Establishing Design Conditions for Climate Resilient Planning and Design of Health Facilities in British Columbia

October 2020 v1.0

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1. INTRODUCTION

To design and construct high performing and cost-effective health care facilities over the long term in British Columbia (BC), it is imperative to design infrastructure and building systems to be resilient to climate shocks and stresses such as extreme heat (heat waves) and warming temperatures.

Future climate data based on research and modeling of climate change projections across BC is now publicly available[1]. However, future design conditions are not yet part of the National Building Code or the BC Building Code. As a result, there is currently no consistent approach for how to incorporate this new information into capital project planning and design in addition to code compliance requirements.

In the absence of direction from building codes on what design temperatures to use in designing for current and future climates, a methodology has been developed to provide design teams with a clear and consistent approach to interpreting future climate data for use in climate resilient health facility planning and design.

1.1 Objectives

This methodology is focused on how to:

1) Establish design conditions for cooling using future climate data sets,
2) Use future shifted weather files[2] in energy and thermal comfort models to verify the performance of a proposed project design in future climates.

1.2 Context & Limitations

This document is intended to be used in conjunction with the *Climate Resilience Guidelines for BC Health Facility Planning & Design (2020).*

- The methodology referred to in this document focus primarily on changes pertaining to building cooling. Planning for changes in heating will be included in subsequent version of this document.
- The methodology referred to in this document does not address other important climate change indicators such as air-quality, vector-borne illness, or changes in precipitation.
- The document is not intended to provide design solutions, nor lay out every detail of the climate assessment outcomes for each new construction project. It is rather intended to show examples of how projects can use the data consistently in evaluations, along with examples for how to assess the long-term planning implications for decision-making today.
- The methodology is based on information available as of August 2020 and will be updated as research evolves, building code updates become available, or other information referenced herein changes.

[1] Pacific Climate Impacts Consortium, University of Victoria, (Feb. 2019). Statistically Downscaled Climate Scenarios. Downloaded from https://data.pacificclimate.org/portal/downscaled_gcms/map/ Method: BCCAQ v2, RCP8.5

[2] *Future shifted weather files*, or *adjusted weather files*, are terms used inter-changeably.

1.3 Document Structure

The document is structured per the following:

- **Section 1 - Introduction:** provides context, objective, and limitations of the methodology.
- **Section 2 - Climate Data References:** summarizes available data sets (per August 2020) for use when establishing future design conditions.
- **Section 3 - Methodology to Establish Future Design Conditions:** describes the methodology of how to establish future design conditions on a project.
- **Section 4 - Developing or Preserving Pathways:** summarizes example outcomes of a climate assessment that can be used to develop pathways for planning and design of new health care facilities today.

Burnaby Hospital is used throughout this document as a reference example of how to use the data sets in the methodology. It should be noted that this location is included as an example only. Each project location will have to use data sets pertinent to their location.

2. CLIMATE DATA REFERENCES

The following climate data references are used in the methodology to establish future design conditions:

- ✓ BC Building Code 2018 design temperatures
- ✓ Projected climate change indicators for the 2020s, 2050s and 2080s
- ✓ Future adjusted weather files for the 2020s, 2050s and 2080s

2.1 BC Building Code 2018

The BC Building Code design temperatures[3] are used as a baseline in establishing the future design conditions. Space class design criteria (Type I, II, III and Class A-1, A-2, B and C) per CSA Z317.2 will also need to be considered as applicable for each project to establish the 1%, 2.5% (or 5%) design temperature condition.

Example for Burnaby location:

Table 1: *BCBC 2018 Design Temperatures for Burnaby Hospital*

Burnaby	Design Parameter	Design Value
January	2.5%	-7 °C
	1%	-9 °C
July	2.5% Dry-bulb	25 °C
	2.5% Wet-bulb	17 °C

[3] BCBC 2018 Division B - Appendix C, Table C-2: Climatic Design Data for Selected Locations in British Columbia

2.2 Projected Climate Indicators

The methodology includes and references indicators of projected future climate for the RCP-8.5 (Representative Concentration Pathway) scenario using data obtained from the Pacific Climate Impacts Consortium (PCIC). This scenario represents the 'high-emissions' case where emissions continue to rise throughout the 21st century. It has been chosen as the pathway to use in climate resilient planning of health care facilities in BC to be prepared for the possibility of severe climate change.

PCIC has also produced *future shifted weather files*[4] to be used for energy modeling. These weather files (in .epw format) also follow the RCP-8.5 scenario and use CWEC 2016 files for their baseline hourly data. Adjustments are made to dry-bulb, dew-point, humidity, and pressure based on the RCP-8.5 projections adjusted to each weather station location in BC.

The files are available for each weather station in BC that is present in the CWEC dataset, referenced as the 2020s (2011-2040), the 2050s (2041-2070) and the 2080s (2071-2100). The 2020s file is not intended to represent the climate of the year 2020, but rather for a typical year in the time frame of 2011-2040.

Summary tables, including climate indicators, have been produced by PCIC to accompany the weather files and they provide information of parameters that are relevant to building design (refer to Table 2 for example summary).

The future shifted weather files and summary tables produced by PCIC are available at:

- https://www.pacificclimate.org/data/weather-files

The data sets currently available for download include:

- Future shifted weather files (in .epw format) to use for energy modeling
- Summary tables of climate indicators for 2020s, 2050s and 2080s

For clarity, the climate parameters in PCICs summary tables are not derived in the exact same way as climate parameters used in BC Building Code (refer to footnotes of Table 2 for definitions). However, the projected *change* of each climate indicator is expected to be similar even if the exact derivation is slightly different between BCBC and PCICs climate indicators. This *change* in climate is used to establish the future design conditions as explained in Section 3.

For most scenarios, the *average* change (example per Table 2) is sufficient to use for future climate scenarios predictions, while the *90th percentile* change (example per Table 2) represents the high range of temperature change scenarios. It should be noted that the average, low, and high range of climate indicator change resemble the spread of results from 10 climate models used by PCIC and are should be assumed equally likely to happen.

[4] Derived from an ensemble of 10 downscaled (BCCAQv2) global climate models selected for Western Canada. For more information refer to PCIC: https://pacificclimate.org/data/statistically-downscaled-climate-scenarios

Example for Burnaby location:

***Table 2:** PCIC Climate Indicators for Burnaby Hospital for 2020s, 2050s and 2080s*

Burnaby Hospital	2020s Change[5]		2050s Change		2080s Change	
Climate Indicator	**Average[6]**	**Range (10%-90%)[7]**	**Average**	**Range (10%-90%)**	**Average**	**Range (10%-90%)**
HDD (Heating Degree Days)[8]	-452	(-570 to -287)	-821	(-1104 to -495)	-1278	(-1634 to -870)
TNN (°C)[9]	1.9	(1.2 to 2.7)	2.8	(1.3 to 3.8)	5.1	(3.8 to 6.2)
Heating 99% (°C)[10]	1.6	(1.2 to 2)	2.8	(1.6 to 3.4)	4.7	(3.3 to 5.5)
Heating (Wet bulb) 99% (°C)	1.6	(1.2 to 2)	2.8	(1.6 to 3.3)	4.6	(3.3 to 5.4)
CDD (Cooling Degree Days)[11]	83	(35 to 123)	244	(100 to 403)	499	(235 to 783)
TXX (°C)[12]	2	(1.2 to 2.8)	4.2	(2.5 to 5.8)	6.6	(4.2 to 9.3)
Cooling 2.5% (°C)[13]	1.7	(1.2 to 2.2)	3.8	(2.3 to 5.2)	6.3	(4 to 8.4)
Cooling (Wet bulb) 2.5% (°C)	1.6	(1.1 to 2.1)	3.6	(2.1 to 5)	5.9	(3.8 to 7.9)

***Table 3:** PCIC adjusted weather files for Burnaby Hospital for 2020s, 2050s and 2080s*

Time Period	Weather file name
2020s	2020s_CAN_BC_Burnaby_Hospital-offset-from-Vancouver.Intl.AP.718920_CWEC2016.epw
2050s	2050s_CAN_BC_Burnaby_Hospital-offset-from-Vancouver.Intl.AP.718920_CWEC2016.epw
2080s	2080s_CAN_BC_Burnaby_Hospital-offset-from-Vancouver.Intl.AP.718920_CWEC2016.epw

[5] *Change* = climate change by the 2020s (2011-2040), 2050s (2041-2070), and 2080s (2071-2100) periods are derived from a 1998-2014 baseline, based on CWEEDS historical data.
[6] *Average* = average change for each time period of 30 years, derived from 10 downscaled climate prediction models.
[7] *Range* = range represents PCICs 10th-90th percentiles from 10 downscaled models. The percentiles are not percentiles of hours in a year, but rather the range of anticipated values in the 30-year average (for the period) to encapsulate the range of plausible future change under the RCP-8.5 (high emission) scenario.
[8] Base temperature 18°C
[9] *TNN* = average annual minimum (of daily minimum temperature) from 10 downscaled climate models.
[10] *Heating 99%* = Difference to BCBC is that coldest day is influenced also by coldest day outside of January.
[11] Base temperature 18°C
[12] *TXX* = average annual maximum (of daily maximum temperature) in 10 climate models.
[13] *Cooling 2.5%* = Difference to BCBC is that hottest day is influenced also by the hottest day outside of July.

3. METHODOLOGY TO ESTABLISH FUTURE DESIGN CONDITIONS

The following section describes the methodology for how to establish design conditions for cooling using the climate data sets as summarized in Section 2.

3.1 Establish Design Baseline

The BCBC 2018 (and CSA Z317.2) design conditions are the baseline design temperatures to be used when establishing future design conditions for dry-bulb and wet-bulb. Refer to Section 2.1 for an example.

3.2 Establish Future Design Temperature

3.2.1 Cooling Design Temperature for 2050s and 2080s

The following approach is suggested for establishing adjustments on cooling design temperatures:

✓ **For the 2050s:** To establish cooling dry-bulb and wet-bulb design temperatures for 2050s, use the 2.5% cooling **high range** *(90^{th} percentile)* change predictions and add this to the project's BCBC 2018 design temperatures. Use this new set of design conditions for the 2050s for system sizing.

- **2050_{90} Dry-bulb °C** = [BCBC 2018 Dry Bulb °C] + [2050s 90^{th} Percentile Change °C]
- **2050_{90} Wet-bulb °C** = [BCBC 2018 Wet Bulb °C] + [2050s 90^{th} Percentile Change °C]

✓ **For the 2080s**: To establish cooling dry-bulb and wet-bulb design temperatures for 2080s use the 2.5% cooling ***average*** **OR high range** (*90^{th} percentile*) change predictions and add this to the project BCBC 2018 design temperatures. Use this new set of design conditions for the 2080s to inform planning pathways.

- **2080_{AVE} Dry-bulb °C** = [BCBC 2018 Dry Bulb °C] + [2080s Average Change °C]
- **2080_{AVE} Wet-bulb °C** = [BCBC 2018 Wet Bulb °C] + [2080s Average Change °C]

OR

- **2080_{90} Dry-bulb °C** = [BCBC 2018 Dry Bulb °C] + [2080s 90^{th} Percentile Change °C]
- **2080_{90} Wet-bulb °C** = [BCBC 2018 Wet Bulb °C] + [2080s 90^{th} Percentile Change °C]

This general approach is to be used unless a Health Authority decides on a case-by-case basis that the *average* change is more appropriate to be used for a specific project for both 2050s and 2080s. While it is not right or wrong to use one over the other, it might be important to evaluate both to understand the range of possible implications. This will depend on the type of facility, project planning timeline, and how sensitive the facility and its context are to long-term (2080s) aggressive climate change planning.

Example for Burnaby location:

Using the data per ***Table 1***, ***Table 2*** and the methodology described in Section 3.2.
The example is considering sizing for normal operation mode using the 1% and 2.5% design temperature conditions as baseline.

1) Cooling Design Temperature for 2050s for system sizing:
   - **2050_{90} Dry-bulb °C** = [25°C] + [5.2 °C] = 30.2°C
   - **2050_{90} Wet-bulb °C** = [17°C] + [5 °C] = 22 °C

2) Cooling Design Temperature for 2080s for planning pathways:
   - **2080_{AVE} Dry-bulb °C** = [25°C] + [6.3 °C] = 31.3 °C
   - **2080_{AVE} Wet-bulb °C** = [17°C] + [5.9 °C] = 22.9 °C

   - **2080_{90} Dry-bulb °C** = [25°C] + [8.4 °C] = 33.4 °C
   - **2080_{90} Wet-bulb °C** = [17°C] + [7.9 °C] = 24.9 °C

3.3 Using the Weather Files

The *future shifted weather files* comprise one synthetic year of hourly climate data constructed by combining typical months. The main purpose of these files is for evaluating project energy consumption, carbon emissions, and thermal comfort modeling. The weather files are not intended to be used to establish design temperatures on the projects. For design temperature establishment, follow methodology per Section 3.1 and 3.2 above.

The weather files are to be used in the energy and thermal comfort models to verify the performance of the project design in future climates. This is not only for peak design conditions, but also for any duration of more extreme conditions as reflected in the weather files.

The weather files are to be used as following:

- ✓ **The 2020s weather file**: is to be used to verify that the facility Design and Construction Energy Target[14] is met. The 2020s file is more appropriate to use for this purpose than the traditionally used (and for code compliance purposes) CWEC 2016 file, as it more accurately describes today's climate for prediction of a facility's energy consumption.
- ✓ **The 2050s weather file:** is to be used to confirm or assess the degree to which the current design and sizing will ensure thermal comfort through the 2050s (using the weather file as the best available representation of future weather), and to evaluate the energy and carbon balance based on 2050s system sizing.
- ✓ **The 2080s weather file:** is to be used to evaluate and document the energy, carbon, and comfort performance of the project design based on the 2080s (using the weather file as the best available representation of future weather), with the main purpose of informing planning pathways.

[14] New construction health care projects in BC have project specific Design and Construction Energy Targets (sometimes referenced as Energy Guarantees and/or Carbon Guarantees) established during business case planning to be verified through design and construction. Refer to each project specific contract documents for the targets.

4. DEVELOPING OR PRESERVING PATHWAYS

To inform and develop climate resilient planning pathways, the data and methodology presented in Section 2 and Section 3 are expected to be used in assessments completed by design teams to help inform decision-making.

The assssment outcomes are based on the general approach that projects will:

- ✓ **Design for the 2050s**; i.e. ensure that cooling and humidification equipment and infrastructure are large enough in design today.
- ✓ **Plan for the 2080s**, i.e. develop retrofit and financial planning pathways to modify systems in future to meet anticipated future conditions.

Section 4 summarizes *examples* of analysis, studies, and deliverables that could be part of such an assessment for a project. The examples are not exhaustive and are only intended to serve as a starting point to use on any new health care project. It is expected that the outcomes of the climate assessment will be reviewed and developed further by both Health Authority stakeholder groups and design teams to align outcomes with each project's specific context.

4.1 Assessment of Design

Based on the established future design temperatures and associated weather files, quantify the following for each time period 2020s, 2050s, and 2080s.

1. **Passive versus Active Measures**
   - Identify passive measures (such as exterior shading) and active measures (such as enthalpy wheels) and their expected life-long impact on managing heating and cooling peak loads.
   - Identify passive and active measures and their ability to improve thermal comfort.
   - Look at the life-cycle impact of each passive or active measure, and its individual replacement and retrofit requirements, to map out appropriate planning pathways for the 2080s.
   - Describe capital cost implications, including life-cycle replacement summarized as Net Present Value.
     - It is anticipated that taking a life-cycle view will help to illustrate the value of some passive measures which may have a high first cost.

2. **HVAC System Design**
   - Establish system and equipment capacity / sizing requirements, including:
     - Major HVAC equipment (chillers, heat pumps, cooling towers, etc.),
     - HVAC distribution systems (AHUs, coils, fans, piping, pumps, etc.),
     - Mechanical and electrical room layout or size implications, and
     - Capacity of utility connections (power, water, district heating/cooling networks, etc.).
   - Develop pathways to 2080s resilience (including a system equipment upgrade timeline) to inform capital cost saving strategies that may delay investments to the future (such as equipment upsizing) while minimizing future disruptions to the fully operational facility.
     - Describe capital cost implications, including life-cycle replacement summarized as Net Present Value.

3. Energy Model

Based on the design approach including considerations of passive and active system sizing, use the energy model and future adjusted weather files (refer to Section 3.3) to verify project performance. Outcomes from the 2050s and 2080s adjusted energy model analysis can include reporting on:

- Annual thermal heating, cooling, dehumidification and humidification loads; duration of loads and how often peak conditions are expected to occur.
- Identification of any equipment part-load performance issues or opportunities.
- The impact on overall energy consumption (MWh) by total building and per energy end-use.
- The impact on overall carbon emissions (tCO2e) by total building and per energy end-use.
- The impact on overall operational costs ($ per year) by total building and per energy end-use.
- Identification of any thermal comfort issues during a peak day or during a heat wave.
- Verification that thermal comfort requirements are met for the 2050s and 2080s.

4.2 Outcomes for Planning & Design

Based on the assessment, the following information can be provided, either as part of a technical submission, design submittal, or to communicate strategies for decision-making:

1. Climate Adaptation Narrative

Provide a Climate Adaptation Narrative along with supporting documents. The narrative should describe the methodology for climate adaptation planning, referenced data sets, assessments completed and their outcomes for project design and operation. The narrative should include, at a minimum:

- ✓ Supporting documents including drawings, specifications, and energy model results,
- ✓ A description of the timelines and the methodology used for design and planning, including:
  - A list all referenced climate change data sets.
  - A high-level summary of how passive strategies are implemented and their impact over time on peak capacity, thermal comfort, and operational energy cost.
  - A list major equipment and infrastructure impacted by the 2050s system sizing analysis.
  - A description of how building life-cycle upgrades have been considered for planning of infrastructure investments today versus 2050s or 2080s
- ✓ A demonstration of the degree to which the proposed design maintains indoor temperature and relative humidity requirements for the facility in each of the design scenarios of 2050s and 2080s.
  - Reference the example of assessment and quantifications of passive and active systems in Section 4.1,
- ✓ Outputs from the energy model as noted under Section 4.1 and a summary of the facility performance relative the proposed solutions; and
- ✓ Developed pathways for 2080s planning including descriptions of passive versus active strategies.
  - Describe capital cost implications, including life-cycle replacement summarized as Net Present Value.

2. Catastrophic Events
Evaluate occupant thermal comfort for the following three scenarios using the 2050s and 2080s weather files:

- ✓ A power outage in which the facility is operating on vital power for the hottest two weeks of the year (determined per the weather file data and including the peak day),
- ✓ A power outage in which there is no electricity available to the facility for a period of two days during the hottest two weeks of the year (determined per the weather file data and including the peak day); and
- ✓ During an identified heat wave (determined per the weather file) including at a minimum 3 consecutive tropical nights[15], with all power available.

The outputs from each of the modeled scenarios should verify, at a minimum:

- ✓ Relative humidity, indoor air temperature, and peak air temperature for most critical rooms per orientation (to limit number of studies) and per space Type I, II and III;
- ✓ Include the number of hours where the outputs (relative humidity, indoor air temperature) do not meet the space requirements and durations (number of hours) when the temperature is above 24°C, 26°C, 28°C and 30°C for the above listed scenarios.

3. Planning Pathways
Include a timeline and a summary matrix laying out the various equipment and system components impacted by climate change and key metrics that will support financial planning of pathways leading up to the 2080s, including but not limited to:

- ✓ Equipment life, sizing capacity requirements, maintenance, or replacement timeline requirements; combined into financial planning and summarized as Net Present Value.
- ✓ If future renovations are required to address the predicted 2080s climate scenario, include an estimate of the costs of any required future work, design information in a level of detail adequate to verify the estimate of costs, to a class D level, as well as the timing of when that work will be required.

Example of a planning pathway summary matrix:

System or Equipment Type	Equipment life (years)	Maintenance Timeline (up to 2080)	2050 sizing req.	2080 sizing req.	NPV 2020 -2050	NPV 2020-2080 Pathway 1	NPV 2020-2080 Pathway 2	Other
Shading	40							
Chiller	20							
CHW piping	40							
CHW pumps	20							
Etc.								

[15] Tropical night refers to a day when the nighttime low temperature is greater than 20°C.

5. PROCESS OVERVIEW

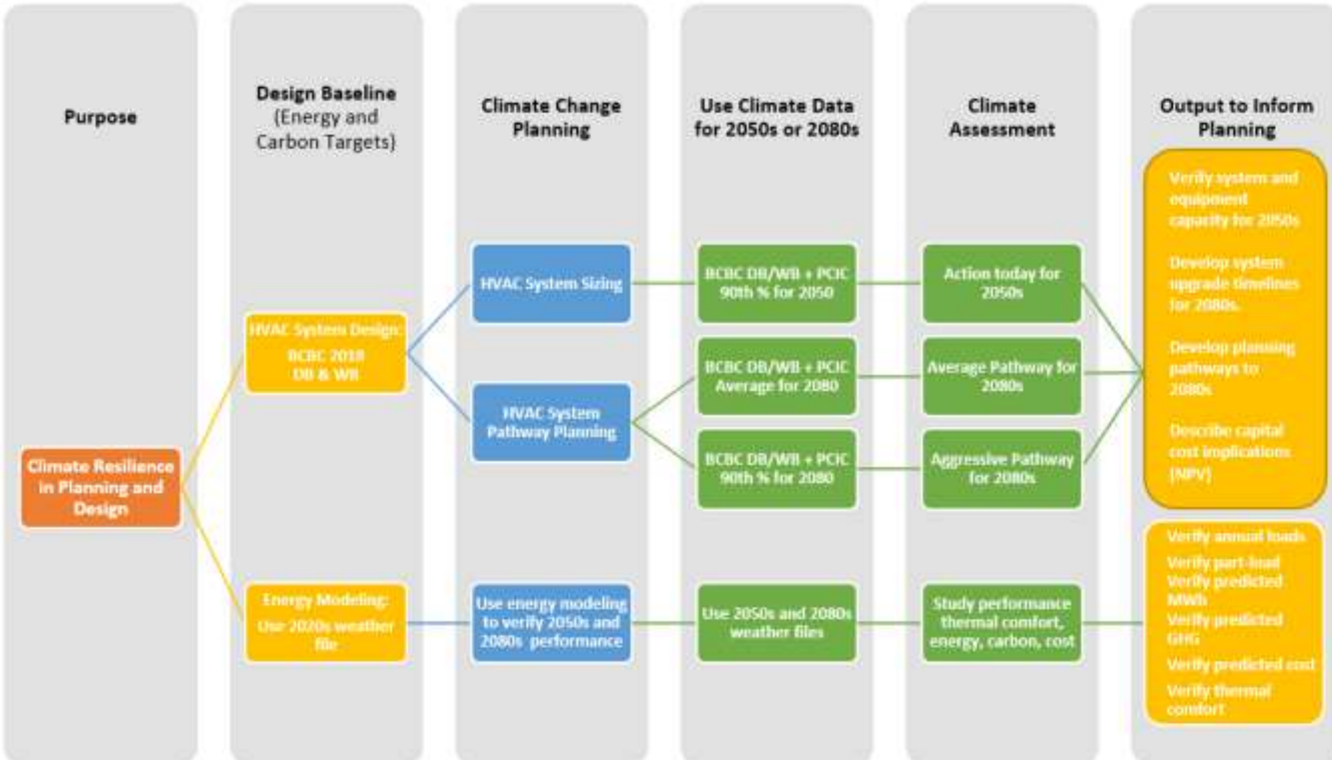

Figure 1: *Overview of methodology and process for how to establish design conditions for 2020s, 2050s and 2080s*

6. GLOSSARY

Average	Average change, for each time-period of 30 years, derived from 10 downscaled climate prediction models.
Change	Climate change by the 2020s (2011-2040), 2050s (2041-2070), and 2080s (2071-2100) periods are derived from a 1998-2014 baseline, based on CWEEDS historical data.
Cooling 2.5%	PCICs definition of cooling 2.5% is based on annual hourly data. Difference to BCBC is that hottest day is influenced also by the hottest day outside of July.
Future shifted	Future shifted weather files refer to weather files in .EPW format produced by PCIC for all BC weather station locations. The files are based on CWEC 2016 as baseline hourly file with adjustments made for changes to dry-bulb, dew-point, humidity and pressure based on the RCP-8.5 prediction for BC for each particular location, derived from 10 downscaled climate predictions models, refer to PCIC for more information.
Heating 99%	PCICs definition of heating 99% is based on annual hourly data. Difference to BCBC is that coldest day is influenced also by coldest day outside of January.
10th -90th percentile	The percentiles encapsulate the range of plausible future change under the RCP-8.5 (high emission) scenario, as derived from 10 downscaled climate prediction models. The percentiles are not percentiles of hours in a year, but rather the range of anticipated values in the 30-year average (for the period).
Planning Pathway	Pathway refers to combinations of design strategies and their implementation over time.
Range	Range represents PCICs 10th-90th percentiles from 10 downscaled models. The percentiles are not percentiles of hours in a year, but rather the range of anticipated values in the 30-year average (for the period).
TNN	Average annual minimum (of daily minimum temperature) from PCIC 10 downscaled climate models.
TXX	Average annual maximum (of daily maximum temperature) in PCICs 10 downscaled climate models.