Number 19

BUILDER INSIGHT

BC HOUSING RESEARCH CENTRE

Builder Insight is a series of bulletins and companion videos designed to provide practical information on new technologies, research results, good building practices and emerging technical issues in residential construction to Licensed Residential Builders and others in the industry.

This bulletin was prepared by Focal Engineering with support from Integral.

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Modelling the Future Climate in Passively Cooled Buildings

Overview

The Province of British Columbia will experience significant changes in climate over the next several decades. Temperature increases of between 1.3 and 2.7°C are projected by 2050, and the province is already experiencing more extreme weather, including frequent and severe heat waves and wildfire events as a result. The impacts of these events pose serious risks to British Columbia's buildings, along with the safety, well-being, and financial investments of their owners and occupants. As building design can play a key role in enhancing our resilience to these current and projected impacts, designers must increasingly consider how to adapt buildings for a warmer world.

This Builder Insight provides an overview of how designers can improve building resilience by considering the risk of overheating as described by the BC Energy Step Code for applicable projects. It includes a methodology for analyzing and reporting the potential for passively cooled buildings to overheat under future climate scenarios.

This document is intended for readers with an understanding of energy modelling who are new to this type of analysis, with the goal of establishing a procedure that can be consistently used across the building industry.

Since projecting future climate conditions is a new and emerging field, further research may indicate additional or alternative means of analysis, at which time this guideline may be updated. For a general overview of the principles necessary to mitigate overheating and air quality risks in building design, see BC Housing's *Overheating and Air Quality Supplement* to the *BC Energy Step Code Design Guide*.

Background

The BC Energy Step Code energy models for Part 3 buildings use Canadian Weather for Energy Calculations (CWEC) weather files that are based on 30 years of historical data. As the climate changes, these files become less representative of the actual weather that occurs in each location. Current conditions are already different from what is represented in CWEC 2016 files, and future conditions are anticipated to vary even further. As such, a future weather file should be used that accounts for anticipated climate change in the building's location.

This Builder Insight addresses these factors in the following sections:

- **Weather Files:** choosing and presenting a future weather file,
- **Overheating Analysis:** analyzing overheating risk in future climate conditions and comparing results between scenarios,
- **Reporting:** outlining key results and providing context from the analysis,
- **Methodology:** summarizing the previous sections into simple steps, and
- **Additional Resources, Acronyms and Definitions:** defining any italicized references, acronyms and definitions from the rest of the document.

The approach to assessing overheating potential discussed herein follows the standards and guidelines referenced by the Step Code. Readers new to the Step Code may wish to review the documents referenced in the final section for a more complete understanding of the approach.

Future Weather Files

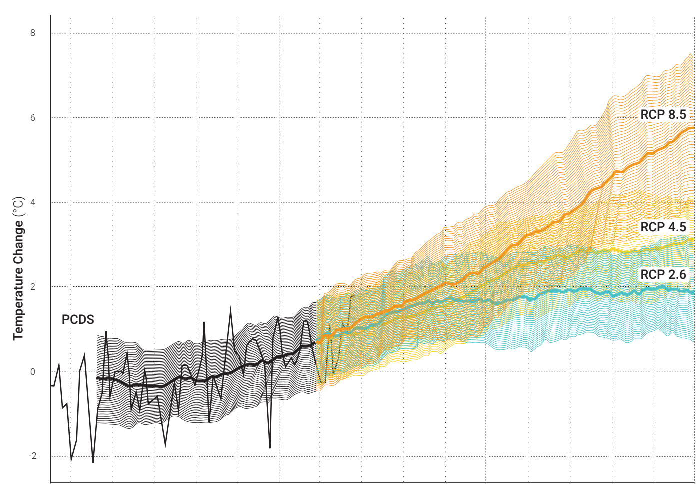
To properly assess a building's future performance, it is first necessary to identify the likely future climate under which the building will operate.

Choosing a Weather File

Three future climate scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) indicate the potential severity of climate change using Representative Concentration Pathways (RCPs). These represent possible trajectories for global temperature changes that differ according to varying global efforts to mitigate atmospheric greenhouse gas (GHG) emissions:

- The **best-case scenario** *(RCP-2.6)* assumes that GHG emissions will be drastically reduced, and existing GHGs will start to be removed from the atmosphere.
- The **stabilization scenario** *(RCP-4.5)* assumes that all countries will undertake measures to mitigate emissions simultaneously and effectively.
- The **worst-case scenario** *(RCP-8.5)* assumes that the planet will experience high population growth and relatively slow income growth with modest rates of technological change and energy intensity improvements.

Figure 1: Global Average Surface Temperature Change



Adapted from Figure SPM.7a from "Summary for Policymakers" by Climate Change 2013: The Physical Science Basis. Lighter colour bands represent the range of potential temperature increases within a single scenario.

To explore how a warmer climate will impact building performance, future weather files exist based on the RCP scenarios listed above for three different time periods: the 2020, 2050 and 2080 decades.

While energy models can analyze building performance under all of these future scenarios and more, starting with the ***RCP* 8.5 file for the 2050s decade** is recommended for the following reasons:

- The file looks a reasonable distance into the future (roughly 30 years from today) and considers the worst-case scenario, helping to ensure the building's resilience regardless of the global measures to reduce emissions that are put in place.
- The difference between the three RCP scenarios in the 2050s is relatively low; as a result, projections for the 2050s are more likely to be accurate than ones further into the future.
- While global efforts to reduce emissions are underway, the current political and economic landscape indicates that emissions will continue to rise, tending towards the RCP-8.5 scenario.

Finding a Weather File

Files should be obtained from a reputable source; current available options include the following:

- **Pacific Climate Impacts Consortium *(PCIC)*** is a leading organization researching impacts of climate change on western Canada. PCIC researchers have developed future weather files for several different locations and scenarios, which are available at the PCIC website.

A Note on Extreme Weather Events

The future weather files that are available today do not represent either extreme weather events that are occurring more frequently or the increased variability that is projected for the future. Further research is needed to better understand and account for those patterns, and future versions of these guidelines may include recommendations for analyzing thermal comfort during heat waves that are not accounted for in currently available weather files. However, using the weather files described in this Builder Insight is a good first step toward improving building resilience.

TIPS

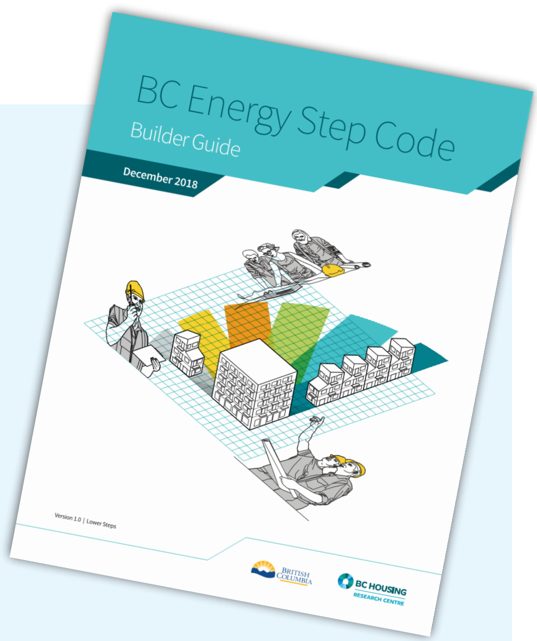
Don't create your own future file!

Anticipated changes in future temperatures are neither linear nor consistent, so modifying a 2016 *CWEC* file manually isn't recommended.

Keep CWEC 2016 results separate and on hand

As the Step Code requires the *CWEC* 2016 files to be used, keep future climate results separate from official permit submissions, and consider using separate modelling files to avoid confusion.

Include comparisons between the projected 2050s and *CWEC* 2016 weather files to provide context when reporting results.



Overheating Analysis

The Step Code has a procedure to assess overheating in buildings that don't have mechanical cooling (i.e. "passively cooled spaces") along with the other metrics of TEDI, TEUI and airtightness.

Overheating Temperature Limits are established by the *Energy Modelling Guidelines* for the Step Code, based on a location's *CWEC* 2016 weather file. Interior space temperatures may not exceed these limits for more than 200 hours during the summer months, or a more stringent 20 hours for buildings that house vulnerable groups (for example, seniors housing, shelter and supportive housing, daycares, schools, healthcare facilities, etc.). For most climates, meeting the 20-hour limit with current and future climate scenarios will likely not be achievable without some form of mechanical cooling. Meeting these limits is not intended as a guarantee of thermal comfort for occupants; rather, these limits are set to encourage designers to be mindful when designing a better envelope, to avoid inadvertently increasing overheating.

TIPS

Modelling Individual Spaces

When constructing the energy model, zone spaces to a level of detail that will assess individual space temperatures in a way that avoids averaging out any hot/cold spots. Guidance on appropriate zoning can be found in the National Energy Code for Buildings *(NECB)* Section 8.4.2.6, "Heat Transfer Between Thermal Blocks".

Step Code Limits

Clearly communicate that the 200-hour limit in the Step Code does not ensure thermal comfort. Teams may wish to consider using the reduced limit (20 hours) or considering some of the Additional Temperature Limits (presented in the next section) in their efforts to design for thermal comfort.

TIPS

Future *Overheating Seasons* will be longer

As the climate warms, months that were previously considered shoulder season may need to be evaluated for overheating, as their average monthly temperature increases above 10°C.

The methodology for establishing *Overheating Temperature Limits* and calculating *Overheating Hours* for future climate analyses is the same as that for the *CWEC* 2016 files and is outlined in this section.

Overheating Temperature Limits

Calculating *Overheating Temperature Limits* for a future weather file follows a methodology that is defined in *ASHRAE Standard 55* and modified by the *City of Vancouver Energy Modelling Guidelines Version 2 (Energy Modelling Guidelines).*

A simple summary of the process is:

1. Extract hourly exterior Dry Bulb Temperature *(DBT)* from the weather file
2. Determine the *Overheating Season*
   - 2.1. Calculate the average *DBT* for each month
   - 2.2. Months with an average *DBT*>10°C must be evaluated, forming the *Overheating Season*
3. Determine *Overheating Temperature Limits*
   - 3.1. Calculate for each month using this formula:

Overheating Temperature Limit [°C] =
(0.31 x average monthly DBT) + 21.3

4. Report the limits for each applicable month

Once again, providing a comparison between the projected 2050s and current *CWEC* 2016 *Overheating Temperature Limits* provides helpful context when reporting results.

Overheating Hours

Once the *Overheating Temperature Limits* have been established, the energy model can be run using the future weather data. For each hour of the *Overheating Season*, the interior *DBT* for each space is compared with the monthly limit, and the number of hours exceeding the limit is totaled for each space.

Any spaces exceeding the 200-hour maximum allowance (or 20, if applicable) must be re-designed and simulated until the allowance is met. Modellers should also review and report other Step Code metrics (TEDI and TEUI) alongside the overheating, as a design strategy that positively impacts one target can negatively impact another. For example, reducing the Solar Heat Gain Coefficient (SHGC) of glazing will help reduce summertime overheating, but will also increase the TEDI by reducing wintertime free heating.

All results should be reported for each design iteration being considered, so that the client and project team can use this information in the decision-making process.

Additional Temperature Limits

While the Step Code overheating analysis focuses on the *extent* of overheating by limiting the time that a space can exceed the limit, it is not a guarantee of thermal comfort as it does not look at the *magnitude* of overheating. Supplementing the Step Code analysis by reporting additional values allows for a more robust overheating assessment.

Until further requirements have been established, two values are recommended:

1. Hours over 26°C, and
2. Peak Interior Temperature.

Hours over 26°C:

A recent study from the University of Ottawa[1] evaluated multiple published studies, standards and recommendations in an effort to establish maximum indoor temperature conditions for human life safety. The findings of the report indicated that limits will vary based on population, activity and personal factors. A common trend suggested maintaining indoor temperatures below 26°C for occupant safety and health.

Similar to the Overheating Hours (section 3.1.3), each passively cooled space can be evaluated to determine the number of hours that the indoor temperature exceeds the limit of 26°C, in a process similar to that outlined in Section 3.1.3. The major difference is that this limit uses a consistent temperature limit across all weather files, whereas the *Overheating Limit* changes based on the location and future projection.

Report the number of hours each space will be above 26°C, highlighting which space(s) will experience the most hours above 26°C.

Peak Interior Temperature

Whereas the overheating limits noted above focus more on the duration of overheating, reporting the peak temperature experienced provides more information about the magnitude of overheating. Even if the period of overheating is short, if it is extreme in magnitude it can have significant impacts on the occupants.

Report the peak temperature and the associated time, date, and zone in which it occurs.

[1] Glen P. Kenny, Andreas D. Flouris, Abderrahmane Yagouti & Sean R. Notley (2019) Towards establishing evidence-based guidelines on maximum indoor temperatures during hot weather in temperate continental climates, Temperature, 6:1, 11-36.

To link to this article: https://doi.org/10.1080/23328940.2018.1456257

Optional Analyses

Depending on the project and the strategies being considered, the following overheating analyses can also be considered.

Sensitivity Analysis

Energy modelling is a powerful tool for comparing the impact of design alternatives. Consider answering the following questions if additional analysis is being performed.

- At what time of year do the outdoor temperature conditions require mechanical cooling to maintain comfort based on the metrics in the previous section, and how does this change with the future climate file?
- How do internal gain assumptions (lighting, equipment, schedules, etc.) impact overheating? For example, if twice the assumed plug load were installed, how does this impact overheating?
- What is the impact of key design features such as orientation, glazing WWR and SHGC, envelope performance, thermal mass of the building, operable windows and shading strategies on any of the limits described above?

Operable Windows

Operable windows are frequently used as means of passive cooling both in design and practice. As they can have a significant effect on overheating risk, it is important to simulate their operation using realistic assumptions, that are clearly communicated alongside the results. Some considerations are listed below:

- Operate windows using reasonable assumptions such as: when it's hotter inside than out (Tin>Tout), at a set limit (such as 26°C), and with a reasonable deadband (0.5 or 1°C).
- Don't operate windows when occupants would be unable or unlikely to operate windows (i.e. when they are away from the building or asleep).
- Consider other operational impacts such as safety features that limit window openings.

Partial Mechanical Cooling

When passive cooling strategies can no longer maintain adequate indoor temperature levels, some projects employ partial cooling to provide relief from hot outdoor air temperatures, without the energy consumption of full mechanical cooling. This is often implemented by adding cooling to a ventilation system that serves multiple spaces or into a shared space such as an amenity room within a residential building.

Since these, and other similar strategies, are not designed to prevent all instances of overheating, projects that employ them should be evaluated using the same overheating process and metrics as projects with no mechanical cooling.

Mechanical Cooling – Future Design Temperatures

Under a warming climate, even the most effective passive cooling strategies will likely be insufficient to ensure thermal comfort during the warmest months of the year. Recognizing this, designers will need to consider mechanical cooling systems. If the analysis is showing that passive cooling methods can meet overheating guidelines with CWEC 2016 data, but not with future climate data, the project team can plan for how mechanical cooling will be added in the future with minimal disruption and cost.

Future weather conditions can be used to estimate how mechanical cooling equipment sizes may need to increase as the climate warms. When making estimates for future cooling equipment sizes, appropriate future design data must be used. Peak temperatures from energy simulation weather files are usually less extreme than design conditions used for mechanical equipment sizing, since weather files are intended to represent a standard year rather than extreme conditions. While there is no published source of future design data, energy modellers can compare peak temperatures in the CWEC 2016 and future weather files and increase the current design temperatures by the same increment. This should be discussed and agreed upon with the entire design team using an integrated design process.

It is not recommended to size cooling equipment based on future climate estimates, as oversizing of any equipment can cause inefficiencies and maintenance issues in the near term. Instead, teams should consider how larger cooling equipment may replace current equipment once it reaches its end of life or how additional capacity can be added to existing systems. For example, a design team might oversize equipment pads, upsize mechanical chases, and/or increase terminal unit sizes to allow for future increased capacity, while sizing central plant equipment for current loads.

Cost Analysis

Nearly all of the strategies discussed in the previous section will have a financial impact to the project. For preliminary cost estimates, a new University of British Columbia (UBC) report *Designing Climate Resilient Multifamily Buildings* provides relative cost comparisons for several passive and mechanical cooling strategies for both new and existing multi-unit residential buildings.

Reporting

Once future climate simulations are complete, it is important to report weather inputs and overheating results clearly, as they may be unfamiliar to the owner and project team.

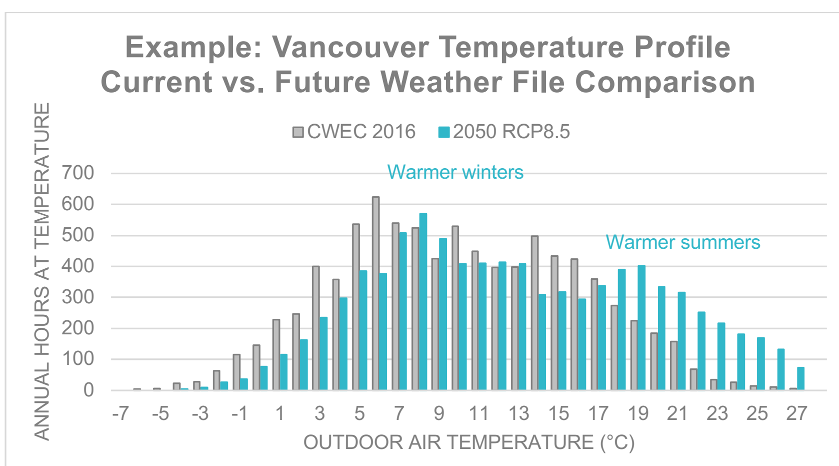
The examples provided in this section are based on a mixed-use residential building in Vancouver using the *CWEC* 2016 and 2050 *RCP*-8.5 future weather files.

Summarizing the Weather File

Begin by providing the following information for the future weather file:

- HDD and CDD, based on NECB 2015 Section 5.3.1.4
- Step Code Overheating Analysis
  - *Overheating Season* (which months need to be evaluated)
  - *Overheating Temperature Limits*
- Temperature Profile

Compare these key characteristics with the more commonly used *CWEC* 2016 file as shown in the table and graph on the next page.



Example: Weather File Comparison	**Current Weather File 2016 CWEC**		**Future Weather File 2050 RCP 8.5**	
Location	Vancouver, BC			
HDD18	2,843		2,137 (25% reduction)	
CDD13	516		1,132 (120% increase)	
Overheating Season	May – October (6 months)		April - October (7 months)	
[All temperatures in °C]	Ave Temp	Temp Limit	Ave Temp	Temp Limit
April	9.5	n/a	12.0	25.0
May	12.4	25.2	15.6	26.1
June	15.4	26.1	19.4	27.3
July	17.9	26.9	22.8	28.4
August	18.0	26.9	22.6	28.3
September	15.5	26.1	19.3	27.3
October	10.2	24.5	12.9	25.3

Overheating Analysis Results

Provide the results from the overheating analysis, focusing on the following metrics:

- Step Code Target *Overheating Hours* (200 or 20)
- Project *Overheating Hours*
  - Note that the overheating season may change between weather files
- Hours over 26°C
- Peak Interior Temperature

Compare the results for the *CWEC* 2016 and 2050 simulations, as well as any passive and mechanical strategies being modelled to address overheating, similar to the example below.

Example: Overheating Analysis	**Current Weather File 2016 CWEC**	**Future Weather File 2050 RCP 8.5**	**Strategy 1 (2050) Exterior Blinds**
Target Overheating Hours	200 (20 if project contains vulnerable occupancy)		
Overheating Hours	92	498	389
Hours over 26°C	874	2,769	2,151
Peak Temperature	31.5°C	32.7°C	32.0°C

Methodology Summary

This section summarizes the previous sections into a simple methodology for the energy modeller to follow.

Step 1: Get future weather files

- Obtain the 2050 RCP 8.5 weather file for the project location.

Step 2: Analyse future weather file

- Calculate key characteristics for the 2050s weather file:
  - The average monthly temperature to determine the *Overheating Season*.
  - The *Overheating Temperature Limits* for each month in the *Overheating Season*.
  - HDD and CDD

Step 3: Run model & perform overheating analysis

- Run the energy model with the future weather file.
- For both the CWEC 2016 and 2050s weather file:
  - Calculate the *Overheating Hours* for each space by comparing indoor temperatures with the *Overheating Temperature Limits* from Step 2.
  - Calculate the hours that space exceeds the indoor temperature limit of 26°C.
  - Extract the peak indoor temperature for each space.

Step 4 (Optional): Future-proof mechanical design

- Consider how mechanical designs can be integrated to meet future climate conditions, keeping in mind that oversized cooling equipment can cause inefficiency and maintenance issues.

Step 5: Report

- Report the key characteristics and temperature profiles from the CWEC 2016 and 2050s weather files determined in Step 2.
- Report the results determined in Step 3: peak *Overheating Hours*, any space(s) that exceed the 200-hour (or 20-hour) allowance, hours above 26°C and peak temperature per space. When peaks are reported, note the space in which they occur.
- Optional: If the *Overheating Hours* are exceeded with the future climate file, consider how the design might plan for added mechanical cooling in the future, such as oversized equipment pads, upsized mechanical chases, etc.

Additional Resources

ASHRAE: Standard 55: Thermal Environmental Conditions for Human Occupancy
https://www.ashrae.org/technical-resources/bookstore

BC Housing: Overheating and Air Quality Supplement to the Step Code Design Guide
https://www.bchousing.org/publications/BC-Energy-Step-Code-Guide-Supplemental.pdf

BC Housing: BC Energy Step Code Design Guide
https://www.bchousing.org/publications/BC-Energy-Step-Code-Design-Guide-Supplement.pdf

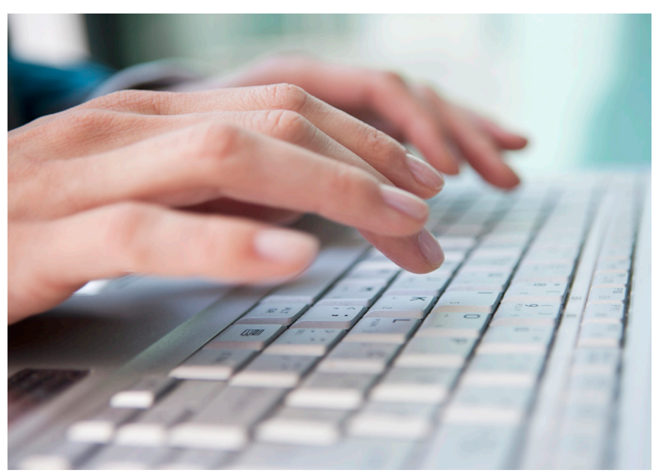
CIBSE: TM52 The Limits of Thermal Comfort: Avoiding Overheating in European Buildings
https://www.cibse.org/Knowledge/knowledge-items/detail?id=a0q20000008I7f5AAC

CIBSE: TM55 Design for Future Climate
https://www.cibse.org/knowledge/knowledge-items/detail?id=a0q20000008I76aAAC

City of Vancouver: Energy Modelling Guidelines (version 2)
https://vancouver.ca/files/cov/guidelines-energy-modelling.pdf

Pacific Climate Impacts Consortium: Future Weather Files
https://www.pacificclimate.org/data/weather-files

Designing Climate Resilient Multifamily Buildings
https://planning.ubc.ca/sites/default/files/2020-05/REPORT_UBC_Climate%20Resilient%20Multifamily%20Buildings.pdf



Acronyms

CDD: Cooling Degree Days

CWEC: Canadian Weather for Energy Calculations

DBT: Dry Bulb Temperature

HDD: Heating Degree Days

IPCC: Intergovernmental Panel on Climate Change

NECB: National Energy Code for Buildings 2015

RCPs: Representative Concentration Pathways

TEDI: Thermal Energy Demand Intensity

TEUI: Total Energy Use Intensity

Definitions

Overheating Hours: Represents the hours that a regularly occupied space's interior temperature exceeds the *Overheating Temperature Limit*.

Overheating Season: Months with an average outdoor temperature above 10°C (dry bulb) form the *Overheating Season* in a given weather file.

Overheating Temperature Limit [C]: Determined for each month in the *Overheating Season* and represents a peak allowable interior temperature. The calculation is based on Figure 5.3 from ASHRAE 55-2013 Section 5.4.2.2, with modifications from the *Energy Modelling Guidelines*.

About BC Housing Research Centre

BC Housing's Research Centre works in collaboration with housing sector partners to foster excellence in residential construction and find innovative solutions for affordable housing in British Columbia. Sharing leading-edge research, advances in building science, and new technologies encourages best practice. The Research Centre identifies and bridges research gaps to address homelessness, housing affordability, social housing challenges and the needs of distinct populations. Mobilizing knowledge and research expertise helps improve the quality of housing and leads to innovation and adoption of new construction techniques, Building Code changes, and enhanced education and training programs. Sign up to receive the latest news and updates from BC Housing's Research Centre at www.bchousing.org/subscribe.

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