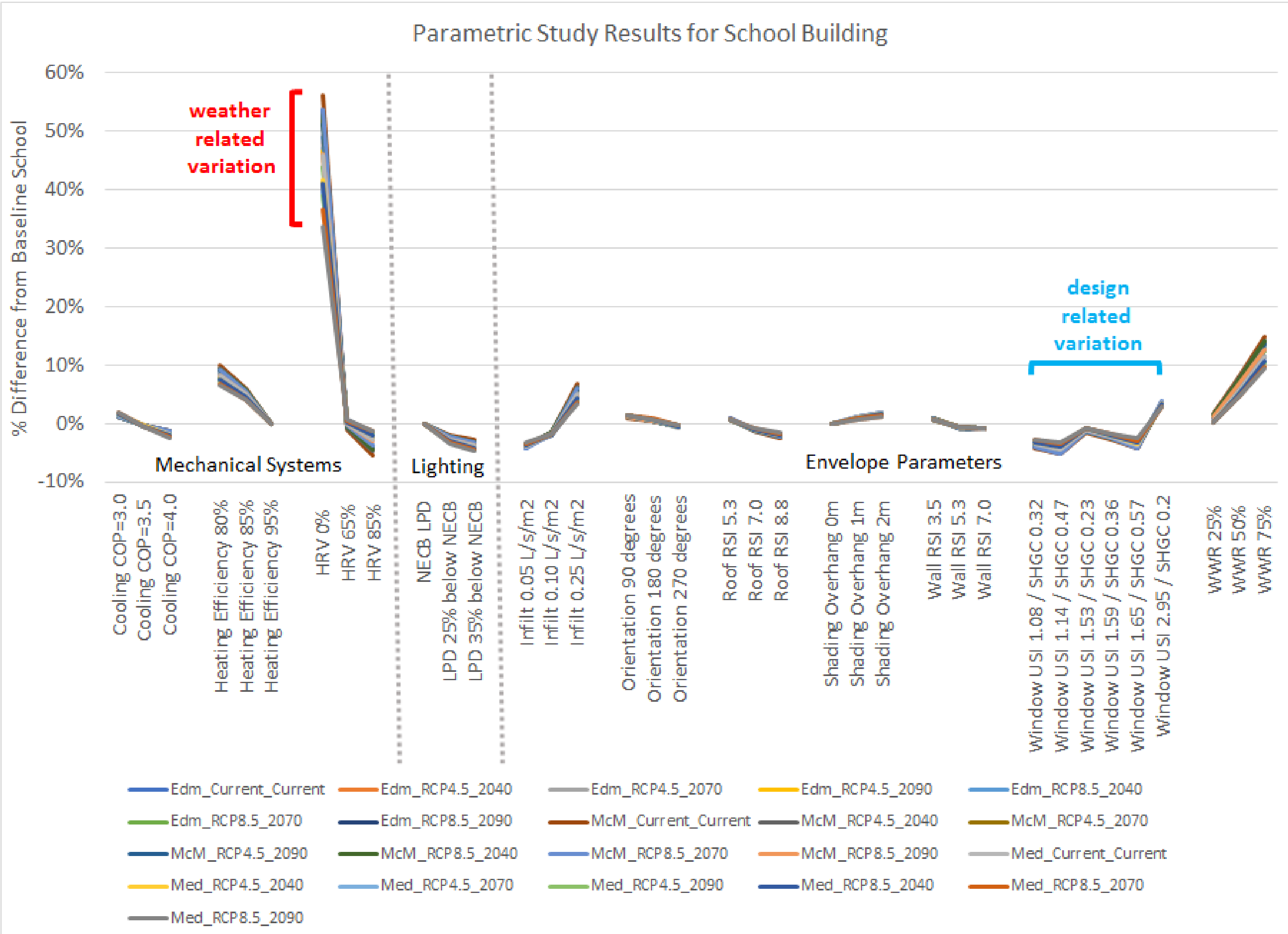

Figure 22 Parametric study results for the school building for all weather scenarios

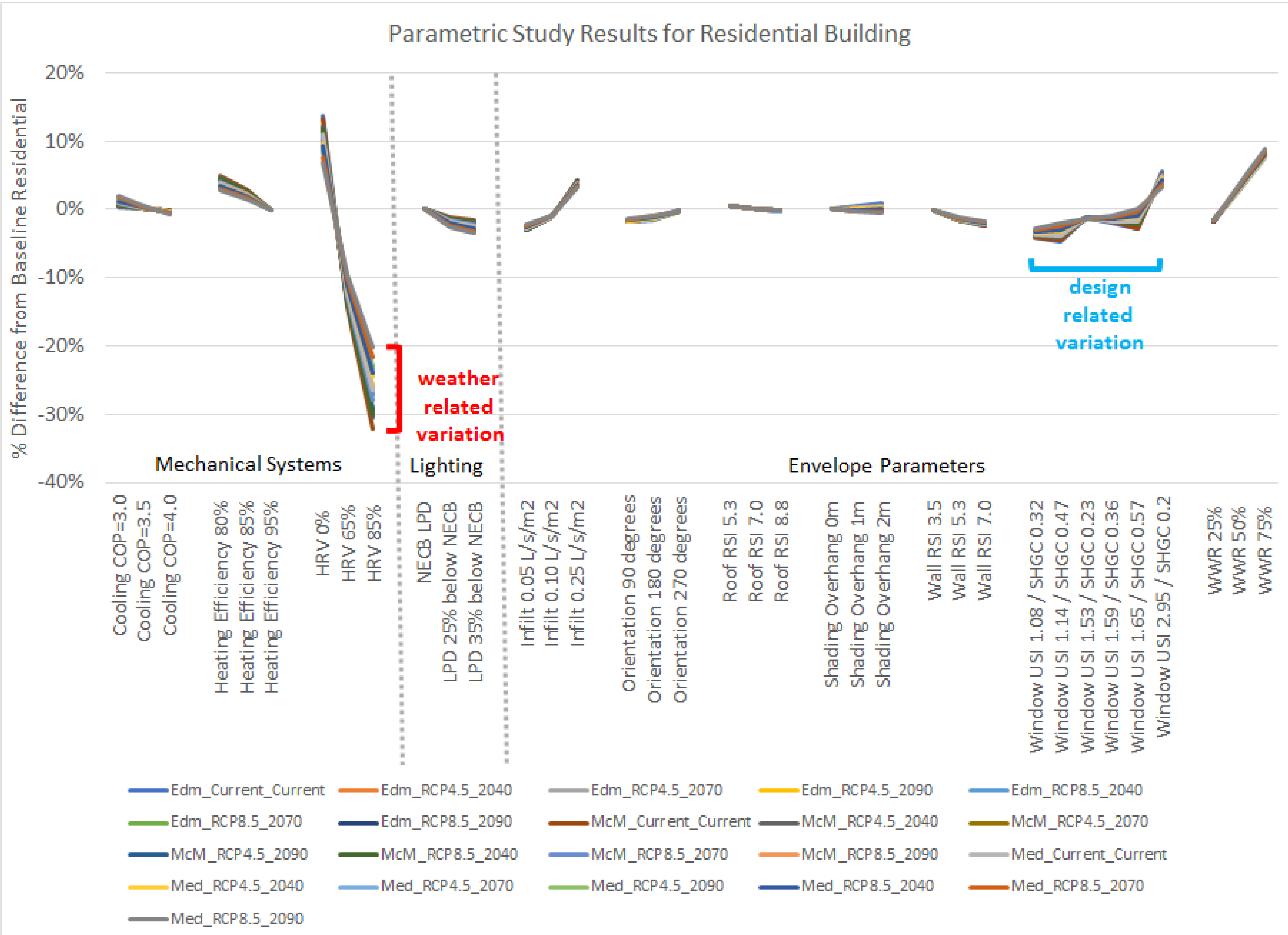

Figure 23 Parametric study results for the residential building for all weather scenarios

5.5 Discussion

The energy modeling portion of this study provides insight into the relative importance of weather and design decisions on the energy efficiency of building designs and the potential to achieve net zero energy status. The following paragraphs provide discussion points about the energy modeling results.

First, it is observed that the CWEC weather files, which are typically used for compliance energy modeling, are based on a 30-year window of historical data with a mid-point year of 1975. In a scenario where climate is considered static over time, this approach provides a statistically robust approach to generating typical meteorological years (TMY). However, in a scenario where temperatures are warming in the future, the method of generating the TMY weather for building simulation requires a different approach. In this study, modified weather files are used to predict the energy use of buildings for the years 2040, 2070, and 2090. For building components that have a relatively long lifespan, such as the envelope, using a future weather file provides a more representative view of heating and cooling loads over the service life of the building.

Next, when the heating degree days (HDD) and cooling degree days (CDD) are calculated for the various weather files, it is observed that the three study locations are predicted to shift to lower climate zones as the temperature warms throughout the century. This change will not only have an impact on the amount of energy that is required to maintain thermal comfort, it also has implications on the design capacity of mechanical systems in buildings. Although mechanical systems are typically updated several times throughout the life cycle of a building, providing an opportunity to recalculate capacities, it may be difficult to reconfigure the type of system that is required in future years based on the original geometry of the mechanical spaces in the building. To avoid future retrofit costs, building mechanical spaces should be designed with flexibility in mind.

Next, to accommodate the goals of implementing a net-zero energy (NZE) ready building code by 2030, consideration is given to the amount of renewable energy that is available from PV installed on the roof of the building. When the baseline archetypal office, school, and residential buildings are simulated under the various weather scenarios, it is observed that none of the buildings' energy use is within the capacity of the PV system at any time in the study period. Only by combining the best of all parametric study parameters does the school building in Medicine Hat achieve net zero energy ready status by 2030. The archetypal office and school buildings in this project do not reach net-zero ready status based on the PV assumptions and design parameter ranges selected.

In general, NZE is easier to achieve with roof mounted PVs for buildings that have higher roof area relative to floor area: i.e. low-rise buildings. The archetypal school in this study has an advantage in this regard, since it is mainly a single storey building with a roof to floor area ratio of 96%. Multi-storey buildings such as the archetypal office and residential buildings in this study have lower ratios, 52% and 21% respectively, which limits the amount of PV energy that can be collected per unit of floor area. For buildings to achieve net-zero ready status in each location, energy use must be decreased or PV energy increased, or both. One option to further reduce energy use includes installing a ground source heat pump to improve heating/cooling efficiency. An option to increase PV potential is to install solar modules on the façade in addition to the roof of the building. Further simulation work is required to delineate the combinations of parameters that will achieve NZE ready status for each archetypal building.

The energy modeling results in this study show the end-use energy consumption of complete buildings, which includes the contributions from the building envelope, lighting systems, and mechanical systems. An option for future work is to highlight the importance of the building envelope on the long-term resilience of buildings in the context of climate change by including analysis of thermal energy demand intensity (TEDI). This metric addresses the heating and cooling loads of the building independently of mechanical systems, which deliver climate control services at varying degrees of efficiency depending on the technologies employed.

Although the results in this section are intended to address the energy consumption of buildings with the underlying goal of reducing emissions associated with climate change, calculation of primary emissions from grid electricity and natural gas is not within the scope of this study. A recommendation for future work is to introduce a carbon emission rate for each energy type and assess the simulation results in terms of greenhouse gas emissions.

6.0 Results: Water Use and Future Precipitation

When we consider the effect climate change will have on buildings, we must consider the impacts of changing precipitation patterns in relation to water used in the buildings. This section presents information on Albertans' water consumption rates, introduces indoor water conservation measures, and then provides a discussion on future precipitation levels in the province in relation to water demand levels.

6.1 Water Use in Albertan Buildings

The baseline interior water used for each of the 3 buildings within this study (school, residence, and office) is analyzed to understand consumption levels. All interior flow and flush fixtures are considered, whereas water equipment such as dishwashers and washing machines are not. Analysis is completed using a LEED v4 BD+C water calculator, which is based on interior building area and calculated occupancy. Baseline water consumption for various fixtures is shown in Table 3 (taken from the LEED v4 BD+C reference guide).

Table 3: Indoor Fixture Baseline Consumption (LEED v4 BD+C reference guide)

Fixture	Baseline (SI units)
Toilet	6 lpf
Urinal	3.8 lpf
Public lavatory faucet	1.9 lpm
Residential lavatory faucet	8.3 lpm
Kitchen faucet	8.3 lpm
Showerhead	9.5 lpm

lpf = litres per flush, lpm = litres per minute

For the purposes of assessing water efficiency, LEED includes standardized information for how often and how long fixtures are typically used. Table 4 shows the duration and uses per day for non-residential buildings. Table 5 shows the same information for residential buildings.

Table 4: Non-residential Default Fixture Uses (LEED v4 BD+C)

Fixture	Duration (s)	Uses per Day	
		Employees (FTEs)	Students
Toilet (female)	NA	3	3
Toilet (male)	NA	1	1
Urinal (male)	NA	2	2
Public lavatory faucet	30	3	3
Shower	300	0.1	0
Kitchen sink	15	1	0

Table 5: Residential Default Fixture Uses (LEED v4 BD+C)

Fixture	Duration (s)	Uses per Day
Toilet	NA	5
Residential lavatory faucet	60	5
Shower	480	1
Kitchen sink	60	4

The following sections show the calculated indoor water use for the three archetypal buildings in this study.

6.1.1 School

The archetypal school building in this study has a floor area of 4,860 m² and a LEED default occupancy of 60 FTEs and 600 students. The building is modeled as open for 200 days/year. Figure 24 shows the breakdown of indoor water use for the school building.

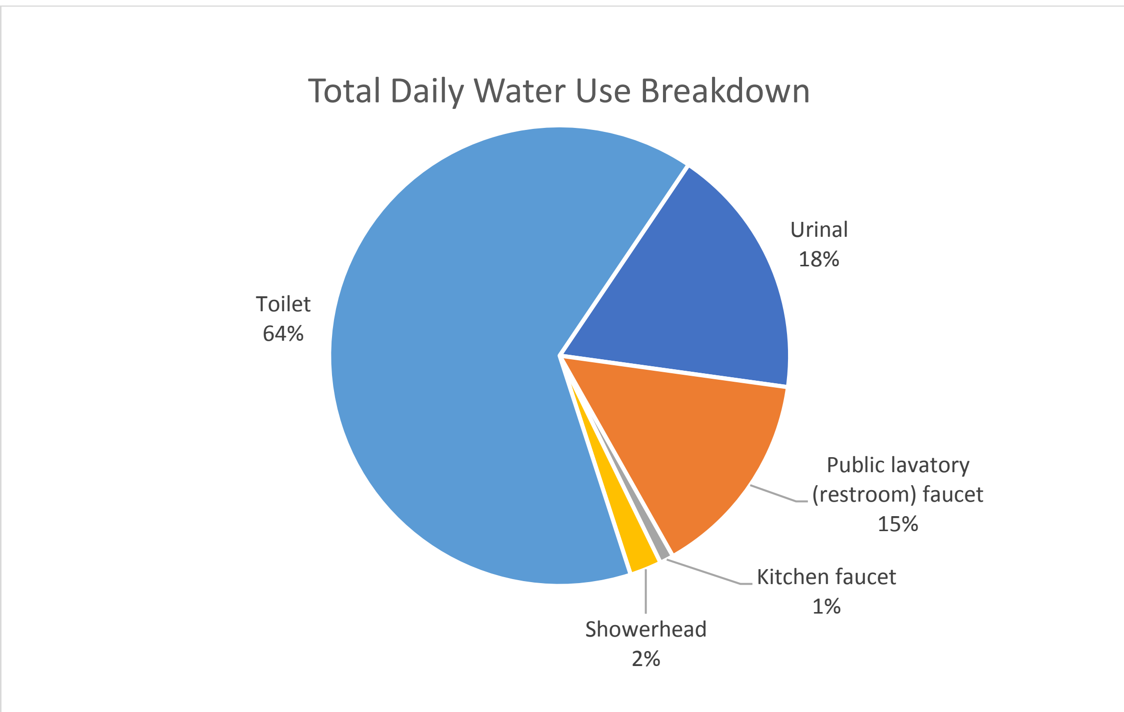

Figure 24 School indoor water use

Overall, we can see that increasing toilet efficiency would have the greatest effect on indoor water use, followed by urinals and lavatory faucets.

6.1.2 Office

The archetypal office building in this study has a floor area of 2,668 m^2 and a LEED default occupancy of 110 FTEs. The building is modeled as being in operation for 252 days/year. Figure 25 shows the breakdown of indoor water use for the office building.

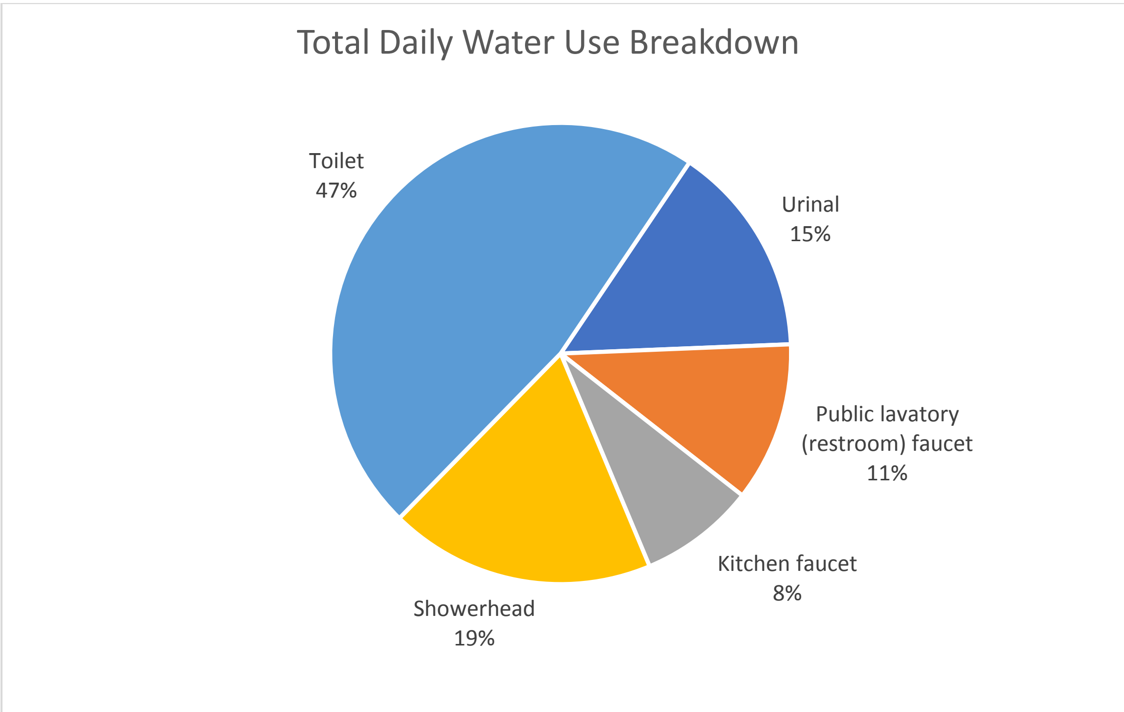

Figure 25 Office daily water use

Overall, we see that similar measures should be targeted in the office building as in the school building, with the focus being on efficient toilets, urinals, and public faucets. It is assumed that employees will be using manual forms of transport to get to and from work, encouraging the use of showers.

6.1.3 Residential

The archetypal residential building has a floor area of 8,200 m^2, with a LEED default occupancy of 10 FTEs and 450 residents. The building is assumed to operate for 365 days/year. Figure 26 shows the breakdown of indoor water use for the residential building.

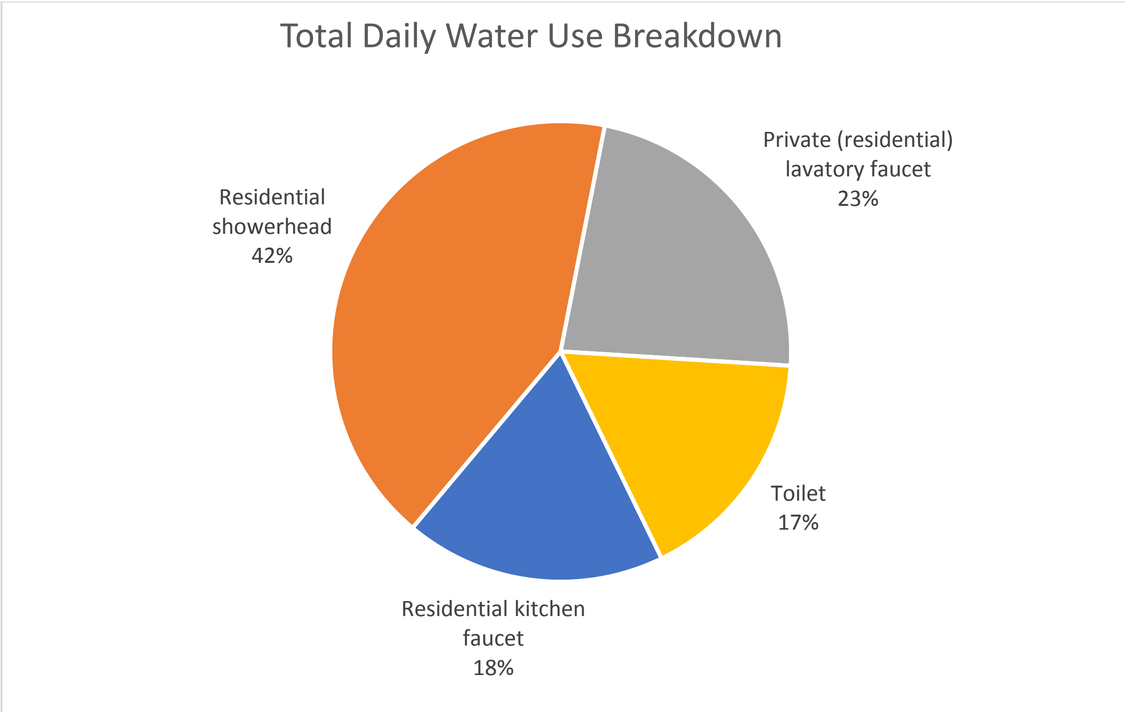

Figure 26 Residential daily water use

All four of the fixtures contribute significantly to the indoor water consumption and should be considered for conservation measures.

6.2 Water Conservation Measures

Canadians are some of the highest per capita water users in the world (Government of Canada, 2010). A significant amount can be done to the buildings themselves to help ensure conservation. These measures are grouped into two categories: water fixture efficiency, and water reuse.

6.2.1 Water Fixture Efficiency

Water fixture efficiency measures are primarily aimed at reducing indoor potable water consumption by the end-user. There are many fixtures and equipment that reduce water usage significantly compared to building code standards by increasing water flow and flushing efficiency. These fixtures are highlighted by rating systems such as the US EPA's WaterSense label. The main water consuming fixtures in a typical building are toilets, urinals, lavatory faucets, kitchen faucets, and showerheads.

Indoor water efficiency modeling is completed by analyzing conservation measures against the baseline water usage for each building. Efficiency recommendations are made based on a good, better, best scale based on their ability to improve water use efficiency. "Good" options represent the scenario where the single fixture with the most amount of water usage is targeted alone. The "Better" option, represents the scenario where the top three water usage fixtures are targeted. The "Best" option recommends that the top three fixtures in the building are targeted, some with ultra-high efficiency fixtures.

6.2.1.1 School

Table 6 shows the good, better, and best scenarios for the school building.

Table 6: Recommended fixtures for school water efficiency improvements

Fixture	Toilet (lpf)	Urinal (lpf)	Public lavatory faucet (lpm)	Kitchen faucet (lpm)	Showerhead (lpm)
Baseline Standard	6.0	3.8	1.9	8.3	9.5
Good: High Efficiency Toilets	4.2	3.8	1.9	8.3	9.5
Better: High Efficiency Toilets, Urinals, & Lav Faucets	4.2	0.5	1.3	8.3	9.5
Best: High Efficiency Fixtures	3.0	0.0	1.3	5.7	5.7

When analyzing the five indoor water fixtures for schools, the most obvious one to target is the toilets, as they account for 64% of baseline water use. The typical toilet reference standard is 6 lpf, but many toilets average much lower volume per flush rates, and it is not uncommon to see 4.2 lpf or less. Table 7 shows the percentage decrease in water use for the baseline and improved scenarios.

Table 7: School water consumption and reduction from baseline standards

Case	Annual Consumption	% Reduction from Baseline
Baseline	2,570,100	0
Good	2,073,300	19
Better	1,558,500	39
Best	1,136,700	56

6.2.1.2 Office

Table 8 shows the good, better, and best scenarios for the office building.

Table 8: Recommended fixtures for office water efficiency improvements

Fixture	Toilet (lpf)	Urinal (lpf)	Public lavatory faucet (lpm)	Kitchen faucet (lpm)	Showerhead (lpm)
Baseline Standard	6.0	3.8	1.9	8.3	9.5
Good: High Efficiency Toilets	4.2	3.8	1.9	8.3	9.5
Better: High Efficiency Toilets, Urinals, & Showerheads	4.2	0.5	1.9	8.3	5.7
Best: High Efficiency Fixtures	3.0	0.0	1.3	5.7	5.7

When considering the water fixture baseline for offices, we see that toilets use the highest percentage of water at 47%, which is almost half of the buildings entire use. Therefore, we targeted toilets for the "Good" scenario by selecting efficient toilets with a 4.2 lpf. For the "Better" scenario, we selected the top three water usage fixtures in the building, including 0.5 lpf urinals and 5.7 lpm showerheads. It should be noted that although showers are considered a high percentage water user in this office analysis, this may not be consistent with all buildings since shower utilization rates are variable from building to building.

For the "Best" scenario, all fixtures have been selected for high efficiency, including public lavatory faucets of 1.3 lpm and kitchen faucets of 5.7 lpm. This results in a water usage reduction of 41% below the baseline standard, as shown in Table 9.

Table 9: Office water consumption reduction from baseline standards

Case	Annual Consumption	% Reduction from Baseline
Baseline	706,167	0
Good	606,375	14
Better	462,231	35
Best	338,877	52

While the office buildings "Best" scenario is not as high as for the school, it is still a significant amount of water which can be reduced.

6.2.1.3 Residential

Table 10 shows the good, better, and best scenarios for the residential building.

Table 10: Recommended Fixtures for Residential Water Efficiency

Fixture	Toilet (lpf)	Res. Lavatory Faucet (lpm)	Res. Kitchen Faucet (lpm)	Res. Shower-head (lpm)
Baseline Standard	6.0	8.3	8.3	9.5
Good: High Efficiency Showerheads	6.0	8.3	8.3	5.7
Better: High Efficiency Showerheads & Faucets	6.0	4.5	5.7	5.7
Best: High Efficiency Fixtures	3.0	1.3	5.7	5.7

When considering the baseline water usage in residential buildings, there are four fixtures that have an influence on the buildings indoor water use, with showerheads having the most significant impact on water usage. For the “Good” scenario, high efficiency 5.7 lpm showerheads are selected, which results in a 17% reduction from the baseline water usage. The “Better” scenario targets the top three fixtures for high efficiency, including kitchen faucets with 5.7 lpm flow rate, and lavatory faucets using 4.5 lpm. The “Better” scenario is shown to result in roughly double the savings compared to the “Good” scenario.

The “Best” scenario converts all four fixtures to high efficiency options, including 4.2 lpf toilets. Since lavatory faucets have a very high baseline water usage, we also selected an ultra-high efficiency faucet that is commonly used in public lavatories. These 1.3 lpm faucets are becoming much more common, and thus it makes sense to incorporate their use in this case. In total, the “Best” scenario results in water savings of 47% against the baseline water use standard.

Table 11 shows the percentage decrease in water use for the baseline and improved scenarios.

Table 11: Residential water consumption reduction from baseline standards

Case Name	Annual Consumption	% Reduction from Baseline
Baseline	20,328,693	0
Good	17,066,469	16
Better	13,911,555	32
Best	10,125,045	50

It is noted that annual consumption is significantly higher for residential buildings than for schools or offices, due to the nature of the occupancy.

6.2.2 Water Reuse

There is potential for water reuse measures for the interior and exterior parts of a building to reduce potable water demand from municipal sources. Although these measures do not necessarily decrease the amount of water being used by the building, they do limit the amount of potable water drawn from the municipal water system.

Water reuse can be split into rainwater collection and reclaimed water. Rainwater is collected during rainstorms or from melted snowfall and is typically captured in large cisterns either above or below ground. With filtering, this water can be used for either irrigation, toilet, or urinal purposes (Government of Alberta, 2010).

Reclaimed water is water that has already been used in some capacity within the building and has been captured to be reused in either irrigation or for indoor use. This water can also be split into 2 categories, black and grey water.

Black water is reclaimed from kitchen sinks, toilets, or urinals, and would need careful filtering to be reusable within the building. However, grey water is from showers, restroom faucets, or washing machines and requires far less filtering than black water. Unfortunately, as of April 2018, grey water is not approved for reuse in any capacity in or around buildings (Government of Alberta, 2016). An Alberta working group is currently in the process of establishing a reclaimed water framework which may allow for some building water reuse in the future. The US state of Washington (State of Washington, 2018) and the city of San Francisco (City and County of San Francisco, 2012) are a few governmental bodies that are helping to define a path forward for reclaimed water, and actively encourage buildings and systems to take advantage of its benefits.

6.3 Future Precipitation Trends

To understand the effects of changing precipitation in each of the three Alberta cities in this study, CMIP5 data is downloaded for future precipitation levels for the years 2006 to 2100 (Government of Canada, 2018). The data is summed to give an overall idea of how each city is expected to be affected on an annual scale, as well as on a seasonal scale. By analyzing each city by season, we can isolate the precipitation changes that are occurring at certain times of the year. Seasons are analyzed by summing the precipitation data by the months shown in Table 12.

Table 12: Selected Months for Seasonal Analysis

Season	Months
Winter	December, January, February
Spring	March, April, May
Summer	June, July, August
Autumn	September, October, November

6.3.1 Medicine Hat

Figure 27 shows the annual precipitation projection for Medicine Hat for the RCP4.5 and RCP8.5 climate scenarios.

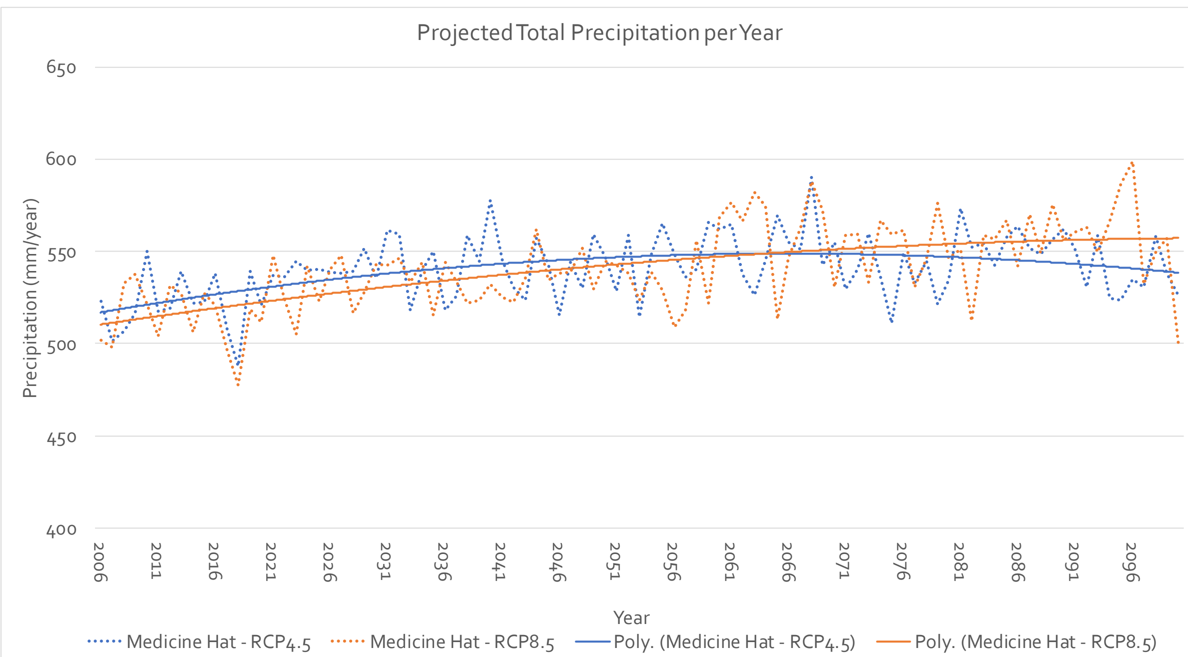

Figure 27 Total Medicine Hat precipitation per year

The precipitation levels for the RCP8.5 projection climb throughout the century, whereas the RCP4.5 projection peaks near mid century and then decreases in the latter portion.

In Figure 28, the seasonal precipitation data for Medicine Hat is shown.

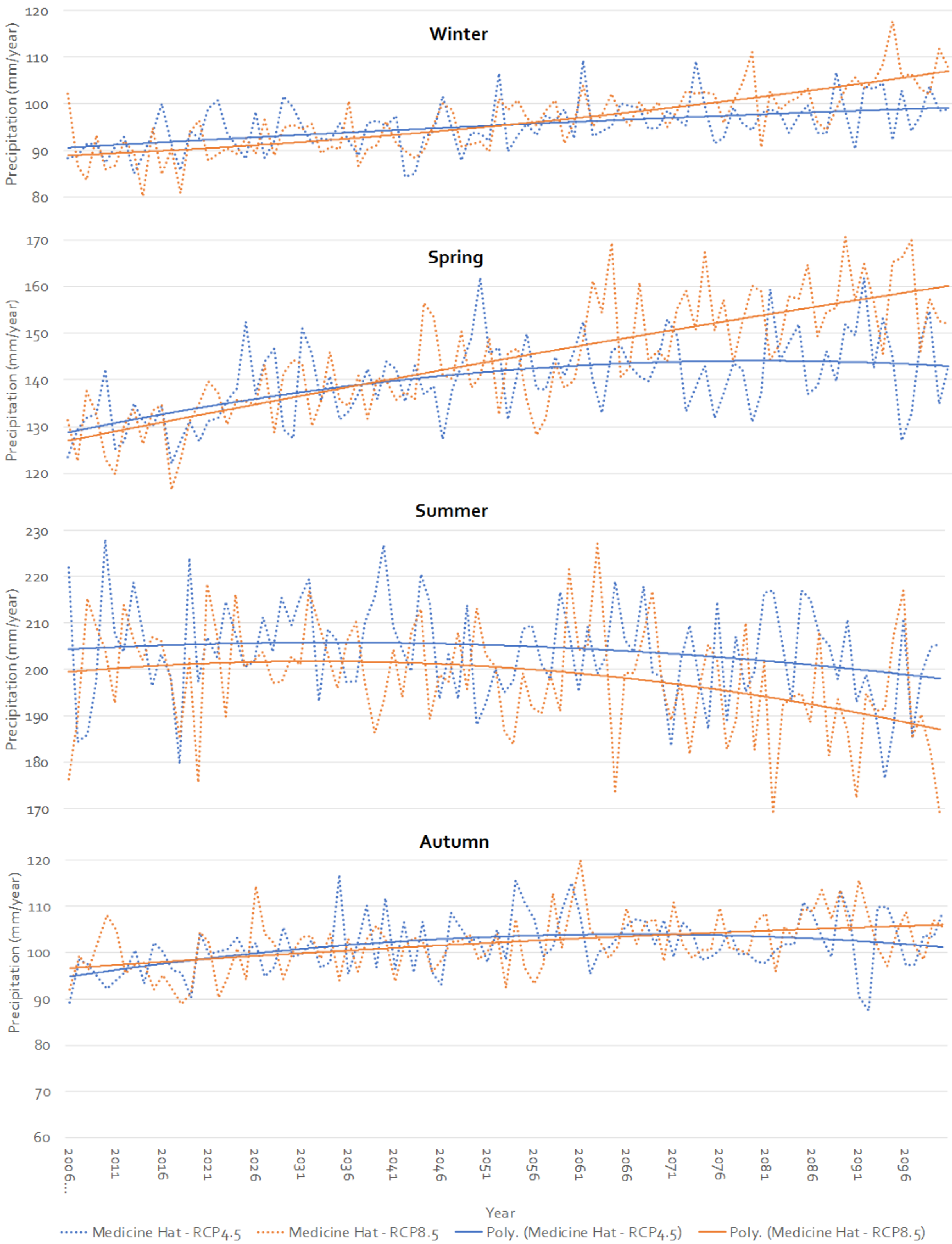

Figure 28 Medicine Hat projected precipitation by season for RCP4.5 and RCP8.5

Precipitation trends are different for each season, and each projection. All seasons, except for summer, show various magnitudes of increasing trends throughout the century for the RCP8.5 scenario, while the RCP4.5 trend flattens or reverses at approximately the midpoint of the century. Summer precipitation values show a relatively flat trend until the mid-point of the century, after which rates begin to decrease.

6.3.2 Edmonton

Figure 29 shows the annual precipitation projections for Edmonton for the RCP4.5 and RCP8.5 climate scenarios.

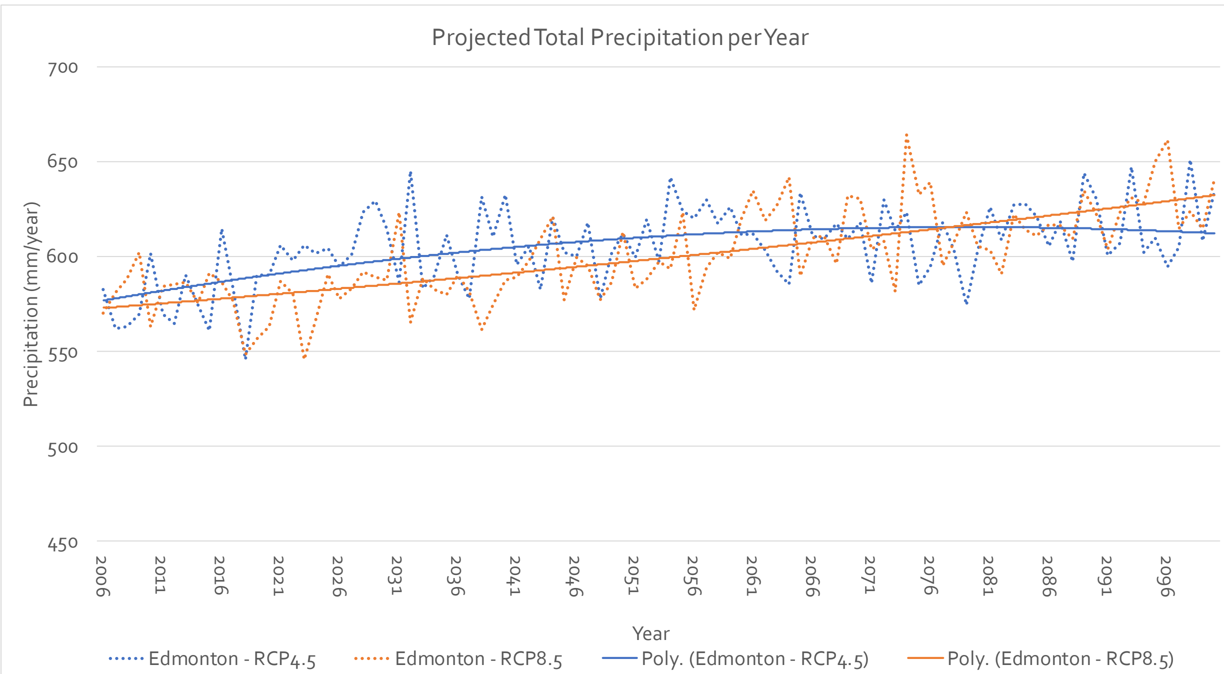

Figure 29 Total Edmonton precipitation per year

The precipitation trends are increasing for both projections for the first half of the century, with the RCP4.5 values plateauing in the second half of the century.

Figure 30 shows the seasonal precipitation projections for the Edmonton area.

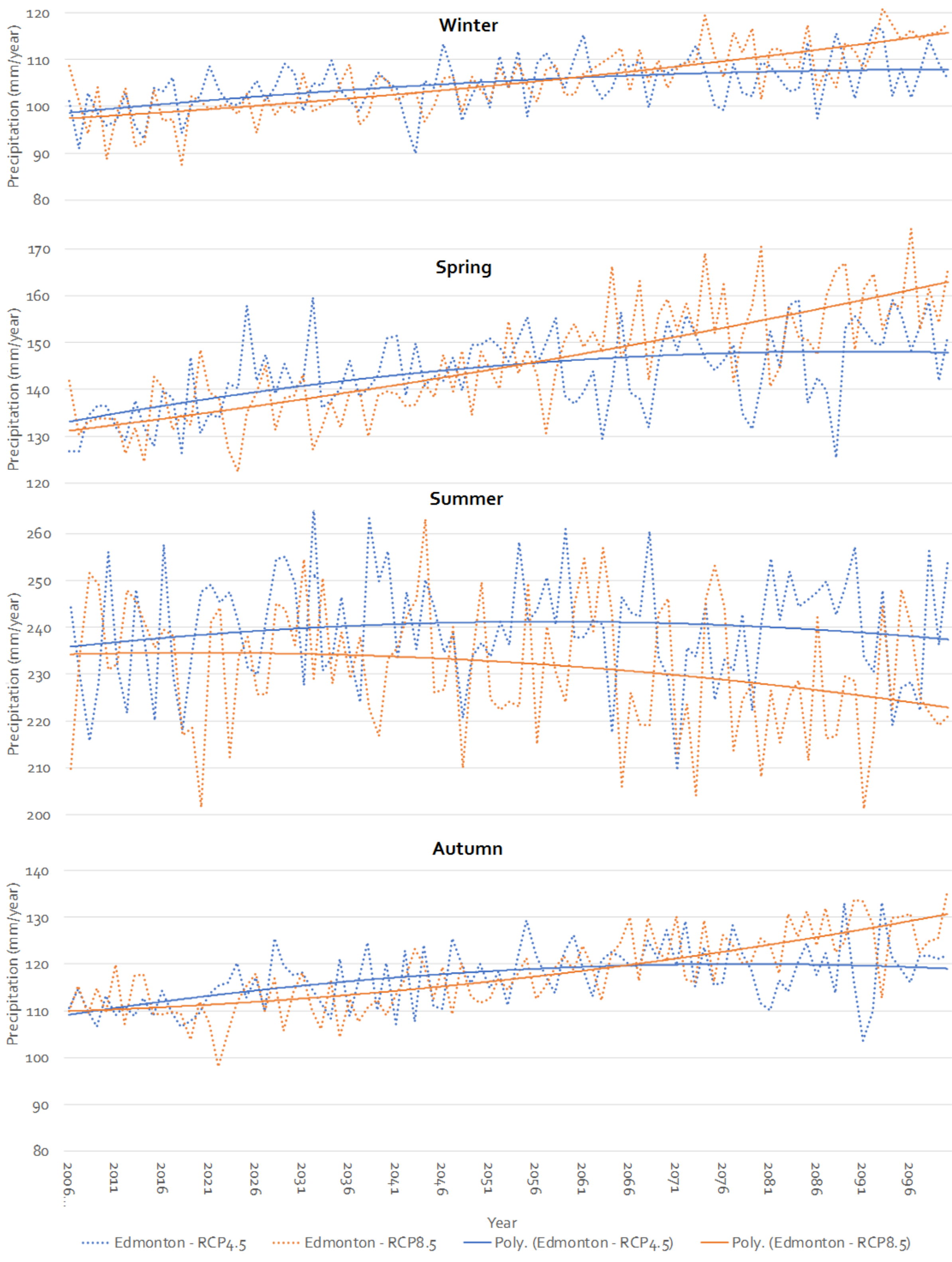

Figure 30 Edmonton projected precipitation by season for RCP4.5 and RCP8.5

For Edmonton, the winter, spring, and autumn seasons show similar trends, with RCP8.5 values climbing steadily and RCP4.5 trends flattening out at mid-century. Summer precipitation is relatively flat for the RCP4.5 projection, while the RCP8.5 projection shows an accelerating decrease throughout the century. The magnitude of precipitation is highest in the summer, followed by spring, autumn, and lowest in winter. The summer precipitation data shows a significant amount of variability in precipitation from year to year. This highlights the potential for extremes in future summer precipitation for this area.

When we consider overall Edmonton precipitation trends, there are a few key things we can notice. The first is the large amount of variability in the data in the spring and summer months. This would seem to show there is a significant amount of unpredictability in precipitation between months and years and would indicate that extreme weather events could become more common. The projections show that swings of 30 – 50 mm in precipitation between years will become the norm, as precipitation levels slowly increase overall through the century. The RCP4.5 trend indicates that if emissions are capped, precipitation will start to plateau and decrease, but if not, RCP8.5 shows precipitation increasing continuously, mostly in the spring, while summers become drier.

6.3.3 Fort McMurray

The projected yearly precipitation profile for Fort McMurray shows a similar trend to Edmonton, in that RCP4.5 shows a steady increase and slowly starts to plateau and decrease by the end of the century, while RCP8.5 precipitation continuously rises from 2006 to 2100. Figure 31 shows the annual precipitation trends for the RCP4.5 and RCP8.5 projections.

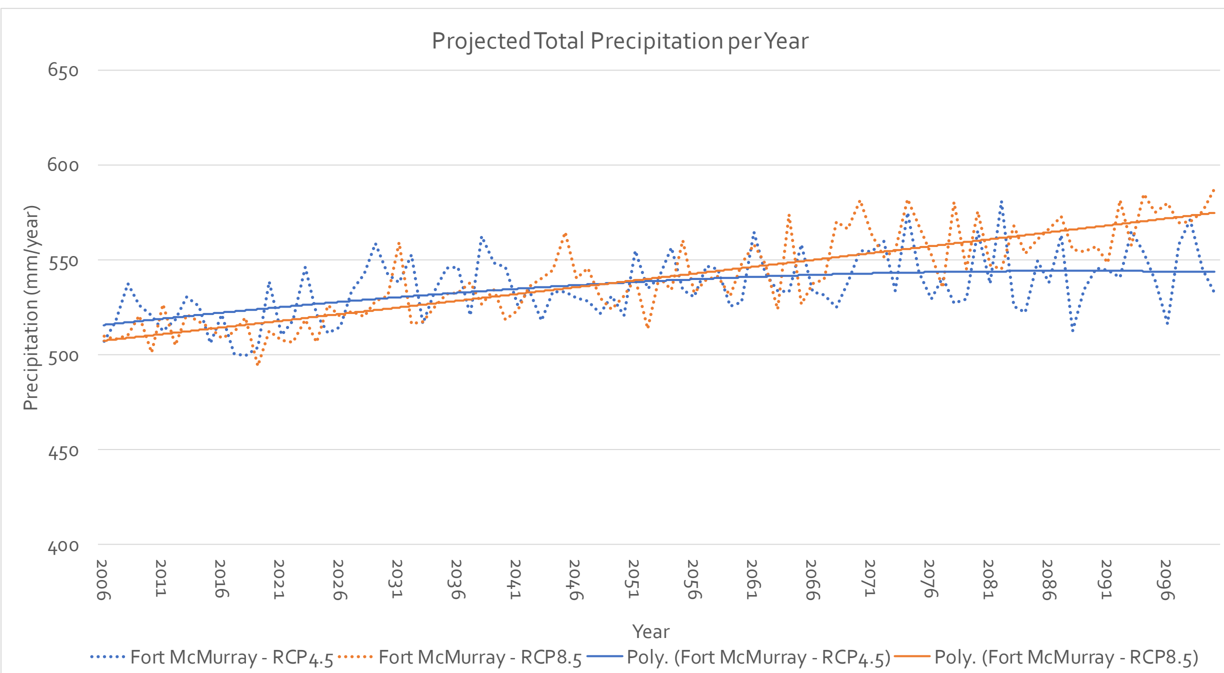

Figure 31 Total Fort McMurray precipitation per year

Figure 32 shows the seasonal precipitation projections for Fort McMurray.

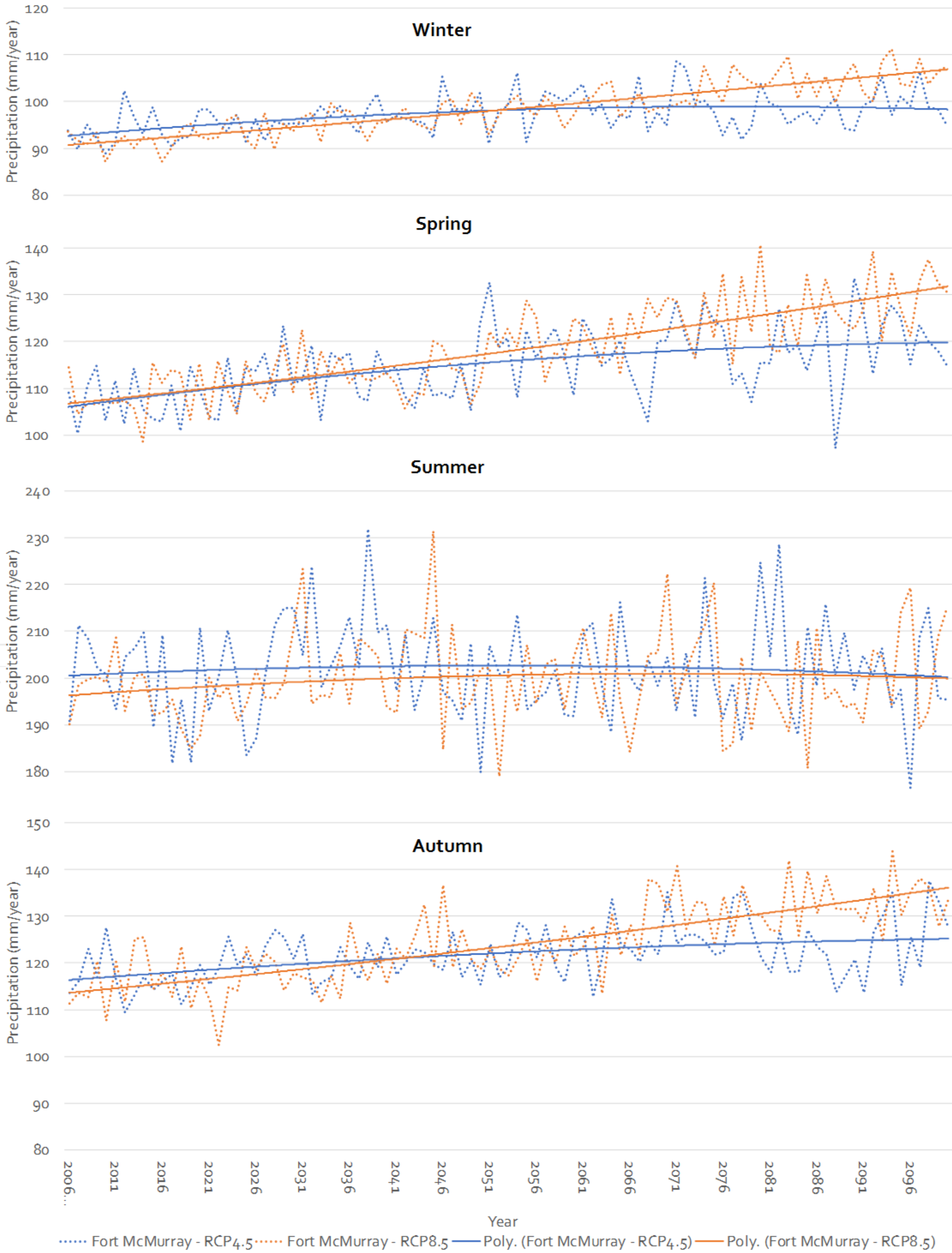

Figure 32 Fort McMurray precipitation for each season

Once again, the winter, spring, and autumn precipitation projections increase steadily through the century for the RCP8.5 scenario, whereas the RCP4.5 scenario increases until mid-century after which it flattens out. Summer precipitation can fluctuate significantly for both projections from year to year but follows a fairly flat trend throughout the century.

6.4 Rainwater Capture Volumes

The following paragraphs provide analysis to show the theoretical capability of each building, in each location, to offset indoor water consumption using captured precipitation volumes. The percentage of municipal water that can be offset is shown for the RCP8.5 projection in the year 2040, since it has the lowest precipitation volumes of all the scenarios.

The amount of rainfall that can be captured by each of the buildings to offset municipal water is calculated by summing the precipitation collected from 100% of the roof area during the non-winter months (March 1 to November 30). For this analysis, it is modeled that the storage capacity is capable of accommodating all predicted precipitation events. This represents the best-case scenario (i.e. the upper limit) of the water volume that can be captured.

The non-winter precipitation data is averaged over a 20-year window for each of the studied time periods; 2040, 2070, and 2090 for each location. Table 13 and Table 14 show the average non-winter precipitation volumes for the three study locations and time periods for the RCP8.5 projection and RCP4.5 projection, respectively.

Table 13 Non-winter precipitation for a 20-year period for each location, for RCP8.5

Non-winter Precipitation (mm)	2040	2070	2090
Fort McMurray	583	607	614
Edmonton	650	677	679
Medicine Hat	591	608	604

Table 14 Non-winter precipitation for a 20-year period for each location, for RCP4.5

Non-winter Precipitation (mm)	2040	2070	2090
Fort McMurray	582	593	594
Edmonton	667	666	680
Medicine Hat	599	594	600

Using the indoor water consumption data from Table 7, Table 9, and Table 11, and the RCP8.5 precipitation projection for 2040, the percentage of municipal water that can be offset for each building, in each location, is shown for the "baseline" and "best" fixture scenarios in Table 15 and Table 16.

Table 15 Percentage of baseline indoor water use collected from rainfall from the roof for RCP8.5 for 2040

% Water Use from Rainfall	Office	School	Residential
Fort McMurray	86%	79%	2%
Edmonton	99%	91%	3%
Medicine Hat	89%	81%	3%

Table 16 Percentage of "best" option indoor water use collected from rainfall from the roof for RCP8.5 for 2040

% Water Use from Rainfall	Office	School	Residential
Fort McMurray	180%	179%	7%
Edmonton	206%	205%	8%
Medicine Hat	185%	184%	8%

In both the "baseline" and "best" fixture option scenarios, the residential building indoor water use is much higher than the volume of rain that can theoretically collected from the roof. For the office and school buildings, upgrading fixtures to the "best" option allows for a complete substitution of rainwater for municipal water. As noted, these volumes are based on a theoretical calculation which modeled that all rainwater can be collected and does not take into consideration the limitations introduced by storage capacity.

6.5 Discussion

The following paragraphs provide discussion on the indoor water use and future precipitation results in the study.

Baseline indoor water use is calculated using the LEED v4 BD+C water calculator using interior building area and calculated occupancy. By selecting more efficient fixtures, water consumption is reduced by 14% to 52% for the office, 19% to 56% for the school, and 16% to 50% for the residential building for a range of options.

The amount of greywater available for re-use as a percentage of total consumed water varies for each building in the study. For the office building, 30% of indoor water consumption is classified as greywater. 17% of the water used in the school is classified as greywater, and 65% for the residential building.

Future annual precipitation volumes increase steadily throughout the century for all three studied locations for the 4°C average global warming scenario (RCP8.5). For the 2°C average global warming scenario (RCP4.5), annual precipitation volumes peak near mid-century and either flatten out or decrease slightly. Summer precipitation levels are relatively flat for Edmonton and Fort McMurray throughout the century for both RCP4.5 and RCP8.5, while Medicine Hat shows a decreasing trend for both projections. Non-summer precipitation levels generally show an increasing trend throughout the century for the RCP8.5 projection, and a plateauing near mid-century for the RCP4.5 projection.

Based on a theoretical calculation of rainwater capture volumes, it is shown that the office and school could be self sufficient for water use in each study location, if storage capacity is unlimited and "best" option water fixtures are used. Residential water consumption levels are much higher than the available volume of rainwater for all scenarios. Although precipitation during non-winter months is increasing in the future, the theoretical capture volumes do not reflect the practical limitations associated with storage capacity to handle high intensity rainfall events. TDR recommendations are made to highlight the potential for rainwater capture/storage and greywater re-use to offset municipal water requirements. An option for future work is to conduct detailed modeling of captured/stored precipitation and greywater to displace municipal water for various locations, building types, water fixture types, and climate scenarios.

7.0 Conclusion

This report makes recommendations to improve the Alberta Infrastructure Technical Design Requirements (TDR) document based on Mission Green Building's expertise in energy modeling, water use calculations, and sustainability certification programs for buildings. A range of climate change scenarios, building types, and geographic locations are evaluated to establish a foundation of knowledge from which to make the recommendations.

The report is made up of three main parts, including recommendations to update the TDR document, energy modeling, and water use and future precipitation. Archetypal building models are selected for an office, school, and residential building from real recently completed projects to represent Alberta Infrastructure building stock. Fort McMurray, Edmonton, and Medicine Hat are selected as geographic locations to represent the various climate zones in the province. Climate change projections are selected to investigate a 4°C average global warming scenario (RCP8.5), where emissions continue to rise at a high rate throughout the century, and a 2°C average global warming scenario (RCP4.5) where emissions peak by the year 2040 (RCP4.5).

Under the RCP4.5 scenario, energy modeling results show that the warming climate reduces total energy use for the office, school, and residential building by 6-11% compared to the baseline model, and by 10-18% for RCP8.5. Regardless of geographic location, none of the baseline archetypal buildings are capable of net-zero ready status based on available PV area on the surface of the roof without major energy efficiency upgrades.

A parametric study is conducted to investigate the impact of various building design energy upgrades and climate scenarios for the three archetypal buildings, three geographic locations, and two climate projections. The Medicine Hat school building is capable of net-zero energy status when all parameters are optimized. The energy use in the other two buildings is cannot be offset under any of the modeled scenarios by current PV technology mounted on the roof of the building.

Indoor water use, calculated for each of the three buildings, is shown to be reduced by 14-56% by substituting high efficiency fixtures. By collecting rainfall for the non-winter months, it is shown that all of the indoor water use can be supplied for the office and school buildings in each of the locations using the "best" fixture options for water efficiency. Although the residential building water consumption levels cannot be met by rainfall collection, the potential to reduce water demand is relatively higher than the other two buildings, since 65% of water used can be re-used using greywater capture.

Future precipitation levels are found to follow a similar pattern for each of the locations. For the RCP8.5 scenario, non-summer precipitation amounts trend upwards throughout the century, while summer precipitation remains flat or declines. For the RCP4.5 scenario, non-summer precipitation amounts trend upwards until mid-century and then plateau, while summer precipitation remains relatively flat or declines.

Recommendations to improve the TDR address several topics, including resilience to climate change, net-zero energy targets, improved sustainability goals, water use reduction, and preparation for future retrofits.

8.0 References

Arup North America Ltd, Argos Analytics LLC, & Slate Policy and Design. (2018). Weathershift. Retrieved from www.weathershift.com

Carmody, J., & Haglund, K. (2012). *Measure Guideline : Energy-Efficient Window Performance and Selection*.

City and County of San Francisco. (2012). On-site Non-potable Water Use, 24.

City of Edmonton. (2018a). Change for Climate. Retrieved April 9, 2018, from https://changeforclimate.ca/about

City of Edmonton. (2018b). Climate Change Adaptation and Resilience Strategy. Retrieved April 9, 2018, from https://www.edmonton.ca/city_government/city_vision_and_strategic_plan/climate-change-adaptation-strategy.aspx

Collins, M., Knutti, R., Arblaster, J., Dufresne, J.-L., Fichefet, T., Friedlingstein, P., … Wehner, M. (2013). Long-term Climate Change: Projections, Commitments and Irreversibility. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 1029–1136. https://doi.org/10.1017/CBO9781107415324.024

Government of Alberta. (2010). Alberta Guidelines for Residential Rainwater Harvesting Systems, 133.

Government of Alberta. (2015a). *Climate Leadership: Report to Minister*.

Government of Alberta. (2015b). Climate Leadership Plan. Retrieved February 15, 2018, from https://www.alberta.ca/climate-leadership-plan.aspx

Government of Alberta. (2016). Reclaimed Wastewater. Retrieved April 10, 2018, from http://www.municipalaffairs.alberta.ca/1176

Government of British Columbia. (2017). *BC Energy Step Code A Best Practices Guide for local governments*. Retrieved from http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/construction-industry/building-codes-and-standards/guides/bcenergystepcode_guide_v1.pdf

Government of Canada. (2010). Household Reclaimed Water. Retrieved April 10, 2018, from https://www.canada.ca/en/health-canada/services/environmental-workplace-health/water-quality/household-reclaimed-water-water-quality.html

Government of Canada. (2016). Pan-Canadian Framework on Clean Growth and Climate Change. Retrieved April 9, 2018, from https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework.html

Government of Canada. (2018). CMIP5 gridded data. Retrieved March 5, 2018, from http://climate-scenarios.canada.ca/index.php?page=gridded-data

Hirsch, J. J. (2006). Weather Data & Weather Data Processing Utility Programs. Retrieved February 21, 2018, from http://doe2.com/index_Wth.html

IPCC, 2012: Glossary of terms. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 555-564.

NAIMA Canada. (2018). Building Codes and Standards. Retrieved February 20, 2018, from http://www.naimacanada.ca/for-professionals/building-insulation/codes-standards/

Natural Resources Canada. (2017). Photovoltaic and solar resource maps. Retrieved April 19, 2018, from http://www.nrcan.gc.ca/18366

Pembina Institute, & Energy Innovation. (2018). Energy Policy Solutions. Retrieved April 3, 2018, from https://canada.energypolicy.solutions/scenarios/home

Resilient Design Institute. (2013). The Resilient Design Principles. Retrieved February 21, 2018, from http://www.resilientdesign.org/the-resilient-design-principles/

State of Washington. (2018). Reclaimed water. Retrieved April 10, 2018, from https://ecology.wa.gov/Water-Shorelines/Water-quality/Reclaimed-water

Taylor, K. E., Stouffer, R. J., & Meehl, G. A. (2012). An overview of CMIP5 and the experiment design. *Bulletin of the American Meteorological Society*, *93*(4), 485–498. https://doi.org/10.1175/BAMS-D-11-00094.1

The City of Calgary. (2011). Calgary Community GHG Reduction Plan Energy in the City.

UNFCCC. (2016). The Paris Agreement - main page. Retrieved March 2, 2018, from http://unfccc.int/paris_agreement/items/9485.php

White Box Technologies. (2018). CN2014 Weather Files. Retrieved March 7, 2018, from http://weather.whiteboxtechnologies.com/CN2014

World Energy Cities Partnership, & The City of Calgary. (2009). *Calgary Climate Change Accord*.

9.0 Appendixes

9.1 Appendix A - TDR Review and Summary Report

Section Title	Section Number	Description	Commentary	Importance
Sustainability				
References	1.1	NA	NA	
General	1.2	NA	NA	
	1.2.1	Promoting sustainability	NA	
	1.2.2	All projects must meet LEED silver standards	NA	
	1.2.3	LEED v4 description	NA	
	1.2.4	Mandatory LEED v4 credits. See table	NA	
	1.2.5	NECB 2011 energy compliance	NA	
	1.2.6	Use an energy model consultant, and utilize multiple resources	NA	
	1.2.7	LCCA is to be used	NA	
	1.2.8	Integrated design process is to be used	NA	
	1.2.9	Sustainable design to be used	NA	
	1.2.10	Incorporate active living	NA	
	1.2.11	Universal design	NA	
	1.2.12	Should use as many sustainable design concepts as budget allows	NA	
	1.2.13	Use FSC products, recycled wood, etc.	NA	
Healthcare	1.2.14	Improve sustainability	NA	
Sustainability Summary		Although the values and ideas that Sustainability contribute to producing adaptable and resilient buildings are very important, there is no one section that will have a direct impact on the energy efficiency of a particular building itself. However, it is recommended that the Sustainability section be regularly reviewed to see how it can be improved in the face of climate change.		3
Building Envelope				
References	2.1	NA	NA	
General	2.2	NA		
	2.2.1	Envelope assemblies separate spaces	NA	

Section Title	Section Number	Description	Commentary	Importance
	2.2.2	PERSIST approach (Pressure Equalized Rain Screen Insulated Structure Technique)	NA	
	2.2.3	AI recommends PERSIST because it's forgiving and minimizes: Moisture deterioration Exposure from UV, temperature, moisture Thermally induced movement	Noted	3
	2.2.4	Allow envelope to shed water, ice, snow	NA	
	2.2.5	Suitable materials should be used that can withstand weather	NA	
	2.2.6	Materials should require minimal maintenance	NA	
	2.2.7	Avoid combining design approaches	NA	
High Interior Humidity	2.3			
	2.3.1	Indoor humidity of >30% can result in condensation	NA	
	2.3.2	Provide low humidity buffer spaces to separate spaces with high humidity. Use mechanical air pressure differentials	This could have a potential effect based on changing humidity	2
	2.3.3	If no buffer, envelope will need to compensate	NA	
Air Barrier	2.4			
	2.4.1	Design air barrier to meet Construction Specs Canada TEK-AID 01795 AIR BARRIERS	This should not be affected regardless of temperature and humidity changes	3
	2.4.2	Locate plane of the sealing element exterior	NA	
	2.4.3	Minimize the number of materials needed for air barrier	NA	
	2.4.4	Minimize changes of plane in air barrier	NA	
	2.4.5	Pay more attention to barrier at connection points (e.g., framing, wall/roof connections, changes in plane, etc.)	NA	
	2.4.6	Large scale details on how air barrier is achieved	NA	
	2.4.7	Do not use foamed-in-place insulation as a substitute for air barrier.	This should not be affected regardless of temperature and humidity changes	3
Insulation	2.5			

Section Title	Section Number	Description	Commentary	Importance
	2.5.1	Designed to be secure and in direct contact with air barrier	NA	
	2.5.2	Specify effective RSI values for envelope according to mandatory LEED credits, and minimum effective RSI for NECB 2011. Consider all elements of the envelope when designing energy model.	Insulation RSI would be directly affected by temperature and humidity changes. This would thus affect the entire envelope energy model	1
	2.5.3	Design to prevent condensation on interior surfaces.	This could also be affected by humidity changes	2
Roofs	2.6			
General	2.6.1			
	2.6.1.1	Meet ARCA Roofing Application Standard Manual requirements	NA	
	2.6.1.2	Identify roof slope, drains, penetrations, etc.	NA	
	2.6.1.3	Refer to mechanical section roof drainage	NA	
Near-Flat Roofs	2.6.2			
	2.6.2.1	Roof membrane should consist of two-ply modified bituminous membrane (MBM)	Could be affected by more intense weather patterns (e.g. more rain, snow)	2
	2.6.2.2	Slope roofs to drains	Could be affected by more intense weather patterns (e.g. more rain, snow)	2
	2.6.2.3	Change roof slope with structure, not insulation	This would be affected by temperature if insulation was used	2
	2.6.2.4	Backslope may be formed using insulation	This could be affected by temperature increases	2
	2.6.2.5	Perimeter to roof	NA	
	2.6.2.6	Each roof area should have min of 2 100mm drains	Could be affected by more intense weather patterns (e.g. more rain, snow)	2
	2.6.2.7	Overflow scuppers if only 1 roof drain	NA	
	2.6.2.8	Size of scupper determined by max one day rainfall. (min 150mm x 300mm)	Size of scupper could change with increasing rainfall	2
	2.6.2.9	Curb height around roof penetrations (min 200mm above membrane)	Height could change with increased rainfall	2
	2.6.2.10	Roof-wall, wall penetration heights	NA	
	2.6.2.11	Roof-wall connections	NA	
	2.6.2.12	Protected membrane info	NA	

Section Title	Section Number	Description	Commentary	Importance
	2.6.2.13	For cast-in-place concrete (e.g. roof deck) info	NA	
	2.6.2.14	If building is 3m or higher, provide main access from inside building	NA	
Steep Roofs (slope 1:6 and greater)	2.6.3			
	2.6.3.1	Membrane design. Use PERSIST with SBS	NA	
	2.6.3.2	Roofing membrane under metal roofing/flashings	NA	
	2.6.3.3	Configure roof and perimeter so there will be no safety, maintenance, or appearance problems. (e.g. pedestrians below, ice patches, etc.)	Should be aware of potential design changes with more intense rain/snow	2
	2.6.3.4	Eavestrough water flow, snow, ice resistance design. (min of 125 mm wide)	Should be aware of potential design changes with more intense rain/snow	2
	2.6.3.5	Locate rainwater leaders to direct discharge. Reduce icing on pavement, erosion	Should be aware of potential design changes with more intense rain/snow	2
	2.6.3.6	Eavestroughs and leaders maintenance	NA	
	2.6.3.7	Shingle slope application	NA	
	2.6.3.8	Minimize ice damming	Could be indirectly affected through insulation change	2
Green Roofs	2.6.4			
	2.6.4.1	Local plants	Would change with changing temperature. (current plants may be affected)	2
	2.6.4.2	Intensive systems (min 200 mm soil depth)	NA	
	2.6.4.3	Drainage requirements	May be affected by more intense rainfall, etc.	2
	2.6.4.4	Leak detection	NA	
	2.6.4.5	Live and dead loads	NA	
Re-Roofing	2.7			
	2.7.1	Re-roofing decisions	NA	
	2.7.2	Re-roofing decisions	NA	
	2.7.3	Roof condition report	NA	
	2.7.4	Roof fixing	NA	
	2.7.5	Sheathing	NA	
	2.7.6	New parapet construction	NA	
	2.7.7	Roof supports	NA	

Section Title	Section Number	Description	Commentary	Importance
	2.7.8	Roof curbs for hot pipes	NA	
	2.7.9	Insulation depth of 50 mm at drains	May be affected by changing temperature?	2
	2.7.10	Max thickness of sloped insulation should be 150 mm	May be affected by changing temperature?	2
	2.7.11	Review water ponding height on roof	May be affected by increased rainfall?	2
	2.7.12	Min of 2 100 mm drains per zone. (same as flat roofs)	May be affected by increased rainfall	2
	2.7.13	Re-roofing specs	NA	
	2.7.14	Cut tests	NA	
	2.7.15	Determine roof to wall air seal	Would affect energy loss. Might be worse do to changing temperature	2
	2.7.16	Membrane detail	NA	
	2.7.17	Generally use MBM. Might want to use SBS (fire resistant)	Interesting point on potentially using more fire resistant roofing if fire hazard is a growing risk	3
	2.7.18	Roof drainage	NA	
	2.7.19	Roof drains	NA	
	2.7.20	Rain leaders wall freezing issues	Might not want to allow if rainfall increases	2
	2.7.21	Roof mech equipment	NA	
	2.7.22	Reinstalling roof units	NA	
	2.7.23	Walkways to roof	NA	
	2.7.24	Install new roof openings	NA	
	2.7.25	Curb clearance	NA	
	2.7.26	Instructions	NA	
	2.7.27	Instructions	NA	
	2.7.28	Remove old piping	NA	
Walls	2.8			
	2.8.1	Use PERSIST assemblies	NA	
	2.8.2	Wall cavity sizing of min 25 mm	May be influenced by temperature change	2
	2.8.3	Weep holes for drainage	May need to assess for increased rainfall	2
	2.8.4	Air space compartments	NA	
	2.8.5	Deflection joints	NA	
Windows, Doors, and Glass	2.9			

Section Title	Section Number	Description	Commentary	Importance
	2.9.1	Model windows for LEED and NECB, preventing energy loss and condensation	Windows and doors would be directly affected by temperature and/or humidity change	1
	2.9.2	Curtainwall design	NA	
	2.9.3	Window frame massing	NA	
	2.9.4	Design window, trim, etc. for easy movement of heated air	NA	
	2.9.5	Vestibules at entrances	Distance/size of these could change depending on humidity and changing temperature	2
	2.9.6	Glazing selection	Could change depending on solar heating increase	2
	2.9.7	Low emissivity glass coating	Could be affected if climate zone shifts	2
Skylights and Sloped Glazing	2.10			
	2.10.1	Vertical clerestory glazing	NA	
	2.10.2	Skylights often become energy problems. Not recommended by AI	Also not recommended if temperature increases	2
	2.10.3	Consult technical services if still decide to use	NA	
Concealed spaces	2.11			
	2.11.1	Dead space	NA	
	2.11.2	Heated interior	NA	
	2.11.3	Unheated spaces	NA	
Crawl Spaces	2.12			
	2.12.1	Design	NA	
	2.12.2	Accessibility	NA	
	2.12.3	Ground covers	NA	
	2.12.4	Lighting	NA	
	2.12.5	Mech ventilation	NA	
	2.12.6	Health facility design	NA	

Section Title	Section Number	Description	Commentary	Importance
Building Envelope Summary		Two key Building Envelope sections have been identified as being directly affected by climate change. The first is insulation, and the second being windows, doors and glass. These two areas of the building envelope would be directly affected by temperature and potential humidity changes in the local climate. There are multiple other areas that could be indirectly affected, either through changing temperatures causing more intense weather events (such as increased rainfall in shorter periods of time), or due to the change of another part of the building to compensate for climate changes which would cause another part of the building to be changed, etc.		3
Interior Design				
Fit-Up Design Guidelines and Requirements	3.1			
References	3.1.1	NA	NA	
General Fit-Up Requirements	3.2	NA	NA	
Interior Finish and Material Considerations	3.2.1	NA	Should strive to always use sustainable, low/no VOC products, if AI's goal is to reduce their GHG contribution	3
Reflected Ceiling	3.2.2	NA	NA	
Paint	3.2.3	NA	All paint should be low/no VOC	3
Wallcovering	3.2.4	NA	Consider using recycled drywall. Consider using fire or flood-resistant wallcoverings	2
Carpet Tile	3.2.5	NA	Consider using fire/water resistant carpets or underlay. Use water resistant materials on main floor of buildings if there is potential to flood	2
Broadloom Carpet	3.2.6	NA	Consider using fire/water resistant carpets or underlay. Use water resistant materials on main floor of buildings if there is potential to flood	2

Section Title	Section Number	Description	Commentary	Importance
Sheet, Tile, and VCT Flooring	3.2.7	NA	Potentially use more of this type of flooring if there is risk of fire or flooding	2
Accessories	3.2.8	Transition strips, stair nosing, base, etc.	NA	
Architectural Woodwork	3.2.9	NA	NA	
Glazing	3.2.10	NA	NA	
Signage and Wayfinding	3.2.11	NA	NA	
Window Treatment	3.2.12	NA	NA	
Specialty and Accent Light Fixtures	3.2.13	NA	Should be LED/low energy fixtures	3
Tackable and Writable Surfaces	3.2.14	NA	NA	
Partitions	3.2.15	NA	NA	
Moveable Wall Systems	3.2.16	NA	NA	
Demountable Wall Systems	3.2.17	Parts and pieces are delivered on-site and then assembled, whereas movable are all prefabricated.	These systems could be more fire/flood resistant than drywall	3
Flexibility and Adaptability Planning Criteria	3.3			
Overview	3.3.1	Provide functional and flexible spaces	NA	
Space Area Definitions	3.4			
BOMA	3.4.1	Defines space using this guideline	NA	
Density Target	3.4.2	18 m2/occupant	NA	
Calculating Density	3.4.3	NA	NA	
Design Guidelines and Planning Criteria	3.5			
Space Allocation Overview	3.5.1	NA	NA	
Functional Profile Decision Tree	3.5.2	NA	NA	
Workspace Allocation	3.5.3	NA	NA	
Workspace Allocation and Planning Criteria	3.6			

Section Title	Section Number	Description	Commentary	Importance
Overview	3.6.1	NA	NA	
Hoteling Workspace	3.6.2	NA	NA	
Alternative Workplace Arrangement	3.6.3	NA	NA	
Rover Workspace	3.6.4	NA	NA	
Resident Staff	3.6.5	NA	NA	
Senior Manager	3.6.6	NA	NA	
Exec Director	3.6.7	NA	NA	
Assistant Deputy Minister	3.6.8	NA	NA	
Deputy Minister	3.6.9	NA	NA	
Support Space Allocations and Planning Criteria	3.7			
Overview	3.7.1	NA	NA	
Adjacency Matrix	3.7.2	NA	NA	
Waiting Area	3.7.3	NA	NA	
Open Collab Area	3.7.4	NA	NA	
Phone Room	3.7.5	NA	NA	
Meeting Spaces	3.7.6	NA	NA	
Java Centre	3.7.7	NA	NA	
Lunchroom (Not Standard)	3.7.8	NA	NA	
Custodial Room	3.7.9	NA	NA	
First Aid Room	3.7.10	NA	NA	
Document Management Allocation and Planning Criteria	3.8			
Print Area	3.8.1	NA	NA	
Resource Area	3.8.2	NA	NA	
Storage Area	3.8.3	NA	NA	
Special Purpose Spaces	3.9			
Planning Guidelines	3.9.1	NA	NA	
Security	3.10			
Planning Guidelines	3.10.1	NA	NA	

Section Title	Section Number	Description	Commentary	Importance
Finishes and Materials	3.11	NA	Should strive to always use sustainable, low/no VOC products, if AI's goal is to reduce their GHG contribution	3
Acoustics	3.12	NA	NA	
Moveable Wall Systems	3.13	NA	NA	
Furniture	3.14			
Overview	3.14.1	NA	NA	
Asset Management's approach to Furniture Management	3.14.2	NA	NA	
Logic	3.14.3	NA	NA	
Standing Offer Furniture	3.14.4	NA	NA	
Non-Standing Offer Furniture	3.14.5	NA	NA	
Equipment	3.14.6	NA	NA	
Photographs of Finished Spaces	3.15	NA	NA	
Interior Design Summary		There are not any direct impacts on the interior design of a building due to climate change. However, there are a few indirect areas of which to be aware of. Sections such as Wallcoverings and Flooring (Carpet Tile, Broadloom Carpet, and Sheet, Tile, and VCT Flooring) could be affected by more intense weather patterns. If flooding or fire potential becomes more prominent, it may make sense to move away from materials that are more susceptible to being affected by these issues. AI should also strive to move towards using low/no VOC materials, to help reduce their greenhouse gas contribution.		3
Structural				
Specified Design Loads and Analysis	4.1	Floor load analysis based on different floor requirements	Could be a consideration for roof loads if there is more	2

Section Title	Section Number	Description	Commentary	Importance
			intense amounts of rain or snowfall	
Foundations	4.2	NA	Foundational analysis should be undertaken if the building is located in an area with permafrost, as rising temperatures can impact foundational and structural integrity	2
Structure	4.3	NA	NA	
Interaction with other Disciplines	4.4	Building aspects to be aware of when interacting with other parts of the building	NA	
Vibration Requirements	4.5	Be aware of vibration due to mech systems	NA	
Design Info to be shown on the Contract Drawings	4.6	NA	NA	
Structural Summary		There were no direct impacts on Structural areas, but there were two areas that could be indirectly affected. Load analysis should be completed considering the case that there could be more intense amounts of rain or snowfall, leading to larger roof loads at different times of the year. Foundational and structural analysis should also be completed on buildings in areas with permafrost, in which melting over time could cause structural issues.		3
Mechanical				
General Mechanical Requirements	5.1			
Intent	5.1.1	NA	NA	
References	5.1.2	NA	NA	
Design Development Submission	5.1.3	Written info and drawings	NA	
Contract Documents	5.1.4	Drawings and AI document info	NA	
Accessibility	5.1.5	Be able to access equipment	NA	

Section Title	Section Number	Description	Commentary	Importance
Coordination with other Disciplines	5.1.6	NA	Integrative process is important in energy systems, especially with the changing climate. Should be continually communicating with building envelope and electrical design teams.	3
Commissioning	5.1.7	NA	AI already utilizes LEED enhanced commissioning + monitoring, and considering how the temperature and climate could be changing in the future, it could be recommended that using envelope commissioning would contribute significant value as well.	2
Renovations and Additions	5.1.8	When renovated, all mech, air, water, and energy systems will be rebalanced, and updated based around energy and water saving measures.	This is very important, considering the large amount of existing buildings, which should be considered as much, or more, of a priority as new buildings. These buildings could have existing systems which could be detrimental to AI's energy, climate, and sustainability goals.	1
Acoustic and Vibration Control	5.1.9	NA	NA	
Emergency Power	5.1.10	Connections to normal and essential electrical system	NA	
Energy Efficiency and Sustainability	5.1.11			
Standard Design	5.1.11.1	Mech system design according to ASHRAE and NECB standards	NA	
	5.1.11.2	Don't compromise performance for savings	NA	
Conservation Options	5.1.11.3	Energy conservation measures include:		

Section Title	Section Number	Description	Commentary	Importance
	5.1.11.3.1	Plumbing and Drainage: Rainwater, Graywater, low-flow fixtures, condensing water heaters, hot water controls	All of these measures could give greater control and efficiency to the mech system, mitigating against temperature and climate changes.	2
	5.1.11.3.2	Ventilation Systems: Various air-handling unit capabilities, Heat recovery devices, Variable fan control, CO2 controls, temperature schedule control	All of these measures could give greater control and efficiency to the mech system, mitigating against temperature and climate changes.	2
	5.1.11.3.3	Heating Water Systems: Heat recovery in boilers, variable speeds on pumps, pump controls, condensing boilers	All of these measures could give greater control and efficiency to the mech system, mitigating against temperature and climate changes.	2
	5.1.11.3.4	Chilled Water/ Condenser Water: Airside/waterside economizers, Variable speeds on pumps, Pump controls, Magnetic bearing chillers, Variable speed chillers	All of these measures could give greater control and efficiency to the mech system, mitigating against temperature and climate changes.	2
	5.1.11.3.5	Control Systems: Load shedding, demand response	All of these measures could give greater control and efficiency to the mech system, mitigating against temperature and climate changes.	2
LEED	5.1.11.4	All tier 1 projects subject to LEED v4 silver and mandatory credits	LEED measures will help mitigate against climate change as it increases the adaptability and efficiency of the building	2
Monitoring	5.1.11.5	Metering of (at a minimum): Natural gas, Water, Electrical, Heating water	To increase adaptability of energy and water systems in the face of climate change, metering of the majority of building systems is recommended.	2
Mechanical Design Criteria	5.2			

Section Title	Section Number	Description	Commentary	Importance
HVAC Design Criteria	5.2.1			
	5.2.1.1	HVAC will be designed to allow for controllability of indoor enviro systems.	Multiple climate change factors would affect this based on what you are trying to control, and to what degree.	2
	5.2.1.2	Designed to provide heating and cooling based on outdoor ambient temperatures	This would definitely be affected based on temperature fluctuation	1
	5.2.1.3	Indoor humidity conditions	This could be affected based on changing temperature and humidity.	2
HVAC Room Design Parameters	5.2.2	Meet ASHRAE indoor enviro and ventilation system standards	NA	
School/Healthcare HVAC	5.2.2 tables	Various air flow standards for schools and healthcare	These standards would be affected based on changing temperature	1
Drainage Systems	5.3			
General	5.3.1	National plumbing code	NA	
Sanitary Sewer System	5.3.2	NA	NA	
Lab/Hazardous Waste Drainage System	5.3.3	NA	NA	
Storm Drainage System	5.3.4		Discharge from storm water could be collected and used in irrigation systems	2
	5.3.4.1	Storm water piped separate from sanitary	NA	
	5.3.4.2	Avoid controlled flow roof drainage	NA	
	5.3.4.3	Internal drainage with 100 mm diameter pipes	May be affected by increased rainfall intensity	2
	5.3.4.4	2 drains per roof	May be affected by increased rainfall intensity	2
	5.3.4.5	Dome strainers over roof drains	NA	
	5.3.4.6	Storm water drain discharge standard	NA	
	5.3.4.7	Sumps	NA	
	5.3.4.8	Sumps	NA	
Plumbing Fixtures and Equipment	5.4			

Section Title	Section Number	Description	Commentary	Importance
General	5.4.1	Must meet National Plumbing Code. Trim considerations	Nothing stated about requiring high efficiency water fixtures. Considering the impacts of climate change (high temperatures, watershed loss), this should be an important consideration	3
Floor Drains	5.4.2	Equipment drains	NA	
Interceptors	5.4.3	Provide interceptors for sediment, etc.	NA	
Water Closets	5.4.4	Flush-valve activated preferred. Hands free, low flow toilets.	Low flow is mentioned, but nothing explicit about flush amounts. This should be important considering water impacts	2
Urinals	5.4.5	Hands free flush valve activation.	Nothing about low flow urinals. This should be important considering water impacts from climate change.	2
Washroom Lavatories	5.4.6	Hands free, low flow faucets.	Mentions low flow. Should be more explicit about flow amounts considering water impacts	2
Sinks	5.4.7	Stainless steel sinks, unless other requirements by healthcare.	No mention of low flow, although may not want to compromise sink performance.	2
Emergency Fixtures	5.4.8	Must allow for quick flushing of eyes or body if necessary	NA. Performance based.	
Tubs and Showers	5.4.9	Only for Healthcare. Barrier free.	Showerheads could be low flow.	2
Hose Bibbs	5.4.10	Non-freeze hose bibs every 30 m for irrigation.	NA	
Drinking Fountains	5.4.11	Fountains and bottle fillers	NA	
Domestic Water and Specialty Water Systems	5.5			
General	5.5.1	Conform with National Plumbing Code, Alberta Building Code	NA	
Domestic Cold Water System	5.5.2			
	5.5.2.1	Backflow prevention	NA	
	5.5.2.2	Not to exceed 2 m/s in piping	NA	
	5.5.2.3	Distinct connection markings	NA	
	5.5.2.4	Pressure booster pumps	NA	

Section Title	Section Number	Description	Commentary	Importance
	5.5.2.5	Pipes shall be insulated with vapor barrier	Changing temperatures could affect insulation levels needed	2
	Healthcare	Graywater shall not be used	Could graywater be used in non-healthcare buildings to reduce water use?	3
Domestic Hot Water System	5.5.3		This system would be directly impacted by changing temperatures. This system could also impact climate change depending on what source is being used to heat the water.	1
	5.5.3.1	Water heater redundancy	NA	
	5.5.3.2	Hot water system should be separate from building heating unless energy savings are demonstrated to have them together	Energy savings should be demonstrated on every energy system	2
	5.5.3.3	Branch piping should not exceed 8 m	NA	
	5.5.3.4	Not to exceed 0.76 m/s in piping	NA	
	5.5.3.5	Check valves	NA	
	5.5.3.6	Dishwater water temperature	NA	
	Healthcare	On demand hot water	NA	
Soft Water System	5.5.4			
	5.5.4.1	Determine chemistry of the water	NA	
	5.5.4.2	Soft water for: Steam humidification, laundry, dishwashing, steam boilers, reverse osmosis	NA	
	5.5.4.3	Water softening requirements	NA	
	5.5.4.4	Downstream soft water sample	NA	
	5.5.4.5	Soft water sample	NA	
	5.5.4.6	Soft water connections	NA	
Distilled, Demineralized, Pure, and Treated Water Systems	5.5.5	If demand is low, source externally instead of providing in house	NA	
Fuel Oil Systems	5.6			
General	5.6.1	Code requirements	Fuel oil systems contribute to climate change. Alternative energy sources should be preferred.	2
Specialty Gases and Vacuum Systems	5.7			

Section Title	Section Number	Description	Commentary	Importance
Laboratory Gas Systems	5.7.2	Pressure regulation. Flammability	NA	
Dental Compressed Air System	5.7.3	Air requirements	NA	
Dental Vacuum System	5.7.4	Vacuum system requirements	NA	
Central Vacuum Cleaning System	5.7.5	Vacuum system requirements	NA	
Medical Gas Systems	5.8			
General	5.8.1	Requirements	NA	
Medical Air System	5.8.2	Requirements	NA	
Medical Vacuum System	5.8.3	Requirements	NA	
Medical Oxygen	5.8.4	Requirements	NA	
Carbon Dioxide	5.8.5	Requirements	NA	
Nitrogen	5.8.6	Requirements	NA	
Nitrous Oxide	5.8.7	Requirements	NA	
Anesthetic Gas	5.8.8	Requirements	NA	
Fire and Life Safety Systems	5.9			
General	5.9.1	Meet Codes	NA	
Fire Pumps	5.9.2	Meet Codes	NA	
Standpipe System and Hose Valve Cabinets	5.9.3	Meet Codes	NA	
Sprinklers	5.9.4	Meet Codes	NA	
Fire Extinguishers	5.9.5	Meet Codes	NA	
Smoke Management	5.9.6	Meet Codes	NA	
Heating Systems	5.10		This system would be directly impacted by climate change and increasing temperatures.	1
General	5.10.1			
	5.10.1.1	Heating Criteria	This would be directly impacted by climate change and fluctuating temperatures	1
	5.10.1.2	Heating Source: keep your heating system separate from hot water unless savings can be demonstrated.	Energy savings should be demonstrated on every energy system	1

Section Title	Section Number	Description	Commentary	Importance
	5.10.1.3	System Cleaning and Chemical treatment	NA	
	5.10.1.4	Accessibility and maintenance	NA	
	5.10.1.5	Pipe Distribution	Piping insulation may change with increasing temperatures	2
Heating Water System	5.10.2			
	5.10.2.1	Heating Water Boilers: Min of 2 boilers sized for 60% of design load, min boiler efficiency of 85%	Boilers would be directly affected by changing temperatures, as well as contributing to climate change	1
	5.10.2.2	Antifreeze	NA	
	5.10.2.3	Heating Water Pumps	NA	
	5.10.2.4	Finned Radiation	The effectiveness of these would be affected by changing temperature	1
	5.10.2.5	Radiant Panels	The effectiveness of these would be affected by changing temperature	1
	5.10.2.6	Terminal Box Reheat Coils	The effectiveness of these would be affected by changing temperature	1
	Schools	Individual Thermal Zoning	The effectiveness of these would be affected by changing temperature	1
Steam Heating and Condensate	5.10.3			
	5.10.3.1	Steam Boilers: Avoid high pressure steam, min 85% eff, steam within 5 mins of cold start	Boilers would be directly affected by changing temperatures, as well as contributing to climate change	1
	5.10.3.2	Makeup Water and Chemical Treatment: requirements	NA	
	5.10.3.3	Steam pipe distribution	These would be affected by changing temperature	1
Cooling Systems	5.11		This system would be directly impacted by climate change and changing temperatures	1
General	5.11.1			

Section Title	Section Number	Description	Commentary	Importance
	5.11.1.1	Cooling Criteria: requirements	This would be directly impacted by climate change. It should be expected that it will require more energy to cool systems	1
	5.11.1.2	Cooling Source: use chilled water, DX refrigeration, or outside air if possible	This would be directly impacted by climate change, especially the possibility of using outdoor air cooling	1
	5.11.1.3	Accessibility and maintenance	NA	
	5.11.1.4	Pipe Distribution	Piping insulation may change with changing temperatures	2
	5.11.1.5	System Cleaning and Chemical treatment	NA	
Condenser Water System	5.11.2			
	5.11.2.1	Sediment Removal	NA	
	5.11.2.2	Cooling Towers: Requirements. Should try to use free cooling	Cooling towers would be directly affected by changing temperatures in their ability to cool air/fluid, and in accessing outdoor air for cooling	1
	5.11.2.3	Condenser Water Pumps	NA	
	5.11.2.4	Remote Condenser Water Tank	Insulation values may change	2
Chilled Water Systems	5.11.3			
	5.11.3.1	Chillers: requirements of chillers based on load profile. Optimize chiller efficiency based on part load capacity	AI design states not to size a chiller for future capacity unless granted approval. May want to reconsider this based on potential increasing temperatures?	3
	5.11.3.2	Chilled Water Pumps	NA	
Critical Cooling System	5.11.4	Separate cooling system for specific uses	This would probably be affected by temperature changes, especially if it was being used at unusual times compared to the normal system	2
Ventilation Systems	5.12			
General	5.12.1			
	5.12.1.1	Duct Distribution	NA	
	5.12.1.2	Ventilation Zones	This area could be affected by changing humidity	2

Section Title	Section Number	Description	Commentary	Importance
	5.12.1.3	Diffusers, Grilles, and Louvers: Intake levels	Intake levels may need to be adjusted based on more intense weather patterns?	2
	5.12.1.4	Duct Cleaning	NA	
	5.12.1.5	Accessibility and maintenance	NA	
	5.12.1.6	Smoke Control	NA	
	Healthcare	Requirements	NA	
Air Handling Units	5.12.2			
	5.12.2.1	Construction	NA	
	5.12.2.2	Location	NA	
	5.12.2.3	Redundancy and Standby Capacity	NA	
	5.12.2.4	Humidification	This might be affected by changing humidity	2
	5.12.2.5	Air Filtration	Air filtration standards may need to be improved as temperatures rise. Increasing temperatures can exacerbate the impact of ground level air pollution and human health-related issues	3
	5.12.2.6	Burner	This could be affected based on changing temperature and humidity.	2
Makeup Air Units	5.12.3	Should have remote control panels	NA	
Terminal Air Devices	5.12.4	Temperature controls in variable air flow	This could be affected by temperature increases	2
Furnaces	5.12.5	Economizer section	Furnace economizers could be affected	2
Emergency Generator Rooms	5.12.6	Requirements	NA	
Rooms Containing Fuel Oil Storage	5.12.7	Requirements	NA	
Exhaust Systems	5.13			
General	5.13.1	Requirements	NA	
Kitchen Exhaust	5.13.2	Requirements	NA	
Smoke Exhaust	5.13.3	Requirements	NA	
Fume and Process Exhaust	5.13.4	Requirements	NA	
Radon Gas Exhaust	5.13.5	Requirements	NA	
Control Systems	5.14			

Section Title	Section Number	Description	Commentary	Importance
General	5.14.1	Requirements	While not directly related, control systems are very important in providing adaptability around climate change and fluctuating temperature.	2
Energy Management Control System (EMCS)	5.14.2	Requirements	While not directly related, control systems are very important in providing adaptability around climate change and fluctuating temperature.	2
Control Point Schedule	5.14.3	Requirements	While not directly related, control systems are very important in providing adaptability around climate change and fluctuating temperature.	2
Sequence of Operations	5.14.4	Requirements and optimizations	This system would be influenced by changing temperature	2
Mechanical Summary		There are many different Mechanical areas which will be directly affected by climate change. These areas include the HVAC system design, hot water systems, all heating systems, and cooling systems, of which all would be affected by increasing temperatures. Multiple areas will also be affected indirectly as well. These range from plumbing, to ventilation systems, to control systems. Mechanical systems show the greatest amount of impact out of any building system when it comes to being affected by climate change.		3
Electrical				
General Electric	6.1		Should prepare buildings for district energy systems and demand response. These could be important in the future	3
Intent	6.1.1	Requirements	NA	
References	6.1.2	NA	NA	
Key Design and Performance Requirements	6.1.3	Requirements	NA	

Section Title	Section Number	Description	Commentary	Importance
Identification	6.1.4	Requirements	NA	
Commissioning	6.1.5	Requirements	This is important to ensure good system operation, especially in the face of climate change and energy efficiency	2
Service and Power Distribution	6.2			
Service Sizing	6.2.1	Services sized based on electrical loads	Load sizing could be affected based on AC, block heaters, more EV stations, etc., due to more equipment based around reducing climate change	2
Single Line Drawings	6.2.2	Requirements	NA	
Protection and Control	6.2.3	Fault devices based on load size	This could be affected also based on changing amount of electrical equipment	2
Service Transformers	6.2.4	Requirements	Transformers should be protected against increased flooding/fire potential	2
Switchgear, Switchboards, Distribution Panel board, etc.	6.2.5	Installation Requirements	NA	
Dry Type Distribution Transformers	6.2.6	Requirements	Transformers should be protected against increased flooding/fire potential	2
Feeders	6.2.7	Requirements	NA	
Power Factor	6.2.8	Requirements	NA	
Motor Protection and Control	6.2.9	Requirements	NA	
Surge Protective Devices	6.2.10	Provide levels of surge protection based upon system importance	With additional renewable systems coming online in the future (to mitigate climate change), buildings should be prepared to handle a certain amount of unpredictability within the grid.	3
Emergency Power	6.2.11	Requirements	NA	
Branch Wiring/Devices	6.2.12			
General	6.2.12.1	Requirements	NA	

Section Title	Section Number	Description	Commentary	Importance
Block Heater Outlets	6.2.12.2	Requirements and load cycling	No mention of EV charging stations	3
Provision for Mech	6.2.12.3	Coordination	NA	
Offices and Workstations	6.2.13			
General	6.2.13.1	Workstation service and outlet requirements	NA	
Lightning Protection	6.2.14	Protection requirements	If there are more frequent rain/thunderstorms, lighting could be a more common occurrence then it already is. Could be useful to mitigate against this	3
Envelope Penetrations	6.2.15	See Envelope requirements	Should mitigate against increased rainfall on roof of building	2
Schools	6.2A	States that emergency generators are not provided in schools	Is this something that should be considered? Especially if many new schools have solar arrays, it seems reasonable to have a generator connected to it. Or does the solar feed directly onto the grid?	3
Lighting	6.3			
General	6.3.1	Requirements: Maximize energy efficiency, minimize glare, maximize contrast, only use task lighting where pre-determined	To utilize the least amount of power and target climate change goals, should be targeting low wattage luminaires with long lifespan. Typically LED, or high efficiency fluorescents.	3
Lighting Design Parameters	6.3.2	Design requirements	NA	
Uniformity	6.3.3	Requirements	NA	
Minimum Maintained Horizontal Illumination	6.3.4	Lighting levels	NA	
Interior Lighting Landscape	6.3.5	Interior plant growth levels	NA	
Daylighting	6.3.6	Use sensor controls. Control glare	NA	
Interior Lighting Sources	6.3.7	Do not use incandescent sources. Use LEDs or high efficiency fluorescents.	This would save energy, and thus contribute to AI's climate change goals.	3
Diffusers	6.3.8	Requirements	NA	

Section Title	Section Number	Description	Commentary	Importance
Fluorescent Ballasts	6.3.9	Requirements	NA	
LED's and Drivers	6.3.10	LED requirements	NA	
Interior Lighting Control	6.3.11	Switch, motion sensor, programmed switch requirements	These controls and practices will save energy, contributing to climate change goals.	3
Emergency and Exit Lighting	6.3.12	Capacity requirements	NA	
Exterior Lighting	6.3.13	Minimum photosensor control. Can also have motion, or programmed control	These controls and practices will save energy, contributing to climate change goals.	3
Communication	6.4			
Structured Cabling - Voice and Data	6.4.1	Cable, installation requirements	NA	
Paging and Public Address Systems	6.4.2	Requirements	NA	
Sound Masking System	6.4.3	Requirements	NA	
Assistive Listening Devices	6.4.4	Requirements	NA	
Clock System	6.4.5	Requirements	NA	
Cable Television / Radio Frequency Television	6.4.6	Requirements	NA	
Electronic Safety and Security Systems	6.5			
General	6.5.1	Requirements	NA	
Electronic Access Control	6.5.2	Requirements	NA	
Intrusion Detection	6.5.3	Requirements	Flood detection/low temperature risk is part of the security monitoring system. Could be relevant to increasing flood risk	2
Video Surveillance	6.5.4	Requirements	NA	
Fire Detection and Alarm	6.5.5	Requirements	Fire alarm system could be relevant to increased fire risks due to climate change	2
Appendix A		Requirements	NA	
Appendix B		Samples	NA	

Section Title	Section Number	Description	Commentary	Importance
Electrical Summary		When considering Electrical systems in climate change, there are no areas which will be directly affected by temperature increases. However, there are a few categories which will see indirect effects. The largest of these would be Service and Power Distribution, which have several areas that could be affected based on implementing climate change mitigation equipment. There are also several Discussion points based around electrical energy equipment which could be implemented to further AI's climate change goals.		3
Acoustical				
References	7.1	NA	NA	
General	7.2	Requirements	NA	
Definitions	7.3	Definitions	NA	
Acoustically Critical Spaces	7.4	Requirements	NA	
Architectural	7.5			
General	7.5.1	Requirements	NA	
Floor Construction	7.5.2	Requirements	NA	
Interior Partitions	7.5.3	Requirements	NA	
Interior Finishes	7.5.4	Requirements	NA	
Open Plan Offices	7.5.5	Requirements	NA	
	Schools	Requirements	NA	
	Healthcare	Requirements	NA	
Mechanical	7.6			
Background Noise	7.6.1	Requirements	NA	
Ducts, Terminal Devices, Heat Components, and Silencers	7.6.2	Requirements	NA	
Plumbing Noise	7.6.3	Requirements	NA	
Vibration Isolation	7.6.4	Requirements	NA	
Community Noise	7.6.5	Requirements	NA	
Electrical/ Communication	7.7			
Ballasts	7.7.1	Requirements	NA	
Transformers	7.7.2	Requirements	NA	

Section Title	Section Number	Description	Commentary	Importance
Sound Masking System	7.7.3	Requirements	NA	
Structural	7.8	Requirements	NA	
Exterior Acoustic Insulation	7.9	Requirements	NA	
Acoustical Summary		There are no direct, indirect, or discussion points around Acoustical design, as it would not be impacted by climate change.		3
Barrier-Free				
Introduction	8.1	Requirements and description	NA	
References	8.2	NA	NA	
Level of Barrier-Free Accessibility	8.3	Requirements	NA	
Design Requirements	8.4			
Use of Reference Documents	8.4.1	Requirements	NA	
Level of Accessibility	8.4.2	Requirements	NA	
Code Analysis	8.4.3	Requirements	NA	
Design Development	8.4.4	Requirements	Potentially worth considering the impact more severe weather events could have on barrier-free building access	3
Barrier-Free Summary		There are no direct or indirect impacts from climate change which would affect Barrier-Free designs, but it could be worth considering the potential of more intense weather storms on access to buildings.		3
Site Services				
References	9.1	NA	NA	
Site Selection	9.2			
	9.2.1	Site must be above design flood elevation	This could be influenced by rain increase and larger flooding events	2
	9.2.2	Environmental liability	NA	
	9.2.3	Archeological restriction	NA	
	9.2.4	Road access	NA	
	9.2.5	Traffic Impact Assessment	NA	
	9.2.6	Planning/zoning	NA	

Section Title	Section Number	Description	Commentary	Importance
	9.2.7	Storm water management	Could be relevant with increased rainfall	2
	9.2.8	Site topography	Could be relevant with increased rainfall	2
	9.2.9	Safe site distances	NA	
	9.2.10	Availability of offsite services	NA	
Site Survey Plan and Site Plan	9.3	Requirements	NA	
Site Access	9.4	Requirements	NA	
Site Signs	9.5	Requirements	NA	
Site Grading	9.6	Water flow grading requirements	Could be influenced by increased rainfall	2
Roads, Walks, and Parking	9.7	Requirements including: Snow removal, grading, pavement/concrete design, etc.	Could be influenced by more intense weather including rain and snowstorms	2
Utilities	9.8	Requirements	NA	
Tanks for Petroleum Products	9.9	Provide above ground tanks, and clean up contaminated sites	NA	
Site Services Summary		There are no direct impacts from climate change on Site Service design, but there are a few indirect impacts. These include site elevation design, storm water management, site water flow, and grading. Many of these areas could be impacted by increasing amounts of rainfall, and should be a consideration when thinking of climate change.		2
Landscape Development				
References	10.1	NA	NA	
Landscape Development Guidelines	10.2			
	10.2.1	Include boulevards in landscapes	NA	
	10.2.2	Min gradient of 2% away from building	NA	

Section Title	Section Number	Description	Commentary	Importance
	10.2.3	Preserve healthy trees and plants on site	With potential changing temperature and rainfall levels, climate zones may shift. This could lead to trees that were once native, struggling to survive in certain conditions. This should be considered when selecting trees and plants.	1
	10.2.4	Plant design layout that is tolerant of local conditions	With potential changing temperature and rainfall levels, climate zones may shift. This could lead to trees that were once native, struggling to survive in certain conditions. This should be considered when selecting trees and plants.	1
	10.2.5	Landscape design that respects visibility and security	NA	
	10.2.6	Design that has ease of maintenance	With potential changing temperature and rainfall levels, climate zones may shift. This could lead to trees that were once native, struggling to survive in certain conditions. This should be considered when selecting trees and plants.	1
	10.2.7	Plant pest infestations	With potential changing climate zones, different types of pests may be introduced into the region. This should be considered in selecting trees and plants.	2
	10.2.8	Ensure proper planting conditions	NA	
	10.2.9	Reduce vandalism through planting	NA	
	10.2.10	Tree sizing	NA	
	10.2.11	Tree location	NA	
	10.2.12	Tree location	NA	
	10.2.13	Tree location	NA	
	10.2.14	Plant and tree beds	NA	
	10.2.15	Sod and seeding	NA	
	10.2.16	Min of 1 year warranty	NA	

Section Title	Section Number	Description	Commentary	Importance
Physical Security Guidelines and Standards for Gov of Alberta Facilities	10.3	Requirements	NA	
Irrigation	10.4	Requirements: Choose efficient systems (e.g. use rain sensors, soil moisture sensors), provide pipe sleeves, etc.	Irrigation uses a significant amount of water. This can contribute to depletion of water from local watersheds. In light of climate change, it would make sense to move towards fully xeriscaped landscapes, or highly efficient systems such as drip irrigation. It could also be considered for all buildings to use rainwater collection for irrigation needs.	2
Environmental and Conservation Consideration	10.5			
	10.5.1	Minimize maintenance requirements	NA	
	10.5.2	Use mulch	Good measure to take in light of climate change	2
	10.5.3	Choose native plants	Good measure to take in light of climate change	2
	10.5.4	Group plants that have similar water demand	Good measure to take in light of climate change	2
	10.5.5	Promote infiltration of surface water	Good measure to take in light of climate change	2
	10.5.6	Utilize rainwater, or alternative water sources	Good measure to take in light of climate change	2
	10.5.7	Use plant material (biomass) for energy requirements	Good measure to take in light of climate change	2
	10.5.8	Use plant material to control snow drifts	Good measure to take in light of climate change	2

Section Title	Section Number	Description	Commentary	Importance
Landscape Development Summary		Landscape Development shows a few key areas which would be directly affected by changing temperatures, which include plant and tree selection for the site. If Alberta's temperature changes, it can shift climate zones away from the building location and put the health of the plants at risk. This should be a strong consideration in choosing plants and trees which are able to survive in wider temperature ranges. Reduced water resources would also contribute an indirect impact, as irrigation would be more expensive, even with potentially increasing rainfall.		2
Environmental Hazards				
Site Considerations - Hazardous Materials	11.1	Requirements	NA	
Building Considerations - Hazardous Materials	11.2	Don't use hazardous materials	NA	
Other Building Considerations	11.3	Avoid using VOC's and other toxic materials	NA	
Radon Mitigation Rough-in Requirements	11.4	Requirements	NA	
Environmental Hazards Summary		There are no direct, indirect, or discussion points around Environmental Hazard considerations, as the hazards typically already exist, and would not be impacted by climate change. However, Environmental Hazards may become less common in the future, if environmental and climate change goals are actually being achieved.		3
Appendixes				