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Delivering Climate Responsive Resilient Building Codes and Standards: A Canadian Perspective

Findings from the Global Resiliency Dialogue Survey of Building Code Stakeholders in Canada

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Executive Summary

This report provides a summary of findings from a targeted survey in December 2020 to map out and outline ongoing efforts and needs in the space of climate adaptation and resilience for buildings, with particular focus on building codes and standards. The survey results were collected through a callout to members of the Infrastructure and Buildings Working Group of Canada's Adaptation Platform.

Canada has been confronting unique challenges in climate change adaptation, due to the fact that the country is warming on average at twice the global rate, and that Canada is a vast country with a diverse landscape. All regions of Canada are experiencing climatic change differently, with some areas such as the northern territories disproportionally affected.

Canada has made significant strides in the space of resilience for building codes and standards, thanks to the Pan Canadian Framework on Clean Growth and Climate Change (PCF), which has enabled conversations and advancement of science and guidance.

The survey shows that numerous stakeholders are well engaged in this area, and generally ideas are well aligned. The survey highlights the progress made in generating the science and information needed to make buildings more resilient, such as climate data, guidance and guide documents, and various incentive programs to promote adaptation and resilience. The survey also outlines a number of areas that remain to be addressed, in order to better inform important policy discussions on the role of the codes in addressing climate resilience, establishing the performance targets and acceptable risk, and having the impact analysis data to justify changes to regulation.

The survey confirms that codes remain only part of the solution to achieving climate resilience in the built environment, and outlines their limitations. It highlights the need for a variety of policy instruments to address adaptation, and identifies a few examples. Quality and source of climate data information, as well as understanding of this information were highlighted as a key area for action. This would include a commitment to improving and updating climatic design data/maps in a changing climate and to educating both decision makers and the public. Involvement of decision makers at all levels of government, industry, and public in a coordinated matter was seen as critical, with the current codes system seen as providing a good forum to ensure all the main stakeholders are on board and aligned.

It is recognized that climate adaptation is not a standalone solution – climate mitigation actions to reduce greenhouse gases in the atmosphere must be implemented in parallel to slow global warming and reduce the degree of adaptation required in the longer-term. Adaptation can also contribute to achievement of other objectives, including for climate mitigation, public well-being and biodiversity. For example, use of natural infrastructure at the building scale can reduce extreme heat risk and contribute to management of stormwater, while also increasing energy efficiency, carbon sequestration and biodiversity. Resilient construction has been shown to contribute to reduction in lifetime GHG emissions.

Survey Structure

Survey questions are provided in Appendix A. A total of 13 responses were received, representing a wide range of stakeholders including: engineers, climate scientists, municipalities, home builders, standards organizations, and researchers. Additional input on this document was sought from members of the National Model Code Development System, other government departments and the insurance industry. It should be noted that this report presents the aggregate voice of survey respondents. The wording reflects these external perspectives in order to stay true to the diverse set of valuable insights shared.

Research Status

Introducing Climate Resilience into Building Codes

Canada has been highly involved in the area of climate change adaptation for the buildings sector, thanks to the policy coverage of the Pan Canadian Framework on Clean Growth and Climate Change (PCF)[1]. The PCF was developed by the Government of Canada with the Provinces and Territories (PTs) and through engagement with Canada's indigenous peoples. In addition to providing a plan to meet Canada's emissions reduction targets, the PCF aims to grow the economy while building resilience to a changing climate. To that end, the PCF includes commitments to invest in climate-resilient infrastructure, and develop climate-resilient codes and standards. Both regulators and industry have carried out key initiatives. While barriers do remain, the need to avoid the potential impacts is driving significant action.

Current and Recent Initiatives

Major initiatives targeting climate resilience through codes and standards began in 2016 and include the National Research Council of Canada's (NRC) Climate Resilient Buildings and Core Public Infrastructure (CRBCPI) Initiative, and the Standards Council of Canada's (SCC) Standards to Support Resilience in Infrastructure Program (SSRIP)[2].

In 2016, NRC undertook an ambitious 5-year initiative with funding from Infrastructure Canada (INFC). This CRBCPI initiative aimed to integrate resilience to climate change and extreme events into Canada's infrastructure and building codes and standards. The initiative has enabled NRC and its over 100 collaborators (including non-profit organizations, academics and industry associations) to be at the forefront of the discussion on buildings and resilience. CRBCPI has developed a new approach to climatic design data which incorporates the impact of climate change for potential use by the National Building Code (NBC), developed national guidance on wildland urban interface design and flood-resilient construction, updated standards referenced in the NBC including the CSA S478 standard on durability of buildings, and triggered policy discussions within the Canadian code system. With additional support from INFC, NRC is now embarking on a follow-on initiative, wherein NRC will seek to build upon the previous work, develop tools for asset owners and design professionals, and develop additional guidance in new areas including nature-based solutions to prevent overheating and urban flooding.

The Standards Council of Canada (SCC) has also been leading efforts in this space through its Standards to Support Resilience in Infrastructure Program (SSRIP). Through SSRIP, the SCC has developed 36 standardization strategies and tools including: the development of standardization guidance for weather data, climate information and climate change projections; the funding of new infrastructure standards and updating of existing standards to ensure that infrastructure projects across Canada are climate-ready; and investing in new technical standards targeted toward infrastructure adaptation and resilience in northern Canada. This effort is also planned to continue for another 5 years, with funding from Infrastructure Canada.

In addition to these two major federally funded initiatives, various other initiatives are contributing to the development of standards and guidance for climate adaptation of buildings.

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[1] Pan Canadian Framework on Clean Growth and Climate Change, 2016. https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework/climate-change-plan.html

[2] SCC, Standards in Action: Building a Climate Resilient Future, 2021. https://www.scc.ca/en/about-scc/publications/general/standards-action-building-a-climate-resilient-future

In the financial sector, awareness is increasing about both the economic impact of inaction and the potential to invest in resilient solutions. This has led to collaboration between the insurance sector and academia. The Intact Centre on Climate Adaptation, University of Waterloo, is an applied research centre funded by Intact Financial Corporation. The Intact Centre, works with 100s of subject matter experts to develop national guidance on climate adaptation, as well as working with homeowners, communities, governments and businesses to implement identified actions to reduce the impacts of extreme weather and climate change. Work is focused on reducing risks posed by flooding and erosion, wildfire and extreme heat, as well as the use of natural infrastructure and the engagement of capital markets to reduce climate risk. The Institute for Catastrophic Loss Reduction (ICLR), a not-for-profit centre established by Canada's property and casualty (P&C) insurance industry, carries out multi-disciplinary disaster prevention research and communication.

At the provincial and municipal levels, governments are also starting to take action on climate change adaptation. A few notable projects include: BC Housing's Mobilizing Building Adaptation and Resilience (MBAR)[3], the City of Toronto's Minimum Backup Power Guideline for MURBs[4], and the Federation of Canadian Municipalities (FCM)'s Municipalities for Climate Innovation Program[5]. Additional information on Canadian buildings-related initiatives is available through climatedata.ca's Buildings Module Context page[6].

Barriers

There are currently a number of barriers and specific knowledge gaps to overcome in introducing climate resilience into Canadian construction codes. Those barriers are related to a need for consistency, the need for guidance, the limitations of the National Model Codes, and the need to define a clear minimum level of performance.

First, consistent approaches are needed for assessing a full range of impacts (social, economic, environmental), including impacts on Canadian businesses (including construction trades, contractors, manufacturers, suppliers, and architects/designers) and on housing affordability. Consistency is also needed in addressing the vulnerability of specific buildings, and identifying any appropriate interventions.

Second, guidance is needed to support code change requests, guide and justify adaptation investment decisions, and account for the ability of contractors, builders and the supply chain to adapt to the changing regulation landscape. Significant training and education of trades and professions is needed to ensure codes are applied consistently in the way intended.

Third, Canada's National Model Codes remain limited in their ability to address climate change adaptation. Current limitations include:

- Current codes, the 2015 edition at time of publishing this white paper, do not treat durability as a central, primary design goal and address resistance to deterioration through individual material standards as a means to achieve the current objectives, which may require new objectives and a definition of service life.

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[3] BC Housing, Mobilizing Building Adaptation and Resilience (MBAR). https://www.bchousing.org/research-centre/library/residential-design-construction/MBAR

[4] City of Toronto, Minimum Backup Power Supply for MURBS, 2016. https://www.toronto.ca/wp-content/uploads/2017/11/91ca-Minimum-Backup-Power-Guideline-for-MURBs-October-2016.pdf

[5] Federation of Canadian Municipalities (FCM)'s Municipalities for Climate Innovation Program https://fcm.ca/en/programs/municipalities-climate-innovation-program/climate-change-adaptation

[6] Climatedata.ca, Building Module Context Page, https://climatedata.ca/buildings-module-context/

The National Model Codes (with the exception of the Fire Code) apply at time of construction, and therefore don't take into consideration changes that occur over the lifespan of the building;
- Codes currently apply primarily to new buildings and not existing ones. Alterations to Existing Buildings (AEB) is currently under consideration by the Canadian Commission on Building and Fire Codes (CCBFC).[7]
- Codes do not have the mandate to inform community and urban planning aspects, especially those essential to achieving resilience goals, including the use of natural infrastructure for reduction of urban heat islanding and flooding.
- Codes do not currently focus on overheating or extreme heat.
- While most of the Code's technical provisions apply to Indigenous or First Nations Communities, there are specific regional conditions, especially in northern and remote communities, which need to be addressed. To address this gap, targeted guidance for residential buildings is being developed in conjunction with the First Nations National Building Officers Association.

Even within their current scope and objectives, the National Model Codes have to address a number of competing priorities including structural safety, fire safety, energy efficiency, health, and accessibility. The current codes system has limited resources to address competing priorities and moves at deliberate pace, in order to properly assess the impacts of code changes and to consider the views of various stakeholders. The process is such that only a few systemic or broad changes can be addressed with every Code cycle. For resilience to be addressed within the codes system in the upcoming codes cycles (for 2025 or 2030), it will need to be identified as a high priority by the PTs, as well as by the Canadian Commission on Building and Fire Codes (CCBFC).

The updates to National Model Codes are published every 5 years, which are then adopted by the Federal, Provincial and Territorial government which all have different timelines for adoption. Recently, Canada's code system has been undergoing a transformation, with the recent Construction Codes Reconciliation Agreement[8]. In this agreement, Canada's PTs have committed to increasing harmonization between their codes and the National Model Codes, and to timely adoptions of Construction Codes. This is expected to promote a coordinated approach at all levels of government, which is a key component of addressing climate resilience.

Finally, establishing what should be considered the minimum level of performance requires clearer guidance. Providing such guidance creates two challenges. The first challenge is related to the need for clearer interpretation of the (1) uncertainty in climate models; and (2) degree of resilience for future risk mitigation. In many instances, historic data may be sufficient to drive change, particularly climate hazards already pose a significant threat. For example: historic fire hazard is sufficient to justify implementation of the NRC National Guide for wildland-urban-interface (WUI) fires in moderate and high hazard areas. The second challenge is to define the design objective in addressing changing climate loads, and whether the focus should be on the: (a) initial reliability, (b) minimum annual reliability, (c) average reliability over the service life, (d) reliability at the end of service life, or (e) minimum performance level throughout the structure's service life. In all cases, the reliability should not be lower than what is currently acceptable.

At the root of all those challenges is the question of defining acceptable risks, which differ in scale among the different climate loads. Those risks differ across the geographic scale (for example: extreme wind, flooding, wildfire, extreme heat) and may differ in time scale, as some may increase in the coming decades (temperature and extreme rainfall) while others decrease (snow loads in some regions).

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[7] Canadian Commission on Building and Fire Codes, Final Report – Alterations to Existing Buildings, 2020. Available : https://nrc.canada.ca/en/certifications-evaluations-standards/codes-canada/codes-canada-publications/final-report-alterations-existing-buildings

[8] Canadian Free Trade Agreement, Construction Codes Reconciliation Agreement Summary, 2019. https://www.cfta-alec.ca/wp-content/uploads/2021/08/Construction-Codes-RA-2019.pdf

Impacts

In the context of future natural hazards influenced by climate change, the update of codes may lead to positive outcomes in resilience, provided it is supported by the appropriate mix of policy instruments and incentives. A mix of policy instruments, including codes and standards, has the potential to decrease the impacts of future climate events and to prevent a number of negative consequences, as outlined in a recent impact analysis for the National Guide for Wildland-Urban Interface Fires[9]. These include:

1. Future property repair and reconstruction costs;
2. Additional living expenses and other costs of residential displacement;
3. Future losses associated with business interruption, both direct and indirect.
    a. Direct losses due to facility damage that leads to production loss, transportation delays, communication interruptions, etc.;
    b. Indirect losses due to value-chain interruptions, leading to revenue loss due to damage at other facilities.
4. Increased insurance costs and decreased tax revenues;
5. Costs for emergency response;
6. Loss of service to the community, especially for fire stations and hospitals;
7. Increased maintenance and repair costs;
8. Magnified negative public-health outcomes: deaths, nonfatal injuries and disability, and post-traumatic stress disorder;
9. Job losses and some job creation;
10. Historical and other cultural impacts.

Additional consequences highlighted by survey respondents include:

11. Increased reliance on local services (e.g. solid waste management);
12. Environmental impacts (e.g. soil, water, air contamination from building materials destroyed in wildland fires, the GHG impacts of having to dispose of and replace prematurely failed materials and systems);
13. Infrastructure lifespan (e.g., associated with better installation and maintenance of stormwater and wastewater infrastructure associated with reducing urban flood risk).

Drivers

In Canada, a major driver for action is financial loss avoidance for governments and the insurance industry. It is defined as the economic impacts of inaction in addressing natural hazards, just as extreme events increase in frequency and severity.

Economic impacts take centre stage in several chapters of the recently released National Issues report from Natural Resources Canada (including Sector Impacts and Adaptation; Costs and Benefits of Climate Change Impacts and Adaptation; and Climate Disclosure, Litigation and Finance): "Communities of all sizes across the country are experiencing the impacts of climate change on their infrastructure, health and well-being, cultures and economies. Local action to reduce climate-related risks is increasing, although limited capacity is challenging the ability of many communities to act."[10]

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[9] Institute for Catastrophic Loss Reduction and SPA Risk LLC, An impact analysis for the National Guide for Wildland-Urban Interface Fires, 2021. https://www.iclr.org/wp-content/uploads/2021/05/ICLR-SPA-Risk-Impact-Analysis-for-the-National-WUI-Fire-Guide-2021.pdf

[10] Natural Resources Canada. Canada in a Changing Climate: Issues Report: 2021. https://changingclimate.ca/national-issues/

The need for action is highlighted by recent costly extreme events including the 2013 Alberta floods, and the 2016 Fort McMurray fire, as well as major urban flooding events. Canada is currently seeing $1.8B in annual insured losses (2008-2018), significantly increased from a historic average of $0.4B/year (1983-2007).

Health and well-being of Canadian communities is also a key driver, as reflected in the chapters on Cities and Towns and Rural and Remote Communities of the National Issues report, and the recent report from the Canadian Institute for Climate Choices, "The Health Costs of Climate Change"[11]. In particular, the consequences of extreme heat events, such as the recent 2021 record breaking heat in Western Canada, or the 2018 extreme heat event in Quebec, are a significant health threat. National, Provincial, Territorial and Municipal Health organizations are leading the call to action to mitigate the impacts of urban heat islanding. [12] Specific guidance to reduce overheating in buildings is being produced by the building science community. [13,14]

The survey highlighted that ultimately, actions need to be evidence-based: informed by advances in climate-science and enhanced knowledge of future climate-loads and their impact on buildings. Additionally, de-risking of technology and guidance is needed to support these actions and ensure the selection of appropriate adaptation measures.

Data & Research

In general, there are two design approaches at the scale of the built environment to achieve climate resilience. The positions vary between:

- Simple but significant overdesigning/overbuilding to target resilience to extreme climate events;
- Continuously changing the construction regulations to adapt to adjusted climate loads.

The choice between those approaches depends on the specific problem at hand. The design approach will be informed by additional research, guidance/decision making tools, and discussions on how to translate the results of climate change modeling and apply them at the scale of the built environment, where design decisions are made. The approach also needs to consider the impacts of continually changing regulations on the ability of industry and regulators to adapt.

Climate Research

Research is needed to improve confidence and certainty in climate modelling, and to develop more robust estimates of codes and standards-relevant climatic data and weather events at the local scale. While some uncertainty in future climate conditions is impossible to address through climate research alone (for example, uncertainty due to socioeconomically-regulated future human emission pathways, or uncertainty due to fundamentally chaotic natural climate variability or 'noise'), there nonetheless remains significant scope for climate research advances to contribute. For example:

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[11] Canadian Institute for Climate Choices, The Health Costs of Climate Change, June 2021. https://climatechoices.ca/reports/the-health-costs-of-climate-change/

[12] Health Canada. Reducing Urban Heat Islands to Protect Health in Canada. https://ghhin.org/wp-content/uploads/Reducing-Urban-Heat-EN.pdf

[13] Aziz Laouadi, Climate resilience buildings: guideline for management of overheating risk in residential buildings, NRC, 2021. https://nrc-publications.canada.ca/eng/view/object/?id=9c60dc19-ca18-4f4c-871f-2633f002b95c

[14] Kesik, Ted et al.,Thermal Resilience Design Guide, University of Toronto, 2019. https://pbs.daniels.utoronto.ca/faculty/kesik_t/PBS/Kesik-Resources/Thermal-Resilience-Guide-v1.0-May2019.pdf

1) Higher spatial resolution in global and regional climate models is needed to yield more reliable local-scale weather and climate information. This will reduce the need for frequent regulatory changes as models are updated and data changes. This will also clarify the link between the changes simulated by climate models and those appearing at the local scale in precipitation and wind speed.
2) At the local scale, better model-based characterizations of complex extreme weather and climate events and their potential design consequences are needed, including of:
   a) Extreme ice storms
   b) Extreme hail
   c) Extreme rainfall and snowfall (in particular IDF curves)
   d) Extreme sea level rise-enhanced coastal flooding
   e) High wind events (especially for severe convective storms)
   f) Riverine flooding
   g) Extreme temperature conditions and related impacts (e.g. heat waves, wildfires, and infrastructure heat and air quality stress factors).
3) Improvements are required in the development of continental-scale domain modelling, as would be required for Canada-wide codes and standards-relevant climate data. National-scale data would include (for example) consistent, nationwide assessments of present and future extreme wind gust conditions, flood conditions, wildfire mapping, rainfall amounts, solar outputs and codes/standards-relevant climate thresholds (e.g. degree days);
4) In all cases, advances in climate science and modelling need to be supported by a strengthened body of consistently observed climate and weather data.

Building Science

Research is also needed to better understand the impacts of climate change on building performance including:

1) Advanced collaboration between experimental testing, field monitoring and building modelling to balance competing design priorities (including: environmental impact, cost, and health and safety), and to advise on optimum building design and operations for both new and retrofit constructions.
2) Advances in the development of material and system evaluation test methods to quantify the impacts of climate change on the future of building envelope construction.
3) Advances in hygrothermal testing, models and approaches to modelling to improve building system durability and component selection in a changing climate.
4) Advances in experimental testing and fire modelling to improve understanding and prediction of the impacts of wildfire, including the impact of firebrands/embers, radiation and direct flame, on the potential fire ignition of building components and systems.
5) Advances in experimental testing and modelling to study the impacts of nature-based solutions at the building level, including their ability to contribute to building design and operation, as well as their broader co-benefits.

Guidance

Clearer guidance is needed regarding the methods to translate the results of climate change modeling to impacts at the scale of the built environment. While there has been progress in that regard, more guidance is needed regarding the types of expected extreme events and their return period, as well as decision making tools such as risk mapping.

1) Support for choice of Representative Concentration Pathway (RCP) is needed, in order to determine the far-future level of performance of buildings and housing. Where organizations in Canada have issued well-posed guidance and tools on how RCP choice relates to risk and vulnerability, this guidance should be actively disseminated.

   In principle, risk and vulnerability assessments should be conducted to appropriately identify future climate scenarios. Since codes generally establish acceptable minimum requirements, it may be reasonable to consider lower-end emission scenarios (for example, the CSA Canadian Highway Bridge Design Code, for its part, is considered RCP6.0). However, in building design practice, the consensus appears to favour erring on the side of caution, and the use of RCP 8.5 is most common.

Environment and Climate Change Canada's (ECCC) has provided the following preliminary recommendations[15]:

a) For the 50-year horizon, it is recommended that a warming level associated with the RCP8.5 scenario be used since the incremental change in design data relative to those for RCP4.5 or RCP6.0 is not large for this time frame;
b) For the 75-year time horizon, selection of an appropriate scenario is more complicated because the difference between different scenarios near the end of the century can be quite large. In this case, a judgement must be made on which scenario to target. Consultation with experts to assess the probability of different forcing scenarios may be needed to arrive at a final decision.

2) There is a need for clearer guidance regarding the expected type of extreme event (extreme rainfall, snow loads, and wind loads at the local scale) and their return periods as a function of emission scenario and time frame. Those return periods are much longer than currently tabulated in Table C2 of the NBC. Studies noted that (1) very long period return level estimates may be subject to substantial statistical uncertainty and bias, and (2) the length of the observational record from which these estimates can be calculated accumulates slowly (i.e., in real time);
3) Regarding risk mapping:
   a) There is a specific need for better floodplain mapping, with consideration of future climate scenarios. Maps should ideally include detailed information on present and future flood-specific water depth and velocity to inform structural design of flood-resilient buildings. This could be informed by recent NRC research on floodplain mapping[16];
   b) There is also a need for readily-accessible maps that include multiple-hazards (e.g. flooding (riverine, coastal and urban), urban heat islanding, wildfire, extreme wind, permafrost) including future scenarios and information on vulnerability of populations. This type of information would make risk-assessment and resilient design more easily accessible.
4) Overall, guidance would be greatly improved via a central database of up to date historic and future climatic design data. Ideally, this database would be relied upon for reference by codes and standards. The data could be presented in a geographic context, and formatted in linked tables, directly referenced from a central source. Those tables need to include both updated historic data and future projected data, and include all locations and climate variables provided in "Division B – Appendix C Climatic and Seismic Information for Building Design in Canada". Currently, there is no consistent funding for updates to the historic climate data referenced in the Codes, with updates limited to one or two climate variables per 5-year cycle. Ongoing support for updates to both historic and future data will be essential to the successful uptake of a central database and to Canada's ability to design for future climate conditions.

   Currently, ECCC's Canadian Centre for Climate Services (CCCS) currently offers a central portal for climate change data and adaptation. They have been conducting a survey of building industry professionals to determine the format of future climate data on the ClimateData.ca web portal, and discussing with NRC the best way to make the design data developed under CRBCPI accessible for use by codes and standards. Agencies such as the CCCS may be best-placed to host targeted datasets intended for use in close, regulated, coordination with published codes and standards.

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[15] ECCC, Climate-Resilient Buildings and Core Public Infrastructure: an assessment of the impact of climate change on climatic design data in Canada, 2020. https://climate-scenarios.canada.ca/?page=buildings-report-overview

[16] Khaliq, Naveed, An Inventory of Methods for Estimating Climate Change-Informed Design Water Levels for Floodplain Mapping, NRC, 2019. https://nrc-publications.canada.ca/eng/view/ft/?id=d72127b3-f93b-48fb-ad82-8eb09992b6b8.

Design approaches

Discussions continue regarding how to approach the risk from extreme weather events in the design of buildings in a non-stationary climate, as it will inform the decision regarding which design approach to take. Two potential approaches include:

1) Uniform-risk based design approaches that strive to achieve uniform and acceptable risk of failure of buildings and infrastructure across Canada. This approach would require overcoming challenges with extrapolation and uncertainty in climate models.
   a) Risk based approaches to design could be required in core public infrastructure and public buildings;
   b) Some performance-based design requirements could include climate data from datasets that include the most up to date climate information;
2) A more flexible approach could recognize the difficulty in quantifying all relevant sources of uncertainty in climate change projections. It would lead to estimating sources of uncertainty such as natural unforced climate variability. It would consider that extreme value distributions do not need to be probed as deeply in the tails (increasing confidence that it might be possible to capture climate change induced changes); and would rely on expert judgement from both engineers and climate scientists to adjust load factors as necessary. However, design that is left to judgement without clear guidance could result in different interpretations and could lead to enforcement issues.

Going forward, it is likely that a hybrid approach would be followed, a mixture of both approaches. A clearer understanding of risk would go a long way towards providing support for design decisions to balance cost, energy performance, greenhouse gas emissions and resilience. Those issues are approached through tools such as life cycle environmental analysis (LCA) and life cycle cost analysis (LCCA). Those, and similar cost/benefit tools and analysis, still need to provide a full account of:

1) Costs and benefits in terms of social capital (including direct losses, but also all downstream implications for society including displacement, employment, etc.) to advise discussions and justify investment in resilience;
2) Co-benefits of adaptation measures to health, energy, environment, economy to support their adoption.

Pilot studies can help to demonstrate the benefit of implementing resilient design from the start. At present, a step-wise adaptation approach is worth considering, to enhance the ability to modify a building design with ease to adjust to new climate loads. This approach has the potential to lessen the investment up front and to spread adaptation costs throughout the design life of the building, and only as required.

Policy Implementation

Federal Policy Goals

The Pan Canadian Framework on Clean Growth and Climate Change (PCF) is an overarching document that provides guidance in this space. It sets the stage for exploring the role of the many complementary tools to be considered in advancing policy actions that help achieve resilience to climate change.

Overall, regulations may not be well suited to issues that may cause frequent foreseeable changes. To that end, discussions are underway to help define resilience to climate change in the context of the built environment, and to determine how best to update codes. Discussions also take into account the fact that regulatory instruments, such as codes, are one of many tools in the toolbox. This is especially the case since the Code only focuses on new construction, and the issue of alterations to existing buildings remains to be fully fleshed out. Codes are also often the most expensive tool, which makes it important to consider all tools prior to codifying changes.

Policy Discussions for National Codes

Policy discussions by the participants and stakeholders of the national codes system are needed related to (1) the durability of structures and assemblies, and the (2) scope of the National Building Code.

1) The current standard on durability (CSA S478) is referenced in the appendix of the building code. Discussions are needed to determine whether service-life should be set through the code, and if so, whether a new objective or an expansion of scope is required. It also remains unclear how liability or maintenance factors in, as in the case when a product fails before the specified service life;
2) Extreme events caused by climatic change raise questions as to the scope of the code:
   a) Localized extreme events, such as flooding, raise questions of the role of the codes with regards to property protection. One National Building Code objective (OP2) currently covers protection from damage of loss of use due to structural failure or lack of structural serviceability, which could be argued to already include flood loads. The current Code also addresses the principle of property protection to a limited extent in objectives (OP3, OP4) relating to property protection of adjacent property from Fire and Structural damage.
   b) Regional-scale events raise issues related to the scope of the code beyond the building envelope. In the case of wildfire, buildings are only one element of a “resilience chain” that extends beyond the building to the landscaping and community design and maintenance. While wildfire resilience measures at the building alone were shown to have a very good return on investment, relying on long-term vegetation management (which often requires neighbourhood level cooperation) rather than fire-resistive materials cuts costs by 3 times and increases the benefit cost ratio proportionately.[17] In the case of overheating, while building design has a significant impact on indoor temperatures and can also potentially contribute to cooling through green roofs and other measures, community design remains essential to reducing the urban heat island effect.

The discussions may not necessarily lead to an expansion of the Code. There are, in many cases, other policy instruments that may prove more effective than regulation, or are needed in addition to achieve effective regulation.

1) Support programs, such as voluntary programs for builders’ commissioning of buildings and systems, or the facilitation of decision making at the community level. The insurance industry could help in this respect, by providing incentives for compliance and promoting climate-resilient construction. However, incentives from insurers are seen as unlikely to drive significant change, with refusal of coverage having a potentially higher impact (see 2.);
2) Zoning evolution over time to move buildings out of high-risk areas such as the elimination of building in floodplains, or the retention/utilization of green infrastructure. The insurance industry is forcing this by refusing coverage to multi-event areas, increasingly segmenting covering to allow sections of coverage to be sub-limited or removed for high risk individuals (e.g. water damage, flood, WUI fire), or capping financial assistance to a lifetime limit (e.g. the Quebec government capping lifetime flooding assistance at $100K[18]);
3) Capacity building initiatives such as education for building sector professions and trades. They could be supported by case studies that demonstrate return on investment and affordable ways of achieving resilience to climate change and extreme events;
4) Guidelines for resilient construction, supported by the certification of resilient buildings, systems, or materials;
5) Complementary regulations, such as development and update of supporting Standards and Guidelines, or master specifications for construction projects incorporating resilience requirements.

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[17] Porter, Keith et al. An Impact Analysis for the National Guide for Wildland Urban Interface Fires, Institute for Catastrophic Loss Reduction, 2021. ICLR-SPA-Risk-Impact-Analysis-for-the-National-WUI-Fire-Guide-2021.pdf

[18] Ministère de la Sécurité publique, Gouvernement du Québec, Homeowners and Tenants: General Indemnity and Financial Assistance Program Regarding Actual or Imminent Disasters – Flooding, 2021. Simplified Guide - Homeowners and Tenants - General Indemnity and Financial Assistance Program (quebec.ca)

The approached outlined the recent study by ICLR/SCC[17] concerning wildland urban interface (WUI) fire is an example of standard approaches to data collection post-disaster to identify vulnerabilities of buildings that can be addressed through code changes.

6) Technological solutions, such as stormwater retention technologies and natural infrastructure solutions to mitigate urban flooding;
7) Tools/methods to support a more fulsome assessment of costs and benefits, and promote a culture of risk mitigation;
8) Small-scale, simple measures such as on-site, low-risk stormwater retention, basement flood protection or diligent post-installation testing of new materials.
9) Public education campaigns supporting practical actions and behavioural changes to adapt to climate risks.

These policy discussions will ultimately lead to determining which changes should be addressed in the Codes, and which other policy instruments are necessary or better suited to achieving climate resilience goals. Discussions will also help ascertain whether any additional Codes objectives are needed; the Code currently has five objectives of safety, health, accessibility, fire and structural protection of buildings, and environment. Ultimately, a national level view and coordination of policy instruments including codes is needed to achieve resilience goals, to discuss and weigh options, and provide trusted solutions.

Alterations to Existing Buildings

In Canada, addressing existing building retrofit is essential. While by definition the National Model Codes do apply to the *alteration, reconstruction, demolition, removal and relocation and occupancy of all existing buildings,* in practice, the Codes don't have specific provisions about alterations. This is why the Codes system has now begun a focused effort on alteration to existing buildings.[7] Regarding existing buildings, the Code cannot be the only tool. When/if the code begins addressing alterations to existing buildings, the necessary voluntary action would require incentive programs, climate vulnerability assessments, as well as training/capacity building programs.

Incentive Programs

Under the current system, incentives for adaptation are not well aligned. While societal benefits are clear, the often high costs of alterations to existing buildings for climate resilience are often fully borne by the owner, while the benefits may be seen by future owners or society in general. Due to the cost of repairs and retrofits, adaptation measures generally have a poor uptake.

To ensure success, retrofits must be supported by incentive programs for voluntary action (by grants, tax credits, insurance programs) to help recover initial investments in risk mitigation over the long term. Incentive programs would mitigate these costs, and also help meet the needs of vulnerable populations, who may disproportionally depend on such "legacy" systems.

To increase uptake, adaptation retrofit programs could consider coupling with energy retrofit programs such as the Federation of Canadian Municipalities' Community Efficiency Financing program[19], Canada's Greener

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[19] Federation of Community Municipalities (FCM), Community Efficiency Financing. https://fcm.ca/en/programs/green-municipal-fund/community-efficiency-financing

Homes Grant[20], or the Canadian Infrastructure Bank investments in public buildings under Green Infrastructure[21].

Currently, one of the most widely applied type of program for retrofit for disaster risk across Canada is basement flood protection/retrofit programs, typically offered by municipal governments. At last count, there were ~40 such programs. They provide typically $1000-5000 subsidies for households that have experienced or are at risk of basement flooding, or that contribute to basement flood risk through private-side contributions of inflow-infiltration. In all but a very small number of cases, uptake of these programs is extremely low - often under 10%. Similar programs offered by insurance companies (where households are offered retrofit funding following a flood claim) also experience low uptake. This is potentially due to the limited understanding by the public of low probability, high consequence events.

This results in homebuyers with limited interest in paying more for these measures. Additionally, while insurance companies may provide some incentives, home builder associations tend to oppose new interventions that drive up the cost of buildings without a proven cost-benefit to justify the change. Supporting the home building industry in the development of strategies to market resilience is needed.

There are examples where access to higher levels of funding or other supports for resilient assets can also drive adoption. Germany's "1000 roofs" demonstrates the efficacy of funding support for resilient assets. The program to introduce solar collectors by paying the capital cost of the units. It was a huge yearly investment over 40 years, starting in the 80s. It created both industry capacity (manufacture, installation, repair, maintenance, architectural integration, etc.), and acceptance and awareness by homeowners who are now increasingly choosing a mainstream solution. On the other hand, while Canada has many existing, comprehensive retrofit programs for homeowners, they have received very limited uptake. Because of limited adoption, they may not successfully serve to address the needs of Canadians with respect to resilience.

One potential solution to drive uptake is to make project funding contingent on meeting minimum resilience requirements. Finance or insurance schemes that provide incentives could also play a significant role. At a minimum, upgrades could be targeted at publicly owned buildings in vulnerable areas, such as schools, community centres, healthcare hubs. These locations would act as emergency shelter during extreme weather events. Large scale community adaptation strategies should also be considered (floodplain, stormwater/sea-level rise management).

Capacity Building

Capacity building is needed to increase understanding of disaster risk and the potential impact of future climate changes. This information ideally needs to come from a reliable and trusted source, such as insurance agents, local government, contractors, and social networks (e.g. neighbours, family). To that effect, education programs are needed to help building and home owners understand both their climate risk and potential actions to take. Bringing in trades to the resilience discussion (including potentially orienting economic incentives directly to them rather than homeowners), and better understanding of household behaviour (e.g., through behavioural economics) are required for these solutions.

Capacity building may be supported by behavioural research, to provide insight into measures which will trigger uptake. Capacity building could also proceed in conjunction with incentive programs. Programs could also be put in place for installers/contractors to promote resilient practices during key windows of opportunity

[20] NRCan, Canada Greener Homes Grant. https://www.nrcan.gc.ca/energy-efficiency/homes/canada-greener-homes-grant/23441

[21] Canadian Infrastructure Bank, Sector: Green Infrastructure. https://cib-bic.ca/en/partner-with-us/growth-plan/green-infrastructure/

(basement flood protection when basements are finished, high wind/hail resistant roof covers when roofs are re-shingled).

Capacity building is also critical for decision-makers to improve the ability for decision-making amid deep uncertainty. A wider understanding of the latest risk assessment methodologies and adaptation approaches would enhance the ability to utilize data which may not be in a format that we need to make cost-effective decisions. In particular, outreach and education of Codes committee members in regards to climate science and the role of buildings in mitigating risk from climate change and extreme events is essential, as they will be tasked with the review of resilience-oriented code change requests.

Communication

Canada has many innovative examples for communicating with and engaging stakeholder, providing and exchanging information, as well as identifying and highlighting best practices. The current codes system itself provides a solid example of a platform designed for communication and engagement, to balance inputs from various stakeholders and reach consensus.

Stakeholder engagement

Ultimately, engaging stakeholders in the development of guidance and regulation is critical to its adoption. Many stakeholders are already engaged, due to the efforts over the past 5 years. To that effect, the current National Model Codes process allows for engagement of all affected (traditional) stakeholders: manufacturers, builders, architects, engineers, general interest, academia, and provincial and territorial officials. There is a need to involve non-typical stakeholders such as municipal planners, insurers, financial institutions, senior government officials, Indigenous representatives, ecologists, landscape artists, health, and public housing officials. Survey respondents were clear that they consider EVERYONE to be important to the effort – all levels of government, insurance industry, government agencies, planning professionals, municipal asset managers, hydrologists, developers, banks, engineers, authorities having jurisdiction (regulators), committees of the NBC.

A stakeholder analysis of relevant codes committees could potentially be undertaken, with the view of incorporating additional stakeholders into the codes process. This would guide efforts to increase engagement of underrepresented stakeholders in the codes system including communities, users and builders, to inform the practical aspects of implementation and to build capacity to support adaptation efforts and regulation. It's also important that these non-traditional stakeholders develop a better understanding of the codes processes, what is required for an effective proposed change, and that they can become involved in standing committee meetings as observers.

Those efforts would be supported by a coordinated approach to ensure the best possible outcomes.

Information and format

There are many instances of local authorities developing their own approaches to account for potential impacts of climate change, resulting in a disjointed/mixed approach. In order to assess the full range of impacts (social, financial, environmental, etc.), consistent approaches and clear guidance are needed. They would depend on a clear policy direction to prioritize, integrate and enable climate resilience in decision making and investment, and to understand how resilience fits with the bigger picture: sustainability, accessibility, aging population, fire safety, structural safety, etc.

1) Radical collaboration is needed to change the business case – including insurance and finance models. Innovations could include disclosure of climate risks at point of sale, and the implementation of lifecycle assessment (including climate risks) at the design and procurement stage;
2) Guidance is needed on "navigating a sea of information" on climate data, and to support code change requests, and to guide and justify adaptation investment decisions. Federal government efforts such as the

Canadian Centre for Climate Services (CCCS) and climatedata.ca provide trusted and central platforms for climate information.

This can be supported by de-risked, evidence-based, code-ready material with a solid justification (impact analysis) that can simplify the work of codes and standards committees. This type of material can be prepared outside of the formal codes system, under initiatives such as the CRBCPI, with the oversight of balanced committees of stakeholders, representing diverse backgrounds and regions. Guidance can be further de-risked through pilot projects. For homes in particular, homebuilders should be engaged in developing and demonstrating resilience solutions that are effective (e.g., easy to install, affordable, etc.), in order to ensure comfort and market buy-in.

Best practices

Canada has many examples of developing significant work through stakeholder engagement which extend beyond the conventional knowledge transfer activities of workshops, formal training, and webinars. Notable examples from the CRBCPI Initiative include:

1) The development of the National guide for wildland-urban-interface fires: Guides were developed with a technical committee consisting of academics, firefighters, communities, home builders, municipalities, industry. These guides are expected to proceed to standardization in the next few years, for potential reference in regulation.
2) The development of future looking climatic design data for use in the design of infrastructure and buildings. This data was developed through engagement of climate scientists, engineers and codes committee members and is now proposed for consideration in the 2025 NBC, and planned for use in the 2025 Canadian Highway Bridge Design Code.
3) CSA A123.26, *Performance Requirements for Climate Resilience of Low Slope Membrane Roofing Systems*– wherein NRC worked closely with a consortium of major North American roofing manufacturers to identify and address their needs.

Notable examples from SCC's Standards to Support Resilience in Infrastructure Program include:

1) The Northern Advisory Committee (NAC): This committee of representatives from the Northwest Territories, Nunavut, Yukon, and Nunavik, along with Crown-Indigenous Relations and Northern Affairs Canada, prioritizes project selection for standards for Canada's North. SCC works with this committee, and its members undertake their own engagement, to ensure that the unique issues facing Northern infrastructure and buildings are addressed through standards, such a permafrost thaw. The NAC has championed the standards produced, identifying opportunities for training, uptake, and integration of standards into policy and other requirements. (reference: https://www.scc.ca/en/nisi)
2) Roadmap on flood mapping standardization: SCC, Natural Resources Canada, and Public Safety Canada are working to standardize flood mapping across Canada, and brought together approximately 70 participants representing provincial and territorial governments, municipalities, federal agencies, Indigenous communities, Conservation Authorities, Standards Development Organizations, industry and not-for-profit organizations to produce a practical roadmap. (reference https://www.scc.ca/en/news-events/news/2020/national-workshop-outlines-path-toward-flood-mapping-standards-canada)

Other successful programs include:

1) On the more advanced energy efficiency (climate mitigation) side, there are many good models for engagement of the building industry on innovative practices. They include: Local Energy Efficiency

Partnerships (LEEP) Program[22], labelling programs (ENERGY STAR Canada[23], R2000[24], LEED[25]), and energy retrofit programs which have set the stage for the adoption of Energy Efficient Codes (Tiered energy codes towards Net Zero Energy Ready performance are set to be released in the first quarter of 2022). Best practices and lessons learnt from these programs could be applied to the climate adaptation effort;

2) ICLR has been working with insurers to develop a rebuild better program to incorporate resilience into full and partial losses following climate events;
3) The Intact Centre on Climate Adaptation has developed training courses on home flood protection for a range of professionals[26], including home inspectors, mortgage professionals, insurance brokers and municipal staff, as well as a 14-week college-level “Home Flood Risk Assessment Training” training course for home inspectors.[27]
4) A few important studies have also been undertaken to quantify the impacts of climate change adaptation in order to inform policy direction including: an impact analysis for the National Guide for Wildland Urban Interface Fires[9], and estimating the benefits of CRBCPI[28].

Where to Apply/not Apply Regulations

Current Codes apply primarily to new construction. The case of regulating existing buildings within the National Model Codes is currently being made. The question then becomes which aspects of adaptation and resilience need regulation and to which built environment elements should these regulations apply.

In Canada, the evolution of regulation would depend on a consensus position on what should be regulated by all provincial and territorial jurisdictions, and should ideally be guided by a thorough analysis of the role of regulation within a suite of policy instruments. The regulatory approach may be gradual: first applied for core public infrastructure, and then scaled-up as appropriate.

1) Regulation could be considered for core public infrastructure and public buildings as a starting point, to model the way and to mainstream approaches to resilience. At this level, regulation could be used to establish risk-based or performance-based requirements to achieve resilience.
2) As regulations are scaled-up, regulators should be mindful that risk-based approaches may not work well for the construction of Part 9 buildings (housing and small buildings) as they typically do not include a team of design professionals. A prescriptive design approach would likely be preferable or potentially necessary for success.

While the way in which resilience applies to a specific project does not necessarily need to be regulated, goals and requirements still need to be specified. Resilience goals would be incorporated into regulation where

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[22] Local Energy Efficiency Partnerships (LEEP). https://www.nrcan.gc.ca/energy-efficiency/homes/local-energy-efficiency-partnerships-leep/17338

[23] ENERGY STAR Canada. https://www.nrcan.gc.ca/energy-efficiency/energy-star-canada/18953

[24] R2000. https://www.nrcan.gc.ca/energy-efficiency/homes/buying-energy-efficient-new-home/r-2000-environmentally-friendly-homes/20575

[25] Canada Green Building Council – LEED. https://www.cagbc.org/CAGBC/Programs/LEED/LEEDv4/leed_v4.1_apc_updates.aspx?WebsiteKey=7e592978-5927-4a4c-9794-de62b4606664

[26] Intact Centre on Climate Adaptation, Flood Protection Training. https://www.intactcentreclimateadaptation.ca/programs/home_flood_protect/training/

[27] Fleming College, Home Flood Risk Assessment Training. https://flemingcollege.ca/continuing-education/courses/home-flood-risk-assessment-training

[28] Porter and Scawthorn, Estimating the benefits of Climate Resilient Buildings and Core Public Infrastructure (CRBCPI), ICLR and SPA RISK LLC, 2020. https://www.iclr.org/wp-content/uploads/2020/03/SPA-Climate-resiliency-book.pdf

regulation sets levels of service / performance for the asset. Requirements for resilient design would reflect the new reality of a changing climate, and balance additional design goals like energy efficiency, health and safety.

Goals and requirements for climate resilience would need to be geographically or situationally dependent. For example: fire resilience codes should be regulated in the wildland-urban interface; minimum flood resilience codes should be regulated liberally in riverine/creek floodplains, adjusted for climate change intensification (e.g. 100 year flood plus 2100 intensification), including during substantial building retrofits; maximum permitted indoor air temperatures may require regulation in multi-residence buildings.

Experience to date in Canada suggests that regulation will be a very important part of increasing the resilience of buildings. However, regulation has limitations:

1) First, regulation can be slow. While it was noted by some survey respondents that removing barriers so that Local Governments have the power to enact their own requirements can be effective, this goes against the Construction Codes Reconciliation Agreement[8], wherein Federal, Provincial and Territorial governments are actively working to increase consistency of regulation across the country. There are other effective tools at the disposal of municipalities, such as zoning and retrofit programs, which can be used to drive adaptation.
2) Second, there is a concern with premature standardization and regulation. It might lock onto apparently rational approaches and solutions in such a way that subsequent innovation and improvement of methods and practices is stifled. A detailed analysis could be conducted to determine the desired outcome and the cost, risk, administrative burden, legal impact and societal consequences from regulation. This should be compared with any positive outcomes that could be achieved through voluntary policy instruments (education, training, incentives, and gov't programs).
3) Third, regulation is typically the policy instrument with the highest associated cost - due to compliance cost for businesses and administrative costs for governments (including building permits and inspections). Cost-benefit of regulation needs to be carefully considered.

Regulation may be necessary to reach so-called "code min/max" regions in Canada, where practice that exceeds minimum code requirements cannot be mandated or required by lower levels of government, and almost all buildings are constructed to code minimums. Other policy instruments may reach much further with the same initial investment and ongoing cost, especially in cases where there is a need for a quick turnaround and one-off changes in direction/knowledge, practices. Internationally, there are successful examples and better ways of regulatory schemes, using behavioural insight research to find out which measure or concept triggers the best 'compliance' rate and buy-in.

Insurers may also need regulation in order to apply resilience incentives. High competition in the industry (there are hundreds of P&C insurance companies) limits the ability of individual insurers to engage in resilience investments for their customers (investing in resilience risks driving up premiums for their customers, causing customers to switch to a different insurer). Regulation would help to provide a level playing field – and incorporate resilience by default.

Implementation in Codes

The extent to which regulations are the most effective instruments to achieve resilience goals should be considered and eventually answered by the building code policy authorities. These are classic policy analysis questions that can help determine, for any specific goal, the cases where regulations should be considered, where they should not, and what are the appropriate alternatives that may achieve the same goal.

Further policy questions concern the threshold for code changes, and the frequency of climate data updates. The consensus appears to be for updates at least every 5 years, to provide for additional observed data, and to provide industry time to prepare for and adapt to changes in regulation.

Open questions remain related to whether and how to address uncertainty about the future climate, and how to address the non-stationarity of climate in codes. A challenge also remains on how to balance cultural, heritage, and environmental issues in codes or otherwise. This affects how to define the ideal design service life of building types, whether it is independent from climate change considerations, and whether/how occupancy type/building importance should factor into design considerations.

Thresholds for Code Changes

It should be noted that the Code Cycle itself determines the speed at which action can be taken and changes can be made. While strides are being made to decrease the time to adoption of the National Model Codes, major changes concerning resilience are expected to be incorporated into the codes in 2025 or 2030, and adoption will lag code publication. Under the Construction Codes Reconciliation Agreement, jurisdictions have committed to adopting or adapting the National Model Codes into regulation within 18 months of publication as of the 2025 codes.

Failing to keep up with changing climate loads could have significant safety and economic effects. For example, above a critical threshold, a 25 percent increase in peak wind gust strength can generate a 650 percent increase in building claims. It is for this reason that there are calls for all codes to be updated for climate change, as quickly as possible, as new infrastructure is being built every day with lifetimes which will spanned into the 2050/2080/2100 time horizon, in which climate impacts are significant. While many survey responses favoured rapid action to mitigation impacts from climate change and extreme events, it was noted by some that care needs to be taken in the approach, as fast-tracked regulatory schemes bear the risk of unintended (safety and economic) consequences.

Much depends on a definition for acceptable minimum levels of reliability. This will allow us to assign thresholds, which can be determined through a joint assessment of climate trends and cost-benefits. With regular reliability audits we could determine whether a threshold is being breached, and whether there are changes in the frequency with which that minimum criterion is being attained.

Frequency of Climate Data Updates

Referencing future climate data in codes and standards is seen as a major move forward, compared to the use of historic data, and often well out of date historic data, in the design of buildings and infrastructure.

Survey responders suggested that climate data updates should occur every 5 years, to provide for additional observed data, advancements in climate modeling, and to be in line with the 5-year code cycle.

Another option which was suggested, is to tie climate data updates to updates of the key global climate model datasets within the Couple Model Intercomparison Project (CMIP) and the related UN IPCC Assessment report, likely every 6-7 years. These include both updates to observed data, and updates to projected future climate conditions.

While some form of automatic update was seen as potentially desirable, concerns were expressed about having climate data updated too frequently – as this could result in the need for re-tooling and professional re-training, cause challenges for industry to adjust/adapt, and have the potential to create negative effects for building and homeowners as their assets could depreciate with each climate update. Updates more frequent than or out of line with the codes cycle could also lead to legislative challenges, as archived design data, from previous versions of the codes, are often referenced in legal cases. Currently Provinces and Territories expect the data to be stable for at least one code cycle.

Additionally, for the data to be updated every codes cycle, an in depth impact analysis will need to be undertaken to understand the impact of the proposed changes – which will also require substantial time and resources.

The idea of setting a once-and-for-all performance target (e.g. a 1 in 500 or 1 in 1000 year return period) was also explored by some survey-respondents – to minimize the frequency of change and the resulting impacts described above.

Whether and How to Address Uncertainty about the Future Climate

Climate loads in codes are dealt with by probabilistic modelling of load and resistance. To address uncertainty in future climate states and climate modelling, they should focus on methods that measure what is and project what is reasonable.

- In limited cases (where data is available) uncertainty can be captured in probabilistic / reliability frameworks such as done for the Canadian building and bridge codes. Those methods address uncertainty and communicate it using random variables or stochastic processes, with explicit values of the mean values, extreme design values and coefficient of variation;
- In cases where relevant data is available from climate models, information from future climate projections could be integrated into code data tables or associated online data portals to inform future design and future-proofing. This could also be used to inform potential requirements for additional or adaptable building infrastructure to more easily accommodate changes in building systems.

How Non-Stationary Climate Can be Addressed in Codes

Non-stationarity (such as the one linked to climate change) can be captured in design codes and standards by considering it probabilistically.

Already, initial efforts have been undertaken to consider climate non-stationarity in the development of climate change provisions for the National Building Code and Canadian Highway Bridge Design Code. Additionally, the recently published American Society of Civil Engineers' Manual of Practice 140 on Climate Resilient Design includes guidance for the implementation of uncertainty and non-stationarity.

The focus should remain on supporting the Code's objective to keep the occupants safe and protect the structure well enough in order to ensure that it remains safe and serviceable in cases when the service environment changes (exterior climate). In this manner, as the building's service environment changes, so should the requirements. The objective is to ensure that the level of building performance remains acceptable.

Wherever possible, new buildings should be designed to accommodate the climate conditions throughout their expected service life as upfront costs are typically less costly than retrofits. Some planned future retrofit (adaptive design) should also be considered. Adaptable design is being discussed provincially. It remains to be determined how it would be incorporated in the Code.

Ideal Design Service Life

The projections of future climatic data depend on the service life or planning horizon. The longer the service life or planning horizon, the higher the temperature change, the higher the precipitation change and the higher the change in wind for some regions. It is therefore necessary to define the design life of a building or infrastructure in order identify the climatic design data since the climate is not anymore stationary as is assumed in most building and infrastructure codes.

While service life is not explicitly defined in the NBC, the CSA standard on durability in buildings (CSA S478) sets out the following values of design service life:

Table 1. Design service life values from CSA S478:19

Design service life category	Building type	Minimum design service life	Range of design service life
Medium life	**Low-rise commercial and office buildings / Stand-alone parking structures / High Hazard Industrial buildings**	25 years	25 to 50 years
Long life	**Single-unit residential / Multi-unit residential / Mid- and high-rise commercial and office buildings, Post-disaster buildings**	50 years	50 to 99 years
Permanent	**Monumental and heritage buildings**	100 years	100 to 300 years

The building structure is designed to last much longer as long as it is adequately protected. In practice, buildings can be much older than this, as their expected service life often extends far beyond their design service life (DSL), and so does the expected service life of the building systems. In the case of the building envelope elements (roofs, windows, etc.), materials may have a much lower service life.

With older buildings, the issue becomes more that of maintenance than the initial design life. Routine renewals and maintenance of key elements will then dictate actual service life, though the frequency is unclear. This has two aspects:

1) In theory, carefully planned design will allow systems to be replaced as necessary without having to deconstruct or demolish. With attention to future proofing of the building, buildings will last 60+ years without issue;
2) In practice, it is unclear whether one can reasonably assume renovation and replacement of key elements over the lifespan of a building; for example, while siding may have a 30 year lifespan, it may never be replaced after that period of time.

Canadian regulators have been addressing this issue, with standards such as CSA S478-19 Durability in Buildings that specifies durability requirements for materials and systems. The standard sets forth minimum requirements to assist designers in creating durable buildings. In addition, other annexes to the Standard provide general guidance on the environmental and other design factors that have an impact on the durability of a building, a building material, and/or a building component.

In general, any increase in service life should be specifically proposed and justified. In practice, there is a limit to what codes can achieve based on estimated or desired service-life expectations. One limitation is that components have a different service life, whether by themselves or as part of assemblies. To avoid any “wasted durability”, it is imperative that designs take this into account to allow for ease of renewals and replacement so as not to affect other systems with much longer service lives.

Whether/How Occupancy Type/Building Importance should Factor into Design Considerations

The distinction is made depending on whether a building is critical or not, and on the expected frequency of occurrence of the forecasted climatic impact.

For most types/buildings, the importance factor should remain the same way they do now; there is no need to change types of buildings or their importance due to a change in external loads.

There are considerations for critical infrastructure that may be needed post-disaster that should be designed to have continued function after an extreme event. These would have design implications. One example is care housing and social housing, where the community may expect higher level of resilience and energy performance. A mention was made for some investment properties, such as buildings managed via pension fund. However, others would argue that these are all policy decisions outside of buildings codes, since communities can either move to less threatened areas or prioritize certain type of occupancies.

The overall consensus is that the Code should still leave as much initiative to engineers as possible, due to the complex nature of the built environment and the challenges it faces. To do so, the Code could provide tools for designers, such as any of the following three options:

(1) Use different importance factors for different occupancy types as it is now in the building code;
(2) Define appropriate and different reliability indices or probabilities of failure for different occupancy types of buildings;
(3) Define appropriate ultimate return periods for different occupancy types of buildings.

In this manner, critical infrastructure would benefit from protection against failure, enforced by regulation based on criticality and presence of vulnerable populations. For example, parameters such as permissible maximum indoor temperature could be defined for multi-residence buildings, schools and healthcare facilities, with special provisions generation to ensure mobility of senior populations or populations with disabilities.

By contrast, for the construction of housing, a mix of prescriptive (construction) and simple performance (design) approach is necessary, that comes with supporting guidance, training and design tools – as having a team of engineers or specialists on board is not a feasible, affordable or reasonable approach for every project.

Balancing Policy Goals

Policy needs to work hand-in-hand with science to determine the best designs which balance all considerations. By integrating experts from diverse backgrounds into codes and standards committees optimal outcomes can be achieved. For example: health experts could be included on codes committees to provide guidance on preventing overheating or to ensure indoor air quality during wildfire events, and public safety experts could be included in the development of standards for wildland urban interface design.

To guide decisions, it is essential to quantify the co-benefits of resilience and adaptation to climate change, including social and natural capital benefits. For example: resilient design can minimize retrofit needs throughout the service life of the building, avoiding maintenance costs and GHG emissions, and ultimately achieve a cost-effective and environmental solution. Resilient design may also achieve co-benefits such as improving ecosystem services, which also support the local economy. Life Cycle Environmental and Cost Analysis case studies of buildings that achieve resilience in an affordable and sustainable way would help support the move towards climate-resilient design.

Acronyms

BC – British Colombia

CCBFC – Canadian Commission on Building and Fire Codes

CCCS – Canadian Centre for Climate Services

CMIP – Couple Model Intercomparison Project

CRBCPI – Climate Resilient Buildings and Core Public Infrastructure Initiative

DSL – Design Service Life

ECCC – Environment and Climate Change Canada

FCM – Federation of Canadian Municipalities

GHG – Greenhouse Gas

IBWG – Infrastructure and Buildings Working Group

ICLR – Institute for Catastrophic Loss Reduction

INFC – Infrastructure Canada

IPCC – Intergovernmental Panel on Climate Change

LCA – Life Cycle environmental Analysis

LCCA – Life Cycle Cost Analysis

LEEP – Local Energy Efficiency Partnerships

MBAR – Mobilizing Building Adaptation and Resilience

MURBs – Multi-Unit Residential Buildings

NBC – National Building Code

NRC – National Research Council of Canadas

P&C – Property and Casualty

PCF – Pan Canadian Framework on Clean Growth and Climate Change

PTs – Provinces and Territories

RCP – Representative Concentration Pathway

SCC – Standards Council of Canada

SSRIP – Standards to Support Resilience in Infrastructure Program

UN – United Nations

WUI – Wildland Urban Interface

Glossary

Climate adaptation: The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. [29] Adaptation aims to manage the unavoidable.

Climate resilience of buildings: The ability of a building, structure and its component parts to minimise loss of functionality and recovery time without being damaged to an extent that is disproportionate to the intensity of a number of current and scientifically predicted future extreme climatic conditions (i.e., wildfires/bushfires, storms, hurricanes/cyclones, flooding, and heat).[30]

Co-Benefits: An investment which can provide two types of benefits. In the context of resilience, investment may reduce costs of a disaster, as well as improve economic growth and wellbeing through a number of co-benefits that occur even in the absence of a disaster.[30]

Design service life: the service life specified by the designer in accordance with the expectations of the owners of the building and the requirements given in this Standard.[31]

Durability: the ability of a building or building element to perform its functions to the required level of performance for its design service life in its structure environment under the influence of environmental actions.[31]

Mitigation: Measures taken before a disaster aimed at decreasing or eliminating its impact on society and the environment. For climate change, mitigation refers to actions to address the causes, usually involving actions to reduce anthropogenic emissions of greenhouse gases that contribute to the warming of the atmosphere. It seeks to avoid the unmanageable.[30]

Natural hazards: Naturally occurring rapid onset events that could cause a serious disruption to a community or region. Natural hazards include: snowstorms, wildfires/bushfires, cyclones/hurricanes, tornadoes, floods, severe thunderstorms or storm surges, earthquakes, landslides and hail etc. Heatwaves are also considered one of the most potentially dangerous natural hazards that are receiving increasing consideration in disaster risk reduction planning. [30]

Predicted service life: the service life forecast from demonstrated effectiveness, tests, or modelling, or some combination thereof.[31]

Representative Concentration Pathway (RCP): RCP is a greenhouse gas concentration (not emissions) trajectory adopted by the Intergovernmental Panel on Climate Change (IPCC). The various pathways (from 1.9 to 8.5) describe different climate futures, all of which are possible depending on the volume of GHG emitted in years to come.

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[29] GlobalABC, Buildings and climate change adaptation: A call to action, 2021
[30] Global Resiliency Dialogue, Delivering Climate Responsive Resilient Building Codes and Standards, 2021
[31] CSA S478:19 – Durability of Buildings

Resilience: The ability of a system, community or society exposed to hazards to resist, absorb, adjust to and recover from their effects in a timely and efficient manner, including initiatives to preserve and restore essential structures and functions.[32]

Service life: the actual period of time during which the building or building element performs to the required level(s).[31]

Social impact: The effect of disasters on people's health and wellbeing of individuals and families, and/or the effect on the social fabric of affected communities. [30]

[32] UNDRR, United Nations International Strategy for Disaster Reduction Terminology on Disaster Risk Reduction, UNEP, Geneva, 2009. https://www.undrr.org/publication/2009-unisdr-terminology-disaster-risk-reduction

Appendix A – Survey Questions

1. Ideal State
1a. What impacts and outcomes can potentially be achieved from the design of Codes to ensure life safety and building durability in the context of future natural hazards influenced by changes in climate? (i.e. social, financial, design goals)
1b. What barriers (e.g. understanding the science and how to integrate it, organization learning, capacity for change, political will, cost, etc.) exist to achieving this ideal end state?
1c. What are the main drivers for achieving resilient codes? What entities are leading the discussion/movement?
1d. In which cases should regulation be considered for achieving resiliency goals? In which cases should it not? What alternatives exist to achieving the same goals?
1e. Should entities be established/assigned to monitor and evaluate changing conditions to inform code changes? If yes, should those entities be governmental or non-governmental?
1f. Should thresholds be established to help inform when a code may need to change?
2. Data and Research Requirements
2a. What data and supporting research is needed to enable codes to consider future climate states and extreme weather events? (Examples: measured data, maps, material properties, pilot studies, etc.)
2b. Describe any studies that were undertaken or are planned to identify these gaps
2c. Describe any ongoing research or planned research/programs to address these gaps
2d. What is the ideal source and format of future climate data for Codes?
2e. How often should the climate data referenced in the Codes be updated to achieve resiliency goals?
3. Climate Science

3a. What advancements in current climate modeling are needed to support Codes?
3b. Describe any efforts underway or planned to advance climate science in support of codes.
3c. How can (or should) the uncertainty in future climate states and climate modeling be addressed and communicated in codes?
4. Choice of Future Climate Scenario
4a. In what ways can/should non-stationary climate (climate change) be addressed in Codes? Describe any efforts or discussions currently underway (e.g. design for end of service life, design to adapt, etc.).
4b. What needs to be/is being considered in selecting a future climate scenario (RCP) for design? What scenario is currently being used or considered by practitioners?
4c. What is the ideal expected service life of different types of buildings?
4d. What is the ideal expected service life of different types of building systems and materials? (e.g. windows, roofing, cladding)
4e. How does or should differences in occupancy type or importance of buildings factor into design considerations?
5. Extreme Events
5a. What are the current challenges in predicting future risk of extreme weather events?
5b. How should risk from extreme weather events ideally be considered in the design of buildings in a non-stationary climate? (For example: uniform risk vs uniform hazard - should the facility be designed to adapt to changing conditions or should the code include criteria for monitoring change, etc.?)
5c. Is the current solution for designing for extreme events limited by the state of climate science? Will a different solution be possible in the future?
6. Stakeholder Engagement
6a. What stakeholders need to be engaged to ensure the successful integration of resiliency into codes?
6b. What information, and in what format, is needed to successfully engage stakeholders?

6c. Describe any best practices for engaging stakeholders and communicating climate change related information.
6d. What policy discussions are needed to introduce resiliency in codes? Have any occurred in the past or are already underway?
7. Achieving a Culture of Resilience
7a. In addition to Codes, what complementary tools or activities are needed to achieve a culture of resilience in the building sector?
7b. What can be done to ensure equal access to resilient buildings? (Codes generally apply to new buildings, and only the population who can afford new homes will be initially impacted by codes changes)
7c. How can/should cost, mitigation and resilience considerations be considered and balanced in the design of buildings?
7d. What could happen to buildings that are impacted by an extreme weather event? (e.g. rebuilt, rezoned, loss of insurance)
7e. How is land use regulation and attitudes towards land use adapting to changes in climate? (e.g. managed retreat)

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