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Research summary: Exploring the role of building codes in protecting occupants from overheating — a Canadian perspective

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1 Executive Summary

Extreme heat events are increasing, with residential buildings a primary locus of heat-related illness and mortality. Building codes are a key adaptation lever: while recent Canadian actions are important first steps, gaps remain in standardized evaluation, passive protection, flexibility, and use of future climate data. This document summarizes a research paper that synthesizes evidence from health sciences and building engineering on how building codes can protect occupants from overheating, using Canada as a case study. Below are some highlights from the paper's findings.

Standards and Tools: Standardized overheating evaluation methods, better guidance, and accessible compliance tools are needed to ensure consistent, reliable outcomes across jurisdictions and builder types.

Prioritize passive measures: Exterior shading, operable windows/natural ventilation, and low-SHGC glazing should form the foundation of overheating mitigation, reducing dependence on mechanical cooling and improving resilience during power outages.

Enable flexible compliance: Codes should offer both prescriptive and performance pathways to reflect varied project resources and risk tolerances, while allowing innovative passive/adaptive strategies alongside active cooling.

Integrate future climate data into design: National guidance is needed on using future weather projections (including extreme heat events and urban heat islands) for code compliance and design, and on planning buildings to accommodate future cooling capacity upgrades.

Link overheating metrics to health outcomes: Overheating criteria and thresholds in codes must be grounded in health evidence and protective of vulnerable populations to ensure universal thermal safety.

2 Introduction

With climate change bringing increased frequency and intensity of extreme heat events (EHEs), the risks to public health, infrastructure, and economies are increasing. These risks emphasize the need for robust adaptation strategies to protect populations from overheating, especially in residential buildings where most heat-related deaths occur.

Elderly people, people living alone, people with mental illness, and those in low-income households are disproportionately affected by the effects of EHEs. Several studies from around the world have reported increased emergency room and hospital visits during heatwaves. EHEs have been reported to kill hundreds, thousands, and in some cases tens of thousands of people. Climate projections point to worsening risks from EHEs for populations around the world. A recent study found that 30% of the world's population is already exposed to potentially fatal heat conditions for 20+ days annually. This value is expected to rise to 48 – 74% in the future. Another study found that annual heat-related mortality in older adults could increase by 370% worldwide by mid-century.

Additionally, heat-attributed healthcare costs are substantial. A study of the city of Perth (Western Australia) projects heat-attributed hospital healthcare costs of up to 190M AUD_{2012} between 2046 and 2052. Similarly, a report prepared for the province of Québec projects heat-related costs between 2015-2065 to be in the range of 250M-600M CAD_{2012}.

Recent data from the 2021 British Columbia (B.C.) heat dome has shown that in many cases the indoor temperatures of residential buildings exceed the outdoor ones in homes without air conditioning. Indeed, 98% of the heat related deaths during the B.C. heat wave were caused by heat injuries occurring indoors in a residence. While air conditioning offers protection, power outages, financial barriers, or misuse can undermine its effectiveness.

Building codes are emerging as a tool to ensure thermal resilience of new buildings. With this summary, we present an overview of work by Siu et al[1]. That article aims to synthesize the most relevant research on overheating resilience, from health sciences to building engineering, to inform residential building code evolution. It also offers a framework for integrating overheating protections in national codes, using the Canadian context as a case study. The paper advocates for evidence-based approaches that acknowledge both health risks and local needs associated with overheating

[1] C. Y. Siu *et al.*, "Exploring the role of building codes in protecting occupants from overheating—A Canadian perspective," *Energy Build.*, vol. 338, p. 115673, Jul. 2025, doi: 10.1016/j.enbuild.2025.115673.

concerns. While the paper pays special attention to the Canadian context, other jurisdictions are also discussed in more details.

3 Building Codes as a Tool for Climate Adaptation

3.1.1 Building Code Pathways

Early building codes relied on mandatory prescriptive requirements for materials and construction practices that were understood to provide acceptable levels of safety for occupants. These codes have continually evolved and nowadays include performance-based compliance pathways. These performance pathways are focused on outcomes and allow more flexibility for builders and designers.

3.1.2 Canadian Context

The 2020 edition of the National Building Code of Canada (NBC) only includes one overheating protection method. Part 9 (Housing and Small Buildings) requires buildings following the performance path to limit peak cooling load. However, it is not clear how peak cooling loads relate to various overheating metrics. Furthermore, most builders of small residential buildings follow the prescriptive path which offer no overheating protection.

In addition to the NBC, some jurisdictions have taken action to reduce risks of overheating in residential buildings. For example, the 2024 version of the British Columbia Building Code requires that at least one living space in a home be maintained below 26°C. In another example, the City of Toronto has a bylaw mandating that, if air conditioning is present in a building, it must be operated from June 2nd to September 14th to maintain indoor temperatures below 26°C.

3.1.3 NBC 2025

Motivated by the events of the 2021 B.C. heat dome, two additional strategies for addressing overheating are being considered in the 2025 edition of the NBC:

1. Limiting solar heat gain coefficient (SHGC) in windows.
2. Requiring air conditioning in houses under certain conditions (with the aim of maintaining indoor temperature of 26°C or below)

These are a good first step in reducing risk of overheating. It is worth noting that active cooling is currently not required in Canadian housing and therefore any requirement for active cooling will help reduce rates of overheating. However, there are some limitations with the proposed measures. These include:

- Builders of small residential buildings lack simple simulation tools to be able to show compliance in ways other than prescriptive.
- The proposed approach determines solar heat gain coefficient (SHGC) limits based on climate zone (defined by heating degree days). However, many parts of Canada face both cold winters and hot summers. In these regions, heating degree days-based limits may fall short in addressing the risk of excessive solar gains during summer months. Conversely, some areas experience mild winters and summers and may not require strict SHGC controls. To effectively reduce overheating risk, SHGC requirements should be driven primarily by summer climate conditions (e.g. cooling degree days).
- Several aspects of how overheating affects health remain uncertain, especially within the Canadian context. Strengthening this evidence base is crucial for developing effective policies and regulations.

4 Current Challenges and Gaps in Code Development

When further developing building code on managing overheating, there are several limitations and challenges that will need to be considered or addressed.

4.1.1 Technical Limitations

From a technical perspective, one of the greatest limitations at present is the lack of a standardized approach in overheating evaluation using building performance simulation. Defining a standardized approach is important to demonstrate compliance through the performance pathway, since different modelling assumptions made by different simulation modellers can greatly impact the outcome of the simulation analysis. Some key aspects that require standardization includes:

Assumptions on occupant behavior:

Occupants play an important role in adaptation, therefore a reasonable representation of occupant behavior is needed. For example, whether they open windows or not when it is hot inside, how long the windows stay open, and the number of windows they are able to operate may affect the level of indoor overheating.

Weather data selection:

Standardizing the type of weather data used in building performance simulations is crucial, as it should reflect the conditions a proposed building is expected to experience during its operating life. Although future projected weather data, covering both typical and extreme conditions, is becoming increasingly available, the use of historical typical year weather files remains standard practice in simulation. Further guidance and standardization on incorporating future weather data are needed to ensure buildings and their systems are designed for appropriate operating conditions. In particular, building code researchers and committees should determine whether residential buildings should be resilient to future typical or extreme thermal conditions, balancing design objectives such as housing affordability, energy use, and occupant safety.

Establishing a consistent overheating assessment framework, with standardized assumptions for occupant behavior, weather data, and future climate and urban heat island projections would enable comparable design evaluations across jurisdictions. This standardization would reduce confusion among practitioners and local officials, support both prescriptive and performance-based provisions, enable accessible compliance tools for small builders, and support periodic reassessment of in-place measures as extreme heat events become more frequent.

4.1.2 Administrative Limitations

Due to its simplicity, many small builders prefer compliance using the prescriptive pathway. However, this may limit the adoption of innovative building technologies (such as operable external shading), since the current prescriptive requirements are established based on proven solutions (limiting solar heat gains through windows, and air conditioning). A limitation that needs to be addressed in future versions of the building code is the inclusion of passive/adaptive strategies (such as operable windows and/or shading), to reduce the sole reliance on active cooling solutions, since they may not be effective in certain scenarios (such as power outages) or circumstances (seniors with lowered sensitivity to heat, or people experiencing energy poverty may not operate air conditioning even when needed).

4.1.3 Implementation Challenges

Without a well-defined standardized approach in overheating evaluation, there could be inconsistent adoption and enforcement across different jurisdictions, since local building code officials will need to review and determine whether the submitted evaluations are reasonable based on their own assumptions. This may also further discourage builders (especially small-scale builders) from choosing compliance using the performance pathway (which is more comprehensive), since they have limited capacity to model and evaluate overheating risks.

5 Next Steps for Beyond 2025

The following next steps for integrating overheating resilience into residential buildings are proposed. They are the result of a synthesis of current knowledge in health science, building engineering, and regulatory practice, and are tailored to Canada's NBC.

To ensure thermal safety during the lifespan of the building, future typical and extreme weather projections should be integrated into building codes. This will provide a better understanding of buildings' overheating performance in future warmer climates and under more frequently experienced extreme conditions and whether air conditioning is required. We propose that researchers and NBC committees investigate how to incorporate future climate data into codes for overheating compliance.

Using these future climate projections, residential buildings should be designed to accommodate future installation or expansion of cooling systems (e.g., space for larger ducts, electrical load capacity). This design foresight will reduce the need for costly retrofits as climates evolve. While current climate data may be sufficient for sizing the initial mechanical cooling systems, residential buildings will outlast these systems, making it important to plan for future requirements. NBC committees could start this work by investigating how this could fit in the framework of the current building code, and how it could be implemented.

Passive measures such as exterior shading, natural ventilation (operable windows), low-SHGC glazing should be the foundation of overheating mitigation. These strategies reduce reliance on mechanical cooling and help maintain habitable conditions even when mechanical cooling systems fail, such as during power outages. To start this work, research is needed that provides strong evidence to NBC committees of effective measures, and their impacts on energy efficiency.

Because older adults and people with health conditions are more vulnerable to the effects of extreme heat, buildings should be designed to protect the most at-risk occupants. Although occupant health and demographics are generally unknown at the design stage—and may change over time—universal design for thermal safety is essential. Health research is ongoing, and this should a core driver for future building code decisions.

Finally, builders across different regions and building types face varying constraints and capabilities. As such, building codes should offer flexible compliance pathways, including both prescriptive and performance-based options, to support diverse implementation needs.