






Delivering Climate Responsive Resilient Building Codes and Standards

Findings from the Global Resiliency Dialogue Survey of Building Code Stakeholders in Canada, Australia, New Zealand and the United States

November 2021

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
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The Global Resiliency Dialogue is a voluntary collaboration of building code developers and researchers from Canada, Australia, New Zealand and the United States (CANZUS).

As an independent, non-partisan and publicly funded collaborative body, the Global Resiliency Dialogue seeks to inform the development of building codes that draw on building science and climate science to improve the resilience of buildings and the communities that live, work, and spend time in them, to intensifying risks from weather-related natural hazards, including heat waves. Learn more at www.globalresiliency.org.

COVER IMAGES

clockwise from top left:

1. A wall of clouds with funnel cloud formation and downpour over east Toronto, Canada (image: iStock)
2. Houses on the Quebec side of the Ottawa River in Canada impacted by record setting flooding in April 2019 (image: iStock)
3. Coastal resilient construction, Gulf Coast, United States, USA. Photo credit: U.S. Federal Emergency Management Agency.
4. Queenslander house stands alone in a flooded area on January 13, 2011 in Milton, Brisbane, Queensland, Australia. License: Royalty free - Editorial use only. Photographer: Markus Gebauer
5. A haze from distant wildfires blankets the sky in Vancouver, Canada, July 5th 2015 (image: iStock)
6. Second floor separated from main structure due to high winds and flooding following Hurricane Michael, Mexico Beach, FL USA, October 2018. Photo credit: Karl Fippinger, International Code Council.
7. Property at Strathewen, Victoria, Australia, that survived the 2009 'Black Saturday' bushfires. Photographer: Nick Pitsas on February 25, 2009. Under the terms of a creative commons license.
8. Flooding in Edgecumbe, New Zealand, caused by a cyclone in 2017 which damaged over 300 homes (credit: Whakatāne District Council)

ACKNOWLEDGEMENTS

The Global Resiliency Dialogue members would like to thank all of those organisations and individuals across Canada, Australia, New Zealand and the United States of America (CANZUS) that gave their professional experience and time to respond to the second CANZUS building resilience survey.

Their respective contributions provided valuable insights into the diverse and complex set of challenges in developing building codes and standards that are more climate responsive to the subject of building resilience. This material produced by the CANZUS partners, together with the first Global Resiliency Dialogue report – The Use of Climate Data and Assessment of Extreme Weather Events Risks in Building Codes Around the World, released in January 2021 – will feed directly into the development of a future set of international resiliency guidelines.

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EXECUTIVE SUMMARY

The threats of climate change are real and urgent.[1] Disasters and their impacts on communities across the world are increasing as the climate changes, population numbers exposed to a range of natural hazards rise and levels of urbanisation intensifies.

The built environment, and therefore the people living, working and spending time within buildings, is particularly at risk from extreme weather events and natural hazards, including the impacts of heatwaves. Globally, governments, property owners, industry and professional stakeholders are increasingly recognizing that more needs to be done to enhance the level of resilience offered by buildings and structures.

This report presents the findings of a building codes resilience survey developed by the members of the Global Resiliency Dialogue[2] – the Australian Building Codes Board (ABCB), the National Research Council of Canada, the New Zealand Ministry of Business, Innovation, and Employment, and the International Code Council (ICC, based in the United States).

The survey, which was circulated to a range of diverse building code stakeholders in each of the participating countries, focused on the current challenges and potential strategies to incorporate future-focused climate science and risk in building codes and standards. It also sought to investigate what further research is needed to advance change and influence effective implementation. This report provides a summary of findings from this survey and is another opportunity for interested parties to better appreciate and outline ongoing efforts and needs in the space of climate adaptation and resilience for new buildings and structures. Specific results and findings from each of the participating countries are presented in stand-alone reports available on the Global Resiliency Dialogue website.

Orewa, a suburb of Auckland New Zealand, an example of a community at risk from greater frequency of storms, as well as rising sea levels (credit: Rodrigo.NZ/Shutterstock.com)

This survey report details the diverse and complex challenges of enhancing resilience as it relates to building codes and standards. The report 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. It explores the types of codes ideally required (with an emphasis on buildings), the climate data and evidence needed to support changes to their requirements, as well as how to ensure future codes and standards can incorporate predictive climate data, and how often such data needs to be updated.

The survey also explored the policy questions that need to be taken into consideration in relation to future-looking hazard assessments and what additional research is likely to be required to enable building codes and policy makers to determine proportionate and cost-effective responses to climate-related risks.

Many of the findings support the initiative of the Global Resiliency Dialogue and the value that will be derived by developing international resiliency guidelines, the purpose of which will be to offer a common set of principles for building codes and standards to be benchmarked in their suitability for an appropriate level of resilience to current and future extreme weather events influenced by climate change.

The forthcoming guidelines are anticipated to provide a useful resource for national, state/provincial and local building regulators in their quest to ensure that the construction of future buildings and structures and the renovation and retrofit of existing buildings are fit for future climate conditions and can better cope with diverse and sometimes overlapping natural hazard risks. It is also anticipated that the report will provide further insights and potential future joint research initiatives for the Global Resiliency Dialogue to consider.

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[1] IPCC, Climate Change 2021: The Physical Science Basis Contribution of Working Group to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Summary for Policymakers, Cambridge Uni Press, 2021 available at https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/.

[2] For more information about the Global Resiliency Dialogue, please visit www.globalresiliency.org.

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INTRODUCTION

The global climate is changing rapidly and the supporting scientific evidence is overwhelming.[3] Whilst predictions vary in how the climate will change, there is unanimous agreement that it will be different from what we have experienced in the past hundred years and will almost certainly reach a 1.5°C rise in temperature compared to pre-industrial times, even with the implementation of the most optimistic of international mitigation measures. What is quite alarming, based on the science, is that the Earth could be just ten years from heating more than 2°C – a threshold beyond which even more serious and frequent fires, droughts, storms, floods, tornadoes, cyclones and hurricanes are expected.[4]

The threat of extended heatwaves is particularly challenging given the steady increase in the world's population living in urban settlements, be they cities, towns or villages. Not surprisingly, to address these growing threats, governments, businesses, industry and building regulators are increasing their focus on the buildings in which we live, work, study, shop, and recreate. This is especially concerning given that people in urbanised areas spend as much as 90% of their time in some sort of building structure.[5]

When discussing the resilience of the building stock to future climate conditions, many terms are frequently referenced. Concerns relating to 'vulnerability' to extreme weather events and potential 'risk 'and 'hazard' are some of the more commonly used terms. 'Risk', 'vulnerability' and 'hazard' should not be used interchangeably.

A wall of clouds with funnel cloud formation and downpour over east Toronto, Canada

The 'hazard' is usually fairly constant, but within the context of climate change, the size, impact and geography of the 'hazard' is changing. 'Vulnerability' is generally taken to be factors that increase the susceptibility of a community to the impact of a hazard. It can be used as a measure of how well prepared and equipped a community is to minimise or cope with the hazard. The 'risk' is the potential effect that a hazard has on a structure or on life, accounting for the probability of occurrence and the likely consequences. The risk increases as the size and frequency of the hazard increases – unless of course, an increased hazard is taken into consideration in how we build (building design) and where we build (land use planning). The added complication is how we use a building and maintain it, which are beyond the scope of many building codes.

International research predicts that by 2050, 1.6 billion urban dwellers will be regularly exposed to extreme high temperatures and over 800 million people living in more than 570 cities will be vulnerable to sea level rise and coastal flooding.[6] Reports of disaster events have become a regular occurrence in daily news coverage. Most recently, the world has witnessed the impacts of Hurricane Ida, the heatwaves over North America, the flooding in parts of China and central Europe and the devastating bushfires in Greece, California and those that burnt for six months in many parts of Australia over the 2019/2020 fire season.

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[3] IPCC, Climate Change 2021: The Physical Science Basis, 2021.

[4] GlobalABC, Buildings and climate change adaptation: A call to action, Paris, January 2021 available at https://globalabc.org/resources/publications/buildings-and-climate-change-adaptation-call-action.

[5] UNEP, A Practical Guide to Climate Resilient Buildings and Communities, Nairobi, 2021 available at https://wedocs.unep.org/xmlui/bitstream/handle/20.500.11822/36405/Adapbuild.pdf.

[6] GlobalABC, Buildings and climate change adaptation: A call to action, 2021.

The seriousness of the climate challenges facing the world was reinforced most recently when the International Panel on Climate Change (IPCC) released its sixth report.[7] The latest report found that even in its most ambitious mitigation scenario, global warming is likely to hit 1.5°C by 2030. More alarming are the scenarios that lie beyond this if the international community does not radically and immediately cut emissions.

> "UNDERESTIMATING EXTREME EVENTS AND POTENTIALLY SUFFERING SIGNIFICANT FUTURE BUILDING FAILURES IS A BIG CHALLENGE IN PREDICTING THE FUTURE RISK OF EXTREME WEATHER EVENTS."
>
> – *Building System Performance, New Zealand Ministry of Business, Innovation and Employment*

The role the built environment plays in mitigating the causes and adapting to the impacts of climate change has been addressed through an explosion in initiatives at all levels of government and amongst business and industry stakeholders in aspects of policy development and advocacy. An example of the latter being the creation of a new global collaboration of related groups who have agreed to come together to tackle decarbonising their sector. The #BuildingtoCOP26 Coalition includes C40, the Global Alliance for Building and Construction (GlobalABC), World Business Council for Sustainable Development (WBCSD), the Resilience Shift, and the World Green Building Council (WGBC).

With the increasing level of climate science predicting more extreme weather events, building regulators have started to investigate how to make buildings and structures more resilient to climate change.

The United Nations Environment Programme (UNEP) notes that buildings and the construction sector is a major contributor to climate change, responsible for 38 percent of global related $C0_2$ emissions.[8] At the same time, as new global construction and urbanisation proceed at a rapid pace, the world's current building stock is already experiencing pressure on the safety and amenity/comfort of building occupancy, as well as a substantial increase in damage and the cost of repairing and rebuilding structures following various climate induced disasters.

Given the expected impacts of a changing climate on buildings and structures and the likely increase in weather-related hazard risks, it is understandable that governments, business, industry and local communities are seeking to better understand their likely scope and frequency, and what measures can be taken to limit their impacts. As part of this, it is important to evaluate what this means for building codes and standards in order to understand whether they are fit for purpose for current and projected weather-related natural hazards (by geography and severity) and what role they can play in helping communities to be more resilient in the face of such events.

It is widely recognised that building codes have long been a solution for establishing a minimum level of protection from external climate conditions. International studies have found significant benefits arising from having and implementing

Decadal benefits of using modern building codes, Rockport, Texas, USA. Years of construction captured left to right: 2017, 2008 (update of original 1970 structure), 2001, 1972, 2000.

[7] IPCC, Climate Change 2021: The Physical Science Basis, 2021.

[8] UNEP, A Practical Guide to Climate Resilient Buildings and Communities, 2021.

contemporary building regulations and standards. For instance, in the U.S., the National Institute of Building Services (NIBS) found the regular adoption of model building codes from 1990 through 2018 produced a national benefit of $11 for every $1 invested.[9] The Australian Business Roundtable for Disaster Resilience and Safer Communities found similar benefits.[10] These benefits are not just through avoided impacts of disasters when they occur; they also incorporate the much broader co-benefits of avoided casualties, community cohesion, reduced business interruptions and insurance costs.

Contemporary codes, when fully adhered to, and proper ongoing building maintenance can assist to ensure buildings and structures sustain less serious structural damage and therefore can experience speedier recovery following a range of extreme weather events and natural hazards. In countries like Canada, Australia, New Zealand and the U.S., buildings and structures built to modern code requirements fare much better than buildings built to older standards. However, there are many places in the world where building codes are either not adopted, deficient in scope, poorly implemented, not enforced or are simply dated.[11]

Another reality is that modern buildings in many advanced economies have long expected service lives and contain significant amounts of embodied energy. Given this fact, it is not surprising that there are increasing demands by governments, industry and communities for building regulations to be fit for the future and relevant for a changing climate and hazard risk profile. Many of today's buildings approved under current building regulations and standards will be around for 50 to 75 plus years. Other significant public buildings will be standing well into the next century and possibly longer.

What specific future code and standard provisions may be necessary to help improve building resilience is a key issue. But so is the contextual need to understand that measures also need to be proportional. There are many other factors that will influence the performance of a building and it is important to not create unrealistic expectations about what can be achieved, particularly if temperature abatement is not effectively managed. The Global Resiliency Dialogue has been established to engage in this subject and share international learnings and experiences to assist countries around the world in developing ways of enhancing resilience in the built environment, with a focus on the role of building codes and standards.

> "BUILDING CODES ARE ESSENTIAL TO ACHIEVE RESILIENT BUILDINGS THAT ARE ABLE TO PROVIDE THE PROTECTION AND COMFORT OF THE OCCUPANTS THAT IS REQUIRED IN THE EXPECTED CLIMATES."
>
> – *Australian survey respondent*

[9] Natural Hazard Mitigation Saves: 2019 Report, www.nibs.org/mitigationsaves.

[10] Australian Business Roundtable for Disaster Resilience and Safer Communities, Special report: Update to the economic costs of natural disasters in Australia, Deloitte Access Economics, October 2021 available at https://www2.deloitte.com/au/en/pages/economics/articles/building-australias-natural-disaster-resilience.html.

[11] UNEP, A Practical Guide to Climate Resilient Buildings and Communities, 2021.

Global Resiliency Dialogue: Background

The Global Resiliency Dialogue was launched in October 2019 by building code development and research organizations, along with interested government and non-governmental stakeholders, based in Canada, Australia, New Zealand and the United States. The joint goal of this international collaboration is seeking to collectively identify solutions to help address the global challenge posed by the impact of increasingly frequent and extreme weather events and hazard risks on buildings and structures. Common hazards of interest included flooding, high winds, cyclones/hurricanes/typhoons, wildfires/bushfires, and heatwaves.

The Global Resiliency Dialogue has two overarching objectives. Firstly, it is about sharing leading practice and helping to inform the ongoing development of building codes that draw on the latest technical building practices and climate science to enhance the resilience of buildings and structures. Secondly, it is about enhancing the utility of existing building codes, which have largely been designed in response to past climate and weather events, to respond proportionately to rapidly changing and predicted extreme weather events.

The founding members of the Global Resiliency Dialogue, together with supporting stakeholders, recognize that current building codes around the globe may not provide the same level of safety and resilience for future extreme weather events as they have in the past.

CANZUS and Dialogue partners agree in principle that it is desirable and increasingly necessary for codes and standards to respond to the latest research and data from the perspective of both building/technical science and climate/environment science if they are to maintain not only an expected level of safety and amenity, but also an appropriate level of resilience. By working together, the participating organizations can pool their collective resources, experience and knowledge to create guidelines and research that will be of both national value and global benefit.[12]

Relationship between surveys

The initial work of the Global Resiliency Dialogue, culminated in a report,[13] which used a survey to investigate how climate-based risks are currently treated in national building codes and standards. In addition to input from the four founding Global Resiliency Dialogue participants, responses to this survey were also received by counterpart organizations in Europe (Germany, the Netherlands, and Norway) and Asia (Japan). This broadening of international interest offered a more contemporary snapshot of the current status and approaches to integrating climate science in existing building codes around the world.

A second survey sought to better understand and determine what possibilities and different types of climate modelling exist or are under development, to enable building codes to be more predictive and forward-looking, in anticipation of extreme weather events and hazards that are likely to impact the built environment.

With the release of the results of this survey in a second report, the expectation is that the findings from both reports can and will provide the foundation for the development of international resilience guidelines, which are likely to be released in the second half of 2022.

[12] See https://www.iccsafe.org/wp-content/uploads/Findings_ChangingRisk_BldgCodes.pdf.

[13] Global Resiliency Dialogue, The Use of Climate Data and Assessment of Extreme Weather Event Risks in Building Codes Around the World, January 2021 available at https://www.iccsafe.org/wp-content/uploads/21-19612_CORP_CANZUS_Survey_Whitepaper_RPT_FINAL_HIRES.pdf.

BUILDING CODES' ROLE IN RESILIENCE

The development, implementation and enforcement of building codes is widely recognized as a highly effective strategy to deliver safety, amenity, accessibility, sustainability, and productivity outcomes in the built environment. Codes are designed to regulate how buildings should be constructed, usually through meeting minimum standards, be they performance based or through specific prescriptive requirements. They can provide guidance on the use of what materials are permitted, how much energy is used, and how they may be designed to reduce vulnerability to identified risks, such as earthquakes, extreme wind and wildfire/bushfire.

Typically, building codes use historical climate data to engineer responses to risks and hazards that may occur during the life cycle of buildings and structures. Given the changing climate and risk profiles, it is becoming evident that new buildings and major renovations/rebuilds should be designed to be adaptable to a projected change in climate conditions. This needs to be further examined as there may be situations where buildings may be able to be modified later to adjust to changing climate conditions and hazard risks, rather than being designed for a spectrum of possible future climate scenarios up front.

Property at Strathewen, Victoria, Australia that survived the 2009 'Black Saturday' bushfires

Photographer: Nick Pitas on February 25 2009

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The second international survey found that building codes remain limited in their ability to address climate change adaptation (noting that differences exist amongst the four countries). Current limitations identified that codes:

- have yet to adequately address durability, which may require new objectives and a definition of service life;
- currently apply primarily to new buildings or substantial renovations and not existing buildings;
- have yet to incorporate broader community and urban planning resilience goals, including the use of green and blue infrastructure[14] for ameliorating the impacts of urban heat island effect and flooding; and
- with the exception of some building energy codes, do not currently focus on overheating or extreme heat, with no mention of cooling degree days or thermal comfort in summer months.[15]

Even within their current scope and objectives, building codes already need to address a number of competing priorities including structural, life and fire safety, weatherproofing, amenity, energy efficiency, health, accessibility and disability access, indoor air quality, and water safety and efficiency.

[14] *Green infrastructure* generally refers to using nature-based solutions to protect a community from natural hazards, such as flooding or excessive heat, or to improve air, soil or water quality. *Blue infrastructure* refers specifically to urban infrastructure relating to water.

[15] The ICC's International Energy Conservation Code (IECC) does include provisions on cooling and limiting solar heat gain in summer months.

All current code systems operate within a broader regulatory environment, which includes urban planning and environmental protection. This building regulatory ecosystem incorporates additional competing priorities that operate within agreed processes that have been developed to properly assess the potential impacts of proposed 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 within every code cycle. For resilience to be addressed within the codes system it is necessary to have clear policy direction and develop an appropriate body of evidence. Only then can the codes be properly evaluated, consulted, and subjected to impact assessment, before changes can be introduced, vetted, and implemented.

> "THE CODE PROCESS ALLOWS FOR ENGAGEMENT OF ALL AFFECTED TRADITIONAL STAKEHOLDERS (MANUFACTURERS, BUILDERS, ARCHITECTS, ENGINEERS, GENERAL INTEREST, ACADEMIA). THE SUBJECT OF RESILIENCE – ESPECIALLY DURING AN INITIAL POLICY DISCUSSION – SHOULD INVOLVE SOME NON-TYPICAL STAKEHOLDERS, SUCH AS MUNICIPAL PLANNERS, INSURERS, FINANCIAL INSTITUTIONS, SENIOR GOVERNMENT OFFICIALS."
>
> – *Frank Lohmann, Director, Building Science, Canadian Home Builders' Association (CHBA)*

Before we proceed to discuss the challenges of more broadly embedding resilience into building codes and standards, we need to first understand what is actually meant by resilience when applied to how buildings and structures are constructed in a weather hazard risk environment and changing climate.

Re-sil-ience (/re’zil’ yens/)
Noun

1. The ability to absorb shock in a time of crisis and spring back into shape.
2. The capacity to recover quickly after a disaster or sudden shock.

The word ’resilience’ is used by many these days, especially the current global pandemic and in relation to mental health. It was first used in the 17th century by engineers where elasticity was needed in materials used within structures such as bridges. Today, many definitions proliferate.

Although the word ‘resilience’ is not new, it has recently joined ‘sustainability’ as essential to achieve when dealing with future challenges, especially changing weather/climate conditions and natural hazard risks.

An important starting point for any work in the climate related resilience space is to understand what the term ‘resilience’ might mean in its application to the construction of new buildings.

An analysis of ways used to describe resilience has identified some common elements:

- of what;
- to what;
- when; and
- a purpose.

Less common within the descriptions, but of importance in applying it, is a clear statement of who should benefit from resilience. The descriptions do not commonly reference proportionality, to recognise that some things will need to be more resilient than others due to the consequences of their failure and what society is willing to pay.

Given the myriad of pressures on society from natural and human-induced hazards, and social and economic stresses, resilience in its broadest sense must recognize these realities. While this holistic vision is important for setting international, national and sub-national goals, achieving these requires action within individual disciplines or segments of the economy.

Defining Climate Resilience of Buildings

The concept of ‘climate resilience’ of buildings can also be defined in multiple ways. None are wrong per se, but depending on the definition adopted, may well have unintended or unrealistic implications.

Focusing specifically on the resilience of buildings and using the common elements of the descriptions, the following should be included in a definition of the climate resilience of buildings.

Resilience…	Applied to buildings
Of What	Buildings or parts of buildings and the contribution this makes to the broader community.
To What	Future extreme weather events, which are anticipated to change in frequency, duration, intensity and/or distribution.
When	Before (i.e. adapt), during (i.e. durability) and after (i.e. recovery), short and longer term.
Purpose	Health and safety of: 1. intended occupants of the building, and 2. those who rely on essential systems, services, or infrastructure provided by or from the building

Given that building codes are generally focussed on achieving goals of life safety, amenity and sustainability, there is a need to ensure that any goal of building resilience is placed in the right context to deliver better and achievable building outcomes. There is a real policy danger in failing to achieve an agreed-upon definition of resilience in a buildings context. Resources may be allocated inefficiently, regulatory tools may prove ineffective, unintended consequences may be generated and a loss of public confidence may arise.

For this reason, there is merit in considering existing definitions of resilience and either adopting those that appear to sufficiently scope and do justice to the international resilience challenge or editing existing adopted definitions.

It is important to bound the 'resilience to what' definitional element. While building codes cover multiple hazard types, the current focus of the Global Resiliency Dialogue is on those associated with climatic and weather-related events likely to be influenced by a changing climate, where some geographic boundaries can be reasonably established to reduce the unnecessary application of regulatory measures.

Finally, it is worth asking if an agreed-upon single definition should also include some commentary or reference to who actually benefits from increased levels of resilience. The question of who benefits is an important one and will need to be considered when developing regulatory and non-regulatory interventions that building resilience is seeking to solve. After all, the beneficiaries are not only key stakeholders in the quest to deliver better building resilience outcomes, but are ultimately the justification for key decision makers to be engaged in this space.

Based on analysis of the ways to describe resilience, existing definitions, consultation and the unique application being considered in the case of buildings and extreme weather events influenced by climate change over time, the following has been arrived at as a working definition to take forward at this stage:

> ***Climate Resilience of Buildings*** is 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).

BUILDING CODES RESILIENCE SURVEY OVERVIEW

A survey focused on the current challenges and potential strategies to incorporate future-focused climate science and risk in building codes and standards was developed collectively by the CANZUS members and circulated by each to a select group of stakeholders in each of the partner countries. The scope of questions proposed to stakeholders were extensive and totalled thirty in number. A copy of the survey questions is found in **Appendix A.**

Those surveyed were asked their views on both the opportunities and constraints of achieving higher levels of resilience in building codes as well as the climate science challenges relating to modelling and developing climate scenarios. The remaining questions examined how best to incorporate risk in the design of buildings and the multitude of issues relating to what future oriented codes should consider. The survey was also seen as a way to discover best practice examples of climate change communication and engagement and what research gaps stakeholders believe still exist.

The majority of stakeholders were highly engaged, interested and supportive in the topic and the inherent need of enhancing the levels of resilience in building codes and standards. Responses were received from a wide range of stakeholders including: architects and engineers, climate scientists, municipalities, home builders, standards organizations and researchers.

Additional input was invited from members of national code development organizations, government departments, industry and professional associations and the insurance industry. While some of the responses received were specific to the respondent's country and the relevant policies there, a number of more universal themes emerged from surveyed stakeholders in each of the four countries.

The executive summaries extracted from each CANZUS partner's separate survey reports are included in **Appendix B** to provide an outline of the main findings. Complete country reports are provided on the Global Resiliency Dialogue webpage for reference.

Overall, the survey responses highlighted the ongoing challenge facing governments and building regulators in generating the climate science and technical information needed to make buildings more resilient. Specific science challenges that were identified included obtaining accurate climate data, climate modelling and scaling to relevant geographical localities.

The survey findings uncovered a number of issues stakeholders identified as needing to be addressed in order to better inform important public policy discussions. These insights related to the role of codes in contributing to climate resilience, establishing appropriate performance targets and levels of acceptable risk, and the required impact analysis data to justify possible changes to regulations and standards.

The survey findings confirmed that building codes remain only part of the solution to achieving climate resilience in the built environment, with improvements in urban and regional planning highlighted by a number of those who responded.

The quality and source of climate data and future projections, as well as understanding of this information were highlighted as key areas for action. This included the need to improve and update climatic design data/maps in a changing climate and to educate both decision makers and the public on what this means in a practical, everyday sense.

From a communication perspective, involvement of decision makers at all levels of government, industry and the public in a coordinated manner was seen as of critical importance. Expanding on existing codes and standards systems was seen as providing a good forum to ensure all the main stakeholders are engaged and aligned.

It was recognized by many stakeholders that adaptation is not feasible in isolation of other interventions. The case for net-zero energy housing and other related mitigation actions were discussed, as was the critical need for society to do everything possible to avoid the need to adapt in the first place and thereby limit or at least reduce the amount of costs that need to be spent in increasing levels of resilience in future new builds. It was also argued, however, that adaptation options should be recognised as part of the mitigation solution – as more resilient construction methods have been shown to make a significant contribution to reducing lifecycle greenhouse gas emissions.

The survey responses acknowledged that actions need to be evidence-based and driven by contemporary advancements in climate science and knowledge of future climate loads and their impact on buildings.

Current Climate Change and Resilience Initiatives

The feedback arising from the survey found that numerous climate change initiatives were underway in each of the CANZUS jurisdictions. These initiatives were typically undertaken to better understand and appreciate what challenges and opportunities exist in enhancing building codes to better address building resilience in a changing climate.

Canada

In 2016, the National Research Council of Canada (NRC) undertook an ambitious 5-year initiative with funding from Infrastructure Canada (INFC). This Climate Resilient Buildings and Core Public Infrastructure (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.

The CRBCPI has developed future climatic design data 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, the NRC is now embarking on a follow-on initiative, wherein the 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 2016 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. The development of a National Adaptation Strategy is also now underway, with targeted completion for fall 2022.

"A WIDER, SOCIETAL VIEW SHOULD BE CONSIDERED WHEN UNDERTAKING IMPACT ANALYSES FOR RESILIENCE-RELATED CODE CHANGES. THE DIRECT LOSSES FROM EXTREME EVENTS ARE FAR OUTWEIGHED BY A MULTITUDE OF 'INTANGIBLES' THAT ARE NOT ACCOUNTED FOR IN TRADITIONAL IMPACT ANALYSIS PRACTICES."

–Dan Sandink, Director of Research, Institute for Catastrophic Loss Reduction (ICLR)

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 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 hundreds 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), the City of Toronto's Minimum Backup Power Guideline for MURBs, and the Federation of Canadian Municipalities (FCM)'s Municipalities for Climate Innovation Program

Australia

In Australia, the national building regulator – the ABCB --has been examining the implications of extreme weather and hazard risks on buildings and structures for the past several years. The ABCB has engaged the national science agency – Commonwealth Science and Industrial Research Organisation (CSIRO) -- to undertake a "climate scan" that will provide a formal work plan to investigate which areas of the National Construction Code (NCC) would benefit from further study in 2022 and beyond, to enhance the level of overall resilience in future buildings and structures.

At a national level, the Australian Commonwealth Government is actively in the process of drafting a National Climate Resilience and Adaptation Strategy (NCRAS). The strategy will provide a roadmap for Australia to understand, monitor and respond to its changing climate, based on the best available science. The NCRAS will also showcase Australia's current adaptation and resilience actions, and look to future needs.

Climate scenario modelling is being led by the Commonwealth Department of Agriculture, Water and the Environment (DAWE). The Department is working closely with the newly established Australian Climate Services (ACS) to develop future national climate scenarios.

> "CODES PRESENT AN OPPORTUNITY TO HELP MITIGATE EXISTING AND NEW CLIMATE RISKS BOTH AT AN ASSET AND COMMUNITY LEVEL. BENEFITS REALISED THROUGH THIS INCREASED RESILIENCE WILL BE WIDE FOR ASSET OWNERS, OPERATORS, OCCUPANTS AND THE WIDER COMMUNITY."
>
> *– Australian survey respondent*

Also at the national level, the recommendations arising from the Royal Commission into National Natural Disaster Arrangements (November 2020) and the creation of the new National Recovery and Resilience Agency (NRRA) (July 2021) are two specific initiatives that a number of stakeholders thought would encourage and promote more collaborative engagement between governments and industry sectors when it comes to building greater levels of resilience, particularly with respect to developing more climate and hazard responsive building codes.

Research and policy development arising from organisations such as the former Bushfire and Natural Hazards Cooperative Research Centre (BNHCRC), the newly established Natural Hazards Research Australia, the Australian Institute for Disaster Resilience, Geoscience, various universities and private research agencies including Risk Frontiers and James Cook University Cyclone Testing Centre were acknowledged.

Other key entities that were identified as currently leading the discussion and move towards enhancing built environment resilience in Australia included: Australian Sustainable Built Environment Council (ASBEC); the deliberations of National Energy Ministers and initiatives of various industry groups, peak professional bodies, local governments and Standards Australia. The latter specifically proposing to examine opportunities to how best to tackle the legacy challenge of trying to encourage greater levels of resilience take up in the existing building stock.

Australia is also seeing considerable climate adaptation initiatives happening at the state, territory and local government levels.

New Zealand

The New Zealand Government has agreed to implement a framework to drive climate change policy towards low greenhouse gas emissions and climate resilience. In 2019, it passed the Climate Change Response (Zero Carbon) Amendment Act and established an independent Climate Change Commission (CCC). A national climate change risk assessment has been completed.

A National Adaptation Plan is also in development. The plan intends to include outcome-focussed action plans for homes, buildings and places, and infrastructure.

When it comes to planning and development, there is a major restructuring of the country's resource management legislation underway. The NZ Resource Management Act, which promotes the sustainable management of the country's natural and physical resources such as land, air and water, is intended to be replaced by three new laws: the Natural and Built Environments Act, the Strategic Planning Act, and the Climate Change Adaptation Act.

"PLANNING REGULATIONS SHOULD BE DEVELOPED IN PARALLEL WITH BUILDING CODES, TO HARMONISE THE APPROACH TO RESILIENCE TAKEN IN BOTH."

– Building Innovation Partnership, University of Canterbury

The New Zealand Government is investing in research programmes addressing the impacts of climate change, and modelling to predict the future climate of the country. Initiatives include two National Science Challenges addressing greater understanding of the role of warming of the Antarctic and the Southern Ocean on the country's natural resources (The Deep South), and how the country can anticipate and adapt to changing natural hazards (Resilience to Nature's Challenges). Total funding for these cross disciplinary collaboration programmes exceeds NZ$110 million over 10 years.

Unlike Canada, Australia and the U.S., New Zealand does not have state or provincial governments. This means that there is one less layer of government to engage with, and that implementation and enforcement of legislation relies heavily on local entities.

United States

The U.S. is seeing a strong increase in both policy and investment action designed to tackle the challenge of climate change in both mitigation and adaptation activities. The new Administration has placed a strong priority on addressing climate change including advancing climate science, investment in research and sharing of data. In particular, the Federal Department of Energy (DOE), National Institute of Standards and Technology (NIST) and National Oceanic and Atmospheric Administration (NOAA) have more climate-focused activity under the current Administration, but work is still in the development stage. As examples, in early 2021, NIST held a workshop on climate science and building codes, and DOE initiated work on passive survivability criteria.

A new development involves a collaboration between the U.S. Global Change Research Program (USGCRP) and the White House Office of Science and Technology Policy to create a federal data commons in the cloud and a consolidated climate mapping service that would permit overlay of all federal geospatial datasets with climate data. The partnership also aims to move tools, such as Locating and Selecting Scenarios Online (LASSO) or Climate Explorer, into the cloud as services. Bringing users, including designers and the insurance industry, into the discussion to understand how the data delivery can be optimized for their needs is the next step, which could result in the need for additional investment.

While the NIBS has traditionally provided a setting for discussion on integrating climate science and building science, there are now proposals for NIST and NOAA to support the incorporation of climate science into building codes and standards.

U.S. stakeholders identified numerous entities that are advocating for change and beginning to accept the challenge of addressing the resilience of buildings to extreme weather and hazard risks. Some of those identified included the International Code Council, World Federation of Engineering Organizations; American Association of State Highway and Transportation Officials; American Society of Civil Engineers; U.S. Green Building Council; ASHRAE; Insurance Institute for Business and Home Safety; the Global ESG (Environmental, Social and Governance) Benchmark for Real Assets; and the real estate industry in general; Federal Alliance for Safe Homes; the Federal Environmental Protection Agency (EPA) and energy advocates; NIBS; and Reinsurance Association of America.

Work at the state and municipal level is also very active, and much of it predates the current Administration. For instance, jurisdictions like New York City, which have mandated resilient design for capital projects, are leading the way by example to eventually introduce climate resilient design into the local building code. The City's Climate Resiliency Design Guidelines (NYC 2020) were developed to provide step-by-step instructions to go beyond existing building codes and standards, by also looking to specific, forward-looking climate data for use in the design of city facilities.

Resilience Value Proposition

Stakeholders agreed that enhancing building codes to strengthen resiliency outcomes in the context of future natural hazards influenced by climate change could potentially deliver significant benefits at many scales.

Survey respondents across the four countries generally agreed that individuals and households would benefit from residing and working in more resilient and sustainable buildings through improved levels of comfort, safety and overall wellbeing. The logic being that the indoor environment of buildings acts as a buffer against the external environment that is subject to extreme weather conditions and hazard risks. The stronger and more climate appropriate the buffer is, the more comfort, safety and wellbeing is experienced by the occupants.

More resilient buildings have the potential to save considerable resources by preventing or at least reducing the cost of property repairs and reconstruction. Disasters can inflict significant displacement costs on impacted communities given there can be a need to find alternative accommodation, schools and other critical public infrastructure.

Some survey responses drew attention to increasing or maintaining the availability and continuity of insurance as a significant benefit arising from delivering more resilient buildings and structures. Natural catastrophic losses remain largely uninsured worldwide. Even in highly developed markets such as those in Canada, Australia, New Zealand and U.S., there is a considerable gap between economic losses suffered and the amount covered by insurance.

As the climate changes, certain areas are posing an increased risk to insurance companies and the products they offer. As risks increase so do premiums and insurance either becomes prohibitive or is simply not offered. This leads to increased cost of doing business, property affordability and transfer of private risk to the public. The more governments need to do in post climate disaster events, the less resources are available to other equally important community needs.

Stakeholders provided numerous detailed examples of the other potential societal benefits that may be generated by enhancing resilience in the built environment. These included: a reduction in first responder investment (ambulances, policy, and emergency management officers), reduced need for medical and psychological care, reducing the indirect losses incurred due to value-chain interruptions and the considerable opportunity costs that arise when there is a need for significant rebuilding of structures.

In strict financial terms, stakeholders generally agreed that the social impacts of disasters are usually at least, if not greater than, the more tangible losses to property and infrastructure. Many stakeholders argued that considerable costs, public health losses (including post-traumatic stress), disruptions and extended recovery time could be avoided with improved levels of building resilience.

Barriers

Given the benefits of implementing more resilience identified by respondents, the survey turned to asking what might be stopping or at least slowing down the roll out of stronger building regulations in the space of extreme weather building resilience.

Survey respondents across the four countries were fairly unanimous in that short term perspectives and the upfront and perceived costs acted as the major barriers to improving building performance and resilience.

> "THIS HAS BEEN THE BIGGEST BALANCING ACT IN MY 30-YEAR CAREER. HOW TO DESIGN AND CONSTRUCT LONG-LASTING, SAFE BUILDINGS THAT EVERYONE CAN AFFORD."
>
> *– Cindy Davis, CBO, Deputy Director, Division of Buildings & Fire Regulations, Virginia Department of Housing & Community Development*

The question of costs is difficult when taking into account the predictive nature of events impacting buildings, and when seeking to assign the benefit to society that might be derived from making buildings more resilient. But internationally, the evidence is increasing that the cost-benefit returns are likely to be substantial.

Interestingly, many of the surveyed stakeholders indicated that potential costs for builders, contractors and the supply chain, with respect to design, materials, time to construct and maintenance, will be considerably lower as solutions become more widely implemented. How to best educate and sell the whole-of-life costs and benefits to property owners, the occupants and users of these buildings, and the community, is a real challenge.

The issue of fairness and equity was also raised as a potential barrier. Who should pay for enhancing levels of resilience in the built environment given that building codes usually only apply to new builds and substantial renovations. The existing building stock would benefit from enhancements, but building codes and standards are typically not applied retrospectively to buildings that complied with regulations at the time they were constructed. Additionally, substantially more of the impacted owners or tenants in buildings requiring upgraded resilience features are traditionally underserved populations.

> "THE GOAL OF BUILDING CODES SHOULD BE MOVING BEYOND A LIFE SAFETY FOCUS (LARGELY ACHIEVED IN NZ) TO ADDRESSING THE BROADER ISSUE OF BUILDING DURABILITY, RESTORATION AND RESILIENCE."
>
> – *Resilience to Nature's Challenges: National Science Challenge, a government-funded industry/research collaboration programme in New Zealand*

Introducing significant change in the building regulation space was raised as a barrier. The building code development process is deliberative and can be slow to adapt. In part this is because they set minimum standards aimed at protecting life-safety and not property or the ability of buildings to support the ongoing function of buildings. Further, resilience has not been prioritized and the rapid pace of change in weather events, coupled with the use of historical data, means that the codes lag years if not decades behind the reality of the hazards that are currently being experienced, much less what we will be seeing in the future. These limitations may require new objectives around durability, service life, functional recovery, and social and economic resilience. Further, and in order to avoid unrealistic expectations as to how buildings will perform in all extreme events, how we build needs to be complemented with how we can better locate and design our communities through planning and urban design.

A number of respondents recommended the development of clearer guidance as to what constitutes the minimum level of resilient building performance in codes. Providing such guidance creates two challenges. The first is related to the need for a clearer interpretation of the underlying uncertainty in climate models, coupled with the actual level of desired resilience for future risk mitigation. In some instances, historical climate data may be sufficient to drive change, particularly for those extreme weather events and natural hazards that already pose significant risks, but that data may fail to predict the increased severity in events and hazards in 10, 20 or more years.

The second challenge is to define the actual resilience design objective in addressing changing geographic 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.

At the root of these challenges is the question of how best to define acceptable risks, which differ in scale when evaluated against different climate loads. These risks also differ across geographic scale (for example: extreme wind, flooding, wildfire/bushfire, extreme heat) and may differ in temporal scale, as some may significantly increase in the coming decades (temperature and extreme rainfall) while others decrease (snow loads in some regions). Additionally, the risk factors applied to different community functions (e.g. water, transport, energy and communication systems) can vary considerably, impacting community-level resilience.

Capacity of the code system is another barrier identified by some stakeholders. Even within their current scope and objectives, building codes must address multiple competing priorities including structural and fire safety. As such, the current systems of managing building codes in all jurisdictions are resource constrained and there is limited capacity within industry to absorb the breadth of issues now encompassed within codes. This becomes more important when considering the need to look at design as a holistic exercise, where the response to one subject has the potential to impact the ability to achieve the requirements for another.

Designing for future climate conditions rather than continuing to base regulations on past climate events is a major shift in how codes have been developed to date. Introducing such changes will require support from every level of government, industry and the community at large.

"IN A PERIOD OF CHANGE, CODES NEED TO BE FORWARD LOOKING, NOT BACKWARD LOOKING."

– Australian survey respondent

Data and Research Needs

Stakeholders were in general agreement that it was best left to government agencies to fund and curate climate data. Ideally, all such data should be available from an open source, be integrated with agreed performance data, updated regularly and made available to inform building code provisions or updates.

Stakeholders also argued that any climate models used for code development should be peer-reviewed scientific research, and should ideally provide a demonstration of various future scenarios in a manner that is comprehensible by policy makers, designers, contractors, investors and consumers.

Other challenges identified by many of the stakeholders included the need to have data at an appropriate geographic scale (generally, the scale of information at too high a level is not detailed enough to inform local policy) and to better understand how climatic changes would, over time, interact with changes in building typology and construction methodology.

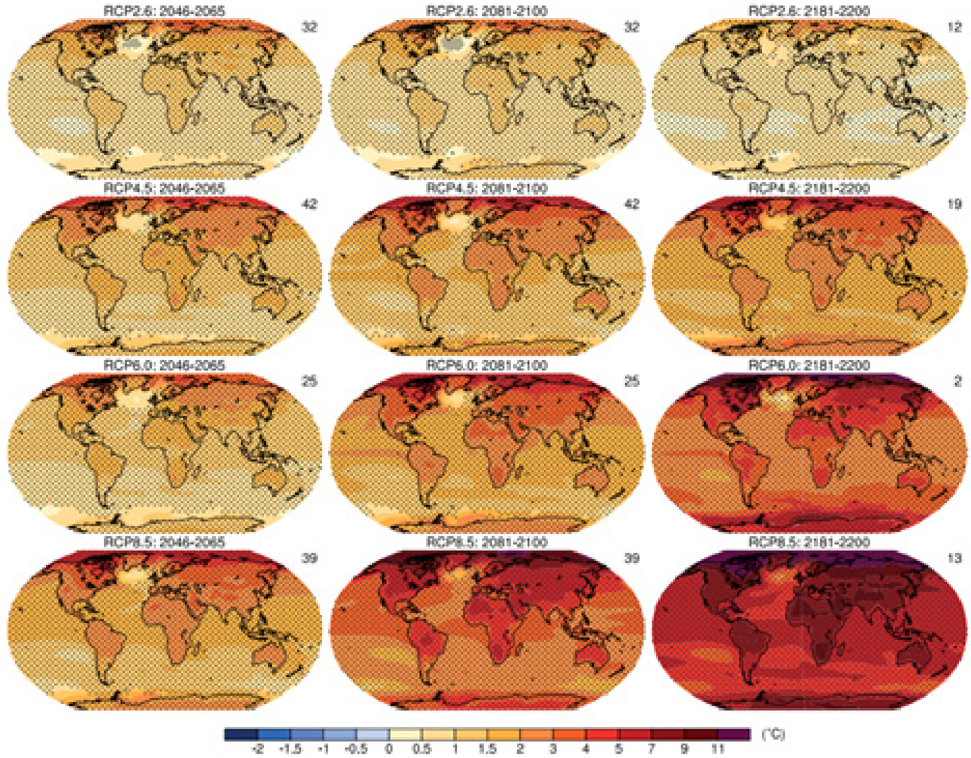
Whilst the CANZUS members will engage in separate resilience journeys, it would appear from stakeholder responses that the gaps they are experiencing with data and research needs are similar. These include:

- the relationship between building design, climate and occupant/public wellbeing to support the development of design tools and building solutions;
- performance of current buildings to projected future climates; and
- evaluating future building systems to agreed future climatic conditions and risk profiles, including heat stress.

RCP for Future Scenarios

The need for appropriate downscaling of climate information and adopting the right Representative Concentration Pathway (RCP) for future scenarios were acknowledged in all of the jurisdictions as issues requiring further investigation. The RCP scenarios measure the trajectory of greenhouse gas (GHG) concentration in the atmosphere through to the year 2100, which provides relative levels of emissions that will impact global warming.

The range offered starts with a best-case scenario (RCP1.9) to a worst-case scenario (RCP8.5). The RCP1.9 is a pathway that limits global warming to below 1.5°C, the aspirational goal of the Paris Agreement. RCP8.5, is the worst-case scenario under which emissions continue to rise throughout the century. The pathways describe different climate futures, all of which are considered possible depending on the volume of GHG emitted in years to come.



Annual mean surface air temperature change by RCP[16]

The RCP4.5 scenario of the IPCC's fifth assessment report[17] is described as an intermediate scenario. Emissions in RCP4.5 peak around 2040, then decline. RCP4.5 is more likely or not to result in global temperature rise between 2°C, and 3°C by 2100 with a mean sea level rise 35% higher than RCP2.6.

A high-emissions scenario corresponds with the RCP8.5 scenario. This reflects a trajectory where current emissions trends continue, and countries take little additional action on emissions reductions and other forms of mitigation. This scenario results in an average global temperature increase of about 4.3°C by 2100, relative to pre-industrial temperatures.

From the survey responses, there does not appear to be any consistency across the CANZUS countries in how risk tolerances are being considered using existing climate scenarios. As the U.S. has highlighted, some architecture and engineering firms have begun incorporating climate risk in their projects, but there is no universal approach.

[16] IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp. available at https://www.ipcc.ch/report/ar5/wg1/.

[17] IPCC, Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC, Geneva, 2015 available at https://www.ipcc.ch/report/ar5/syr/.

The Canadians appear to have made some progress in the methods adopted to translate the results of climate modelling to impacts at the scale of the built environment. But more guidance is needed regarding the types of expected extreme weather events and their return period, as well as decision making tools such as risk mapping.

The survey findings in Canada indicate that more support for choice of RCP is needed. Organizations have issued various guidance material and tools on the topic of risk and vulnerability assessment, but there is no agreement on the RCP scenario that should be adopted. However, in building design practice, the consensus does appear to favour erring on the side of caution, and the use of RCP8.5 is most common.

Environment and Climate Change Canada (ECCC) has provided the following preliminary recommendations[18] :

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, it is argued that a judgement must be made on which scenario to target. It concludes that ongoing consultations with experts to assess the probability of different forcing scenarios may be needed to arrive at a final decision.

"FOR BUILDINGS WITH SHORTER SERVICE LIVES, UP TO ABOUT FOUR DECADES, THE AMOUNT OF EXPECTED WARMING BY THE END OF SERVICE LIFE TURNS OUT TO BE ESSENTIALLY INDEPENDENT OF EMISSIONS SCENARIO. FOR BUILDINGS WITH LONGER SERVICE LIVES, A CHOICE NEEDS TO BE MADE AS TO WHICH EMISSIONS PATHWAY TO CONSIDER SINCE GLOBAL WARMING LEVELS BEGIN TO DIVERGE DISCERNIBLY AFTER ABOUT FOUR DECADES."

–Francis Zwiers, Director, President and CEO, Pacific Climate Impacts Consortium (PCIC)

New Zealand respondents suggest that, although these is no consensus on which scenario to adopt, most are choosing RCP8.5, on the basis that it would make sense to adopt the worst-case option, and it is the one that the world is currently tracking. However, the selection of a climate scenario needs to be context specific, and should consider impacts on material durability, building performance and occupant health and safety. It was also highlighted that, by under or overshooting future climate and hazard risks, there is a real risk of either underestimating extreme weather events and potentially suffering significant building failures, or locking in excess embodied carbon and higher building costs than is necessary.

The majority of Australian stakeholders agreed that future climate models should be based on a 'worst-case scenario'. However, some also argued that even if one adopts a 'best-case scenario,' this will still drive much needed improvements to building codes. Interestingly, the majority of respondents failed to nominate a preferred RCP and this indicated that there appears to be confusion and uncertainty with how the science and climate models are developed.

"NOT EVERYONE WILL AGREE BUT WE NEED TO GET ON WITH IT. MAKE A DECISION AND EMBED THE REQUIREMENTS IN THE CODE SIMILAR TO HOW WE ADDRESS HISTORICAL AVERAGES NOW."

–Bernie Deneke, Professional Engineer (U.S.)

Survey respondents were not asked what value they saw in adopting Shared Socioeconomic Pathways (SSPs). This relatively new climate model was incorporated into the latest IPCC assessment report released after the survey was conducted.

[18] Cannon, A.J., Jeong, D.I., Zhang, X., and Zwiers, F.W., Climate-Resilient Buildings and Core Public Infrastructure: An Assessment of the Impact of Climate Change on Climatic Design Data in Canada, Government of Canada, Ottawa, ON, 2020 available at https://climate-scenarios.canada.ca/?page=buildings-report-overview.

Policy Implementation

Feedback from stakeholders identified the extent to which they felt policy and regulations can be applied to achieve resilience goals. These are ultimately policy analysis issues that can help determine, for any specific goal, the case where regulations should be considered and what are the appropriate alternatives that may achieve the same goal.

Further, policy implementation issues concern the threshold for code changes and the frequency of climate data updates required to ensure resilience benchmarks are continuously recalibrated. The consensus amongst survey respondents appears to be in favour of updates at reasonable lengths of time.

The Canadian stakeholders seemed to think at least every five years was enough time to acquire additional and beneficial observed data, and also to provide the building industry enough time to prepare for and adapt to any proposed changes in regulation.

The New Zealanders had mixed views. Some thought 10 years, and five years if and when an agreed threshold was exceeded. Another view proposed a more dynamic adaptive approach. Given climate impacts and trajectories are constantly changing, building regulations should always strive to reflect the best available climate evidence.

Australians nominated various time scales from three to five years to five to seven years. A few argued that the time frame should be very regular – annually or at least every two years. One respondent thought every second review of the National Construction Code (NCC) would be appropriate. It would appear that the consensus landed around every five years.

The U.S. respondents also nominated various time periods, but also suggested specific thresholds that may be adopted to trigger regulatory changes. Specific metrics that could trigger code changes included:

- indicators or 'tipping points;'
- time schedule;
- number of disasters over a set period of time;
- financial cost of damages over a set period of time;
- availability of commercial insurance;
- measurement of the impact of climate change on the evolution of compound hazards (i.e., wind + rainfall);
- level of peril;
- atmospheric CO_2 ppm with RCP models; and/or
- ISO 31000 risk management standards.

When changes are triggered and proposed by events or metrics such as those listed above, the consideration of code changes should be accompanied by a probability of occurrence and statistical analysis to assess the true necessity of the proposed changes in order to prevent unnecessarily frequent and minor code changes. U.S. respondents also argued that it was important to recognize that the thresholds will vary from code to code and hazard to hazard.

There was less consensus about how regularly the climate data referenced in the codes should be updated. Some suggested they may be tied to the availability of new climate data studies, a new scientific consensus around future climate data, or perhaps based on a pre-established trigger. Alternatively, the climate data in codes could be updated as the codes are updated (three years for the International Codes used throughout the U.S. and numerous international jurisdictions), or on a different regular basis (four years, five to ten years).

An unresolved policy issue for all CANZUS stakeholders would appear to be the need for an all-of-government approach to policy development and implementation in order to support the inclusion of resilience considerations in building codes. A key discussion needing to take place was around how different building and resilience regulations, standards, and policy commitments/arrangements at different levels interact. For instance, how do governments propose to link international commitments such as the Paris Agreement and Sendai Framework for Disaster Risk Reduction with what needs to be done at a building codes and standards level? Equally, how does resilient infrastructure development and land use planning regulations complement the outcomes sought through national building codes?

Policy challenges were also identified when it came to how the achievement of resilience might overlap with other building regulations. As previously highlighted, building codes already struggle meeting different objectives and priorities. Agreeing on new resiliency thresholds for code changes is likely to be problematic, given the different perspectives and views stakeholders believed would be expressed.

The uncertainties of projecting future risk, coupled with the challenge of addressing something before it is a problem, are combining to contribute to the difficulty of incorporating future-looking risk into building codes. The challenge is exacerbated by different climate model assumptions, data inputs, and so on, including the fundamental complexity of the discussion.

Communication

There appears to be wide agreement amongst stakeholders about the need to improve and target messaging about the value of driving resiliency to better adapt buildings to future climate conditions and hazard risks.

Many of the survey responses argued the need to develop a clear communication strategy that embraces risk-based information, presented in clear language, which would provide useful evidence to key policymakers. Such a strategy, coupled with supporting policy incentives and disincentives, could likewise be used to educate home buyers, developers, investors and governments to demand resilience in the properties they purchase and equally reject or financially discount investments that are not adequately resilient.

Other key participants that need to be invited into the communication space include:

- scientists (earth, environmental and climate);
- urban planners, policy officers (including public policy analysts and economists);
- industry (including insurance, finance, construction companies);
- professional contractors;
- industry and professional associations, real estate developers and agencies and designers;
- researchers;
- the diverse range of community stakeholders; and
- specialised NGOs that are directly involved in housing and/or property and infrastructure investment.

The need to also provide strong imagery, including interactive mapping that could illustrate where and how future climates may change in geographic locations was seen as very beneficial in communicating the need for greater levels of resilience.

CONCLUSION

This report provides an appreciation of the significant and diverse set of challenges that need to be addressed in seeking to enhance the levels of resilience in building codes and standards. It shares the perspectives of different stakeholders across Canada, Australia, New Zealand and the United States, and provides a valuable resource for jurisdictions and policy makers. This international survey confirms and recognizes the significant threats of climate change and the complexities that create real vulnerabilities for buildings and the people who experience them.

A community's vulnerability and an effective approach to achieve resilience is based on multiple decisions, including where to live, what structure to build and how to use and maintain buildings, among others. Equally important aspects of enhancing building resilience include land use planning, provision of supporting social services, education and of the design, operation and upgrading of physical infrastructure such as water, stormwater, sewerage and electricity.

Understanding how different building types and uses will function over time and under different climate scenarios will assist how communities plan for rapidly changing climate and hazard risks, including heatwaves. This is especially the case when it is acknowledged that resilience to climate change risks is not a static state but rather a continuous ongoing series of considerations.

Actions taken to improve resilience and reduce vulnerability of the built environment and the communities they are part of can be grouped into three periods of time: prior to the event, during the event and post event. All three periods play a role in enhancing the resilience of buildings and structures. What this means for potential regulation change is unclear, other than reinforcing the fact that adhering to building regulations being enforced at the time when a building is constructed is not the panacea for ensuring building resilience. The proper repair after a disaster and on-going maintenance, and perhaps upgrading, of a building and its systems and structure are equally important.

Whilst the value proposition for introducing greater resilience thresholds in building codes appears significant, it should not be forgotten that no community can ever be completely resilient to every possible event.

There is no defined set of interventions that will address all the needs within a community. A range of expertise will need to be engaged to determine the best opportunities to be pursued. Survey respondents accepted that there is no definitive arbiter of 'policy correctness' when it came to resilience and building regulations and standards.

Achieving resilience is only truly known following an adverse event. Future losses avoided is a very difficult metric to define and is not easily incorporated into economic and policy decision-making. These two factors make the challenge of enhancing building codes and standards considerable on multiple levels. This and those solutions identified to achieve resilience may impact the implementation of other code objectives adds to the policy development complexity.

Extreme climatic events and hazards are already a significant burden for governments and communities at the local and household levels. The built environment's response to climate change will have profound economic and social consequences (direct and indirect), as extreme weather events intensify, increase in magnitude and expand their geographic exposure. Climate liability is on the rise, and will impact not only homeowners. Increasingly, companies and governments whose buildings and infrastructure are threatened by climate risks will be facing significant financial burdens.

With all these issues in mind, it is not surprising that some of the survey respondents argued that adaptation to climate change should be integrated into both the building's conception (initial design) and the choice of its physical location (land use planning). By changing the building construction process and materials used, it is possible to integrate climate change resilience into the built form. This will, however, require a systemic approach to how buildings are constructed, going beyond current practices that are often dictated by immediate pressures. In practical terms, focusing on each phase of the extended life cycle is a first step towards establishing frameworks for action for the adaptation of buildings to future climate change and extreme weather events and hazard risks.

On a cautionary note, there is a risk that trying to project climate variables and uncertainty too far can lead to uneconomic or unachievable designs. The focus should remain on supporting the objective of codes to keep the occupants safe, healthy and comfortable, and to protect the structure well enough in order to ensure that it remains liveable and serviceable in cases when the natural environment changes.

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; however, it remains to be determined how this would be incorporated in building codes.

Buildings, be they homes, businesses, schools, hospitals, offices or community centres are central to the well-being of households and the functioning of businesses, governments, and communities. Access to safe, healthy, and comfortable buildings is the foundation to a strong and prosperous community. Institutional, commercial, and industrial buildings are vital locations for work, trade, public services, and recreation.

Convincing stakeholders of the value and role of codes as important instruments that contribute to achieving climate resilience of buildings is not to be underestimated. This is particularly the case in a global pandemic where housing affordability is under increasing pressure and governments, of all persuasions, have been leaning towards more free market orientated solutions and reducing the reliance on regulation and enforcement.

Regardless of the significant challenges facing those wishing to enhance the resilience of building codes and standards to future climate conditions and risks, the CANZUS stakeholders agreed on two fundamental points. The first being that building codes are fundamental to assuring buildings continue to support the health, safety, welfare and economic wellbeing of communities, especially when facing life threatening hazardous events, including heatwaves. The second, achieving any level of built environment adaptation is only possible by developing a stronger evidence base (including both climate and building science) as well as a comprehensive strategy that seeks to fully engage the public, private and interest groups on the journey to be more resilient.

GLOSSARY

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.[19] Adaptation aims to manage the unavoidable.

Building codes: A set of rules that specify the requirements for the design, construction and renovation of buildings and other structures.

Climate: A statistical description of weather in terms of mean and variability of relevant quantities over a period ranging from months to thousands of years.

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).

Disaster risk reduction: The practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors, including initiatives to reduce exposure to hazards and the vulnerability of people and property, judiciously manage land and the environment, and improve preparedness.[20]

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. (This may also be referred to as 'double discount'.)

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.[21]

Embodied carbon: The amount of greenhouse gases (measured in a quantity of carbon dioxide equivalent) emitted to produce a building, including extraction and transport of raw materials, and the manufacture of building components and systems. The corresponding amount of energy consumed in these processes, required to physically construct the building before it is ready for occupancy, may also be referred to as 'embodied energy'

Greenhouse gases: Gases that trap heat in the atmosphere including carbon dioxide, methane, nitrous oxide and fluorinated gases.

Intangible costs: Captures direct and indirect damages that cannot be easily priced such as death and injury, or health and wellbeing impacts and community connectedness. Intangible costs include the opportunity cost of the next best alternative use of the resource that is foregone. For instance, if time is spent in hospital due to injury caused by a disaster, the opportunity cost could include lost wages.

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.

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.

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[19] GlobalABC, Buildings and climate change adaptation: A call to action, 2021.

[20] United Nations Office for Disaster Risk Reduction (UNDRR), 2009 Global assessment report on disaster risk reduction, UNEP, 2009 available at https://digitallibrary.un.org/record/762672?ln=en.

[21] CSA Group, CSA S478:19 Standard on Durability in Buildings, CSA Group, April 2019.

Net-zero energy building: An energy efficient building with all remaining energy supplied from on-site and off-site renewable energy sources. The net final consumption of energy would be zero or negative.[22] (May also be referred to as a 'net-zero building', 'positive energy building', or 'zero energy building').

Preparedness: A set of actions, knowledge and skills used to reduce the impacts of disasters.[23]

Prevention: To hinder, deter or mitigate disasters, while maintaining readiness to deal with them.

Recovery: The coordinated process of supporting disaster-affected communities to rebuild physical infrastructure and restore emotional, social, economic and physical wellbeing.

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.

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.[24]

Response: To act rapidly and decisively during and after a disaster event to manage its immediate consequences.

Shared Socio-economic pathways (SSP): Scenarios of projected socioeconomic global challenges to 2100.They are used to derive greenhouse gas emissions scenarios with different climate policies. They have been developed in order to facilitate the integrated analysis of future climate impacts, vulnerabilities, adaptation, and mitigation.

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.

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[22] UNEP, A Practical Guide to Climate Resilient Buildings and Communities, 2021.

[23] Randrianarisoa, A, Richardson,J; Brady,J and Leguy,L., Understanding preparedness and recovery: A survey of people's preparedness and recovery experience for emergencies, Australian Red Cross, North Melbourne, July 2021 available at https://www.redcross.org.au/getmedia/ab257262-e978-4aa3-b8fb-a7f16010e52d/Preparedness-Report-JULY-2021.pdf.aspx.

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

ACRONYMS

- ABCB = Australian Building Codes Board
- ACS = Australian Climate Service
- ASBEC = Australian Sustainable Built Environment Council
- BNHCRC = Bushfire and Natural Hazards Cooperative Research Centre (Aus)
- BRANZ = Building Research Association of New Zealand
- C40 = Cities around the world taking bold climate action
- CANZUS = Canada, New Zealand, Australia and United States partnership
- CCC = Climate Change Commission (NZ)
- CSIRO = Commonwealth Scientific and Industrial Research Organisation (Aus)
- DAWE = Department of Agriculture, Water and the Environment (Aus)
- DOE = Department of Energy (U.S.)
- ECCC = Environment and Climate Change Canada
- EPA = Environmental Protection Agency (U.S.)
- GHG = Greenhouse Gas
- GlobalABC = Global Alliance for Building and Construction
- ICC = International Code Council (U.S.)
- IPCC = Intergovernmental Panel on Climate Change
- LASSO = Locating and Selecting Scenarios Online
- MBIE = Ministry for Business, Innovation and Employment (NZ)
- NRC = National Research Council of Canada
- NCRAS = National Climate Resilience and Adaptation Strategy (Aus)
- NRRA = National Recovery and Resilience Agency (Aus)
- NIBS = National Institute of Building Sciences (U.S.)
- NIST = National Institute for Standards and Technology (U.S)
- NOAA = National Oceanic and Atmospheric Agency (U.S.)
- RCP = Representative Concentration Pathway
- SSP = Shared Socioeconomic Pathways
- UNEP = United Nations Environment Programme
- UNDRR = United National Office for Disaster Risk Reduction
- USGCRP = United States Global Change Research Program
- WGBC = World Green Building Council

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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. ow often should the climate data referenced in the codes be updated to achieve resiliency goals?
3. Climate Science
3a. What advancements in current climate modelling 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 modelling 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)

APPENDIX B: COUNTRY SURVEY REPORTS - EXECUTIVE SUMMARIES

Canada

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 info 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 reductions in lifetime GHG emissions.

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.

Australia

Close to thirty Australian building code stakeholders were invited to share their views and opinions on both the climate science and technical challenges and opportunities for enhancing resilience outcomes within the context of building codes and standards. This report provides a high-level analysis and discussion of the subsequent responses.

The overarching finding was that all the stakeholders who responded to the CANZUS survey support and appreciate the diverse impacts, barriers and drivers when it comes to climate adaptation and resilience for new buildings. The urgent need to investigate how building codes and standards can best reduce vulnerability risks to Australia's current and future building stock from changing climate and natural hazards was one of the key messages.

The challenges posed by climate change have been seriously debated in Australia for over two decades. The continent is vulnerable to a range of natural hazards including bushfires, storms, hail, tropical cyclones, floods, coastal inundation and extreme heat. It is estimated that natural disasters influenced by the climate cost the Australian economy A$38 billion per year on average. A high emissions scenario could see annual costs rise to A$94 billion by 2060.[25]

Governments at all levels have responded to the significantly higher costs from climate related natural disasters by looking to integrate natural disaster resilience into the future planning for Australia's cities and regions. Many have established agencies to coordinate responses to natural disasters and target investment efforts at improving resilience. Examples include the NRRA, Resilience NSW, and Queensland Reconstruction Agency.

Most of Australia's building stock –constructed since 1996 (if properly maintained) complies with the NCC. By default, these buildings are reasonably prepared for the impacts of extreme weather events and various hazard risks based on past events.[26] Nevertheless, stakeholders agreed that given impending climate change projections, it is legitimate and necessary for building regulators and standards developers to investigate what, if any, changes need to be made to existing building codes and standards to reduce the vulnerability of buildings to Australia's already changing climate.

The majority of survey responses showed stakeholders are highly engaged in this area, and their views are generally consistent. The survey findings reinforce that more progress needs to be made in generating useful climate projections and technical information on how best to make future buildings more resilient to changing climate conditions and hazard risks.

The survey findings also outline several 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 levels of risk, and having the strong evidence to support regulatory impact assessment. Climate models, scenarios and time lines for projections are all important in this regard.

Stakeholders agreed building codes remain only part of the solution to achieving climate resilience in the built environment and outlined some of their limitations. Respondents highlighted the need for a variety of policy instruments to address adaptation and suggested a few examples of the kind of initiatives governments should be encouraging more of. Better land-use planning and green infrastructure were both seen as complementary actions needing to contribute to desirable changes.

The quality, reliability and scale of climate data information is seen as one of the areas requiring urgent attention. Educating building codes developers and decisions makers to interpret climate projections and what this means for technical building standards was identified as a key action, as was the need to improve and update climatic design data/maps.

While reviewing and updating building codes and standards to changing climatic risk profiles was acknowledged, so was the opinion that climate adaptation is not a standalone solution. Respondents accepted climate mitigation actions to reduce GHG are needed if Australia is to reduce the degree of adaptation interventions and levels of investment required over the longer-term. Delivering on net-zero housing and greater levels of renewable energy was noted.

Finally, the involvement of decision makers at all levels of government, industry, finance/insurance and the community in a coordinated manner was seen as a critical success factor in enhancing building resilience.

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[25] Australian Business Roundtable for Disaster Resilience and Safer Communities, Special report: Update to the economic costs of natural disasters in Australia, 2021.

[26] BRANZ, *An Assessment of the Need to Adapt Buildings for the Unavoidable Consequences of Climate Change.* Australian Greenhouse Office, 2007.

New Zealand

Climate change and its potential impacts right across society and the economy is centre stage in New Zealand (NZ), and the Government as well as a number of cities have declared climate emergencies.

New Zealand is a signatory to the Paris Agreement and the Climate Change Response (Zero Carbon) Amendment Act 2019 requires the government to publish the emissions reduction plan by 31 May 2022. This will set out how NZ will meet its climate targets. The Act also requires the publication of a National Climate Change Risk Assessment (completed in 2020) and a National Adaptation Plan (scheduled to be completed in 2022).

NZ has had a performance-based Building Code since 1992 and it is primarily focused on life safety. Feedback from the 2020 Global Resiliency Dialogue survey identified that there is an opportunity to address issues of building resilience and occupant wellbeing in the face of expected changes to the climate in the NZ Building Code. Outcomes of improving requirements for resilience identified in the survey included:

- reduced conomic losses,
- improved public health, safety and wellbeing, and
- faster post-disaster recovery.

People living and working in buildings that are more resilient would have greater confidence in surviving climate change induced scenarios, such as extreme weather events. This would positively contribute to social stability, both in the short term and long term.

Improved requirements for greater resilience requirements has the perceived potential for reduced social disruption to residents and communities, and a reduced number of "uninsurable" buildings. Recovery times could be reduced and there would be less financial strain on communities and service providers.

Barriers to achieving this include a perception of increased upfront building costs, as well as lack of industry capacity and expertise. The need for improved quality and availability of future climate data in suitable formats for government agencies, local government, other end users and the public was highlighted, and a role for central government agencies to fund and curate this was identified.

Drivers for change include the NZ Government's National Adaptation Plan, which will address climate resilience across the whole NZ economy, and MBIE's Building for Climate programme, which is considering changes to the building regulatory system specifically, including NZ Building Code settings, in light of projected future climate scenarios.

While building codes have an important role to play, they are only part of what is required. Society needs 'the right buildings in the right places'. The resource management and planning systems need to be responsive to climate change and prevent buildings and infrastructure being built in locations where climate change will exacerbate natural hazards and risk damage and stranded assets. A current restructuring of the resource management regulatory system in NZ offers an opportunity to address the disconnect between central and local government policy in this space.

In addition to building code settings and resource management and planning systems, there is a range of non-regulatory levers such as information and guidance (e.g. a web portal) that can be used to drive interest and momentum in more climate resilient buildings. These can also target existing buildings where building codes usually have limited application, such as in major refurbishments and alterations. The availability and cost of insurance will also play a role in where and how buildings can be built.

United States

Communities are becoming increasingly vulnerable to the detrimental impacts associated with a changing climate. As natural hazards continue to intensify in magnitude and occurrences, it is critical for communities to adapt to their unique and changing risks. The development of building codes that draw on both building science and climate science have been identified as an essential strategy to improve the resilience of buildings and communities to intensifying risks from weather-related natural hazards.

This report explores the drivers that have the potential to push beyond the barriers to recognize the benefits of resilient building codes and standards, with special focus on the U.S. entities leading the path forward in addressing the resiliency of buildings to extreme weather events. The report also highlights New York City as a model case study to inform the use of forward-looking climate projections in building codes and standards.

There is little dispute about the value of integrating more resilient measures focused on future-looking scientific data into building codes and of fortifying new and existing buildings for resilience against future hazards. However, the challenge is how to achieve balance between protecting buildings in the future with ensuring their present affordability, especially in consideration of vulnerable populations. The survey explores this, and other challenges including the need for universal acceptance and use of current climate science, gaps in existing climate data, inconsistency in existing climate scenarios and uncertainties in risk assessment.

U.S. stakeholders acknowledged that the greatest climate data need is for more localized models that utilize baselines that climate and building scientists can agree upon because adoption and enforcement of building codes in the U.S. is localized. Additionally, the need for more resilient structures is very localized, even based on anticipated hazard events that utilize forward-looking scientific data. Currently, there is a lack of high-quality data at the local scale, which is necessary to inform local codes.

Survey results also highlighted the need for an authoritative source to guide building owners and designers in translating their risks into concrete adaptation strategies. Building owners and designers recognize the uncertainty and the numerous strategies to address future climate risks that are currently used. Stakeholder responses eluded that building owners and designers are seeking an authoritative source to cut through that confusion and provide clear direction.

Current code language does not incorporate up-to-date climate research and provide actionable requirements. This report explores the existing barriers, both from data and policy perspectives, limiting the application of available climate data to proactively incorporate future-looking risk into building codes to enhance resilience. Participating stakeholders highlighted expanded collaboration across sector experts and increased regulation and incentives for resiliency standards as essential actions to increase service life of critical infrastructure in response to the changing climate.

The survey responses concluded that uncertainties of projecting future risk have empowered a business-as-usual mindset, limiting the application of available climate data to proactively incorporate future-looking risk into building codes. There is a sense that climate scientists and the developers of building codes and standards need to agree upon a path and just do it, with the anticipation that the future-looking science will need to be recalibrated regularly as the codes are updated.

Adoption and enforcement of modern building codes and standards to mitigate the impacts of the changing climate is essential. The survey highlights the many barriers in current climate science for their effective incorporation into codes and standards as a mechanism for adaptation to enhance building climate resilience.