BUILDING DESIGN STRATEGIES FOR FUTURE CLIMATE

Based on the *UBC-Designing Climate Resilient Multifamily Buildings* study

THE UNIVERSITY OF BRITISH COLUMBIA
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AUTHORSHIP

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The content, including graphs and tables, is drawn from the report *UBC - Designing Climate Resilient Multifamily Buildings*, prepared for the University of British Columbia by RDH Building Science Inc. in 2020. The report describes in detail the analyses of the performance of different climate adaptation and mitigation measures for four different residential building archetypes, in current and future climate conditions, and provides policy and design recommendations based on the results.

Readers are encouraged to review the full report, available for download from UBC: https://planning.ubc.ca/sites/default/files/2020-05/REPORT_UBC_Climate%20Resilient%20Multifamily%20Buildings.pdf

Developing energy efficient, low carbon and resilient neighbourhoods is an important area of focus for the University of British Columbia. A growing collection of research and actions plans in this area can be found online at https://sustain.ubc.ca/research/research-collections/low-carbon-and-resilient-neighbourhoods

Cover photograph: Javier Landaeta

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IMPACTS OF FUTURE CLIMATE CONDITIONS

The Intergovernmental Panel on Climate Change (IPCC) reports that human activities have significantly contributed to 1°C of global warming over time and that global temperatures are likely to further increase to 1.5°C by 2050s (IPCC 2018). The changing climate caused by this warming is affecting humans' settlements and natural environments around the world, and in recent years, there has been a growing recognition of the need to prepare for the greater future impacts of climate change.

While understanding of the local impacts from climate change are still emerging, some of the impacts currently being experienced in British Columbia have significant implications for the built environment.A climate risk assessment recently conducted for British Columbia identified fifteen risk events that will be faced by the province by 2050; the three highest risk events are frequent heat waves, seasonal water shortage and severe wildfire season (MoECC 2019).

IMPORTANCE OF CONSIDERING FUTURE CLIMATE CONDITIONS

Historically, British Columbia has experienced mild climate conditions in both summer and winter, but that is changing. In the next 50 years, the Metro Vancouver region is predicted to experience warmer temperatures, increased summer droughts, and more intense winter precipitation (Metro Vancouver 2016). These trends have implications on buildings and energy supplies to maintain comfortable environments for their inhabitants. Warming temperatures will likely lead to a decrease in heating demand by almost one third and increase in cooling demand by nearly five times over current demand by the 2050s (Metro Vancouver 2016). These changes will have a significant impact on building design and retrofits in the future.

Consideration of the implications of future climate conditions on building design is vital to creating resilient buildings that can prepare, respond and adapt to the changing climate events. Designing for future climate resiliency leads to a building design that can respond to the rising temperatures, while also reducing the energy consumption and carbon emissions by decreasing the rising demand for mechanical cooling.

DESIGNING BUILDINGS FOR FUTURE CLIMATE CONDITIONS

BC ENERGY MODELLING PRACTICES

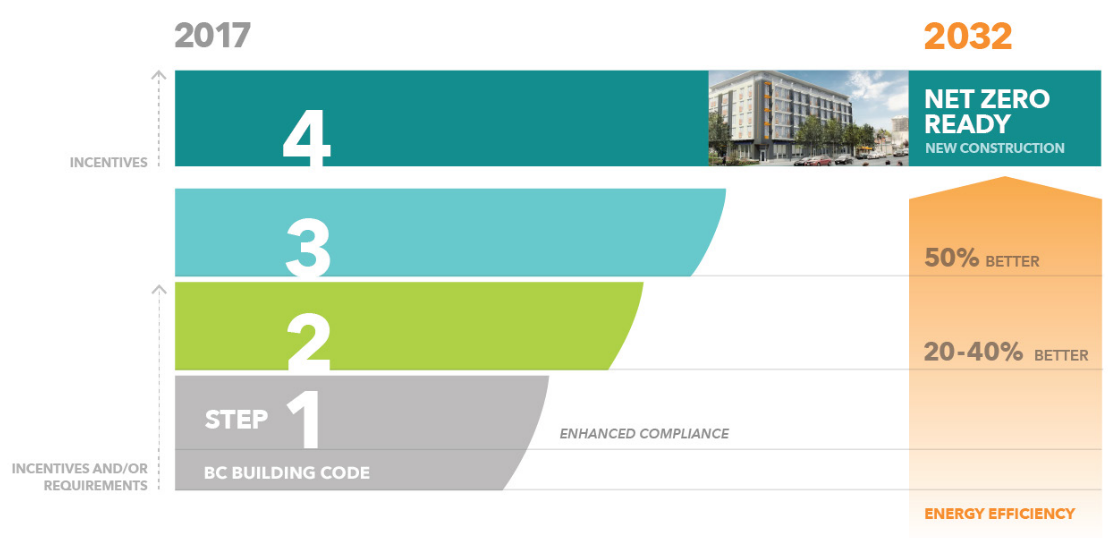
Many jurisdictions in British Columbia are beginning to incorporate energy performance targets into local policy through the *B.C. Energy Step Code* (BC ESC). To comply with the BC ESC, a building's design process includes energy simulation modelling to demonstrate that the building's energy performance meets certain standards. The energy models follow the *City of Vancouver Energy Modelling Guidelines v2.0* (referenced by the BC ESC), which include directions and requirements for the use of weather files (City of Vancouver 2017). Since outdoor weather variables have a significant impact on the building's energy, heating and cooling demand, the weather files are used to test the performance of the design measures in varying climate conditions throughout the year.

Currently, the BC ESC requires use of the 2016 version of the *Canadian Weather Year for Energy Calculation* (CWEC) file for energy modelling. These weather files are generated as *Typical Meteorological Year* (TMY) files that represent typical weather conditions over a certain time. A fundamental issue emerging from this methodology is that TMY files are created from historic weather data and do not reflect the effects of climate change that are occurring and will accelerate in the future. As a result, energy modelling may lead to building designs that meet the energy targets and heating and cooling requirements for past climate conditions, but cannot adapt to anticipated future climate conditions. Therefore, it is important to develop a modelling methodology that can use weather files that are representative of future climate conditions.

B.C Energy Step Code: an optional compliance path under the *B.C. Building Code* that local governments may use to mandate or incentivize greater levels of building energy efficiency than is currently required in the *B.C. Building Code*.

For Part 3 multi-unit residential buildings, it frames four steps of incremental improvement in energy performance, with the highest step as net zero energy ready new construction (BSSB 2018).

Image credit: BC Energy Step Code Council: energystepcode.ca



FUTURE CLIMATE READY BUILDINGS

In 2019, the University of British Columbia (UBC) engaged RDH Building Science to conduct a study assessing the future climate impacts on the buildings at UBC's Vancouver campus. The analysis and results are described in the *UBC - Designing Climate Resilient Multifamily Buildings* report, on which this case study is based.

To test the performance of the buildings in future climate conditions, the study identified metrics for analysis of thermal comfort, energy use and greenhouse gas (GHG) emissions. These were based on standards and guidelines including the *City of Vancouver Energy Modelling Guideline v2.0*, which references the *ASHRAE 55* thermal comfort standard, the *B.C. Energy Step Code Design Guidelines* and the *Vancouver Building Bylaw* (City of Vancouver 2017).

The use of future climate weather files in energy modelling was crucial to determine future building performance. The study uses the future climate files for UBC's Vancouver campus location provided by the Pacific Climate Impact Consortium (PCIC) based on the *IPCC Representative Concentration Pathway* (RCP) 8.5 scenario (PCIC 2020). The RCP-8.5 scenario models 'business as usual' GHG concentrations in the atmosphere and projects future climate conditions for the 2020s, 2050s and 2080s, if no committed actions are taken to reduce GHG emissions. As shown in Figure 1, RCP-8.5 scenarios for the 2020s, 2050s and 2080s show an increase in monthly average, minimum and maximum temperatures from the current modelled conditions, CWEC 2016, with the highest values recorded for the 2080s weather file.

While the 2080s is beyond the lifespan of most existing and many newly constructed buildings, and the climate projections are more uncertain than for the 2020s or 2050s, the study included the 2080 scenario as a sensitivity analysis for two reasons. First, since the weather file representing 2050s is based on weather averages, which do not include heatwave events, the 2080s scenario can act as a proxy for these hotter summer events in earlier years. Second, the 2080s scenario represents a pessimistic case, as the 2050s scenario may underestimate the scale of change that will occur.

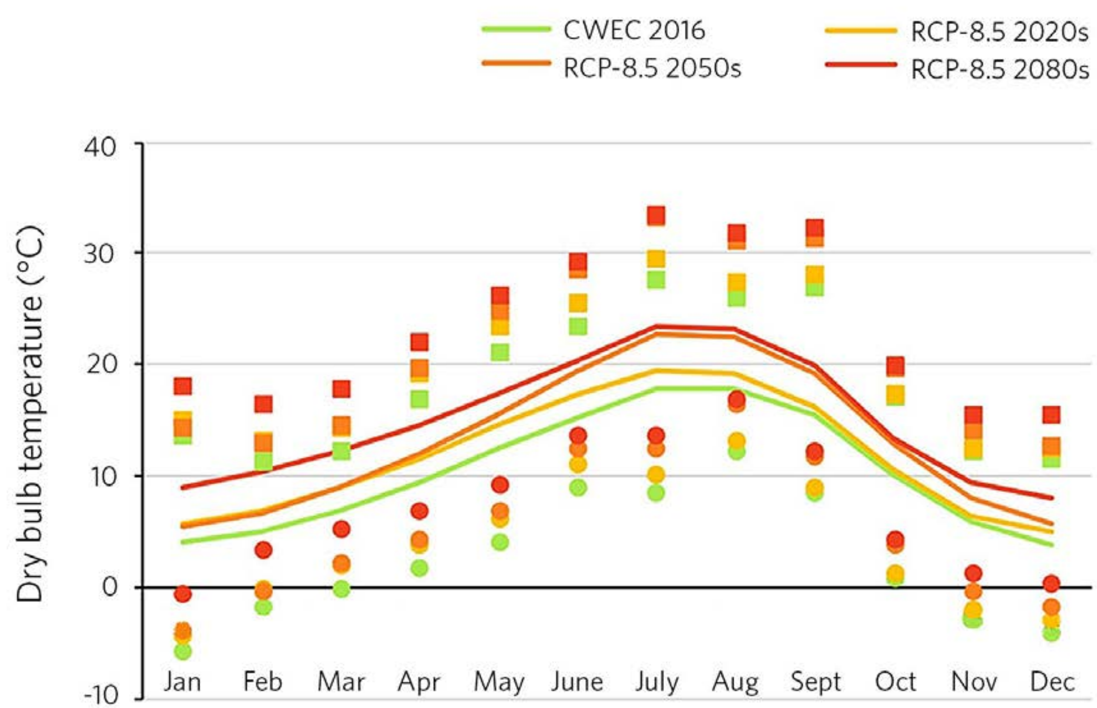


Figure 1. Monthly average, maximum, and minimum air-dry temperature (°C) for CWEC 2016 and RCP-8.5 2020s, 2050s, and 2080s climate files for UBC

DESIGN STRATEGIES FOR FUTURE CLIMATE CONDITIONS

CLIMATE ADAPTATION AND MITIGATION MEASURES

A compilation of climate adaptation and mitigation measures (CAMMs) was developed for the analysis of four building archetypes in the *UBC - Designing Climate Resilient Multifamily Buildings* study to address the impact of future climate conditions on the building design. The four archetypes– new building low-rise, new building high-rise, existing building low-rise and existing building high-rise–are broadly representative of common building typologies in UBC's residential neighbourhoods and across the B.C. Lower Mainland. Key differences between the archetypes included construction techniques, structural materials, heating and cooling equipment, and the use of mechanical cooling.

The CAMMs used in the study were chosen based on project experience, stakeholder consultation, and other climate adaptation and mitigation studies, and were expected to perform well in the RCP-8.5 2050s climate scenario. The selected measures focused on design mitigation and adaptation strategies for the building and its systems, and did not include strategies related to the property management, behaviour change or other protocols.

The CAMM measures were categorized into passive and active strategies. Passive strategies include solar heat gain reduction and improving the enclosure performance of the building. Active strategies include the use of mechanical systems required to maintain thermal comfort in the buildings. The list of passive and active strategies used in the *UBC - Designing Climate Resilient Multifamily Buildings* study, and which could also apply to the wider context of the Lower Mainland, is summarized in Table 1.

Table 1. Summary of the climate adaptation and mitigation measures (CAMMs) for building design strategies used in the UBC - Designing Climate Resilient Multifamily Buildings study.

Passive Strategies	Solar Heat Gain Reduction	• Reduce window-to-wall ratio (WWR) • Implement shading devices (operable/fixed) on east, west and south-facing facades • Reduce solar heat gain coefficient (SHGC) • Install dynamic glazing which responses to the changing weather throughout the year
	Improved Enclosure Performance	• Improve wall, window and roof thermal performance with specified R-value and U-values
Active Strategies	Mechanical Systems	• Use high-efficiency heat recovery ventilator (HRV) that can operate in either boost, bypass mode, corridor pressurization or cooling coil as needed • Use an air source heat pump (in-suite/ductless) which provides heating and cooling

CLIMATE ADAPTATION AND MITIGATION MEASURE BUNDLES

Multiple CAMMs can work synergistically and be bundled together to improve building performance and adaptability. In the *UBC - Designing Climate Resilient Multifamily Buildings* study, a set of bundles were designed for each building archetype based on the results of individual climate measures and cost analysis.

Two categories of bundles were designed: one with only passive measures and one combining passive and active measures. The passive bundles focused on optimizing the impact of passive cooling strategies. The combined passive and active bundles focused on passive measures along with highly efficient mechanical cooling options.

For each archetype, different bundles were designed to model the requirements of different steps of the B.C. Energy Step Code to analyse how well building designed to these standards today would perform in future climate conditions for Part 3 residential buildings. Different passive and combined CAMM bundles were added to these baseline Step Code designs to determine which combinations of design strategies were most effective in adapting to future climate scenarios.

The CWEC 2016 weather file, representing recent past climate conditions, was used as a baseline and the performance of the CAMMS were assessed for conditions using the RCP-8.5 2020s, 2050s and 2080s weather files. The study focused on RCP-8.5 2050s climate scenario, since the 2050s falls within the expected lifespan of new and existing buildings today but is anticipated to have a warmer climate throughout the year.

KEY RESULTS OF CAMM BUNDLE ANALYSIS

NEW BUILDING LOW-RISE ARCHETYPE

Current building design practice sets performance standards for the interior environmental conditions of buildings, including the range of acceptable indoor temperatures. The number of overheated hours (the amount of time the indoor temperature is above the upper limit) of new low-rise buildings must not exceed 200 hours per year (ASHRAE 55 2010, section 5.3). As the climate gets warmer, the number of overheated hours per year increases.

The study found that, for new low-rise buildings, applying CAMMs to design the building to meet BC ESC Step 3 are vulnerable to overheating in future climate scenarios (RCP-8.5 2050s and 2080s), as shown in Figure 2. This highlights the need for building design strategies that go beyond the current BC ESC requirements to address future overheating issues.

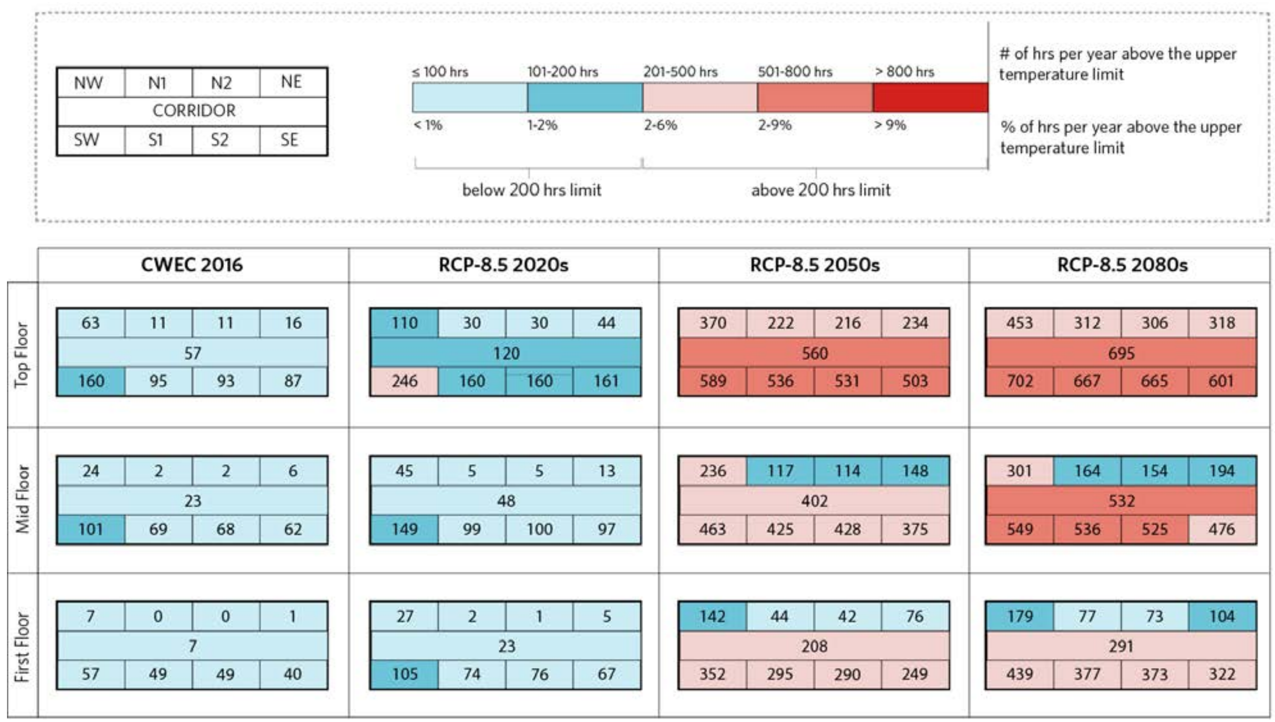


Figure 2. The number of overheated hours for a new low-rise building, with CAMMs designed to Step 3 requirements, in the CWEC 2016, RCP-8.5 2020s, 2050s and 2080s climate scenarios.

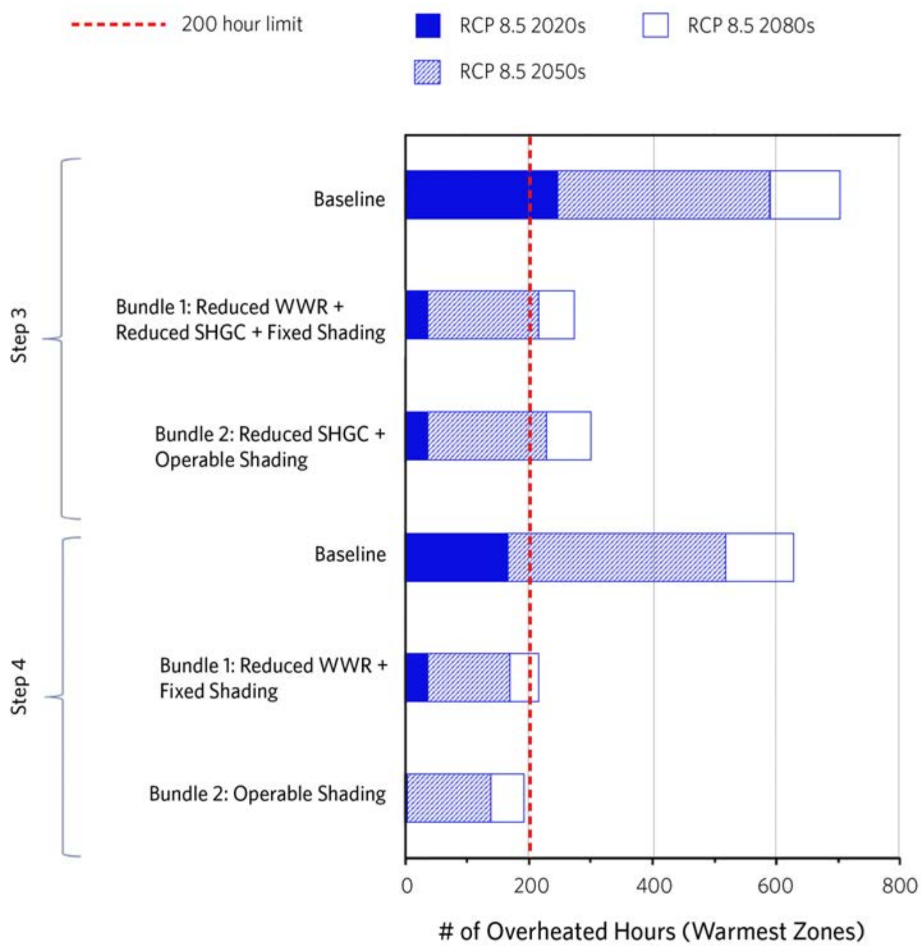


Figure 3. The number of overheated hours for the warmest zone in a new low-rise building for RCP-8.5 2020s, 2050s and 2080s climate scenarios. The baselines include only active CAMMs designed to meet the requirements of Step 3 or Step 4. Bundles 1 and 2 for each Step Code level included different combinations of passive measures in addition to the baseline measures.

Further analysis of the thermal comfort showed that for new low-rise buildings following the higher BC ESC requirements (Step 3 and Step 4) will not mitigate overheating in the building. However, combining passive and active measures significantly lowered the number of overheating hours, as shown in Figure 3.

Passive measures, such as reducing the window-to-wall ratios and solar heat gain coefficient of the envelope, and adding fixed or operable shading, reduced the number of overheating hours for Step 3 buildings designs. This was enough to almost meet the 200-hour threshold for the 2050s climate scenarios, but not the 2080s. Fewer passive measures were required for similar reduction in Step 4 building designs. Reducing window-to-wall ratios and adding shading was enough to meet the 200 overheating hour threshold for both the 2050s and 2080 climate scenarios.

TEDI:thermal energy demand intensity is an established metric for the amount of space heating energy required to maintain a building's internal temperature at a comfortable level. The BC Energy Step Code includes TEDI targets for Steps 2, 3 and 4 (BCBC 2018a, section 10.2.3).

CEDI: cooling energy demand intensity is an emerging metric for the amounting of energy required to cool a building to a comfortable level, calculated the same way as TEDI. There are no CEDI targets in the Energy Step Code.

NEW BUILDING HIGH-RISE ARCHETYPE

New high-rise buildings in B.C. typically have a mechanical cooling system. This limits overheating of the building but can also increase the energy consumption. As part of the study, the energy demand intensity for thermal heating and cooling in new high-rise buildings designed to Step 2, Step 3 and Step 4 under current climate conditions and 2020s, 2050s and 2080s climate conditions. The analysis indicates that for all Step Code designs, TEDI declines over future climate periods, however CEDI increases, most substantially in the 2050s and 2080s periods as shown in Figure 4. This indicates that cooling loads are likely to become significant contributors to building energy consumption under future climate conditions.

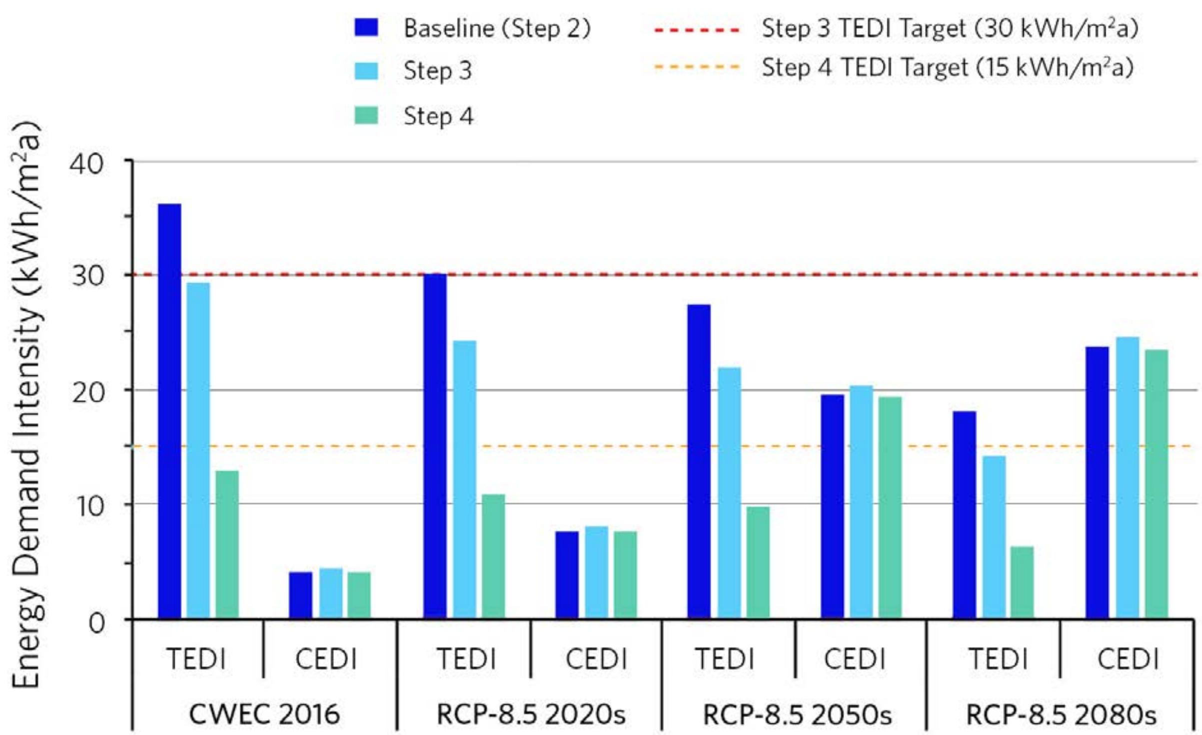


Figure 4. TEDI and CEDI for new high-rise buildings designed to Step 2, Step 3 and Step 4 for CWEC 2016, RCP-8.5 2020s, 2050s and 2080s climate scenarios.

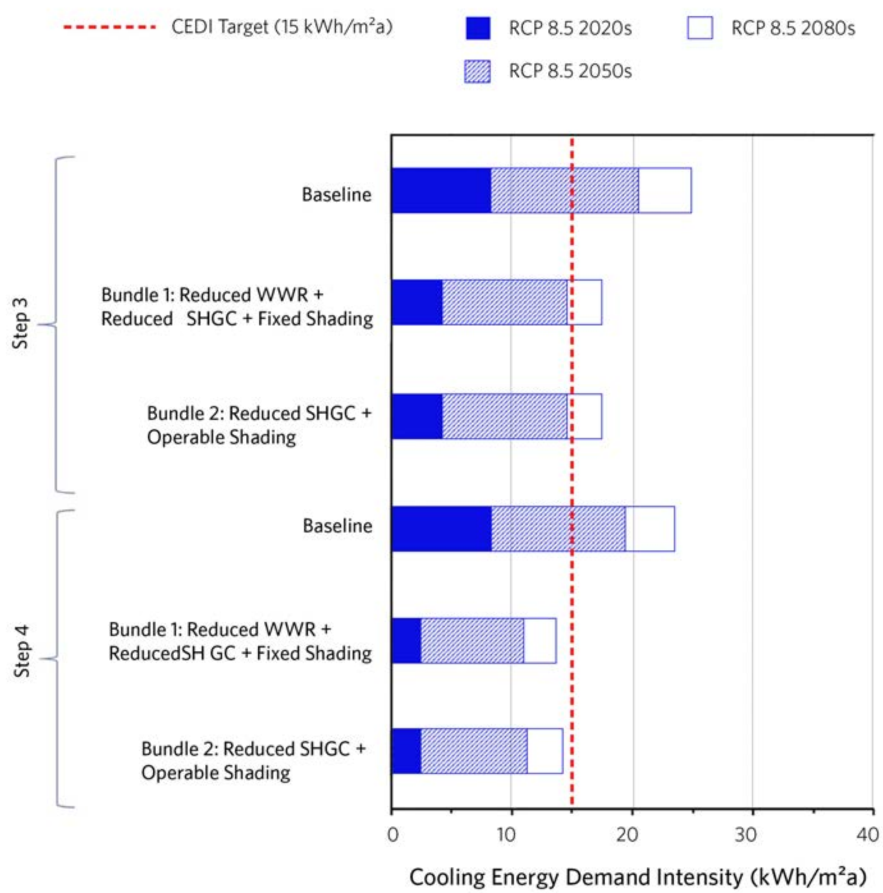


Figure 5. Cooling Energy Demand Intensity (CEDI) for a new high-rise building for RCP-8.5 2020s, 2050s and 2080s climate scenarios. The baselines include only active CAMMs designed to meet the requirements of Step 3 or Step 4. Bundles 1 and 2 for each Step Code level included different combinations of passive measures in addition to the baseline measures.

The BC ESC has established Energy Demand Intensity targets for each Step. Currently, these targets are applicable for heating energy only, in the form of TEDI. However, as cooling demand increases in future climate conditions, it will also need to be included in the energy demand accounting. Analysis of the energy demand intensity for new high-rise building archetype showed that following the higher BC ESC requirements (Step 3 and Step 4) would not keep CEDI within the currently established TEDI targets. However, incorporating passive design measures with the active measure can significantly reduce CEDI, as shown in Figure 5.

Including passive measures, such as reducing the window-to-wall ratios and solar heat gain coefficient of the envelope, and adding fixed or operable shading, brought the CEDI of Step 3 buildings below the Step 4 energy demand intensity target of 15 kWh/m^{2}a for 2050s climate conditions. Step 4 buildings perform even better than Step 3 when passive measures are implemented, with CEDI below 15 kWh/m^{2}a for both 2050s and 2080s climate scenarios. The results also illustrate the benefit of high performing building enclosures in mitigating peak cooling demand, maintaining thermal comfort and meeting the energy and emission reduction targets.

The study conducted an analysis for the new high-rise building archetype to understand its resiliency to future climate conditions in the case of a power outage, when the mechanical cooling systems would turn off. The analysis compared indoor temperatures of a building designed to Step 4 requirements and a Step 4 building with passive design measures during a hot summer week during the 2050s period. The results show that under normal operation, with power available, the building maintains the temperatures within an acceptable comfort level. However, during a power outage event, the Step 4 building with passive measures maintains internal temperatures near an acceptable comfort level, but the baseline Step 4 building exceeds the threshold of thermal comfort, as shown in Figure 6. These results suggest that buildings with passive cooling design features will be more resilient to weather variations and other events under future climate conditions.

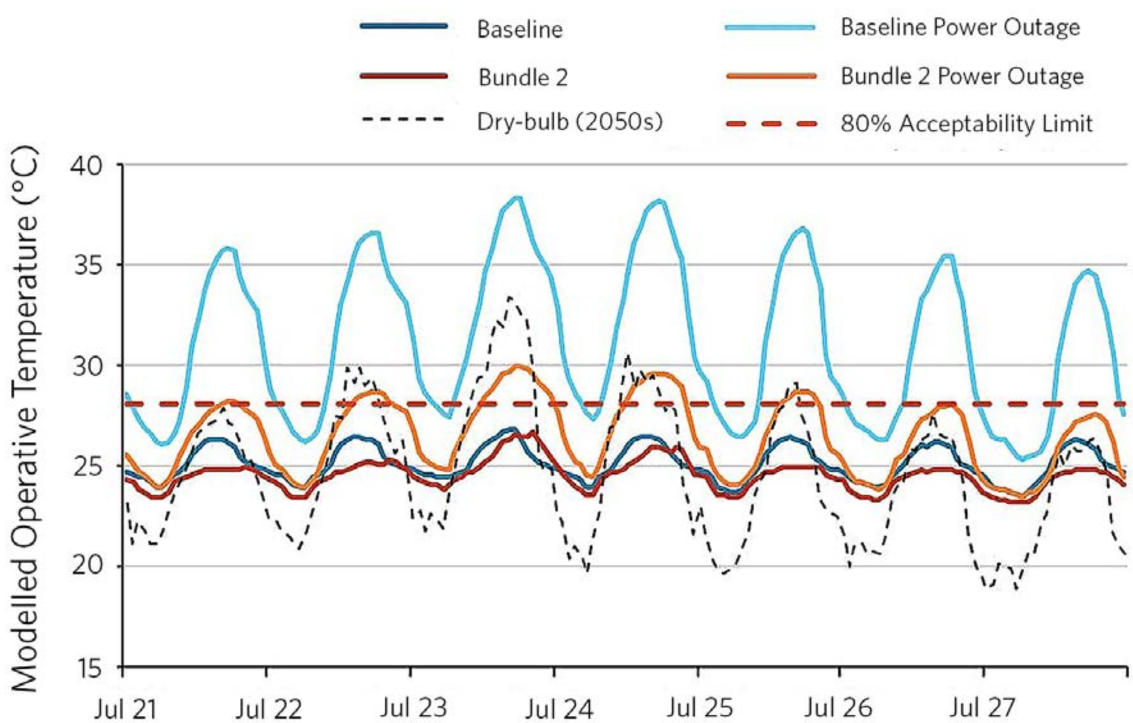


Figure 6. Modelled operative temperature for Step 4 new high-rise building designed to Step 4 requirements (Baseline) and including both passive and active measures (Bundle 2), during normal operation and during a power outage for a hot summer week in the 2050s.

EXISTING BUILDING ARCHETYPES (HIGH-RISE AND LOW-RISE)

Historically, the Lower Mainland of B.C. has enjoyed a relatively mild climate. Consequently, many existing buildings in the Metro Vancouver region do not have mechanical cooling systems or incorporate passive cooling measures into their designs. The study conducted a thermal comfort analysis of existing high-rise building archetype to gain an understanding of risk of overheating under future climate conditions.

The results, as shown in Figure 7, suggest that not only do existing high-rises buildings not meet the thermal comfort criteria for future climate scenarios; they exceed the overheating hours limit of 200 hours per year under current climate conditions. This indicates that existing high-rise buildings are likely experiencing overheating today, and may not be able to adapt to future climate conditions, at least not without major retrofits.

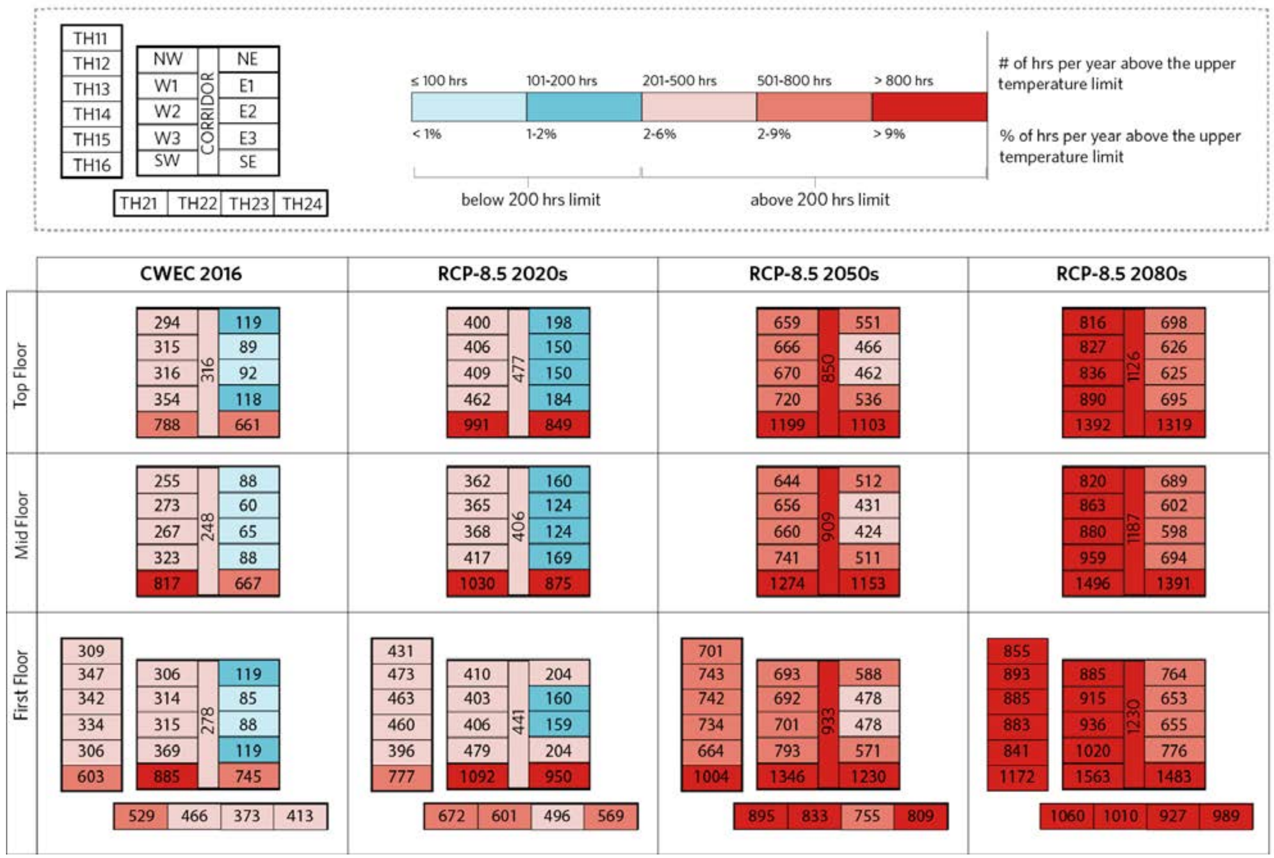


Figure 7. The number of overheated hours in the existing high-rise building model under CWEC 2016, RCP-8.5 2020s, 2050s and 2080s climate scenarios.

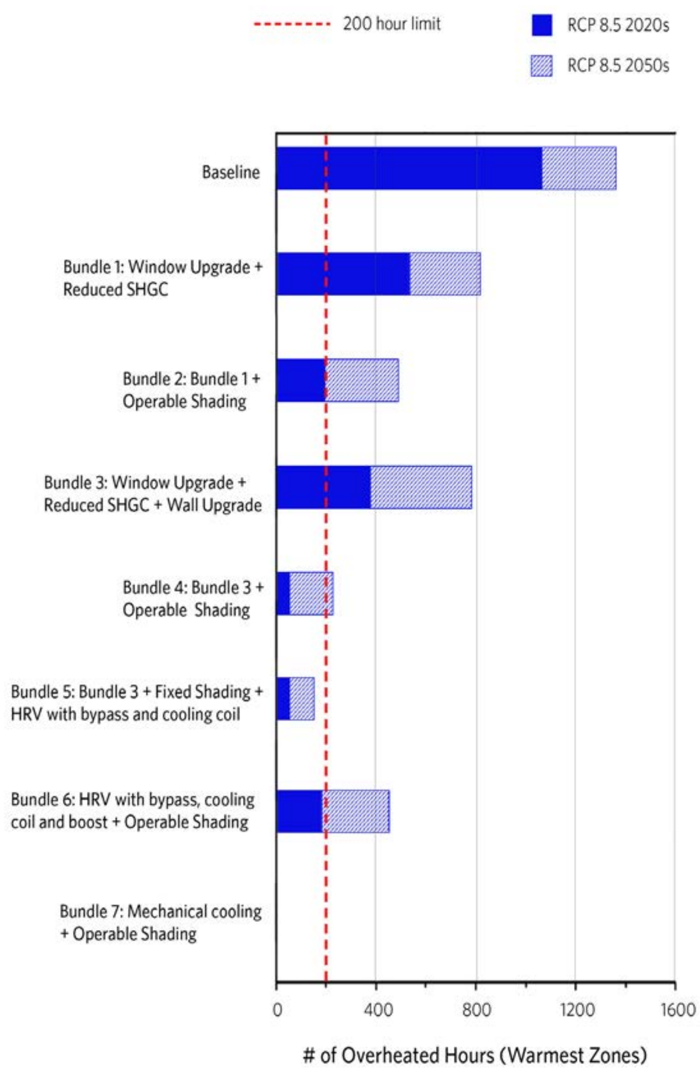


Figure 8. The number of overheated hours for the warmest zone in the existing high-rise building (baseline) and with the application of different CAMM retrofit bundles for RCP-8.5 2020s and 2050s climate scenarios.

The results of the thermal comfort analysis for existing high-rise building CAMM bundles suggest that for optimized results, passive measures will have to be combined with active measures to meet the thermal comfort threshold. The study analysed seven combinations of CAMMs as retrofits packages for existing high-rise buildings, as shown in Figure 8.

Overall, combining passive and active design strategies for this archetype decreased the number of overheating hours per year in both 2020s and 2050s climate scenarios. Certain passive strategies, such as operable shading helped bring the overheating within the acceptable threshold for 2020s conditions, but not 2050s. The most successful were combinations of mechanical cooling plus operable shading that included reduced solar heat gain coefficients and exterior wall and window upgrades, along with operable shading or fixed shading (bundle 4) and HRV with bypass and cooling coil (bundle 5). The combination with mechanical cooling plus operable shading (bundle 7) reduces all overheated hours.

In the case of retrofit projects, however, the effectiveness of the solutions are highly dependent on the life cycle stage of the building elements (e.g. equipment, building envelope, glazing, windows, etc.) in relation to the specific building. Durability and replacement rates, and associated costs, have to be balanced against their impact on the building's thermal comfort and energy demand, as well as the base building's own life cycle.

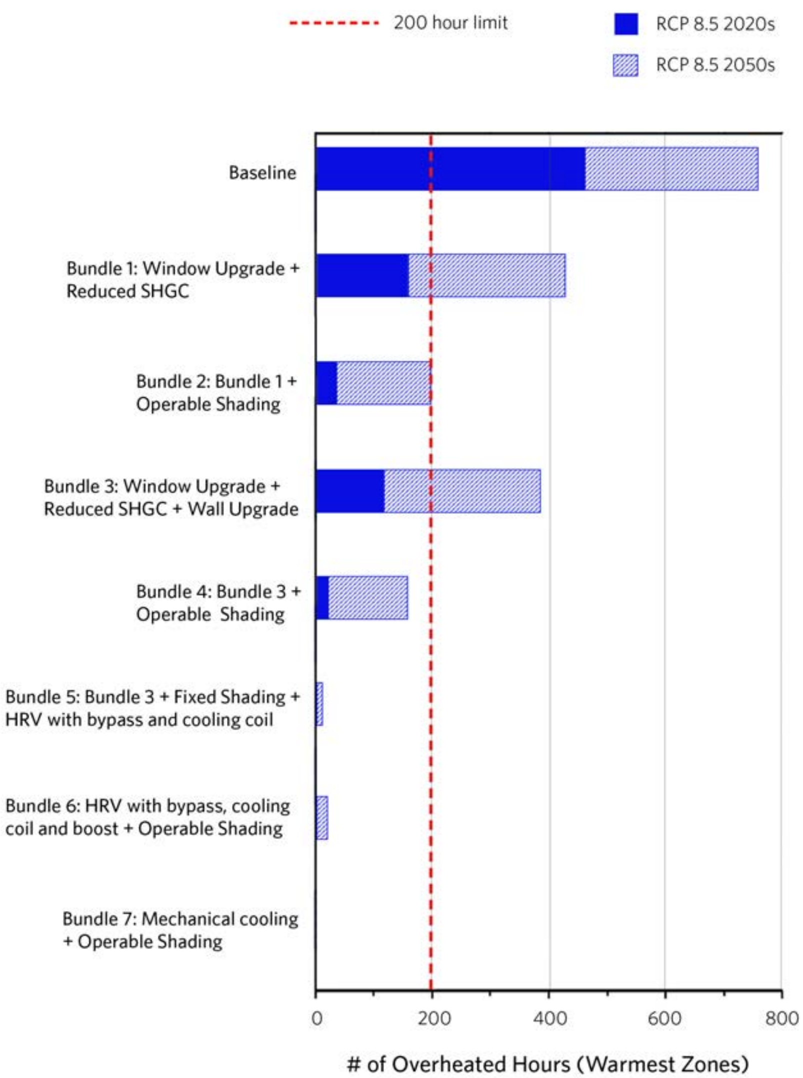


Figure 9. The number of overheated hours for the warmest zone in the existing low-rise building (baseline) and with the application of different CAMM retrofit bundles for RCP-8.5 2020s and 2050s climate scenarios.

For the existing low-rise building archetype, the study analysed the seven combinations of CAMMs as retrofit bundles, as shown in Figure 9. Five different combinations were able to keep the overheating hours below the acceptable threshold for the RCP-8.5 2050s climate scenario. Unlike the high-rise archetype, some of these were bundles of solely passive measures (bundles 2 and 4) that included operable windows, reduced solar heat gain coefficient, window upgrades and wall upgrades. Combined bundles (bundle 5, 6 and 7), which included HRV with bypass and cooling coil or mechanical cooling with the passive measures, performed very well, almost eliminating the number of overheating hours in both 2020s and 2050s climate scenarios.

DISCUSSION/CONCLUSION

Design strategies that have been used to maintain comfortable internal environments in BC are not going to be sufficient for the climates of the 2050s or 2080s. Results from the *UBC-Designing Climate Resilient Multifamily Buildings* study shows that for multi-unit residential buildings, designing to B.C. Energy Step Code is not enough to provide comfortable future buildings, particularly in hot summer months. Additional cooling measures will be needed to prevent overheating, with a potentially significant increase in energy demand. Combinations of passive and active cooling measures provide the best performance, in terms of both comfort and energy demand, in future climate scenarios. The inclusion of passive strategies also improved the resilience of the buildings in responding to extreme events, such as power outages or heat waves.

Climate weather files used for energy modelling are currently based on past weather conditions, but as scientific models of global climate change show, rapidly warming temperatures mean that future conditions will be very different from those in the past. Building energy modelling is still a relatively new practice and assessing performance against future climate conditions is an emerging area of research and practice. Although the use of future weather files is necessary for energy modelling to support climate resilient building design, projections of future climate conditions include considerable uncertainties. Additionally, there are no standard modelling practices for certain passive strategies, such as natural ventilation, which can heavily influence both the thermal comfort and energy performance of a building. Further research is needed to validate the use of future climate conditions and the incorporation of a greater range of passive strategies, and to develop guidelines for modelling practices.

BIBLIOGRAPHY & ADDITIONAL RESOURCES

BIBLIOGRAPHY

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers). 2010. Section 5.3. Optional Method for Determining Acceptable Thermal Conditions in Naturally Conditioned Spaces. ASHRAE Standard 55. http://arco-hvac.ir/wp-content/uploads/2015/11/ASHRAE-55-2010.pdf

BCBC (British Columbia Building Code). 2018a. Section 10.2.3. Energy Step Code. Division B Revision 2.10. BC Building Code 2018. http://free.bcpublications.ca/civix/document/id/public/bcbc2018/bcbc_2018dbs102r2

BSSB (Building and Safety Standards Branch). 2018. How the BC Energy Step Code Works. Retrieved from Energy Step Code. https://energystepcode.ca/how-it-works/

City of Vancouver. 2017. Energy Modelling Guidelines Version 2.0. Land Use and Development Policies and Guidelines. Planning, Urban Design and Sustainability Department. https://vancouver.ca/files/cov/guidelines-energy-modelling.pdf

IPCC (Intergovernmental Panel on Climate Change). 2018. Summary for Policymakers. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf

Metro Vancouver. 2016. Climate Projections for Metro Vancouver. http://www.metrovancouver.org/services/air-quality/AirQualityPublications/ClimateProjectionsForMetroVancouver.pdf

MoECC (Ministry of Environment and Climate Change). 2019. Preliminary Strategic Climate Risk Assessment for British Columbia. Report prepared for the Government of British Columbia, Victoria, BC. https://www2.gov.bc.ca/assets/gov/environment/climate-change/adaptation/prelim-strat-climate-risk-assessment.pdf

PCIC (Pacific Climate Impact Consortium). 2020. Weather Files. https://www.pacificclimate.org/data/weather-files

ADDITIONAL RESOURCES

BC Housing. 2019. BC Energy Step Code Design Guide. https://www.bchousing.org/research-centre/library/residential-design-construction/bc-energy-step-code-design-guide

RDH Building Science, 2017. UBC Modelling Study: Residential Archetypes. https://planning.ubc.ca/sites/default/files/2019-11/REPORT_Residential%20Archetype%20Modelling%20Study%20Final.pdf

Vancouver Building Bylaw. 2020. https://vancouver.ca/your-government/vancouver-building-bylaw.aspx

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